

Connection Details for Prefabricated Bridge Elements and Systems



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Federal Highway Administration



Priority, Market Ready
Technologies and
Innovations

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

Foreword

This document has been developed for the purposes of promoting the use of prefabricated elements and systems in bridges as part of accelerated construction projects. Accelerated construction and long term durability are integral parts of the Federal Highway Administration (FHWA) Bridge Program. Part of this program focuses on a need to create awareness, inform, educate, train, assist and entice State DOT's and their staff in the use of rapid construction techniques.

This document represents the "State of the Practice" at this time with respect to accelerated bridge construction. Most of the details were obtained after an extensive search process that included the following sources:

State Departments of Transportation
Industry organizations
Private consultants
International organizations

In several cases, details were developed by the authors where details did not surface during the search process. These details have been labeled as "conceptual". The authors developed these details based on experience with similar details and materials. Owners should evaluate the effectiveness of these details for use in specific bridges.

This information contained herein should be used to develop designs that have the purpose of accelerating the construction of bridge projects. This will assist designers in determining which details would be appropriate for accelerated construction techniques. Some of the considerations for accelerated construction are:

- Improved work zone safety.
- Minimizing traffic disruption during bridge construction.
- Maintaining and/or improving construction quality.
- Reducing the life cycle costs and environmental impacts.

Prefabricated components produced off-site can be quickly assembled, and can reduce design time and cost, minimize forming, minimize lane closure time and/or possibly eliminate the need for a temporary bridge.

This document is organized so that designers can pick and choose the details that will eventually make up the final bridge. In most cases, several options are presented for a particular connection. The details are presented on concise one page (2 sided) data sheets that can be pulled and copied. This will allow the designer to quickly build a "detail library" that will be specific to the intended project.

This document only focuses on "details" for connections of prefabricated bridge elements and systems. Some guidance is given for general accelerated construction techniques. The Federal Highway Administration will publish a more encompassing accelerated bridge construction manual in the future, that will likely include or reference this work.

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The details and information included in this document are examples from previous projects. The agency that developed and used the detail is listed on most of the data sheets. Users of this manual are encouraged to contact the original agencies to ensure that the detail is appropriate for use on the intended project.

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16. Abstract Prefabricated components of a bridge produced off-site can be assembled quickly, and can reduce design time and cost, minimizing forming, minimize lane closure time and/or possibly eliminate the need for a temporary bridge. This document has been developed to promote the use of prefabricated elements and systems in bridges and focuses on "Connection Details" as part of accelerated construction projects. Accelerated Bridge Construction is one of the prime focus areas of the Office of Infrastructure of Federal Highway Administration. It focuses on a need to create awareness, inform, educate, train, assist and entice State DOT's and their staff in the use of rapid construction techniques. This document represents the "State of the Practice" at this time with respect to connections between prefabricated elements in accelerated bridge construction projects. Most of the details were obtained from State Departments of Transportation, industry organizations, and private consultants. This information contained herein should be used to develop designs and determine which details would be appropriate for accelerating bridge construction projects.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
f	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	f
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

LISTING OF ACRONYMS

The following is a listing of typical acronyms that may be found in this document.

Acronym	Definition
ADT	Average daily traffic
AMVA	American Association of Motor Vehicle Administrators
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AISC	American Institute of Steel Construction, Inc.
AISI	American Iron and Steel Institute
AMTRAK	National Railroad Passenger Corporation (Amtrak is not a governmental agency; it is a private company called the National Railroad Passenger Corporation)
ANSI	American National Standards Institute
ASBI	American Segmental Bridge Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
C SHRP	Canadian Strategic Highway Research Program
CD	Compact Disc
CERF	Civil Engineering Research Foundation
CFLHD	Central Federal Lands Highway Division
CFR	Code of Federal Regulations
CRP	Cooperative Research Program (TRB)
CSD	Context sensitive design
DOT	Department of Transportation
ECMT	European Conference of Ministers of Transportation
EFLHD	Eastern Federal Lands Highway Division
EIT	Electronic information and technology
EU	European Union
EUREKA	European Research Coordination Agency
F SHRP	Future Strategic Highway Research Program (now known as SHRP 2)
FAA	Federal Aviation Administration
FAQs	Frequently Asked Questions
FHWA	Federal Highway Administration
FRP	Fiber-reinforced polymer
FY	Fiscal year
GIF	Graphic Interchange Format
GSA	U.S. General Services Administration
HBP	Highway Bridge Program
HBRRP	Highway Bridge Replacement and Rehabilitation Program
HITEC	Highway Innovative Technology Evaluation Center
HRTS	Office of Research and Technology Services
HSIP	Highway Safety Improvement Program
HTML	HyperText Markup Language
IBTTA	International Bridge, Tunnel and Turnpike Association
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
JPEG	Joint Photographic Experts Group
LRFD	Load and resistance factor design
NAS	National Academy of Sciences

NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NCHRP	National Cooperative Highway Research Program
NCSRO	National Conference of State Railway Officials
NDE	Nondestructive evaluation
NEXTEA	National Economic Crossroads Transportation Efficiency Act of 1997
NHI	National Highway Institute
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NIST	National Institute of Standards and Technology
NRC	National Research Council
NSF	National Science Foundation
NTSB	National Transportation Safety Board
OSHA	Occupational Safety and Health Administration
PCA	Portland Cement Association
PCC	Portland cement concrete
PCI	Precast/Prestressed Concrete Institute
PDF	Portable Document Format
PI	Principal Investigator
QC/QA	Quality control/quality assurance
R&D	Research and development
SAFETEA	Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003
SCOBS	Subcommittee on Bridges and Structures (AASHTO)
SCOH	Standing Committee on Highways (AASHTO)
SCOR	Standing Committee on Research (AASHTO)
SFLHD	Southern Federal Lands Highway Division
SHA	State highway administration
SHRP	Strategic Highway Research Program
TIFF	Tagged Image File Format
TRB	Transportation Research Board
TRIS	Transportation Research Information Services (TRB)
TRL	Transportation Research Laboratory
USACE	U.S. Army Corps of Engineers
USDOT	U.S. Department of Transportation
WFLHD	Western Federal Lands Highway Division

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Full Depth Precast Concrete Deck Slabs

Precast Column Connections

Column to Cap Connection using mild reinforcement embedded in grouted post-tensioning duct

Precast Column Connections

Precast Column Connections using Grouted Reinforcing Splice Couplers

Appendix B: Proprietary Products

Prefabricated Superstructure Systems

Inverset

Effideck™

CON/SPAN® Bridge Systems

BEBO® Concrete Arch System

HY-SPAN® Bridge System

Grouted Reinforcing Splice Couplers

NMB Splice Sleeve

Dayton Superior DB Grout Sleeve

Erico Lenton Interlok Rebar Splicing System

Proprietary Retaining Wall Systems

Reinforced Earth® and Retained Earth™ Retaining Walls

Doublewall Retaining Wall

T-WALL® Retaining Wall System

Post-Tensioning Systems

Dydiwag Systems

VSL Post-Tensioning Systems

Williams Threadbar Systems

Appendix C: Sample Construction Specifications

New Hampshire DOT – Prefabricated Substructures

New Hampshire DOT - Full Depth Precast Concrete Deck Slabs

Maine DOT – Prefabricated Integral abutments, piers and approach slabs

Texas DOT Precast Column Connections:

Column to Cap Connection using mild reinforcement embedded in grouted post-tensioning duct

Appendix D: Case Studies

New Hampshire DOT

Mill Street over the Lamprey River, Epping, New Hampshire

Texas DOT

State Highway 36 over Lake Belton, Belton, Texas

Texas DOT
Short Span Local Bridges in Texas
Hypothetical Bridge Replacement Project using All Prefabricated Components.
Details taken from this document
Appendix E: Glossary
Appendix F: References

Introduction

The Federal Highway Administration (FHWA) has undertaken a program called Highways for LIFE. The word "LIFE" in this program title is an acronym for:

L = Long lasting
I = Innovative
F = Fast construction
E = Efficient and safe

The thrust of this program is to change the way we design and build our highways. A former Deputy Secretary for the US Department of Transportation put it best when he stated:

"Change the way we build highways. We need to build them faster, have them last longer, have them be safer and at a lesser cost. Be BOLD and AUDACIOUS in your thinking."

The Highways for LIFE program motto is: "Get In, Get Out, and Stay Out". The first two portions of the motto are self explanatory. The "Stay Out" portion refers to the inherent lasting quality of prefabricated components that are produced in the controlled environment of a fabrication site. Just because something can get built fast does not mean that we need to sacrifice quality. In fact, the exact opposite is true. We can build highways faster and better.

The focus of this Manual is on connections used in prefabricated bridge construction. Prefabrication is not a new concept. The vast majority of bridges built today employ some form of prefabrication. Steel and pretensioned concrete beams are two of the most common prefabricated components. Using prefabrication, large portions of the structure are manufactured off site before construction begins. There are many benefits to the use of prefabricated components; however, this Manual will focus on prefabrication as a means of accelerating bridge construction.

Numerous agencies have experimented with rapid construction techniques when bridges needed to be constructed quickly. There have been many successes, and a few failures. The next logical step in the evolution of this process is to make accelerated construction more commonplace and effective.

This type of evolution is not unprecedented. Forty years ago, parking garage structures were constructed primarily with cast-in-place concrete (either all concrete or concrete on steel framing). Today, in most parts of the country, total precast concrete parking structures are the norm and construction times for these structures have been dramatically reduced as a result. The fact that structures using prefabricated elements and systems are common in a competitive construction market also indicates the economies of this type of construction.

Accelerated Construction Technology Transfer Program (ACTT)

The FHWA has sponsored numerous three-day workshops under their Accelerated Construction Technology Transfer Program (ACTT). During each workshop, a team of national experts visited a state highway agency to brainstorm on a particular project proposed for accelerated construction techniques. Each workshop provided the state agency with a wealth of information to be used as the building blocks for a successful accelerated

construction project. During these workshops, the following were identified as common needs for successfully implementing accelerated bridge construction:

- Quality details
- Long-term performance and durability
- Design methodologies and training
- Construction methodologies

Manual Intent

This Manual is intended to focus primarily on the first three items listed above. Construction methodologies have been partially addressed in previous FHWA manuals and will be further addressed in a future FHWA manual.

This Manual has been prepared through the perspective of an owner agency. It is intended to be used by bridge design engineers at the structure type study phase of a design project. Each bridge will have unique design constraints. The details included in this Manual are not intended to be simply inserted into a design. The bridge design engineer will need to adapt each detail for the specific geometric criteria and structural demands that are anticipated.

The development of a manual on connection details for prefabricated bridge elements and systems must evaluate what techniques have been used in the past. To be considered viable, any connection detail or process needs to pass a test:

- Does it result in a rapid construction process?
- Does it transmit the forces between elements and systems effectively?
- Is it durable?
- Has it performed well under traffic and in exposed environments?
- Is it cost effective?
- If a process or connection is proprietary, can it be incorporated into numerous projects without producing contracting issues?

If the answer to any of these questions is “no”, then the connection should not be considered. The details included in this Manual have passed this test. Performance ratings are given for each detail. In most cases, these ratings were assigned by the agency that submitted the detail and are, therefore, subjective. Users of this Manual should critically evaluate each detail and judge whether it is appropriate for the intended use. The agency and person who submitted each detail are listed. Users are encouraged to contact these engineers for further information on specific details.

Sources of Details

This Manual includes a compilation of details used by various agencies. The vast majority of connection details have been put into practice on bridges. There are several details in the Manual that have not been used on actual bridges; therefore, these are labeled as conceptual.

The details in this Manual were obtained by a solicitation to all 50 state highway agencies; 19 state highway agencies responded. Federal agencies, suppliers, industry groups and fabricators were also contacted. The details that met the criteria listed above were sent to the authors for development of this Manual. In many cases, the details were simply copies of the original contract plans. These

details were re-drafted in order to present a consistent representation throughout the manual. The authors recommend that users of this Manual contact the agency that provided the detail if there are questions. To assist the user, the following information is presented for each connection included in this Manual:

- Agency providing the detail
- Contact person's name, address, telephone number, and e-mail address
- Project description

It is understood that not all contact persons may be available in the future. However, with the information provided, a user should be able to locate persons in each agency who are familiar with the details.

The details provided in this document by no means represent all prefabricated bridge construction projects in the United States. The authors are aware of numerous other projects that were not submitted by the owner agencies. In addition, there are numerous planned prefabricated bridge construction projects that are either in construction or awaiting bidding. Designers should keep apprised of further developments in prefabricated bridge elements and systems through the Federal Highway Highways for LIFE website at:

www.fhwa.dot.gov/hfl/

Manual Format

The Manual has been divided into four chapters. Chapter 1, "General Topics," addresses issues that are common to most connections in bridge construction. Chapters 2, 3 and 4 address issues which are specific to the major portions of typical bridges, in accordance with the terminology in the AASHTO LRFD Bridge Design Specifications [1]:

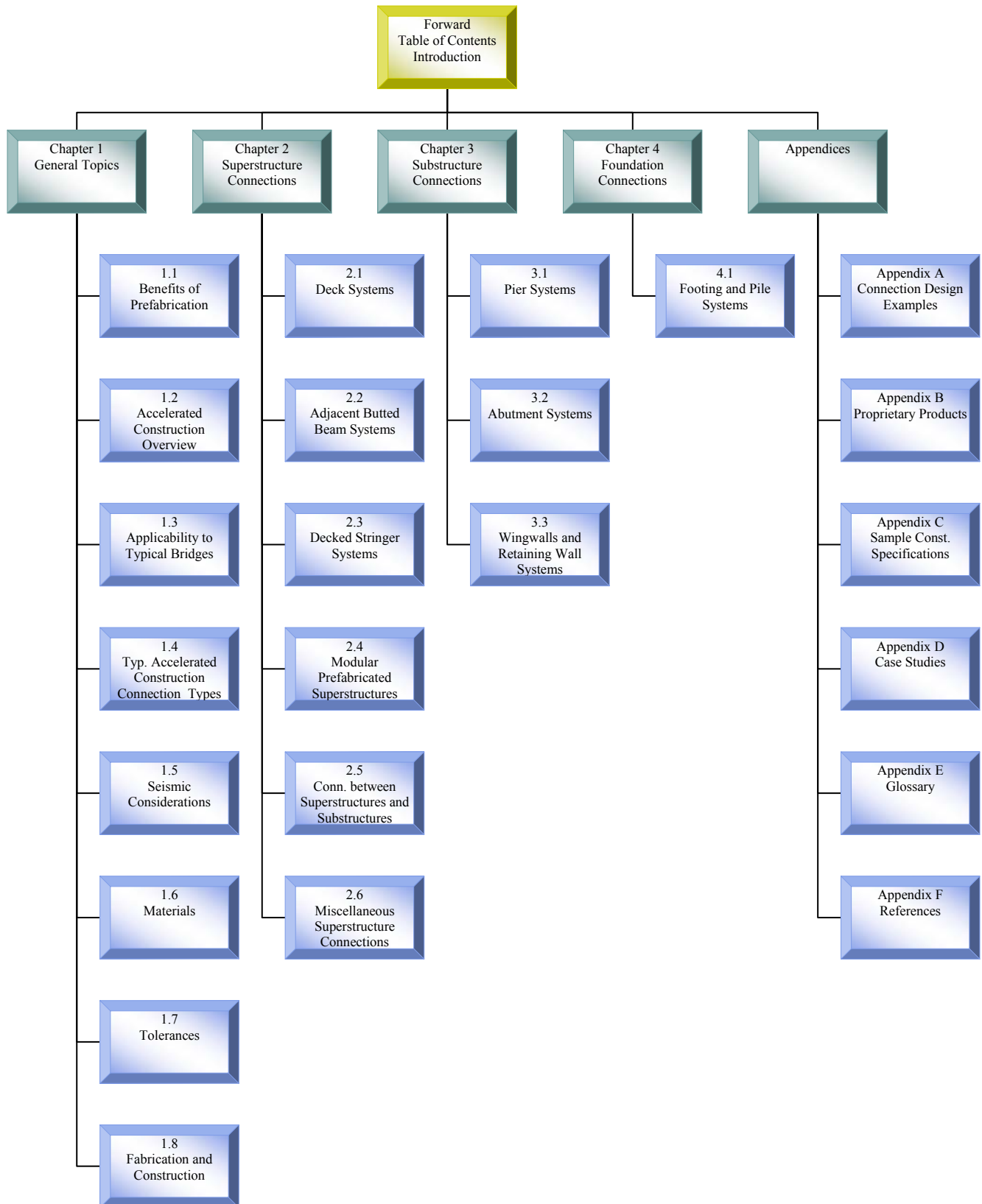
Chapter 2: Superstructures: Decks, beams, stringers, modular
superstructure prefabricated systems, connection between
superstructures and substructures, and miscellaneous
superstructure details

Chapter 3: Substructures: Piers, abutments, walls (to top of footings)

Chapter 4: Foundations: Footings, piles

This Manual is formatted to help users find the correct detail through a logical hierarchy that will be consistent with a web site application. The chart in Figure 1 depicts this Manual layout:

Figure I-1: Manual Format



Detail Classification

To help users of this Manual understand the practicality of each detail, the authors and members of the FHWA Office of Bridge Technology Staff developed a level classification that categorizes each detail based on its frequency of use and effectiveness. This level classification is somewhat subjective; however, it provides the user a measure of effectiveness of the detail. By assigning these levels, the authors and the FHWA staff do not endorse or guarantee the performance of each detail. Users of this Manual are reminded that sound engineering judgment must be applied to all bridge designs.

Three classifications have been developed for this Manual based on the following general criteria:

Level 1

This is the highest classification level. It is assigned to connections that have been used on multiple projects or that have become standard practice by at least one owner agency. Level 1 details are typically practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Some Level 3 details have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in the Level 3 classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

Connection Detail Data Sheets

The authors intend users of this Manual to be able to “shop” for details for use on new projects. To facilitate this use, the details are presented on simple two-page data sheets that can easily be removed and copied from the Manual. Each data sheet contains the following information:

Originating Organization Information:

This information includes the organization, contact person information and a description of the project where the detail was used.

Connection Details:

In most cases, the original contract details are presented; when available, multiple details are presented in order to properly present each connection.

Description, Comments, Specifications and Special Design Procedures:

This section contains additional information on the connection including design information and issues that may have been encountered during the construction of the connection. If photographs were available, they are presented in this section.

Performance Data:

This section contains information on the age and durability of the connection. Agencies were asked to rate the performance of each connection on a scale of 0 to 10 as part of the submission. The ratings include:

- Speed of Construction
- Constructability
- Cost
- Durability
- Inspection Access
- Future Maintenance

Figure I-2 presents an abbreviated sample connection data sheet.

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection

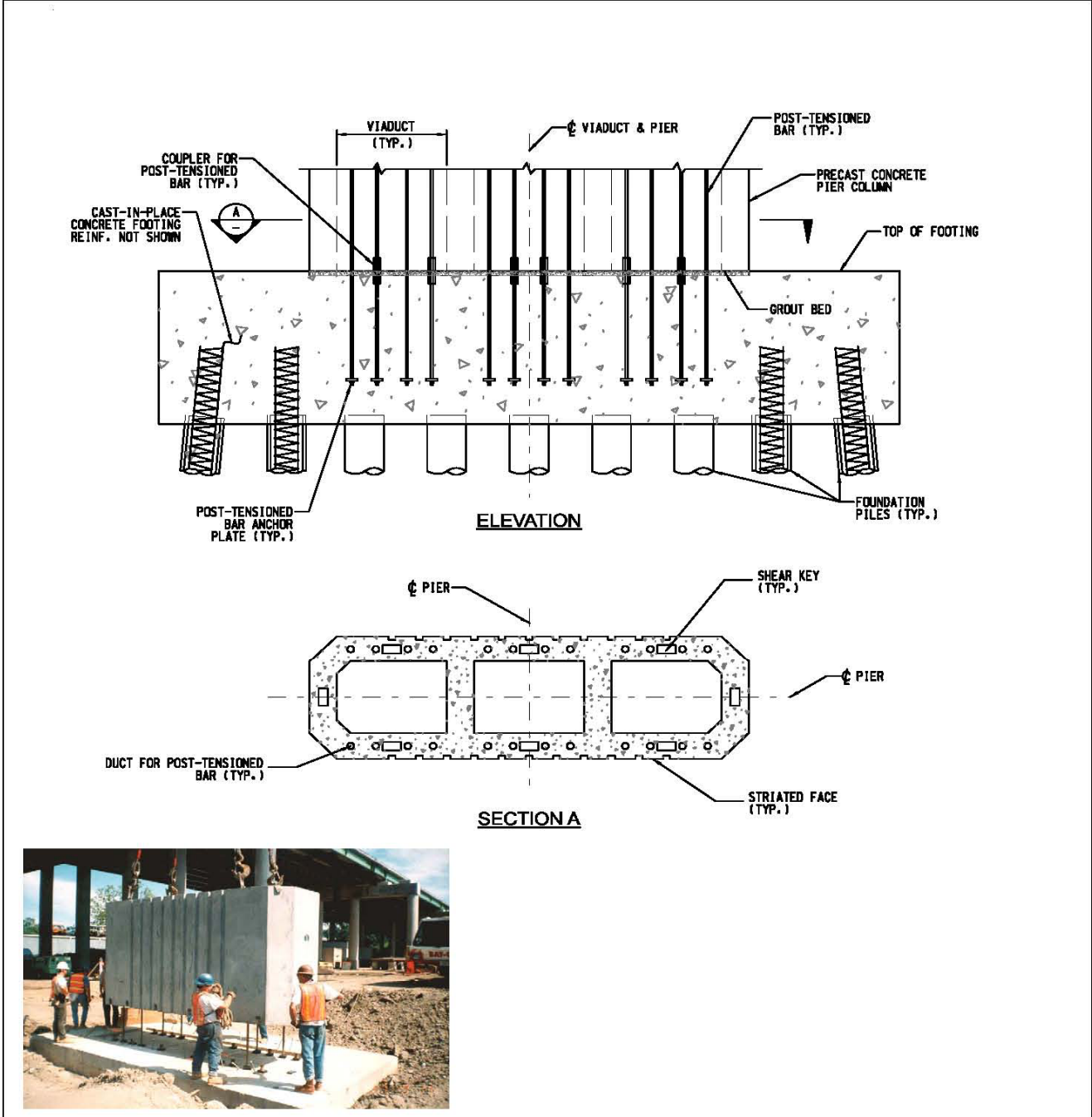


Figure I-2
 Sample Connection Data Sheet – Page 1

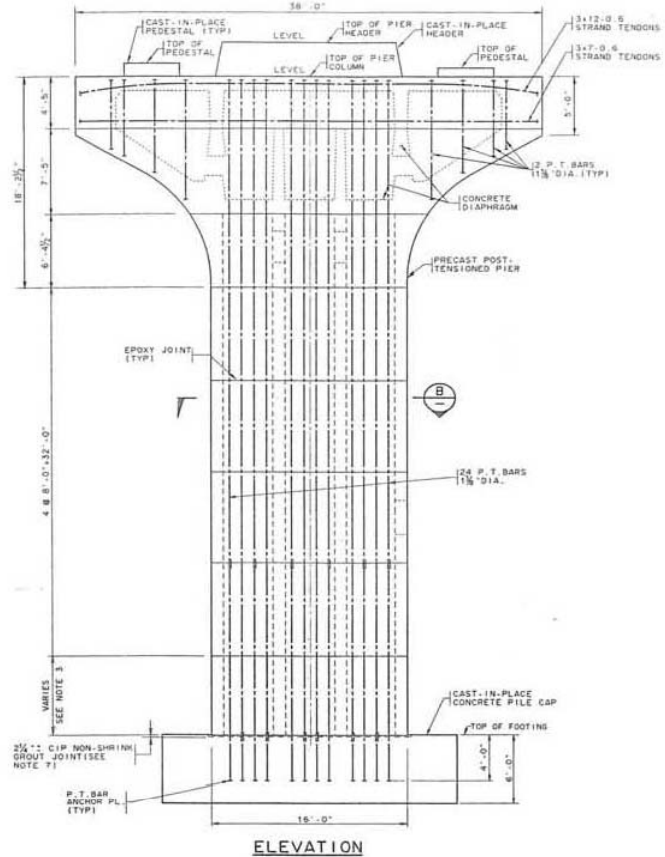
Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast post-tensioned pier were used to speed up the construction. Due to smaller footprint at bottom, this type of pier can be used for viaducts or for elevated rail or expressways in the median of an existing roadway section. This approach is expensive for a small bridge, but it is fast and economical for multiple span bridges with heavy traffic. The subject bridge had 8 bents with 3 piers each = 24 piers.

The detail shown is the connection between the bottom pier segment and the footing. The piece was placed in a grout bed. Intermediate joints were connected sealed and bonded with epoxy adhesive. Shear was transferred between pieces by means of shear keys in the precast pieces.

PT rods were embedded in the cast in place footing and spliced with couplers at several levels. Upon the completion of the installation of all segments, the entire pier was post tensioned.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Figure I-2
Sample Connection Data Sheet – Page 2

Chapter 1 – General Topics

1.1 Benefits of Prefabrication

There are numerous benefits to the use of prefabrication beyond accelerated bridge construction. Prefabrication can improve the quality of bridge elements and systems since they are constructed in a controlled environment using high quality materials and standardized production processes. Improved quality leads to an extension of the structure service life. Prefabrication can also reduce bridge construction costs and life-cycle costs.

A major advantage of prefabrication is that it can reduce onsite construction time, resulting in several key benefits when compared to conventional on-site construction practices:

- **Traffic:** The disruption of traffic is often cited as a reason for using accelerated construction techniques. Reduction in lane closures and the number of days of traffic detours can have a measurable affect on the user costs of a highway system.
- **Safety:** By reducing the amount of construction that takes place at the site, the amount of time that construction crews and motorists are exposed to the dangers of work-zones is also reduced. In addition, prefabrication can improve construction crew safety when working over water or in hazardous conditions such as when construction is adjacent to high voltage power lines.
- **Environmental:** Often environmental permitting requirements limit onsite construction, for example, to certain seasons of the year. These limitations effectively reduce the number of available calendar days for construction. Prefabrication and accelerated construction can keep a project on schedule even with fewer available working days and other environmental limitations at the site.
- **Weather:** As with environmental constraints, many areas of the country have limited work seasons due to severe winter weather. Prefabrication and accelerated construction can be used to complete more construction during a short construction season.

1.2 Accelerated Construction Overview

This section includes a brief overview of the accelerated construction process for bridges. Several FHWA documents on accelerated construction already exist and are hereby referenced to supplement this section:

- Decision-Making Framework for Prefabricated Bridge Elements and Systems (PBES) [2]
- Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges [3]

A future FHWA manual is planned that will present information on accelerated bridge construction systems and processes that are not directly related to connections. This manual will include concepts such as total bridge prefabrication and installation.

1.2.1 When to Use Accelerated Construction

There are a number of scenarios where accelerated bridge construction is appropriate. On many projects, construction of the bridges is the critical path to the overall completion of the project. This may not be the case for large roadway projects where there are few bridges. In this case, the roadway construction is usually the critical path.

At this time, there can be a cost premium for using accelerated bridge construction techniques. Many designers believe that this will change in the future as more accelerated bridge construction projects are undertaken. Contractors and fabricators will continue to become more proficient in the techniques, thereby improving the economy of accelerated construction. Other common scenarios that can offset or justify additional costs for accelerated construction include:

- **Improved Safety:** Any change to traffic flow can increase safety risks to motorists. Reducing onsite construction time reduces these safety risks to both motorists and construction crews in the work zone.
- **Elimination of Temporary Bridges:** Temporary bridges are often used for projects where detours are undesirable and staging is not feasible. However, a short-term detour combined with accelerated bridge construction can often be used instead of a temporary bridge, thereby reducing the overall project cost.
- **Elimination of Detour Repairs:** Roads used for detour routes are often not designed for the high traffic volumes over the extended periods required for conventional construction. Accelerated construction can eliminate the need for detour repairs.
- **Reduced User Costs:** User costs for highly congested highways can be significant, often exceeding the additional cost of accelerated construction. Several states account for user costs for projects in the preliminary design phase of most projects in order to make educated decisions on the approach to the project. The user costs are factored into the cost for each construction option considered.

1.2.2 Rehabilitation Projects

Several types of rehabilitation projects commonly use accelerated construction techniques. Often bridge rehabilitation projects present the greatest challenges for maintaining traffic flow during construction. Common rehabilitation projects that use accelerated construction techniques are:

- **Bridge Deck Replacement:** Many states (especially in northern environments) are experiencing bridge deck life-spans that are less than the life span of the overall bridge. New high performance materials and protective coatings can extend the life of a bridge deck; however, a large percentage of the national bridge inventory includes bridges with decks that will need to be replaced in the next 30 years. Prefabricated bridge deck elements made with precast concrete, filled steel grids and fiber reinforced polymers have been successfully installed on existing bridges with either weekend or overnight lane closures.
- **Superstructure Replacement:** Bridges with deteriorating bridge decks often have deteriorating support beams as well. The cost of removing lead paint on steel or repairing deteriorated concrete can approach or exceed the cost of new beams. If a bridge deck is already scheduled to be replaced, and repairs are anticipated to the support framing, it may be cost effective to replace the entire superstructure. In this case, a full prefabricated superstructure can be a means to replace the entire bridge superstructure in as little as one night.

1.2.3 Typical Accelerated Construction Approaches

During the development of this Manual, there have been several common types of approaches to accelerated bridge construction projects:

1.2.3.1 Short-term Full-Closure Projects

This approach involves the full closure of the roadway for an extended (but shortened) period of time. In this case, the contractor is given free use of the entire site, which will often result in very fast construction. This option is feasible if there is a reasonable detour around the project area. There are impacts with local businesses with this option; however, several states have noted that the businesses can better tolerate a short-term full closure when compared to a lengthy construction process.

1.2.3.2 Weekend Closures

On many bridge sites, traffic volumes drop off dramatically during weekends. This is especially true for urban environments. In many cases, multiple lanes and even entire roadways can be closed for approximately 50 hours during a typical weekend. By using prefabrication, bridge decks and entire superstructures can be replaced and re-opened to traffic during this time frame.

1.2.3.3 Overnight Closures

A typical overnight construction window is limited to 8 hours or less. This limits the amount of work that can be accomplished even with the use of prefabrication. In this scenario, full or partial

superstructure prefabrication is often employed. Several projects have been successfully completed using these techniques. The most dramatic involved the placement of an entire superstructure in less than one hour.

1.2.4 Examples of Prefabricated Elements

For the purposes of this manual, the term “Elements” describes individual prefabricated components that make a system, e.g., deck panels are elements that make a superstructure system and bent caps are elements that make a substructure system.

Prefabrication is not a new concept. The vast majority of bridges built today employ some form of prefabrication. Steel and pretensioned concrete beams are two of the most common prefabricated elements on typical bridges. Partial-depth precast concrete deck panels have also been used in some regions for many years. Other common accelerated bridge elements include:

- Full-Depth Prefabricated Decks: Several different types of prefabricated decks are used, including full-depth precast concrete panels, steel grids (unfilled, filled and exodermic), fiber reinforced polymer panels, and glue laminated timber panels.



Figure 1.2.4-1 Full Depth Precast Deck Panels

- Pier Caps: Several states use precast pier caps due to the difficulties of casting a large concrete element high in the air or over water. Precast pier caps have been used on both pile bent piers and standard concrete pier bents.



Figure 1.2.4.-2 Precast Pier Cap

In recent years, states have used more prefabricated elements to build bridges faster. These include:

- Pier columns
- Pile cap footings
- Abutment stems
- Integral abutments
- Footings
- Barriers

These elements will be discussed in more detail in the following chapters.

1.2.5 Opportunities for Architectural Treatments

An ancillary benefit of prefabrication is the opportunity to incorporate architectural features. Many prefabricated elements are made with precast concrete. Several states (Texas in particular) have taken advantage of precasting to apply significant architectural features to the prefabricated bridge elements. Figure 1.2.5-1 shows a precast pier cap constructed on a pair of cast-in-place columns. Architectural treatments typically found in building construction can also be applied to bridge projects. This gives designers significant opportunities to work with communities in the context sensitive design process to produce bridges that are preferable to the users.



*Figure 1.2.5-1 Lake Belton Bridge
(Photo Courtesy of TX DOT)*

1.3 Applicability to Typical Bridges

Prefabrication and accelerated construction are not limited to large scale or signature bridges. Many states are applying this technology to ordinary bridges. Prefabrication and accelerated construction techniques can be applied to a variety of bridge projects, as discussed below:

1.3.1 New Bridges

New bridge construction offers a significant advantage when compared to rehabilitation or replacement projects in that there is often little or no conflict with traffic. These sites are often the least constricted; therefore, larger equipment can be used to move and erect the prefabricated pieces. Even if traffic control is not an issue, prefabrication and accelerated construction can be used to minimize impacts to the environment and to build a bridge faster in a harsh environment. In addition, the use of identical repeating elements, for example, precast pier caps, reduces costs.

1.3.2 Replacement of Existing Bridges

Bridge replacement projects differ from new bridge projects in that there is usually a need to maintain traffic on the roadway. In some cases, a detour can be arranged; however, detours can have a devastating impact to local communities and businesses. Prefabrication and accelerated construction can be used to reduce the time that detours are in place to minimize the impact of the project on the community.

In cases where traffic must be maintained, accelerated construction can be used to reduce the time for lane closures and diversions. It can also eliminate the need for temporary bridge structures. If a bridge can be replaced with an existing detour route combined with accelerated construction, the owner agency can save the significant costs and eliminate the environmental impact of a temporary bridge.

1.3.3 Rehabilitation of Existing Bridges

In parts of the country where there is already a mature highway network, a large portion of the assigned bridge projects involve rehabilitation of existing bridges. In many cases, this involves deck replacements, superstructure replacements, and bridge widening. Prefabrication and accelerated bridge construction techniques have proven very valuable for these types of projects, especially where lane closure limitations are severe. Many prefabricated bridge rehabilitation projects, for example, deck replacements, have been successfully completed in as little as one weekend.

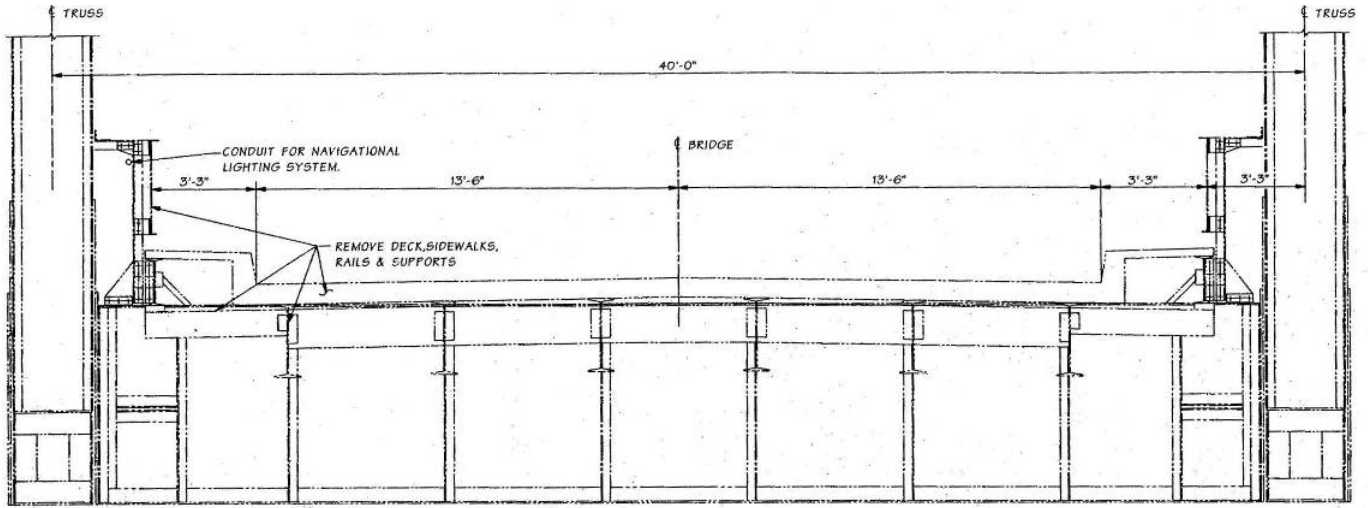
1.3.4 Issues with Curved, Skewed and Flared Bridges

The complexity of the geometry of curved, severely skewed, or flared bridges combined with the lack of repetitive details makes prefabrication for these types of bridge a challenge. This does not preclude the possibility of using prefabrication for these structures, however. Prefabricated bridge deck replacement projects have been completed on bridges with significant skews and flared exit ramps, and prefabrication can be the solution of choice when widening or rehabilitating these

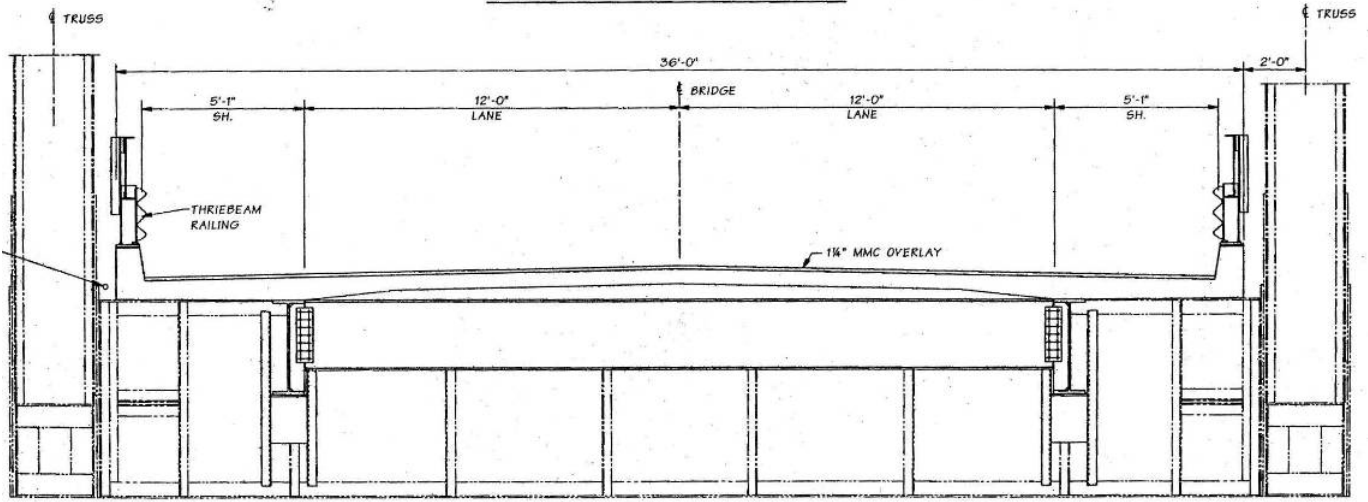
structures over traffic. Attention to tolerances and field fit-up is essential for these complex structures.

1.3.5 Truss Bridges and Girder-Floorbeam Bridges

Truss bridges and bridges with girder-floorbeam systems offer unique challenges, but also an opportunity for prefabrication. During one successful project, the entire floor system was replaced with only overnight traffic closures. In this example, the deck on the Lewis and Clark Bridge in Washington State was replaced using a precast deck/stringer system. Figure 1.3.5-1 shows the original and the final cross-section of the bridge. The floorbeam system on the truss bridge was highly stressed in bending, but had reserve shear capacity. By varying the spacing of the stringers, the designers were able to reduce the bending moments in the floorbeams, thereby increasing the load capacity of the bridge. By using an innovative gantry crane, full-width sections were removed and replaced with full-width prefabricated sections during night closures.



SECTION - EXISTING DECK



SECTION - NEW DECK INSTALLED

*Figure 1.3.5-1 Lewis & Clark Bridge
(Detail Courtesy of Washington State DOT)*

1.4 Typical Accelerated Construction Connection Types

During the development of this manual, information on various types of prefabricated connections were collected from across the country. The details can be categorized into several common types. These types make up the majority of connections discussed in this manual.

1.4.1 Steel Elements

1.4.1.1 Bolted

Bolted connections have been used to connect prefabricated bridge elements for many years. The process of bolting two pieces of steel together can be very fast for some connections and slow for others. Girder splices tend to be slow connections due to the large number of bolts required to make the connection.

One way to speed up construction of bolted connections is to allow a contractor the option to place only a portion of the bolts before the crane releases a particular piece. The National Steel Bridge Alliance is currently writing a steel bridge erection guide that will likely recommend that 50 percent of all bolts in each portion of a connection be installed prior to member release. This means that 50 percent of the bolts in the flanges and the webs need to be in place. By allowing a crane to release an element faster, the overall construction can proceed more rapidly.

1.4.1.2 Welded

Field welding is not as common as field bolting in most states. This is due to several factors:

- Lack of certified field welders
- Difficulties with welding in colder environments
- Concerns with the quality of field welds
- Time

Recently, several states have started to expand the use of field welding and have developed procedures that address these concerns. These new procedures show promise to increase the speed of steel element connections.

1.4.1.3 Cast-in-Place Concrete Closure Pours with Shear Studs

Several structure types make use of concrete to connect two steel elements. The idea of connecting two girders at a bridge pier shows the most promise. The concept is to design the girders as simple spans for dead load and as continuous spans for live load. This concept has been used for many years in the precast industry. The connection of two steel girders can be made by encasing the girder ends in a concrete closure pour. The live load continuity connection is transferred through the reinforced closure pour and back to the steel member via welded stud shear connectors, or bearing plates. Depending on the geometry of the closure pour, the shear studs can be placed on the girder flanges or webs.

1.4.2 Concrete Elements

1.4.2.1 Principles of Emulation Design

The American Concrete Institute has published a document entitled “*Emulating Cast-in-Place Detailing in Precast Concrete Structures ACI-550.1 R01*” [4]. The goal of emulation design is to achieve performance of a prefabricated system that is comparable to a cast-in-place system. For emulation design in seismic regions, the goal is for a prefabricated system to be comparable to a cast-in-place system in performance such as energy dissipation, ductility, stiffness, strength, and similar reliable failure modes. Cast-in-place concrete structures are built with construction joints that usually involve lapped reinforcing bars. The principal of emulation design is to substitute an alternate connection that mimics or “emulates” the standard lap splice. This approach has been developed primarily by the precast parking garage and hotel industry. By using emulation, a bridge designer or contractor can substitute precast concrete elements for traditional cast-in-place elements.

ACI-550.1 goes into great detail on different connections; therefore, the authors suggest referring to this document. The following sections outline some of the most common emulation connections:

Grouted Reinforcing Splice Couplers

Several manufacturers have developed couplers that can splice large diameter reinforcing steel bars within precast elements. These couplers are typically hollow cast steel sleeves (similar to a pipe). The sleeve is cast into the end of one element and a protruding reinforcing bar is cast in the end of the adjacent element. The elements are connected by inserting the protruding bars from one element into the hollow end of the coupler in the other element. The joint between the pieces is then grouted, and grout is pumped into the couplers to make the connection.

Casting tolerances are important with these couplers; however, the precast industry has demonstrated on many projects that the required tolerances are achievable on plant produced precast products.

Large diameter bars can be spliced in distances that are much less than conventional development lengths; an attribute which makes this connection desirable for substructure connections with large bars (pier caps, columns, etc.). These connections can be made quickly in tight confines. It is reasonable to obtain a full moment connection in as little as 12 hours. Temporary struts can be used to allow erection of the elements prior to grouting.

Sleeved connections are most often used in the vertical direction. They can be used in the horizontal direction, but this can complicate the erection procedure because of the difficulty of rigging a large element with small tolerances.

These connections have been thoroughly tested and can develop up to 125%, 150% and even 160% of the specified yield strength of the reinforcing bars.

Grouted Post-Tensioning (PT) Ducts

Several states have experimented with the use of PT ducts for connections between precast concrete elements. These connections are similar to grouted reinforcing splice couplers in that reinforcing bars or threaded rods are inserted into a sleeve made up of standard post-tensioning duct. The difference is that the duct is non-structural; therefore, additional confinement reinforcing is required around the pipe to develop a significant connection. The PT duct is much larger than a grouted coupler; therefore, tolerances are not as strict. Research to date has demonstrated that significant moments can be achieved with this system; however, the system is currently not recommended for high seismic areas that require plastic hinging of connections. These connections have not demonstrated the required ductility required in high seismic zones.

Grouted Voids

Like PT ducts, these connections are similar to grouted splice couplers except the coupler is simply replaced with a void cast in the receiving element. These connections typically have been used on connections that are considered pin connections that will transfer little or no moment between the elements.

Traditional Post-tensioning (PT)

PT connections have been used between precast concrete elements for years. The most common type of PT connection is between pieces in a segmental box girder bridge. Several states have also used PT for connections in pier columns and pier caps. Another common use of PT is in precast concrete bridge decks. Many states have used PT combined with grouted shear keys to connect deck elements (typically the PT is run in the longitudinal direction on typical stringer bridges). The PT systems often used include multiple grouted strands in ducts and grouted high strength thread bars.

Welded Connections

Precast elements can be connected using welding. This process is common in the building and parking garage industry. Steel plates are embedded in the precast elements and a welded connection is made after erection. Several states have developed and researched welded connections for precast butted beam systems such as slabs, double tees and even deck bulb tee girders.

Bolted Connections

Bolting of precast elements is rare, due to the difficulties of working with the tight tolerances required for quality bolting.

Several states have used bolting to connect steel diaphragms on parallel precast stringer bridges; however, differential camber between members can make this connection difficult. Another use of bolting is to connect precast concrete parapet elements. Several states have used bolts that are drilled and grouted into the bridge deck to secure the precast parapet to the deck. Designers should check with each state regarding these connections; some have not been crash tested and approved for use on the national highway system.

Cast-in-place Concrete Closure Pours

One of the simplest connections that can be made between two precast concrete elements is to leave a small area between the elements to allow for a closure pour of cast-in-place concrete. This is often done on horizontal connections that make sleeved connections difficult to achieve. The connection is usually made using simple lap splices.

1.5 Seismic Considerations

During seismic events, connections between bridge elements must resist the highest force demand and cyclic effects. This section discusses current criteria for seismic details, and provides information on current and proposed research.

1.5.1 General Criteria

The design and detailing of elements and connections in a prefabricated bridge for seismic forces generally needs to be similar to designs and details in non-prefabricated bridges. All provisions specified in AASHTO LRFD Bridge Design Specification [1] need to be satisfied in any bridge. This includes, but is not limited to, reinforcing steel in footings, plastic hinge zones, column confinement, and connections between the superstructure and substructure. There is on-going research into alternate connection designs for high seismic regions [5]

1.5.2 Connection of Superstructure to Substructure

There are several methods of connecting normal stringer bridges to the substructures. In most cases, these connections are designed to transmit lateral seismic forces from the superstructure to the substructure. It is also possible to make the connection integral.

Pinned Connections

In most states, the connection of the superstructure to the substructure is detailed as a pinned connection. Integral connections are also specified, but are not as common. The most common type of pinned connection is through the bearing device. The forces are transmitted from the superstructure, through the bearing and then into the substructure. Often this is accomplished using anchor rods. However, the current AASHTO design specifications do not address the resistance of embedded anchor rods in concrete. A pending revision to the AASHTO specifications will include a reference to the American Concrete Institute Building Code Requirements for Structural Concrete (ACI 318), Appendix D [6]. This ACI code addresses

the issue of resistance of imbedded anchor rods in great detail.

Another means to provide lateral restraint is to install keeper assemblies adjacent to beams. Keeper assemblies usually consist of concrete keys placed between two interior beams to transmit lateral forces from the superstructure to the substructure. The assemblies are usually cast after the beams have been erected; therefore, tolerances are not a significant issue. Longitudinal seismic forces can be resisted by the abutment backwall. Keeper assemblies are often the most cost effective means of restraining a bridge for seismic events in low seismic zones. They are especially desirable on skewed concrete pier bents where the tight confines of reinforcing steel make installation of anchor rods very difficult (if not impossible). The location of the reinforcing steel in the keeper assemblies is not as critical as an anchor rod; therefore they can be easily adjusted to fit the field conditions. Figure 1.5.2-1 shows a typical keeper assembly used in the northeast states.

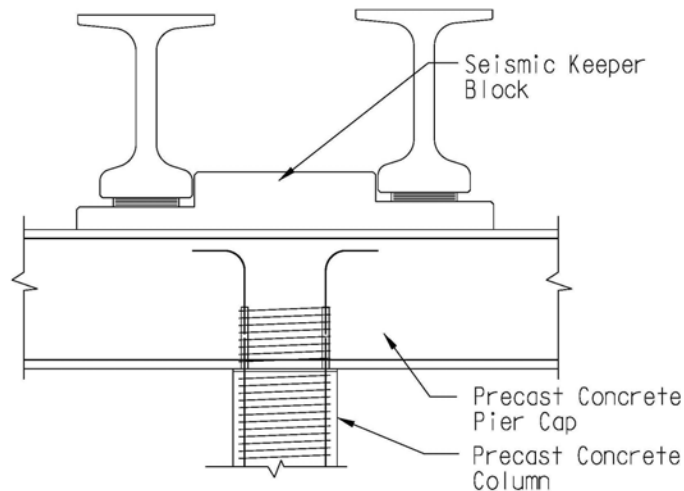


Figure 1.5.2-1 Concrete Keeper Assembly

There are other options for seismic restraint such as cable restrainers and seismic isolation devices. These methods are also acceptable; however, they are not commonplace and are therefore not included in this Manual.

Moment Connections

Moment connections between substructures and superstructures are used to provide additional stability to the structure during seismic events and to eliminate bridge deck joints. These connections can also reduce lateral displacements of the structure and reduce forces in the foundations. Integral pier connections and integral abutment connections are common in high seismic regions. This requires high moment demand on the connections. The most common type of connection between prefabricated elements is a cast-in-place closure pour. There is concern in the

industry that grouted reinforcing splice couplers and grouted PT ducts are not capable of developing plastic hinges in these high demand connections; therefore their use has been limited. It is anticipated that future research will address these concerns. See Section 1.5.4 for more discussion on this topic.

1.5.3 Superstructure Connections

In conventional stringer bridges having no integral connection between the superstructure and substructure, there is relatively low force demand on superstructure elements. The superstructure does see seismic forces; however, the majority of the seismic induced forces are found in the substructure. If the superstructure is integrally connected to the substructure, large seismic forces can be transmitted to the superstructure. In this scenario, engineers must take care in designing connections between prefabricated bridge superstructure elements in addition to connections in substructure elements, including superstructure design for overstrength conditions.

1.5.4 Columns and Column Connections

Columns are often the most heavily loaded elements during a seismic event. Special care must be taken to properly detail connections in precast concrete column elements. In high seismic regions, columns are designed to form plastic hinges and contribute to dissipation of seismic forces. The high demand region on a typical column is at the ends where the column connects to the footings and pier caps.

Semi-ductile moment connections can be made in precast elements by using grouted reinforcing splice couplers for longitudinal reinforcing steel confined by transverse reinforcing steel. Research from Japan has shown that the grouted reinforcing splice couplers can fully develop the longitudinal reinforcing bars as well as contribute to shifting the plastic hinge away from the extreme end of the column [7].

Grout filled reinforcing splice couplers are capable of developing 125% reinforcing steel yield strength. Some states require at least 150% of the specified steel yield strength of the bar be developed for splices in plastic hinge zones. Some grout filled reinforcing splice couplers and grouted post-tensioning duct can also achieve this level of strength.

The AASHTO specifications allow for splicing 100% of the longitudinal bars with mechanical splices at one location for low to moderate seismic zones. Low seismic zones are defined Zones 1 and 2 in the LRFD Specifications [1]. For higher seismic categories and zones, the codes require staggering every other bar by a distance of 24 inches (Section 5.10.11.4.1f of the LRFD Specifications [1]). A grout filled reinforcing splice coupler behaves differently than a lap splice. The strength of the splice is not dependent on the concrete surrounding the sleeves. Therefore, limitations for locations of lap splices caused by lack of cover concrete in the hinge zones in theory should not be applicable to mechanical connectors. There are ongoing discussions within the industry on this topic, and future research may explore this issue.

There is one way to meet the AASHTO requirements using grouted reinforcing splice couplers. The designer can detail one-half of the sleeves on one side of the connection and one-half of the sleeves on the other side of the connection. Another way to accomplish this is to place the mechanical connectors within the footing where loss of confinement is not a factor; however, locating the connectors in a pier cap connection may still be an issue due to possibility of loss of cover on the side faces of the pier cap.

Confinement Reinforcement

Some designers believe that the only way to confine column reinforcing is to use spiral confinement reinforcing that passes into the footing or pier cap, making precast columns impractical. This, however, is not the case. AASHTO provisions for confinement based on cast-in-place concrete construction should be followed.

Longitudinal bars can be confined with transverse ties detailed in accordance with the AASHTO specifications. Transverse ties can be used in place of spiral stirrups as long as they are properly detailed to achieve confinement. The AASHTO LRFD Specifications [1] states:

“Column transverse reinforcement, as specified in Article 5.10.11.4.1d, shall be continued for a distance not less than one-half the maximum column dimension or 15.0 in. from the face of the column connection into the adjoining member.”

Section 5.10.2.2 states:

“Seismic hooks shall consist of a 135°-bend, plus an extension of not less than the larger of 6.0 db or 3.0 in. Seismic hooks shall be used for transverse reinforcement in regions of expected plastic hinges. Such hooks and their required locations shall be detailed in the contract documents.”

These provisions do not require the confinement steel to pass through the joint between the column and pier cap or footing. Therefore, it is acceptable to properly terminate the transverse tie confinement steel at the end of the precast column, and also in the adjoining member by using ties in place of spiral reinforcement. The AASHTO Subcommittee on Bridges and Structures continues to look into these issues; therefore, users of this Manual should refer to the AASHTO specifications for the latest requirements.

1.5.5 Footings

The design of precast footings for seismic forces should follow normal procedures for cast-in-place concrete footings. Requirements must be met for confinement of column dowels.

1.5.6 Deep Foundations

If precast pile caps are used, special details may be required to provide

pile uplift and moment capacity in precast footings. Several states have developed details for footing connections that consist of extending the pile reinforcing into a concrete closure pour pocket. Several conceptual methods for connecting a precast footing to steel or precast piles have also been developed by the Northeast Regional PCI Bridge Technical committee and are included in data sheets in this manual.

Several states have used prefabricated concrete panels to form a cofferdam on top of precast piles and drilled shafts. These cofferdams eliminate the need for deep sheeting and dewatering that have been commonly used for years. The prefabricated panels form a pier box that when used in conjunction with a tremie concrete pour provide a platform and area in which to cast the pier footing and connect it to the drilled shaft or pile below.

1.5.7 Research

There is ongoing research into connections between prefabricated elements in high seismic zones, including column and cap-to-column connections using various types of connectors. Designers should refer to the results of these research projects for guidance.

1.6 Materials

This section provides an overview of the many different types of materials used in prefabrication and discusses the impact of the materials on accelerated construction processes.

1.6.1 Concrete

Concrete is a popular material for prefabrication and accelerated construction projects. The ability to build elements off site in virtually any shape makes this material a prime choice for designers. Common prefabricated concrete elements include beams and girders, full depth deck slabs, and pier caps. Several states have built entire bridges using precast concrete elements including pier columns, abutment stems, footings, and retaining walls.

Concrete is also used for making connections between different prefabricated bridge elements. These connections often require the use of high early strength concrete to allow for accelerated construction processes.

Durability is a major concern of bridge owners. The new generation of high performance concretes offer durability that far exceeds the performance of past concretes. Plant produced precast concrete also has the advantage of being constructed in a controlled environment with higher production and curing standards than normally found in the field. This benefit of accelerated construction projects is often overlooked by designers.

1.6.2 Structural Steel

Steel elements are well suited for prefabrication and accelerated construction. There is a high degree of control over fabrication tolerances; therefore, complex connections can be employed using structural steel. Common elements include steel beams and girders, steel grid decks (including concrete and grid exodermic decks), and steel railings. Other less common applications include steel pier columns and bents.

One advantage that steel has over precast concrete is that it typically weighs less than an equivalent concrete element. This factor can be critical when shipping and crane capacities limit the amount of room for erection. A disadvantage relative to precast concrete is steel's greater flexibility. More attention is required to ensure deflections and internal stresses of elements and systems are not exceeded during transport.

1.6.3 Timber

Timber bridges were common in the 1800's. There has been a resurgence in the use of timber as a bridge material during the last two decades. The use of glue laminated products and the introduction of composites make the design of larger timber bridge elements more practical and cost effective. Common types of prefabricated timber bridge elements include glue laminated deck panels and glue laminated beams and stringers.

1.6.4 Fiber-Reinforced Polymers (FRP)

There has been much research into the use of fiber-reinforced polymers in recent years. Many states and universities have experimented with these materials. The development of carbon fiber polymers has made the use of FRP materials practical for bridge applications. Types of FRP bridge elements include beams and stringers and full-depth deck panels. The state of New York has had FRP deck systems in place for almost a decade with excellent performance.

1.6.5 Grouts

The majority of precast concrete elements discussed in this Manual are joined with grout. The connections between precast concrete elements require the use of grout to fill the void between the adjoining elements. Nominal width joints are required for several reasons. The primary reasons are to allow for element tolerances and to make adjustments in the field. See Section 1.7 for more information on element tolerances.

Non-shrink cementitious grout is most often used to easily and efficiently provide a durable, structurally stable connection between precast concrete elements. Epoxy grouts can be used; however, they tend to have a low modulus of elasticity and are expensive when compared to cementitious grouts. In order to achieve desired results, careful selection and specification is required when using non-shrink grouts.

1.6.5.1 Grout types

There is no such thing as a generic non-shrink grout. There are several different types of grouts, each with its own advantages and disadvantages. Cementitious non-shrink grouts are inexpensive, generally easy to work with, and develop adequate strengths in reasonable time. These grouts are often pre-packaged and can be extended using small diameter stone for larger pours. Cementitious grouts are ideal for static and light dynamic loadings. This section will focus on cementitious non-shrink grouts since they are adequate for virtually all prefabricated connections. Other grout types may be acceptable for precast connections but require additional specification and suitability considerations on the part of the designer.

Ideally a non-shrink cementitious grout will not exhibit dimensional change in the plastic or hardened state. To achieve non-shrink characteristics in grout, additives are mixed into the grout to counteract the natural tendency of grouts to shrink. There are different types of additives for cementitious grouts in the market. The additives have certain advantages and disadvantages. Several common additives are as follows:

Gas generating:

This is the most common grout type. A chemical substance is added to the grout mixture to control shrinkage. In most cases, an aluminum powder is used. A chemical reaction occurs with the

aluminum powder and the alkalis in the cement during the plastic phase to form hydrogen gas. The generated gas is used to promote expansion.

However, because small amounts of aluminum powder are used, the expansion can be difficult to control under various conditions. This uncontrolled expansion can cause bleed water to form at the grout surface that can cause loss of support and bond. This has led to the development of alternative compounds that can ensure a quality grout under varying conditions.

Ettringite:

Ettringite expansive grout relies on the growth of ettringite crystals during the hardened state to counteract shrinkage.

Air release:

Air release grouts do not rely on a chemical reaction to achieve expansion. The additive reacts with water to release air and cause expansion.

1.6.5.2 Environmental Conditions

Each of the additives mentioned above rely on specific conditions to achieve a desired result:

Temperature:

The temperature at the time of placement needs to be carefully controlled for some grouts. In particular, gas generating non-shrink grouts have a small window of acceptable temperatures for achieving the desired expansion. Cold temperatures can inhibit the chemical reaction, thus limiting expansion. Higher temperatures can cause rapid expansion that limits placement time. The typical temperature range for grout placement is between 40 and 90 degrees Fahrenheit. Designers should investigate manufacturer's requirements for grouting in temperatures beyond these typical ranges. For extreme conditions, the area may need to be heated or cooled during the curing process.

Moisture:

Water should always be added to non-shrink grout in strict accordance with the manufacturer's specifications. Deviation from specified water content can adversely affect the performance of the grout. Trial batching of grout should always be specified in contract documents.

For example, ettringite crystals grow during the grout's hardened state. If too little water is added or if water is drawn out of the mixture due to a dry surrounding substrate, the expansive growth will be less than desired. Conversely, over-watering can cause segregation, increased shrinkage and reduced strength. Over-

watering can cause bleed water to accumulate at the grout surface, leading to loss of support and bond.

Surface preparation:

Additives used in non-shrink grouts rely on moisture to achieve expansion and counteract shrinkage. A dry concrete substrate will draw water out of the grout mixture and cause a weak layer to develop at the grout member interface.

Surface preparation is of particular importance for grouts with low water content, since a small loss of grout moisture can lead to a brittle grout. Concrete surfaces should be wetted to a saturated surface dry (SSD) condition prior to application of grout. SSD conditions are achieved when the base concrete is moist; however, there can be no standing water present.

There are common misconceptions as to how to achieve a SSD condition. Many contractors will simply apply water to the interface just prior to grout placement. Proper SSD conditions usually require pre-soaking the area for a specified time. Each manufacturer has recommended pre-soak times, which should be followed. (Note that epoxy grouts do not require pre-soaking).

1.6.5.3 Placement Methods

Depending on the size and location of the void to be grouted several different techniques are used for placement:

Dry Pack:

Dry pack grouting does not require the use of formwork; however, dry packing is labor intensive and requires highly skilled workers in order to place the grout properly. This method involves using a very dry grout that can be balled up in the hand. Dry packing should only be used for small voids that are easily accessible. The process involves ramming the grout into place with tools (not only by hand). If the space is not confined, there will be no place to pack the grout against, which will result in loose placement and a poor quality joint.

Pouring:

By varying the water content according to the manufacturer's specifications, grout can exhibit a near fluid consistency. Fluid grouts can be poured into voids by gravity feed if there is access to the void from the top. Placing grout by pouring requires the use of forms and a head box to ensure containment and proper placement. The forms should be designed to resist the hydraulic head that will develop in the connection. Foam backer rods have very limited resistance to significant pressure and should only be used for very small vertical pours. Solid forms should be used for most applications.

Pumping:

Typical pumping applications use grouts that exhibit a flowable consistency that is stiffer than fluid consistency. Therefore, less water can be used in the grout which will result in higher compressive strengths. Pumping should be used for large grout installations or areas with accessibility problems. Unlike pouring it does not require the use of a head box. The void that is to be grouted will need to be formed. Grout delivery tubes and air vent tubes are also required to ensure that all voids are filled. Pumping grout into confined pockets needs special attention to quality control. Specifications should require trial pours in mock-up joints. These mock-ups can be disassembled and inspected for voids. Adjustments to air vent locations may be required after the mock-up testing.

Post-tensioning Duct Grouting

Many details in this manual involve the use of post-tensioning (PT) systems. Grouting of post-tensioning is a specialized field that required quality products and expertise. Many state DOT's have developed standard PT grouting specifications. Users of this manual are encouraged to contact specific DOT's for more information on approved PT grouting materials and methods. Information can also be obtained at the American Segmental Bridge Institute (ASBI) website (www.asbi-assoc.org) or from post-tensioning material manufacturers.

1.6.5.4 Curing

There are several methods for curing cementitious grouts. The most important factor is to follow the manufacturer's specified curing methods. Each particular grout manufacturer may have unique curing characteristics that are required in order to achieve the desired grout properties. The following curing procedures are most common:

Wet Curing:

Wet curing is used to prevent loss of surface water. During wet curing, all exposed surfaces should be covered with continuously wetted burlap for a specified time. Most manufacturers recommend a minimum of three days of wet curing.

Curing Temperature:

For most grouts, the surrounding substrate should be kept at a temperature between 40 and 90 degrees Fahrenheit for a minimum of 24 hours during and after grouting.

Curing compounds:

Curing compounds can be applied to the exposed surface of the grout in place of continuously wet curing. Curing compounds do not replace wet curing, they simply reduce the amount of time required for wet curing. Application of curing compounds can vary by product; and therefore, it is necessary to follow the manufacturer's recommendations for use of curing compounds. Typically, all surfaces should be wet cured for at least one day

before the curing compound can be applied to all surfaces. Curing compounds for grouting should meet the requirements of ASTM C 309, Type 2, Class B [8].

1.6.5.5 Specifications

Non-shrink cementitious grouts are sometimes simply specified as “non-shrink grout”. However, without specifications to control material properties the resulting product may shrink, resulting in a poor quality connection. Therefore, it is imperative to use ASTM standards when specifying any “non-shrink” grout. The following are a list of standard specifications that should be used when specifying grout.

1. ASTM C 1107 - Standard Specification for Packaged Dry, Hydraulic-Cement Grout (nonshrink) [9]
2. ASTM C 928 - Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repair [10]
3. CRD C-621 – Army Corp of Engineers Specification for Non-Shrink Grout [11]

These documents specify testing and sampling methods for grouts as well as batching, mixing, and proportioning requirements. Grout compressive strength is measured using two-inch square cubes in place of test cylinders (ASTM C 109 [12]). Shrinkage is measured via a vertical height change method. There are two methods commonly used. ASTM C 827 [13] measures height change in the plastic state. ASTM C 1090 [14] measures height change in the hardened state. These standards also reference specifications for flowability, consistency, and working time. ASTM D6449 [15] is the standard flow cone test for flowability. This test is often the most critical for controlling quality of flowable grouts.

Most state transportation agencies have approved non-shrink grout product lists. During the design process of a prefabricated bridge project, designers should carefully review each state-approved product to see if it is appropriate for the particular connection being used. The grouts that meet the project requirements should be clearly specified. Designers should carefully evaluate any request from contractors to substitute other grout materials.

1.6.5.6 Quality Control

A properly specified grout is the first step necessary to ensure a quality final product. Quality control from the manufacturer to the contractor can be the cornerstone of a job well done. For initial grouting procedures and trial batching, the designer should specify that a manufacturer’s representative be on site as the grouting process begins. This can avoid guesswork on the part of the contractor when it comes time to proportioning and placing materials.

Test Pours, Trial Batching and Mock-ups:

For complex void grouting, trial batching, test pours and test mock-ups are recommended. This is especially true for large or irregular shaped pours and pumping operations. The layout and placement of delivery and vent tubes in large pumped grout voids may require testing of several different layouts to achieve a quality product. Wood mock-ups of portions of each element to be joined can be used to test grouting procedures. After curing, the mock-up can be dismantled and the grout void inspected. If significant voids are found, the contractor can modify the placement of delivery and vent tubes and repeat the test. It should be noted that this testing procedure should be completed prior to fabricating the precast elements to be joined since the delivery and vent tubes are often embedded in the elements.

Grouting of Post-Tensioning Ducts

Quality control during grouting of post-tensioning ducts is critical to a successful long lasting system. There have been several problems with corrosion and failures of post-tensioning systems in Florida. Improved quality control is thought to be the best approach to eliminating these problems in the future.

The American Segmental Bridge Institute (ASBI) offers a Grouting Certification Program that is intended to provide supervisors and inspectors of grouting operations with the training necessary to understand and successfully implement grouting specifications for post-tensioned structures.

Individuals, who successfully complete the ASBI Grouting Certification Training and have three years of experience in construction of grouted post-tensioned structures, are certified as "ASBI Certified Grouting Technician." Some State DOT's already require this certification for grouting procedures involving post-tensioning ducts. States that plan to employ significant post-tensioning designs in the future should consider this program. More information on this topic can be found at the ASBI website (www.asbi-assoc.org).

1.7 Tolerances

Tolerances can be the source of most problems in accelerated bridge construction projects. Field fit-up is also one of the major concerns of agencies who are considering an accelerated bridge project using prefabricated elements. Designers of a prefabricated bridge project should assume that nothing is perfect and that tolerance will need to be accounted for in every connection. The following sections discuss the issues with tolerance in prefabricated bridge elements.

1.7.1 Element Tolerances

A common misconception by designers of prefabricated bridge projects is that the elements are built to exact dimensions. In fact, all prefabricated elements are built to some tolerance. The designers should be aware of the specified construction tolerances for cambers, sweep, and overall dimensions in all elements. The locations of holes, inserts and blockouts are also very important.

Prefabrication and accelerated bridge construction projects usually do not need to be designed with elements having stricter tolerances than conventional construction. The tolerances specified by the various industries are usually sufficient. A designer of prefabricated bridges should be familiar with the design tolerances in the states in which each project is located and account for these tolerances in the design and details. Consideration should also be given to whether tolerances used in conventional construction can be increased for prefabricated construction to ease fit-up in the field.

1.7.2 Dimensional Growth

If designers do not account for element tolerances, a phenomenon called “dimensional growth” can occur. For example, if ten panels that are each ten feet wide are placed side by side, the overall length of the system will typically be greater than 100 feet. This is due to the tolerances of the edge of the adjoining pieces. Match casting of concrete projects can minimize this problem, but minor dimensional growth of the structure is inevitable. To address this problem, designers should compensate for member tolerances in the joint designs or allow for minor overall variation in the structure dimensions.

Another form of dimensional growth has to do with the detailing of tolerance limits for multiple protruding elements, post-tensioning ducts, and embedded attachments. It is important to specify that the location tolerance be measured from a common working point. If center-to-center spacing tolerances are used, the layout error tolerance can become additive and affect the connection of the elements.

1.7.3 Hardware Tolerances

The location of hardware in prefabricated elements can be critical to the success of the project. Some hardware elements are more critical than others; therefore, designers need to specify the location tolerances of all hardware and attachments.

1.7.3.1 Post-tensioning Systems

Post-tensioning systems usually require the installation of strand or thread bars after the erection of the individual elements. It is important to specify the tolerance of the location of the ducts, especially at the ends of the element. Match casting is often used to keep these tolerances to a minimum. If small grout keys or closure pours are used, there is a greater likelihood of post-tensioning duct offset at the joints. In this case, it is recommended that ducts be oversized to allow for minor offsets in the duct at the joints.

1.7.3.2 Grouted Reinforcing Splice Couplers

Couplers require a certain degree of tolerance that is attainable in normal precast concrete construction. One method for accounting for tolerances is to oversize the couplers. The typical coupler can accommodate minor variation in bar locations. It is also possible to use an oversized coupler (by two bar sizes) to provide even greater tolerance. This provides approximately $\frac{1}{2}$ inch of tolerance adjustment, which is well within normal tolerances for precast elements.

Precast manufacturers can maintain the level of tolerance between pieces by using frames and jigs as templates to position and support the reinforcing steel and couplers. If a design requires the connection of a precast element to a field cast portion of the bridge, it is recommended that the precast producer provide a template jig to the general contract to ensure proper fit-up in the field during erection. The designer should clearly specify the responsible parties for this approach.

1.7.3.3 Embedded Attachments

The level of tolerance for embedded attachments is a function of the tolerance for the attaching member. If the attachment is for a utility pipe hanger that has adjustability, then the tolerance will not be as strict as it will be for other elements. Designers should clearly identify the required level of tolerance for all embedded attachments.

1.7.4 Layout and Joint Widths

When grouted joints are used between elements, the layout of the structure should be based on nominal element spacing. The actual width of the elements should be equal to the element spacing minus the specified joint width. The width of the joints between the elements should be based on the maximum specified element tolerance, accounting for member sweep, variation in overall dimensions, and variation in the side forms. Typical joint widths range from one-half inch to one-inch depending on the element. Larger elements tend to have larger joint widths.

1.7.5 Closure Pours

Closure pours can allow for large construction tolerances. They are often used to make up for dimensional growth and for unknowns in the field.

Even large match-cast structures, such as segmental bridges, use closure pours where large portions of the bridge are joined.

1.7.6 Camber Issues

Camber tolerance is often not given enough forethought by designers in prefabricated bridge projects. Steel and concrete beams have significant camber tolerances. Most designers allow for camber tolerance by requiring a variable web gap or haunch between the top of the beams and the underside of the deck. This is recommended for prefabricated bridge decks as well. Attempting to set prefabricated deck elements directly on top of steel or concrete will result in numerous fit-up problems.

1.7.7 Specification Requirements

In most cases, normal specification tolerances for typical members such as beams and girders are sufficient for prefabricated bridge projects. For specialty elements such as deck slabs and substructure elements, the designer should include tolerance requirements within the specifications or the contract plans. A recommended guide for developing tolerances for elements is the Precast Prestressed Concrete Institute (PCI) Manual entitled "*Tolerance Manual for Precast and Prestressed Concrete Construction (MNL 135-00)*" [16]. This manual offers recommended tolerances for all types of precast products. Designers are also encouraged to contact local producers to discuss appropriate tolerances.

Another approach is to use a performance type specification that requires the contractor to determine the applicable tolerances for each element and then be responsible for the fit-up in the field. The PCI manual could be used as a reference in the specification.

1.8 Fabrication and Construction Issues

The basis of prefabrication is the construction or fabrication of elements off site or near the construction site. Large-scale prefabrication raises issues not normally encountered on typical bridge projects. Prefabricated elements are large and heavy, requiring special means of fabrication, transport and assembly. This section discusses fabrication and construction issues related to prefabricated bridge projects.

1.8.1 Quality Assurance and Quality Control (QA/QC)

Most transportation agencies have well established QA/QC procedures. Prefabricated bridge projects can encounter different conditions that are not typically encountered on regular bridge projects. For instance, a contractor may choose to make portions of the bridge near the bridge site in a temporary fabrication facility. An agency may have one set of QA/QC procedures for field construction and a separate set of procedures for permanent fabrication plants. A near-site temporary fabrication yard may need special QA/QC procedures that are a combination of procedures for site construction and plant fabrication.

1.8.1.1 Fabricator Certification

There is debate in the industry about certification of fabricators for prefabricated bridge projects. Some states require that all elements be fabricated by producers certified by the Precast/Prestressed Concrete Institute. The positive side to this approach is that the elements will be manufactured by a known source with internal quality controls in place. The negative aspect to this approach is that all the elements will need to be shipped from fabrication plants to the site. This can limit the size of the elements and lead to higher costs. PCI plant certification is recommended for complex elements such as beams and girders. Information on the PCI Plant Certification can be found on the PCI website (www.pci.org).

1.8.1.2 Near Site Fabrication

Several states have allowed near site fabrication. This approach is common in the segmental bridge industry; however, it is not often used for smaller bridges. The cost and time of setting up a certified fabrication facility near the bridge site can be significant. One option may be to allow prefabrication of the less complicated elements in the field. Examples of these elements are footings, abutment and wall stems, and pile caps. Often these elements are the heaviest elements in the prefabricated bridge. If these elements can be fabricated in a location that does not require shipping over roads, the weight of the elements can be increased dramatically. It is not uncommon to move 200-ton segmental bridge sections from a near-site fabrication yard.

1.8.1.3 Inspection

Inspection of prefabricated bridge elements is critical. In order to ensure the proper fit of prefabricated elements, a higher degree of inspection will be required. Forming of concrete in the field will be replaced by prefabricated pieces that will need to be constructed to a

specified tolerance. The success of a prefabricated bridge project will hinge on the level of quality and accuracy of each element.

1.8.2 Handling and Shipping

1.8.2.1 Element Weight and Shipping

There are many factors that can affect the maximum size of an individual element. The following are some of the most common factors:

Over-the-Road Shipping Limits:

Every state has requirements for shipping of oversize and overweight loads that can limit the permissible size of the elements. Because designers do not know where an element will be fabricated, investigation of possible shipping routes is not possible. Designers should become familiar with the shipping requirements of the state where the bridge exists, and any neighboring states, to set reasonable limits on element size and weight.

Designers can often facilitate shipping over the road by identifying any deficient bridges or height and width restrictions on main roads leading to the site. Contractors usually do not have the time or resources to determine exact shipping routes for heavy elements in the short time allotted for bidding. A defined access road to the site from major highways would be beneficial to prospective bidders.

Barge and Rail Access:

Access to the bridge site by rail and water can allow for larger element sizes and weights. Barge access may allow large-scale prefabrication, including the potential for total superstructure prefabrication. Barge access should be identified in the project plans if this option is viable. The necessary permits for the project (environmental, Coast Guard, etc.) should identify barge access points, anchor sites and staging areas.

Near Site Shipping:

If near-site fabrication is an option, the size of individual elements can be increased dramatically. It may be possible to prefabricate an entire multi-span superstructure with substructure.

Crane Capacities:

If lifting of elements is to be done by cranes, the size of the elements may be limited. Large elements will require large cranes that may not fit within the construction site. This is often the case for bridge replacements where maintenance of traffic is required. Also, the cost of large cranes can become prohibitive.

Lifting Hardware:

Normal lifting procedure for individual elements is a four-point sling. This involves four cables attached to four discrete points on the piece. Typically, erection engineers assume that only two of the points are supporting the load at any time. The capacities of lifting hardware are sometimes limited, especially if the element being moved is a thin concrete panel. It is possible to use more complex lifting arrangements. Designers should consult with erection contractors for lifting of very large or heavy elements.

Use of Self-Propelled Modular Transporters (SPMTs):

In the U.S., entire superstructure spans have been lifted, carried, and placed in final position with SPMTs. In Europe, SPMTs have been used to install multi-span superstructures complete with substructures, with weights up to 3600 tons moved from near-site staging areas.

Member Stresses During Lifting

Often precast elements are lifted from point that different than the final support points. This can have a significant affect on the component. This is especially true for pretensioned members that are highly prestressed. Lifting a pretensioned beam far from the beam end can easily overstress the beam and lead to cracking and even failures. Non-prestressed concrete members can also experience cracking during handling. Designers of precast concrete components should investigate handling stresses.

It may be desirable to incorporate minor amounts of prestressing in components that are designed with mild reinforcement in order to minimize the potential for cracking during handling. It should be noted that this approach will most likely increase the cost of the component since it may need to be cast in a prestressing bed.

1.8.2.2 Recommended Design Approaches to Element Weight

Virtually all items listed in Section 1.8.2.1 are unknown to the designer of a prefabricated bridge project. This makes the layout and size of elements difficult, and it raises the possibility of claims from contractors if they find that they cannot ship the elements.

One approach that has been used by the New Hampshire DOT is to detail a schematic layout of the bridge and its elements on the plans and to allow the contractor to determine the number of segments in an element, for example, the number of segments in an abutment backwall, as part of a detailed assembly plan that is submitted to the engineer for approval. The designer notes certain limits on joint locations, but leaves the maximum segment size and weight and the exact location of all joints up to the contractor.

Another approach is to simply detail the bridge as a cast-in-place bridge, and show details for typical prefabricated connections. The contractor can then develop an assembly plan based on the geometry of the bridge and the details provided.

By using these methods, element size and weight can be set by the contractor to provide the most cost effective bridge, taking into account all the factors that the designers simply do not have during the design phase of a project.

1.8.2.3 Imperfections, Damage and Repairs

The process of fabricating, shipping and handling of elements can lead to damage and subsequent repairs. The Precast Prestressed Concrete Institute has recently published a document entitled “*Manual for the Evaluation and Repair of Precast, Prestressed Concrete Bridge Products (MNL-37-06)*” [17]. This document includes information on imperfections and damage that occur from fabrication through erection of precast concrete products. The manual is written for typical bridge products such as girders and beams. Designers may want to establish similar criteria for other prefabricated bridge elements.

Steel elements tend to be easier to handle and ship without damage than precast concrete elements. If damage occurs to a prefabricated steel element, there are well established procedures for repair outlined in typical project specifications, as described in the ANSI/AASHTO/AWS Bridge Welding Code [18].

1.8.3 Constructability

Constructability can be a major factor in the development of a prefabricated bridge plan. This is especially true for projects within tight confines. Contractors are often required to work in limited space and time constraints. Existing and future FHWA manuals will address these issues in detail. The following sections are presented as an overview on constructability.

1.8.3.1 Cranes

Crane capacities and crane footprints can have a major impact on the constructability of a prefabricated bridge. Designers should attempt to provide as much room as possible for crane setting locations. Designers should also provide enough time for crane set-up and breakdown if the cranes are to be placed in travel ways.

1.8.3.2 Self-Propelled Modular Transporters (SPMTs)

A new generation of heavy lifting equipment has been developed by the shipping and petrochemical industries. The piece of equipment that provides the most flexibility and speed is the Self-Propelled Modular Transporter. SPMTs can lift very large loads and move them in multiple directions with a high degree of accuracy. The following photo shows the new Providence River Bridge in Providence, Rhode Island. SPMTs were used to move this six-million-pound bridge from a shipping pier onto two large shipping barges where it was then shipped to the project site. The prefabrication of this superstructure

and the use of SPMT's saved the contractor approximately one year in construction time.



*Figure 1.8.3.2-1 Providence River Bridge
(Photo Courtesy of Mammoet)*

The FHWA has published a detailed manual on the use of SPMTs [3]. Designers are encouraged to review this manual to learn more about the use of SPMTs.

1.8.3.3 Temporary Support of Elements

In a typical prefabricated bridge project, portions of the bridge may need to be supported on temporary falsework until the bridge is whole. Designers should account for the space needed to install temporary supports, as well as the time required for assembly and disassembly. In some cases, the structure will be supported in a configuration that is quite different from the finished product. Figure 1.8.3.2-1 shows a steel arch being temporarily supported at the third points, which had a dramatic effect on the internal stresses in the structure. Temporary framing (vertical struts) needed to be designed in order to keep the stresses within tolerable limits. Any structure that is to be placed on temporary supports needs to be checked for these temporary stresses. If the lifting method is shown on the contract drawings, then the designer should verify the feasibility of the lifting method. If the method is proposed by the contractor, the stresses should be checked by the contractor's engineer.

1.8.3.4 Time Constraints

Each prefabricated bridge project will have different time constraints. Section 1.2.3 outlines some typical approaches to accelerated bridge construction projects. The time constraints will affect the feasibility of various methods of prefabrication. The designers need to develop a structure type and prefabrication approach that can be executed within the time constraints of the project site.

Connections play a critical role in this approach. Often the time to develop a structural connection is a function of cure times for grouted

connections, and the time to make a welded or bolted steel connection. The development of a connection can be the critical path in a short duration construction project. Designers should contact manufacturers to determine reasonable construction times for each connection.

1.8.3.5 Assembly Plans

It is common for designers to require the submission of erection plans for conventional construction projects. This is normally limited to the erection of beams and girders. Bridges built with prefabricated elements require special erection and assembly procedures due to larger number of elements that need to be erected. The New Hampshire Department of Transportation required the contractor to submit an assembly plan for their first fully prefabricated bridge project. The assembly plan is similar to an erection plan; however, it also includes information such as grouting and grout curing procedures, timing and sequence of construction, and temporary shoring of substructure elements during each phase of construction. It is recommended that projects built with prefabricated elements contain specifications requiring the submission of a detailed assembly plan.

Chapter 2 – Superstructure Connections

This chapter is devoted to connections in superstructure systems. Superstructures are defined by AASHTO as “Structural parts of the bridge that provide the horizontal span.” This is a very general definition. For conventional bridges, the superstructure is often defined as the portion of the bridge above the bridge bearings.

Integral abutments and integral piers are special bridge elements that are not clearly identified by the AASHTO definition. An integral abutment connection is a connection between the superstructure and the substructure. For the purpose of organizing this Manual, the integral connection between the superstructure and the substructure has been categorized as a superstructure connection, and is included in this chapter.

The following sections discuss typical systems of superstructure connections used on most bridges. These systems include decks, stringers/beams, and large modular systems.

2.1 Deck Systems

Because prefabricated decks are typically designed and constructed as complete systems, this section is divided into common types of systems, rather than individual connection types. Deck systems are the most commonly used for accelerated bridge construction projects, due to several distinct advantages. First, the conventional construction of a concrete deck (concrete is the most common material for decks), can be very time consuming because of the significant amount of forming required to cast the deck. Prefabrication can minimize or eliminate the need for field forming of concrete. Second, the elements are smaller and easier to transport and place than are most other bridge elements.

Most bridges are parallel stringer structures where the beams run parallel to the roadway centerline. In these bridges, the deck is analyzed and designed as a one-way slab with the strength design being in the transverse direction. In a concrete deck, the primary strength bars run perpendicular to the bridge beam. The reinforcement that runs parallel to the beams is used for distribution of strength. Some structures, such as trusses and girder/floorbeam bridges, have the support framing running perpendicular to the roadway centerline. In this case, the strength direction is in the longitudinal direction.

The design of connections between prefabricated deck elements is largely a function of whether the connection will be used to transfer moments and shears caused by wheel loads (transverse reinforcement between supporting members) or to assist with distribution (typical reinforcement parallel to supporting members). Most systems presented in this Manual can be used in either direction; therefore, the description of the connections will be as follows:

Strength Direction:

This is a connection used to resist forces (moments and shears) based on the strength design of the deck element. For example: On a typical stringer bridge with a concrete deck, the strength direction forces are resisted by the transverse reinforcing steel in the deck.

Distribution Direction:

This is a connection used to distribute forces laterally between elements. For example: On a typical stringer bridge with a concrete deck, the distribution direction forces are resisted by the longitudinal reinforcing steel in the deck.

2.1.1 Full-Depth Precast Concrete Deck Slabs

Full-depth precast concrete deck systems have been used by a number of states. A group of northeast states, working as a PCI Bridge Technical committee, has published design and detailing standards for this type of system. In general, this system is designed as a one-way slab between supporting beams using either mild reinforcement or prestressing.

There has been significant research [19-36] in this area; therefore, many of the details are thoroughly tested and the behavior of the systems is well known. Most research has focused on the connection between the deck and the supporting beams. Composite action is a prerequisite for most designers; therefore, this connection is critical. Most of this research has been completed on steel beam connections, and several studies have been completed on precast concrete beams. More research is underway on the connection of deck slabs to concrete beams; therefore designer should keep apprised of further work in this area.

A number of bridges built with full-depth precast concrete decks have been in service for more than 10 years, and the performance has been excellent. One notable bridge is the Woodrow Wilson Bridge that crosses the Potomac River near Washington, D.C. This bridge carries Interstate 95 and is one of the most heavily traveled bridges in the country. In the 1980's, the deck was replaced with full-depth precast lightweight concrete slabs [37]. The Maryland DOT has noted that the deck had performed very well under the most severe environment until it was replaced by the new Outer Loop Bridge in the summer of 2006. Several bridges in Connecticut were re-decked in the early 1990's using this system. These bridges have been in service for over 10 years and are in excellent condition.

The following sections contain information on the typical connections used in full-depth precast concrete deck slab systems.

2.1.1.1 Connections Between Slab Elements

There are two distinct types of element connections used between adjacent slab elements; one in the strength direction and one in the distribution direction:

Strength Direction:

This connection is used to transfer primary deck moment and shear from one deck element to another. The most common applications of the connection are to make connections between construction stages, and to provide a cross slope change in the deck. This is often done by placing a small cast-in-place closure pour between the adjacent panels

Experience has shown that the need to provide a small reinforced closure pours does not preclude the use of precast deck slabs for accelerated construction projects. High early strength concrete can be used to make this connection and the bridge can often be opened to traffic in less than one day.

Distribution Direction

This connection is primarily used to transfer shear and minor distribution moments between adjacent panels. The most common form of this connection is a grouted shear key with longitudinal post-tensioning placed across the key to insure that the joint remains in compression under the worst loading condition, which normally is a live load negative moment area. Several agencies have experimented with joints without post-tensioning; however, leakage through these joints has been noted.

There is on-going research into improving this connection and possibly developing a connection that does not require post-tensioning [22]. Post-tensioning is a slow and costly process. Elimination of post-tensioning would further accelerate the construction of a precast concrete deck slab system. Users of this Manual should keep apprised of the results of this research.

Connection Design Considerations

The strength direction connection needs to be designed to transfer the full moments and shears in the deck slab. This is important for the performance of the deck as well as the performance of the bridge framing below.

The design requirements for the distribution direction connection are not as well defined. Some designers believe that the connection only needs to transfer shear; however, many designers understand that this connection also needs to resist some bending moment caused by the localized effects of a wheel load. This is the reason that post-tensioning designs are used by many agencies.

Some guidance on these connections is available in the AASHTO LRFD specifications. Section 9.7.5 [1] recommends that longitudinal post-tensioning be used at mid-depth of the deck, and that the effective prestress force not be less than 250 pounds per square inch (psi). It should be noted that 250 psi is a *net* effective value used on several successful designs. However, if a bridge is continuous, designers should consider increasing the post-tensioning stress over piers to overcome any tension in the deck caused by composite dead loads. Some designers also increase the post-tensioning to account for live load tension stresses in the deck.

2.1.1.2 Connections to Steel Beam Framing

The connection of precast concrete full-depth panels to steel beams usually consists of a rectangular or oval pocket above the beam that allows the installation of welded stud shear connectors after the panels are set. Some designers prefer the oval shaped pocket to minimize the potential for cracking in the precast panels emanating from the corners of the pocket. The oval pockets are more expensive to fabricate, but the additional cost is usually insignificant.

Once filled with grout, the pocket has proven to develop full composite action. Often the pockets are tapered in the vertical direction to provide more of a mechanical connection between the grout and the panel.

The design of the composite action using this system is the same as conventional shear connector design, except the spacing of the studs needs to match the spacing of the pockets. The variation in shear strength required is accounted for by varying the number of studs in the pockets. The maximum spacing of the pockets is 2 feet on center, based on requirements of Article 6.10.10.1.2 of the AASHTO Specifications [1]. This section states:

The center-to-center pitch of shear connectors shall not exceed 24.0 in. and shall not be less than six stud diameters.

This provision has been in the AASHTO Bridge Design Specification for many years, though its source is not well known. Current research [22] has shown that the maximum spacing of shear connectors may be increased. Typically, increasing the spacing also requires increasing the size of the shear connectors. Users of this Manual should keep apprised of any changes to the AASHTO Design Specification that may result from this research.

2.1.1.3 Connections to Concrete Beam Framing

Most full-depth precast concrete deck systems have been installed on steel framing. As stated in the previous section, the connection to steel framing has been well researched and verified. The connection to concrete beams is not as thoroughly researched, but several universities have recently researched this connection [32-33]. The approach is to use a system similar to the steel framing connection. Hooked reinforcing steel and welded stud shear connectors projecting from the beam have been studied. For systems with headed studs, two options have been studied. One option is to embed a steel plate in the beam and field weld studs in a manner similar to a steel girder connection. There are concerns that this welding might result in cracking of the surrounding concrete due to thermal effects. This concern has not manifested itself in laboratory testing and in the field on several projects. It is recommended that the thickness of the embedded plate be kept thick in order to better disperse the heat from the weld. Another option is to embed a headed stud directly into the

beam. The difficulty in these systems is the location of embedded bars or studs. The layout of these bars needs to be carefully planned during fabrication of the beams so that the studs will line up with the blockouts in the precast slab above.

Another option for connecting to concrete beams is to drill and grout the connectors in the field after erection and placement of the deck panels. Drilling into the top of a prestressed beam will not be a problem in most cases because the prestressing steel is usually located near the bottom of the beam.

Recent research at Virginia Polytechnic Institute & State University [33] indicates that the provisions in the AASHTO Specifications for Interface Shear Resistance are adequate for the design of projecting reinforcing steel grouted in a pocket in a precast deck slab. The provisions for interfaces not intentionally roughened most closely matched the research data. This research also confirmed the validity of a connection with welded stud shear connectors attached to an embedded plate. In this case the AASHTO provisions for design of welded stud shear connector was validated. Specific provisions for the design of these connections will likely be published in the AASHTO Design Specifications in the near future.

2.1.1.4 Connections of Parapets, Curbs, and Railings

The connection of a parapet, curb or railing to a precast concrete full-depth deck panel needs to satisfy all the criteria for a non-prefabricated system. FHWA requires that all parapets and railings on the National Highway System (NHS) be crash tested. This requirement has limited the number of prefabricated parapet and railing connections. States may use parapets and railings designed according to the AASHTO Specifications [1] for non-NHS projects.

Some states anchor prefabricated barriers to full depth slabs by through bolting the barrier or railing to the deck. In this scenario, the bolt projects down below the deck and is secured with a nut and an anchor plate. This type of connection has been problematic. If the bolts are placed in pre-formed holes, water can migrate through the hole and corrode the anchor plate and the underlying framing. If this connection is used, it should be properly sealed.

The AASHTO LRFD Bridge Design Specifications [1] require that all barriers and railing be crash tested in accordance with the requirements outlined in NCHRP Report 350 entitled "Recommended Procedure for the Safety Performance Evaluation of Highway Features" [47]. This document is published by the Transportation Research Board and is available for download at the Transportation Research Board online publication website. There is at least one proprietary precast concrete barrier that has been approved for use. Clampcrete™ is a system that uses polyester resin anchors that are drilled into the bridge deck. This barrier is approved for use on the

federal highway system. Figure 2.1.1.4-1 shows the features of the Clampcrete™ system.

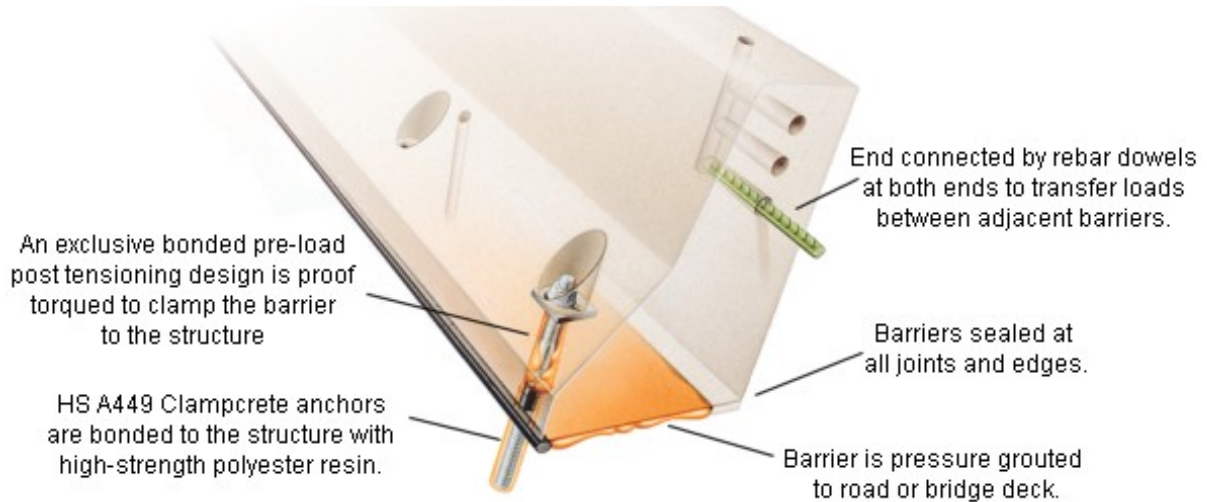


Figure 2.1.1.4-1 Clampcrete™ Barrier System
Detail Courtesy of Clampcrete™

The New York DOT has developed a static load procedure for parapets based on the LRFD Bridge Design Specifications [1]. This procedure is useful for testing of parapet sections that have shapes similar to standard parapets. The test verifies the structural integrity of the parapet, but not the vehicle impact performance. The theory is that the reaction of the vehicle to the barrier is a function of the shape, assuming that the barrier has close to zero deflection during impact. If a precast parapet has a shape similar to a crash tested shape, then only the structural integrity of that parapet needs to be evaluated. Note that this is a New York State DOT requirement, which may not be acceptable in other states.

The following methods have been used for this connection:

Concrete Parapets and Curbs

Most states do not have crash-tested precast parapets; therefore a cast-in-place parapet may be the only option. However, this does not eliminate the potential use of full-depth precast concrete deck systems for accelerated construction projects. In Connecticut, the construction of the parapet was expedited by eliminating construction joints in standard concrete parapets, allowing a full length single pour for the parapet on each span. Using this system, the parapet was installed at a rate of 250 linear feet per day. Some shrinkage cracking was noted; however, these cracks were easily sealed and had no effect on the structural integrity of the parapet.

Another option used to open the bridge to traffic as soon as possible is to place a temporary barrier in front of the proposed

barrier. Once the temporary barrier is secured, the construction of the permanent parapet can proceed behind the temporary barrier during off-peak hours.

Several states do have crash tested railings. Texas DOT has several that have been tested to AASHTO Test Level 4. There are also several proprietary parapet and railing systems that have been successfully tested. Designers should refer to state DOT standards for barriers and railings that are acceptable for use on each project.

New Hampshire DOT and the Vermont AOT are developing a precast open railing system. This system has a bolt down connection that can be made quickly. The system has been static load tested in the laboratory and installed on one bridge. Details of this system should be available shortly from the Northeast PCI Bridge Technical Committee Website (www.pcine.org).

Steel and Aluminum Railings

Prefabricated steel railings can be installed on a precast deck system. The anchor bolts can either be precast into the decks or drilled and grouted in the field. Some states drill the anchor bolts completely through the deck and secure them with an anchor plate and bolts. This method can lead to difficulties with alignment of the bolts. There have also been long term maintenance issues with through bolts because they often provide an avenue for leakage of water through the deck. Usually steel railings are placed on top of concrete curbs to control storm water runoff; therefore, the discussion of casting concrete parapets and curbs in the previous section also applies to the design of steel railings.

Some states have standard aluminum rail systems that are bolted to concrete curbs. If these systems are use, designers should be aware that a galvanic reaction will develop between the aluminum and the base concrete. To avoid this, designers simply need to place a thin (1/8" thick is common) elastomeric sheet under the post base plate. This will disrupt the potential reaction. Type 304 Stainless steel anchor bolts should also be used for the same reason. Aluminum railings have had a very good track record of durability as long as these two features are incorporated into the design.

2.1.2 Open Grid Decks

Open grid decks have been used for many years. They are most common on bridges that require lightweight decks, such as moveable bridges and suspension bridges. However, long term durability of elements below the open grid decks are a concern and should be addressed accordingly.

Grid decks are essentially mini-steel framing systems. They usually consist of main rail members in the strength direction that span between

supporting beams, and transverse cross bars in the distribution direction that run parallel to the supporting beams.

This Manual includes some typical details from past projects. Users of the Manual are encouraged to contact the Bridge Grid Flooring Manufacturers Association for assistance with connections for specific bridge projects (www.bgfma.org).

2.1.2.1 Connections Between Grids

Since these systems are steel framed members, the connection between grids is usually made with a bolted or welded connection. Bolted connections are preferred to minimize the use of fatigue prone welded details.

2.1.2.2 Connections to Steel Framing

There are several options for connecting grids to steel framing. These include welded, bolted or grouted shear connector pockets. Typically the main bearing bars are connected to the supporting framing.

2.1.2.3 Connections of Parapets, Curbs, and Railings

No details of this type were submitted for publication in this Manual; however, in most cases, steel railings are used due to their light weight. Railings are typically connected to the grids using bolted connections.

2.1.3 Concrete/Steel Hybrid Decks

These systems consist of decks that include a combination of concrete and steel components. The most common systems involve the use of steel grid. There are two common options for these systems, as described below:

Partially Filled Grid Decks

These systems include a steel grid deck in which the upper portion of the deck is filled with concrete after placement. In most cases, the concrete is filled over the top of the grid to improve performance

Exodermic DecksTM

An exodermic deck is a proprietary deck system that is similar to partially filled grid decks except the concrete is primarily placed above the grid. The main bars act as mini-composite steel beams in concert with the concrete over pour. These decks are lightweight and lend themselves to precast operations. The connections used for exodermic bridge decks are similar to precast full-depth concrete deck systems. Figure 2.1.3-1 shows exodermic deck details and Figure 2.1.3-2 is a photograph of an exodermic deck installation during a nighttime closure.

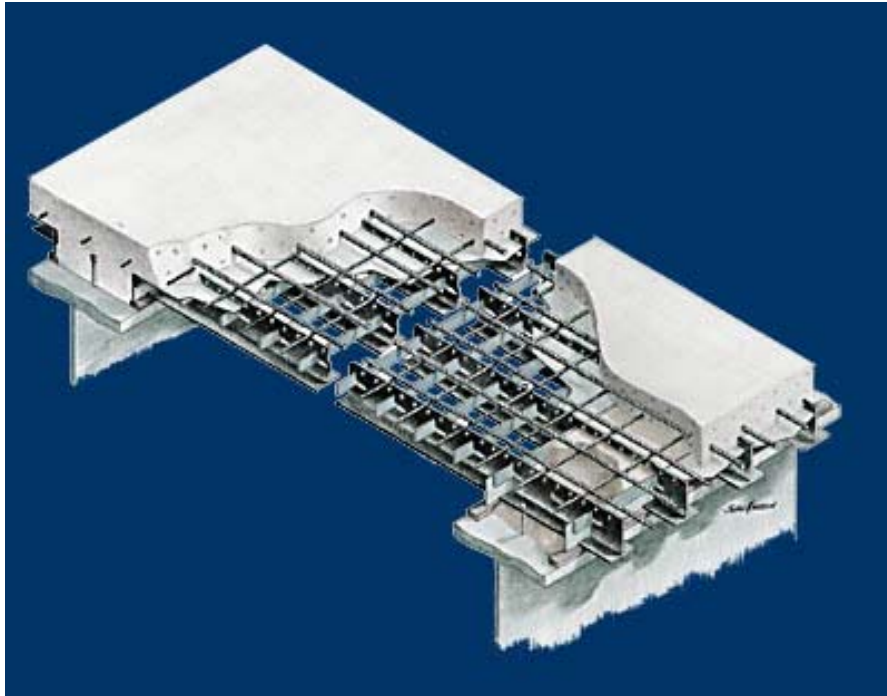


Figure 2.1.3-1 Exodermic Deck Details
Courtesy of the D.S. Brown Company



Figure 2.1.3-2 Exodermic Deck Installation
Photo courtesy of the D.S. Brown Company

Similar systems include the Effideck™ system developed by the Fort Miller Company in New York. Some details provided by the New York State DOT for this Manual are of the Effideck™ system.

This Manual includes some typical details from past projects. Users of the Manual are encouraged to contact the manufacturers of these systems for guidance with connections for specific bridge projects.

2.1.3.1 Connections Between Panels

As with open grid systems, concrete/steel hybrid deck systems are made with steel framed members. The connection between panels can be made with bolts or welds. Bolted connections are preferred to minimize the use of fatigue prone welded details. Grouted keys are also used.

2.1.3.2 Connections to Steel Framing

Since the finished product of concrete/steel hybrid systems is similar to a full-depth precast concrete deck, the connection details are also similar. The connection is usually made with welded stud shear connectors placed in a pocket filled with grout.

2.1.3.3 Connections of Parapets, Curbs, and Railings

In concrete/steel hybrid systems, connections of parapets, curbs and railings are similar to those used in precast full-depth deck panels. Refer to Section 2.1.1.4 for specific information on these connections.

2.1.4 Fiber Reinforced Polymer (FRP) Decks

Fiber reinforced polymers have been used in the aerospace industry for years but have been used only recently in the bridge industry. FRP composites can be manufactured with several different types of fibers combined with polymer resins to form structural shapes. The choice of fiber affects the material properties of the finished product. The most common fibers used are glass fiber and carbon fiber. FRP can be molded into virtually any shape by using established manufacturing methods such as pultrusion and vacuum assisted resin transfer.

FRP products offer the following advantages over other structural materials:

- High strength
- Lightweight
- High Stiffness to weight ratio
- Corrosion resistance
- High quality

These properties have led to the use of FRP decks on load restricted structures. The use of FRP deck panels can have a significant effect on the load capacity of the bridge. To date, most FRP bridge projects have focused on decks. The relatively low modulus of elasticity of FRP products limits their use for elements such as beams and girders. This is not an issue with decks, since the structural spans of the elements are very short. FRP can be molded into cellular panels that can be used as full-depth deck panels. FRP products to date have not been

standardized. Each project has been “one of a kind,” based on the manufacturing process of the supplier.

FRP deck projects are not limited to the details included in this manual. Virginia has installed three FRP decks. West Virginia, Pennsylvania, and Delaware have also installed FRP decks. Ohio had an initiative to install an FRP deck in each of its counties.

2.1.4.1 Connections Between Panels

The process of making FRP panels allows for development of complex shapes and joint configurations. Interlocking panels and male-female shear keys have been used. High quality epoxy adhesives are used to join panels together.

2.1.4.2 Connections to Steel Framing

FRP panels can be made composite with the bridge framing. Typically pockets are formed over the beams to allow for the installation of welded stud shear connectors and non-shrink grout. Bolts have also been used to connect the panels to the framing.

2.1.4.3 Connections of Parapets, Curbs, and Railings

The connection of parapets and railings to FRP panels is not well studied or documented. On several FRP bridge deck projects, the railing was not attached to the panels. Instead, the railings were attached directly to the steel framing below, or to the truss chords adjacent to the panels.

New York DOT used an FRP railing that was attached to the FRP panels using grouted reinforcing bars. The bars were grouted into voids in the deck panels. The barrier was a hollow FRP box used to form a reinforced concrete parapet. This project was the Route 248 Bridge over Bennett’s Creek. Details of this connection are included in this manual.

2.1.5 Partial-Depth Precast Concrete Deck Panels

Partial-depth precast concrete deck panels have been used by many states; for example, 85 percent of all bridges built in Texas use this forming method [38]. These panels are typically 3.5 to 4 inches thick and placed on top of the beams on interior bays. The typical details used in Texas can be found at the Texas DOT Website (www.state.tx.us). Overhangs on bridges with these panels are usually formed using conventional forming methods. The panels have not been cantilevered over the fascia beam because normally the design requires a composite connection between the beam and the deck. A continuous deck panel interferes with this connection. In the past the Texas DOT experimented with a system that used blockouts for shear connectors, but has since decided that it is easier to simply form the overhangs using conventional deck forming techniques.

Once placed, a top layer of conventional reinforcing is placed over the panels and a partial-depth concrete pour is made to finish the composite deck.

These deck panels serve two purposes:

1. They act as a form to support the wet concrete of the deck pour. The slowest portion of reinforced concrete deck construction is the installation of deck formwork. On a conventional bridge, this is accomplished using wood forms or steel stay-in-place forms. These forms need to be fit between the beam flanges within tight tolerances. The precast concrete panels span between the beams and are supported temporarily on bedding strips on top of the flanges until the deck concrete flows underneath them to provide continuous support; therefore, installation is faster and requires less manufacturing tolerance.
2. The deck panels also act as the lower portion of the reinforced concrete deck. This is possible because the moment demand in a deck is primarily positive bending in the middle portion of the bay between beams, and negative bending over the beams. Having a discontinuity over the beams between the panels is not an issue because the moment demand is resisted by the top reinforcing in the cast-in-place top pour.

Research has been completed on partial-depth deck panels. The Texas DOT has sponsored much of this research [39]. There have been laboratory studies and field verification. Strength tests and cyclic live load tests have also been completed. The results of this research show the following:

- Decks composed of precast panels topped with cast-in-place concrete are stronger and stiffer than full-depth cast-in-place concrete decks [40].
- The panels can be considered a part of the structural deck system.
- Composite action between the panels and the topping concrete is possible without the use of horizontal shear reinforcement.
- The panels combined with the concrete topping can be used as a composite deck for the design of the beam.
- It is preferred to use prestressing as the main reinforcement in the panels.
- The amount of force and the size of the prestress strand should be kept as low as possible to minimize cracking and the development requirements of the strand.

Texas and Tennessee have had good performance on their decks where partial-depth precast concrete decks panels have been used. The key to good performance is a positive support between the panels and the top of the girders. Other States have experience problems with the panels where fiber board was used to support the panels and which deteriorated over time or where there was not a positive support between the panels

and the girders. Flexibility of the superstructures should also be taken into consideration. Virginia has experienced significant reflective cracks on flexible steel structures with span lengths greater than 140 feet. These reflective cracks can affect the long term durability of the deck, particularly where deicing chemicals are used.

2.1.5.1 Connection to Steel Beam Framing

The connection between partial-depth precast concrete deck panels and steel beam framing is made using welded stud shear connectors in the gap between adjacent panels. This area is filled with concrete as the deck topping concrete is placed.

There is one key feature of this connection that most states strictly adhere to; the deck panel should have concrete bedding placed between the underside of the deck panel edge and the beam below to provide continuous support for the panels to resist live loads. Earlier installations did not use this concrete bedding and excessive cracking occurred above this connection.

Some states require that the prestressing strand in the panels be extended into the area over the beams. This was done to improve the connection of the panel to the beam. Research has shown that these extensions have no effect on the structural integrity of the connection; therefore, many states allow a smooth edge on the panel [40]. This greatly simplifies the production of these panels and has led to reduced costs.

Grade control is often accomplished by stacking shims under the panels. The shim heights are predetermined following a beam grade survey. Several states use leveling screws embedded in the panel that can be adjusted after installation. These screws are temporary and are removed after grout is placed between the panel and the beams.

2.1.5.2 Connections to Concrete Beam Framing

This connection is almost identical to the steel beam framing connection discussed in Section 2.1.5.1. The only difference is that the composite action is made with standard shear reinforcement extending from the beam into the deck. The same issues noted in Section 2.1.5.1 are applicable to this connection.

2.1.5.3 Joints Between Panels

The partial-depth precast concrete deck panels are usually prestressed in the strength direction. The joint between the panels over the beams is essentially a compression connection since it is in the compression zone of the negative moment section of the deck. The cast-in-place concrete simply transfers compression forces between adjacent panels.

The joints in the distribution direction are simply butted in the field with slight gaps. The connection between the panels is made via the

concrete topping and topping reinforcing. Even with these small gaps between panels, full composite beam action of the entire bridge deck (precast plus topping) is achieved.

2.1.6 Timber Deck Panels

The United States Department of Agriculture Forest Products Laboratory (USDA FPL) has developed standard details for timber bridges, including details for prefabricated timber panels and beams. There is a significant amount of information on timber bridges at the USDA FPL website. At this time, most timber bridges are used on low volume roadways, but may be applicable to higher volume roads as well. Users of this Manual are encouraged to visit the Forest Products Laboratory website for more information on timber bridges (www.fpl.fs.fed.us).

Prefabricated timber beams and panels are normally manufactured using the glue laminating process. This involves gluing nominal dimension lumber side-by-side to create a solid panel. For beams, the wide dimension of the laminations is normally placed horizontal. For deck panels, the wide dimension of the laminations is typically placed vertical. Protection against rotting is controlled by the use of pressure treated wood products. The individual laminations can be pressure treated before being laminated together, or the laminated pieces can be pressure treated after fabrication. The glue used for bridge application must be water proof.

Timber deck panels have been used in two ways:

- Installed on top of glue laminated wood beams
- Installed on top of steel stringers
- Installed as adjacent-deck-slab superstructure for short span bridges

The following sections contain information on the first two uses. The third use is discussed in Section 2.2.4.

2.1.6.1 Connection Between Panels

The connection between wood deck panels is used to transfer shear between the panels. Earlier versions of this system used only steel dowels placed mid-depth between the panels. This system proved to be problematic for higher volume roadways, especially when a bituminous wearing surface was employed. The connections would eventually loosen, leading to cracking of the pavement and leakage through the joints.

The current details include a load transfer beam placed at mid-bay between the support stringers. This beam provides a more significant shear transfer mechanism. Even with this connection, reflective cracking can occur in the overlay pavement. For this reason, it is recommended that a layer of geotextile fabric be installed between the pavement and the panels.

2.1.6.2 Connections to Framing

The currently used connections of timber deck panels to beam framing are not intended to provide composite action between the beams and the deck, but rather, simply to keep the deck in place over the beams. The system consists of bolts and brackets that connect the deck panels to the beams.

2.1.6.3 Connections of Parapets, Curbs and Railings

The USDA FPL has developed crash tested parapet details for some timber bridges. The most common details are for stress laminated timber deck bridges. These details have been crash tested for AASHTO Test Level 2 and 4 and are available at the USDA FPL website. Two Railing Details have also been developed for glue laminated timber deck systems that meet the requirements of AASHTO Test Level 2. Users of this Manual are encouraged to contact the USDA FPL for guidance on these connections.

2.1.7 Grouting Techniques for Deck Systems

Many of the systems described in this chapter make use of grout for the connections. Section 1.6.5 in this Manual contains information on grout materials and placement. There are four major uses of grouts in deck systems, as described below.

2.1.7.1 Joint Grouting

Most joints between panels contain a grouted shear key. It is very important that the grout placed in these keys completely fills the void. The most common form of keyway failure is due to inadequate filling of the keys. If voids are present, the mechanical interlock of the key is lost. Project specifications should require the use of flowable grouts. Another method of placement that has proven successful requires minor rodding of the grout after placement.

2.1.7.2 Shear Connector Pocket Grouting

These grout areas are used to make the deck composite with the beam framing. In most cases, the pockets are exposed on the top of the deck; therefore placement of the grout is a simple process.

There is on-going research (not yet published) at the Virginia Polytechnic Institute & State University that has looked into the issues with grouting of shear connector pockets. They have found that certain grouts can shrink slightly; thereby creating minor shrinkage cracks around the perimeter of the pocket. The cracking was not found to be detrimental to the structural capacity of the connection, but water leakage was a concern. These cracks can be easily sealed with methacralate crack sealers. In lieu of this, Most states that use this system overlay the deck with either a bituminous wearing surface combined with a waterproofing membrane, or a thin concrete overlay. Other states have tried thin polymer overlays. Use of overlays will eliminate the need to seal these cracks. The overlay also dramatically improves the riding surface quality of the deck.

A new blind pocket system was recently developed as part of and NCHRP research project. The grout for these blind pockets needs to be pumped through small ports in the top of the deck [22]. This process is similar to grouting post-tensioning ducts.

2.1.7.3 Post-Tensioning Duct Grouting

Many states have standard specifications for this process. It is critical that whichever specification is followed, the specifications are followed precisely in the field. The grout is used to provide corrosion protection to the post-tensioning system and to provide a bond between the strand and the surrounding concrete. Elimination of voids and bleed water are two important issues that need to be addressed with any specification or construction process. Normally grouting starts at the low end of the deck and bleed water ports are placed at the high end of the deck. See Section 1.6.5.6 for more information on grouting of post-tensioning ducts.

The connection of the ducts between panels is typically done using a simple duct splice with duct tape. Some states have used heat shrink wraps as well; however this may not be possible with polyethylene ducts, and it may be difficult to get the heat all the way around the duct in the limited pocket areas.

2.1.7.4 Bedding Under Deck Panels

Typically a gap is used between the underside of concrete bridge decks and the top of the supporting beams to account for tolerances such as beam camber. This gap needs to be filled with grout so that the panels have continuous support for wheel loads. In order to properly fill these thin gaps, a flowable grout will likely be needed. Some states have specified dry pack grouting in this area. This can be done, but it is very labor intensive. It is recommended that dry pack grouting only be used for repair to voids in poured areas.

Contractors have used several forming techniques for this area. Some states have specified compressible foam forms. It is recommended that the contract details not include a forming technique, since it is part of the contractor's means and methods.

2.1.8 Grade Control and Tolerances

Most deck systems are installed on bridges that have precise grade requirements. The deck panels are required to follow the grade of the road.

Pretensioned concrete beams are cast in flat forms. Upon release of the prestressing strand the beams will camber up due to the eccentricity of the prestressing force with respect to the centroid of the beam. It is also common for bridges to be built on vertical curves. These two parameters lead to the fact that the distance between the top of the beam and the underside of the deck will vary along the beam length. Steel beams and glue laminated wood beams are often fabricated to match the grade of

the proposed roadway; however, tolerances on beam camber still need to be accounted for.

These issues lead to a common detail where the gap between the top of the beam and the underside of the deck will vary along the beam length. This brings about a need to adjust the elevation of deck panels as they are placed. Many states use some sort of leveling device embedded in the deck panels. The most common device is a leveling bolt system. These devices serve two purposes. First, they allow for vertical field adjustment as the deck panels are being placed. Second, they provide temporary bearing for the panel and the proper distribution of the panel weight to the beams. To ensure proper dead load distribution, some agencies require that the torque on the leveling devices be within a specified range. Usually, the torque on bolts is specified to vary by no greater than 20 percent [41]. This has proven to be a reasonable range to obtain in the field. Once the grout is placed between the panels and the beams, the bolts are typically removed, thereby using the grout to distribute dead loads and live loads to the beams.

Tolerances for prefabricated elements are discussed in Section 1.7. Deck systems normally have nominal width joints between the panels; therefore, most tolerances can be handled in the joint. Precast concrete deck systems are often post-tensioned together in the field. The tolerance on the location of the PT ducts is usually the most critical dimension in the element. Designers should specify smaller tolerances for these systems. The tolerance should be based on the post-tensioning manufacturer's recommendations. Another option to specifying tight tolerances on the PT duct is to oversize the duct so that minor misalignments will not lead to binding of the PT system in the duct. Care should be taken to maintain cover over the larger ducts.

2.1.9 Evaluation of Performance and Long-Term Durability of Prefabricated Deck Systems

2.1.9.1 Reflective Cracking and Leakage

Most prefabricated deck systems have performed very well. However, there have been minor problems with reflective cracking through overlays and leakage through joints. The primary causes of these problems were identified as:

Poor Joint Configurations:

Some early systems (not included in this Manual) used joints that were not grouted. Early timber deck systems used simple dowels at transverse joints. These dowels eventually loosened and allowed the panels to work independently (piano key action). This eventually led to pavement cracking and leakage. The addition of a stiffening beam at mid-span may improve this connection. Several stiffening beams at regular intervals would be preferred.

Lack of Post-Tensioning:

There have been several attempts to construct distribution joints without post-tensioning. While these joints are primarily used to transfer shear between panels, there is some moment demand, which leads to cracking and leakage

Reflective Cracking in Concrete Topping Over Partial-Depth Deck Panels:

Reflective cracking in the concrete topping over the transverse joints is not uncommon. Research has shown that this cracking is not a structural deficiency, even under cyclic load testing. Texas research has shown that this cracking is less than occurs in full-depth cast-in-place concrete decks under comparable live loads. Serviceability is a concern, since the cracks are on the top surface of the deck, especially in states that use de-icing chemicals. Some states that use exposed concrete decks use surface sealers to fill these cracks. Other states use membrane waterproofing systems combined with overlays; therefore, the cracks are covered by these systems.

2.1.9.2 Riding Surface Issues

Prefabricated bridge deck systems are composed of discrete elements connected in the field. Many systems are also made composite with the bridge framing. This design requires joints and shear connector pockets exposed to the top surface of the deck.

Even with the best grouting practices, the top of the deck can be rough when compared to conventional concrete deck placement techniques. Most projects that employ these systems include some form of deck overlay to provide the final wearing surface, which dramatically improves the ride quality. Common systems include waterproofing membrane with bituminous pavement or thin concrete overlays. Most states that use bituminous overlays specify 2½" to 3" pavement thicknesses placed in two lifts (thicker overlays have been used in Europe and Japan). The bottom layer is typically a small aggregate mix that will not damage the membrane during placement and compaction. The two layers of asphalt provide better protection to waterproof membrane and minimize any damage to the membrane when the top layer of asphalt is milled off for pavement rehabilitation.

Several states are attempting to develop full-depth precast concrete deck systems that do not need overlays. One approach uses shear connector pockets that are hidden from the top of the deck. The pockets are formed on the underside of the deck and grouted through small grout ports on the top. Early research results show that this system is viable [22]. There has also been discussion about diamond grinding the deck surface at the end of construction to provide a smooth surface, though this approach has yet to be employed on a bridge.

Some states use thin epoxy overlays on prefabricated deck systems. This approach is most effectively employed on bridges with load

capacity restrictions. Thin overlays have historically been subject to debonding and peeling. Careful surface preparation is critical to ensure successful performance of thin overlays.

2.1.10 Estimated Construction Time for Connections

Timelines for construction depend on the weather and site-specific factors such as access, traffic control, and locations for cranes and storage. Nonetheless, it is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Often prefabricated decks are used for replacement of old deteriorated decks. In this case, removal of the old deck can be a significant time constraint, especially if the old deck is composite with the beams. Removal of non-composite decks can be done by carefully prying the deck from the beams. Using this method, a non-composite deck on a single span can be removed in a few hours.

Removal of composite decks required significant labor, especially over the tops of the beams. The size of pneumatic hammers should be limited over the beams to less than 50 pounds so that the top of the beams do not get significantly damaged. Minor flange damage is normally acceptable in positive moment regions. Damage to steel flanges in negative moment regions (notches and gouges) should be repaired by grinding since this may result in future fatigue cracking.

Hydro demolition of the concrete over the beams may also be feasible; however control of the waste water may be difficult. Contractors have demonstrated the ability to remove a composite deck on a typical span (100'±) in approximately 8 hours. This means that replacement of a composite deck during an overnight closure is not feasible; however weekend replacements are reasonable and have been done successfully on numerous projects.

Table 2.1.10-1 contains approximate installation times for the various deck systems included in this section:

System	Minimum Installation Time*	Comments
Full-depth precast concrete deck panels	2 days per span	This includes longitudinal post-tensioning and closure pours. Deck replacements have been completed during a single weekend closure.
Open Grid Decks	1 Day	The lack of post-tensioning needs for these systems can lead to very fast installation
Concrete/Steel Hybrid Decks	2 Days	Some of these systems are similar to full-depth precast decks. They require grouting in order to make the connection to the beam framing
FRP Deck Panels	2 Days	Adhesive connections and grouting are the major installation tasks
Partial-Depth Precast Deck Panels	7 Days	The panels install quickly (1 day); however, placement of the top mat of reinforcement and concrete is needed to complete the deck
Timber Deck Panels	1 Day	This system is simple and requires no grouting or post-tensioning.

Table 2.1.10-1 Approximate Minimum Installation Times for Deck Systems

* Times shown are for single spans. Multiple spans can be completed if multiple crews are used.

2.1.11 Recommendations for Improvements to Current Practices

Many decks included in this section are successful and proven systems. Nonetheless, some factors could be improved, as discussed below:

Elimination of Post-Tensioning:

Distribution connections for deck panel systems are typically made with post-tensioning because this connection experiences some moment demand. However, the post-tensioning of the deck (including duct grouting) is one of the slowest tasks in the deck installation process. If post-tensioning could be eliminated, the speed of installation could be improved. Deck removal and replacement projects can currently be completed in as little as two days. Elimination of the post-tensioning task could make it possible to remove and replace a bridge deck in a single night.

Corrosion of the post-tensioning anchorage assemblies is a concern. If the assembly is placed at the extreme end of the deck, it may be exposed to corrosion attack from leaking joints.

Designers should look into casting a small closure pour between the end of the last precast panel and the bridge joint in order to properly protect this area.

Another issue with post-tensioning in bridge decks is the effect of long term creep of the panels. This phenomenon results in a loss of post-tensioning force and a transfer of stress into the supporting beams. There is on-going research (not yet published) at the Virginia Polytechnic Institute & State University on this subject.

There has been research involving the development of transverse deck connections that do not use post-tensioning [22]. One of the decks studied in this research has been constructed by Texas DOT and is included in this manual. The early results of this research are promising. Users of this Manual should keep apprised of the further development of these systems.

2.1.12 Connection Detail Data Sheets for Deck Systems

The following pages contain data sheets for various details used in prefabricated deck systems. This information was primarily gathered from agencies that have developed and used the systems. Some systems were obtained from manufacturers and industry groups. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected
- Name of project where the detail was used
- Manual Reference Section
 The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

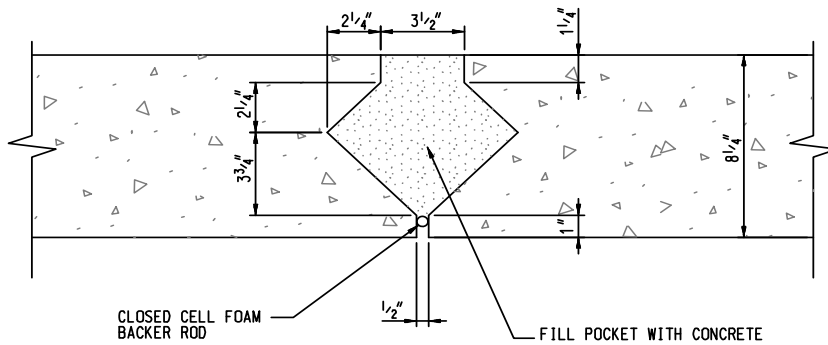
Organization: Iowa Department of Transportation
Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
Address: Office of Bridge and Structures
800 Lincoln Way
Ames, IA 50010

Detail Number: 2.1.1.1 A
Phone Number: (515-239-1393
E-mail: ahmad.abu-hawash@dot.iowa.gov
Detail Classification: Level 2

Components Connected: Full Depth Precast Concrete Deck Panel to Full Depth Precast Concrete Deck Panel

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek

Connection Details: Manual Reference Section 2.1.1.1 See Reverse side for more information on this connection



TYPICAL TRANSVERSE JOINT BETWEEN FULL DEPTH DECK SLAB

NOTE: JOINTS SPACED APPROXIMATELY 8 FEET ON CENTER

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The Boone County IBRC Project utilized full depth precast concrete deck panels on precast pretensioned concrete beams. The precast panels were joined transversely by a keyway cast into each precast panel. The diamond shaped keyway was filled with a early high strength, low shrinkage concrete mix. The transverse joints were later compressed during longitudinal post-tensioning of the bridge deck.

The keyway included a small quantity of concrete and was cast in cold weather. This small quantity required blankets to keep the concrete insulated from the cold to allow for proper curing.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

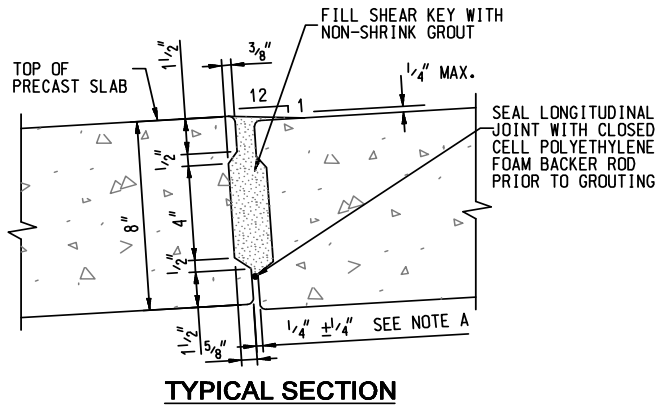
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **2.1.1.1 B**
 Phone Number: **888-700-5670**
 E-mail: **contact@pcine.org**
 Detail Classification: **Level 1**

Components Connected: **Precast full depth slab** to **Precast full depth slab**

Name of Project where the detail was used: **I-84/Rt 8 Interchange, Waterbury, CT**

Connection Details: **Manual Reference Section 2.1.1.1** See Reverse side for more information on this connection



Note A:
 The variation is due to sweep and camber of the slabs. The designer shall add the following note to the plans. "The slabs shall be placed at the nominal spacing shown on the plans with a 1/4" wide gap between the slabs. The width of the gap can vary due to tolerances of the slabs"

Note B:
 The designer shall add the following note to the plans. "Grout for shear keys shall be rodded or vibrated to ensure that all voids in the shear keys are filled"

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between two full depth precast concrete slabs. This connection has primarily been used as a transverse joint (stringer bridges). This detail is typically used in conjunction with longitudinal post-tensioning. Some states have used this detail without PT however there have been problems with leakage. A PT level of 250 psi (concentric) is recommended.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

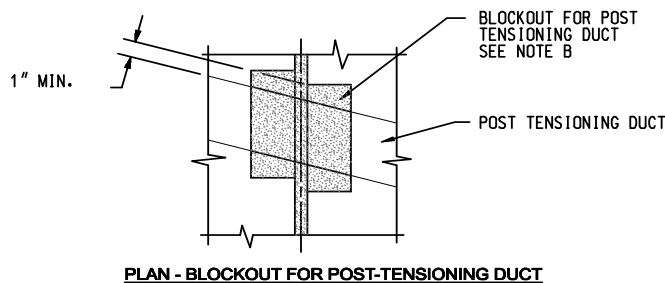
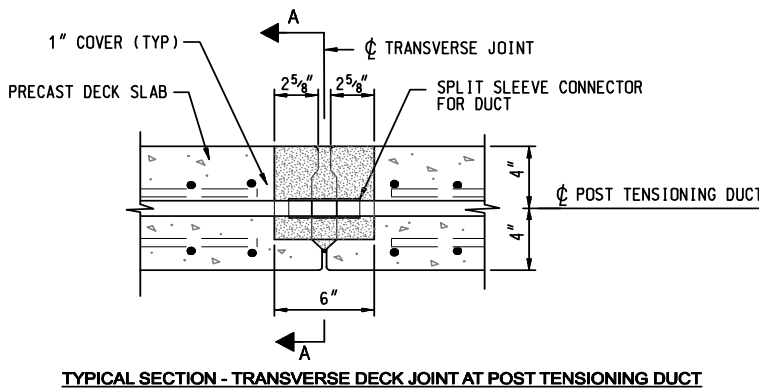
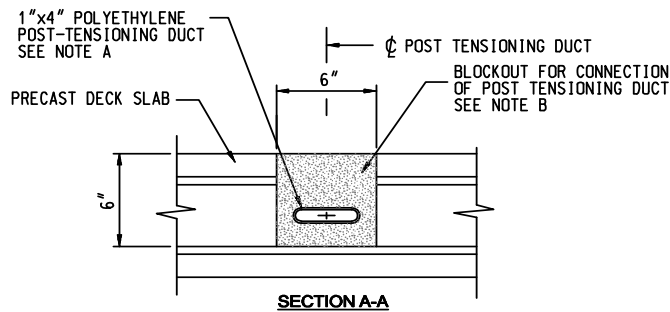
Detail Number: **2.1.1.1 C**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org

Detail Classification: **Level 1**

Components Connected: **Precast full depth slab** to **Precast full depth slab**

Name of Project where the detail was used: **I-84/Rt 8 Interchange, Waterbury, CT**

Connection Details: **Manual Reference Section 2.1.1.1** See Reverse side for more information on this connection



POST TENSIONING DUCT DETAILS

- NOTE A: POST TENSIONING DUCT SHOWN IS FOR FOUR 1/2" DIA. PRESTRESSING STRAND. ALTERNATIVE DUCTS MAY BE USED. THE CONNECTION OF THE DUCT SHALL BE WATER TIGHT.
- NOTE B: FILL HANDHOLE WITH NON-SHRINK GROUT SIMULTANEOUSLY WITH THE TRANSVERSE SHEAR KEYS.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between two full depth precast concrete slabs. This connection is used in conjunction with a grouted shear key. It is very important to seal this connection, since the PT is pulled after the grout has been placed. There have been problems with pushing the PT strand through if the the maximum size and number of strand are used. The ducts should be oversized for the intended PT strand. Tight tolerances should be specified for the location of these ducts. The duct should also be tied to a rebar in order to maintain its alignment during casting.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: PCI Northeast Bridge Tech Committee
Contact Name: Rita Seraderian
Address: 116 Radcliffe Road
Belmont, MA 02478

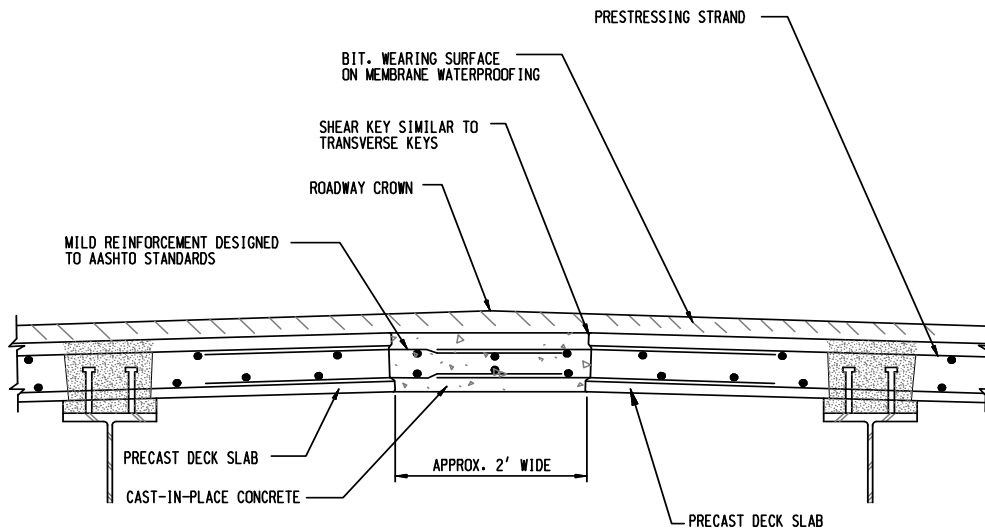
Detail Number: 2.1.1.1 D
Phone Number: 888-700-5670
E-mail: contact@pcine.org

Detail Classification: Level 1

Components Connected: Precast full depth slab to Precast full depth slab

Name of Project where the detail was used: Route 8 Viaduct, Seymour, CT

Connection Details: Manual Reference Section 2.1.1.1 See Reverse side for more information on this connection



TYPICAL SECTION - ROADWAY CROWN DETAILS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between two full depth precast concrete slabs. This connection was used to account for the crown of the bridge deck. This connection can also be used for stage construction joints. High early concrete was specified. This connection was constructed in one day and opened to traffic the next day.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

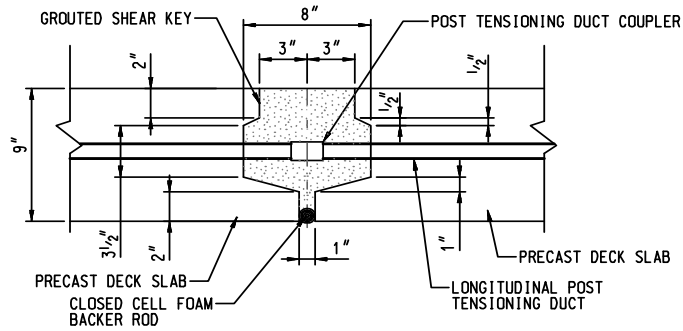
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Detail Number:
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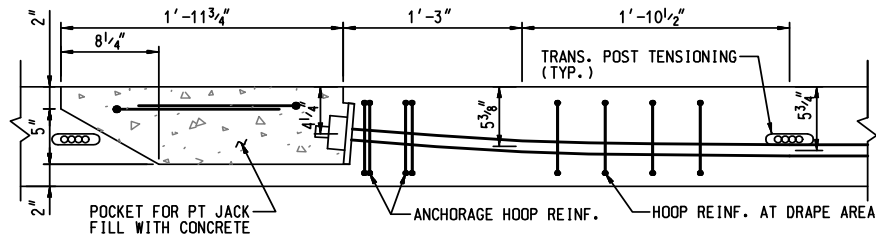
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



TRANSVERSE JOINT DETAILS



IN-SPAN LONGITUDINAL POST-TENSIONING ANCHORAGE

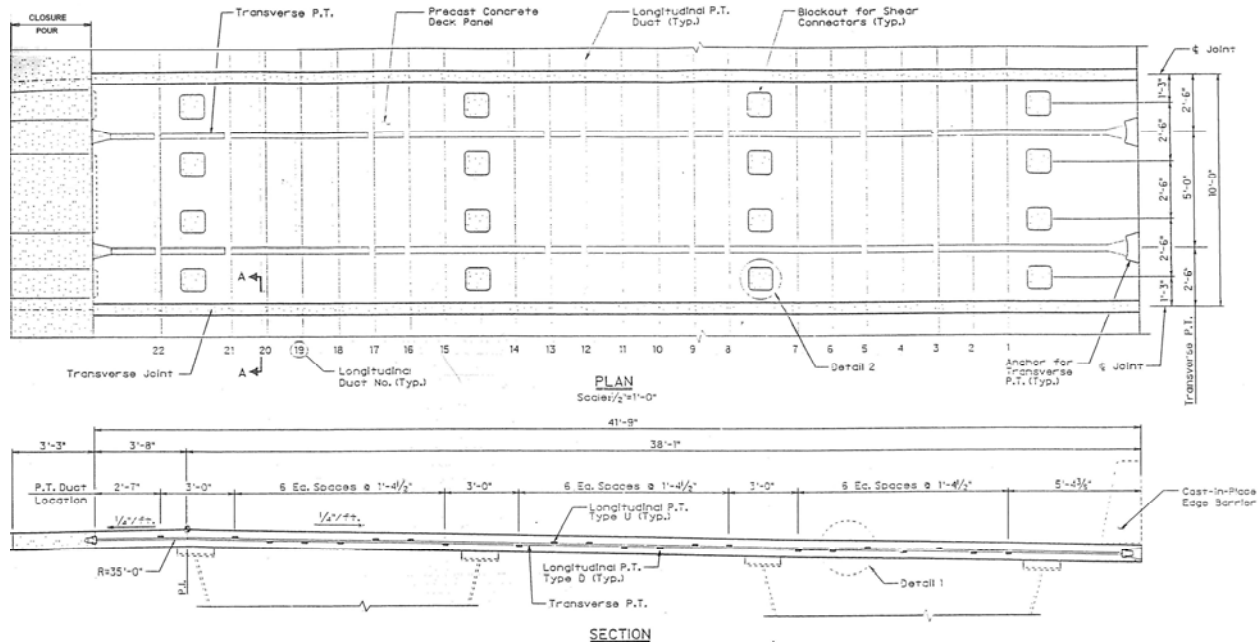
Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast post-tensioned slabs were used to speed up the construction. The design was based on providing minimal tension in deck slab. It is a good option for viaducts with steel box girders.

The detail shown is the transverse joint between adjacent slabs. The connection is post-tensioned longitudinally. The longitudinal post tensioning was staggered with anchorages at various locations throughout the span in order to control the stresses in the slab. The anchorage detail shows an anchorage away from the deck end.

An overall view of the system is shown below.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

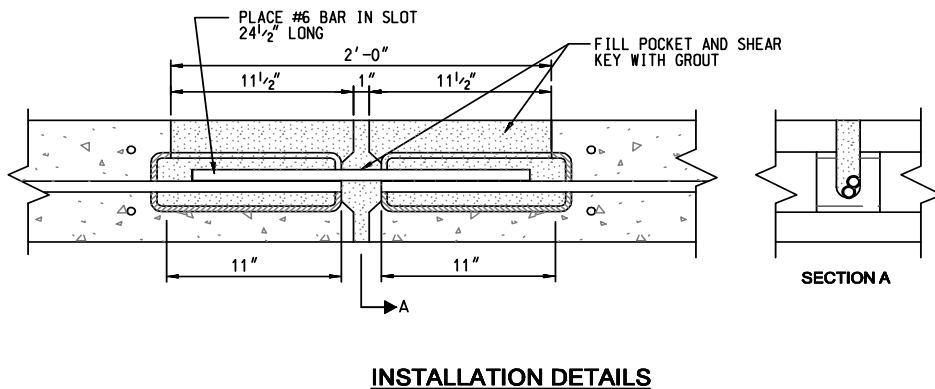
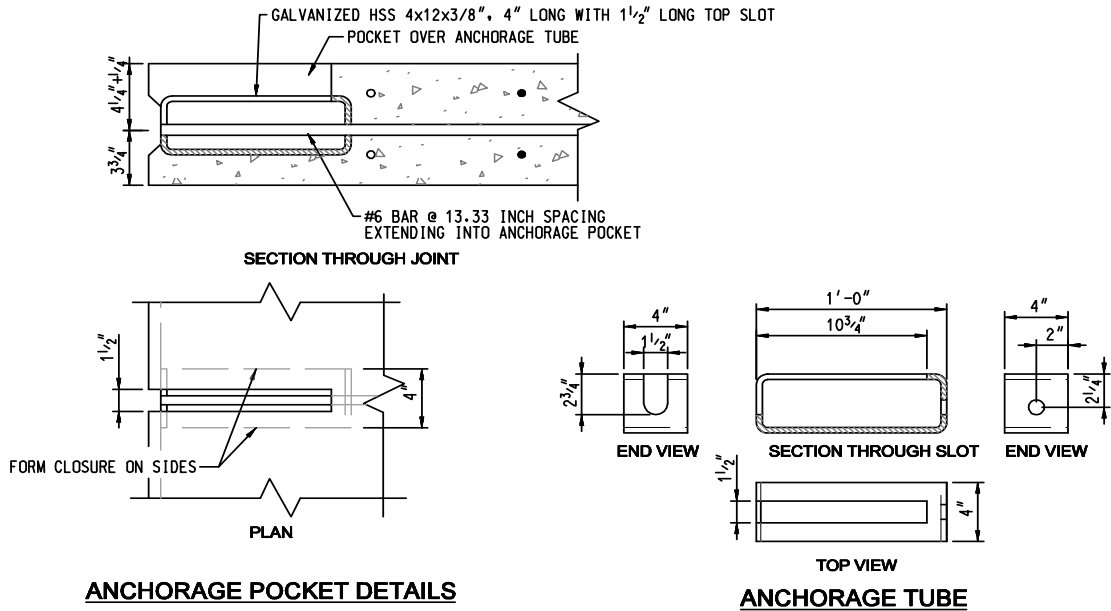
Organization: **Texas Department of Transportation**
 Contact Name: **Michael Hyzak**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.1.1.1 F**
 Phone Number: **512-416-2279**
 E-mail: MHYZAK@dot.state.tx.us
 Detail Classification: **Level 2**

Components Connected: **Precast Full Depth Deck Panel** to **Precast Full Depth Deck Panel**

Name of Project where the detail was used: **Live Oak Creek Bridge**

Connection Details: **Manual Reference Section 2.1.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This is believed to be the first use of the details developed and tested under NCHRP Project 12-65. The results of this research are available in NCHRP Report 584 entitled "Full Depth Precast Concrete Bridge Deck Panel Systems" authored by Sameh S. Badie at George Washington University and Maher K. Tadros at the University of Nebraska-Lincoln.

Features of the connection:

1. Longitudinal post-tensioning is not required to connect the deck panels in the field. Short reinforcing bars are placed in reinforced blockouts and grouted in place.
2. The bridge is a multi-span non-continuous structure, however the deck panels were run continuous over the beam to create a continuous deck. This approach is taken on many Texas bridges. Minor cracking is expected over the beam ends, which is acceptable in the arid environment.
3. A 1/4" thick sacrificial surface is cast in the panel so that grinding of the deck after installation is possible.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used?

Condition at last inspection (if known)

How many times has this detail been used?

Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

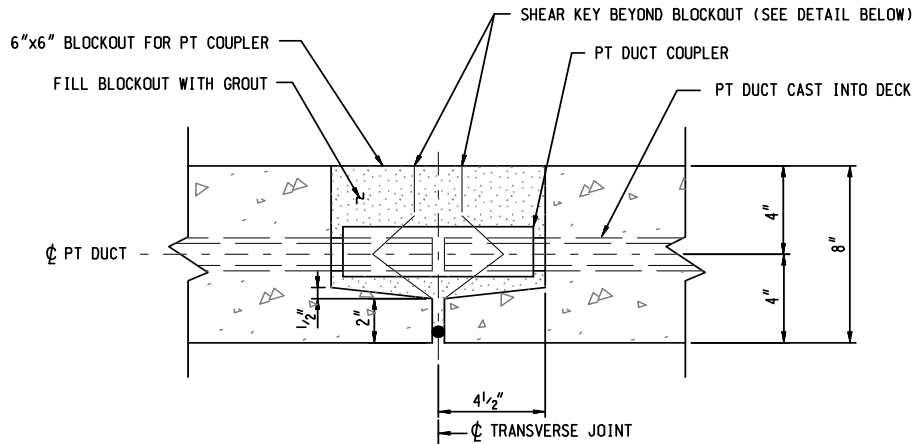
Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
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 Detail Classification:

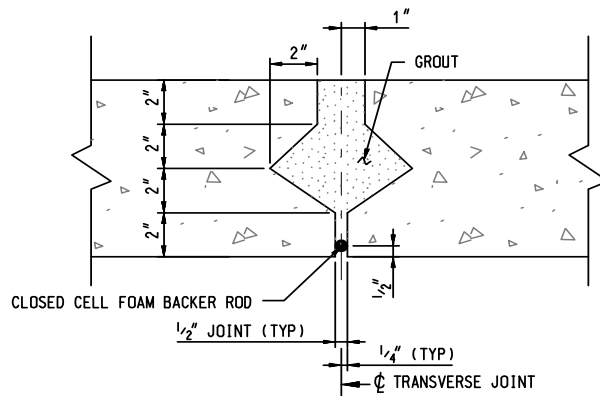
Components Connected: to

Name of Project where the detail was used:

Connection Details: **Manual Reference Section 2.1.1.1** See Reverse side for more information on this connection



TRANSVERSE JOINT @ DUCT COUPLER BLOCKOUT



TRANSVERSE JOINT BETWEEN DUCT COUPLER BLOCKOUTS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This project consisted of an option to use full depth 8" precast deck panels with a 2" ACP overlay (instead of a 9" C.I.P. concrete deck).

This option was included because of the remoteness of the site. Procedure is as follows:

- place and level panels (see other details)
- place duct couplers and grout transverse joints
- post-tension strand starting at bridge centerline and alternating each side of centerline
- grout shear connector blockouts (see other details) and post-tensioning ducts
- grind deck areas with relief of greater than ¼", construct barriers and place overlay

20 ducts were used with one strand per duct spaced at 1'-6".

The precast deck option was not chosen by the contractor on this project, however the details may be used on future projects.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

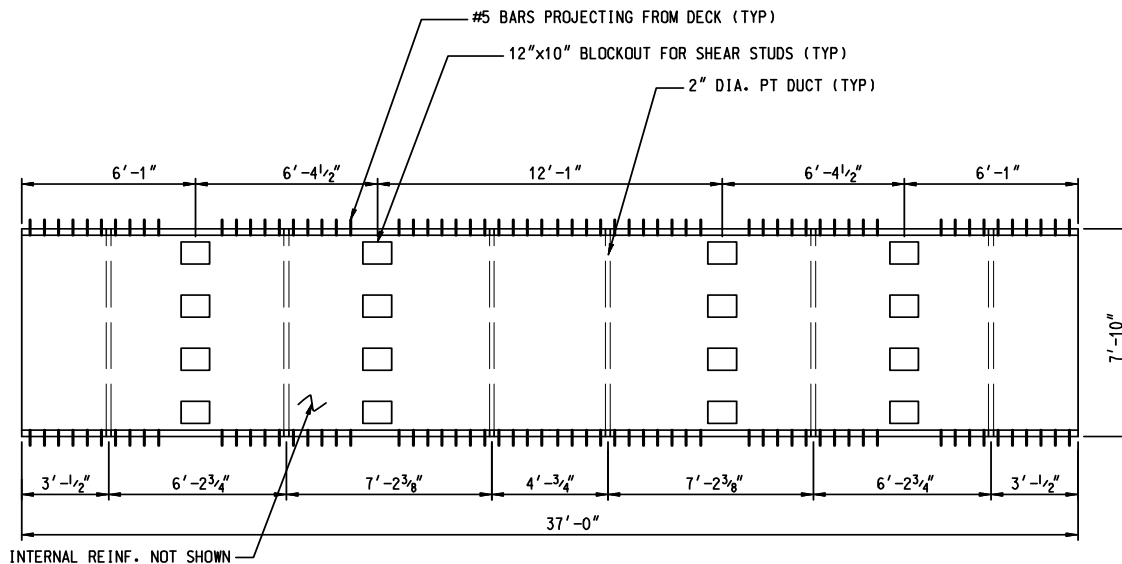
Organization: Colorado DOT
 Contact Name: T. Mashsha
 Address: 4201 East Arkansas Avenue
 Room 330
 Denver, CO 80222-3400

Detail Number: 2.1.1.1 H
 Phone Number: 303-757-9352
 E-mail:
 Detail Classification: Level 2

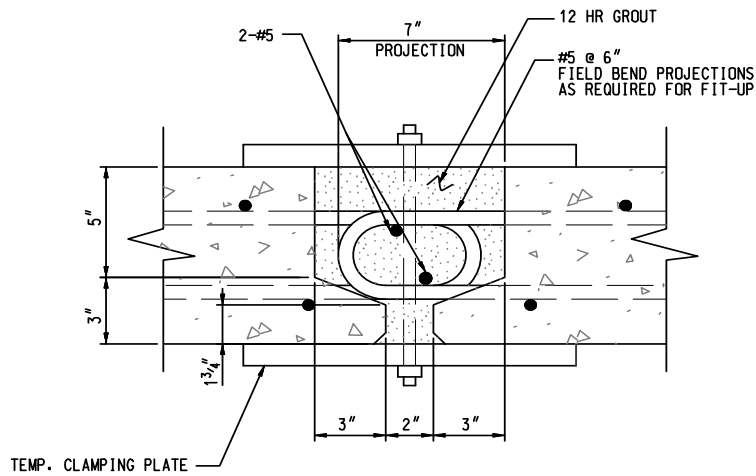
Components Connected: Precast Deck Slab to Precast PT Tub Girders

Name of Project where the detail was used: Richmond Road over US285

Connection Details: Manual Reference Section 2.1.1.1 See Reverse side for more information on this connection



PLAN - TYPICAL PANEL

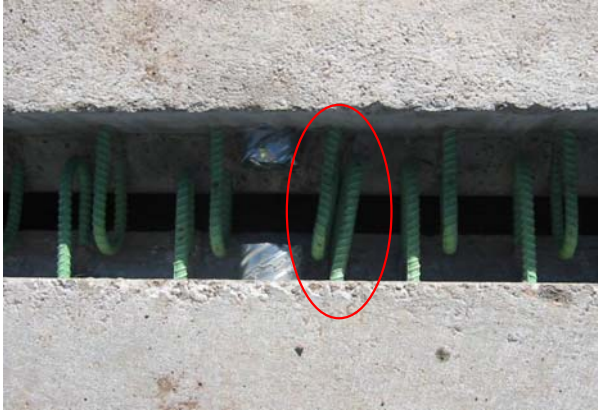


PANEL CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The connections between the precast slabs were made by using the reinforced concrete closure pour shown. They did have fit up problems with the precast panels because the projecting tie bars conflicted with the adjacent panels. These bars had to be bent in the field (see photo). The contractor also had difficulty feeding the transverse #5 bars in the closure pour between the two panels due to conflicts with the PT Ducts (see photo); therefore prestress strand was used as a substitute. The prestress strand should have been coated. The joint was filled with self consolidating concrete (SCC). Initially the SCC leaked through the forms. Subsequent pours were sealed properly.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment Compression x Tension x Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

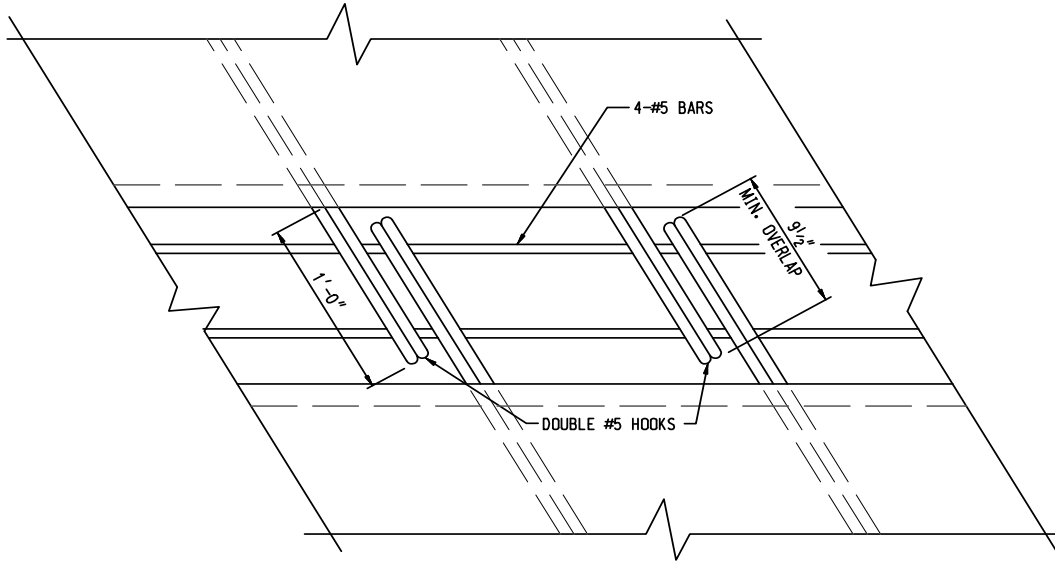
Organization: Iowa Department of Transportation
 Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
 Address: Office of Bridge and Structures
 800 Lincoln Way
 Ames, IA 50010

Detail Number: 2.1.1.1 I
 Phone Number: (515-239-1393
 E-mail: ahmad.abu-hawash@dot.iowa.gov
 Detail Classification: Level 2

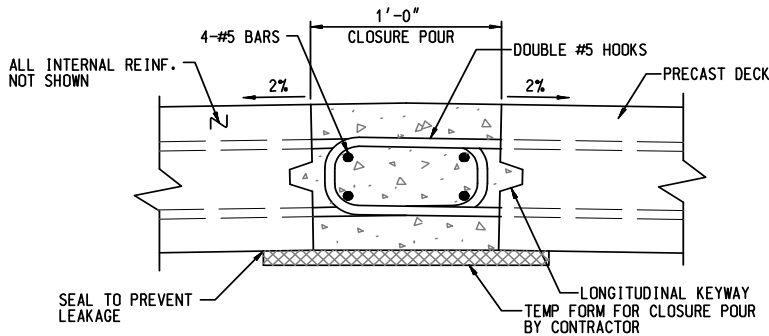
Components Connected: Full Depth Precast Concrete Deck Panel to Full Depth Precast Concrete Deck Panel

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek

Connection Details: Manual Reference Section 2.1.1.1 See Reverse side for more information on this connection



PLAN - LONGITUDINAL CLOSURE POUR



TYPICAL LONGITUDINAL CLOSURE POUR

NOTE:
 THE MANUFACTURER SHALL OFFSET THE PLACEMENT OF THE #5 HOOKS BETWEEN THE TWO HALVES OF THE DECK TO AVOID CLOSURE POUR INTERFERENCE. THE HOOKS SHALL BE PLACED UP TO A MAXIMUM OF 5" AWAY FROM THE INTERNAL DECK REINFORCING

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The Boone County IBRC Project had a out to out deck width of 33'-2". This deck was made up of two full depth precast deck panels measuring 16'-1" wide with a 1' wide longitudinal joint running down the centerline of the bridge. The precast panels included #5 bar double hoops extending from each panel into the joint. Four #5 bars where then placed longitudinally in the joint. The joint was then formed and cast-in-place with a high early strength concrete with low shrinkage characteristics.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: Virginia Department of Transportation
Contact Name: Ken Walus
Address: 1404 East Broad St.
Richmond, VA 2319

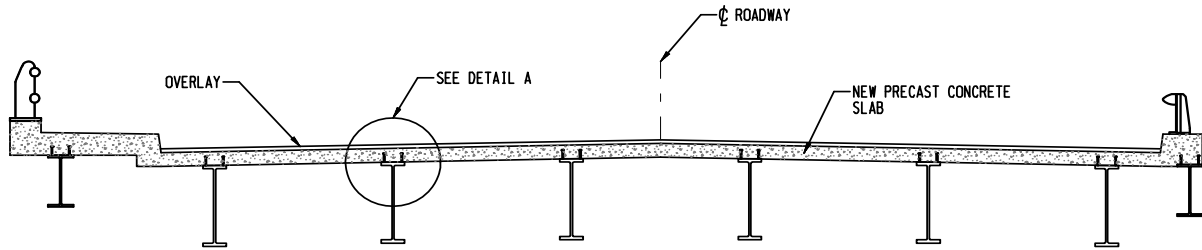
Detail Number: 2.1.1.1 J
Phone Number: (840) 786-4575
E-mail: Kendal.walus@vdot.virginia.gov

Detail Classification: Level 2

Components Connected: P/C Slab Connection For Stage Construction to Steel Girder Superstructure

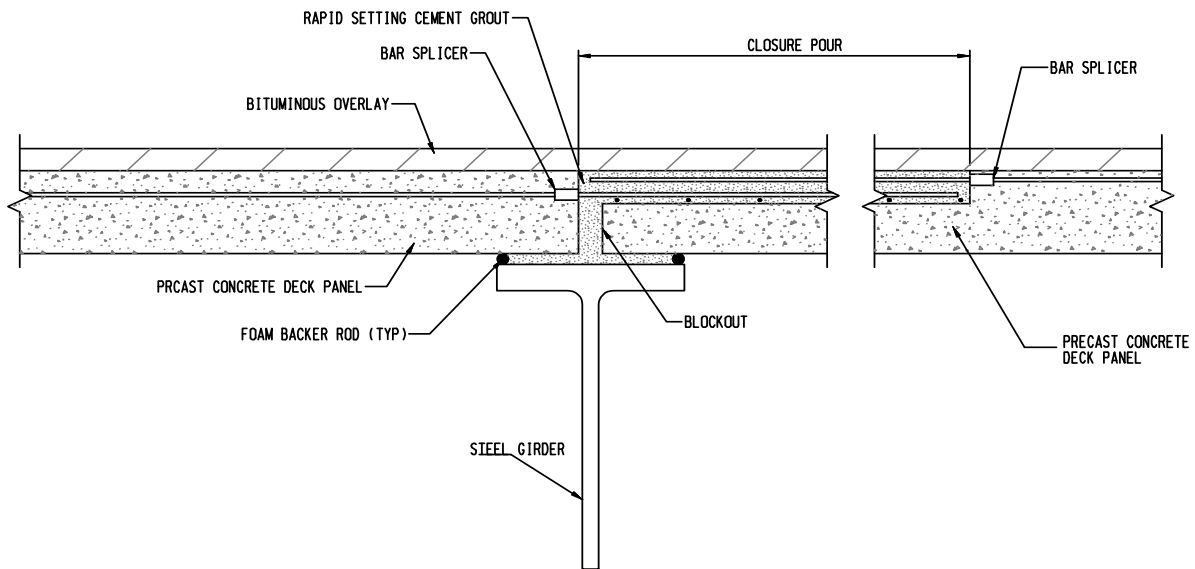
Name of Project where the detail was used: Route 7 over Route 50, 7 Corners

Connection Details: Manual Reference Section 2.1.1.1 See Reverse side for more information on this connection



CROSS SECTION OF STRUCTURE

NOTE: DIAPHRAGMS NOT SHOWN FOR CLARITY



DETAIL A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The existing composite concrete deck is replaced in 3 stages. In each stage, a portion of the transverse section is removed and replaced the full length of the bridge, while two traffic lanes are allowed on the bridge during the replacement. A total of 18 different panel shapes were designed to fit the 3 construction stages and the skewed ends of the deck slab, while conforming to the weight limit for transportability and constructability (10 tons). A typical panel is 10' in longitudinal direction of the bridge (direction of traffic) and its width varies depending on the stage of construction. Light weight concrete (110 lb/cy) is used in fabrication of the panels to compensate for the additional weight of the overlay.

Project Requirements for Precast Construction

The project requirements included the following: 1.)Construction operations shall be conducted in such a manner that all lanes on the bridges are open to traffic from 5:00 a.m. to 9:00 p.m. 2.)During construction (i.e., 9:00 p.m. to 5:00 a.m.) the bridges shall be partially open to traffic at all times. 3.)Weight of the precast concrete panels shall be limited to 10 tons to avoid special shipping and constructability requirements. 4.) Joints between precast panels shall be watertight. 5.)The bridge decks shall be overlaid to provide smooth ride over the precast panel joints. 6.)Joints between precast panels shall not reflect through the overlay. 7.)The dead load of the bridge deck (including overlay) shall not be higher than the dead load of the existing deck. 8.)The bridge deck shall be made composite with the existing steel framing.

Panel Continuity Across Longitudinal Joints

The two longitudinal joints between the three construction stages are oriented over girders to minimize shear forces at the panel longitudinal joints. The negative moment transfer at the longitudinal joints is provided by spliced top transverse bars embedded in a 3' strip of partial depth, high-early-strength, cast-in-place concrete.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

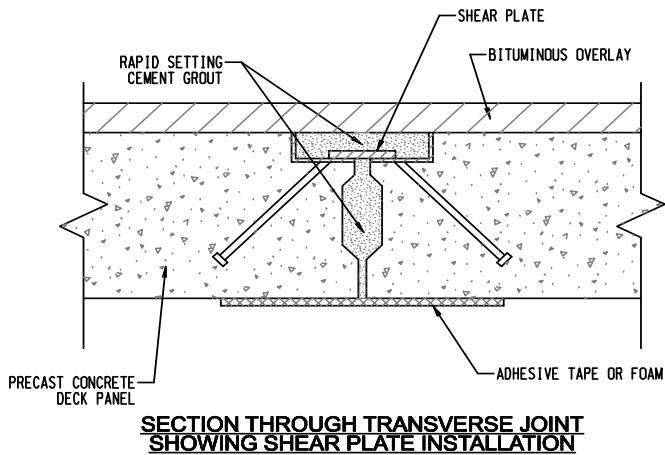
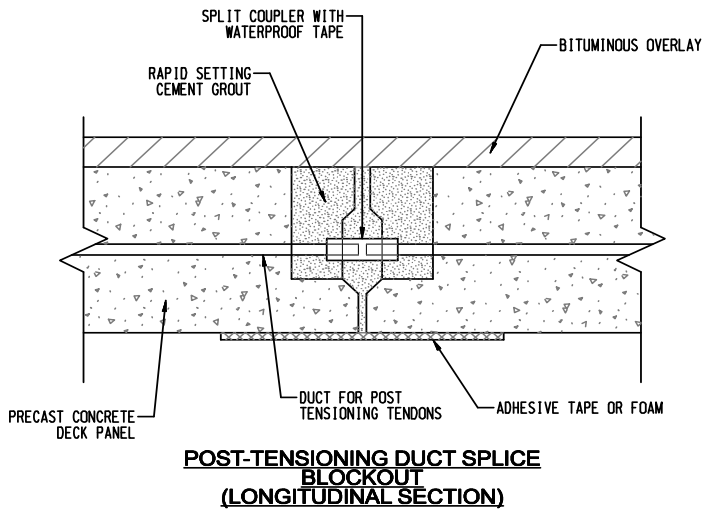
Organization:
Contact Name:
Address:

Detail Number:
Phone Number:
E-mail:
Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The existing composite concrete deck is replaced in 3 stages. In each stage, a portion of the transverse section is removed and replaced the full length of the bridge, while two traffic lanes are allowed on the bridge during the replacement. A total of 18 different panel shapes were designed to fit the 3 construction stages and the skewed ends of the deck slab, while conforming to the weight limit for transportability and constructability (10 tons). A typical panel is 10' in longitudinal direction of the bridge (direction of traffic) and its width varies depending on the stage of construction. Light weight concrete (110 lb/cy) is used in fabrication of the panels to compensate for the additional weight of the overlay.

Project Requirements for Precast Construction

The project requirements included the following: 1.)Construction operations shall be conducted in such a manner that all lanes on the bridges are open to traffic from 5:00 a.m. to 9:00 p.m. 2.)During construction (i.e., 9:00 p.m. to 5:00 a.m.) the bridges shall be partially open to traffic at all times. 3.)Weight of the precast concrete panels shall be limited to 10 tons to avoid special shipping and constructability requirements. 4.) Joints between precast panels shall be watertight. 5.)The bridge decks shall be overlaid to provide smooth ride over the precast panel joints. 6.)Joints between precast panels shall not reflect through the overlay. 7.)The dead load of the bridge deck (including overlay) shall not be higher than the dead load of the existing deck. 8.)The bridge deck shall be made composite with the existing steel framing.

Panel Continuity Across Transverse Joints

Continuity across the transverse joints is accomplished by providing a post-tensioned, grouted shear key. High-early-strength grout is used in the shear key. The gap at the bottom of shear key compensates for the dimensional tolerance of the panels. Post-tensioning provides 200 psi compression at the transverse joint. This amount of compression is sufficient for simple span bridges, since the deck is under compression from superimposed dead loads and live loads. The post-tensioning strands run along oblong ducts placed at mid-depth of the panels. The ducts are spliced at each transverse joint in small blockouts. Each post-tensioning duct utilizes three 0.6- inch diameter, seven wire, low relaxation strands with an ultimate tensile strength of 270 ksi. After post-tensioning, the ducts are pressure grouted and the blockouts are filled with the high-early-strength concrete.

To further improve shear transfer, welded sliding shear plates are installed across each transverse joint.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **PCI Northeast Bridge Tech Committee**
Contact Name: **Rita Seraderian**
Address: **116 Radcliffe Road
Belmont, MA 02478**

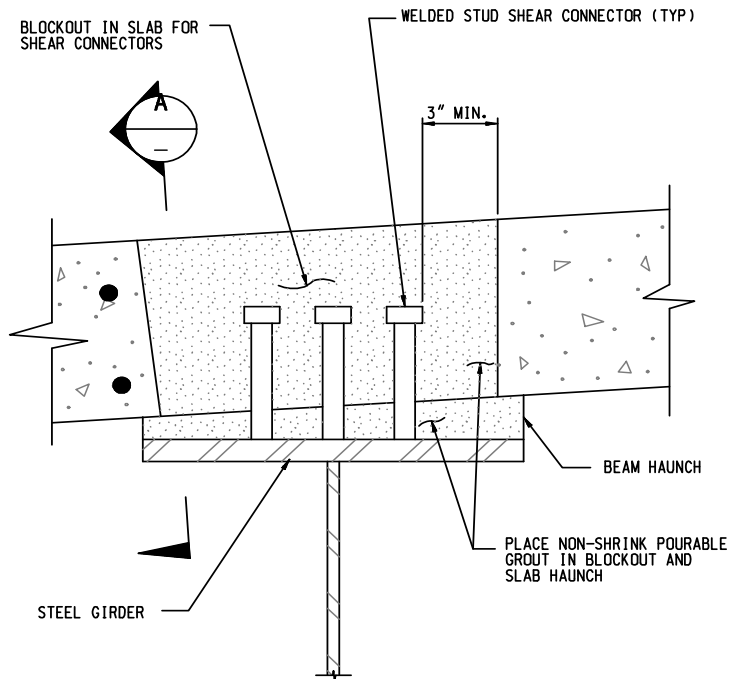
Detail Number: **2.1.1.2 A**
Phone Number: **888-700-5670**
E-mail: contact@pcine.org

Detail Classification: **Level 1**

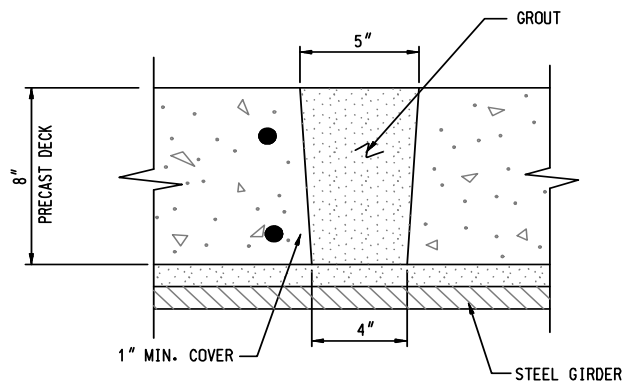
Components Connected: **Precast full depth slab** to **steel beam**

Name of Project where the detail was used: **I-84/Rt 8 Interchange, Waterbury, CT**

Connection Details: **Manual Reference Section 2.1.1.2** See Reverse side for more information on this connection



SHEAR CONNECTOR BLOCKOUT



SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of a full depth precast concrete slab to a steel beam. This detail can be used for stringer beams or floorbeams. This connection was used very effectively on two successful projects. It is important that the shear studs be installed after slab erection. Reinforcing in the slab needs to be adjusted to avoid the blockouts. The design is the same as a cast-in-place slab shear connector. Spacing of blockouts is usually kept to 24" on center. Blockouts have been built with both rounded and square corners. Rounded corners are preferred in order to minimize potential for cracking.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

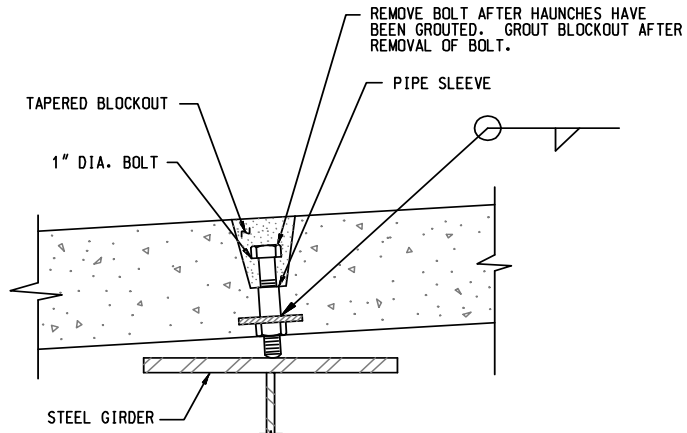
Detail Number:
Phone Number:
E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



LEVELING DEVICE DETAIL

NOTES: USE TWO LEVELING DEVICES PER DECK SLAB PER BEAM LINE TO ENSURE PROPER DEAD LOAD DISTRIBUTION TO THE GIRDERS.

THE CONTRACTOR IS RESPONSIBLE FOR THE DESIGN OF THE LEVELING DEVICE BASED ON THE WEIGHT OF THE SLABS AND THE NUMBER OF DEVICES.

ALTERNATE DEVICES MAY BE SUBSTITUTED WITH APPROVAL FROM THE ENGINEER.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to control grade during installation and to properly distribute the slab dead load to each stringer. Two bolts should be placed on each beam or stringer. Specifications should indicate that the torque of each bolt should all be within 20% of each other so that the dead load is relatively uniform. The details shown allows for removal of the bolt after the grout in the beam haunch has set. The contractor should be allowed to substitute alternate details; however they should be adjustable and should be able to transmit the dead load evenly to each beam below.

This detail should be used in conjunction with grouted shear connector pockets (see details in Section 2.1.1).

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

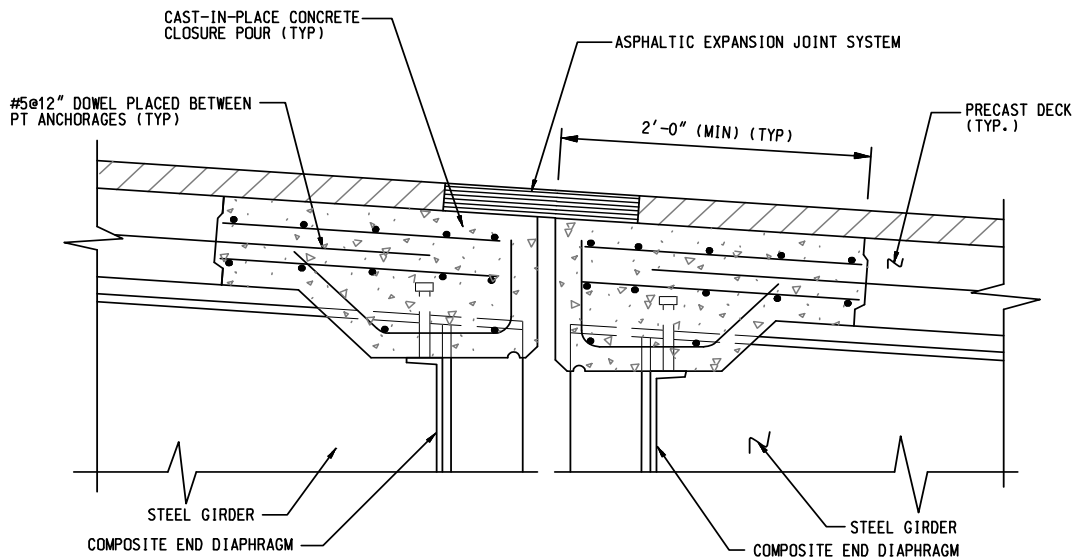
Organization: PCI Northeast Bridge Tech Committee
Contact Name: Rita Seraderian
Address: 116 Radcliffe Road
Belmont, MA 02478

Detail Number: 2.1.1.2 C
Phone Number: 888-700-5670
E-mail: contact@pcine.org
Detail Classification: Level 1

Components Connected: Precast full depth slab to Steel end diaphragm

Name of Project where the detail was used: I-84/Rt 8 Interchange, Waterbury, CT

Connection Details: Manual Reference Section 2.1.1.2 See Reverse side for more information on this connection



TYPICAL SECTION - CLOSURE POURS AT DECK ENDS

NOTES: CLOSURE POURS SHOWN AT A PIER. CLOSURE POURS AT ABUTMENTS SIMILAR.
CLOSURE POUR DETAILS MAY VARY BASED ON DESIGN OF BRIDGE JOINT.
REINFORCEMENT FOR CLOSURE POURS SHALL BE DESIGNED BY THE ENGINEER.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This connection was used to account for field adjustability, accommodate the deck expansion joint, and make a composite connection to the steel end diaphragm. High early concrete was specified. This connection was constructed in one day and opened to traffic the next.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

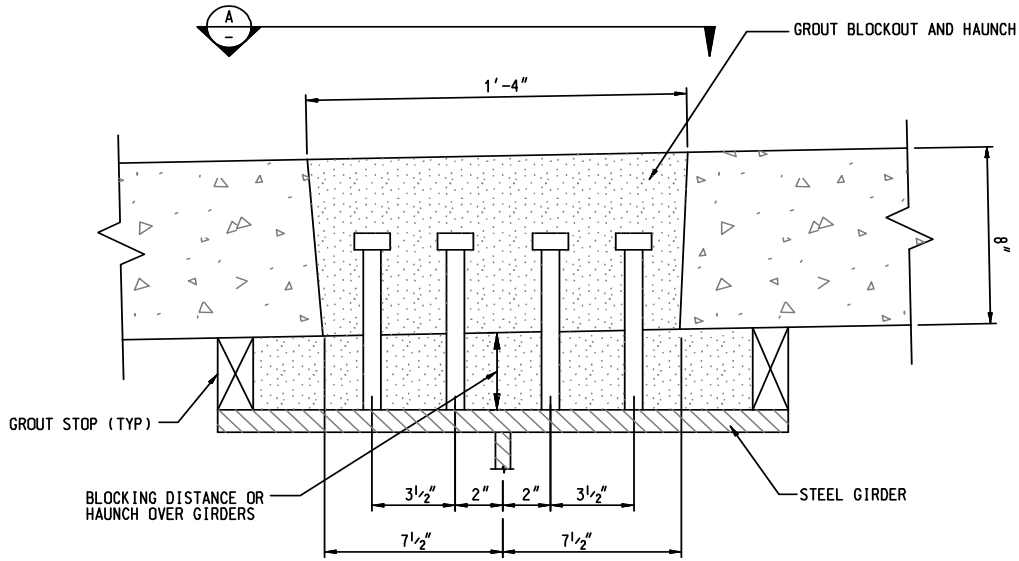
Organization: Washington State D.O.T.
 Contact Name: Eric Ferluga
 Address: Bridge and Structures Office
P.O. Box 47340
Olympia, WA 98504-7340

Detail Number: 2.1.1.2 D
 Phone Number: 360-705-7179
 E-mail: ferluga@WSDOT.WA.GOV
 Detail Classification: Level 1

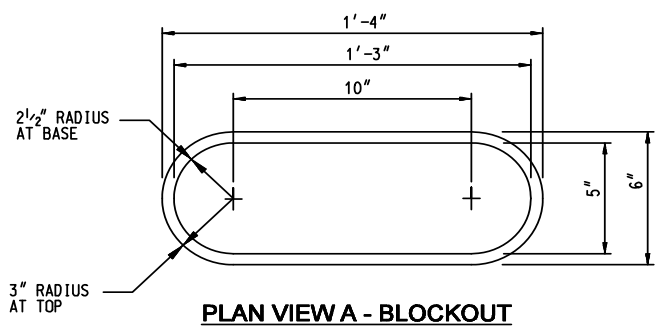
Components Connected: Precast full depth deck to Steel Girder

Name of Project where the detail was used: US 101 ~ Nolan Creek Vic. Bridge and Realignment

Connection Details: Manual Reference Section 2.1.1.2 See Reverse side for more information on this connection



SHEAR CONNECTOR BLOCKOUT



PLAN VIEW A - BLOCKOUT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This project consisted of an option to use full depth 8" precast deck panels with a 2" ACP overlay (instead of a 9" C.I.P. concrete deck).

This option was included because of the remoteness of the site. Procedure is as follows:

- grout stops are placed along girder flanges, place precast deck panels
- adjust leveling bolts to achieve profile and install shear connectors
- construct transverse joints and post tension (see other details) then grout shear connector blockouts
- grind deck, construct traffic barriers and overlay deck

Shear connectors are spaced at 1'-6" o.c. and there are 6 leveling bolts per panel (2 per girder).

Slab reinforcing is adjusted to miss blockouts.

The precast deck option was not chosen by the contractor on this project, however the details may be used on future projects.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

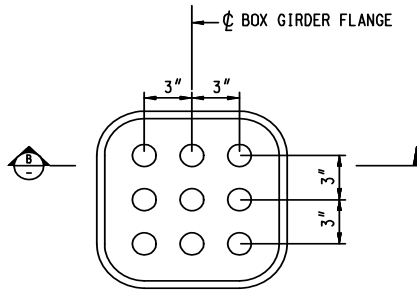
Organization: **New York State DOT**
 Contact Name: **Nicolas A. Choubah**
 Address: **Regional Structures Group
 4 Burnett Blvd.
 Poughkeepsie, NY 12603**

Detail Number: **2.1.1.2 E**
 Phone Number: **(845) 431-7924**
 E-mail: **nchoubah@dot.state.ny.us**
 Detail Classification: **Level 1**

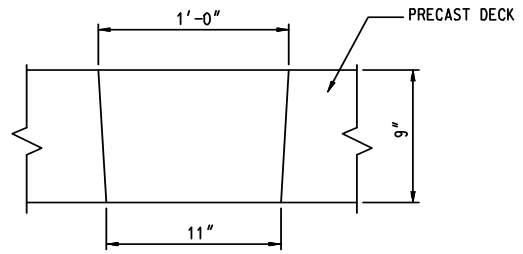
Components Connected: **Precast Deck Slab** to **Steel Box Girder**

Name of Project where the detail was used: **Replacement of I-287 Viaduct over the Bronx River Parkway**

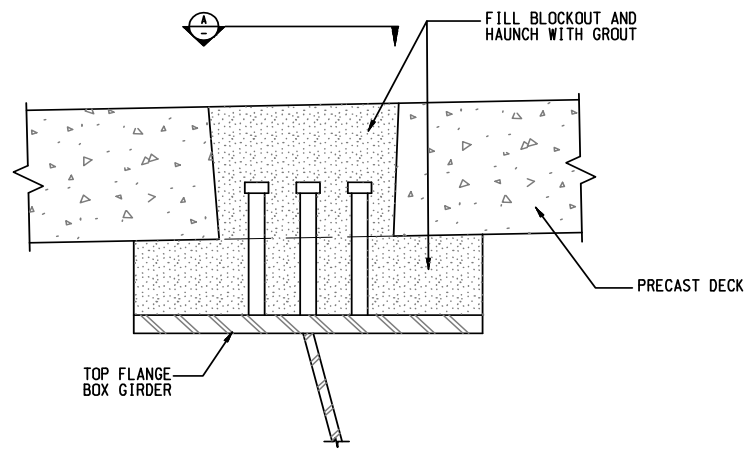
Connection Details: **Manual Reference Section 2.1.1.2** See Reverse side for more information on this connection



PLAN VIEW A- BLOCKOUT



SECTION B AT BLOCKOUT



TYPICAL BLOCKOUT CONNECTION

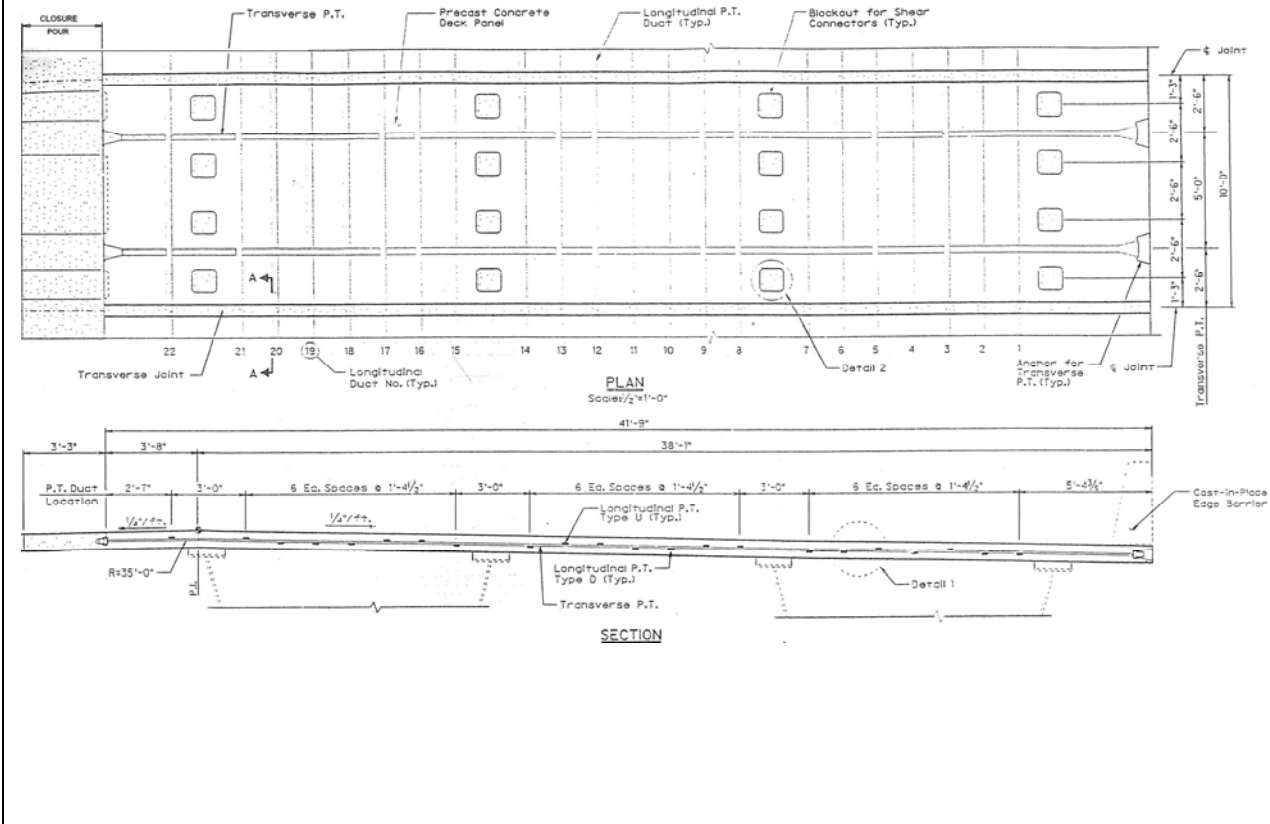
Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast post-tensioned slabs were used to speed up the construction. The design was based on providing minimal tension in deck slab. It is a good option for viaducts with steel box girders.

The detail shown is the connection between the slab and the steel box girder. Up to 12 studs were installed per blockout. The spacing of the blockouts was 2'-6" in order to minimize interference with the transverse and longitudinal post-tensioning ducts.

An overall view of the system is shown below.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

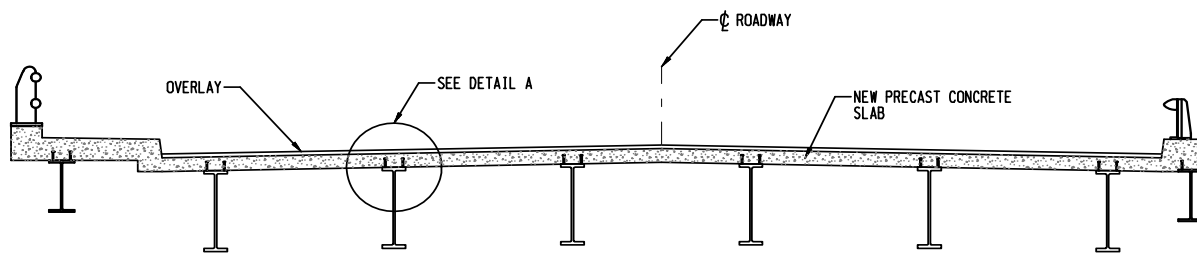
Detail Number:
Phone Number:
E-mail:

Detail Classification:

Components Connected: to

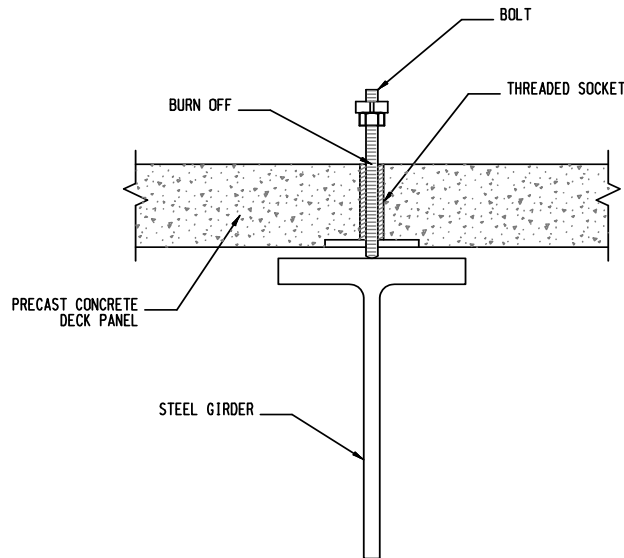
Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



CROSS SECTION OF STRUCTURE

NOTE: DIAPHRAGMS NOT SHOWN FOR CLARITY



DETAIL A - LEVELING BOLT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Panels Elevation Adjustment

The top of panel elevations are adjusted by a leveling bolt system. Each panel has 4 bolts threaded through cast-in-place sockets. These bolts temporarily bear on the existing girders and are adjusted by a wrench. After positioning the panel, the haunch between the panel and girder is built with a high-early-strength concrete. The high-early-strength concrete is a latex-modified concrete that gains 3,000 psi compressive strength in 3 hours sufficient to allow traffic on the bridge. The strength in 24 hours is 6,000 psi.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
 Contact Name:
 Address:

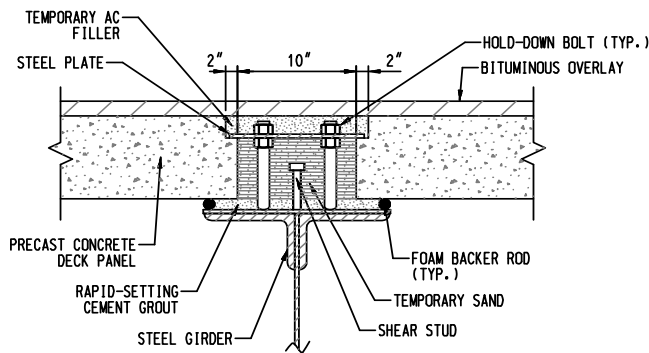
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 Phone Number:
 E-mail:

Detail Classification:

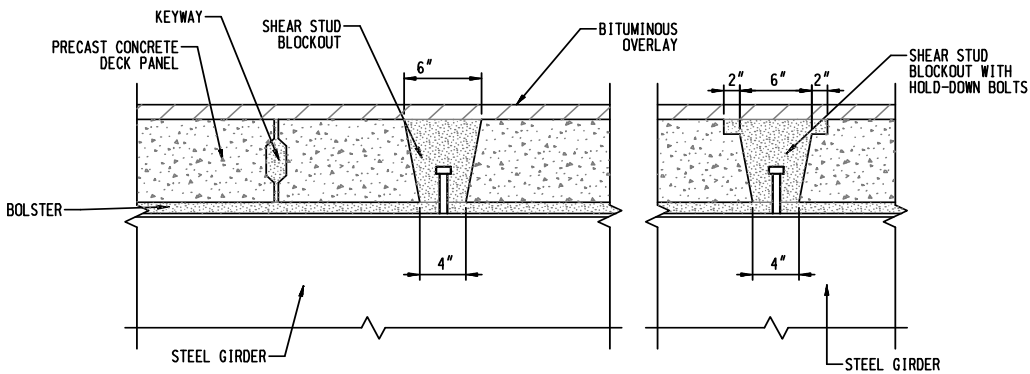
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



SHEAR STUD BLOCKOUT WITH HOLD-DOWN BOLTS



SHEAR STUD BLOCKOUTS LONGITUDINAL SECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Composite Action

The panels have shear stud blockouts located over the girders. Composite action is provided by studs welded to the girders in these blockouts. The blockouts have a tapered wall to prevent uplift of the panel, and they are filled with the high early strength concrete. It should be noted that the shear stud blockouts are filled after post-tensioning, to prevent exerting positive moments onto superstructure from post-tensioning.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

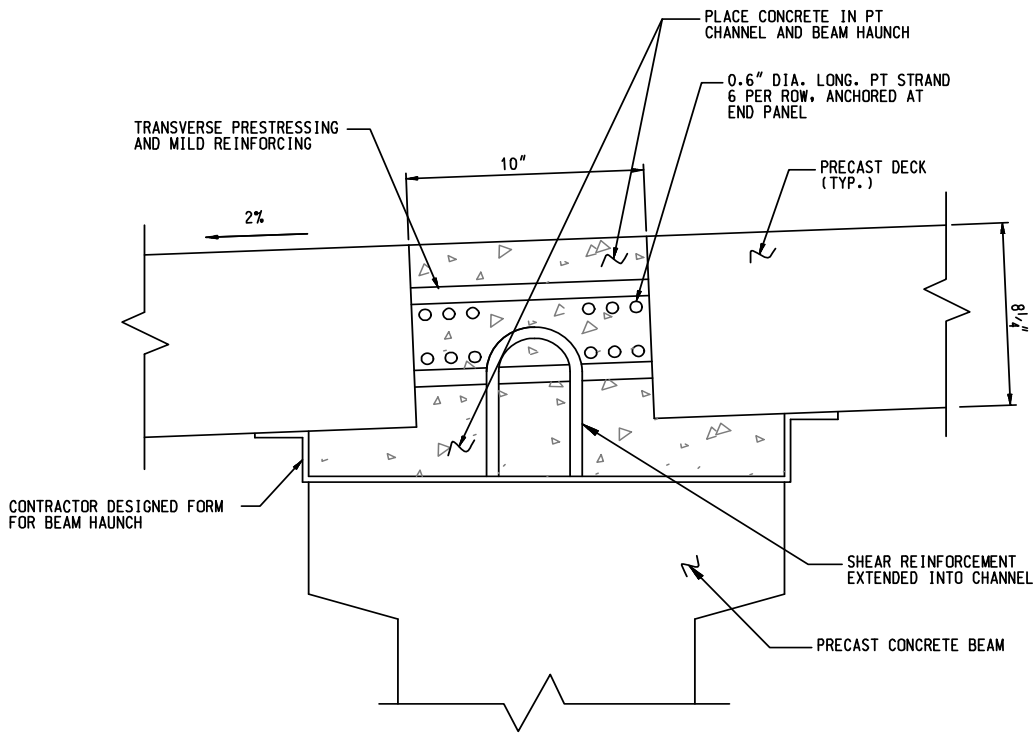
Organization: Iowa Department of Transportation
Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
Address: Office of Bridge and Structures
800 Lincoln Way
Ames, IA 50010

Detail Number: 2.1.1.3 A
Phone Number: (515-239-1393
E-mail: ahmad.abu-hawash@dot.iowa.gov
Detail Classification: Level 2

Components Connected: Full Depth Precast Concrete Deck Panel to Precast Concrete Beam

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek

Connection Details: Manual Reference Section 2.1.1.3 See Reverse side for more information on this connection



PRECAST DECK PANEL POST - TENSIONING CHANNEL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The Boone County IBRC Project utilized full depth precast concrete deck panels sitting on precast pretensioned concrete beams. The beams were cast with stirrup steel extending from the top flanges of the beams. The precast panels were fabricated longitudinal openings measuring 10" across where the panels intersected the beams. Reinforcing steel from the panels extended across the voids. The panels were placed in the beams and raised to the proper elevation using leveling devices that the contractor created. Once leveled, the beam haunches were formed and deck panels post-tensioned together utilizing the void above the beams as post-tensioning ducts. Once post-tensioned, the beam haunches and voids in the panels were cast with a early high strength, low shrinkage concrete.

A number of beam stirrups had to be bent by the contractor to relieve the interference caused by the panel reinforcing steel extending across the opening. The 30 degree skew created a number of interference points. The contractor pointed out that if the beam stirrups had been placed in the beam at a matching skew, no stirrups would have had to been bent to make the panels fit.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

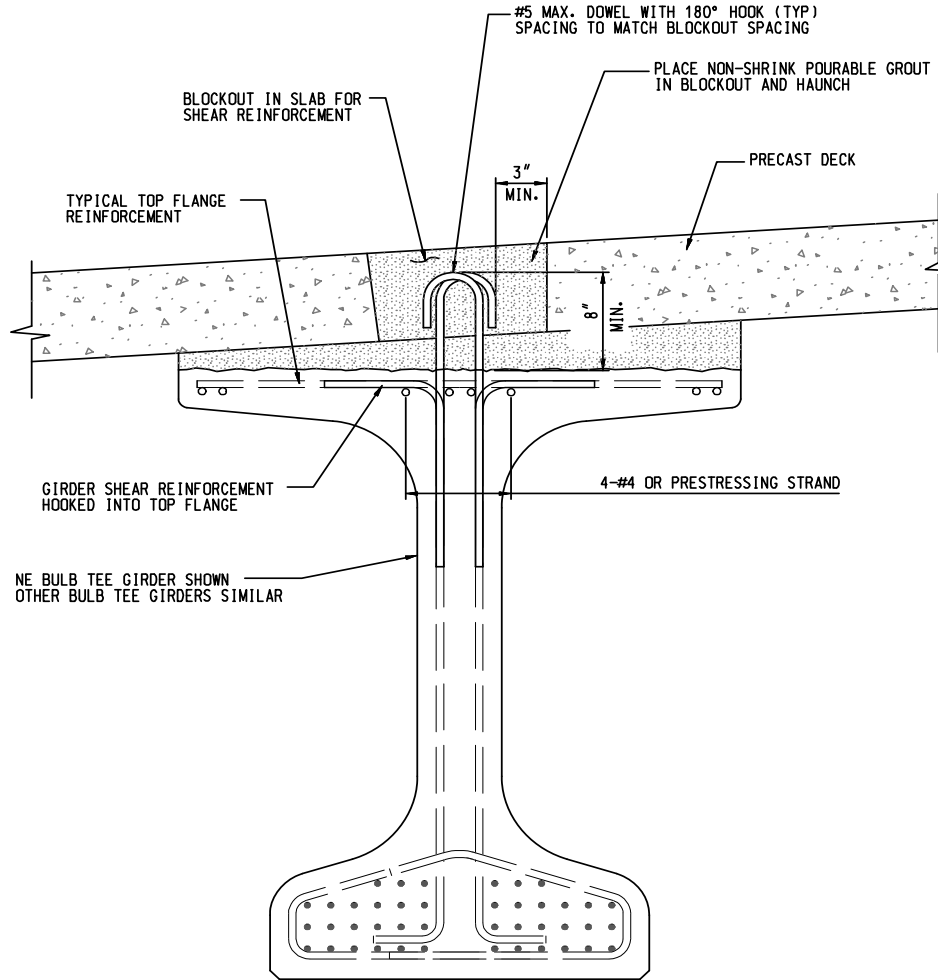
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **2.1.1.3 B**
 Phone Number: **888-700-5670**
 E-mail: **contact@pcine.org**
 Detail Classification: **Level 3**

Components Connected **Precast full depth slab** to **New Prestressed Beam**

Name of Project where the detail was used **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 2.1.1.3** See Reverse side for more information on this connection



PRECAST DECK CONNECTION TO BULB TEE GIRDER

NOTES: HORIZONTAL SHEAR REINFORCEMENT SHALL BE PLACED ALONG THE SKEW OF THE BLOCKOUTS.
 ADDITIONAL HORIZONTAL SHEAR CAPACITY MAY BE PROVIDED BY ADDING AN 1/4" AMPLITUDE CORRUGATED FORM LINER BETWEEN THE BLOCKOUTS ON THE UNDERSIDE OF THE SLAB ALONG THE CENTERLINE OF THE BEAMS.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of full depth precast concrete slabs to precast concrete bulb tee beam. This detail is used to transfer horizontal shear between the beams and the slab. This detail is being studied by several researchers. Design equations for this connection will most likely be issued in the codes in the near future. Preliminary research has shown that the current AASHTO equations for horizontal shear reinforcement may be adequate.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

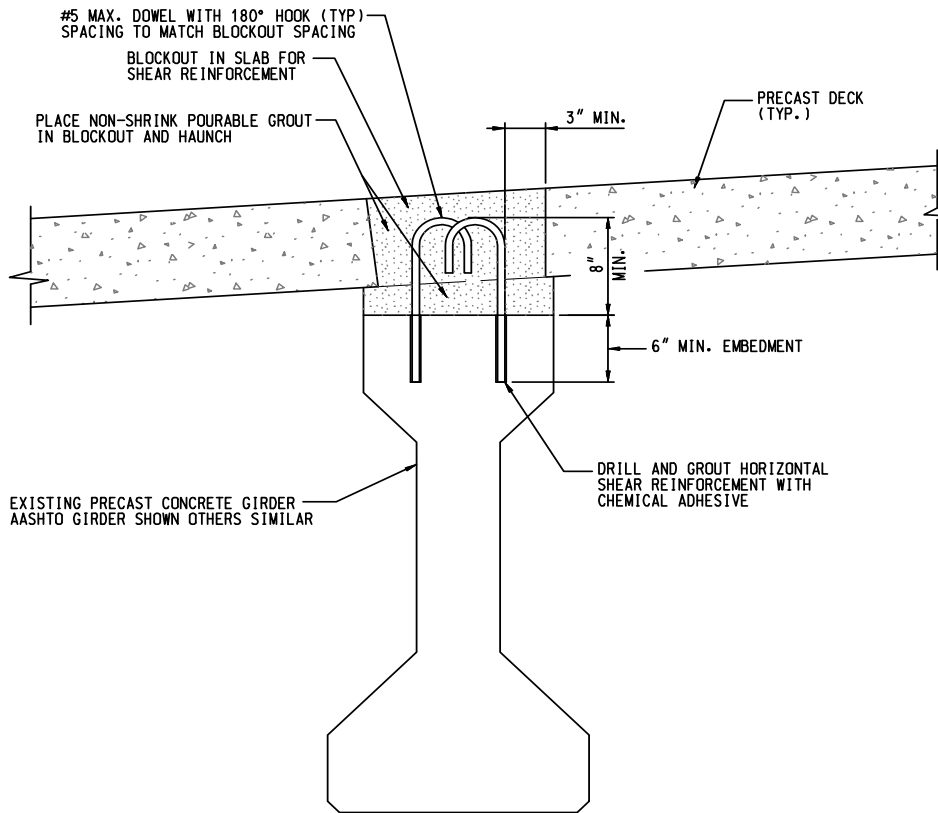
Organization: PCI Northeast Bridge Tech Committee
Contact Name: Rita Seraderian
Address: 116 Radcliffe Road
Belmont, MA 02478

Detail Number: 2.1.1.3 C
Phone Number: 888-700-5670
E-mail: contact@pcine.org
Detail Classification: Level 3

Components Connected: Precast full depth slab to Existing concrete beams

Name of Project where the detail was used: Never used: CONCEPTUAL

Connection Details: Manual Reference Section 2.1.1.3 See Reverse side for more information on this connection



PRECAST DECK CONNECTION TO EXISTING GIRDER
DECK REPLACEMENT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of full depth precast concrete slabs to existing precast concrete beam as part of a deck replacement. This detail is used to transfer horizontal shear between the beams and the slab. This detail can be used for deck replacement projects. This detail is being studied by several researchers. Design equations for this connection will most likely be issued in the codes in the near future. Preliminary research has shown that the current AASHTO equations for horizontal shear reinforcement may be adequate. Drilling into the existing beams should not be problematic since most prestressing steel is placed in the lower portions of the beam.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear x Moment Compression Tension Torsion

What year was this detail first used? NA Condition at last inspection (if known) NA

How many times has this detail been used? 0 Year of last inspection NA

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 10 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 8 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 0 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

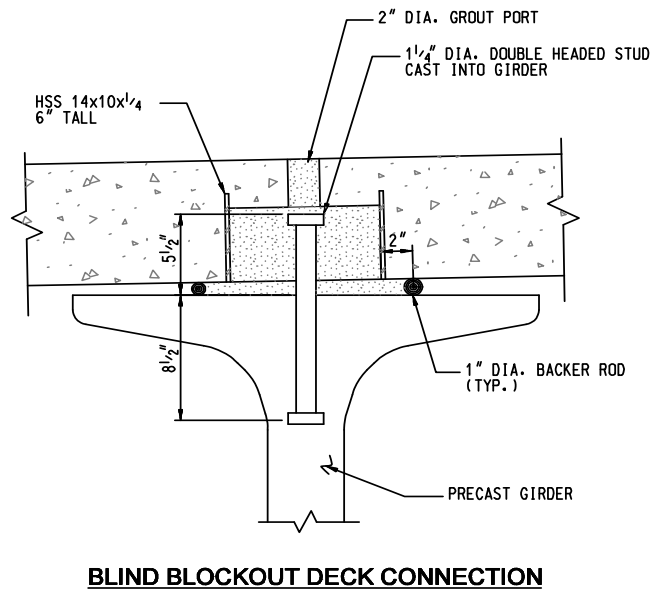
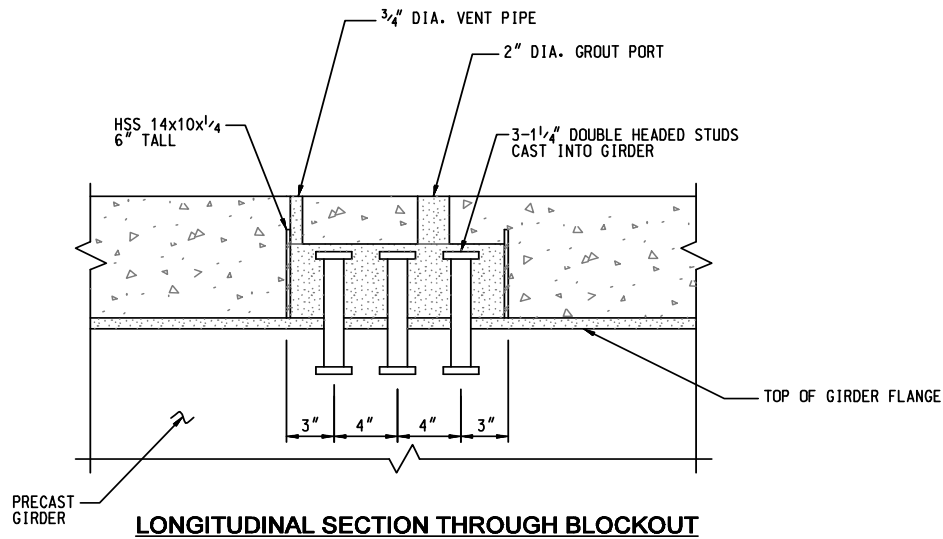
Organization: **Texas Department of Transportation**
 Contact Name: **Michael Hyzak**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.1.1.3 D**
 Phone Number: **512-416-2279**
 E-mail: **MHYZAK@dot.state.tx.us**
 Detail Classification: **Level 2**

Components Connected: **Precast Full Depth Deck Panel** to **Prestressed Concrete I-Beam**

Name of Project where the detail was used: **Live Oak Creek Bridge**

Connection Details: **Manual Reference Section 2.1.1.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This is believed to be the first use of the details developed and tested under NCHRP Project 12-65. The results of this research are available in NCHRP Report 584 entitled "Full Depth Precast Concrete Bridge Deck Panel Systems" authored by Sameh S. Badie at George Washington University and Maher K. Tadros at the University of Nebraska-Lincoln.

Features of the connection:

1. The shear stud pockets are spaced at 4 feet on center, which reduced the amount of grouting required in the field.
2. The pockets for the shear connectors are blind in that they do not penetrate the top surface of the deck. The pockets are grouted through tubes that project through the top of the deck.
3. The limited number of pockets in the top of the deck will provide a better riding surface as a bare concrete deck.
4. A 1/4" thick sacrificial surface is cast in the panel so that grinding of the deck after installation is possible.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

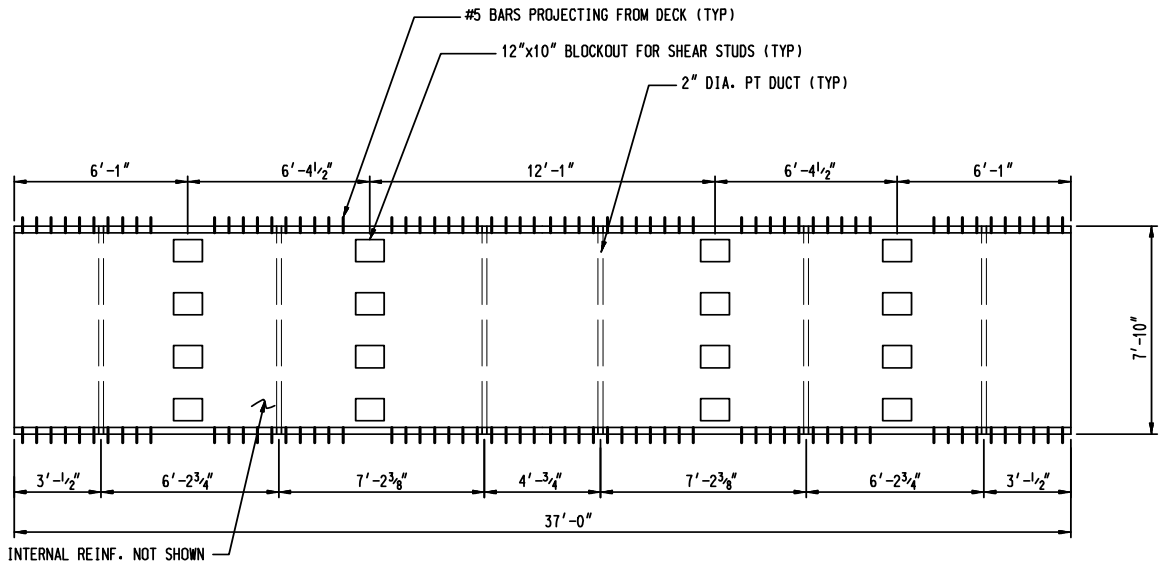
Organization: **Colorado DOT**
 Contact Name: **T. Mashsha**
 Address: **4201 East Arkansas Avenue
 Room 330
 Denver, CO 80222-3400**

Detail Number: **2.1.1.3 E**
 Phone Number: **303-757-9352**
 E-mail:
 Detail Classification: **Level 2**

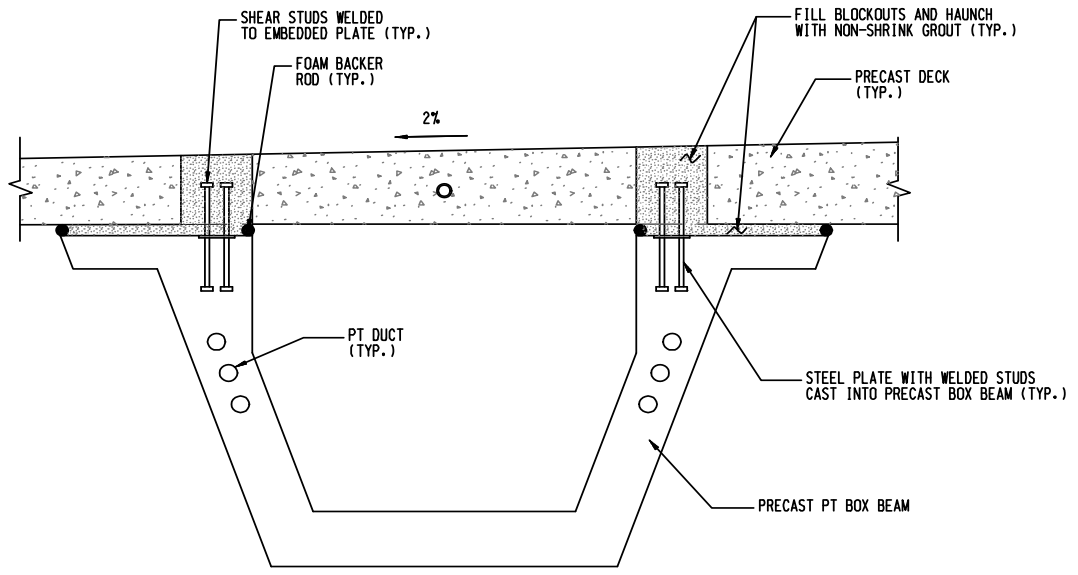
Components Connected: **Precast Deck Slab** to **Precast PT Tub Girders**

Name of Project where the detail was used: **Richmond Road over US285**

Connection Details: **Manual Reference Section 2.1.1.3** See Reverse side for more information on this connection



PLAN - TYPICAL PANEL



PRECAST DECK TO BOX BEAM CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The connections between the precast slabs and the precast beams were made by embedding a steel plate into the top of the precast beams in the fabrication yard. The studs were then welded in the field. The fabricator had difficulty with the installation of the plate at the yard. The slabs were designed with longitudinal post tensioning (4-0.6" diameter prestressing strand per duct) and transverse prestressing.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment Compression x Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **PCI Northeast Bridge Tech Committee**
Contact Name: **Rita Seraderian**
Address: **116 Radcliffe Road
Belmont, MA 02478**

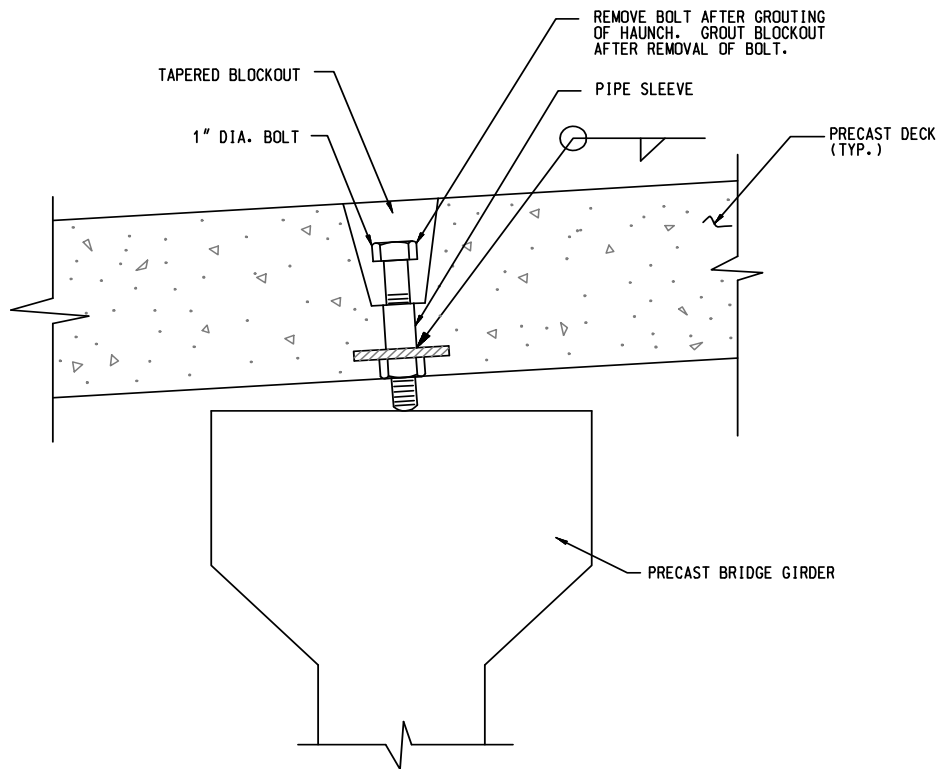
Detail Number: **2.1.1.3 F**
Phone Number: **888-700-5670**
E-mail: **contact@pcine.org**

Detail Classification: **Level 1**

Components Connected: **Precast full depth slab** to **Concrete Beam**

Name of Project where the detail was used: **Various**

Connection Details: **Manual Reference Section 2.1.1.3** See Reverse side for more information on this connection



LEVELING DEVICE DETAIL

- NOTES: USE TWO LEVELING DEVICES PER DECK SLAB PER BEAM LINE TO ENSURE PROPER DEAD LOAD DISTRIBUTION TO THE GIRDERS.
- THE CONTRACTOR IS RESPONSIBLE FOR THE DESIGN OF THE LEVELING DEVICE BASED ON THE WEIGHT OF THE SLABS AND THE NUMBER OF DEVICES.
- ALTERNATE DEVICES MAY BE SUBSTITUTED WITH APPROVAL FROM THE ENGINEER.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to control grade during installation and to properly distribute the slab dead load to each stringer. Two bolts should be placed on each beam or stringer. Specifications should indicate that the torque of each bolt should all be within 20% of each other so that the dead load is relatively uniform. The details shown allows for removal of the bolt after the grout in the beam haunch has set. The contractor should be allowed to substitute alternate details; however they should be adjustable and should be able to transmit the dead load evenly to each beam below.

This detail should be used in conjunction with grouted shear connector pockets (see details in Section 2.1.1).

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

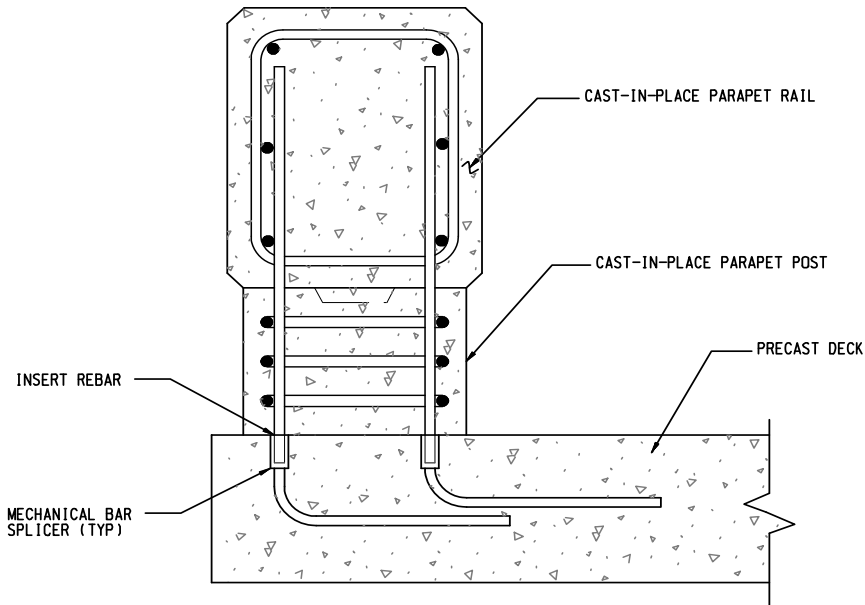
Organization: Iowa Department of Transportation
Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
Address: Office of Bridge and Structures
800 Lincoln Way
Ames, IA 50010

Detail Number: 2.1.1.4 A
Phone Number: (515-239-1393
E-mail: ahmad.abu-hawash@dot.iowa.gov
Detail Classification: Level 2

Components Connected: Full Depth Precast Concrete Deck Panel to Cast-in-place Open Concrete Barrier Rail

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek

Connection Details: Manual Reference Section 2.1.1.4 See Reverse side for more information on this connection



CONNECTION OF DECK TO PARAPET

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The Boone County IBRC Project utilized full depth precast concrete deck panels. The fabricator was given two options for precast deck panel to barrier rail connections. The first option was a traditional option with reinforcing steel bars extending from the deck as typical in cast-in-place deck construction. The second option involved the use of mechanical splices placed in the precast deck panels for the barrier rail connection. The fabricator elected to use the mechanical splice connection

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

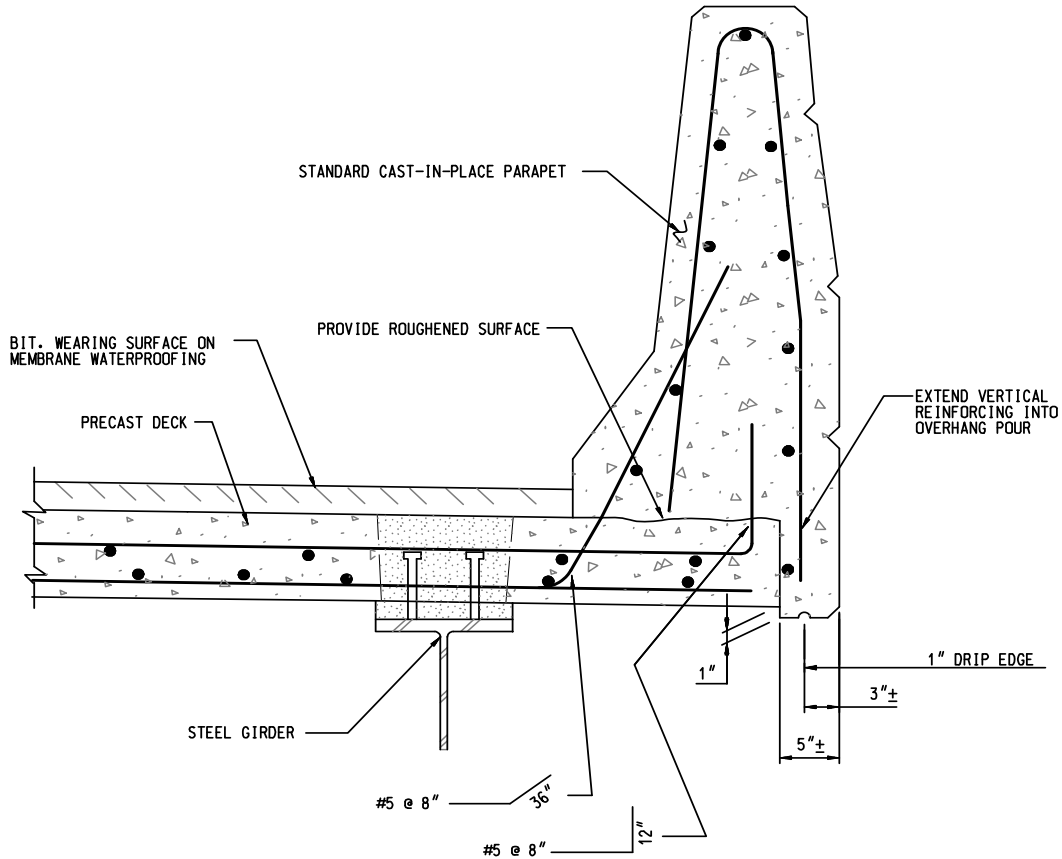
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **2.1.1.4 B**
 Phone Number: **888-700-5670**
 E-mail: **contact@pcine.org**
 Detail Classification: **Level 1**

Components Connected: **Precast full depth slab** to **CIP Parapet**

Name of Project where the detail was used: **I-84/Rt 8 Interchange, Waterbury, CT**

Connection Details: **Manual Reference Section 2.1.1.4** See Reverse side for more information on this connection



TYPICAL SECTION - DECK OVERHANG AND PARAPET DETAILS

NOTES: CAST PARAPET OVER AND BEYOND THE END OF THE PRECAST DECK SLAB IN ORDER TO PROVIDE A SMOOTH EDGE, AND TO PROTECT END CUT-OFF OF PRESTRESSING STEEL.
 REFER TO STATE STANDARD FOR ACTUAL PARAPET REINFORCING AND LAYOUT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between full depth precast concrete slabs and CIP parapet. This connection was used because of issues with lack of crash tested precast parapets. The parapet was cast over the edge of the slabs in order to hide the edge that has the cut-off prestressing. It also hides the joints between the slabs. To expedite construction, the parapet was cast continuously without joints. This accelerated construction to approximately 250 feet per day.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

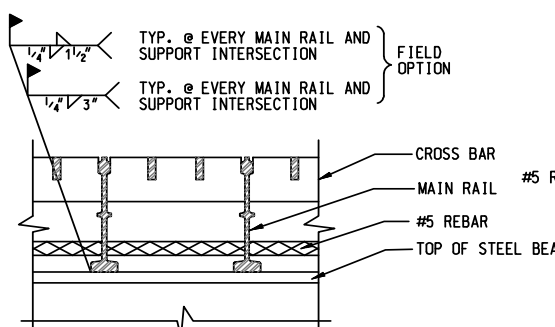
Organization: **BGFMA**
 Contact Name: **Mark R. Kaczinski, P.E.**
 Address: **300 East Cherry Street
 North Baltimore, Ohio 45872**

Detail Number: **2.1.2.2 A**
 Phone Number: **877-257-5499**
 E-mail: **mkaczinski@dsbrown.com**
 Detail Classification: **Level 1**

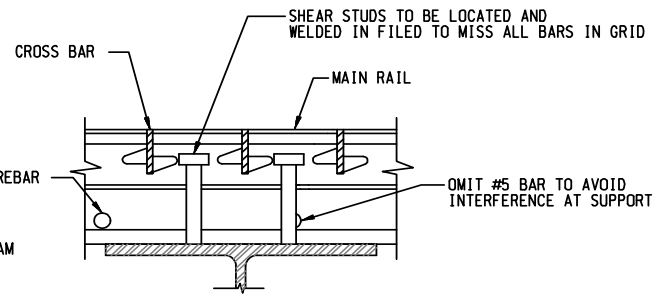
Components Connected: **Grid Deck** to **Steel Beam**

Name of Project where the detail was used: **Various**

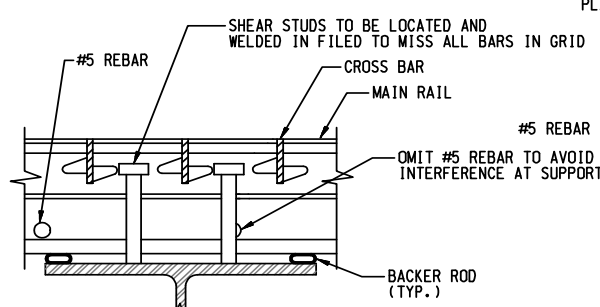
Connection Details: **Manual Reference Section 2.1.2.2** See Reverse side for more information on this connection



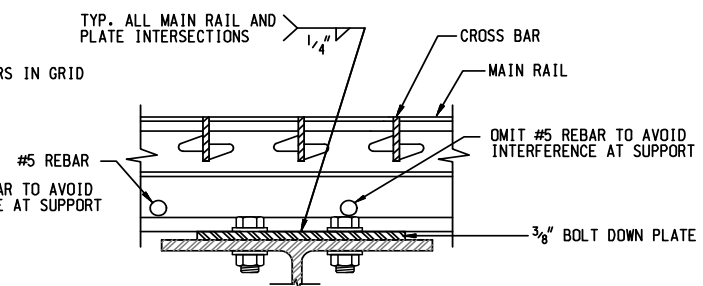
WELDED ATTACHMENT DETAIL



SHEAR STUD CONNECTION



BACKER ROD HAUNCH DETAIL



BOLT DOWN PLATE DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Attachment of an open grid is made by field welds of the grid deck to the supporting steel beams. Partially or fully filled grids are attached to the beams compositely through shear studs. At least one stud between each main bearing bar per beam is recommended regardless whether the design is composite or not, and depends on the requirements of composite design. Open grid decks or filled decks can also be attached by bolting. Minimal allowance for vertical adjustment is permitted with the bolting and welding options.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? unknown Condition at last inspection (if known)

How many times has this detail been used? many Year of last inspection

Would you use it again? yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 7 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 8 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 10 (0 not durable, 10 very durable)

Inspection Access 3 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

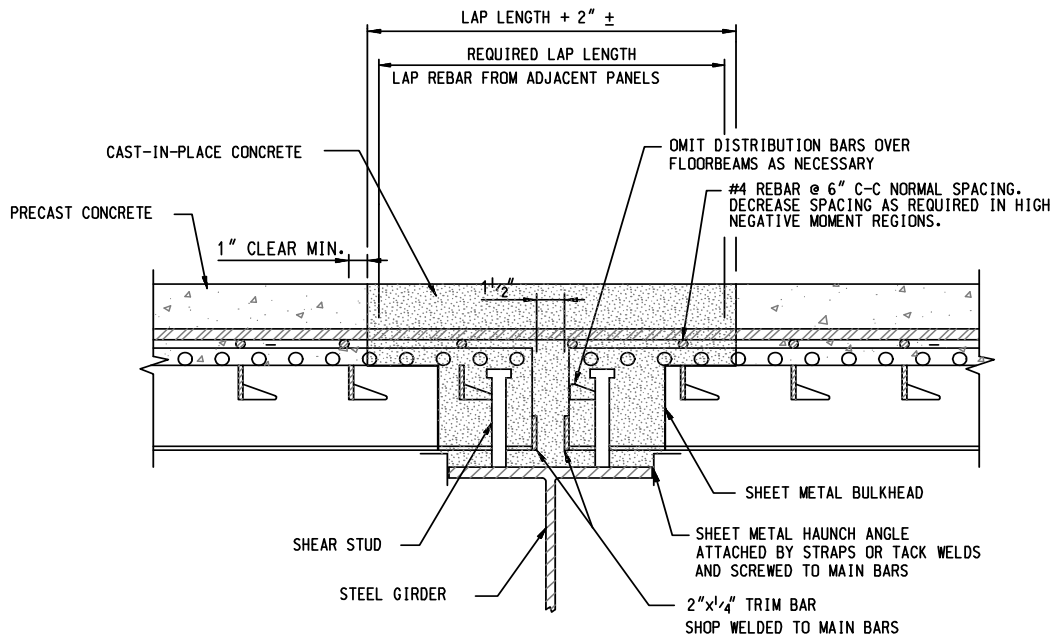
Organization: **BGFMA**
 Contact Name: **Mark R. Kaczinski, P.E.**
 Address: **300 East Cherry Street
 North Baltimore, Ohio 45872**

Detail Number: **2.1.3.1 A**
 Phone Number: **877-257-5499**
 E-mail: mkaczinski@dsbrown.com
 Detail Classification: **Level 1**

Components Connected: **Exodermic Deck panel** to **Exodermic Deck panel**

Name of Project where the detail was used: **various**

Connection Details: **Manual Reference Section 2.1.3.1** See Reverse side for more information on this connection



CONNECTION OF DECK TO STEEL GIRDER

- NOTES: OMIT DISTRIBUTION BARS OVER FLOORBEAMS AS NECESSARY TO PROVIDE CLEARANCE FOR SHEAR STUDS AND LEVELING BOLTS (NOT SHOWN).
 DEEPER TRIM BARS CAN BE BOLTED TOGETHER WHERE THEY MEET OVER A STRINGER. HOWEVER, NORMAL DISTORTION OF THE GRID PANELS DUE TO HOT-DIP GALVANIZING MUST BE TAKEN INTO ACCOUNT IF THIS LATTER OPTION IS SPECIFIED.
 OTHER HAUNCH FORMING OPTIONS POSSIBLE

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This connection is used to splice panels in the "strong" direction. The same connection is used for cast-in-place operations except that the rebar is continuous.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

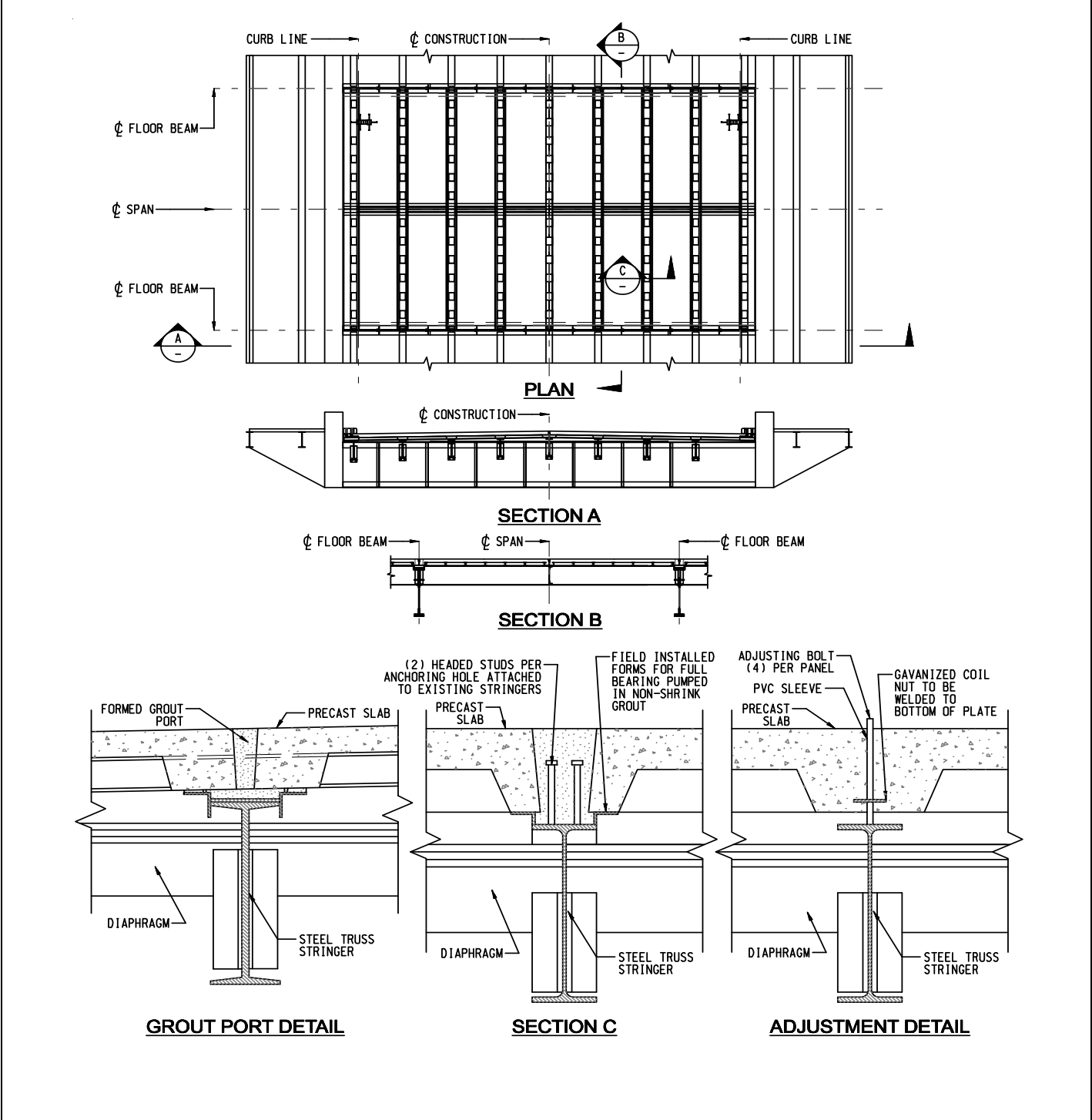
Organization: **NYSDOT**
 Contact Name: **James Flynn**
 Address: **50 Wolf Rd
 Pod 43 Albany NY 12232**

Detail Number: **2.1.3.2 A**
 Phone Number: **518-485-1148**
 E-mail: **jhflynn@dot.state.ny.us**
 Detail Classification: **Level 1**

Components Connected: **precast slabs** to **steel truss stringers**

Name of Project where the detail was used: **Troy Menands Bridge**

Connection Details: **Manual Reference Section 2.1.3.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast deck panels placed onto stringers of a truss structure. Pockets have been left in the panels to create the connection to the stringers. Part of the connection system is grade adjustment that is provided by an adjusting bolt.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

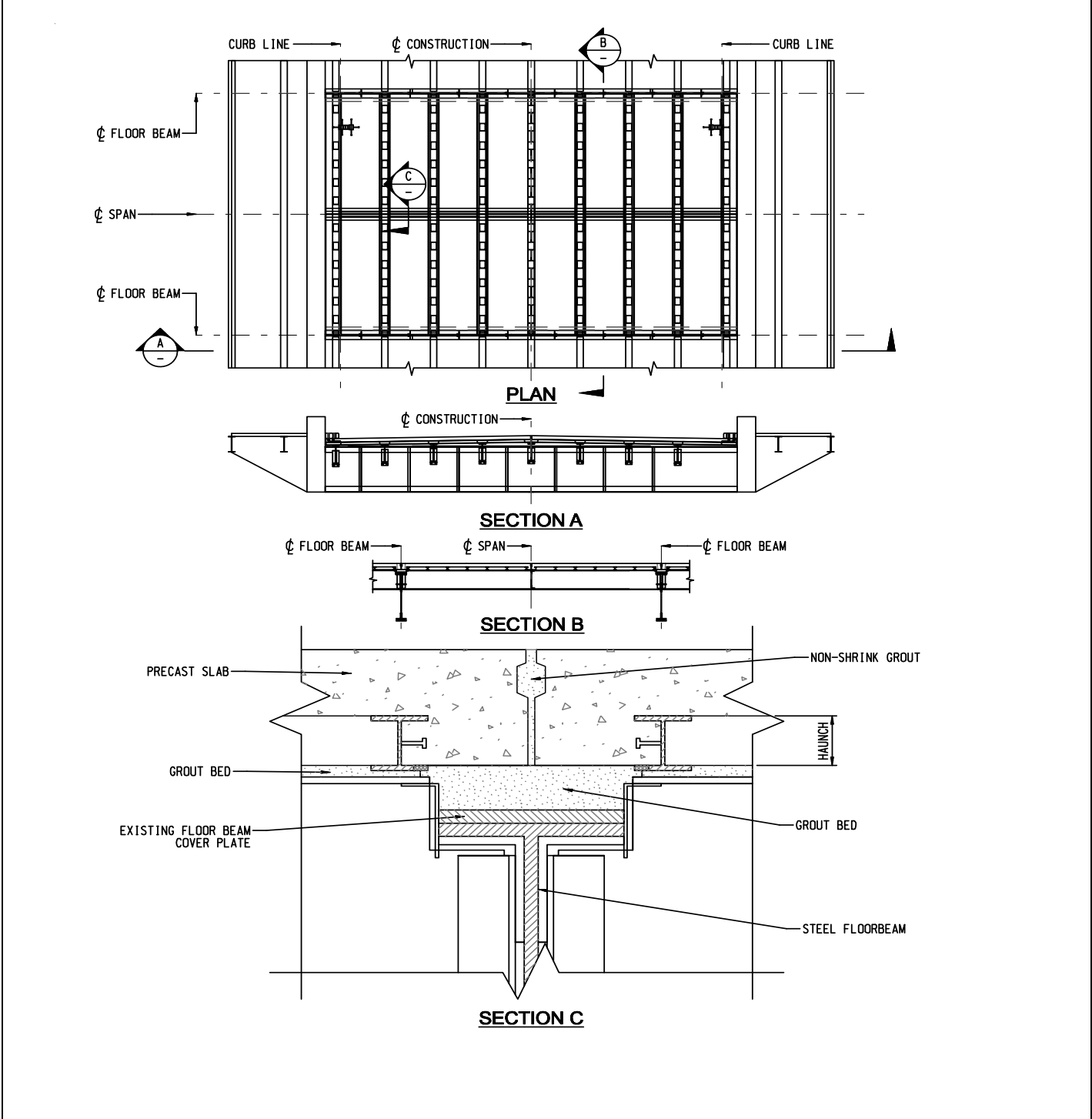
Organization: **NYSDOT**
 Contact Name: **James Flynn**
 Address: **50 Wolf Rd
 Pod 43 Albany NY 12232**

Detail Number: **2.1.3.2 B**
 Phone Number: **518-485-1148**
 E-mail: jhflynn@dot.state.ny.us
 Detail Classification: **Level 1**

Components Connected: **precast slabs** to **steel floorbeam**

Name of Project where the detail was used: **Troy Menands Bridge**

Connection Details: **Manual Reference Section 2.1.3.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast deck panels placed onto stringers of a truss structure. Pockets have been left in the panels to create the connection to the stringers. Connections between slabs are made at the floorbeam locations. This detail shows the connection away from a shear stud pocket.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

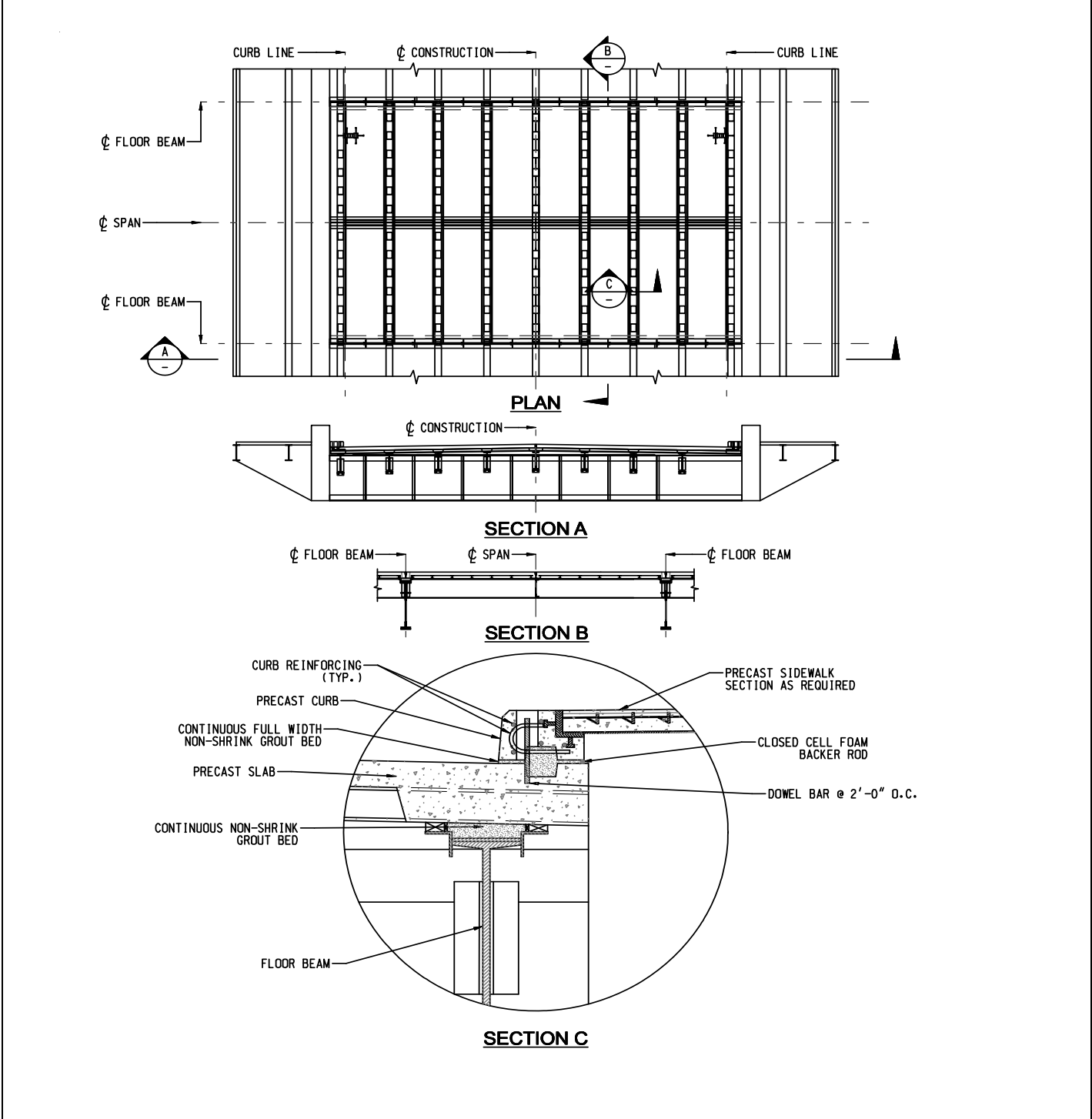
Organization: **NYSDOT**
 Contact Name: **James Flynn**
 Address: **50 Wolf Rd
 Pod 43 Albany NY 12232**

Detail Number: **2.1.3.3 A**
 Phone Number: **518-485-1148**
 E-mail: jhflynn@dot.state.ny.us
 Detail Classification: **Level 1**

Components Connected: **precast slabs** to **precast curb**

Name of Project where the detail was used: **Troy Menands Bridge**

Connection Details: **Manual Reference Section 2.1.3.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast deck panels placed onto stringers of a truss structure. Pockets have been left in the panels to create the connection to the stringers. The connections between slabs and a precast curb section are shown in this detail.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **New York State DOT**
 Contact Name: **Ronald Mauro**
 Address: **107 Broadway
 Hornell, NY 14843**

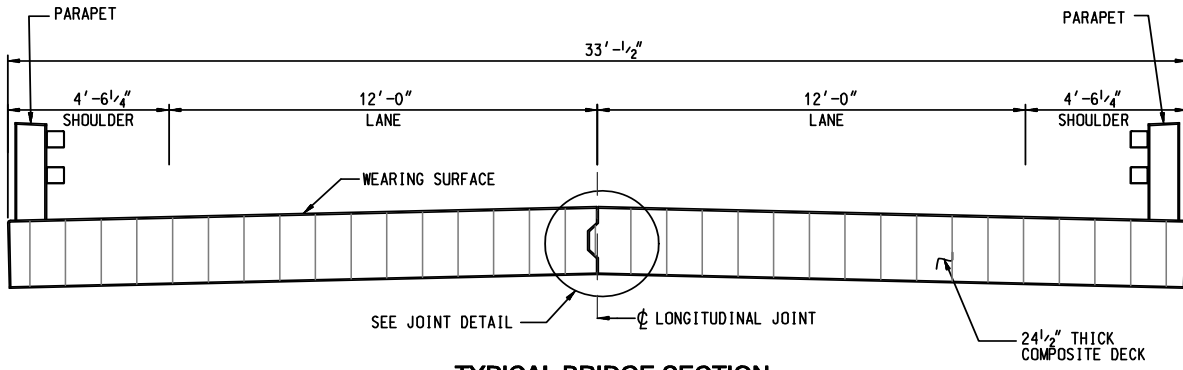
Detail Number: **2.1.4.1 A**
 Phone Number: **607-324-8454**
 E-mail: mauro@dot.state.ny.us

Detail Classification: **Level 2**

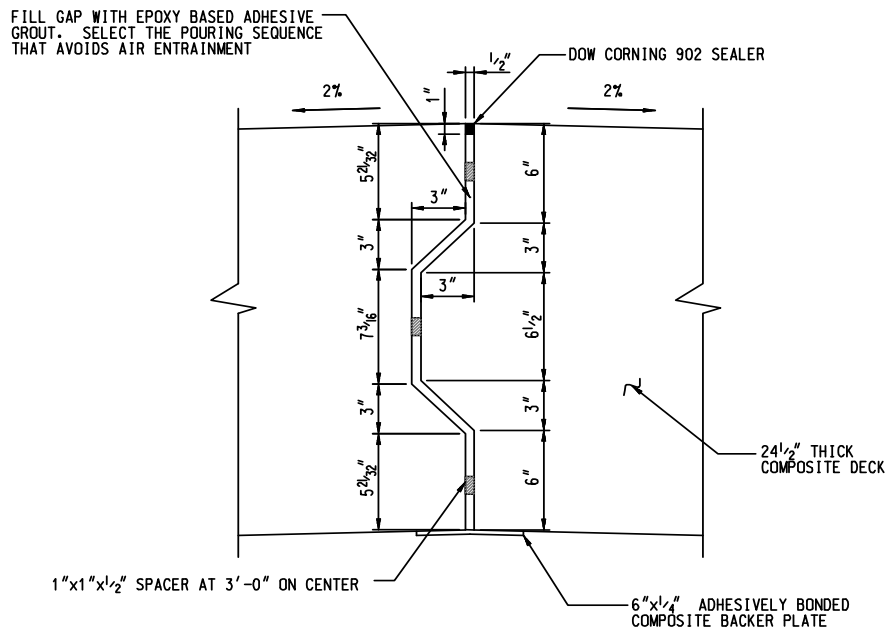
Components Connected: **FRP Superstructure component** to **FRP Superstructure component**

Name of Project where the detail was used: **Route 248 over Bennett's Creek, BIN 1043150**

Connection Details: **Manual Reference Section 2.1.4.1** See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



JOINT DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This project consisted of the replacement of a deteriorated reinforced concrete slab superstructure with an FRP superstructure. The new superstructure was prefabricated in two pieces and was placed on rehabilitated reinforced concrete abutments. The detail above shows the longitudinal connection between two adjacent panels.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: Virginia Department of Transportation
 Contact Name: Ken Walus
 Address: 1404 East Broad St.
 Richmond, VA 2319

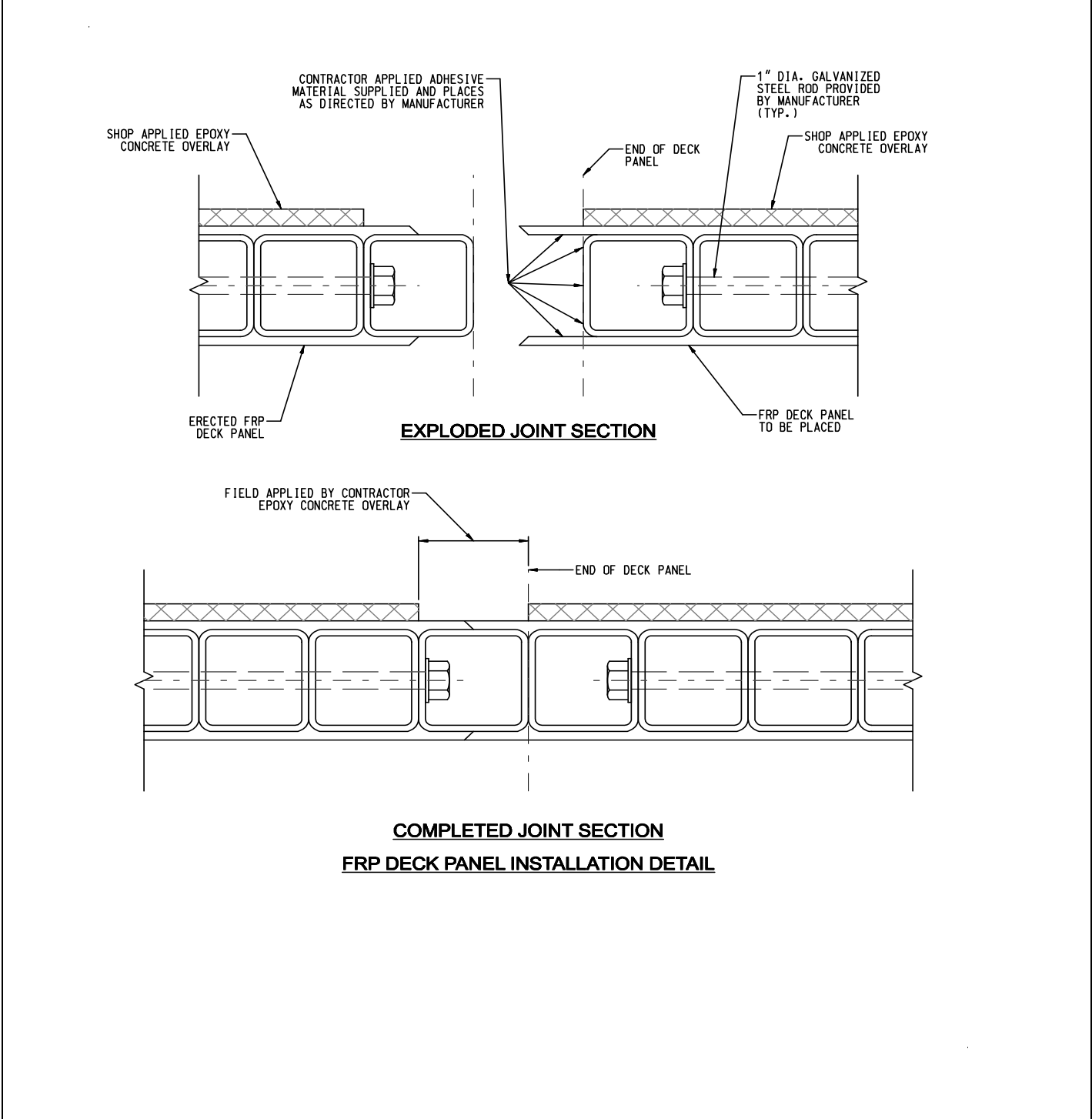
Detail Number: 2.1.4.1 B
 Phone Number: (840) 786-4575
 E-mail: Kendal.walus@vdot.virginia.gov

Detail Classification Level 2

Components Connected Fiber Reinforced Polymer Deck to Fiber Reinforced Polymer Deck

Name of Project where the detail was used Hawthorne Street over CSX Railway

Connection Details: Manual Reference Section 2.1.4.1 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The details consist of a fiber reinforced polymer deck system attached to an existing steel floor beam/stringer system that is apart of a larger steel truss bridge. The riding surface is a 3/8" epoxy concrete overlay.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

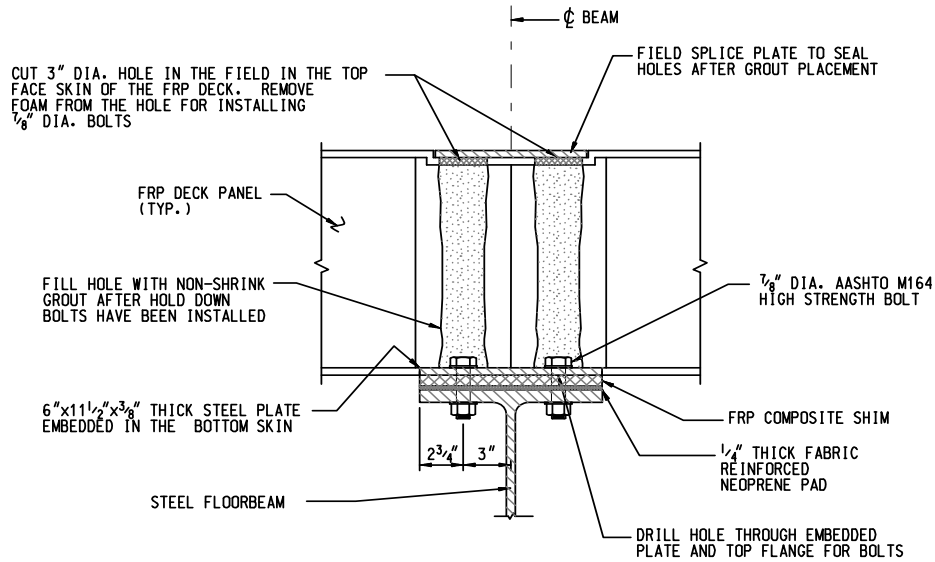
Organization: **New York State DOT**
 Contact Name: **Ronald Mauro**
 Address: **107 Broadway
 Hornell, NY 14843**

Detail Number: **2.1.4.2 A**
 Phone Number: **607-324-8454**
 E-mail: mmauro@dot.state.ny.us
 Detail Classification: **Level 2**

Components Connected: **FRP Deck** to **Steel Floor Beams**

Name of Project where the detail was used: **Route 367 over Bentley Creek, BIN 1046800**

Connection Details: **Manual Reference Section 2.1.4.2** See Reverse side for more information on this connection



SECTION THROUGH FRP PANEL SPLICE AND STEEL BEAM CONNECTION

NOTE: OVERLAY DECK WITH FIELD APPLIED THIN WEARING SURFACE AFTER INSTALLATION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

FRP panels were used to replace the original concrete deck on this steel pony truss. FRP shims were used between the deck and the floor beams to provide the roadway cross slope. Portions of the top skin of the deck were removed to provide access to drill through the bottom of the deck, shims and floor beam flanges in order to bolt the panels to the floor beams. This has worked well but drilling through the shims was very difficult. If we were to do this again, we would probably have the holes in the shims preformed.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

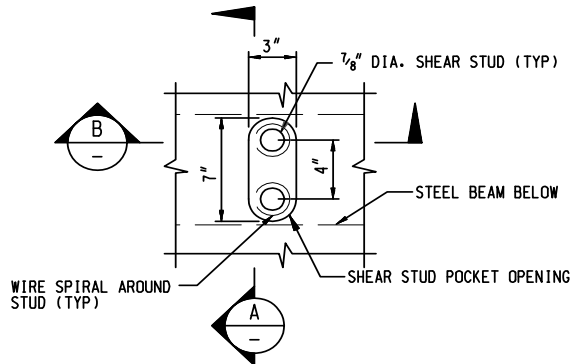
Organization: **New York State DOT**
 Contact Name: **Tom Hoffman**
 Address: **328 State Street
 Schenectady, NY 12305**

Detail Number: **2.1.4.2 B**
 Phone Number: **518-388-0317**
 E-mail: thoffman@dot.state.ny.us
 Detail Classification: **Level 2**

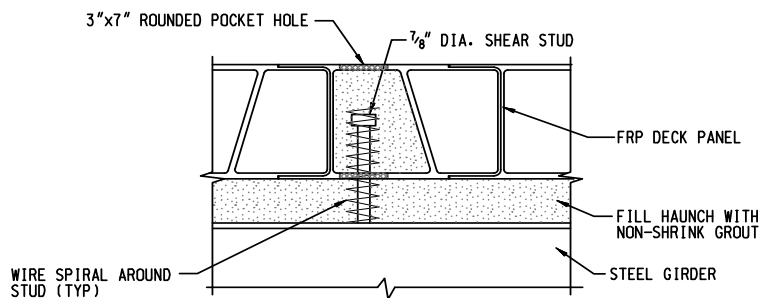
Components Connected: **FRP Deck** to **Steel Truss Floorbeam**

Name of Project where the detail was used: **Rt 418 over the Schroon River BIN 1048240**

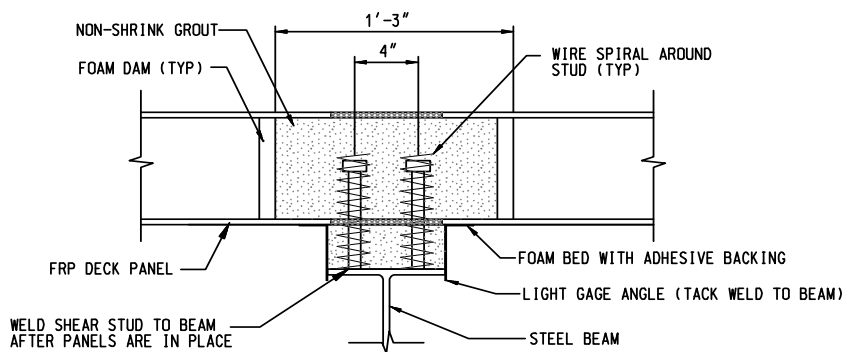
Connection Details: **Manual Reference Section 2.1.4.2** See Reverse side for more information on this connection



PLAN OF POCKET



LONGITUDINAL SECTION B THROUGH POCKET



PANEL TO BEAM CONNECTION SECTION A

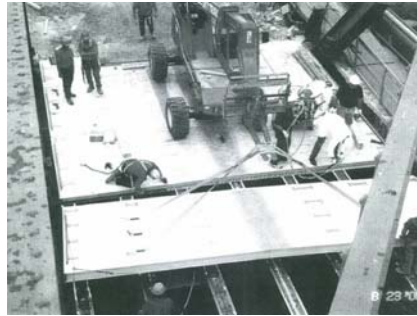
NOTE: APPLY 3/8" THICK POLYMER OVERLAY ON TOP OF PANEL (NOT SHOWN)

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of a FRP deck to truss floorbeams. This detail can be used for stringer beams or floorbeams. Vertical adjustment is made through the use of leveling bolts. This connection was used very effectively on this project. The design is the same as a cast-in-place slab shear connector.

While the connection and FRP deck are working well, the thin overlay has proved to be problematic. Grout pocket reflect through, and surface has worn, possibly from plowing.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used?

Condition at last inspection (if known)

How many times has this detail been used?

Year of last inspection

Would you use it again? (yes/no/maybe) for dead load reduction

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

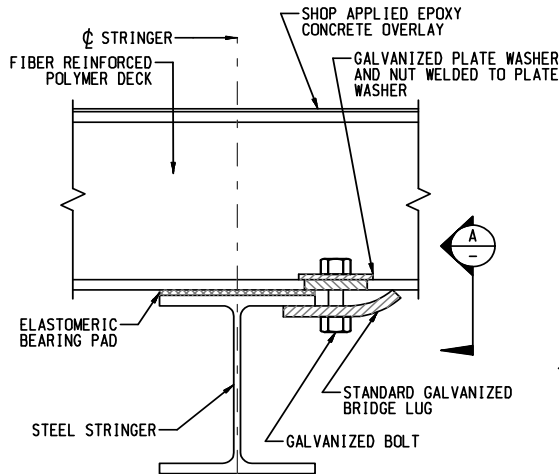
Organization: Virginia Department of Transportation
 Contact Name: Ken Walus
 Address: 1404 East Broad St.
 Richmond, VA 2319

Detail Number: 2.1.4.2 C
 Phone Number: (840) 786-4575
 E-mail: Kendal.walus@vdot.virginia.gov
 Detail Classification: Level 2

Components Connected: Fiber Reinforced Polymer Deck to Existing Floor Beam of a Steel Truss

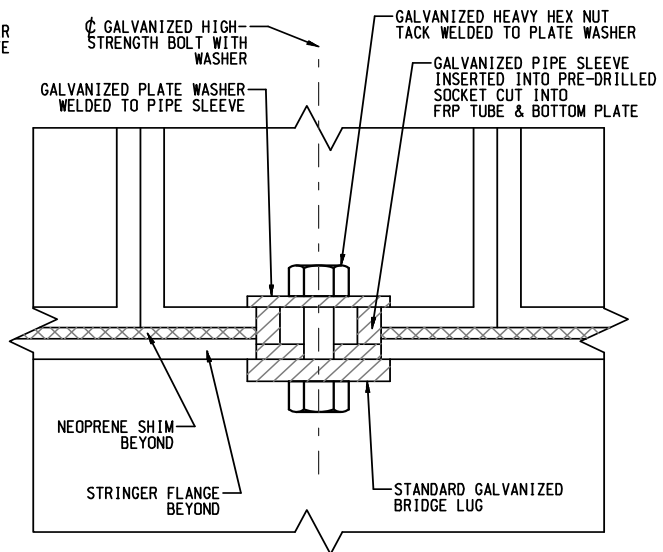
Name of Project where the detail was used: Hawthorne Street over CSX Railway

Connection Details: Manual Reference Section 2.1.4.2 See Reverse side for more information on this connection



SECTION THROUGH STEEL STRINGER

NOTE:
 TWO CONNECTIONS ARE REQUIRED PER DECK PANEL PER STRINGER.
 CONNECTIONS SHALL ALTERNATE FROM SIDE TO SIDE OF STRINGER FLANGE ON
 INTERIOR STRINGERS AND ON THE INSIDE FACE OF FLANGE ON EXTERIOR
 STRINGERS.



SECTION A

**FIBER REINFORCED DECK PANEL
 CONNECTION DETAILS TO STEEL STRINGER**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The details consist of a fiber reinforced polymer deck system attached to an existing steel floor beam/stringer system that is apart of a larger steel truss bridge. The riding surface is a 3/8" epoxy concrete overlay.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

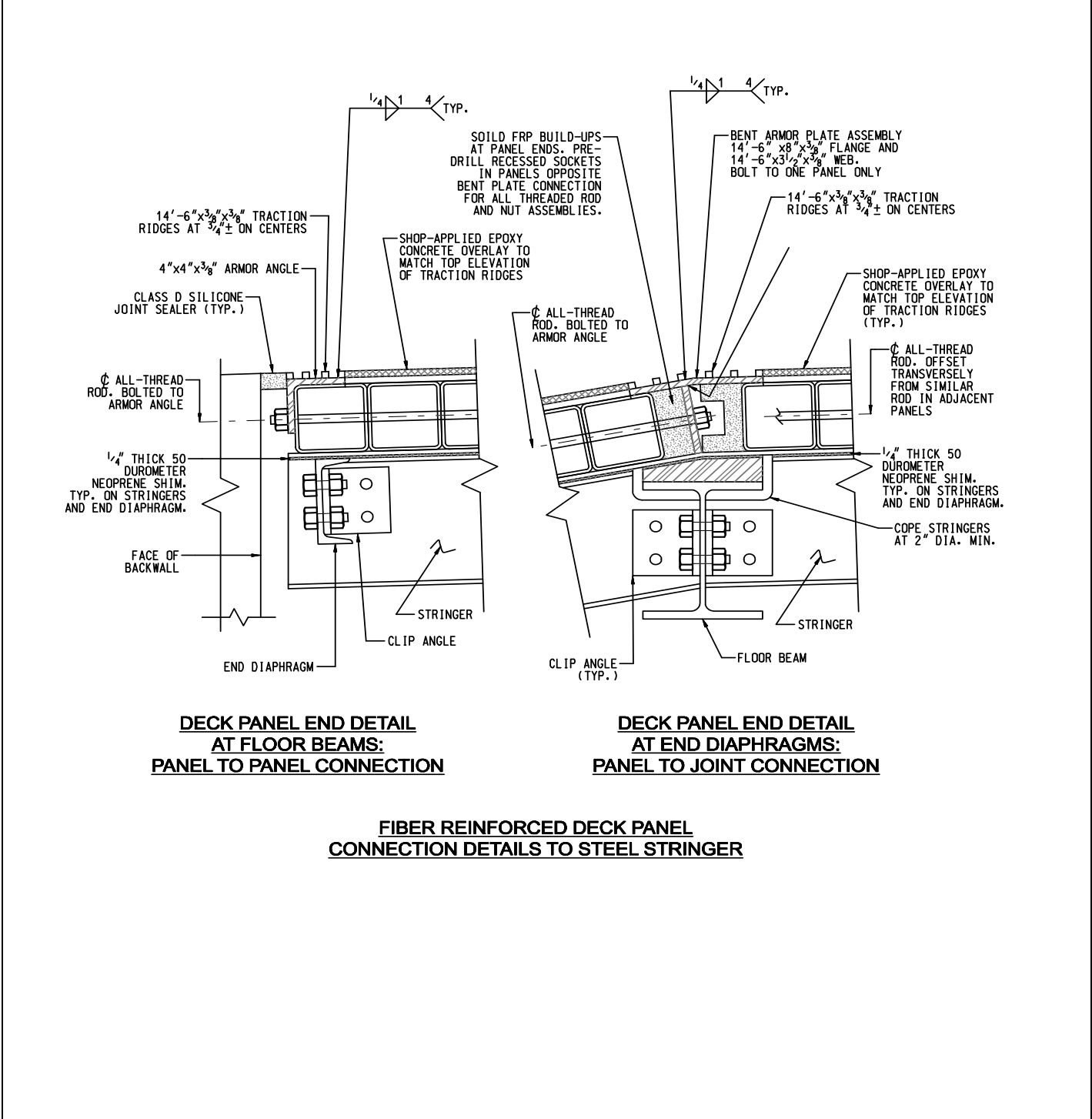
Organization: Virginia Department of Transportation
 Contact Name: Ken Walus
 Address: 1404 East Broad St.
 Richmond, VA 2319

Detail Number: 2.1.4.2 D
 Phone Number: (840) 786-4575
 E-mail: Kendal.walus@vdot.virginia.gov
 Detail Classification: Level 2

Components Connected: Fiber Reinforced Polymer Deck to Steel Superstructure

Name of Project where the detail was used: Route 1302 over Canton Creek

Connection Details: Manual Reference Section 2.1.4.2 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The existing deck had been replaced by a fiber reinforced polymer deck system.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **New York State DOT**
 Contact Name: **Ronald Mauro**
 Address: **107 Broadway
 Hornell, NY 14843**

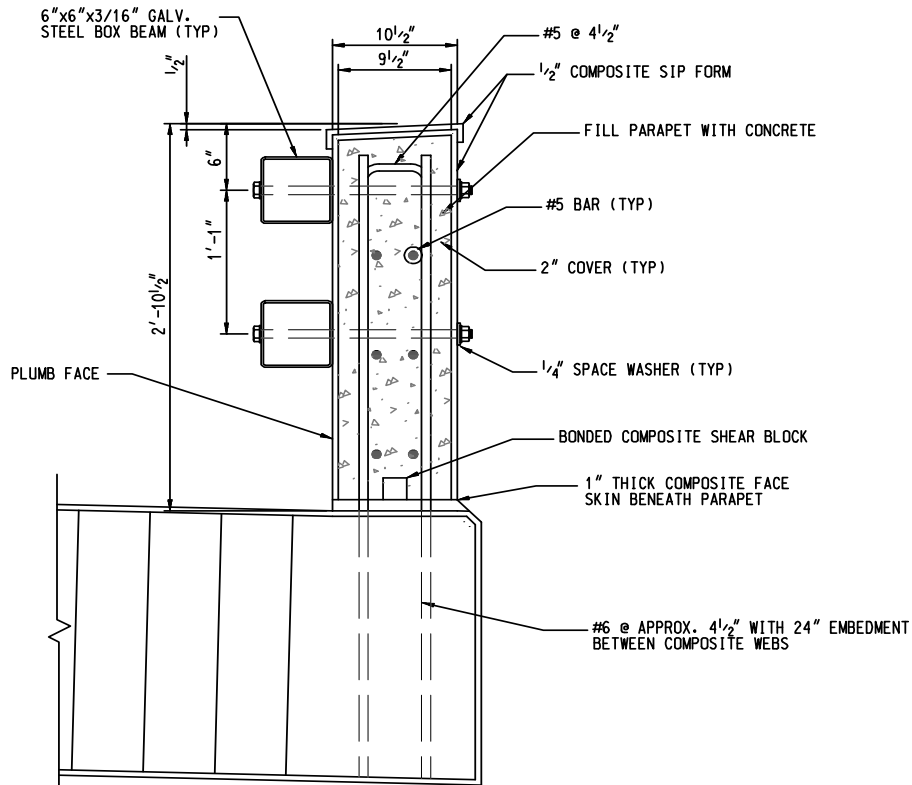
Detail Number: **2.1.4.3 A**
 Phone Number: **607-324-8454**
 E-mail: mauro@dot.state.ny.us

Detail Classification: **Level 2**

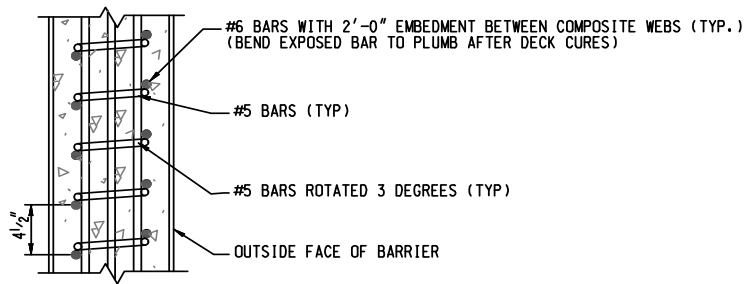
Components Connected: **FRP Superstructure component** to **FRP Barrier**

Name of Project where the detail was used: **Route 248 over Bennett's Creek, BIN 1043150**

Connection Details: **Manual Reference Section 2.1.4.3** See Reverse side for more information on this connection



TYPICAL PARAPET SECTION



PLAN VIEW

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This project consisted of the replacement of a deteriorated reinforced concrete slab superstructure with an FRP superstructure. The new superstructure was prefabricated in two pieces and was placed on rehabilitated reinforced concrete abutments. The detail above shows the connection and makeup of the concrete filled barrier.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

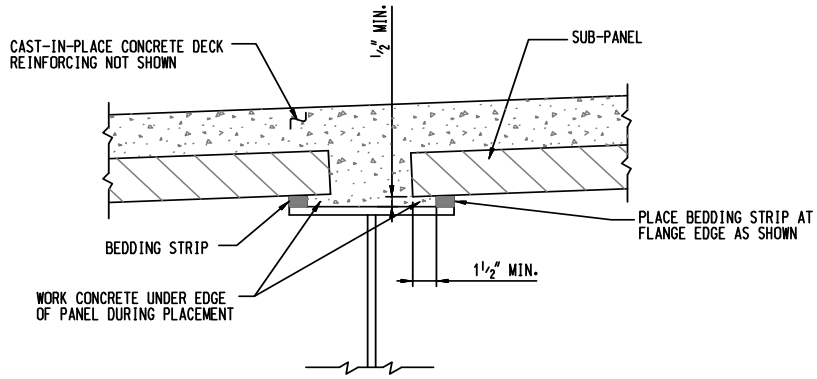
Detail Number: **2.1.5.1 A**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us

Detail Classification **Level 1**

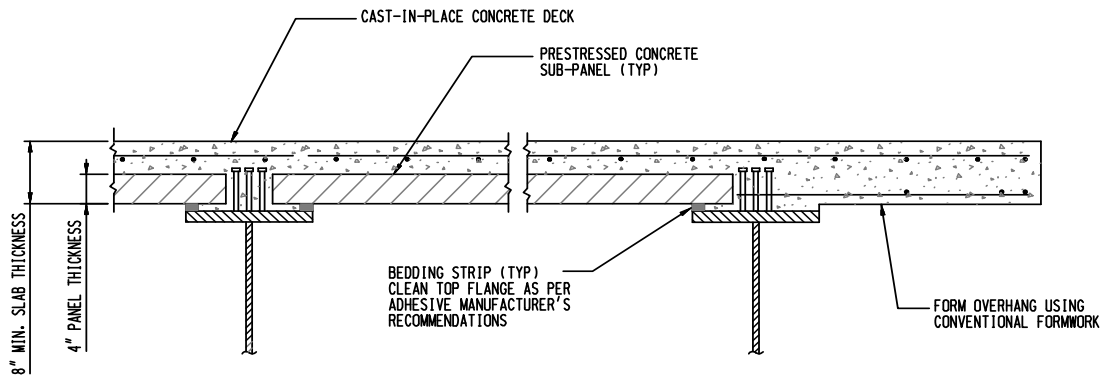
Components Connected **Prestressed Deck Sub-panel** to **Steel Beam**

Name of Project where the detail was used **Commonly used Standard**

Connection Details: **Manual Reference Section 2.1.5.1** See Reverse side for more information on this connection



NORMAL GRADING DETAIL



SUB-PANEL INSTALLATION OVER STEEL BEAMS

Editor's Notes

A key to the performance of the deck sub-panel is to provide positive uniform support of the panels. Many states do this by working the concrete under the panel ends over the beams. If this is specified, the 1/2" minimum dimension between the panel and the top flange should be increase to at least equal to the largest size aggregate in the deck concrete.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

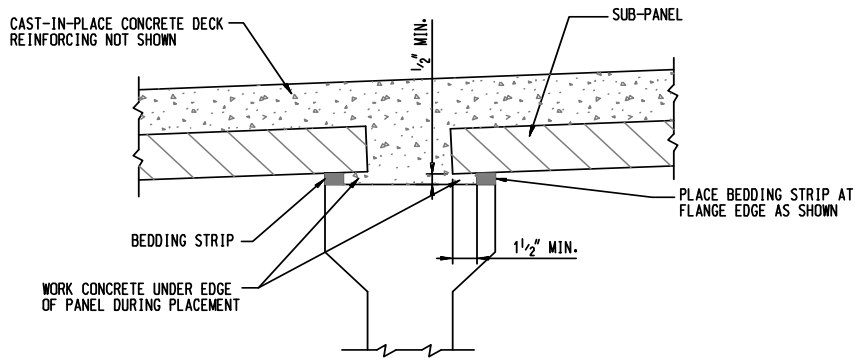
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.1.5.2 A**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us
 Detail Classification: **Level 1**

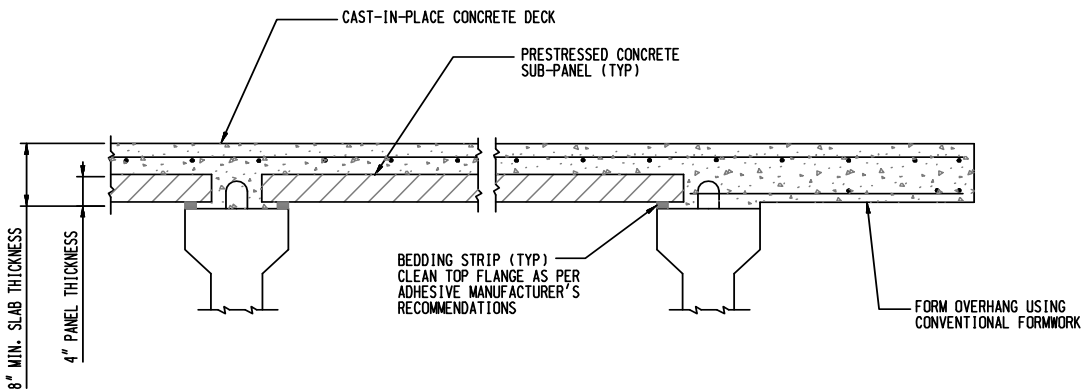
Components Connected **Prestressed Deck Sub-panel** to **Prestressed Concrete I-Beam**

Name of Project where the detail was used **Commonly used Standard**

Connection Details: **Manual Reference Section 2.1.5.2** See Reverse side for more information on this connection



NORMAL GRADING DETAIL



SUB-PANEL INSTALLATION OVER PS CONCRETE BEAMS

Editor's Notes

A key to the performance of the deck sub-panel is to provide positive uniform support of the panels. Many states do this by working the concrete under the panel ends over the beams. If this is specified, the 1/2" minimum dimension between the panel and the top flange should be increase to at least equal to the largest size aggregate in the deck concrete.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

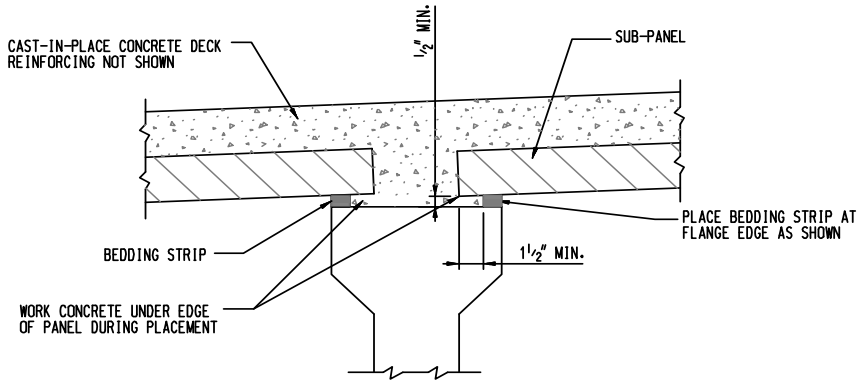
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.1.5.2 B**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us
 Detail Classification: **Level 1**

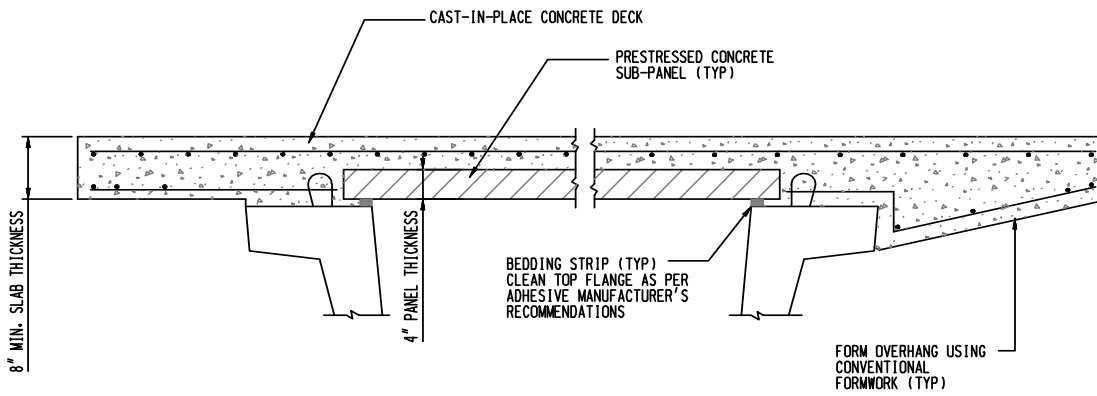
Components Connected **Prestressed Deck Sub-panel** to **Prestressed Concrete U-Beam**

Name of Project where the detail was used **Commonly used Standard**

Connection Details: **Manual Reference Section 2.1.5.2** See Reverse side for more information on this connection



NORMAL GRADING DETAIL



SHOWING NORMAL OVERHANG WITH PRESTR CONC U-BEAMS

SHOWING SLOPED OVERHANG WITH PRESTR CONC U-BEAMS

SUB-PANEL INSTALLATION OVER PS CONCRETE U BEAMS

Editor's Notes

A key to the performance of the deck sub-panel is to provide positive uniform support of the panels. Many states do this by working the concrete under the panel ends over the beams. If this is specified, the 1/2" minimum dimension between the panel and the top flange should be increase to at least equal to the largest size aggregate in the deck concrete.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 10 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 10 (0 difficulty making connection, 10 went together easily)

Cost 10 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 10 (0 not visible, 10 easily inspected)

Future Maintenance 9 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

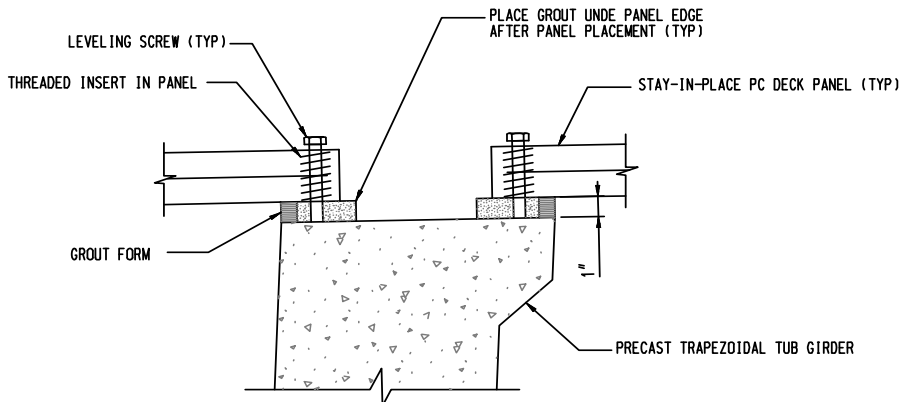
Organization: Washington State Dept of Transportation
 Contact Name: Joseph Merth, P.E.
 Address: Bridge and Structures Office
 PO Box 47340
 Olympia, WA 98504-7340

Detail Number: 2.1.5.2 C
 Phone Number: 360-705-7166
 E-mail: merthjo@wsdot.wa.gov
 Detail Classification: Level 2

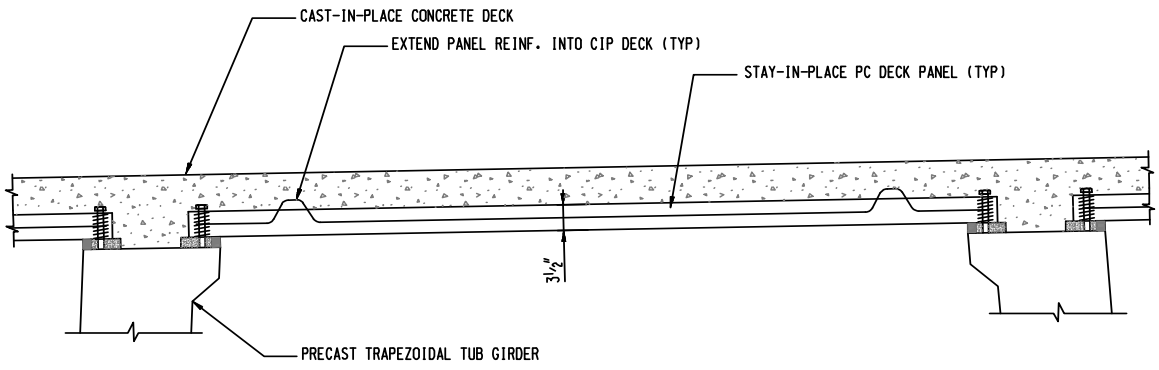
Components Connected: Stay-in-place deck panels to Precast trapezoidal tub girders

Name of Project where the detail was used: SR5 - 38th Street Interchange - Tacoma, WA

Connection Details: Manual Reference Section 2.1.5.2 See Reverse side for more information on this connection



PANEL INSTALLATION DETAIL



STAY-IN-PLACE PC DECK PANEL ON TUB GIRDERS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

To eliminate the need for deck falsework, stay-in-place precast deck panels were used.

After placement, the panels were adjusted for camber by leveling screws in each panel corner.

Grout was then placed below the panels to provide a continuous support.

After the grout cured, the leveling bolts were backed off to eliminate hard points.

Editor's note: Other states have used nylon leveling screws to eliminate the hard points. This eliminates the process of backing them out.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

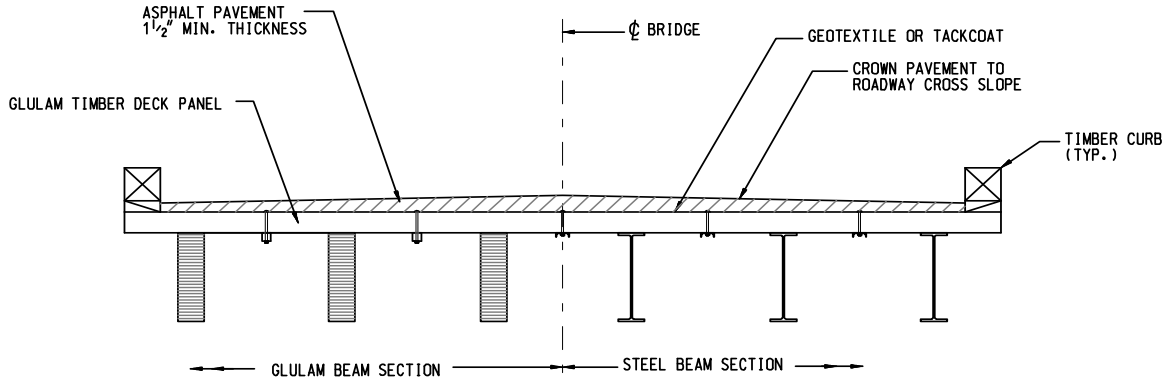
Organization: **USDA Forest Products Laboratory**
 Contact Name: **Jim Wacker**
 Address: **One Gifford Pinchot Drive
 Madison, WI 53726**

Detail Number: **2.1.6.1 A**
 Phone Number: **608-231-9224**
 E-mail: **jwacker@fs.fed.us**
 Detail Classification: **Level 2**

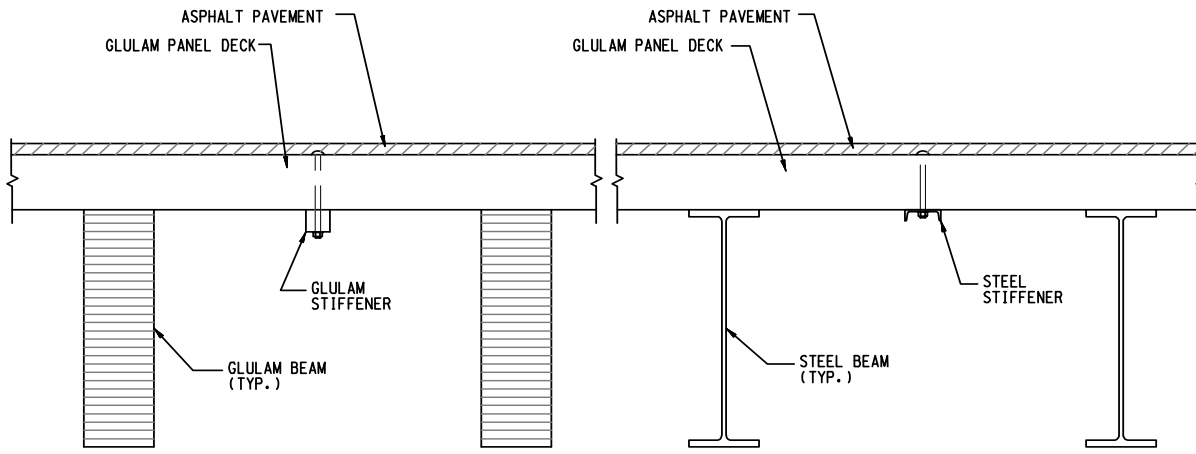
Components Connected: **Glulam wood deck panel** to **Glulam wood deck panel**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.1.6.1** See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



GLULAM DECK PANEL STIFFENER DETAILS

8. For beam bridges, inter-panel movement, or differential deflection between panels, can be minimized by installing a deck panel longitudinal stiffener beams (glulam or steel, see figure at left). This stiffener beam is placed midway between longitudinal bridge beams. Stiffener beams shall be continuous over at least two, but not more than four panel joints (due to moisture changes). See detail on this page and refer to Page 31 for more information regarding types and sizes for stiffener beams.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

1. These asphalt wearing surface details are recommended for most applications involving the timber bridge superstructures included in these drawings. A crowned asphalt wearing surface, when used in combination with a waterproof asphalt layer, or membrane, will shelter the bridge from moisture and potential deterioration. In low-volume traffic applications, the use of an asphalt wearing surface may not be warranted. For additional information about wearing surfaces for timber bridges, refer to *Timber Bridges: Design, Construction, Inspection, and Maintenance* (Ritter 1990).

2. Bituminous asphalt should be dense-graded and is typically the same mix design specified by state and federal agencies with responsibilities for road paving and maintenance. The asphalt should be placed and compacted to a minimum thickness of 1½-in. at the roadway edge, and approximately 3-in. at centerline.

3. For proper wearing surface bonding and performance, the surface of the timber deck should be clean, dry, and free of excess wood preservative. Excess preservative is normally not present when the treating specifications and procedures recommended in these drawings are followed. If there are accumulations of preservatives on the deck surface, applying a surface blotter before paving can greatly improve geotextile and asphalt bonding. The blotter should be removed from the deck prior to paving. Leaving the deck unpaved for a period of 30-45 days will also help remove excess preservative and solvent from the deck surface.

4. Preformed waterproof paving membranes are typically a geotextile fabric or mesh embedded in rubberized asphalt and should be installed according to the manufacturers' recommendations. Prior to selecting a membrane, compatibility of the membrane material with the wood preservative used for the bridge deck should be verified. Paving membranes should never be used in direct contact with pentachlorophenol treated wood. Improved performance may result when the membrane is placed between two asphalt layers. This is typically accomplished by placing an initial asphalt layer that is crowned as required. The membrane is placed on this initial layer and a final 1- to 1½-in.-thick uniform asphalt layer is placed on the membrane.

5. Preformed waterproof membranes may not adhere well to oilborne-preservative-treated timber bridge decks and the rubber may be incompatible with treatment chemicals. A waterproof layer can be created using asphalt cement or polymer modified asphalt emulsion in combination with a standard paving fabric and asphalt hot mix. Performance-graded asphalt cement and paving fabric should be applied in accordance with AASHTO M288-99, Section 9, and Appendix A6. Polymer modified asphalt emulsions may also be used if residual asphalt content meets the residual application rate recommended by the fabric manufacturer. Sufficient time must be allowed and appropriate weather conditions must exist for emulsions to cure prior to the application of fabric. Asphalt cement will normally be applied at a rate of 0.25 gallons per square yard before placing fabric. Polymer-modified asphalt emulsion would be applied at a rate of 0.37 gallons per square yard to obtain the same asphalt residual. The emulsion must cure until the water has evaporated before placing the fabric. Asphalt hot mix would then be placed and compacted between 250 and 320 °F. Polymer modified asphalt emulsions should not be used in direct contact with pentachlorophenol-treated wood.

Editor's Notes

There have been problems with reflective cracking of the asphalt overlay even with these details. Long term maintenance may be required.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

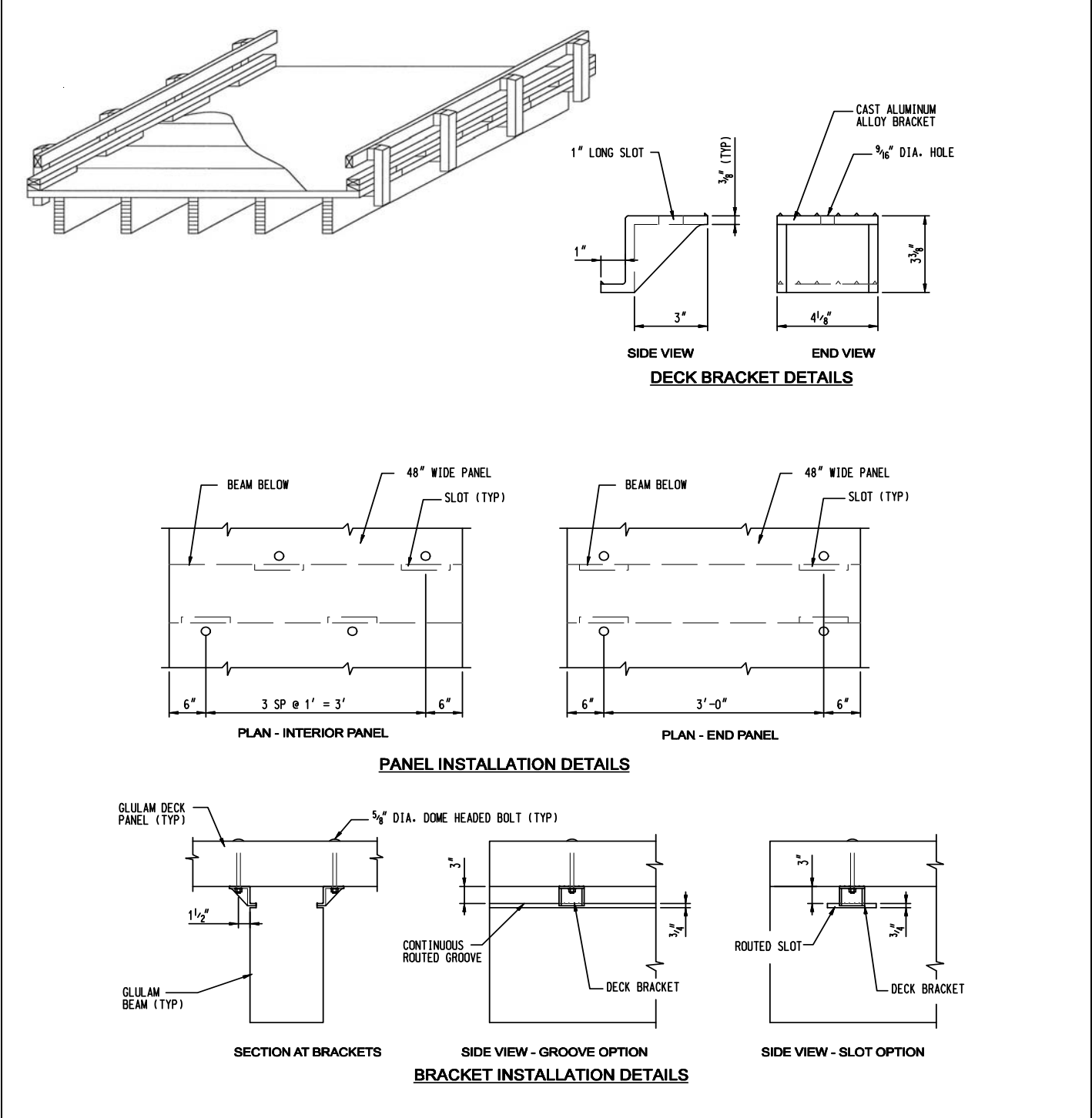
Organization: **USDA Forest Products Laboratory**
 Contact Name: **Jim Wacker**
 Address: **One Gifford Pinchot Drive
 Madison, WI 53726**

Detail Number: **2.1.6.2 A**
 Phone Number: **608-231-9224**
 E-mail: **jwacker@fs.fed.us**
 Detail Classification: **Level 2**

Components Connected: **Glulam wood deck panel** to **Glulam wood stringer**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.1.6.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The deck panels are made up of glue laminated wood members. The details provide the connection between the panels and a glue laminated wood beam. For more information on this bridge type and this connection, see the Manual entitled "Standard Plans for Timber Bridge Superstructures - General Technical Report FPL-GTR-125" published by the United States Department of Agriculture Forest Products Laboratory. It can be obtained at: www.fpl.fs.fed.us.

Notes

1. Deck panels are attached to the supporting stringers with 5/8-in.-diameter dome-head bolts and cast aluminum alloy deck brackets. The deck brackets are typically available from glulam manufacturers and bridge suppliers. For additional information on the cast aluminum deck brackets and other deck attachment alternatives, refer to *Timber Bridges: Design, Construction, Inspection, and Maintenance* (Ritter 1990).
2. As shown on the drawings, deck brackets connect to stringer sides in 3/4- by 8-in. slots or in continuous 3/4-in.-wide grooves.
3. When placing the deck panels, brackets should be attached to the stringers and nuts hand tightened. Nuts should not be completely tightened until all deck panels are in place and properly aligned.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

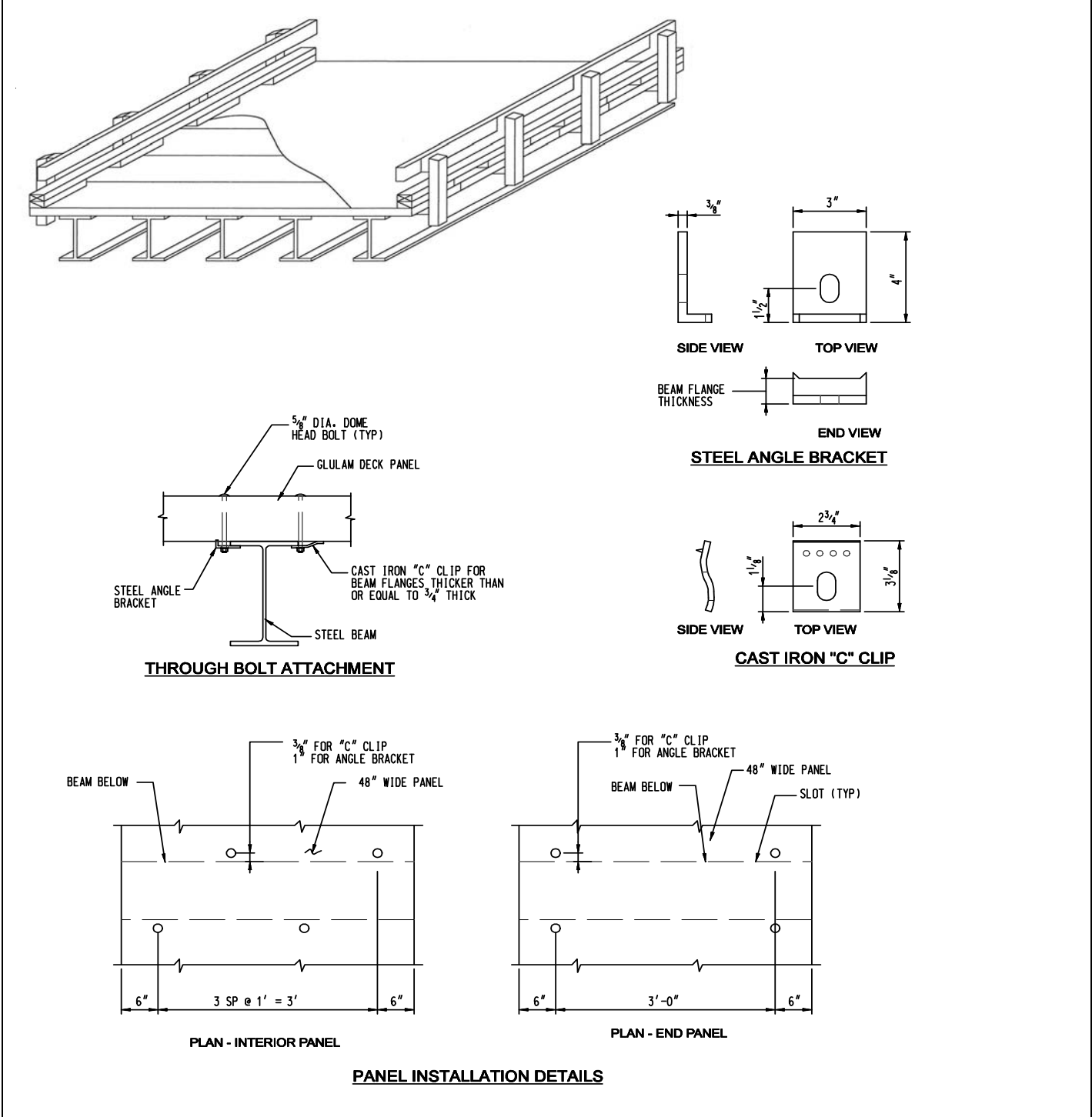
Organization: **USDA Forest Products Laboratory**
 Contact Name: **Jim Wacker**
 Address: **One Gifford Pinchot Drive
 Madison, WI 53726**

Detail Number: **2.1.6.2 B**
 Phone Number: **608-231-9224**
 E-mail: jwacker@fs.fed.us
 Detail Classification: **Level 2**

Components Connected: **Glulam wood deck panel** to **Steel Beam**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.1.6.2** See Reverse side for more information on this connection

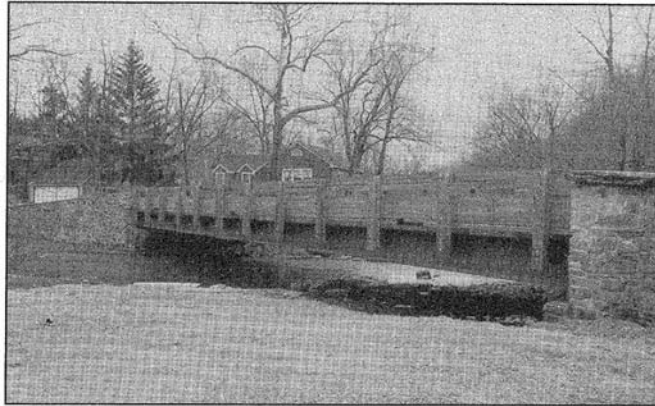


The deck panels are made up of glue laminated wood members. The details provide the connection between the panels and a steel beam. For more information on this bridge type and this connection, see the Manual entitled "Standard Plans for Timber Bridge Superstructures - General Technical Report FPL-GTR-125" published by the United States Department of Agriculture Forest Products Laboratory. It can be obtained at: www.fpl.fs.fed.us.

Notes

1. For steel beam flanges less than 3/4-in.-thick, use a grade 30, cast iron "C" clip. For steel beam flanges greater than 3/4-in.-thick, use an A36 steel angle bracket.

2. Both connector types should have slotted holes sized to two or three times the bolt diameter. See details on this page.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

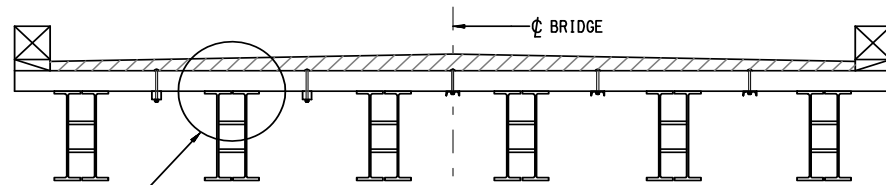
Organization: Virginia Department of Transportation
 Contact Name: Ken Walus
 Address: 1404 East Broad St.
Richmond, VA 2319

Detail Number: 2.1.6.2 C
 Phone Number: (840) 786-4575
 E-mail: Kendal.walus@vdot.virginia.gov
 Detail Classification: Level 2

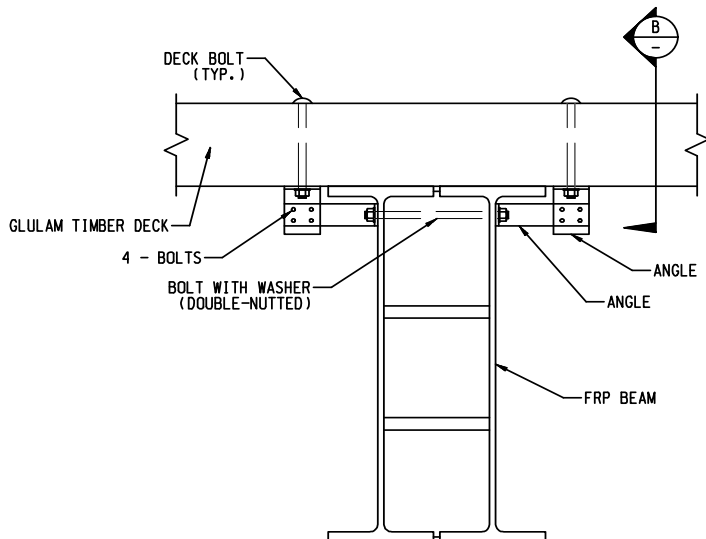
Components Connected: Glulam Timber Deck to FRP Beam Superstructure

Name of Project where the detail was used: Route 601 over Dickey Creek

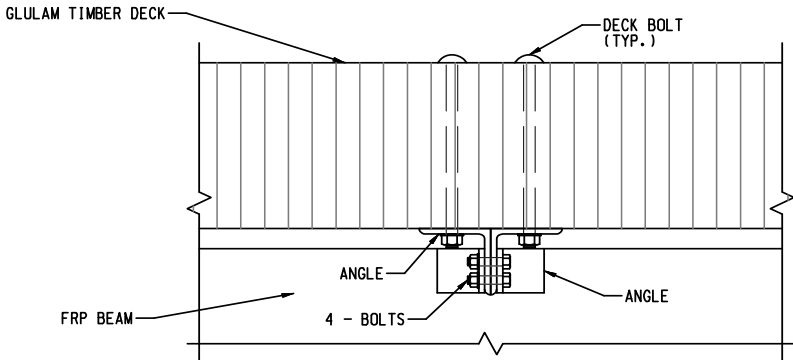
Connection Details: Manual Reference Section 2.1.6.2 See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



DETAIL A - TYPICAL SECTION AT BEAM



SECTION B - DECK TO GIRDER CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The rehabilitation of this single span bridge consists of a fiber reinforced polymer superstructure with a glulam timber deck. The superstructure is attached to an existing concrete abutment.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

2.2 Adjacent Butted Beam Systems

Butted beam systems have been used for many years. These systems are often used for accelerated bridge construction projects to avoid deck forming and, in some instances, deck placement. Many states have standard details for butted systems, though only a few states have submitted details for this Manual. The following sections outline some of the more common systems in use.

Figure 2.2-1 shows typical span ranges for different butted beam systems. The span ranges can vary significantly depending on the specific state standards, but the general span ranges are shown for informational purposes.

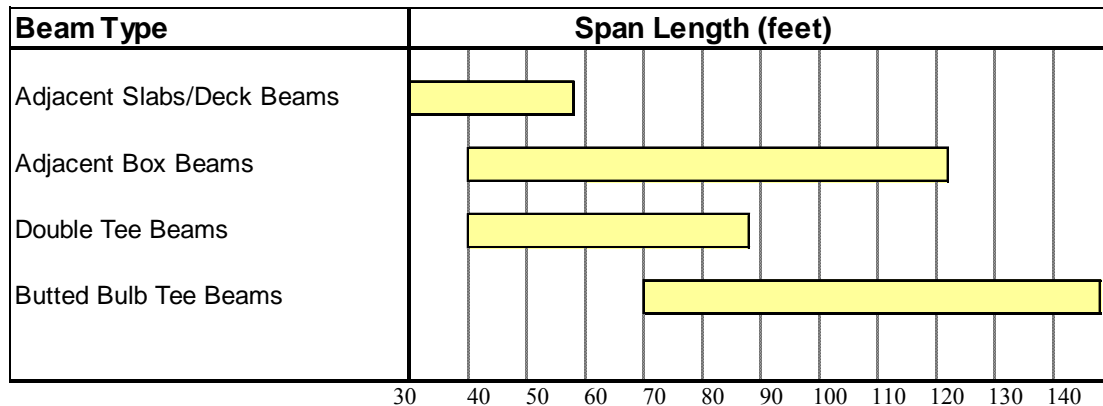


Figure 2.2-1 Typical Span Ranges for Different Butted Beam Systems

Notes:

1. This chart is for information purposes. It should not be construed to mean specific limits.
2. Common span ranges are shown for the type of beams listed.
3. Minimum spans shown are based on common bridges. Shorter spans can be used for all beams. For instance, a bulb tee bridge can be built to a 40 foot span, but this is not common.
4. Maximum spans are approximate based on previous and current studies. The maximum span length will vary depending on many factors such as number of beams, size of parapets and sidewalks, concrete strengths, etc.

2.2.1 Precast Prestressed Concrete Deck Bulb Tee Systems

Many states have standard bulb tee beams. Bulb Tees are precast prestressed concrete I-shaped beams that have two common characteristics. First, the bottom flange is larger than on the older concrete I-beams, allowing for more strands to be placed in the bottom flange. Second, the top flange is approximately four feet wide. The combination of these two features improves the efficiency of the section. The top flange is relatively thin and does not act as a structural slab to support wheel loads. Typically a composite, cast-in-place concrete deck is placed over these beams.

The design and dimensions of bulb tees vary from state to state; however, several regions have agreed to use a common set of sections to facilitate fabrication across state lines.

Following development of precast prestressed concrete bulb tee beams, several states developed sections called deck bulb tees. The difference between these beams and normal bulb tee beams is that the top flange is intended to be the structural deck of the bridge. The top flanges can be as much as eight feet wide. The beams are connected in the field to form a beam/deck system.

When compared to adjacent prestressed box beams, deck bulb tee beams offer a system with improved inspection access and a simpler fabrication process. The undersides of the deck bulb tee beams are exposed for inspection unlike the inside of the most adjacent prestressed concrete box girders. There also are no void forms in bulb tees that need to be held in-place when placing the concrete.

2.2.1.1 Connections Between Beams

The states that use deck bulb tees use a welded tie connection combined with a grouted key. The ties are normally spaced five feet on center along the edge of the beam. This connection is primarily designed as a shear only connection. There is no intent to make this connection a deck moment connection; therefore each flange edge needs to be designed as a cantilever deck overhang.

Connections similar to this have been used in precast parking garage structures for years. There was concern that the welds would fatigue and break over time. The Texas DOT has researched transverse welded connections for adjacent precast members and found that when combined with a grouted shear key, the connection is sound and durable. The Texas research was completed for butted slab beams and double tees; however the results indicate that that the same connection may be viable for larger butted bulb tee systems.

The Washington State DOT detail is similar to details in Texas in that the weld is made in a beveled steel plate groove. This design allows the connection to be made even if there is slight camber differential between the beams.

There is ongoing research (unpublished at this time) on alternate grouted pocket connections between beams. Researchers are investigating the use of a small closure pour with headed reinforcing bars and even wire mesh projecting from the flange edges. This research has not been put into practice, but early testing has produced favorable results.

Some designers have concerns with the long term fatigue behavior of the welded tie connections. Therefore, at this time, it is recommended that these welded tie details be used for bridges with lower truck volumes.

2.2.1.2 Welding and Grouting Issues

Several issues need to be considered when using welded plate connections. First, the bottom portion of the welded plate connector is not protected from the weather on the underside of the connection. If a bridge is to be constructed in a corrosive environment, the designers may want to consider the use of stainless steel plates and rods. Second, it is important that the grout placed in the keys between the beams completely fills the void. The most common keyway failure results from inadequate filling of the keys. If voids are present, the mechanical interlock of the key is lost. Project specifications should require the use of durable, flowable grouts. Another successful method of placement requires minor rodding of the grout after placement. Leakage through grouted joints is a concern for many states. Even with the best grout, minor shrinkage cracking can be expected. For this reason, many states incorporate overlays and waterproofing systems for butted beam systems. If an exposed deck is desired, the cracks can be sealed during construction (see discussion in Section 2.1.7.2 for more information on this subject).

2.2.1.3 Camber Issues

Differential camber of the beams can lead to dimensional problems with the connections. The Texas and Washington DOT details can accommodate minor differential camber. If the differential camber is excessive, the contractors in some states will apply dead load to the high beam to bring it within the connection tolerance.

2.2.2 Precast Prestressed Concrete Tee Systems

Several different precast prestressed concrete tee systems are in use. Texas DOT has a modified deck slab beam with a tee flange extending beyond the sides of the slab as well as a double-tee section. Figure 2.2.2-1 depicts a typical cross section of the Texas decked slab beam with extended flanges. The Texas beams are connected using a welded anchor plate and grout. Other states have double-tees and even a triple-tee. New York DOT built a quad tee system that was the full width of a two lane road.

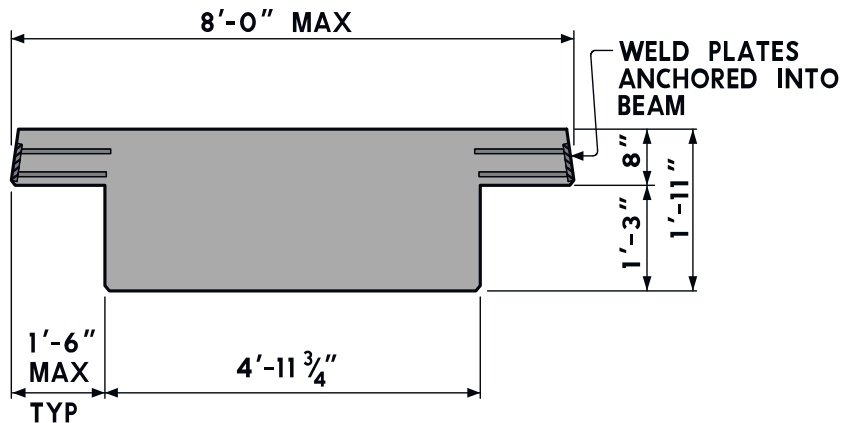


Figure 2.2.2-1 Texas Decked Slab Beam with Flanges

These tee systems are very similar to the deck bulb tee sections described in Section 2.2.1 in that the top flanges of these sections are designed to be the structural deck of the bridge.

2.2.2.1 Connections Between Beams

The connections used for tee beams are essentially the same connection used for the deck bulb tees. See Section 2.2.1 for more information on this connection.

2.2.2.2 Span-to-Span Connections

New York DOT has used a beam end-to-end connection over the supports to provide span-to-span continuity. The negative moment reinforcing was connected using mild reinforcing bar couplers. The design was proposed as part of a value engineering proposal for a large viaduct on Long Island (Robert Moses Causeway). This project involved the use of full width precast superstructure sections (quad-tee). The bridge is designed to act as a simple span for dead load, and as a continuous beam for live load. This concept is not new to the prestressed concrete industry. Prestressed concrete I girders are commonly made continuous for live load by using the cast-in-place concrete deck as a top flange tension connection. The New York detail makes use of the full width top flange of the quad tee to make a small closure pour across the bridge deck. The quad tee system included concrete end diaphragms cast into the pieces, which acted as forms for the small closure pour.

2.2.2.3 Welding and Grouting Issues

See Section 2.2.1.2 for information on welding and grouting issues with prestressed adjacent butted beam bridges.

2.2.2.4 Camber Issues

See Section 2.2.1.3 for information on camber issues with prestressed adjacent butted beam bridges.

2.2.3 Precast Prestressed Adjacent Slab and Adjacent Box Beam Systems

Many states have used precast prestressed adjacent deck slab and adjacent box beam bridges as standard bridge systems for years. The “slab system” or “deck slab system” is typically less than 21 inches deep. The “adjacent box beam system” is typically more than 21 inches deep. The beams are normally three feet or four feet wide; however, some states have used wider sections. Figure 2.2.3-2 shows cross sections of common butted precast prestressed beams.

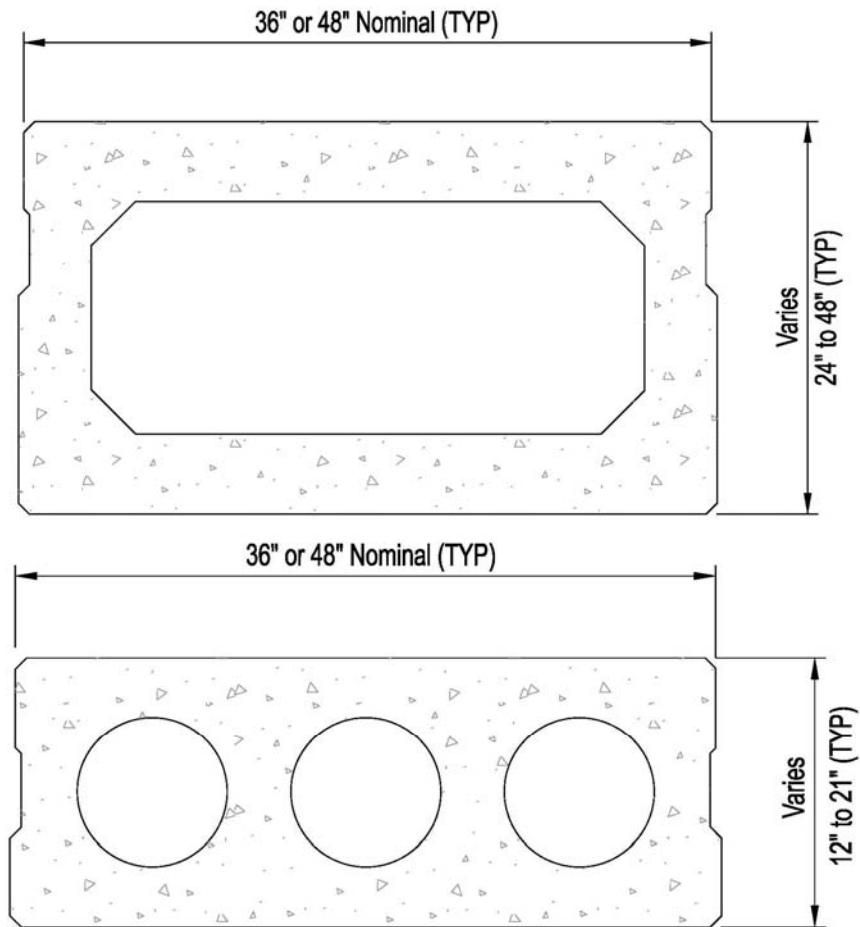


Figure 2.2.3-2 Typical Butted Precast Prestressed Beam Sections
(Box Beams (top), Slab/Deck Beams (bottom))

These deck slab and adjacent box beam systems all function in the same manner; they are intended to act as the structural deck of the bridge. Most are designed so that no concrete deck is required over the beams, often leading to rapid construction. Typical construction involves placement of the beams, connecting the beams with a lateral tie system and grout, and installation of a bituminous wearing surface. It is recommended that an asphalt overlay with waterproofing membrane be used for these systems to extend the service life, particularly where

deicing chemicals are used. Using these systems, construction of an entire superstructure can be completed in less than three days.

Many states have noted that when these bridges are exposed to heavy truck traffic, there is a tendency for the joints between the beams to leak. In extreme cases, the joints have completely failed. There has been a call for more research on this connection; however the research has never been funded.

Even with the current details, the performance of these bridges on lower volume roadways has been very good. Massachusetts has used these structures since the 1950's. Recent inspection reports indicate that these local road bridges are performing very well, even after 50 years of service [51].

Louisiana DOT submitted details for precast approach slabs that are similar to details for precast adjacent slab systems. Since these details are essentially the same as deck slab systems, they have been included in this section. Additional details for connections of approach slabs to abutments can be found in Section 3.2.4.2.

Most states have standard details for connection of these systems, though only a few submitted details for publication in this Manual. It is recommended that users of this Manual refer to the applicable state standards for more information on the specific detail requirements of each state.

2.2.3.1 Connections Between Slabs and Between Adjacent Box Beams

Most of the states using these systems have standard details available on-line. The typical connection systems include a lateral tie system combined with a shear key filled with non-shrink grout. There are no design parameters for these connections in the AASHTO LRFD Design Specifications. The designs have evolved over the years on a trial and error basis. Louisiana has used similar connections to make longitudinal connections between precast approach slab elements.

Traditional Post-Tensioning and Bolted Systems

Most states use a transverse tie system to connect the beams. The ties range from simple threaded rods to sophisticated post-tensioning systems. The spacing of the ties varies, but most are approximately 25 feet maximum on center. The amount of post-tensioning force varies greatly from state to state. Some state use a little as 10,000 pounds per tie, others use over 60,000 pounds per tie.

The AASHTO LRFD specifications [1] have a recommendation for 250 psi transverse post-tensioning between deck slabs. This provision is not recommended for these connections because the connected elements are not deck slabs, and achieving this level of post-tensioning is not easily attainable. There has been research

recommended for this connection by the Concrete Bridge Committee of the Transportation Research Board; however the research has not been funded to date. The Precast Prestressed Concrete Institute is also studying this connection. Users of this manual should keep apprised of future developments of these connections from these two organizations.

The ties are normally placed inside of holes that are cast through the width of the beams. Many states tension the ties prior to grouting the shear keys. The problem with this approach is that the post-tensioning force is taken up through friction in the bearings. Little or no force is actually applied to the interface between the beams.

In the northeast, the ties are tensioned after the grout is set. This approach places the actual grouted joint between the beams into compression, which is a preferred method of making this connection. This means that the post-tensioning system needs to be in a duct so that the shear key grout will not bind the tie. These states typically use an unbonded single strand tendon in a grease filled sheath. The anchorages are epoxy coated and the entire system is sealed with grease.

Reinforced Closure Pours

The Minnesota DOT has developed a new system based on a system developed in France. The important feature of this system is the connection between the beams. Lateral reinforcing steel projects from the sides of the inverted tee beams. Instead of a traditional grouted shear key, a large reinforced concrete closure pour is used between and over the adjacent inverted tee beams to form the bridge deck. Figure 2.2.3.1-1 shows this system under construction. This system has been used successfully on several bridges in Minnesota.



Figure 2.2.3.1-1 Minnesota Adjacent Beam System

Welded Connections

At least one state (Texas) uses a welded plate connection for adjacent deck slab bridges. Please refer to Section 2.2.1 for more information on welded connections.

2.2.3.2 Concrete Over Pours and Composite Toppings

To alleviate longitudinal joint leakage problems on higher volume roads, some states are now specifying reinforced concrete topping slabs over the adjacent beams. These slabs contain one reinforcing layer and are typically five to six inches thick. Even with the concrete topping, these bridges can be constructed much more rapidly than a conventional bridge with a cast-in-place deck because no forming is required to support the wet concrete.

2.2.4 Glue Laminated Timber Adjacent Deck Slabs

The United States Department of Agriculture Forest Products Laboratory (USDA FPL) has developed standard bridge details for timber bridges. These standards include prefabricated timber panels and beams. Most timber bridges are used on low volume roadways, but may be applicable to higher volume roads as well. Users of this Manual are encouraged to visit the USDA FPL for more information on timber bridges (www.fpl.fs.fed.us).

Short span bridges can be built using longitudinal glue laminated timber deck panels that span from support to support. The prefabrication involves gluing nominal dimension lumber side-by-side to create a solid panel. For deck slabs, the laminations have the wide face in the vertical direction. Protection against rotting is controlled by the use of pressure treated wood products. The individual laminations can be pressure treated before being laminated together, or the laminated pieces can be pressure treated after fabrication. The glue used for bridge application must be waterproof.

The connection between wood deck panels is used to transfer shear between the panels. Earlier versions of this system used only steel dowels placed mid-depth between the panels. This system proved to be problematic for higher volume roadways, especially when a bituminous wearing surface was employed. The connections would eventually loosen, leading to cracking of the pavement and leakage through the joints.

The current details include a load transfer beam placed at mid-bay between the support stringers. This beam provides a more significant shear transfer mechanism. Even with this connection, reflective cracking can occur in the overlay pavement. For this reason, it is recommended that a layer of geotextile fabric be installed between the pavement and the panels.

Another type of timber superstructure that has been used quite often is a nail laminated or stress laminated wood deck. These systems consist of dimensional lumber placed side by side that are either nailed together, or post-tensioned together. This type of construction can be completed in a relatively short amount of time. Connection details of laminated decks are not included in this manual because the decks are more of a system as opposed to a specific connection. Users of this Manual are encouraged to visit the Forest Products Laboratory website for more information on nail laminated and stress laminated timber decks (www.fpl.fs.fed.us).

2.2.4.1 Connections Between Slabs

The connection between wood deck slabs is used to transfer shear between the slabs. A load transfer beam placed transversely across the bridge at a specified spacing provides a shear transfer mechanism between the units.

2.2.5 Grade Control and Tolerances

Most adjacent butted systems are constructed with precast pretensioned concrete. Precast beams are normally cast flat and arrive at the project site with minor camber caused by the prestressing force. In order to build a bridge to a specified vertical profile, the thickness of the concrete topping or wearing surface must vary along the beam length to compensate for this camber. For bridges on crest vertical curves, the thickness of the topping or wearing surface will be thicker near mid-span. For bridges on sag vertical curves, the topping or wearing surface will be thicker near the supports. Designers need to account for these variations when designing the beams and setting the grades of the supports.

The grades of the roadway also affect construction of parapets and curbs. The variation in topping and wearing surface thickness must be applied to curb heights as well.

Normal tolerances specified in the PCI Manual entitled "Tolerance Manual for Precast and Prestressed Concrete Construction – MNL 135-00" should suffice for precast prestressed adjacent butted beam systems [16]. A nominal width joint is normally specified between the beams to account for the allowable sweep tolerance in the beams.

2.2.6 Evaluation of Performance and Long Term Durability of Adjacent Beam Systems

As previously stated, adjacent butted beam systems have proven very durable. Some bridges have been in service for over 50 years with no significant deterioration. Most problems with these systems are found on high volume roadways. It appears that the standard grouted shear keys with nominal lateral ties may not be adequate for high volume roads. An informal unpublished study was performed by the Connecticut DOT on failed grouted shear key connections on an Interstate highway bridge. Several joints were cored to inspect the grouted keys. Voids were discovered in the upper half of all joints, indicating that the mechanical interlock of the shear key was lost. Based on this discovery, it was

determined that poor grouting techniques were employed during construction of the bridge, which led to the voids in the keyways. Even with this limited study, there is no consensus about the cause of leakage through longitudinal joints. The cause is either inadequate lateral post-tensioning, or poor grouting techniques.

Several states are addressing this problem by adding reinforced concrete toppings to make a better connection between the beams. This has proven to be a successful way to minimize the problems with leakage through the joints.

The more traditional lateral tie systems with bituminous wearing surfaces appear well suited for local low volume roads. These bridges can be constructed rapidly with minimal field construction, and should require little or no maintenance for many years.

2.2.7 Estimated Construction Time for Connections

Timelines for construction depend on the weather and site-specific factors such as access, traffic control, and locations for cranes and storage. Nonetheless, it is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Table 2.2.7-1 contains approximate installation times for the various adjacent butted beam systems included in this section:

System	Minimum Installation Time*	Comments
Deck Bulb Tee Beams	2 days	Includes erection, welding, and grouting
Tee Beams	2 Days	Includes erection, welding, and grouting
Adjacent Deck Slab and Adjacent Box Beam Systems	2 Days	Includes erection, welding or tie installation, and grouting

Table 2.2.7-1 Approximate Minimum Installation Times for Butted Beam Systems

- Times indicated are for a typical single span bridge. Multiple spans can be built in the same time frame with larger construction crews.

2.2.8 Recommendations for Improvements to Current Practices

Most problems with butted beam systems involve the adjacent deck slab and adjacent box beam systems. The leakage of the joints on high volume bridges without concrete toppings can be problematic. The concrete topping addresses this problem, but adds time and cost to the project. Additional research should study the grouted key construction combined with lateral post-tensioning to determine if a durable grouted key system is feasible.

2.2.9 Connection Detail Data Sheets for Adjacent Butted Beam Systems

The following pages contain data sheets for the various prefabricated butted beam systems. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components Connected
- Name of Project where the detail was used
- Manual Reference Section
The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit

- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: Washington State D.O.T.
 Contact Name: Bijan Khaleghi
 Address: P O Box 47340
Olympia, WA 98504

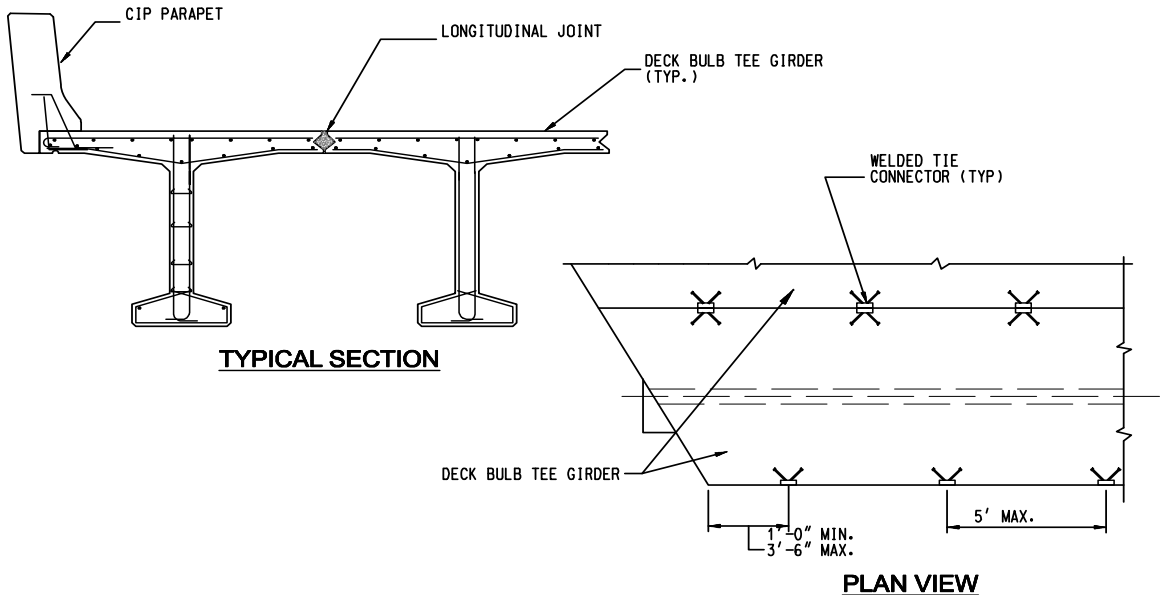
Detail Number: 2.2.1.1 A
 Phone Number: 360-705-7395
 E-mail: KhalegB@wsdot.wa.gov

Detail Classification: Level 1

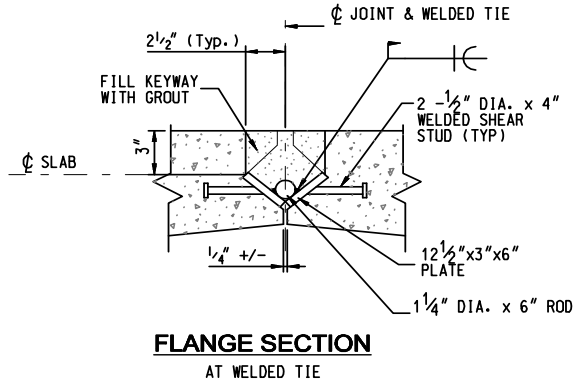
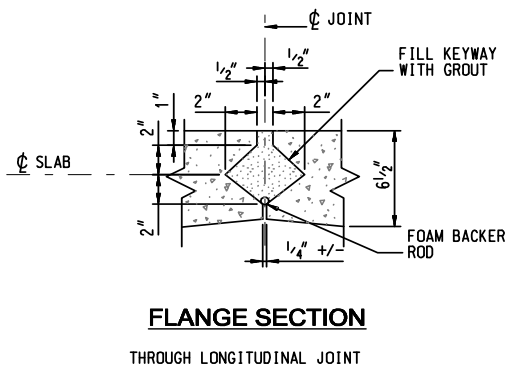
Components Connected: Precast Deck Beam to Precast Deck Beam

Name of Project where the detail was used: Standard Detail

Connection Details: Manual Reference Section 2.2.1.1 See Reverse side for more information on this connection



TYPICAL DECK BULB TEE DETAILS



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

These connections are used for a variety of girder types in Washington State. Girder types include:

- Double tee beams
- Triple Tee (Ribbed) Beams
- Deck Bulb Tees

The welded connections are spaced a maximum of 5 feet on center.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

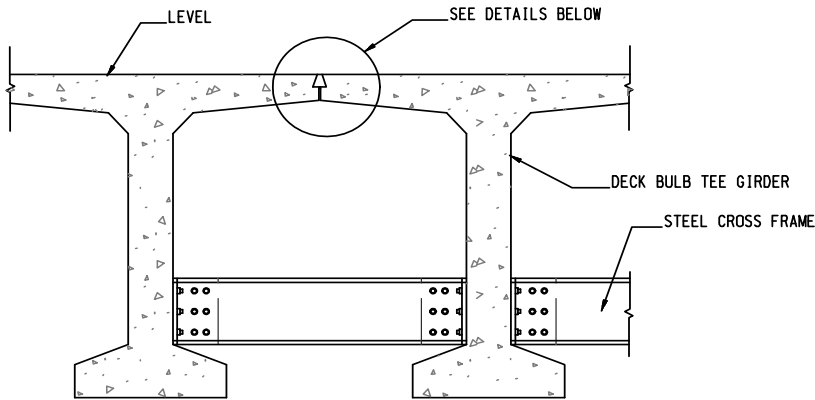
Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

Detail Number: 2.2.1.1 B
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us
 Detail Classification: Level 1

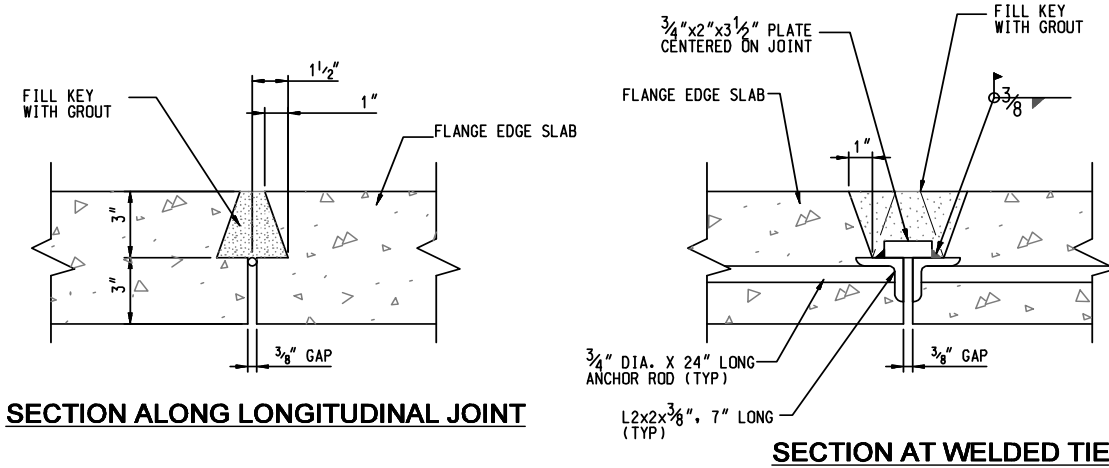
Components Connected: Longitudinal Beam/Slab to Adjacent Longitudinal Beam/Slab

Name of Project where the detail was used: Bridge over middle Fork Crazy Woman Creek (Wyoming Drawing Number 6635)

Connection Details: Manual Reference Section 2.2.1.1 See Reverse side for more information on this connection



TYPICAL DECK BULB TEE DETAILS

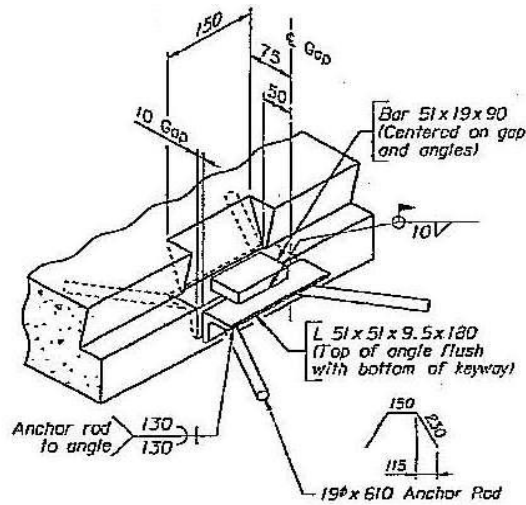


LONGITUDINAL JOINT DETAILS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This is a typical connection used between deck bulb T girders. The welded connection is spaced at approximately 6 foot intervals. Additional surfacing is not typically specified, as the top of the flange is the final wearing surface.



WELD TIE CONNECTION DETAIL
 (Backer rod, non-shrink grout, and near girder flange not shown) (Weld tie assembly and flange blockout is symmetrical)

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

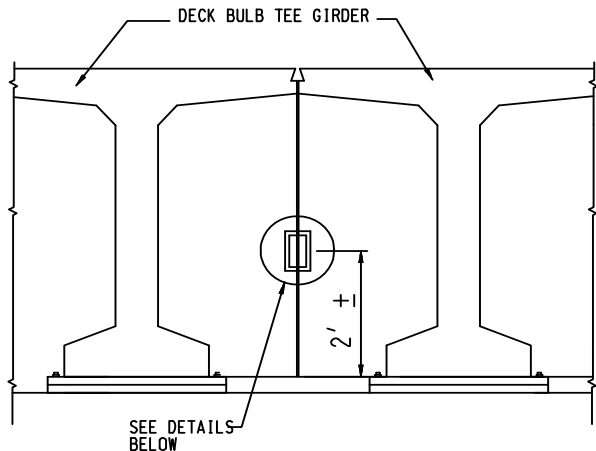
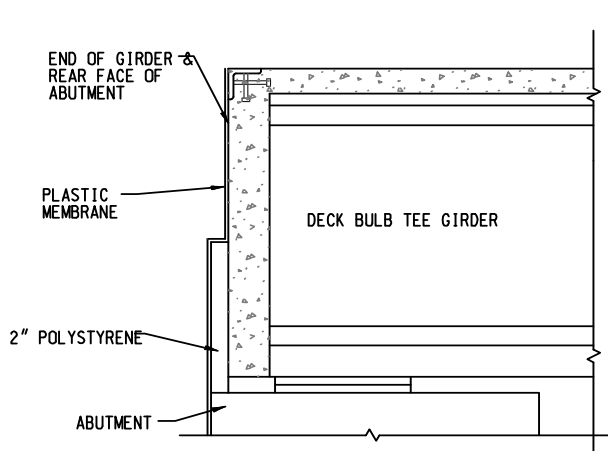
Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

Detail Number: 2.2.1.1 C
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us
 Detail Classification: Level 1

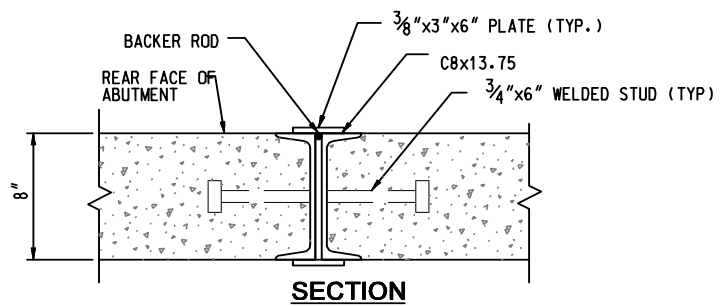
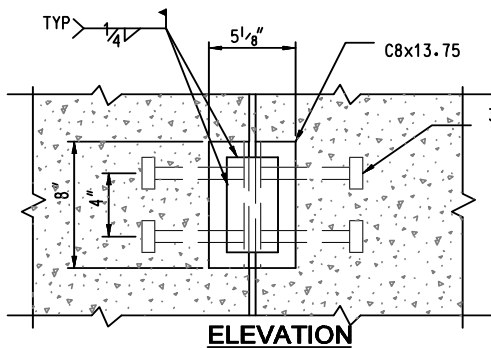
Components Connected: Precast Concrete Backwall Panel to Adjacent Precast Concrete Backwall Panel

Name of Project where the detail was used: Bridge over middle Fork Crazy Woman Creek (Wyoming Drawing Number 6635)

Connection Details: Manual Reference Section 2.2.1.1 See Reverse side for more information on this connection



TYPICAL DECK BULB TEE DETAILS



BACKWALL CONNECTION DETAIL

Editor's Notes

The welded steel plates are somewhat exposed after construction is complete. It is recommended that stainless steel plates and welds be used for this connection.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

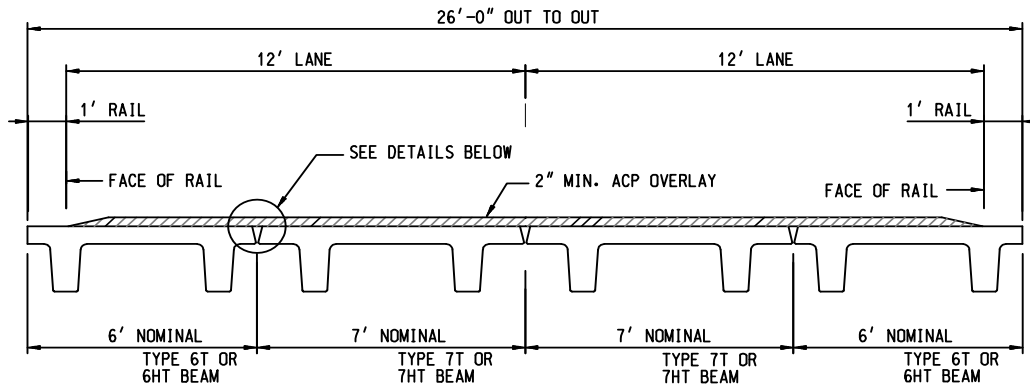
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.2.2.1 A**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us
 Detail Classification: **Level 1**

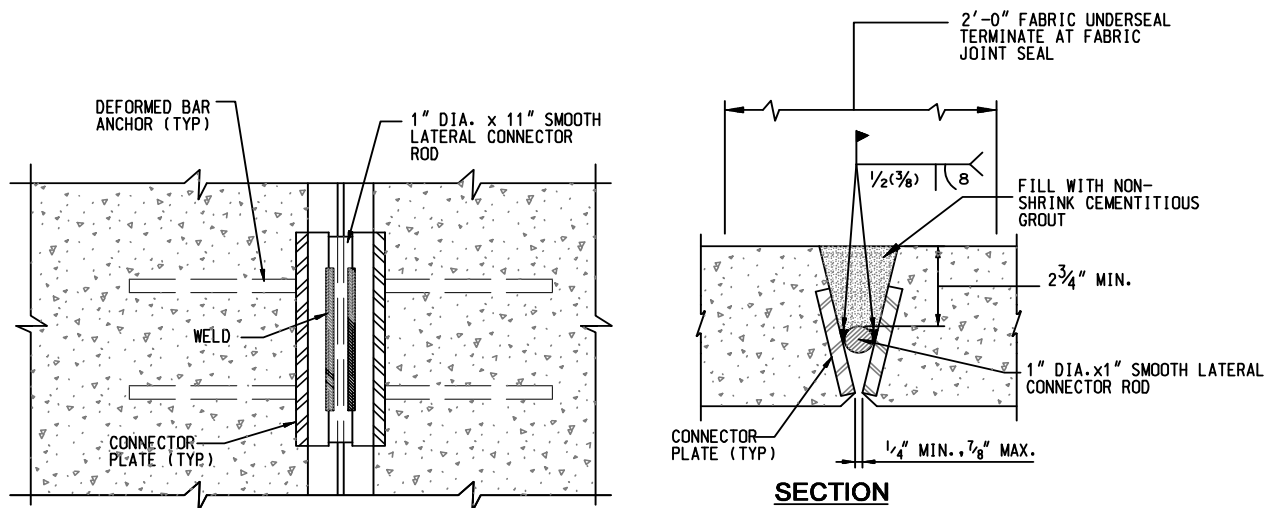
Components Connected: **Prestressed Double Tee Beam** to **Prestressed Double Tee Beam**

Name of Project where the detail was used: _____

Connection Details: **Manual Reference Section 2.2.2.1** See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



(DEFORMED BAR ANCHORS NOT SHOWN FOR CLARITY)

LATERAL CONNECTOR DETAILS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

These connectors are spaced 5 feet on center along the entire length of the beam.

Editor's Notes

The welded steel plates are exposed on the under side of the bridge; therefore it is recommended that stainless steel plates and welds be used to improve durability.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

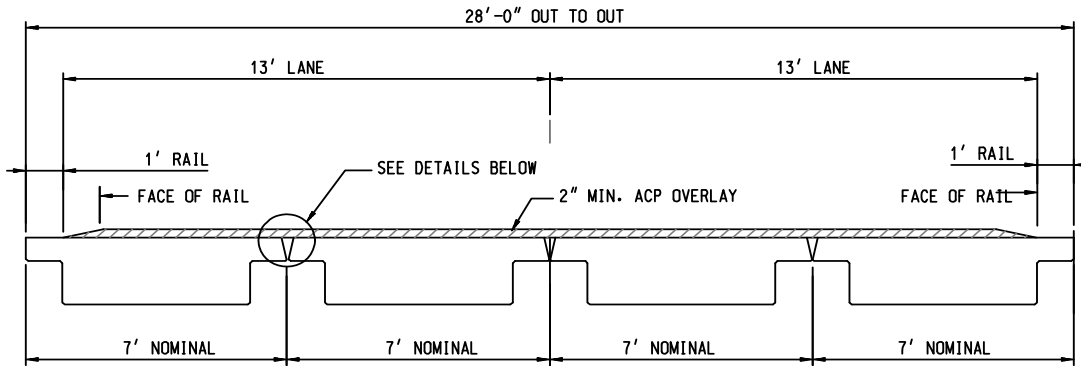
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **2.2.2.1 B**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us
 Detail Classification: **Level 1**

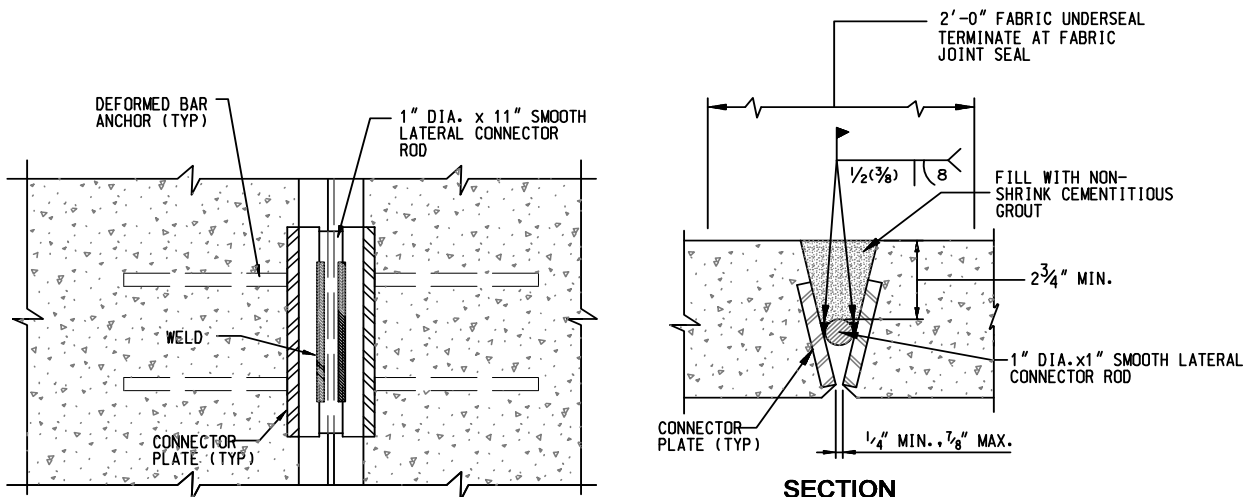
Components Connected **Prestressed T Beam** to **Prestressed T Beam**

Name of Project where the detail was used **Battleground Creek**

Connection Details: **Manual Reference Section 2.2.2.1** See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



LATERAL CONNECTOR DETAILS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

These connectors are spaced 5 feet on center along the entire length of the beam.

Editor's Notes

The welded steel plates are exposed on the under side of the bridge; therefore it is recommended that stainless steel plates and welds be used to improve durability.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

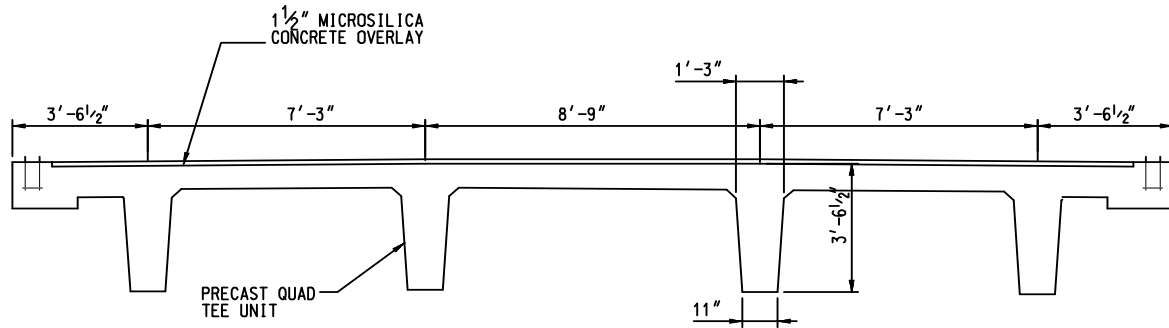
Organization: **New York State DOT**
 Contact Name: **Paul Besmertnik - Regional Struct. Eng.**
 Address: **State Office Building
 250 Veterans Memorial Highway
 Hauppauge, NY 11788**

Detail Number: **2.2.2.2 A**
 Phone Number: **(631) 952-6074**
 E-mail: **pbsmertnik@dot.state.ny.us**
 Detail Classification: **Level 2**

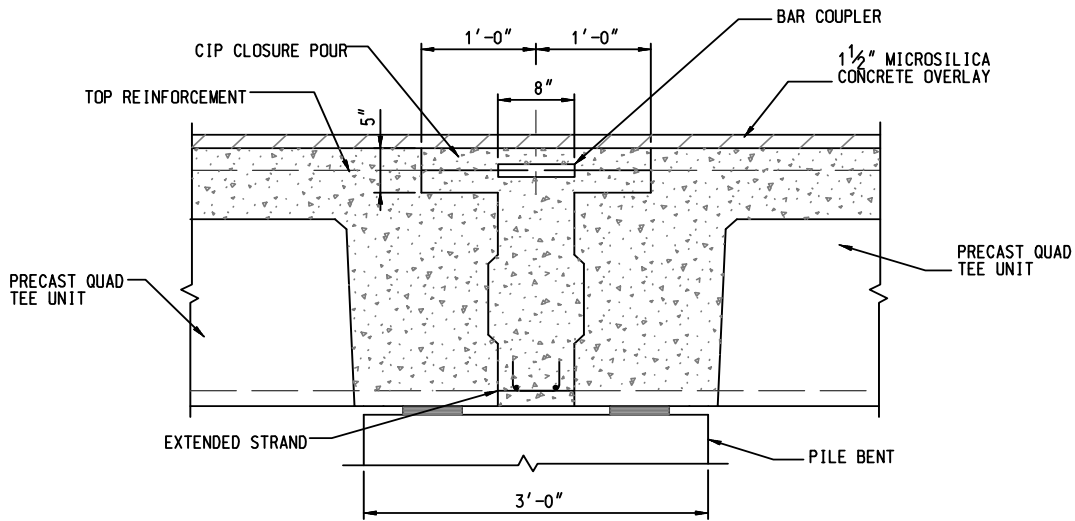
Components Connected: **Precast Quad Tee Superstructure** to **Precast Quad Tee Superstructure**

Name of Project where the detail was used: **Robert Moses Causway Bridge Rehabilitation over Great South Bay**

Connection Details: **Manual Reference Section 2.2.2.2** See Reverse side for more information on this connection



TYPICAL BRIDGE SECTION



CONTINUITY CONNECTION AT PIER

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This is a continuity connection for precast/prestressed quad-T superstructure made continuous for live load. Connecting these units together longitudinally is made with a rebar coupler at the top and overlapping mild steel at the bottom (similar to standard AASHTO I-girders). Upon completion of the connection the entire superstructure was overlaid with a 1.5" microsilica concrete wearing surface. Transverse post tensioning is not needed as the precast units are fabricated the full width of the superstructure. Connection details to the pile cap are similar to NYSDOT's standard connection for precast box girders and AASHTO I-beams with the use of a dowel grouted into the top of the cap beam. Waterway access is necessary to transport these full width units to the bridge site.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

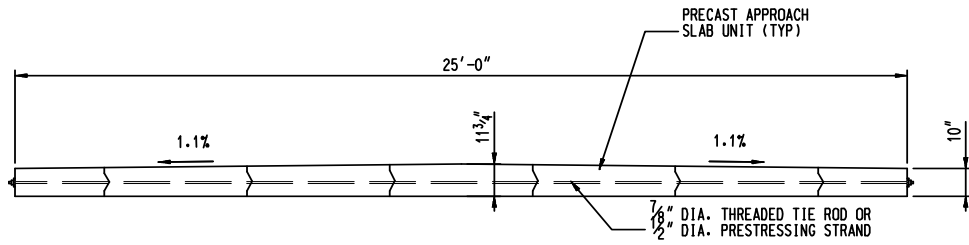
Organization: **Louisiana DOT**
 Contact Name: **Paul Fossier**
 Address: **Louisiana Department of Transportation
 1201 Capitol Access RD
 Baton Rouge, LA 70804-9245**

Detail Number: **2.2.3.1 A**
 Phone Number: **(225) 379-1323**
 E-mail: **PaulFossier@dotd.louisiana.gov**
 Detail Classification: **Level 2**

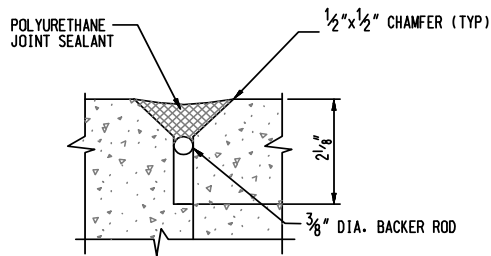
Components Connected: **Precast Approach Slab** to **Precast Approach Slab**

Name of Project where the detail was used: **Louisiana Forest Highway Kisatchie National Forest Clear Creek Bridge**

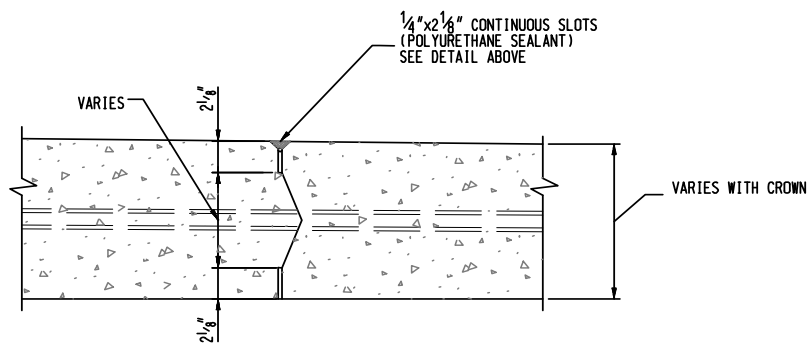
Connection Details: **Manual Reference Section 2.2.3.1** See Reverse side for more information on this connection



TYPICAL APPROACH SLAB SECTION



APPROACH SLAB JOINT INSET DETAIL



TYPICAL DECK SLAB JOINT DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This type of bridge is used on short span bridges on low volume roadways. The approach slabs and deck slabs are made of precast solid slab sections.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear x Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 7 (0 not durable, 10 very durable)

Inspection Access 7 (0 not visible, 10 easily inspected)

Future Maintenance 7 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

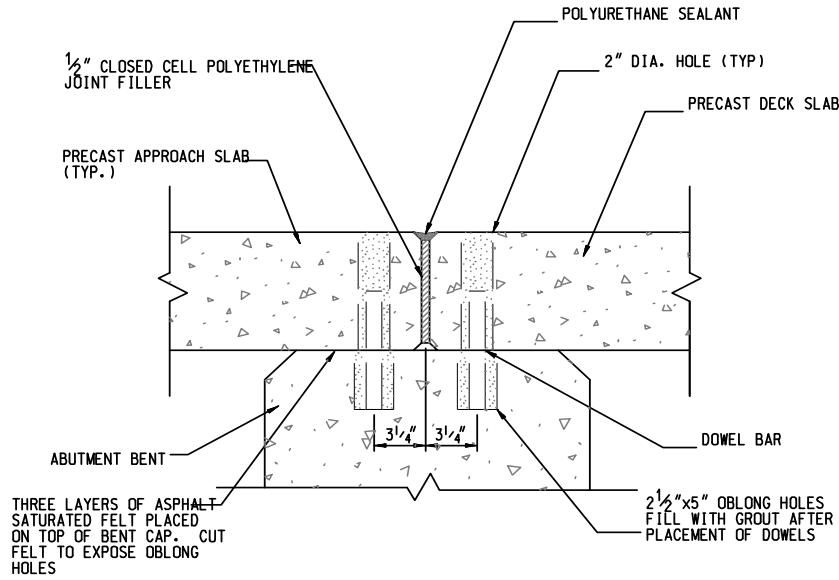
Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: **Manual Reference Section 2.2.3.1** See Reverse side for more information on this connection



APPROACH SLAB TO DECK SLAB DETAIL AT ABUTMENT BENT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This type of bridge is used on short span bridges on low volume roadways. The approach slabs and deck slabs are made of precast solid slab sections.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 7 (0 not durable, 10 very durable)

Inspection Access 7 (0 not visible, 10 easily inspected)

Future Maintenance 7 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

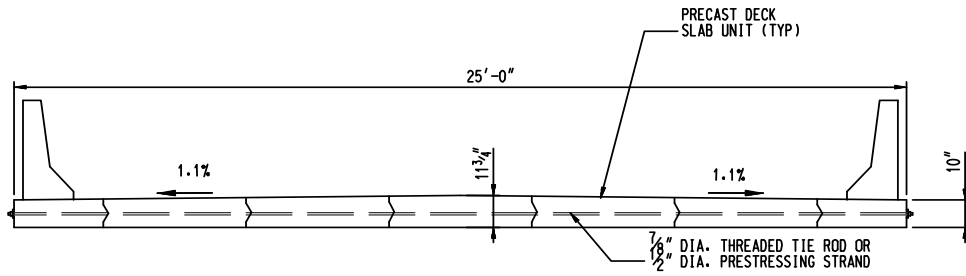
Organization: Louisiana DOT
 Contact Name: Paul Fossier
 Address: Louisiana Department of Transportation
 1201 Capitol Access RD
 Baton Rouge, LA 70804-9245

Detail Number: 2.2.3.1 C
 Phone Number: (225) 379-1323
 E-mail: PaulFossier@dotd.louisiana.gov
 Detail Classification: Level 2

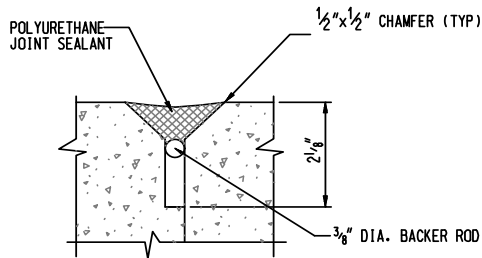
Components Connected: Precast Deck Slab to Precast Deck Slab

Name of Project where the detail was used: Louisiana Forest Highway Kisatchie National Forest Clear Creek Bridge

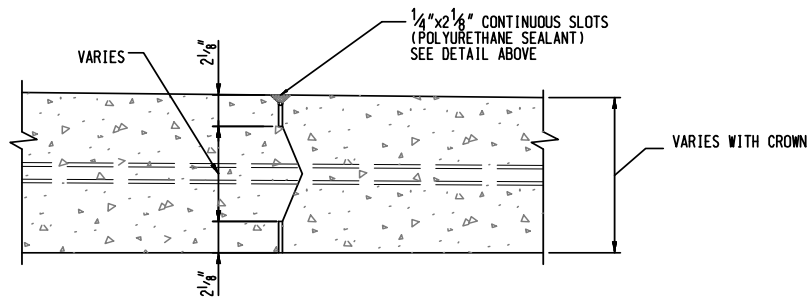
Connection Details: Manual Reference Section 2.2.3.1 See Reverse side for more information on this connection



TYPICAL APPROACH SLAB SECTION



DECK SLAB JOINT INSET DETAIL



TYPICAL DECK SLAB JOINT DETAIL

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 7 (0 not durable, 10 very durable)

Inspection Access 7 (0 not visible, 10 easily inspected)

Future Maintenance 7 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

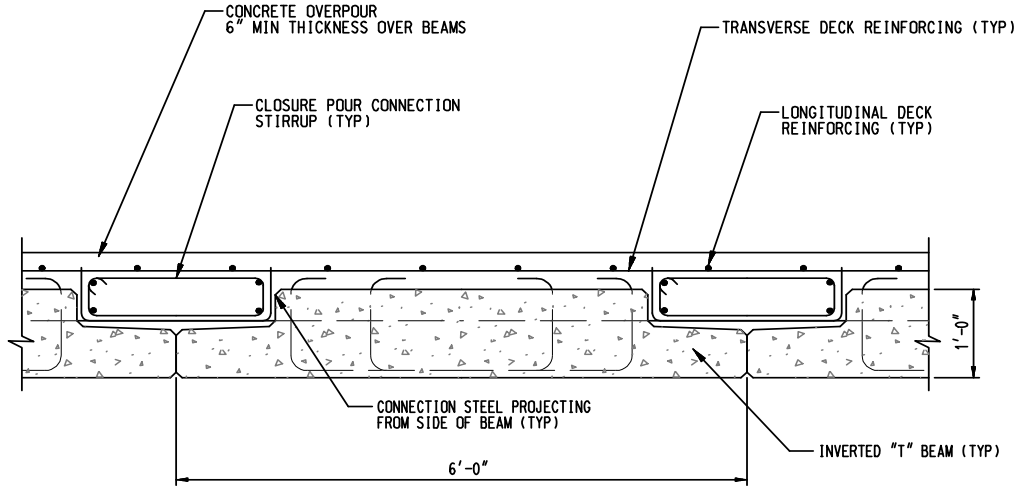
Organization: **MnDOT Bridge Office**
 Contact Name: **Joseph M. Fishbein, P.E.**
 Address: **3485 Hadley Avenue N.
 Oakdale, MN 55128**

Detail Number: **2.2.3.1 D**
 Phone Number: **651-747-2196**
 E-mail: joe.fishbein@dot.state.mn.us
 Detail Classification: **Level 1**

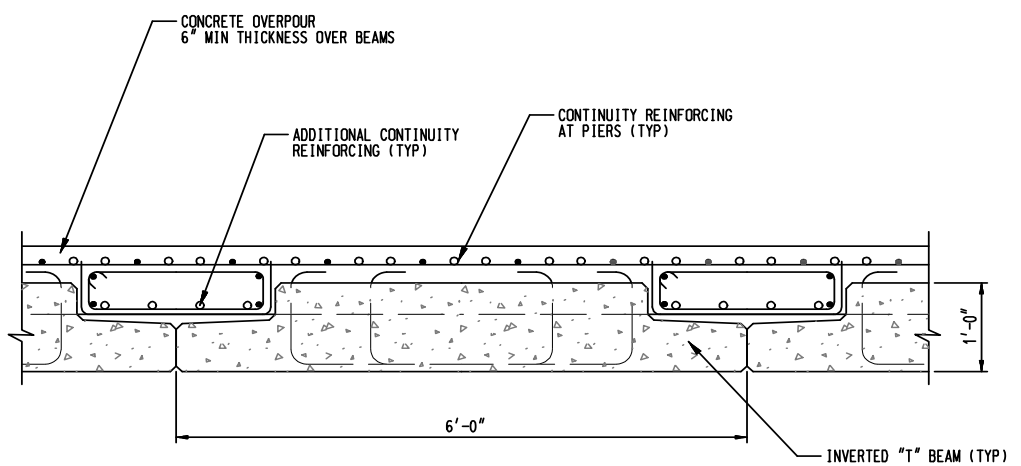
Components Connected **Precast "Inverted-T" Beams** to **Adjacent "Inverted-T" Beams**

Name of Project where the detail was used **Bridge 13004, TH 8 over Center Lake Channel, Center City, MN**

Connection Details: **Manual Reference: Section 2.2.3.1** See Reverse side for more information on this connection



TRANSVERSE SECTION THROUGH DECK
SECTION ALONG SPAN



TRANSVERSE SECTION THROUGH DECK
SECTION NEAR PIERS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between adjacent precast "Inverted-T" beams. The beams consist of a rectangular prestressed section with smaller flanges along the sides. When beams are butted laterally, the flanges form a channel between beams. Rebar hooks cast into the beams overlap in this region, and a pre-tied rebar cage is also placed in the channel. When the deck topping is poured, the beam sections are locked together monolithically.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

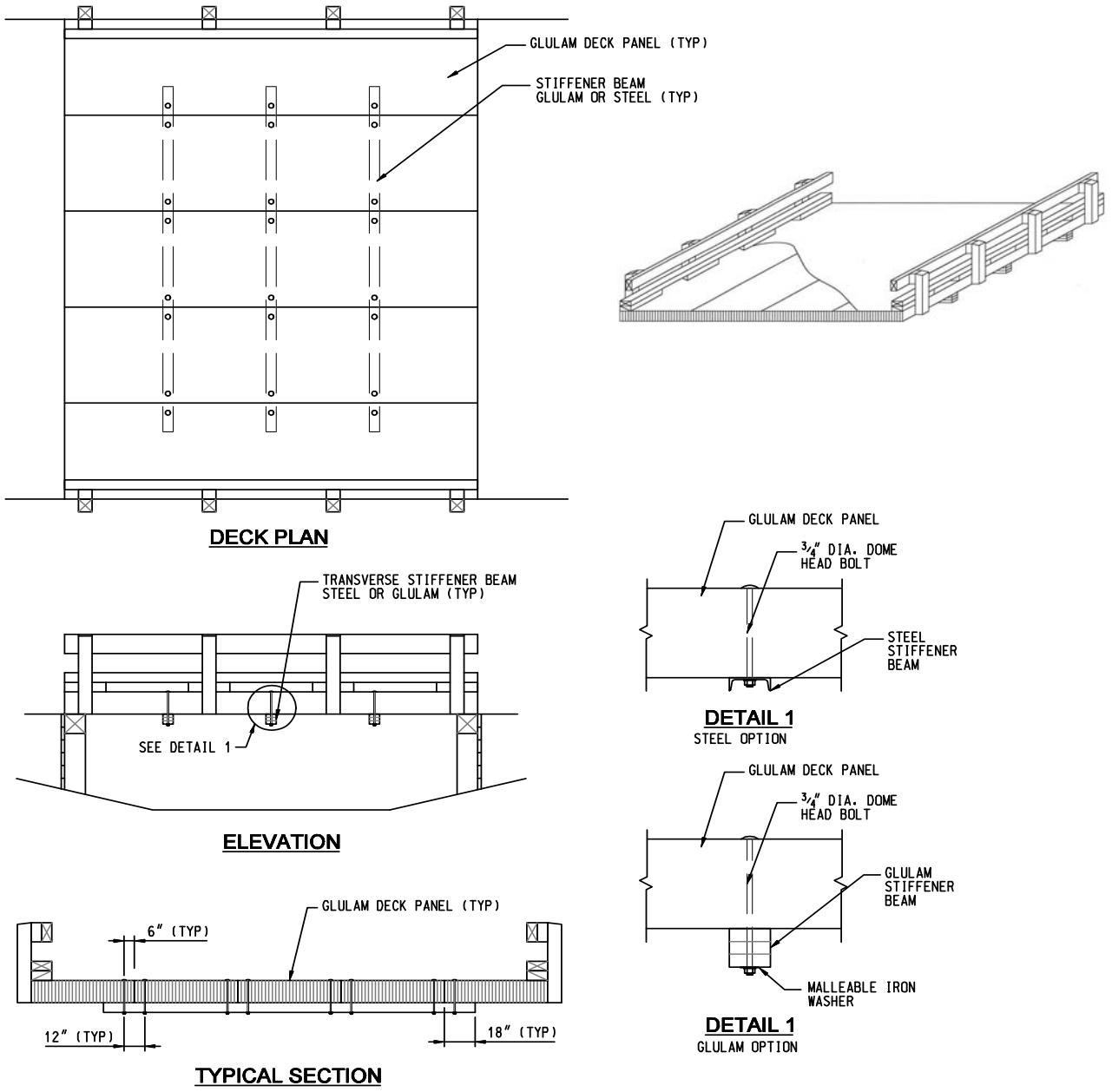
Organization: **USDA Forest Products Laboratory**
 Contact Name: **Jim Wacker**
 Address: **One Gifford Pinchot Drive
 Madison, WI 53726**

Detail Number: **2.2.4.1 A**
 Phone Number: **608-231-9224**
 E-mail: **jwacker@fs.fed.us**
 Detail Classification: **Level 2**

Components Connected: **Glulam wood deck panel** to **Glulam wood deck panel**

Name of Project where the detail was used: **Standard**

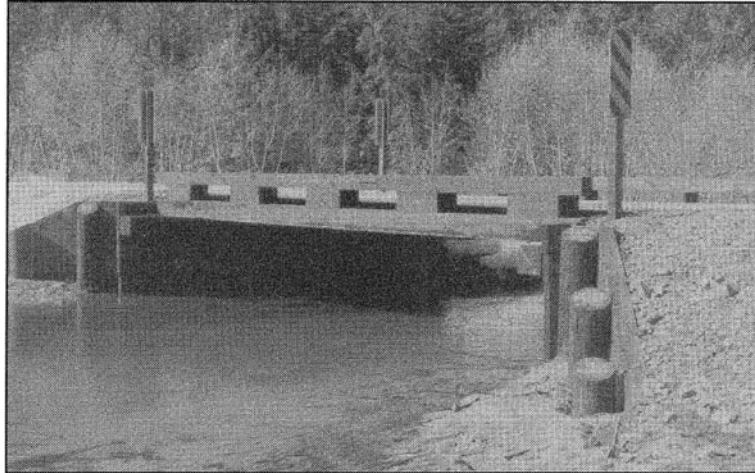
Connection Details: **Manual Reference Section 2.2.4.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The deck panels are made up of glue laminated wood members. The details provide the interconnection between the panels. These bridges are typically used for low volume roadways. For more information on this bridge type and this connection, see the Manual entitled "Standard Plans for Timber Bridge Superstructures - General Technical Report FPL-GTR-125" published by the United States Department of Agriculture Forest Products Laboratory. It can be obtained at: www.fpl.fs.fed.us.



Editor's Notes

There have been problems with reflective cracking of the asphalt overlay even with these details. Long term maintenance may be required.
The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

2.3 Decked Stringer Systems

This section focuses on connections between traditional parallel superstructure stringer beam elements, the most common form of bridge in use today. The connections presented include both transverse connections and longitudinal beam splices.

2.3.1 Transverse Connections

The transverse connection between parallel beam elements is referred to as a cross frame or diaphragm. These connections serve to:

- Assist with lateral distribution of load in the structure
- Provide lateral stability of the beams during construction
- Transfer wind loads from the fascia beam to the interior beams and deck slab.

2.3.1.1. Connections Between Steel Beams

Diaphragms and cross frames for steel bridges are easily attached by bolting or welding. State agencies have standard details for these connections; therefore, they are not presented in this Manual. Most diaphragms and cross frames have bolted connections. To expedite construction, designers should keep the number of bolts required for these connections to a minimum.

2.3.1.2 Connections Between Prestressed Precast Beams

Diaphragms and cross frames for prestressed precast concrete beams are typically more difficult to build than steel bridge members. Often, these elements are made using cast-in-place concrete. The time for forming and curing of the connections can be significant. This section contains details for prefabricated diaphragms and cross frames that have been developed by several states. They include both steel bolt-on diaphragms and precast diaphragm forms.

2.3.2 Longitudinal Connections

2.3.2.1 Steel Beams

Longitudinal connections for steel beams are commonly referred to as beam splices. The most common form of beam splice is a bolted connection. These connections can be quite large and contain numerous bolts; however, in most cases, several connections can be made in one day.

There are ways to expedite the erection of steel beams with bolted splices. The critical time constraint on a steel beam erection site is the time that the cranes are idle while the connections are made. Two things can be done to expedite this process. First, an erection tower can be used to rest the beams after they are set. Second, the designer can allow for early release of the beam by the cranes after a certain number of bolts are installed. The National Steel Bridge Alliance recommends the following practice [42]:

“For splice connections of primary members, as well as connections of diaphragms or cross frames designed to brace

curved girders, fill at least 50 percent of the holes prior to crane release. The 50 percent may be either erection bolts in a snug tight condition or full-size erection pins, but at least half (25 percent of all holes) shall be bolts, and sufficient pins shall be used near outside corners of splice plates and at member ends near splice plate edges to ensure alignment. Uniformly distribute the filled holes.

The 50 percent requirement may be waived if a reduced percentage is calculated as sufficient and shown on the approved erection procedure.”

Welded field splices are not as common as bolted splices. Temporary support towers are usually required to complete a welded field splice.

2.3.2.2 Prestressed Precast Concrete Beams

There are two methods used to splice a prestressed precast concrete beam. The most common splice involves a concrete closure pour combined with longitudinal post-tensioning. Closure pours are used because precast beam elements will arrive in the field with some residual camber from prestressing. The camber leads to beam end rotation that is variable and difficult to estimate. The closure pour can accommodate variations in beam end angles and also allow for minor length tolerance adjustments. The closure pours are reinforced with steel projecting from the beam element and often include shear keys. The post-tensioning ducts are simply spliced within the closure pour area.

The second method that has been used is to match cast the two adjacent elements in the fabrication shop. This method can be problematic if there is any measurable prestress in the beams that would lead to camber growth. Match casting should only be used for beams with little or no pretensioned prestressing.

2.3.3 Simple Span Beams Made Continuous For Live Load

It can be cost effective to construct multi-span bridges that act as simple spans for dead loads and continuous spans for composite dead loads and live loads. This is accomplished using the following construction procedure:

- Erect the beams spanning from support-to-support without a continuity connection at the supports. The beam ends are butted with a minor gap at the piers.
- Cast the bridge decks over the spans but not over the beam ends at the pier.
- Connect the beams by casting a block of concrete between the beam ends. This pour usually includes an integral diaphragm.
- Cast the bridge deck over the pier closure pour. Negative moment reinforcing is normally placed within the deck in this area. The deck is sometimes cast with the beam end closure pour.

From this time forward, the bridge acts as a continuous span because the closure pour is designed to transfer the subsequent composite dead load (e.g., median barrier, parapet, sidewalk) and live load moments from one beam end to the adjacent beam end.

- Complete the bridge construction.

2.3.3.1 Prestressed Precast Concrete Beams

The prestressed concrete industry has been making precast concrete beams for many years. There are special considerations that need to be addressed in a design with prestressed concrete beams. Prestressed concrete beams will continue to experience camber growth after prestress release. Camber growth results in minor rotation of the ends of the beams. After the beams are connected at the piers, the camber growth will either crack the closure pour, or create positive moments in the connection. There have been several research projects regarding this connection. The most commonly reference document is NCHRP Report 322 entitled "Design of Precast Bridge Girders Made Continuous. The basic issues noted in this research are discussed in the following paragraphs.

Different states use different approaches to address the camber growth phenomenon. Some states use little reinforcing in the connection and allow it to crack. Once the crack forms, the connection will be free to rotate and the bridge will behave as a simple span bridge for live load because of the hinging effect of the cracked connection. Even with the cracking, there are advantages to this connection; the bridge will still be jointless and more durable than a simple span bridge with a deck joint.

Another approach to this connection is to reinforce the connection to resist the positive moments at the piers that are generated by camber growth. This will lead to positive moments along the span due to prestress, but will provide significant negative moment capacity that can decrease positive moments along the span. There are two methods used to create the positive moment connection within the closure pour. The first is to extend a number of prestressing strands into the closure pour by bending them near the face of the beam end. The second method is to embed mild reinforcing steel in the beam that protrudes from the beam end and into the closure pour. With either method, the long term internal stresses in the beams need to be calculated and checked, and the negative moment reinforcing in the slab needs to be designed.

Although engineers are taught that continuous span designs are more efficient than simple span designs, simple span structures without deck joints described above can also be efficient, cost effective, and quickly built. The efficiencies are seen primarily in the negative moment regions. A large portion of the sharp moment gradients near interior supports are shifted to the positive moment regions. An added benefit to the simple span designs described above is that the deck joint over the pier will be eliminated, thereby reducing the

potential for future deterioration of the underlying framing and foundations. Depending on the design, minor cracking may occur at the pier, but this can be controlled with waterproofing membranes or in dryer climates, left alone. Also, simple-span construction allows simplified future replacement of beams, e.g., when damaged from below by over height loads, and simplified future widening.

State agencies have standard practices for the design and detailing of this connection. Many use the jointless simple span approach due to the simplicity of the design and detailing. Designers should refer to the specific state standards for this connection. If none exist, the authors of this manual recommend the approach developed by the New Hampshire DOT that is available through the PCI Northeast Bridge Technical committee. The committee has prepared a concise design and detailing guide based on methods developed by the New Hampshire DOT [43].

2.3.3.2 Steel Beams

This method of construction is primarily used by the precast prestressed concrete industry; however, the approach can also be applied to steel beam bridges. There has been recent research into the use of multiple simple span steel bridges that are made continuous for live load only. The idea is to erect each span as a simple span and then make a simple connection at the supports using cast-in-place concrete. This connection eliminates the need for significant field bolting or welds, allowing the cranes to release the beams immediately after they are in position, greatly reducing erection time.

Several states have used this method to make older simple span bridges continuous for live load during deck replacement projects. Once the deck is removed, the bottom flanges can be connected with welded plates. The bridge deck can be designed to act as the tension flange by reinforcing the deck over the pier, thereby eliminating the need for a top flange tension splice. Welded stud shear connectors complete the top flange connection by joining the deck slab to the beams.

2.3.4 Tolerances

Tolerances play a key role in transverse connections between longitudinal beam elements.

Steel beams are fabricated to specific cambers; however, tolerances in manufacturing can affect the cross frame connections. This is not usually an issue because the beams are quite flexible. Some designers have specified the use of slotted holes to accommodate camber tolerance. This approach is not recommended because it can lead to a buildup of erection misalignments. The steel industry suggests simply designing these connections with standard bolt holes.

Concrete beams can be more problematic because the beam camber is constantly changing due to the prestress forces. It is not unusual for camber to vary from one beam to another. The connections need to address this differential camber potential. Slotted holes in steel cross frames and adjustable forms for closure pours are often employed.

2.3.5 Evaluation of Performance and Long-Term Durability of Stringer Beam Systems

Some of the connections discussed in this section are located below the bridge deck and are therefore not subject to corrosive environments. One connection that can have a significant effect on long term durability is the continuity connection on bridges that are designed as continuous for live load. The elimination of deck joints is one of the most effective ways to improve the durability of the entire bridge structure. Leakage from deck joints can cause damage to the beam framing and foundations.

2.3.6 Estimated Construction Time for Connections

The times required for construction depend on a number of factors including site access, traffic control, weather, crane locations and proximity to storage areas. Nonetheless, it is possible to make reasonable estimates of the minimum required construction time for the various systems discussed in this section.

Table 2.3.6-1 provides approximate installation times for various decked stringer systems:

System	Minimum Installation Time*	Comments
Cast-in-place concrete diaphragm on PS beams	2 Days	Time includes forming multiple diaphragms and placing of concrete.
Precast diaphragms on PS beams	1 Day	Multiple diaphragms can be completed in one day
Steel cross frames on PS beams	1 Day	Multiple cross frames can be completed in one day
Bolted beam splices on steel beams	1 Day	Except for very large connections, in most cases multiple connections can be completed in one day.
Welded beam splice on steel beam	2 Days	Large beam splices may take longer
Cast-in-place closure pour splice on PS beams	2 Days	Time includes forming multiple splices and placing of concrete
Live load continuity connections on concrete and steel beams	3 Days	Time includes forming multiple closure pours and placing of concrete

Table 2.3.6-1 Approximate Minimum Installation Times for Decked Stringer Systems

* The time for cast-in-place concrete is based on the use of high early strength concrete that can be cured rapidly.

2.3.7 Recommendations for Improvements to Current Practices

The connections described in this section are quite common and well tested. They result in durable stable connections.

2.3.8 Connection Detail Data Sheets for Decked Stringer Systems

The following pages contain data sheets for the various decked stringer systems. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its

field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Component Connected
- Name of project where the detail was used
- Manual Reference Section
The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

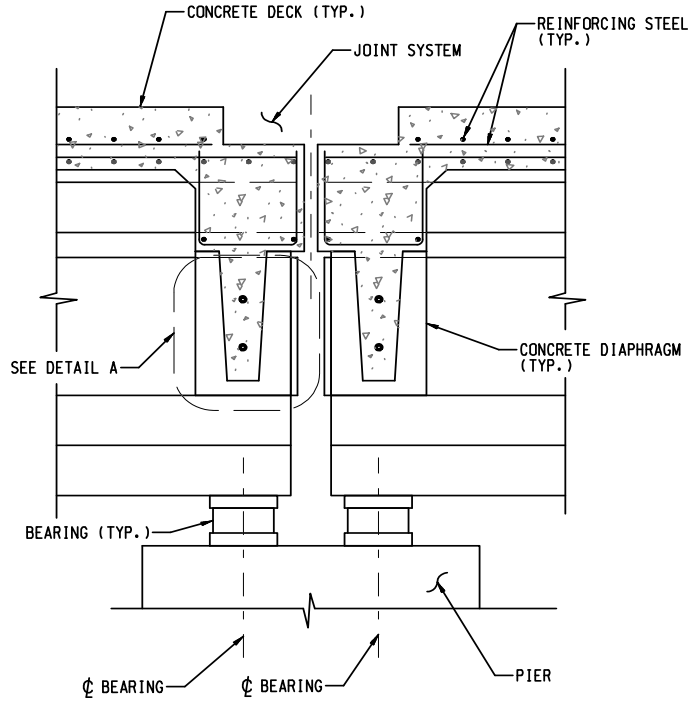
Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

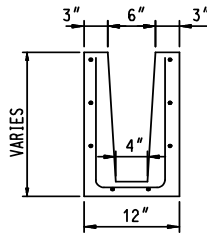
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



LONGITUNIAL SECTION AT PIER



DETAIL A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The detail shown is a precast diaphragm that is attached to precast bulb tees and/or AASHTO I-beams. The precast portion of the diaphragm acts as a form. The precast piece is u-shaped and when it is set in place reinforcing runs through the girder webs and into the diaphragm. CIP concrete is then placed in the precast diaphragm to form the connection.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

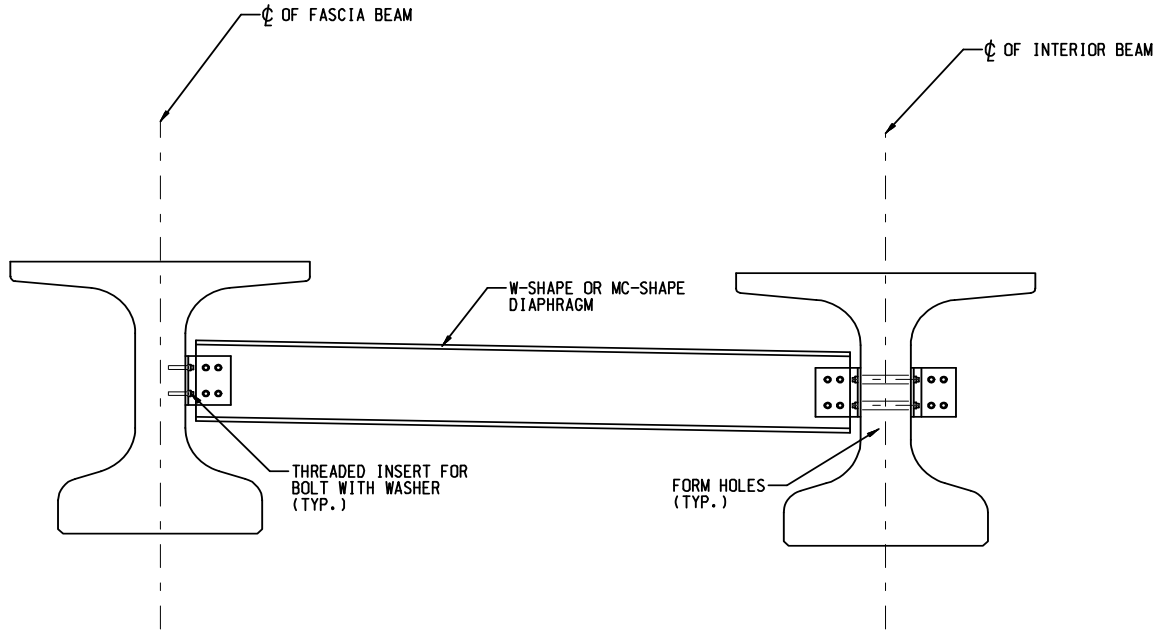
Detail Number:
Phone Number:
E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



INTERMEDIATE DIAPHRAGM - TYPE 1

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The detail shows the connection of steel diaphragms to precast concrete bulb tees/ AASHTO I-beams. The beams have threaded inserts cast into them so the steel can be bolted into the webs. When diaphragms are in line with each other, a hole is placed in the web and diaphragms are bolted to each side.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: New York State DOT
 Contact Name: James Flynn
 Address: POD 43
50 Wolf Rd
Albany NY 12232

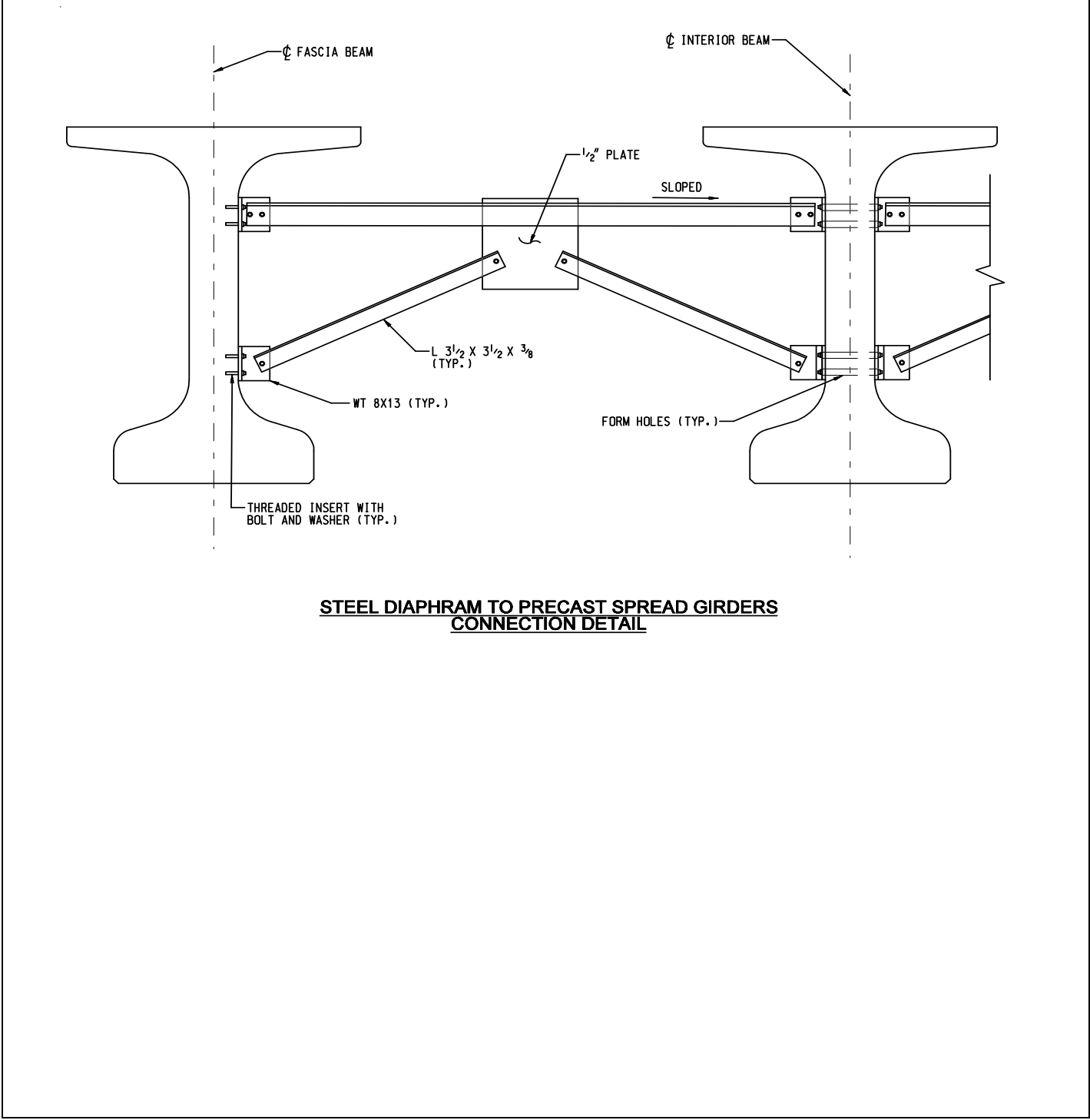
Detail Number: 2.3.1.2 C
 Phone Number: 518-485-1148
 E-mail: jhflynn@dot.state.ny.us

Detail Classification: Level 1

Components Connected: Steel Diaphragms to Precast Spread Girders

Name of Project where the detail was used: _____

Connection Details: Manual Reference Section 2.3.1.2 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The detail shows the connection of steel diaphragms to precast concrete bulb tees/ AASHTO I-beams. The beams have threaded inserts cast into them so the steel can be bolted into the webs. When diaphragms are in line with each other, a hole is placed in the web and diaphragms are bolted to each side.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

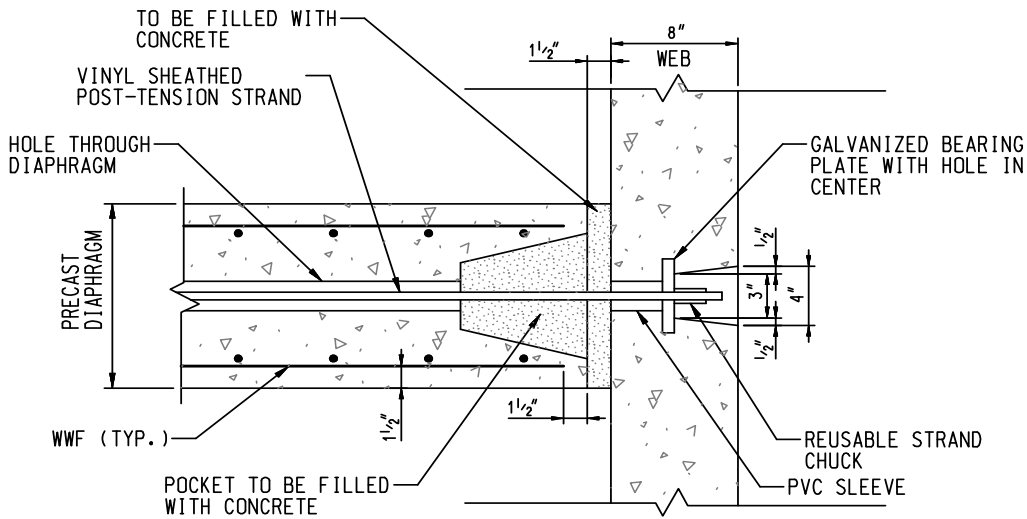
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 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

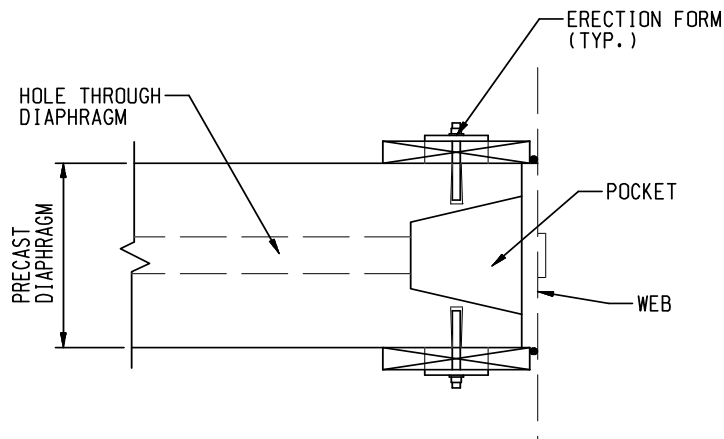
Components Connected: to

Name of Project where the detail was used:

Connection Details: **Manual Reference Section 2.3.1.2** See Reverse side for more information on this connection



TENDON ANCHORAGE DETAIL

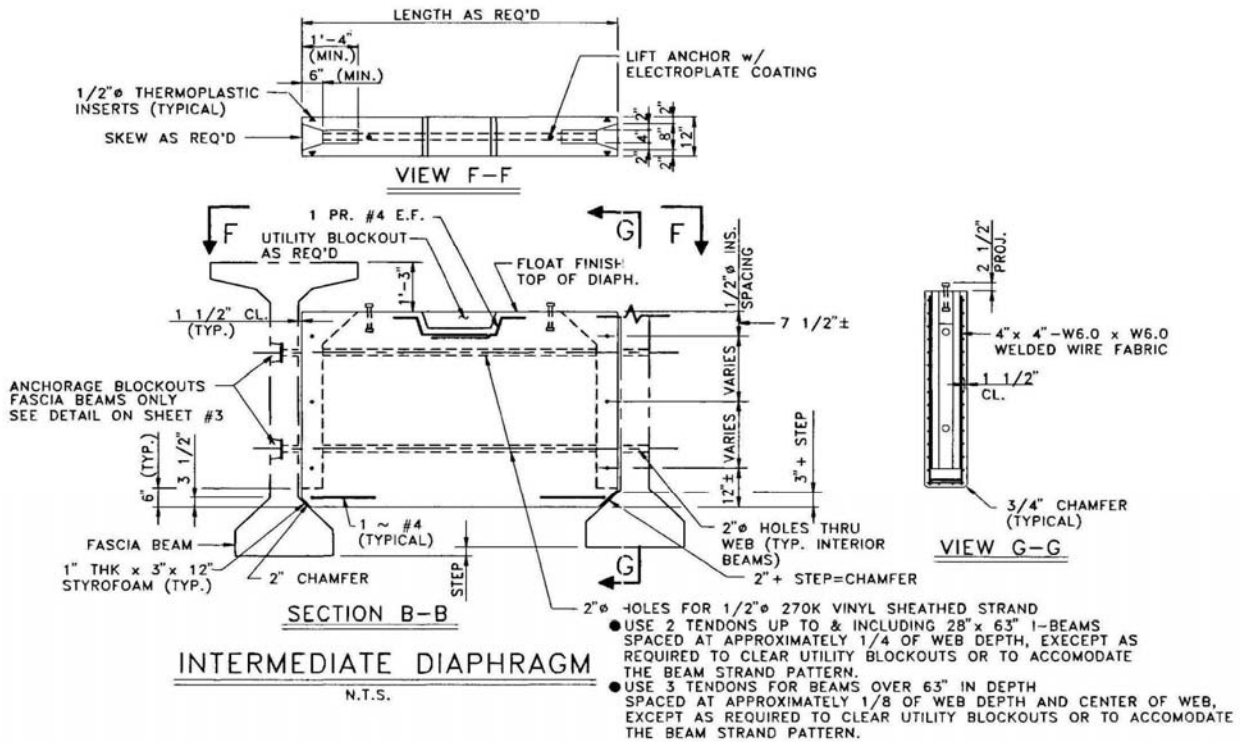


ERECTION PROCEDURE FOR PRECAST DIAPHRAGMS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The diaphragm is attached to the girders by means of a lateral post tensioning system. Small closure pours are used to accommodate sweep tolerances in the girders. Several details are shown. More details for different bridge configurations are available from the DOT.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

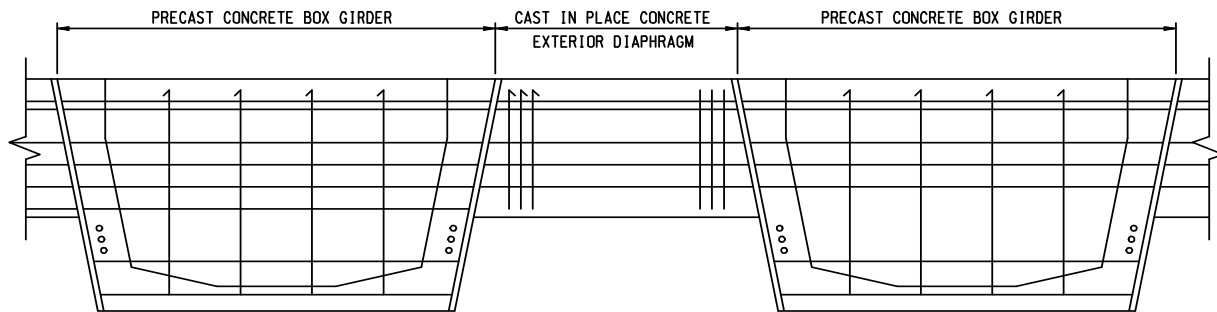
Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

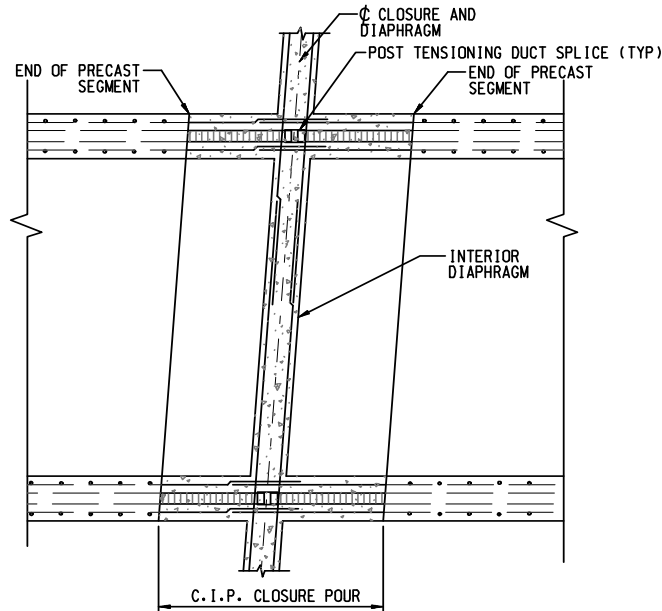
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



SECTION AT INTERMEDIATE DIAPHRAGM



CLOSURE PLAN VIEW

NOTE: ALL REINFORCEMENT NOT SHOWN FOR CLARITY

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The two-span superstructure consists of precast trapezoidal tub girder segments with 3 segments per span. The segments were post-tensioned together after the deck pour. In between each segment is a 3' closure. A partial height intermediate diaphragm spans transversely between segments. Initial design did not include the intermediate diaphragms. However, further interpretation of the AASHTO 16th Edition indicated that they were required.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

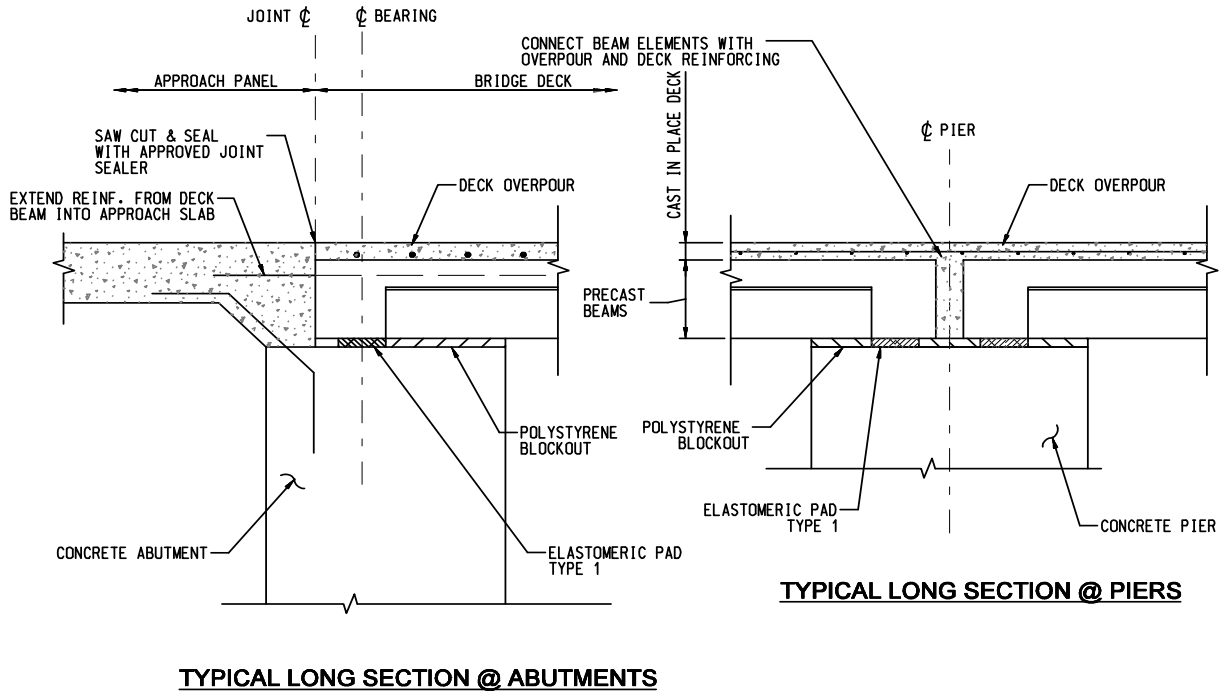
Organization: MnDOT Bridge Office
 Contact Name: Joseph M. Fishbein, P.E.
 Address: 3485 Hadley Avenue N.
 Oakdale, MN 55128

Detail Number: 2.3.3.1 A
 Phone Number: 651-747-2196
 E-mail: joe.fishbein@dot.state.mn.us
 Detail Classification: Level 1

Components Connected: Precast "Inverted-T" Beam to Precast "Inverted-T" Beam at pier

Name of Project where the detail was used: Bridge 13004, TH 8 over Center Lake Channel, Center City, MN

Connection Details: Manual Reference: Section 2.3.3.1 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection at piers between precast "Inverted-T" beams on successive spans and the pier cap. Beams rest on elastomeric pads on pier cap with a 4" space between successive spans. Vertical dowels in pier cap, spaced 12" apart over central 50% of bridge width, are between beams. A prefabricated rebar cage spans across pier cap in the channels formed by adjacent Inv-T beams. When deck topping is poured, the space between beams is filled as well, forming a continuous connection. For design, spans are treated as simply-supported for non-composite DL and continuous for LL and composite DL. Additional analysis for restraining moment due to creep is also performed.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

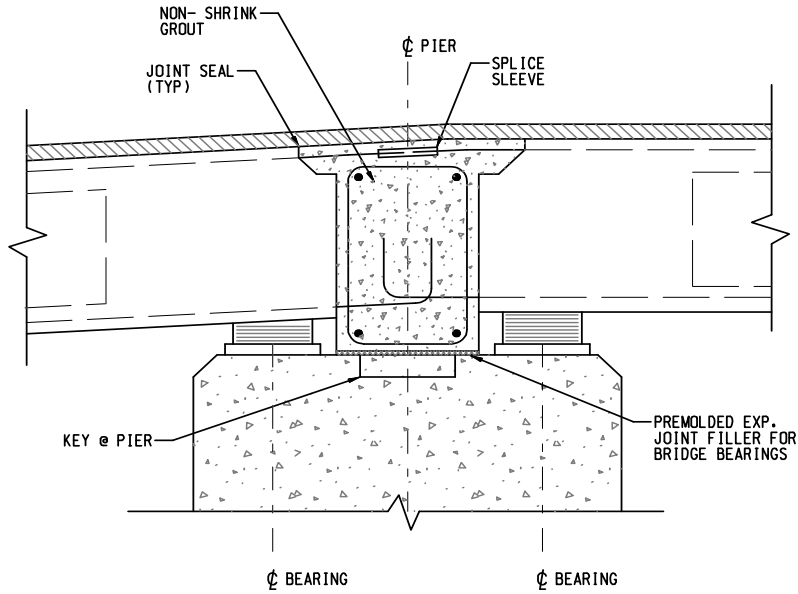
Organization: **NMB Splice Sleeve**
 Contact Name: **Alvin C. Ericson**
 Address: **PO Box 367897
 Bonita Springs, FL 34136-7897**

Detail Number: **2.3.3.1 B**
 Phone Number: **888-446-5376**
 E-mail: **ericson@alum.mit.edu**
 Detail Classification: **Level 2**

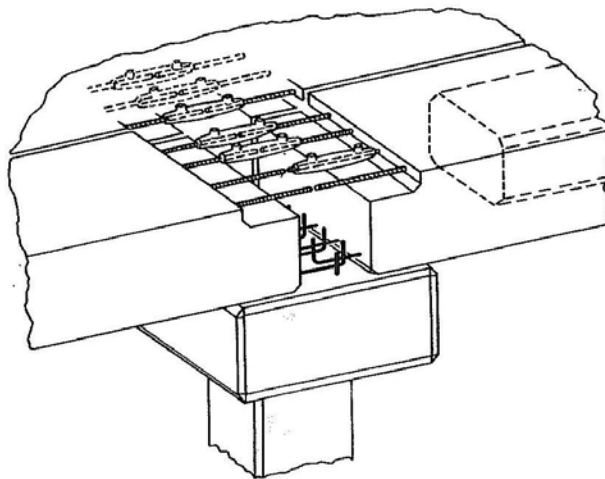
Components Connected: **Precast Box Beam** to **Precast Box Beam**

Name of Project where the detail was used: **Unquowa Road, Fairfield CT**

Connection Details: **Manual Reference Section 2.3.3.1** See Reverse side for more information on this connection



**SECTION THROUGH PRECAST
 BOX BEAM CONNECTION**



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to create a structure that is continuous for live load. Special splice sleeves were used that could be slid to one side and then slid into position after beam placement. The installation procedure is shown below.

INSTALLATION PROCEDURE

Preparation: (Figure 1)

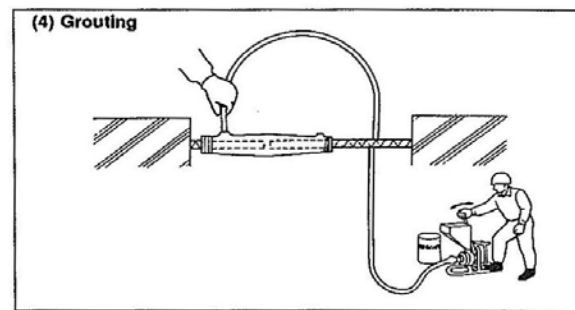
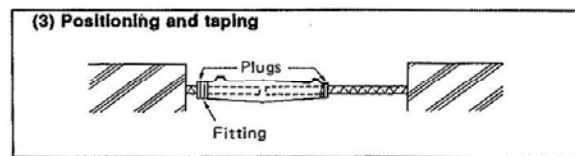
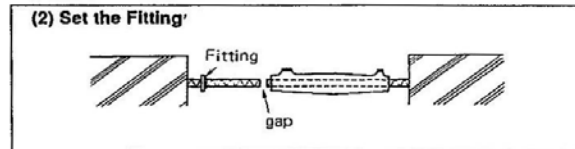
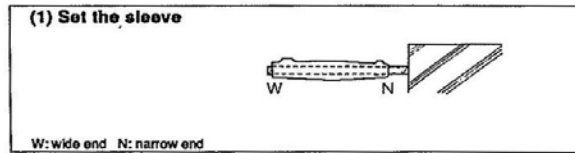
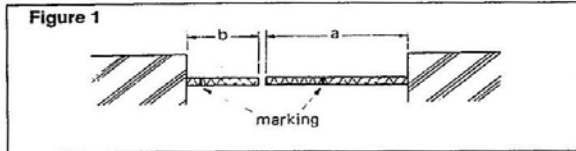
The rebar are marked so that both bars will be embedded to the specified length into the sleeve when it is in its final position.

The Rebar Stop is removed from the Model X sleeve by striking it a firm blow.

Install the Rubber Plug (RP) or split foam plastic washer on the narrow end of the sleeve.

Installation:

- (1) Slide the narrow end of the sleeve onto the horizontal dowel bar protruding from the first concrete member until the entire sleeve is on the bar.
- (2) Install the second concrete member. The gap between the ends of the bars shall not be more than 25/32" (20 mm) for bar sized #5 thru #7 nor 15/16" (24 mm) for bar sizes #8 thru #14. Misalignment of the bars shall not be greater than 25/64" (10 mm).
- (3) Slide the sleeve over the two dowels with the grout inlets on top until it is accurately located between the previously made marks on the bars. Install a centering device if necessary to hold the large end of the sleeve in alignment on the bar. Place a split foam plastic plug (obtainable from the distributor or locally prepared from foam plastic pipe insulation) against the large end of the sleeve. Wrap vinyl tape around the plug overlapping it to the sleeve and the bar in order to prevent leakage.
- (4) Fill the sleeve with grout using a gravity hose or hand-operated grout pump. Seal the inlet and outlet holes with the Hole Seals provided. After grouting, keep the connection from vibration and shock until the grout has gained sufficient strength not to be damaged. The Plugs may be removed, if desired, and the concrete closure placed after the sleeve grout has reached a minimum strength of 3000 psi, which should occur within one day at ambient temperatures above 68°F. In cold weather, heat should be applied to the splices and tests made of the grout strength.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

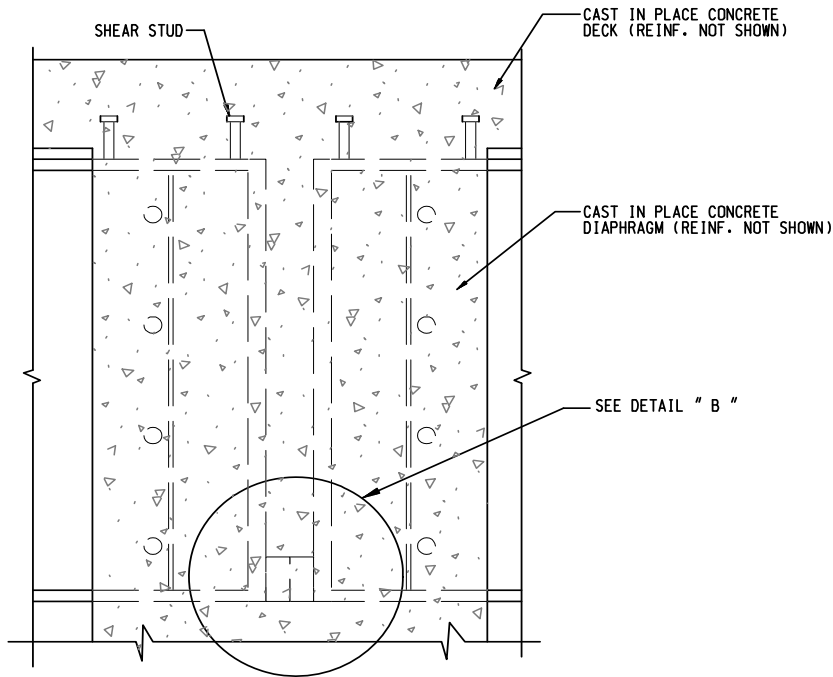
Organization: Highway Bridge Services, L.L.C.
 Contact Name: Atorod Azizinamini
 Address: 4701 Innovation Dr. Suite 106
 UN-Technology Park
 Lincoln, NE

Detail Number: 2.3.3.2 A
 Phone Number: (402) 472-3029
 E-mail: azizi@h-b-s.org
 Detail Classification: Level 1

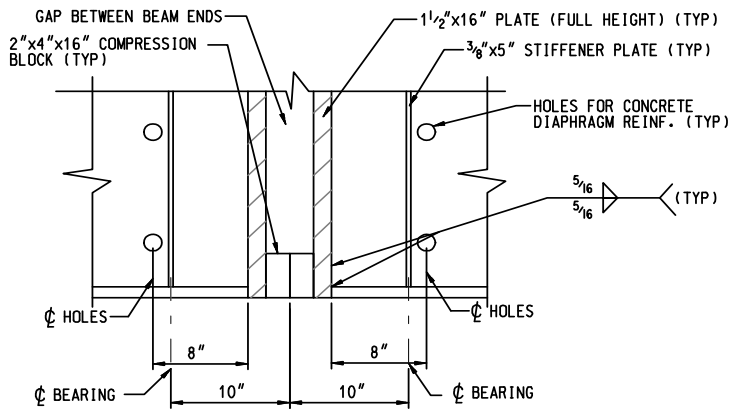
Components Connected: Steel I-Girder to Steel I-Girder

Name of Project where the detail was used: SPRAGUE BRIDGE, Lincoln, NE

Connection Details: Manual Reference Section 2.3.3.2 See Reverse side for more information on this connection



SECTION AT PIER CONNECTION



DETAIL "B"

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is for connecting the pier over the pier for steel bridge systems designed as simple for dead load and continuous for live and superimposed dead loads. Significant research studies were carried out, led by Azizinamini, in developing this detail.

The construction starts by placing the girders over the abutment and pier. The photo on the top right shows the girders after placing over the pier. The plywoods shown are the formwork for placing concrete diaphragm. The bottom of girders are in contact through thick plates welded to end bearing plates. These plates do not have to be in full contact. The construction sequence proceeds with pouring the concrete diaphragm all the way to bottom of the girder top flange. Two design considerations are the type of reinforcements to be placed in the concrete diaphragm before casting and control of cracking when casting the deck slab.

After about three days after casting concrete diaphragm, the concrete deck could be cast. The bottom right photo shows casting the concrete diaphragm prior to casting deck slab. The continuity for the live loads and superimposed dead loads are provided by reinforcement over the pier, prior to casting deck slab.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear X Moment x Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? YES (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

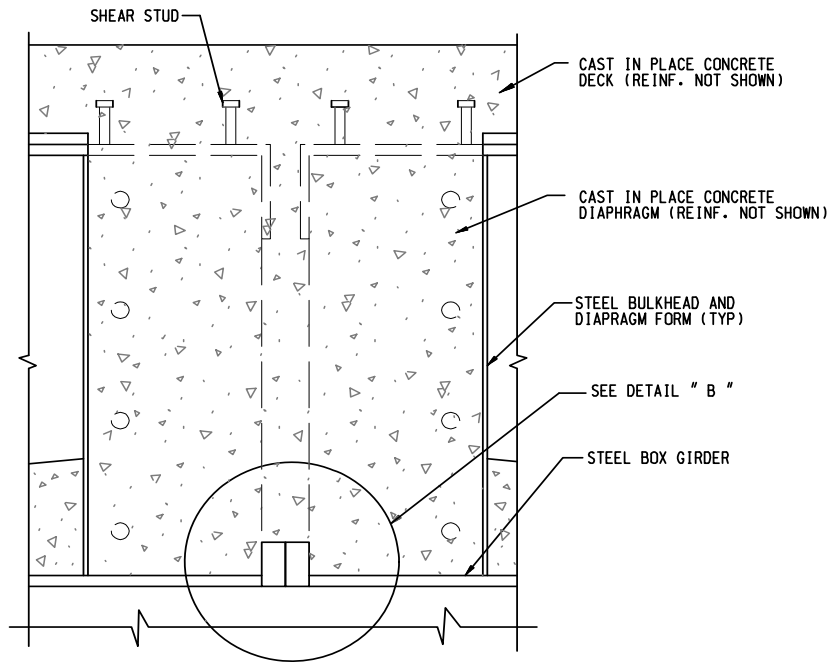
Organization: Highway Bridge Services, L.L.C.
Contact Name: Atorod Azizinamini
Address: 4701 Innovation Dr. Suite 106
UN-Technology Park
Lincoln, NE

Detail Number: 2.3.3.2 B
Phone Number: (402) 472-3029
E-mail: azizi@h-b-s.org
Detail Classification: Level 1

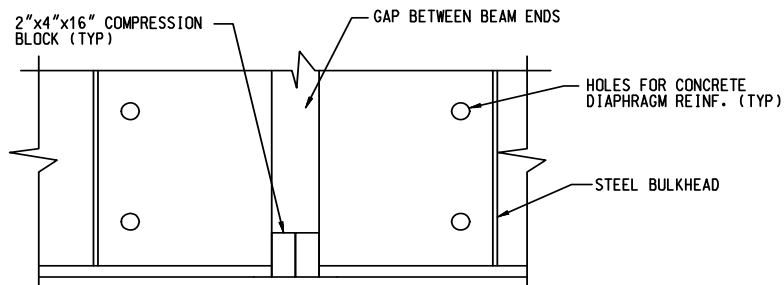
Components Connected: Steel I-Girder to Steel I-Girder

Name of Project where the detail was used: N2 Over I-80, Nearr Grand Island Nebraska

Connection Details: Manual Reference Section 2.3.3.2 See Reverse side for more information on this connection



SECTION AT PIER CONNECTION



DETAIL "B "

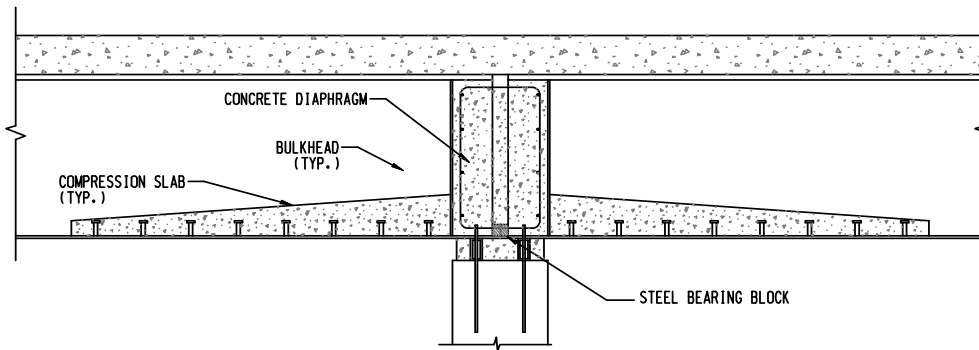
Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This connection detail is for steel bridge systems utilizing the simple for dead load and continuous for live loads and superimposed dead loads concept. It is specialized for steel box girder bridges. This detail is simliar to the one used for I girder bridges using same system.

The end of girders consists of plates welded to top flanges and thick plates welded to bottom flange of box. The end shown is placed over the pier. The two adjacent box girders contact over the pier via plates welded to the bottom flanges.

The steel blukhead shown serves two purposes. It stabilizes the box ends and provides a formwork for placing the concrete diaphragm over the pier. The continuity for the live loads are achieved through reinforcement placed over the pier prior to casting the deck slab. The construction sequence can proceed using the same procedures as specified for I girder option



SECTION THROUGH STEEL BOX GIRDER CONNECTION AT PIER

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **Virginia Department of Transportation**
 Contact Name: **Ken Walus**
 Address: **1404 East Broad St.
 Richmond, VA 2319**

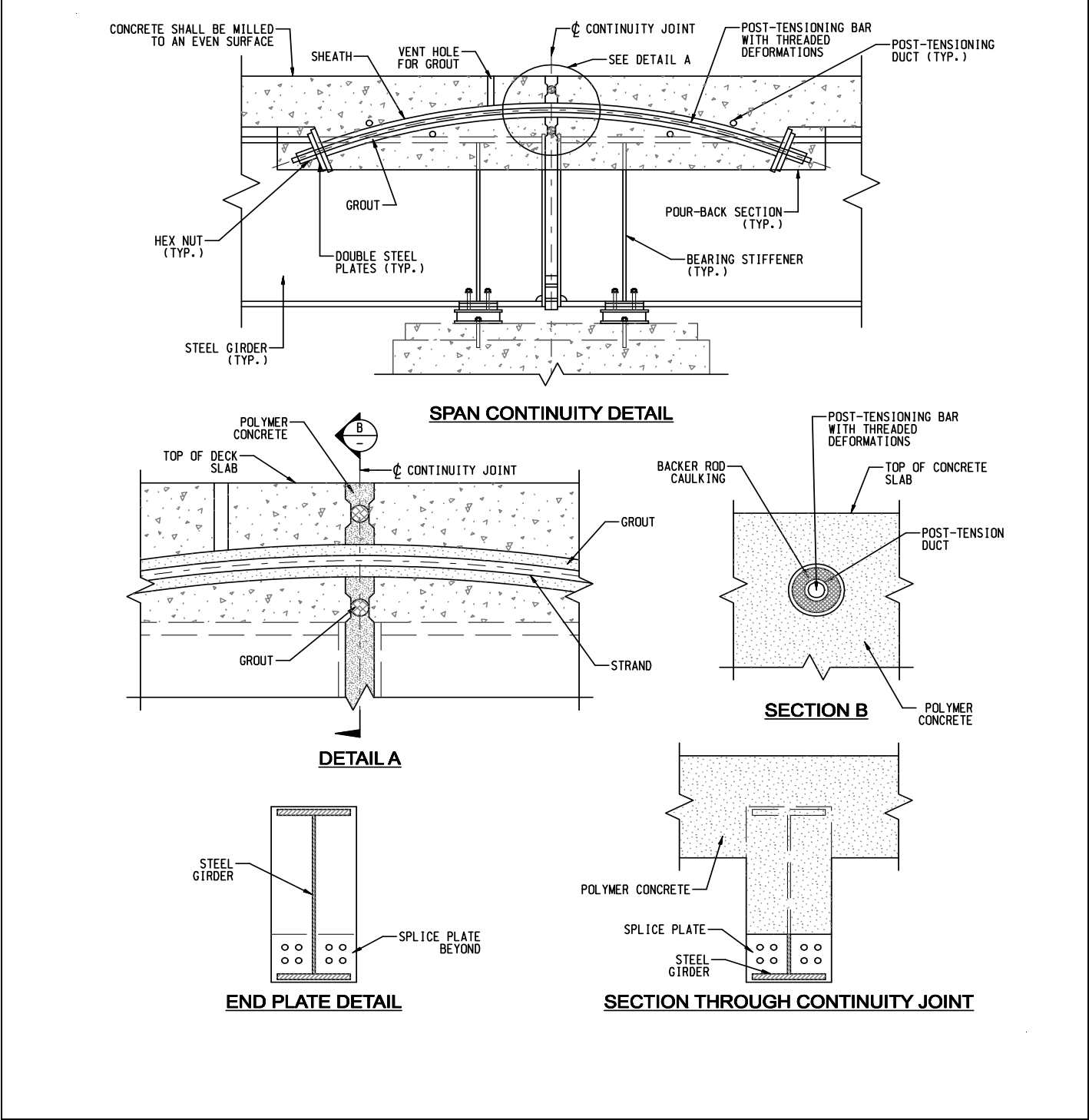
Detail Number: **2.3.3.2 C**
 Phone Number: **(840) 786-4575**
 E-mail: Kendal.walus@vdot.virginia.gov

Detail Classification **Level 2**

Components Connected **Precast Beam/Slab Unit** to **Precast Beam/Slab Unit**

Name of Project where the detail was used **Route I-95 over Lombardy Street and CSX Railroad**

Connection Details: **Manual Reference Section 2.3.3.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to create a structure that is continuous for live load.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

2.4 Modular Prefabricated Superstructure Systems

This section focuses on connections between large prefabricated systems that tend to be composed of larger elements with fewer pieces in the superstructure system. These systems save time during construction because fewer connections are required. These larger systems also have the advantage of fewer joints. Several of these systems are proprietary.

2.4.1 Precast Deck/Stringer Systems (inverset)

One method of prefabrication involves constructing conventional composite stringer bridges off site and installing them rapidly on site. In the 1980's, the inverset system was developed in Oklahoma. The Inverset system consists of two steel stringers supporting a composite concrete deck (see Figure 2.4.1-1 for Details of the system). While this system may not seem original, the method of casting the deck makes the system unique.

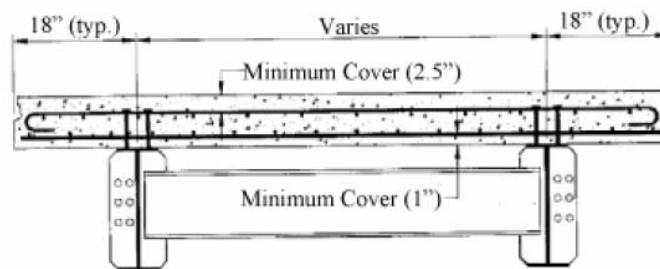


Figure 2.4.1-1 Inverset Deck System Details

The inverset system is cast at the prefabrication yard in an inverted position with the deck forms hung from the steel stringers. This brings about two key features of the system.

- The weight of the wet concrete induces bending stresses in the steel stringers.
- The final top of the deck is against the form, which leads to high quality concrete.

Figure 2.4.1-2 is a schematic of the casting operation.

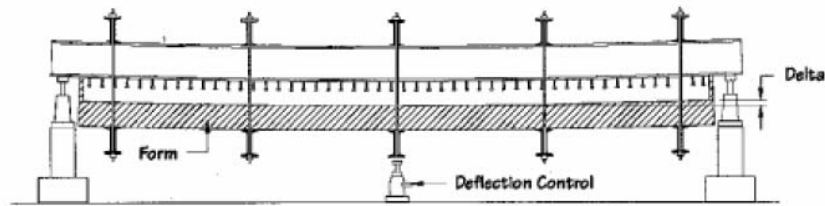


Figure 2.4.1-2 Inverset™ Casting Technique

Once the deck is cast and cured, the entire system is flipped over. The inverted casting technique induces dead load bending stresses in the stringers which are opposite to the future live load stresses when the bridge is constructed. This results in prestress forces in the stringers, which permits smaller stringers or longer spans with shallow girders.

It is possible to construct complex geometries using this system. Skewed supports and vertical curves are possible. Camber is controlled by using deflection control stops in the casting bed; therefore, it is possible to make connections to adjacent units using high strength bolts.

The inverset system was formerly a proprietary system and only manufactured by a few licensed fabricators. This is no longer the case, and these systems can now be used throughout the country without licensing from Inverset.

2.4.1.1 Transverse Connection Between Units

The inverset system is essentially a double tee unit that can be transported to the bridge site and erected quickly. The main connection to adjacent units is accomplished using bolted diaphragm plates. The overhangs of the units are normally kept small so that the connection at the deck level is essentially a shear connection that requires only a grouted keyway.

Several states have used this system. New York DOT has used it extensively to replace aging bridge superstructures and to increase vertical clearance at highway overpasses. There are several details used at the deck connection. The most common is a non-shrink grouted shear key to improve durability. Other details include small closure pours containing hooked reinforcing projecting from the edges of the deck units.

2.4.2 Large Precast Deck/Stringer Superstructure Systems for Bridges with Floorbeams

There are many large steel bridges in the United States that are constructed with either trusses or large girders connected with floorbeams. In most cases, another layer of framing called stringers spans between the floor beams. The stringers normally support the bridge deck. The process of replacing a deck on a floorbeam stringer bridge is cumbersome. If the floor beams are composite, it may not even

be possible to replace the deck without closing the bridge, since removal of the deck would reduce the capacity of the floorbeam.

At least one state (Washington State DOT) has developed a system that can be used to replace the deck of a floorbeam stringer bridge with only nighttime closures. To expedite the process, the existing deck and stringers are replaced with a full-width unit that consists of the full-depth precast deck and all framing between the floorbeams.

This system was used effectively on the Lewis and Clark Bridge, which spans the Columbia River between Washington and Oregon. Designers reduced the number of stringers from six to two in order to reduce the bending moments in the floorbeams, which led to an increase in the load capacity of the bridge. This also reduced the number of connections in each panel.

Figure 2.4.2-1 depicts the bridge cross section before and after the project.

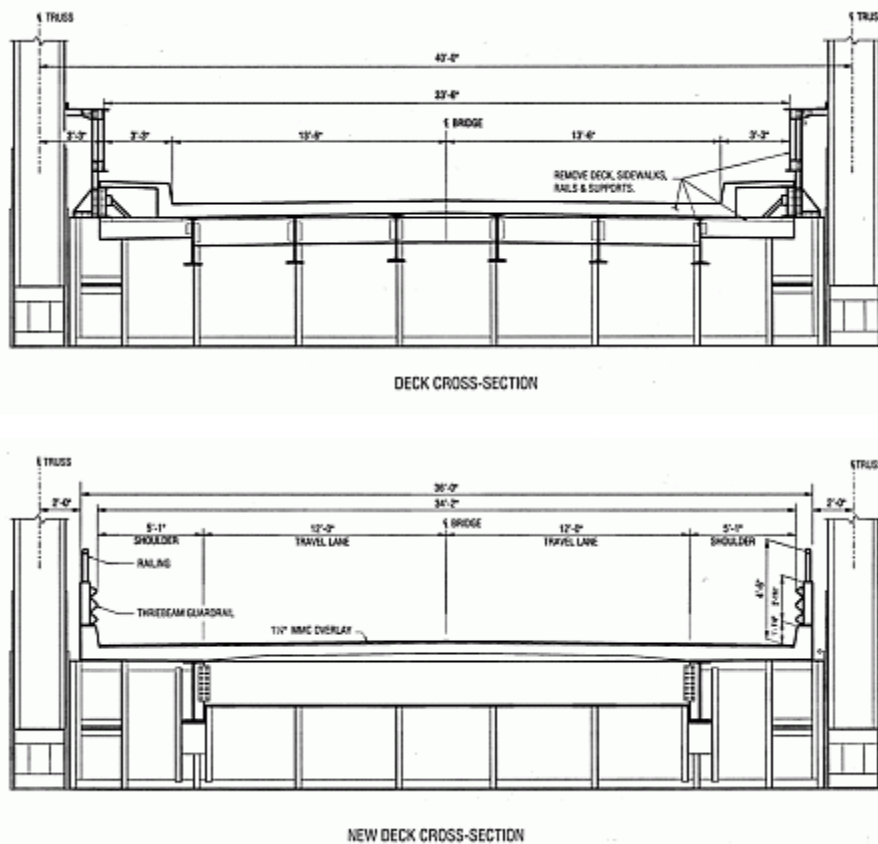


Figure 2.4.2-1 Lewis and Clark Bridge Details
(Courtesy of Washington DOT)

The re-arrangement of the stringer locations on the Lewis and Clark Bridge actually assisted in this operation since much of the framing work

required at the new connection location could be completed before removal of the old bridge deck.

The construction of the deck of the Lewis and Clark Bridge was accomplished with a trailer-mounted gantry crane that was used to remove the portion of the deck between the floorbeams and set the new unit in one operation. This approach was complicated by the overhead framing of the bridge truss. The gantry system was designed to fit within the bridge opening and allowed the replacement of the deck stringer units in overnight operations. Figure 2.4.2-2 is a photo of the completed bridge, showing the limited height available for operation of the gantry system.



Figure 2.4.2-2 Lewis and Clark Bridge
(Courtesy of Washington DOT)

2.4.2.1 Connection to Steel Floorbeams

The connection of a deck stringer system to the floorbeams is critical. The connection needs to clear the top flanges of the floorbeam and be seated properly.

The details presented are for one specific bridge; however, the system can be adapted to many other floorbeam stringer bridge spans.

2.4.3 Precast Concrete Arch Systems

Several precast manufacturers have developed precast concrete arch systems. These systems consist of strip arch segments placed side-by-side to create the bridge span. Most systems are filled arches with granular backfill placed over the arch to complete the structure.

Most precast arch systems are complete span elements that include the vertical stems. Other systems consist of two or three precast arch elements connected in the field to complete the arch. Some of these systems are proprietary and others have been developed by state agencies.

In most cases, the arches are designed as a two-hinge arch. The connection to the footings is designed as a pinned connection. The arch base is simply inserted into a keyway in the footing and grouted in place.

Figure 2.4.3-1 depicts a proprietary arch system call the Con/Span[®] Bridge System. This system, including the arch elements, the spandrel walls, the wingwalls and the footings, can be completely made with precast concrete elements. The connections shown in Figure 2.4.3-1 are described in the following sections.

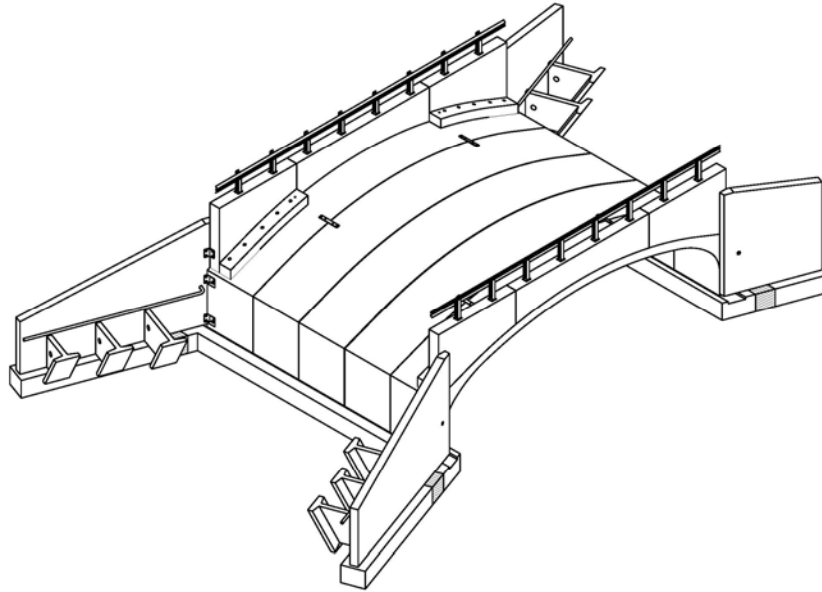


Figure 2.4.3-1 Con/Span[®] Bridge System

2.4.3.1 Connection Between Arch Elements

The State of Tennessee developed a precast arch system for a bridge on State Route 1 over Piney Creek. A similar connection has been developed for the Bebo[®] arch system. The arch segments are cast in two pieces. When erected, the two pieces form a three pin arch to support its self weight (pinned at the base and at the crest). The connection of the arch pieces was essentially a cast-in-place closure pour with lapped reinforcing. Once the connection is complete, the arch behaves as a two hinge arch for all other loads. This greatly reduced the amount of falsework typically required to erect a concrete arch bridge.

2.4.3.2 Connection Between Arch Segments

Most precast arch segments are simply butted together with no structural connection. These joints can be the joints that are shown parallel to the roadway in Figure 2.4.3-1. This lack of connection is accounted for in the arch design. A waterproofing strip is placed over the opening to prevent backfill soils from falling through the joints.

On one system, there is a structural connection between the fascia arch and the interior arches. The lateral forces acting on the spandrel walls impart transverse overturning forces on the fascia arch. A simple tension connection on the top of the arches ties several arch elements together to increase the overturning resistance of the arch structure.

2.4.3.3 Connection of Spandrel Walls

Most arch systems have fill placed over them, requiring the use of spandrel walls to contain the fill soils. The spandrel walls can either be precast onto the fascia arch in the fabrication plant, or precast for installation in the field. The Con/Span[®] Bridge System has precast fascia panels that are bolted to the fascia arch element.

2.4.4 Precast Concrete Box Culverts

Many state agencies have developed standard details for precast concrete box culvert systems. The American Society of Testing and Materials (ASTM) Specification C1433 entitled "Standard Specification for Manufacture of Precast Reinforced Concrete Box Culverts, Storm Drains, and Sewers" [52] can be used to design and detail these systems. This ASTM specification is for single cell box culverts. For multi-cell box culverts, designers typically butt single cell units side-by-side.

The use of precast concrete box culverts has become commonplace across the country; therefore, significant details are not presented in this Manual. Typical connections include the installation of headwalls, and nosings. The connection between boxes is typically a nested shear key that is not grouted, similar to the connection used on reinforced concrete drainage pipe. Some states require rubber gaskets in the keys. Several details are presented in this Manual for information. Readers are urged to contact state highway agencies for more information on the details used in their region.

2.4.5 Grade Control and Tolerances

Grade control and tolerances are critical for most systems presented in this section. This is especially true for large prefabricated deck stringer systems. Detailed surveys of the existing bridge framing are required to ensure proper fit-up of the systems. Designers should also detail minor adjustability to accommodate fabrication tolerances. This is usually accomplished through the use of variable thickness shims.

Grade control and tolerances are not as critical for large precast concrete arch systems and box culverts; however, designers should specify the appropriate casting tolerances to ensure proper fit-up of the elements in the field. The setting of tolerances on proprietary systems is usually left up to the fabricator. ASTM C1433 includes guidance on fabrication of box culverts.

2.4.6 Evaluation of Performance and Long Term Durability of Modular Prefabricated Superstructure Systems

With the exception of precast concrete box culverts, the systems presented in this section are relatively new to the bridge industry. The modular precast deck stringer systems should provide improved resistance to the elements because the systems are constructed with fewer joints and in a controlled environment using high quality concretes.

The inset system uses a casting technique that has the final top surface of the deck cast against a form. It is believed that this process will lead to a denser top surface since the bleed water will exit the slab through the bottom during curing, which in theory will lead to a less pervious surface.

Precast concrete arch systems and box culverts are produced with high quality concrete in a controlled environment, which should result in higher quality products with longer service lives.

2.4.7 Estimated Construction Time for Connections

The times required for construction depend on a number of factors including site access, traffic control, weather, crane locations and proximity to storage areas. Nonetheless, it is possible to make reasonable estimates of the minimum required construction time for the various systems discussed in this section.

Table 2.4.7-1 provides approximate installation times for the various systems included in this section:

System	Minimum Installation Time	Comments
Precast Deck/Slab Systems	1 Day	Can also be installed during an overnight closure operation
Larger Precast Deck stringer systems.	1 Day	Can also be installed during multiple overnight closure operations
Precast Concrete Arch Systems	1-2 Days	A small single-span bridge can be erected in one day after preparation of the site. This does not include the time for backfilling. Total construction can be completed in less than 2 weeks
Precast Concrete Box Culvert	1 Day	Does not include time for site preparation or backfilling

Table 2.4.7-1 Approximate Minimum Installation Times for Modular Prefabricated Systems

2.4.8 Recommendations for Improvements to Current Practices

Each system presented in this section is unique. The standard details for most of these systems have been thoroughly tested and demonstrated on

numerous projects; therefore, the authors have no recommendations for improvements.

2.4.9 Connection Detail Data Sheets for Modular Prefabricated Superstructure Systems

The following pages contain data sheets for the various modular prefabricated superstructure systems. Some systems were obtained from manufacturers and industry groups. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected
- Name of project where the detail was used
- Manual Reference Section

The section(s) of this Manual applicable to the particular detail shown.

- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

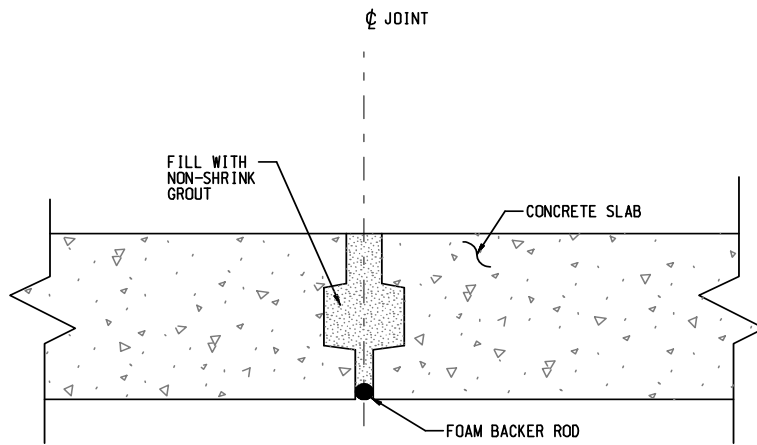
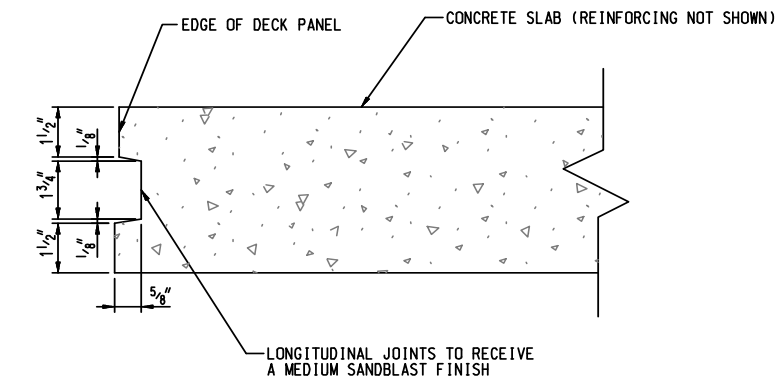
Organization:
 Contact Name:
 Address:

Detail Number:
 Phone Number:
 E-mail:
 Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



TYPICAL PANEL TO PANEL JOINT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The superstructure is prefabricated and cannot be altered, therefore precise surveying is paramount. Replacing existing superstructures with prefabricated components requires modifications to existing pedestals or prefabricated steel bolsters on the abutment seat. This is due to the different geometry of the beams and the desire to meet existing grades and elevations. Pedestals are modified by removing existing masonry plates and pouring quick setting material to the desired elevation. Steel bolsters are installed as-is.

For proper placement, the steel armoring over the abutment headers has to be removed, and the headers themselves are shaved down. From there, field adjustments to the prefabricated system are made. Field adjustments to meet desired elevations are made via horizontal, slotted holes in the prefabricated blockout. The blockout is then to be filled with rapid set latex modified concrete.

The system is known as the Inverset® system developed by the Fort Miller Company in New York. At one time it was a proprietary system. At this time, the system is no longer proprietary. The photo shown below is an example of the system from another project.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

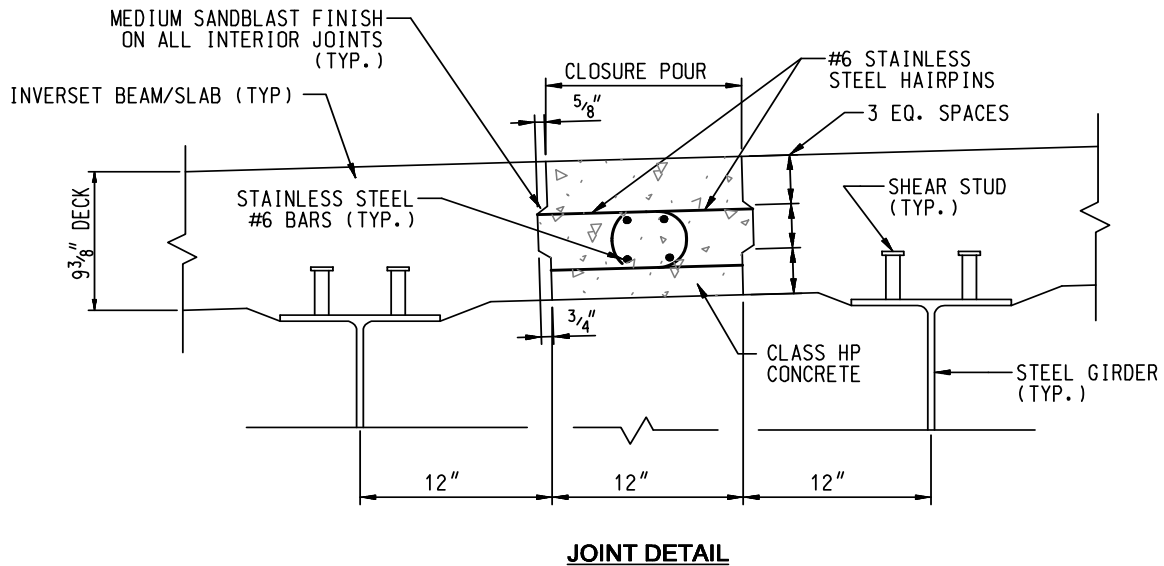
Organization: **New York City DOT**
 Contact Name: **Chris Sklavounakis, PE**
 Address: **NYCDOT
 2 Rector St., 7th Floor
 New York, NY 10006**

Detail Number: **2.4.1.1 B**
 Phone Number: **212-788-2078**
 E-mail: csklavounakis@dot.nyc.gov
 Detail Classification: **Level 1**

Components Connected **Precast Double Beam/Slab Component** to **Precast Double Beam/Slab Component**

Name of Project where the detail was used **Belt Parkway over Ocean Parkway, Brooklyn**

Connection Details: **Manual Reference Section 2.4.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Adjacent prefabricated steel girder/deck units (Inverset®) were fabricated with integral backwalls. The system is comprised of two steel beams precast into a composite slab. The resulting units are similar to precast double tees. The system on this structure also included an integral precast backwall (see additional connection detail sheet).

Adjacent units were installed and backwalls were transversely post-tensioned. (Post-tensioning not shown in section.) The short overhang of the slab reduces the moment demand on the connection. The connection primarily transfers shear between the connections. This detail has been part of a proprietary system, however it may be applicable to other similar systems.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

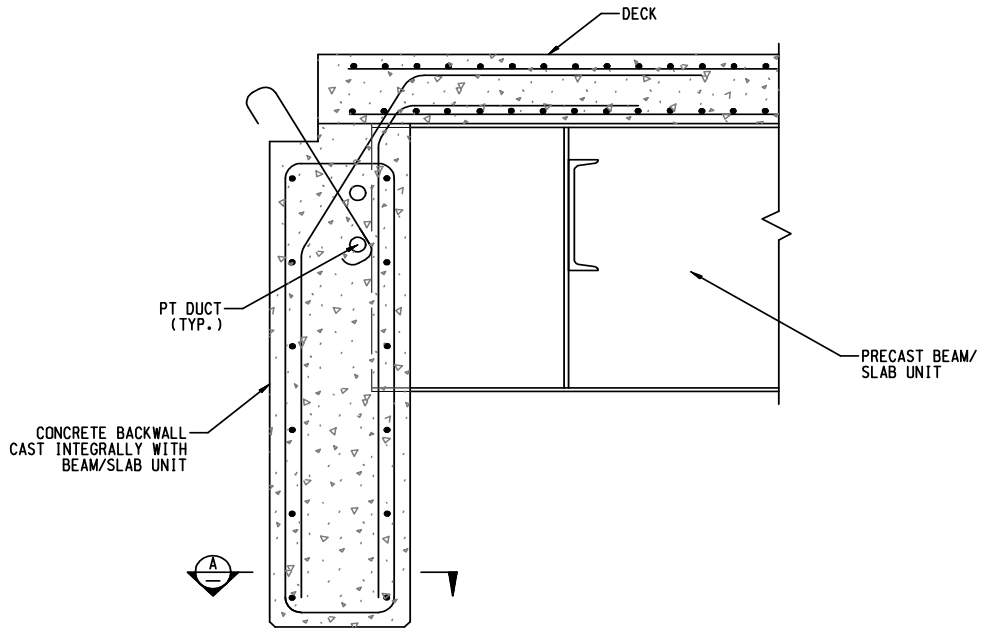
Organization: **New York City DOT**
 Contact Name: **Chris Sklavounakis, PE**
 Address: **NYCDOT
 2 Rector St., 7th Floor
 New York, NY 10006**

Detail Number: **2.4.1.1 C**
 Phone Number: **212-788-2078**
 E-mail: **csklavounakis@dot.nyc.gov**
 Detail Classification: **Level 1**

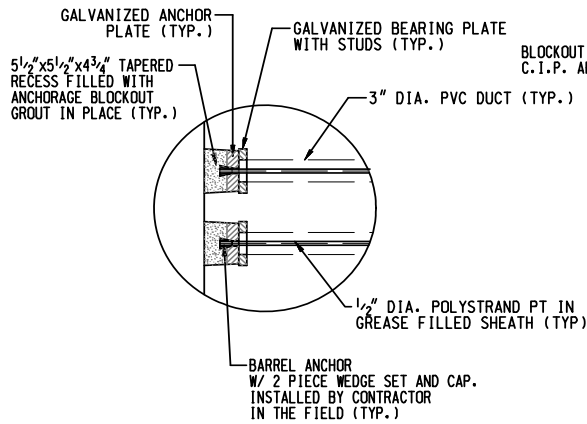
Components Connected: **Precast Double Beam/Slab Component** to **Precast Double Beam/Slab Component**

Name of Project where the detail was used: **Belt Parkway over Ocean Parkway, Brooklyn**

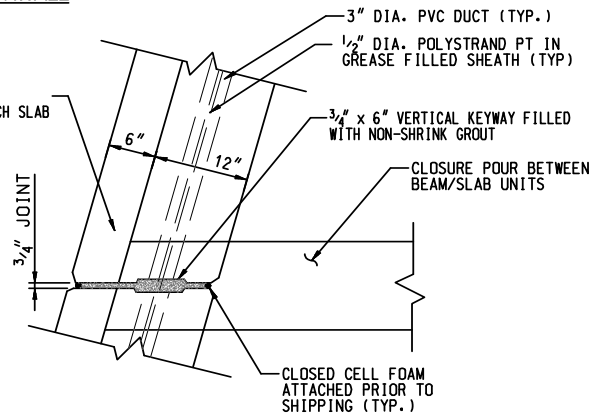
Connection Details: **Manual Reference Section 2.4.1.1** See Reverse side for more information on this connection



SECTION THROUGH BACKWALL



TRANSVERSE PT DETAIL AT END OF ABUTMENT



SECTION A BACKWALL JOINT DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Adjacent prefabricated steel girder/deck units (Inverset®) were fabricated with integral backwalls. Adjacent units were installed and backwalls were transversely post-tensioned. Two post-tensioning ducts were used due to stage construction. Only one duct was used in the one of the stages. This detail has been part of a proprietary system, however it may be applicable to other similar systems.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

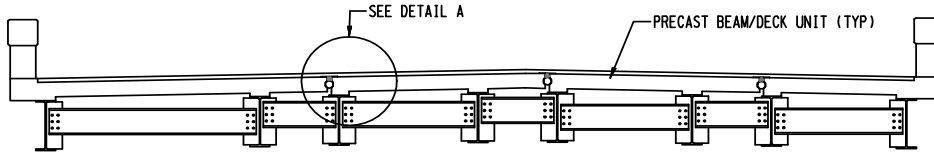
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Contact Name:
Address:

Detail Number:
Phone Number:
E-mail:
Detail Classification:

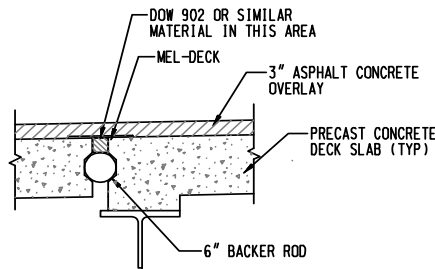
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



BRIDGE CROSS SECTION



DETAIL A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Each segment of this bridge is a precast reinforced concrete deck slab cast compositely with steel rolled beams. The segments are transported to the site for stage erection.

Joint location was set based on staging requirements.

The Middle Diaphragms shall be field installed after superstructure segments on either side of the joint are secured firmly on the bearings. Prior to opening the bridge for the following day-traffic the Contractor shall field-drill 1" diameter doles for 7/8" diameter slip critical bolted connection, on the connection plates and install the Middle diaphragms.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **Washington State D.O.T.**
 Contact Name: **Eric Schultz P.E. / John Olk P.E.**
 Address: **P O Box 47340
 Olympia, WA 98504**

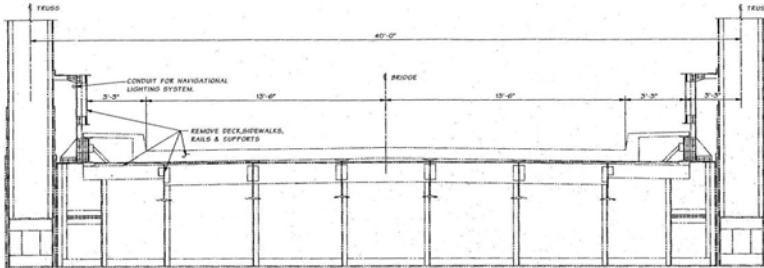
Detail Number: **2.4.2.1 A**
 Phone Number: **360-705-7227 / 360-705-7395**
 E-mail: **schulte@wsdot.wa.gov / olkj@wsdot.wa.gov**
 Detail Classification: **Level 2**

Components Connected **Precast Stringer deck unit** to **Existing Steel Truss**

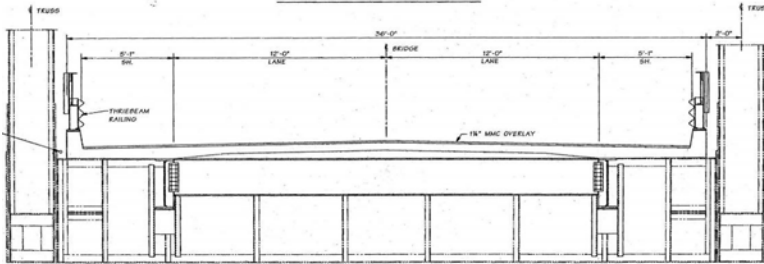
Name of Project where the detail was used **SR433, Lewis & Clark Bridge Deck Replacement**

Connection Details: **Manual Reference Section 2.4.2.1**

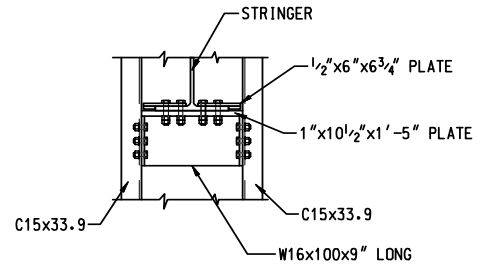
See Reverse side for more information on this connection



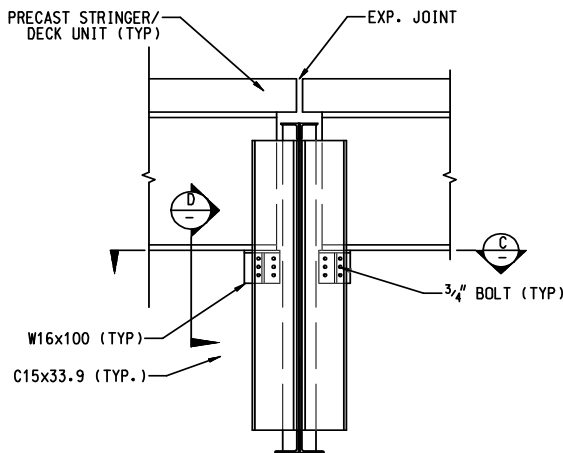
SECTION - EXISTING DECK



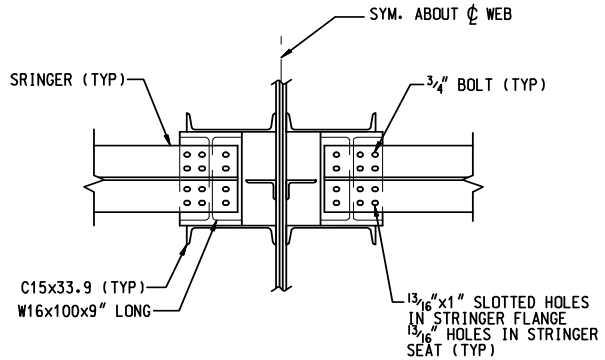
SECTION - NEW DECK INSTALLED



SECTION D



TYPICAL FLOOR BEAM



SECTION C

Description, comments, specifications, and special design procedures

C channels and W shape seats were placed while bridge was under traffic. Panels were constructed on site next to the bridge. Panels were transported to their final location on the bridge during the night time closures using SPMTs (Self Propelled Modular Transporter) and a truss gantry system. One panel placed per night for 4 nights in a row (each week). The design reduces bending moments on the floor beams. Future designs should consider the exact placement method to be used. Design should also consider the methods to obtain accurate as-built dimensions so that connection holes can be fabricated before hand to maintain existing bridge geometry. Drilling holes in place, with heavy installation equipment loads nearby, may lock in unwanted stresses and deformations. Consideration should be given to provided a method of adjustment in the vertical direction so that a smooth roadway profile can be maintained. The photo below shows the connection before removal of the existing stringer.

**Editor's Notes**

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

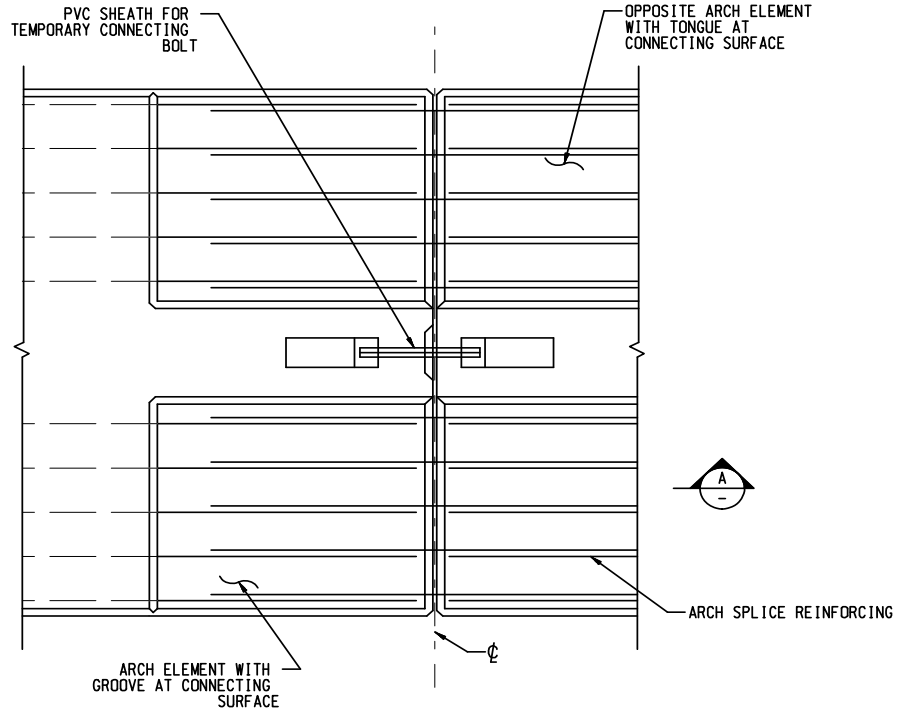
Organization: Pennsylvania DOT
 Contact Name: Tom Macioce, P.E.
 Address: 400 North Street
PO Box 2951
Harrisburg, PA 17105-2951

Detail Number: 2.4.3.1 A
 Phone Number: (717) 787-2881
 E-mail: tmacioce@state.pa.us
 Detail Classification: Level 1

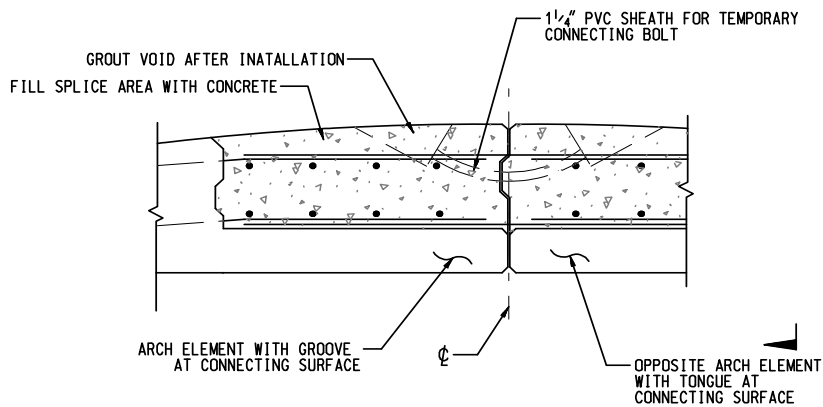
Components Connected: Precast Arch Section to Precast Arch Section

Name of Project where the detail was used: Penn DOT Standard - Proprietary (Bebo Arch System)

Connection Details: Manual Reference Section 2.4.3.1 See Reverse side for more information on this connection



PLAN VIEW CROWN JOINT



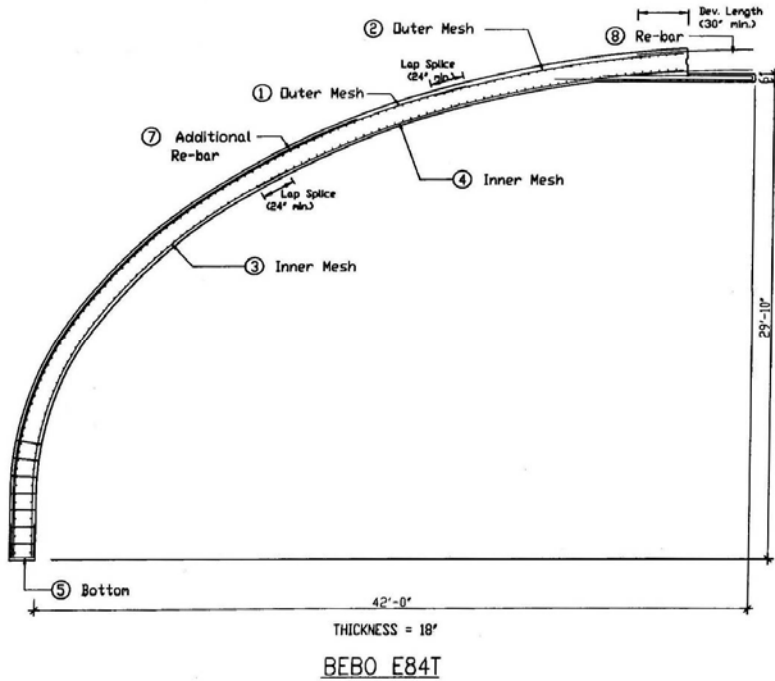
SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The arch elements are designed with an assumed pinned connection at the base and continuous over the span. For long span arches, a mid-span splice is made. This is achieved by installing the arch in two pieces and temporarily bolting them together at the crown. Closure pours are then made between the two pieces. The soffit of the arch acts as a form for the closure pour.

Note: This is a proprietary bridge system.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

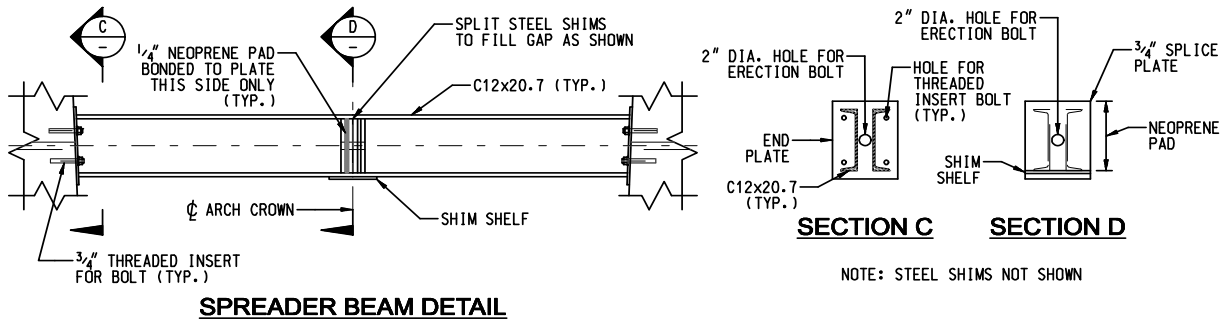
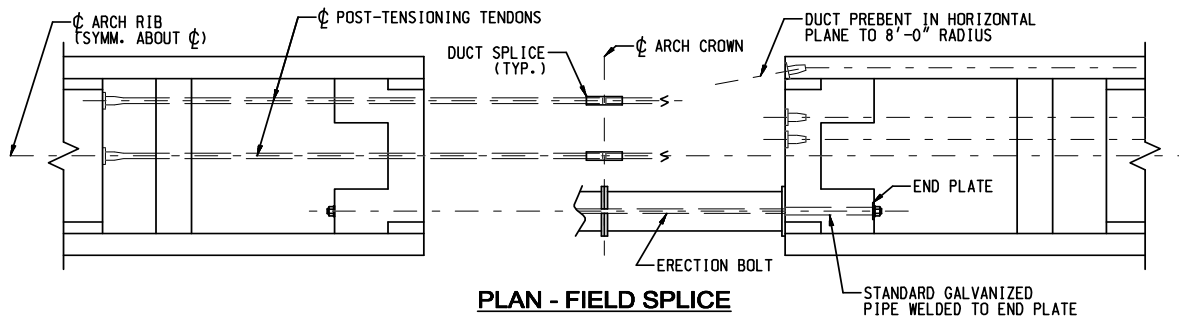
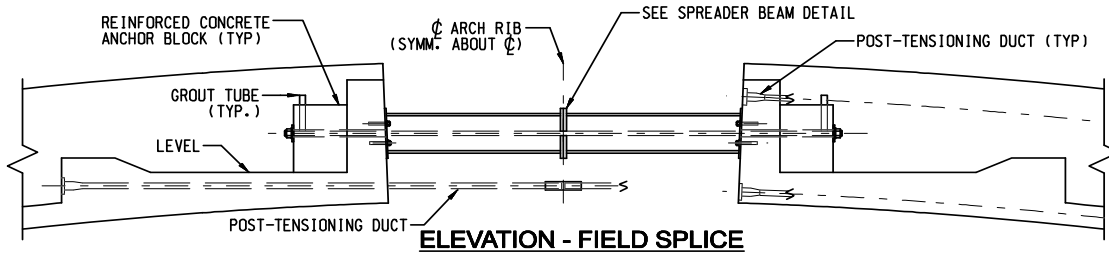
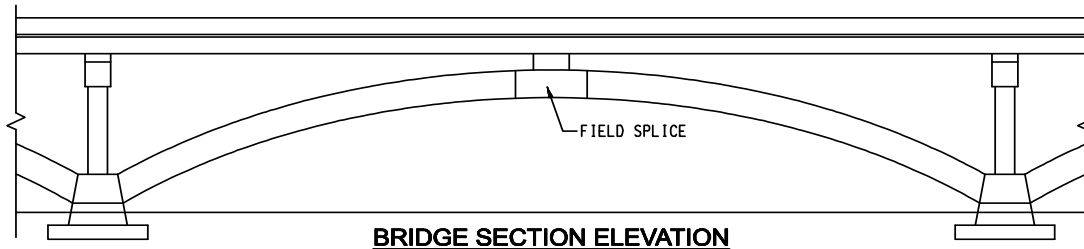
Organization: **Virginia DOT-Structure and Bridge Division**
 Contact Name: **Ken Walus**
 Address: **1404 East Broad St.
 Richmond, VA 2319**

Detail Number: **2.4.3.1 B**
 Phone Number: **(840) 786-4575**
 E-mail: **Kendal.walus@vdot.virginia.gov**
 Detail Classification: **Level 2**

Components Connected: **Precast Post-Tensioned Concrete Arch Rib** to **Precast Post-Tensioned Concrete Arch Rib**

Name of Project where the detail was used: **Route 29 Bridge over Dan River**

Connection Details: **Manual Reference Section 2.4.3.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This bridge uses a precast post-tensioned concrete arch rib. Each rib is set in place and kept apart by steel channels (see Section D-43/43). Once in place, the arch ribs are connected and strengthened by a post tensioning system (see Plan Detail). Then the ribs are filled with concrete. Also, the arches are joined together by a cast in place tie beam.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

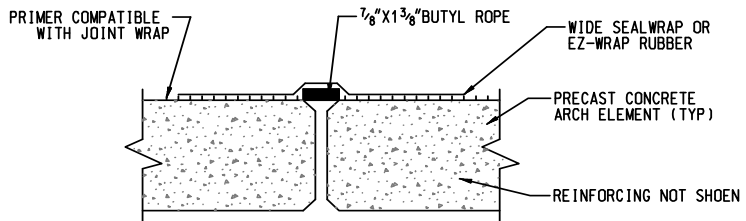
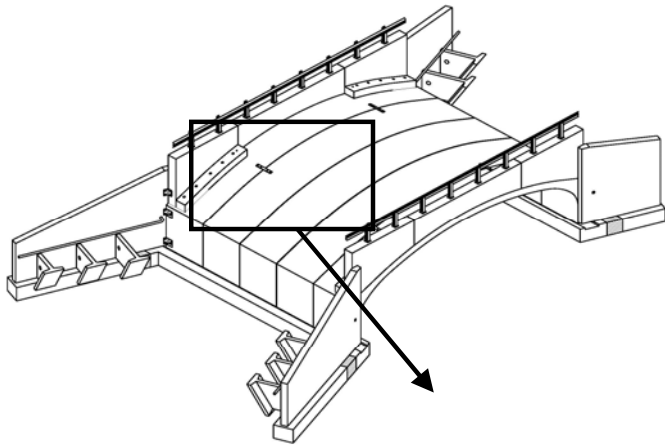
Organization: **Conspan Bridge Systems**
 Contact Name:
 Address: 3100 Research Blvd.
 P.O. Box 20266
 Dayton, Ohio 45420-0266

Detail Number: **2.4.3.2 A**
 Phone Number: 800-526-3999
 E-mail: csinfo@con-span.com
 Detail Classification: **Level 1**

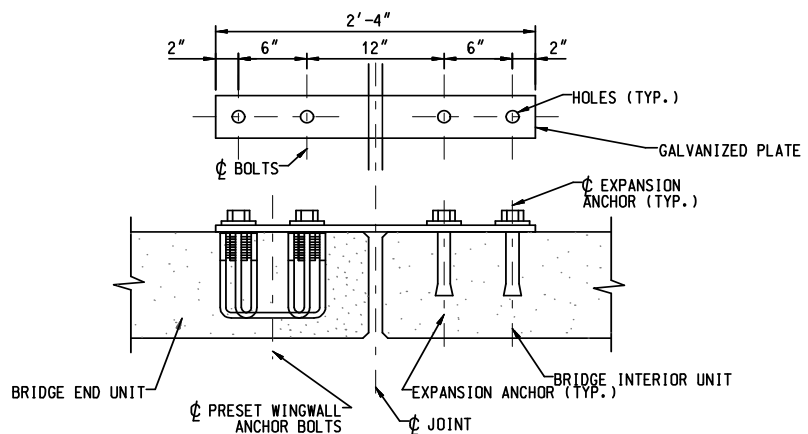
Components Connected: **Precast Arch** to **Precast Arch**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.4.3.2** See Reverse side for more information on this connection



TYPICAL JOINT SEAL DETAIL



**PRECAST ARCH TO PRECAST ARCH
 PLAN AND SECTION**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to connect adjacent precast arch units. The connection is used to resist the lateral soil forces acting on the spandrel walls. A structural connection is only used on the exterior units. Other joints are butted and sealed.

Since the plates are exposed to emnakment soils, the hardware is hot dip galvanized or stainless steel for corrosion protection.

Note: This is a proprietary bridge system.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

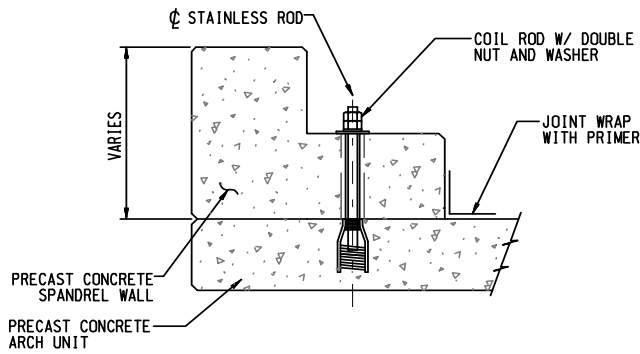
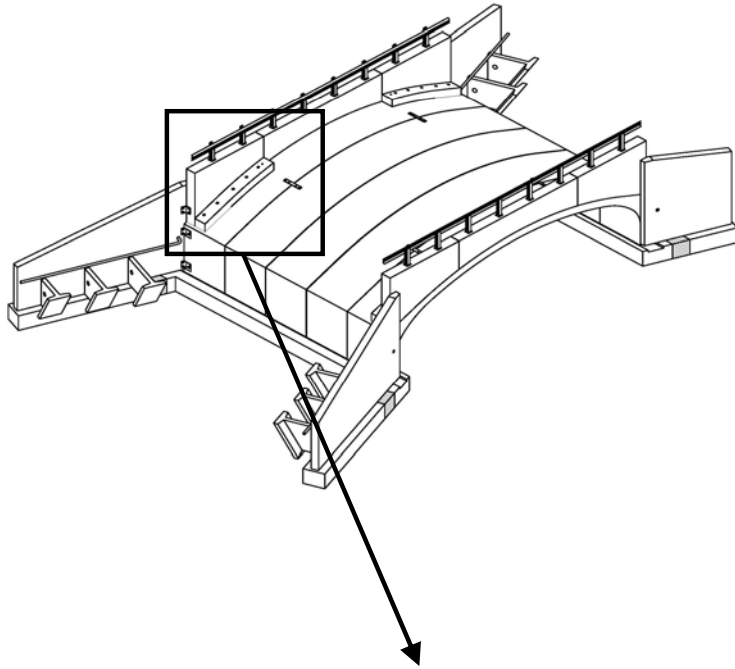
Organization:
Contact Name:
Address:

Detail Number:
Phone Number:
E-mail:
Detail Classification: Level 1

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



SPANDREL WALL TO ARCH CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to connect a precast spandrel wall to a precast arch unit. The connection is a simple spread footing that is bolted using stainless steel bolts. The photo below shows a bridge that has precast spandrel walls in the corners. The spandrel walls at mid span were precast into the arch units at the fabrication yard. This was done due to limited cover at the gutterlines, where the L shaped spandrel unit footing could not be used.

Note: This is a proprietary bridge system.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

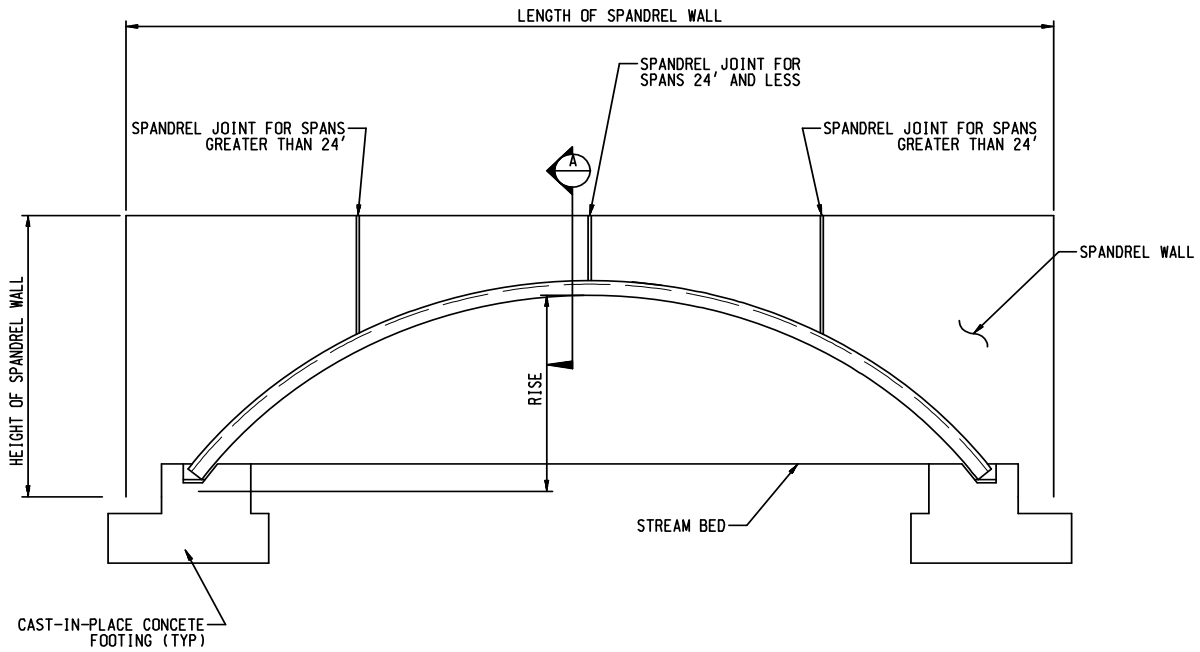
Organization: Pennsylvania DOT
 Contact Name: Tom Macioce, P.E.
 Address: 400 North Street
PO Box 2951
Harrisburg, PA 17105-2951

Detail Number: 2.4.3.3 B
 Phone Number: (717) 787-2881
 E-mail: tmacioce@state.pa.us
 Detail Classification: Level 1

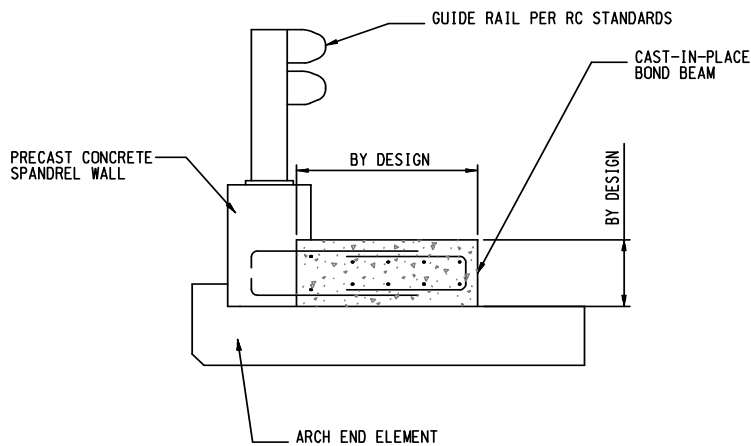
Components Connected: Precast Arch Section to Precast Spandrel Wall

Name of Project where the detail was used: Penn DOT Standard - Proprietary (Bebo Arch System)

Connection Details: Manual Reference Section 2.4.3.3 See Reverse side for more information on this connection



TYPICAL END ELEVATION



SECTION A - IMPACT SPANDREL DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The spandrel wall is attached to the precast arch by means of a cast-in-place concrete bond beam. The bond beam is used to resist the overturning forces due to vehicle impacts. A key in the fascia arch is used to assist with sliding resistance.

Note: This is a proprietary bridge system.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

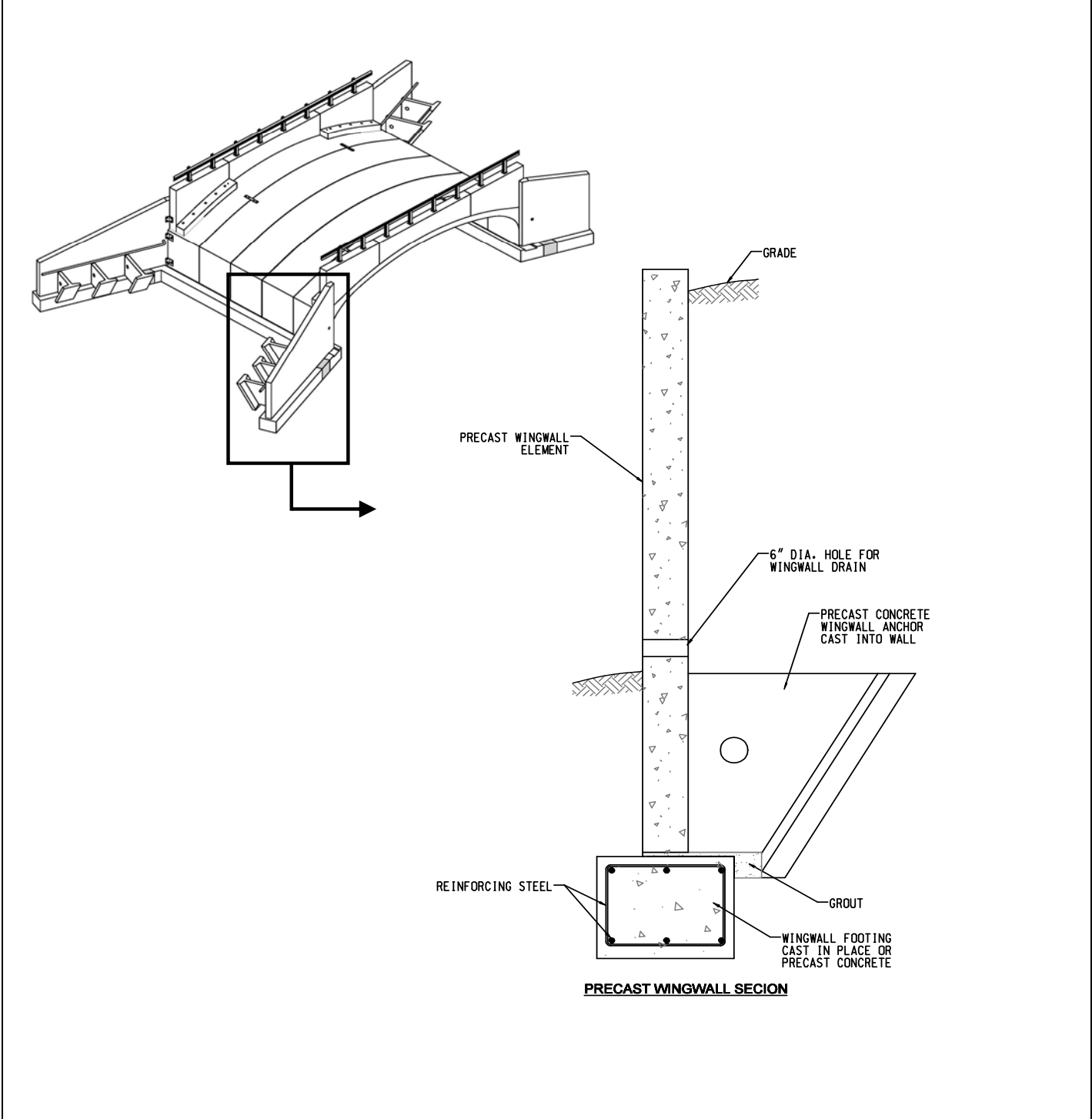
Organization: **Conspan Bridge Systems**
Contact Name:
Address: **3100 Research Blvd.
P.O. Box 20266
Dayton, Ohio 45420-0266**

Detail Number: **2.4.3 A**
Phone Number: **800-526-3999**
E-mail: csinfo@con-span.com
Detail Classification: **Level 1**

Components Connected **Precast Wall Stem** to **Precast Footing**

Name of Project where the detail was used **Standard**

Connection Details: **Manual Reference Section 2.4.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is unique to Conspan Bridge Systems. The retaining wall elements are pinned to the top of the footing via a grouted joint between the wall anchor and the footing. Overturning resistance is achieved through the wall anchor; therefore the footing connection only needs to be pinned.

Note: This is a proprietary bridge system.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? many Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 10 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 3 (0 not visible, 10 easily inspected)

Future Maintenance 9 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

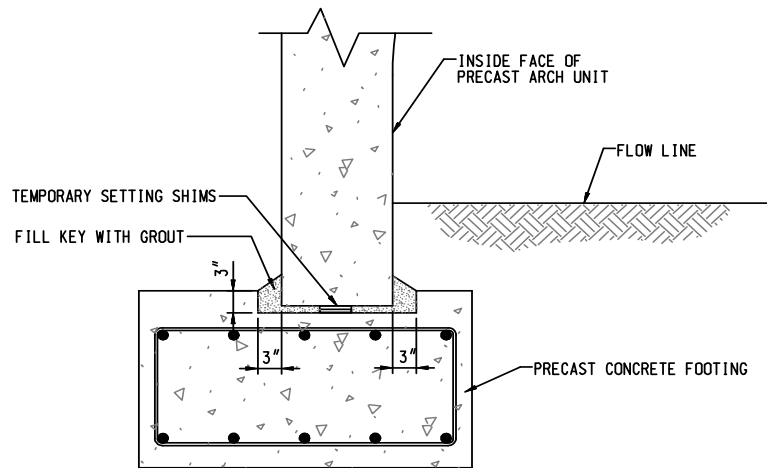
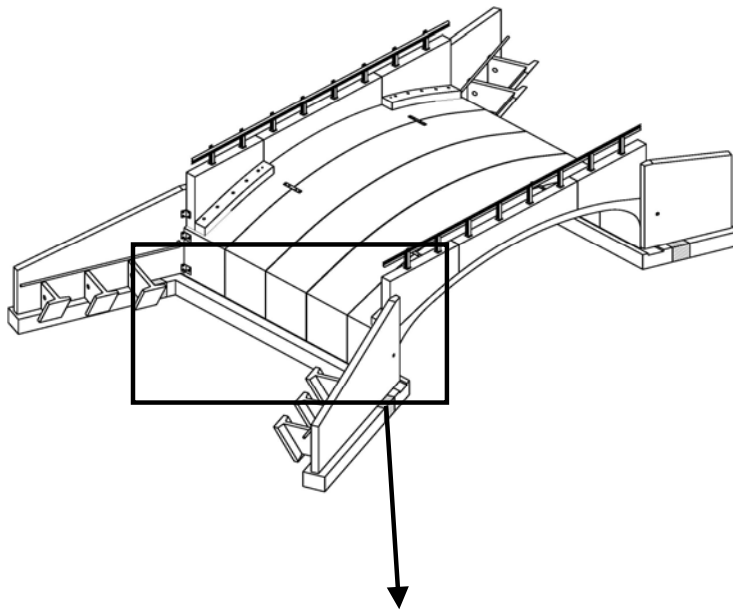
Detail Number:
Phone Number:
E-mail:

Detail Classification: Level 1

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



PRECAST FOOTING TO ARCH CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The arch elements are designed with an assumed pinned connection at the base. This is achieved by installing the arch into a shallow pocket in order to develop the lateral shear. The footings can either be cast in place or precast. The arch units are set on shims to adjust grade and to allow for grouting under the stem.

Note: This is a proprietary bridge system.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

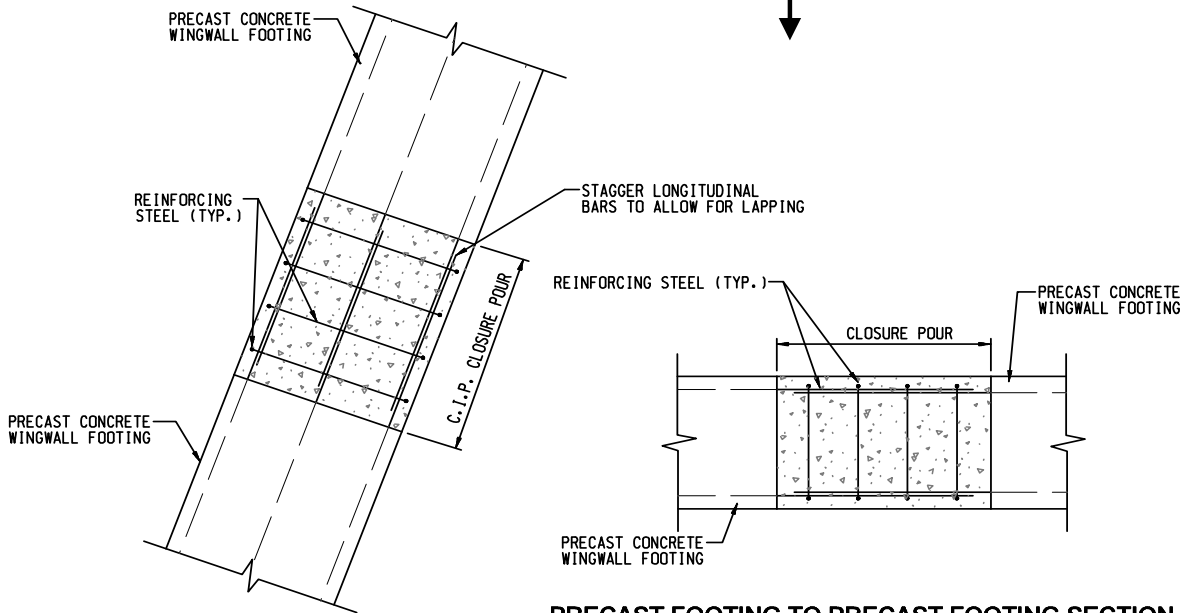
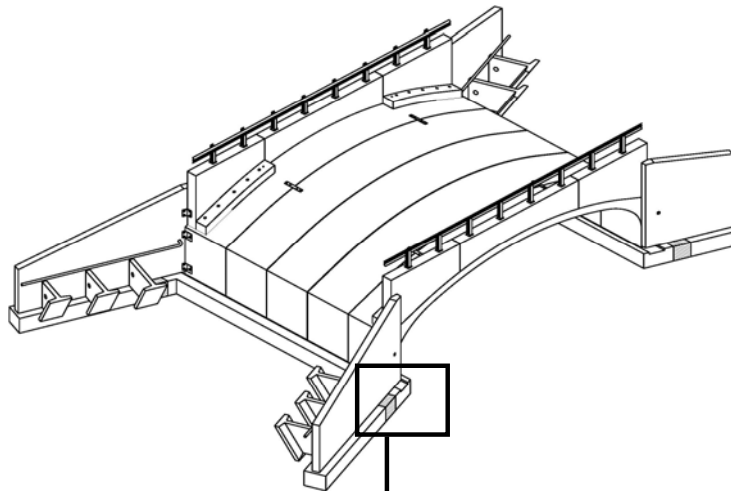
Organization: **Conspan Bridge Systems**
 Contact Name:
 Address: 3100 Research Blvd.
 P.O. Box 20266
 Dayton, Ohio 45420-0266

Detail Number: **2.4.3 C**
 Phone Number: 800-526-3999
 E-mail: csinfo@con-span.com
 Detail Classification: **Level 1**

Components Connected: **Precast Footing** to **Precast Footing**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.4.3** See Reverse side for more information on this connection



PRECAST FOOTING TO PRECAST FOOTING SECTION

PRECAST FOOTING TO PRECAST FOOTING PLAN

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is for a precast concrete footing placed on compacted gravel. The footing joint is used to connect the wingwall footing to the arch footing.

Note: This is a proprietary bridge system.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

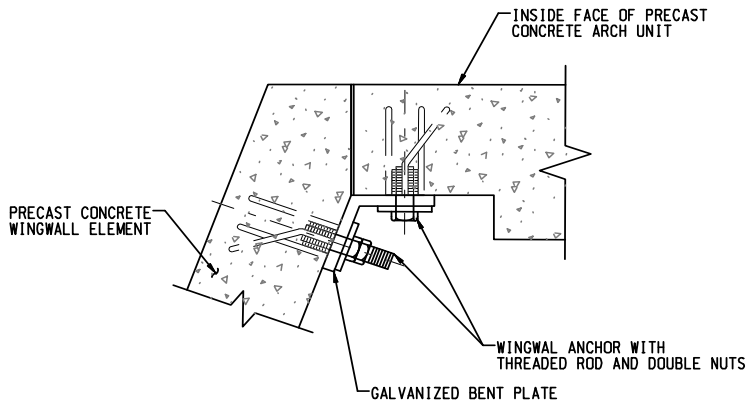
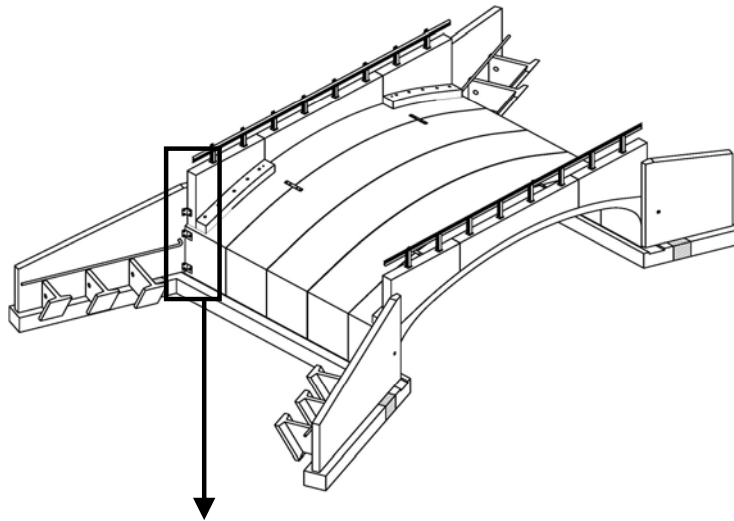
Detail Number:
Phone Number:
E-mail:

Detail Classification: Level 1

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



PRECAST ARCH TO PRECAST WINGWALL PLAN

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to connect a wingwall stem to the precast arch and spandrel wall. The connection is bolted using galvanized steel bolts and plates. The connection is used to maintain alignment during backfilling. The overturning forces on the wingwall stem is resisted by the wall anchors cast into the stem elements.

Note: This is a proprietary bridge system.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

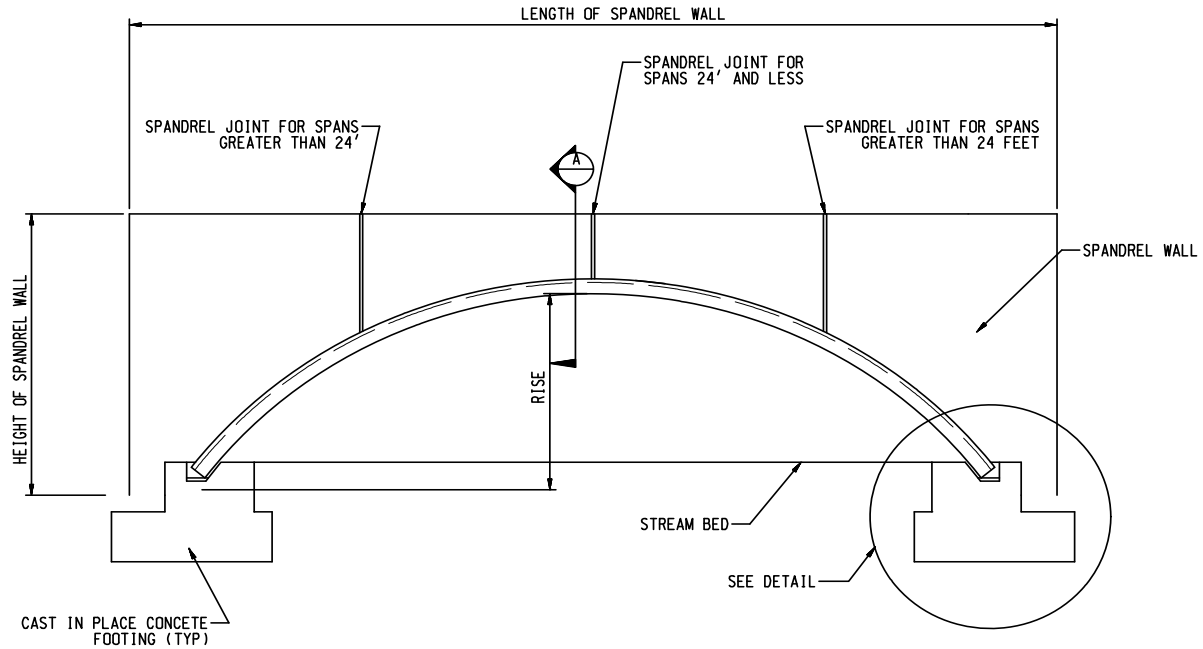
Organization: Pennsylvania DOT
 Contact Name: Tom Macioce, P.E.
 Address: 400 North Street
PO Box 2951
Harrisburg, PA 17105-2951

Detail Number: 2.4.3 E
 Phone Number: (717) 787-2881
 E-mail: tmacioce@state.pa.us
 Detail Classification: Level 1

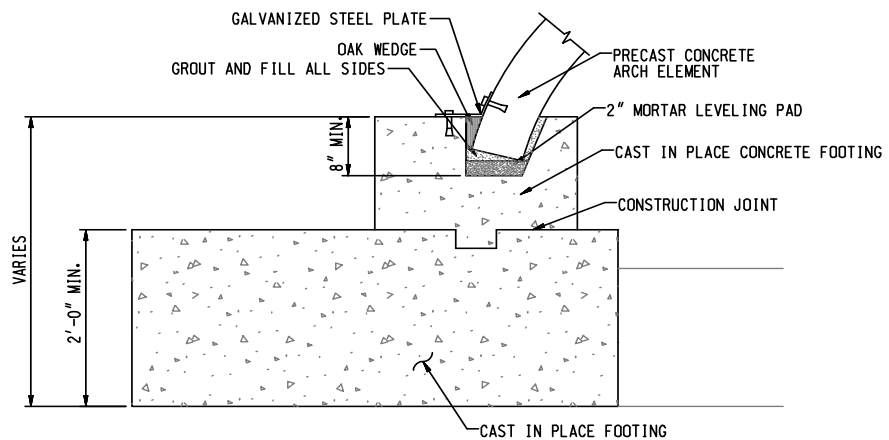
Components Connected: Precast Arch Section to Cast-in-place footing

Name of Project where the detail was used: Penn DOT Standard - Proprietary (Bebo Arch System)

Connection Details: Manual Reference Section 2.4.3 See Reverse side for more information on this connection



TYPICAL END ELEVATION



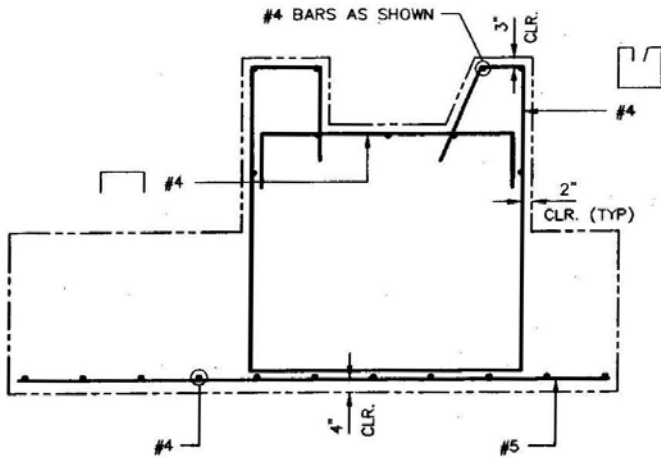
DETAIL A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The arch elements are designed with an assumed pinned connection at the base. This is achieved by installing the arch into a shallow pocket in order to develop the lateral shear.

Note: This is a proprietary bridge system.



FOOTING REINF.
FOOTING SIZE AND REINFORCEMENT
TO BE DETERMINED BY DESIGN

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
 Contact Name:
 Address:

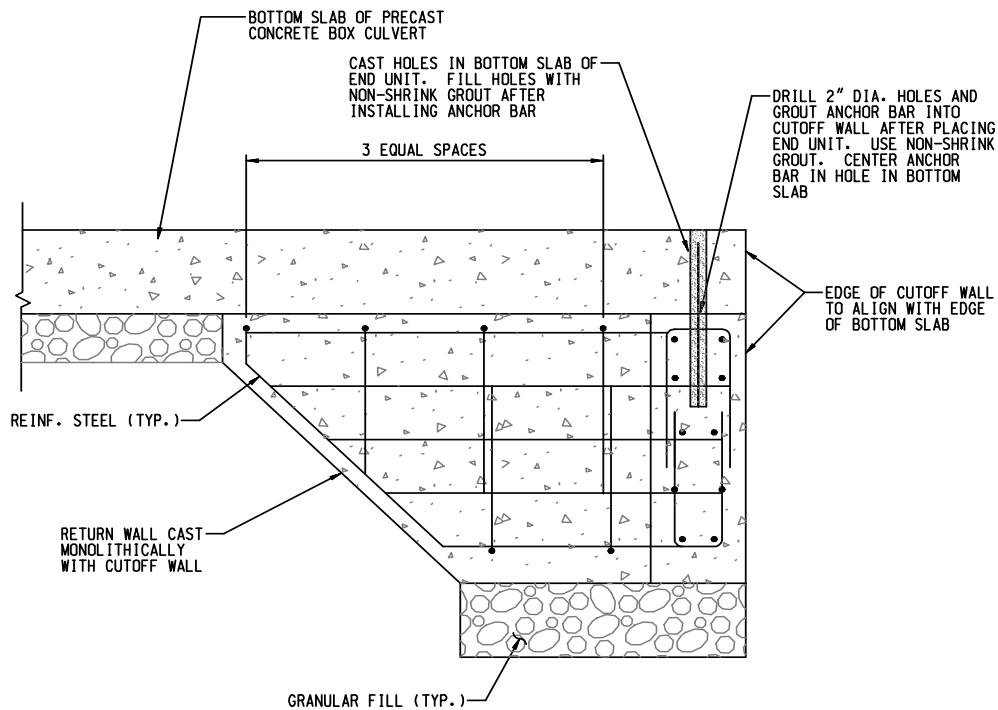
Detail Number:
 Phone Number:
 E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



PRECAST CULVERT SECTION

THIS IS A SIDE VIEW OF THE END OF THE CULVERT AT EITHER THE INLET OR OUTLET. THE BOTTOM SLAB OF THE PRECAST CONCRETE BOX CULVERT IS IN THE UPPER PORTION OF THE DETAIL. THE LOWER PORTION OF THE DETAIL IS THE CAST IN PLACE CONCRETE CUT-OFF AND RETURN WALL.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used to create a scour prevention cut-off wall. The wall is cast prior to installation of the culvert sections. The details are taken from the Connecticut Department of Transportation Bridge Design Manual. The photos are from another state and do not match the details exactly.



Image Courtesy Hoover Dam Bypass Project, 2004



Image Courtesy Premarc Corp., 2007

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment Compression x Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

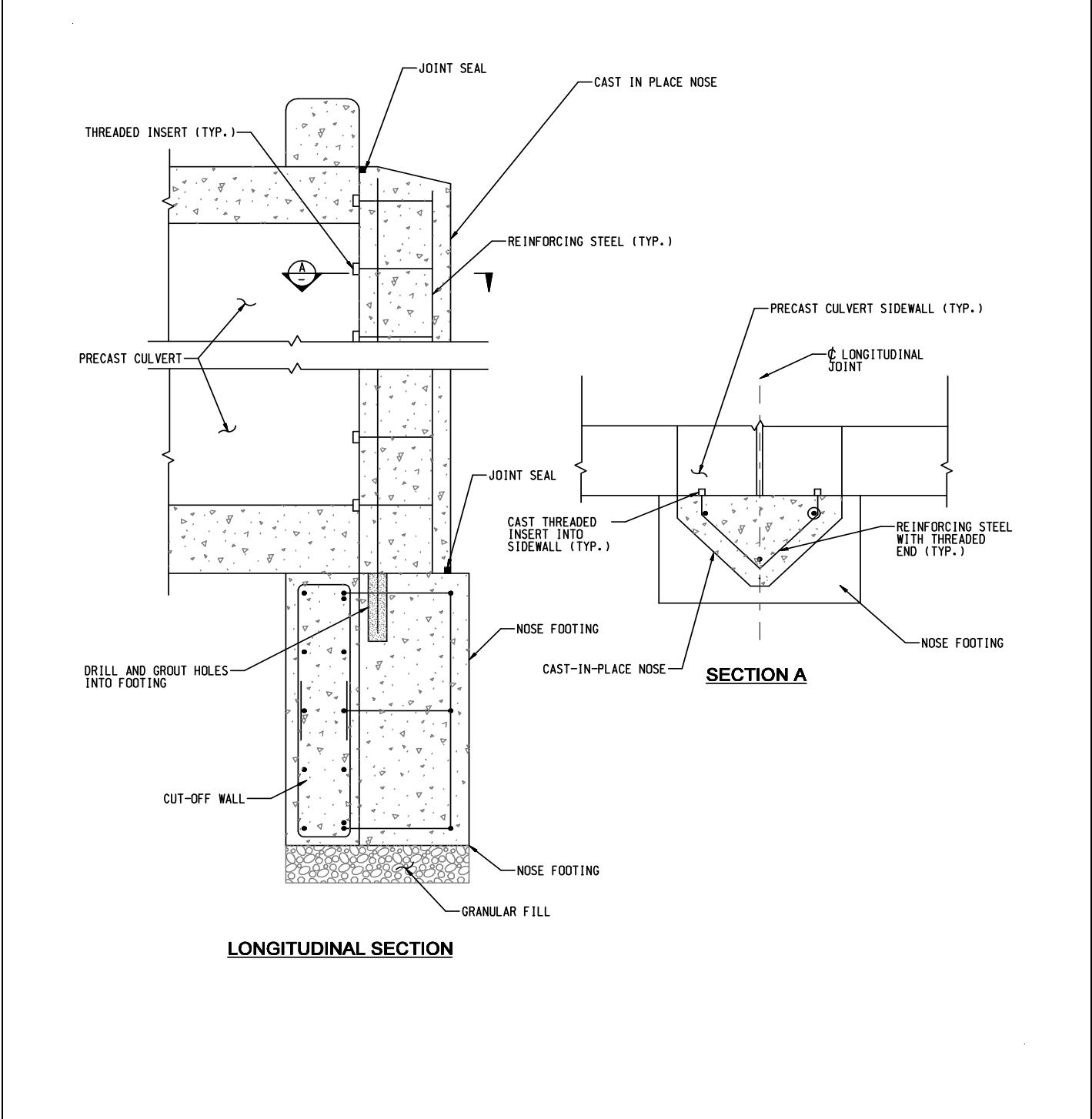
Organization: Connecticut DOT
 Contact Name: Michael Culmo (CME Associates, Inc.)
 Address: CME Associates, Inc.
333 East River Dr, Suite 400
East Hartford, CT 06108

Detail Number: 2.4.4 B
 Phone Number: (860) 290-4100
 E-mail: Culmo@cmeengineering.com
 Detail Classification: Level 1

Components Connected: Precast Concret Box Culvert to Cast-in-Place Nose and Footing

Name of Project where the detail was used: Standard

Connection Details: Manual Reference Section 2.4.4 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is used when a multi-cell culvert is required for hydraulics. The nosing keeps water from infiltrating between the precast concrete box culvert sections and improves the hydraulic capacity of the inlet.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

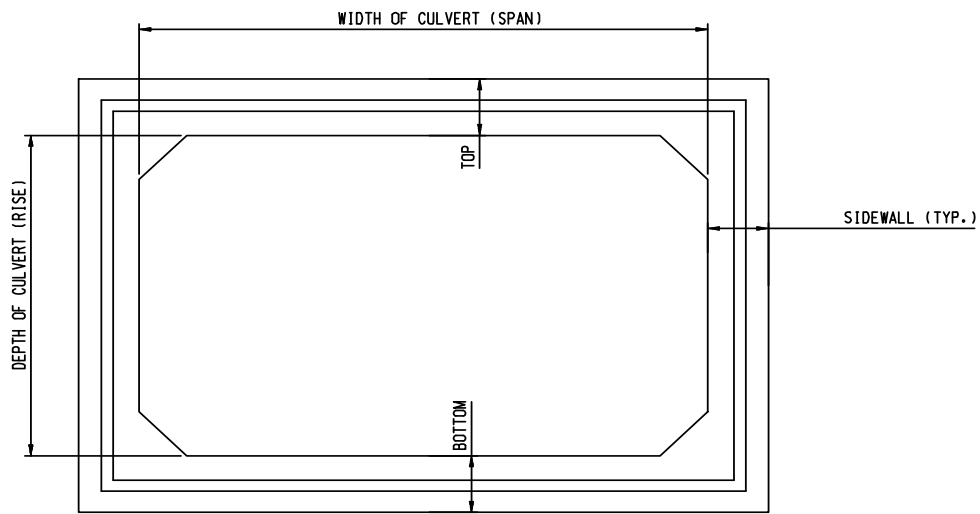
Organization:
Contact Name:
Address:

Detail Number:
Phone Number:
E-mail:
Detail Classification:

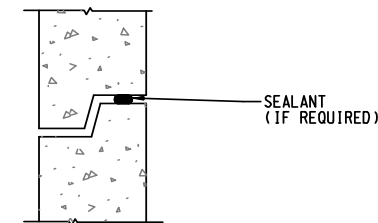
Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



PRECAST CONCRETE CULVERT END VIEW



JOINT SECTION

The connection between adjacent box culvert sections is normally treated as a simple key. The purpose of the connection is to maintain alignment of the culvert sections. It is not intended to be a structural connection. Some states specify rubber gaskets for this joint in order to minimize piping of backfill soils; however, many states have had success with the use of dry joints.



Image Courtesy The Premarc Corporation, 2007

The individual culvert sections are set on compacted gravel or crushed stone adjacent to each other and drawn together.

The sections are designed as a 2d frame in cross section.



Image Courtesy American Concrete Industries, 2007

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

2.5 Connections between Superstructures and Substructures

This section focuses on connections between superstructure systems and substructures. In most cases, agencies place structural bearings at these connections. However, designers are increasingly specifying integral connections. This section will cover both types of connections and how each relates to accelerated bridge construction.

2.5.1 Integral Pier Caps

Several states have built bridges with integral pier caps. Integral piers are common on the west coast due to the high seismic requirements. In many cases, the superstructures are constructed with cast-in-place concrete; however, the connection can also be made using precast concrete in either the pier columns or the superstructure elements.

This connection is often very complicated and congested. There are also tight controls over tolerances and grades. For these reasons, the most common form of connection is a cast-in-place concrete closure pour. Reinforcing is typically extended from the precast concrete elements to form the connection.

2.5.2 Integral Abutments

Similar to integral pier connections, integral abutment connections are often complicated and congested. Cast-in-place closure pours are the common form of connection used for integral abutments.

2.5.3 Semi-Integral Abutments

Semi-integral abutment connections are similar to integral abutment connections except they are not designed for moment transfer between the substructure and the superstructure. Instead, the connection transfers horizontal shear only (in both directions). These pinned connections can be detailed with anchor rods or simply by keying the superstructure to the substructure. The lack of a moment connection allows for a simpler connection that can be made with little or no site-cast concrete. The Maine DOT has developed a connection that uses precast prestressed concrete adjacent box beams keyed into the abutment seat. The beams are keyed in place by side blocks in the abutment and a precast approach slab in the rear of the abutment. This system does not require anchor bolts, allowing for a very fast connection.

2.5.4 Structural Bearings

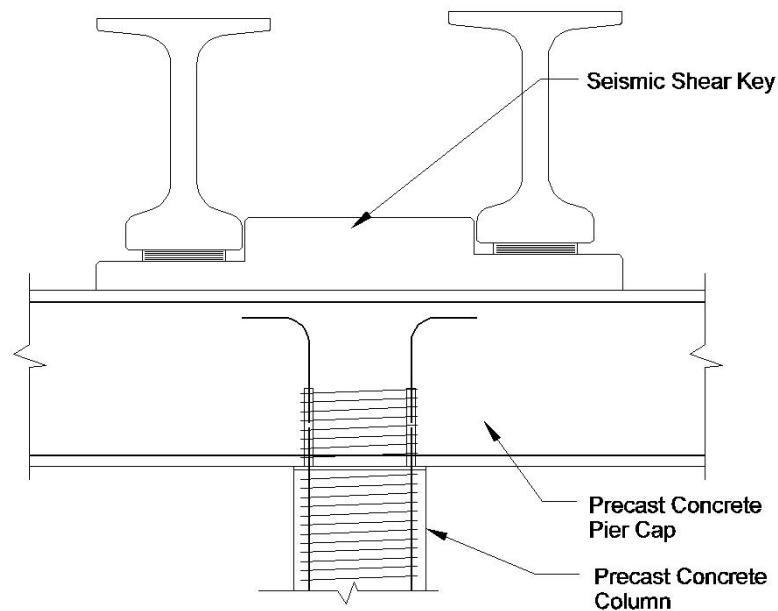
Most bridges built in the United States employ structural bearings between the superstructure and substructure. This connection is usually not the critical path in the construction of a prefabricated bridge.

No bearing details are included in this Manual because each state agency has standard details for bearings. The detailing of bearing connections can be elaborate. Designers should make every attempt to simplify the design of bearings on prefabricated construction projects so that the connections can be made quickly.

2.5.5 Grade Control and Tolerances

The connection between the substructure and the superstructure is a location that lends itself to grade control and tolerance adjustments. This connection is often a cast-in-place concrete pour; therefore, there typically is room for a certain amount of adjustment.

Structural bearings are another location where adjustment can be accommodated. Designers should detail bearing connections that allow for adjustment. One approach is to eliminate anchor bolts at the bearings. Another method to provide lateral restraint is the use of concrete shear keys cast between the beams. Figure 2.5.5-1 shows a seismic shear key for a precast pier cap. By eliminating anchor bolts, the contractor can adjust the layout of the superstructure on the substructure. AASHTO and the National Steel Bridge Alliance (NSBA) have published a document entitled "Steel Bridge Bearing Design and Detailing Guide" [45]. This document, available at the NSBA website and the AASHTO internet bookstore, has more information on anchoring bridge superstructures.



ELEVATION - SEISMIC KEEPER ASSEMBLY

Figure 2.5.5-1 Seismic Shear Key

2.5.6 Evaluation of Performance and Long-Term Durability of Superstructure to Substructure Connections

Most connections listed in this section include the use of cast-in-place concrete. These connections have been used for years on conventional integral abutments and integral pier projects. The details have been adapted for prefabricated bridge construction.

The use of integral connections eliminates bridge deck joints, which are the primary sites of structural deterioration. Cast-in-place closure pours require more time than some connections; however, the durability of an integral connection is normally worth the extra construction time.

2.5.7 Estimated Construction Time for Connections

The times required for construction depend on a number of factors including site access, traffic control, weather, crane locations and proximity to storage areas. Nonetheless, it is possible to make reasonable estimates of the minimum required construction time for the various systems discussed in this section.

Table 2.5.7-1 contains approximate installation times for the various systems included in this section:

System	Minimum Installation Time	Comments
Integral Pier Caps	2-3 Days	Time varies depending on the size and complexity of the connection
Integral Abutment	2-3 Days	Time varies depending on the size and complexity of the connection
Semi-Integral Abutment	1-2 Days	Can be as fast a few hours depending on the details
Structural bearings	1-4 hours	Some simple connections take only minutes to connect

Table 2.5.7-1 Approximate Minimum Installation Times for Superstructure to Substructure Connections

2.5.8 Recommendations for Improvements to Current Practices

In connecting superstructures to substructures, the detailing of structural bearings has room for improvement. There are many bearing details in the industry that are overly complex and difficult to build. The use of elastomeric bearing pads should be the first bearing of choice. These bearings are inexpensive and can be detailed for very simple and fast installations.

It is possible to design and detail bridges with few or no anchor bolts. Improperly placed anchor bolts can be a source of delays and cost overruns. The AASHTO/ (NSBA) document entitled “Steel Bridge Bearing Design and Detailing Guide” [45] offers guidance on the elimination of anchor bolts. Even though this document is written for steel bridges, much of the information can easily be applied to concrete bridges as well.

2.5.9 Connection Detail Data Sheets for Superstructure to Substructure Connections

The following pages contain data sheets for the various substructure to superstructure connections.

Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components Connected
- Name of project where the detail was used
- Manual Reference Section
The section of this Manual that is applicable to the particular detail shown.
- Connection details
- Description, Comments, specification and Special Design Procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

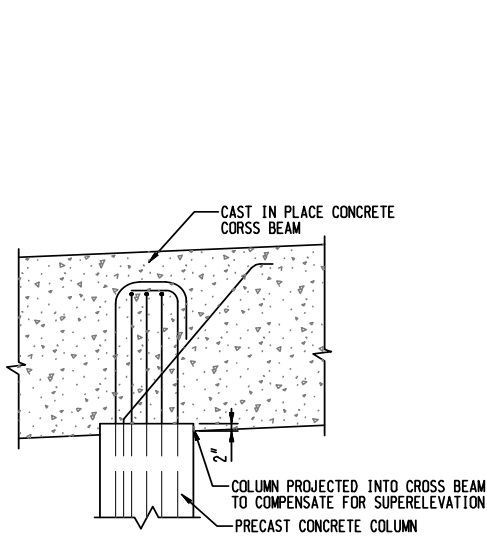
Organization: **WSDOT - Bridge Office**
 Contact Name: **John Olk, P.E.**
 Address: **P O Box 47340
 Olympia, WA 98504**

Detail Number: **2.5.1 A**
 Phone Number: **360-705-7395**
 E-mail: **olkj@wsdot.wa.gov**
 Detail Classification: **Level 2**

Components Connected **Precast Rectangular Column** to **Cast in Place Integral Pier Cap**

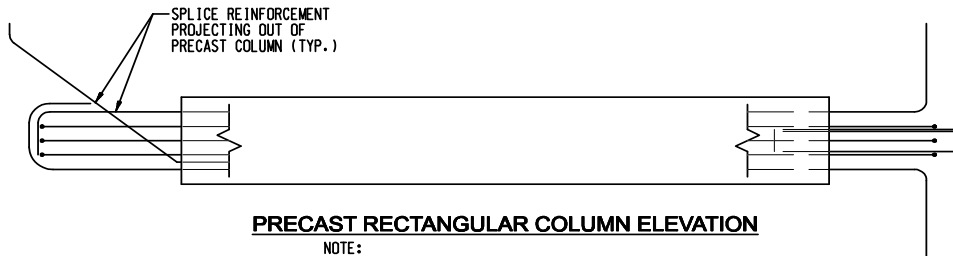
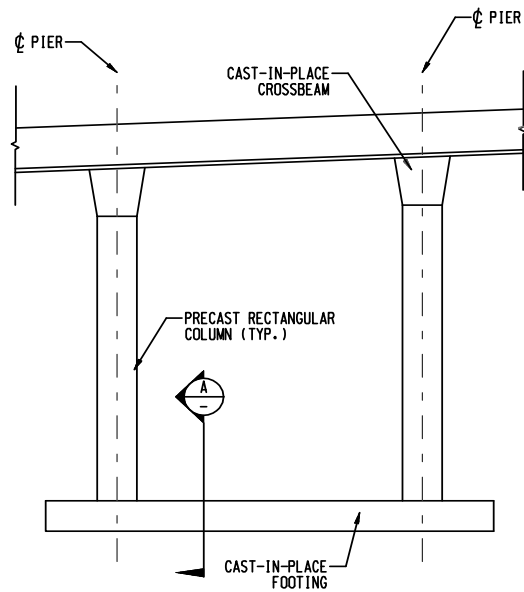
Name of Project where the detail was used **I-405, Bellevue Access Transit NE 4th / NE 6th**

Connection Details: **Manual Reference Section 2.5.1** See Reverse side for more information on this connection



SECTION A

NOTE: COLUMN STIRRUPS AND CAP BEAM REINFORCING NOT SHOWN FOR CLARITY



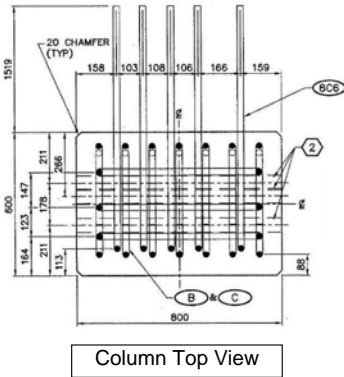
PRECAST RECTANGULAR COLUMN ELEVATION

NOTE:
 MAIN COLUMN REINFORCEMENT NOT SHOWN FOR CLARITY.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of a precast concrete column, temporarily supported, to a cast in place pier cap. This details can be used for any type of cast in place pier cap. The column is precast with a embedded 6x6x3/4 steel angle that is used to support the column temporarily. The angle bears on a 4 by 4 foot, 8 inch concrete pad. The photo below shows the columns in the field, with a temporary concrete pad in the lower left.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

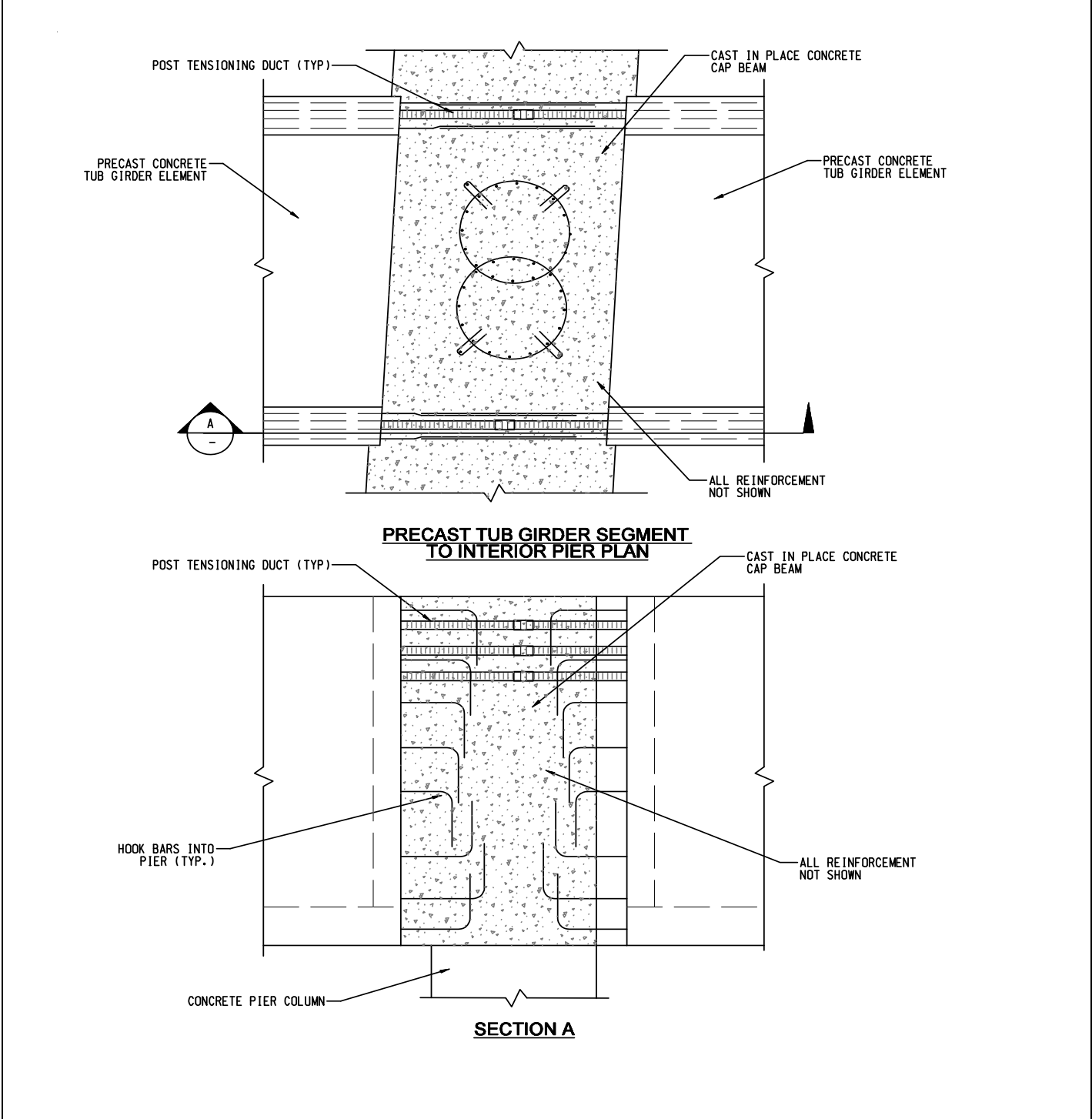
Organization: Washington State D.O.T.
 Contact Name: Joseph Merth, P.E.
 Address: Bridge and Structures Office
PO Box 47340
Olympia, WA 98504-7340

Detail Number: 2.5.1 B
 Phone Number: 360-705-7166
 E-mail: merthjo@wsdot.wa.gov
 Detail Classification: Level 1

Components Connected: Precast tub girder segment to Interior pier

Name of Project where the detail was used: SR5 - 38th Street Interchange - Tacoma, WA

Connection Details: Manual Reference Section 2.5.1 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Prior to casting the crossbeam the precast tub segments were placed on temporary supports. After the crossbeam was cast, the segments were then post-tensioned together and the temporary supports removed.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

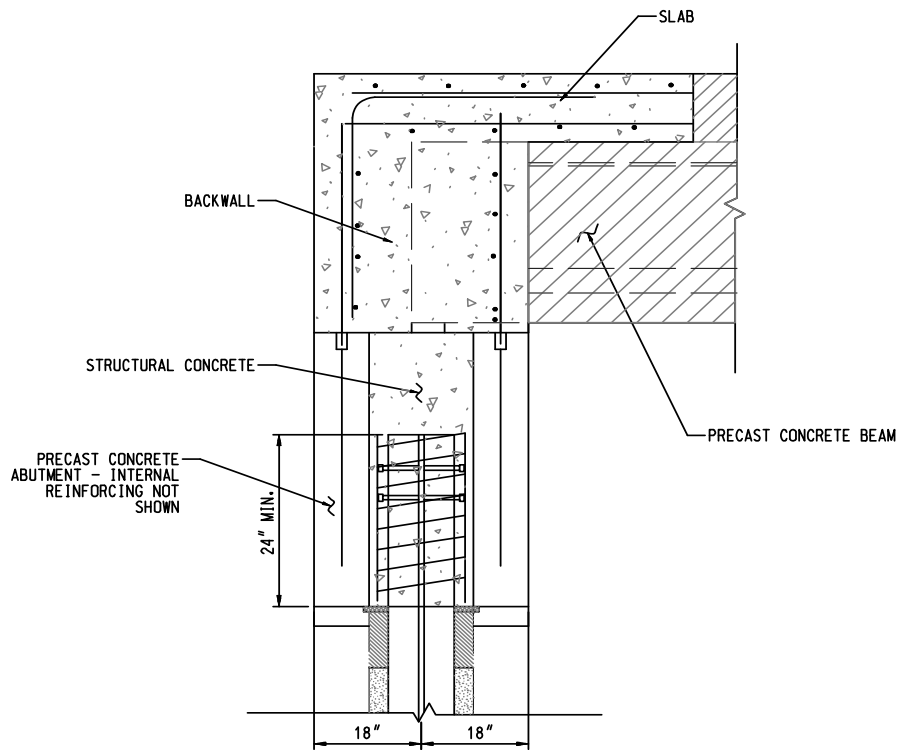
Organization: Iowa Department of Transportation
Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
Address: Office of Bridge and Structures
800 Lincoln Way
Ames, IA 50010

Detail Number: 2.5.2 A
Phone Number: (515-239-1393
E-mail: ahmad.abu-hawash@dot.iowa.gov
Detail Classification: Level 1

Components Connected: Precast concrete beam to Precast concrete integral abutment

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek, Madison County IBRC Project

Connection Details: Manual Reference Section 2.5.2 See Reverse side for more information on this connection



SECTION THROUGH PRECAST CONCRETE INTEGRAL ABUTMENT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This connection was also laboratory tested by Iowa State University as part of the evaluation of the IBRC project. The results of ISU's study will be published at a future date.

The connection to the superstructure is a reinforced cast in place concrete closure pour.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

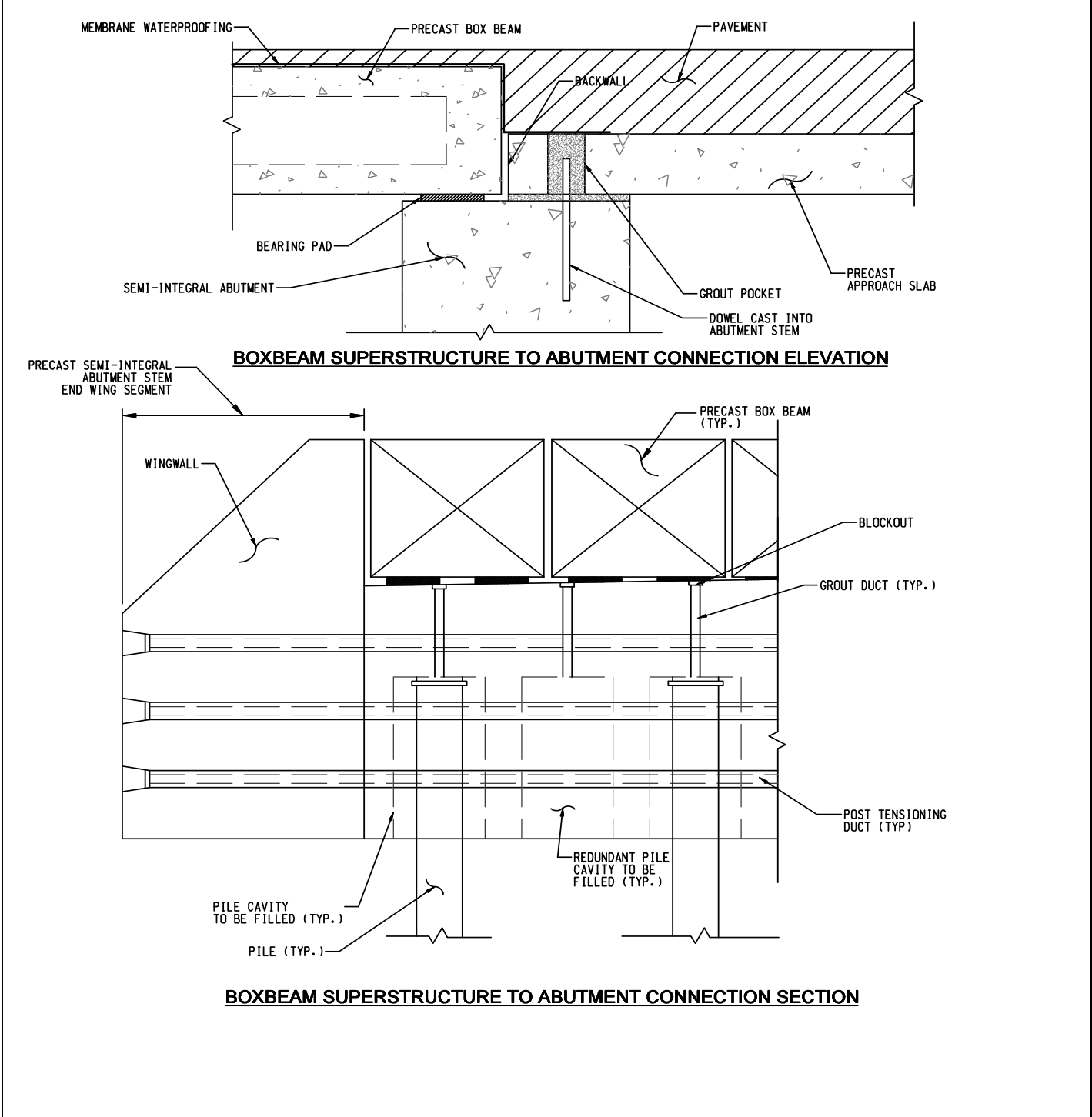
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **2.5.3 A**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 1**

Components Connected: **Precast Adjacent Box Beam Superstructure** to **Precast semi-integral abutment stem**

Name of Project where the detail was used: **Upton Maine Bridge**

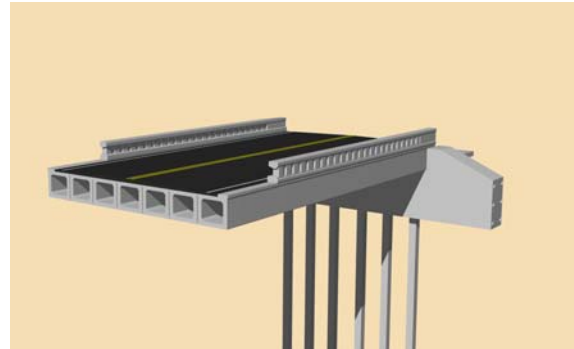
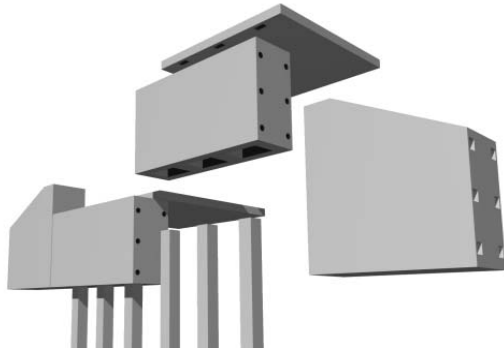
Connection Details: **Manual Reference Section 2.5.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the Maine DOT and adopted by the committee for bridges for semi integral abutment bridges. The pieces were match cast with shear keys in the fabrication plant. The precast components were epoxy bonded in the field and post tensioned. Once the abutment cap was completed, the box beams were set on top and keyed in using the approach slabs.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?
 Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction
 Constructability (0 difficulty making connection, 10 went together easily)
 Cost (0 expensive, 10 cost effective) When compared to other connection methods
 Durability (0 not durable, 10 very durable)
 Inspection Access (0 not visible, 10 easily inspected)
 Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

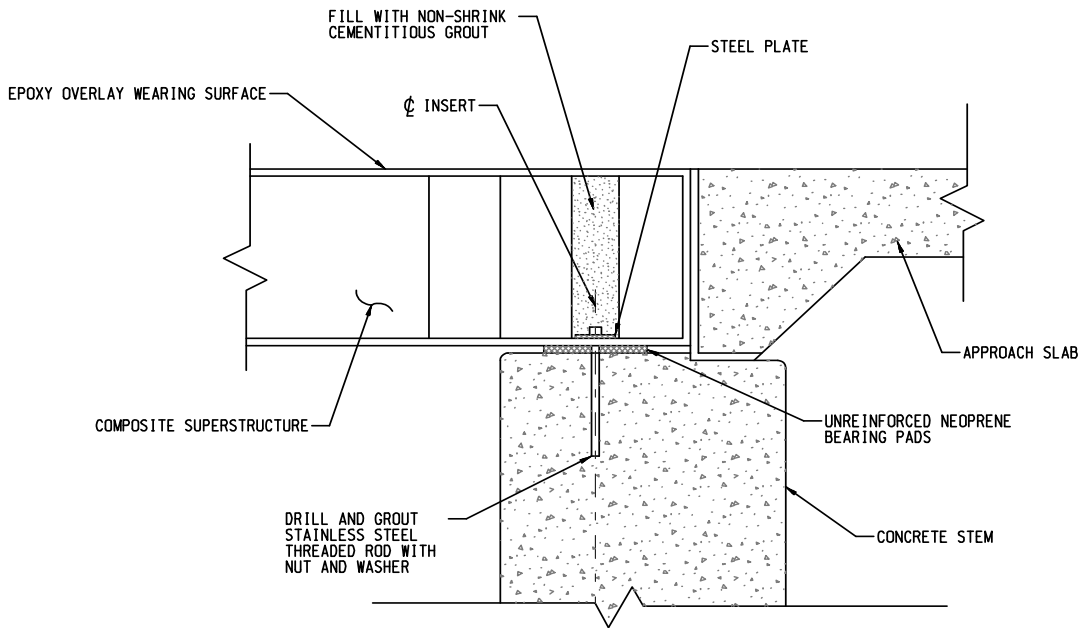
Detail Number:
Phone Number:
E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



FRP SUPERSTRUCTURE TO ABUTMENT CONNECTION DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This project consisted of the replacement of a deteriorated reinforced concrete slab superstructure with an FRP superstructure. The new superstructure was prefabricated in two pieces and was placed on rehabilitated reinforced concrete abutments. The detail above shows how the new superstructure was anchored to the abutments using threaded stainless steel anchor bolts.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

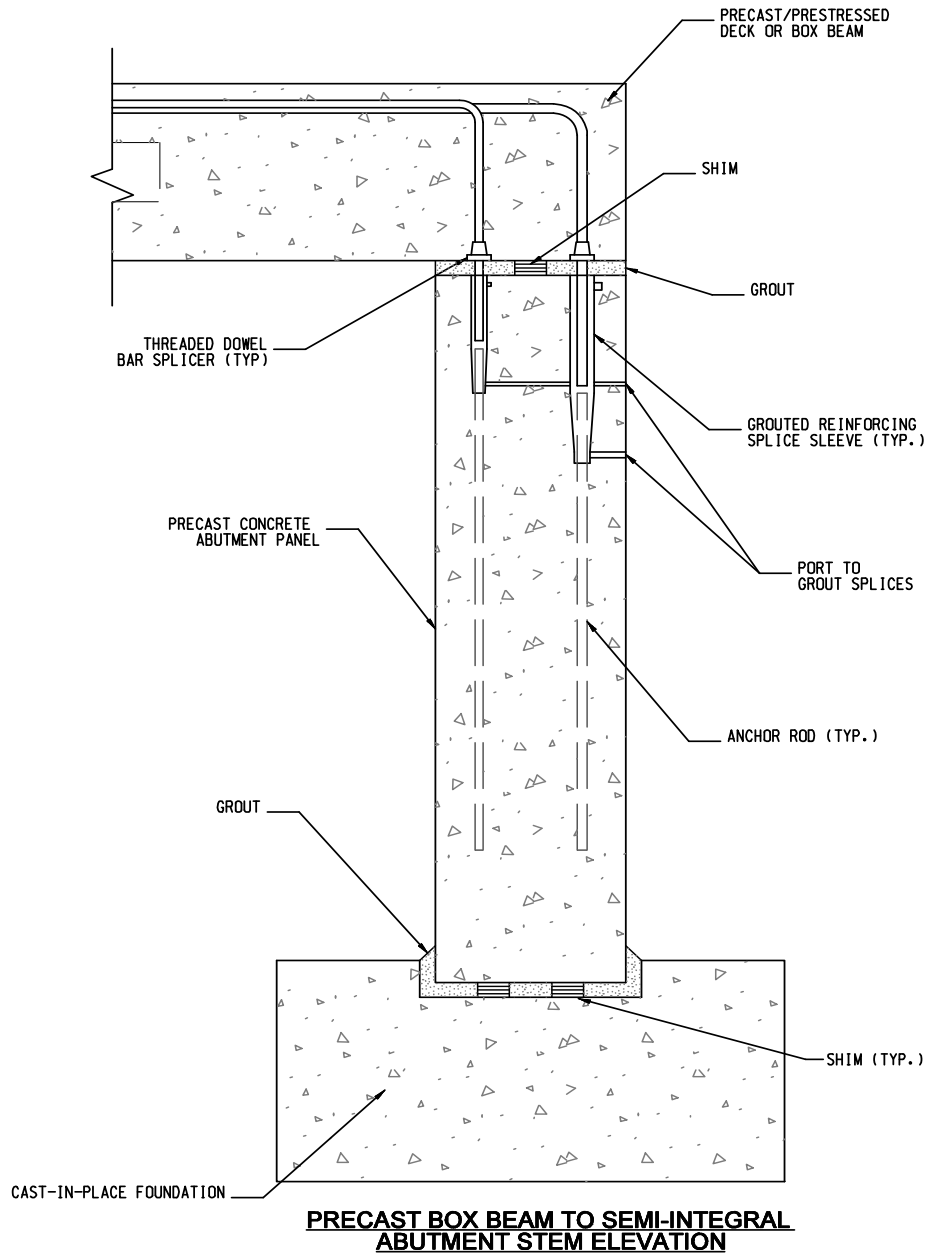
Organization: **NMB Splice Sleeve**
 Contact Name: **Alvin C. Ericson**
 Address: **PO Box 367897
 Bonita Springs, FL 34136-7897**

Detail Number: **2.5.3 C**
 Phone Number: **888-446-5376**
 E-mail: **ericson@alum.mit.edu**
 Detail Classification: **Level 2**

Components Connected: **Precast Box Beam** to **Semi-Integral Abutment Stem**

Name of Project where the detail was used: _____

Connection Details: **Manual Reference Section 2.5.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used on a bridge in Massachusetts to create a semi-integral abutment structure. The beams were adjacent precast prestressed butted box beams.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? 1 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 8 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 5 (0 not visible, 10 easily inspected)

Future Maintenance 9 (0 will need maintenance, 10 no maintenance anticipated)

2.6 Miscellaneous Superstructure Connections

This section focuses on connections of miscellaneous items not covered under other sections in this chapter.

2.6.1 Utilities, Drainage Assemblies and other Appurtenances

No details were submitted by owner agencies for the connection of utilities, drainage assemblies or other appurtenances to prefabricated bridge elements. This does not mean that these connections are not important, only that they are commonplace and not considered integral parts of the bridge structure.

The collapse of several concrete panels on the Boston Central Artery Tunnel underscores the importance of quality connection for these types of connections. The National Transportation Safety Board (NTSB) issued a safety recommendation following their investigation into this collapse. The cause of the collapse has been linked to failed connections that used epoxy adhesive anchors.

The NTSB recommended that epoxy adhesive anchoring systems not be used in connections that experience sustained tensile load because the adhesives creep substantially under long-term loading. In extreme cases, the anchors completely pull out. Designers should investigate other anchoring systems that will perform under the anticipated conditions. The designers should consider the type of loading, the environmental conditions and the vibrations associated with the connections.

Connectors of particular concern are overhead hanger type systems such as utility and drainage systems. Designers should investigate hanging these items from the sides of beams, cross frames or additional utility support members. There may be cases where overhead anchoring is unavoidable. In these cases, designers should use the following guidelines:

- For connections to steel elements, design supports using high strength bolts. Bolts loaded in shear are preferred to bolts loaded in tension.
- For connections to concrete elements, use anchors cast into the overhead element. The ACI document entitled “Building Code Requirements for Structural Concrete - ACI 318” is recommended for the design of anchors embedded in concrete. Appendix D of this document offers guidance on this subject [46].
- Specify anchors that do not use epoxy adhesive. Other anchor types are also not appropriate for situations where vibrations may be present. Designers should carefully evaluate any anchor if vibrations are anticipated.
- If epoxy adhesive anchors are unavoidable, the designer should investigate the long-term affects of the adhesive and specify testing requirements to ensure the durability of the anchor.

2.6.2 Barriers, Curbs and Railings

Section 2.1.1.4 covers connections of barriers and railing to full depth precast concrete deck panels. In some instances, prefabricated barriers and railings are attached to other elements such as cast-in-place concrete decks, and even timber decks. Refer to Section 2.1.1.4 for more information on barrier and railing connections.

The United States Department of Agriculture Forest Products Laboratory (USDA FPL) has developed standard details for timber barriers attached to timber bridges. This connection typically involves the use of bolts and split ring connectors. A split ring connector is a steel casting that is placed at the interface between two members loaded in shear. The connector greatly improves the resistance of the connection by spreading out the shear load to a larger area of wood. This essentially eliminates the crushing of wood against the side of the steel shear bolt. There is a significant amount of information on bridge railing connections at the USDA FPL website. Users of this Manual are encouraged to visit the Forest Products Laboratory website for more information on timber bridges (www.fpl.fs.fed.us).

2.6.3 Evaluation of Performance and Long Term Durability of Miscellaneous Superstructure Connections

The attachments of appurtenances, barriers and railings have different performance requirements. Attachments under bridge decks are not as exposed as barriers; however, these areas can be damp and subject to corrosion. Anchorages for appurtenances should be hot dip galvanized, according to ASTM A123 [48]. Designers may consider the use of stainless steel anchors for improved performance.

Barriers, curbs and railings experience some of the most severe exposure, especially in northern climates. Often the connection of a barrier to the deck is located at the gutter line. The joint between the barrier and the bridge deck should be protected from water infiltration. If this is not feasible, anchors used for the connection should be either hot dip galvanized according to ASTM A123 or made of stainless steel.

2.6.4 Estimated Construction Time for Connections

Exact timelines for construction are dependent on a number of factors including site access, traffic control, weather, crane locations and storage areas. It is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Table 2.6.4-1 contains approximate installation times for the various systems included in this section:

System	Minimum Installation Time	Comments
Miscellaneous appurtenances	1 hour	Depending on the details, numerous connections can be made in one day
Steel Barriers	1-2 Days	Time is for a typical single span bridge; larger bridges may take longer
Precast Concrete Barriers	1-2 Days	This is for a typical single span bridge; larger bridges may take longer
Cast-in-place Concrete Barriers	1-4 Days	The time of construction is a function of the number of pours required to complete the installation

Table 2.6.4-1 Approximate Minimum Installation Times for Miscellaneous Superstructure Connections

2.6.5 Recommendations for Improvements to Current Practices

The most important improvement to current practice is to cease the use of overhead epoxy adhesive anchoring systems. The 2006 collapse of the precast concrete roof panels in the Boston Central Artery Tunnel has indicated the inability of these anchors to support long-term tension loads.

2.6.6 Connection Detail Data Sheets for Miscellaneous Superstructure Connections

The following pages contain data sheets for the various miscellaneous superstructure connections. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization

- Detail Classification Level

- **Level 1**

- This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

- **Level 2**

- This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

- **Level 3**

- This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected

- Name of project where the detail was used

- Manual Reference Section

- The section(s) of this Manual applicable to the particular detail shown.

- Connection Details

- Description, comments, specifications and special design procedures

- Forces that the connection is designed to transmit

- Information on the use of the connection (including inspection ratings)

- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

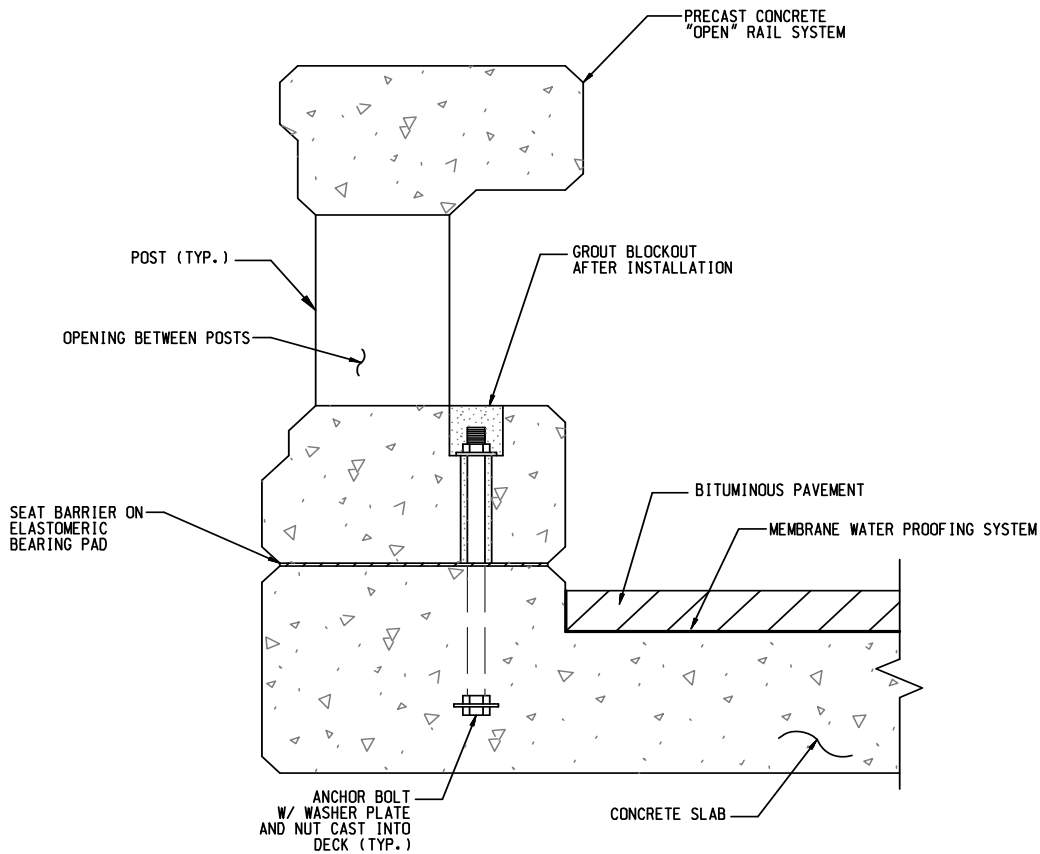
Organization: **NHDOT - Bureau of Bridge Design**
 Contact Name: **David L. Scott, P.E.**
 Address: **PO Box 483
 7 Hazen Drive
 Concord, NH 03302-0483**

Detail Number: **2.6.2 A**
 Phone Number: **(603) 271-2731**
 E-mail: **dscott@dot.state.nh.us**
 Detail Classification: **Level 2**

Components Connected **Precast Barrier** to **Deck**

Name of Project where the detail was used **N.H. Rte. 175-A Over Pemigewasset River in Holderness/Plymouth, NH**

Connection Details: **Manual Reference Section 2.6.2** See Reverse side for more information on this connection



TYPICAL BARRIER SECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This parapet was developed through a cooperative effort between the New Hampshire DOT and the Vermont AOT. The parapet design is based on a similar Texas DOT cast in place parapet. The intent is to use this parapet on bridges in urban environments and where historic bridges need to be replaced. The section has been static load tested to LRFD Performance Level 2 in a University of New Hampshire laboratory. Several different opening shapes are proposed. This can be modified by changing the inserts in the steel forms (see photo below). This parapet has been used on one bridge project so far. Several other projects are also proposed.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

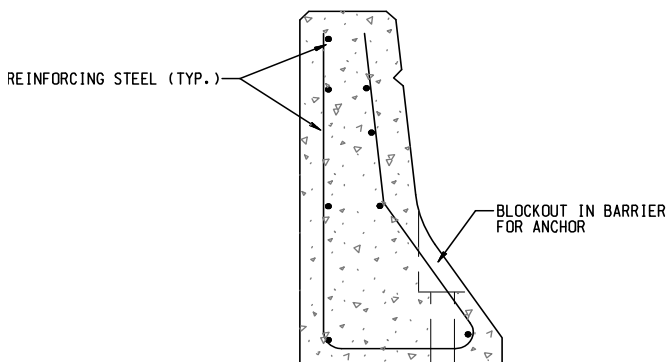
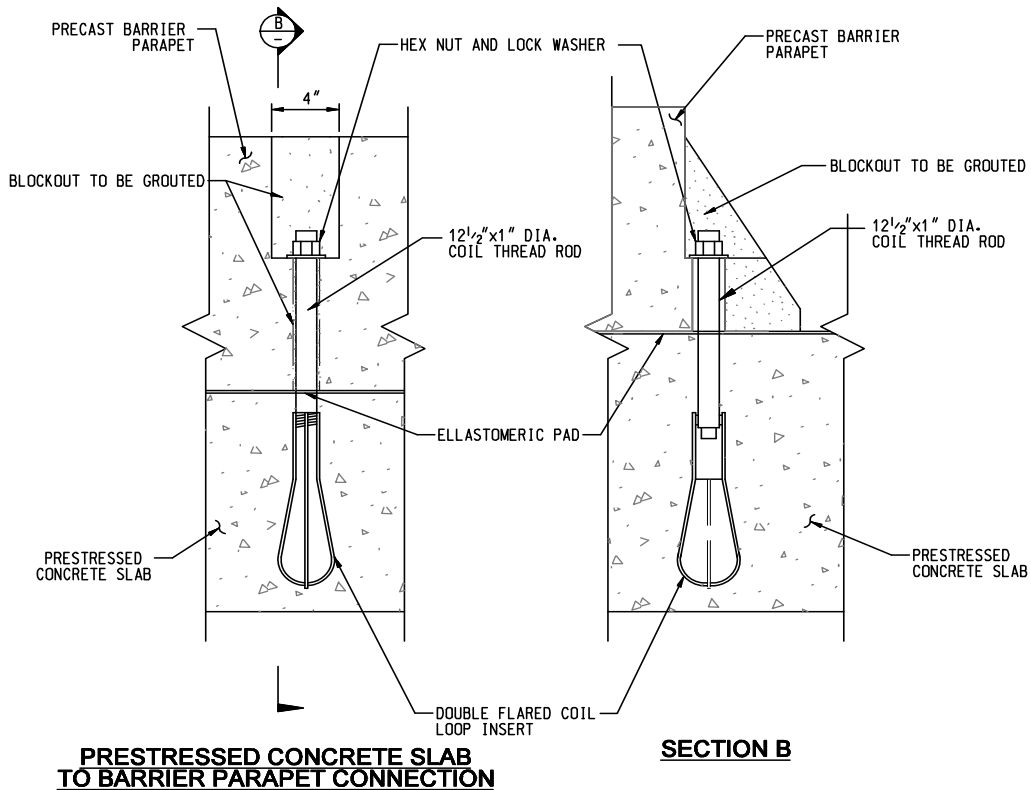
Organization: South Carolina DOT
 Contact Name: Barry Bowers
 Address: Post Office Box 191
Columbia, South Carolina 29202

Detail Number: 2.6.2 B
 Phone Number: 803-737-4814
 E-mail: bowersbw@scdot.org
 Detail Classification: Level 1

Components Connected: Prestressed Concrete Slab to Precast R. C. Barrier Parapet

Name of Project where the detail was used: Maintenance Bridges

Connection Details: Manual Reference Section 2.6.2 See Reverse side for more information on this connection



- NOTES:**
- THREADED ROD SHALL BE ASTM A709 GRADE 36
 - COIL THREAD ROD SHALL BE B-12 WITH A SAFE WORKING LOAD OF 50,000 LBS.
 - COIL NUT SHALL BE B-13 WITH A SAFE WORKING LOAD OF 24,000.
 - BOTH MANUFACTURED BY DAYTON SUPERIOR OR AN APPROVED EQUAL.
 - ALL HARDWARE SHALL BE GALVANIZED ACCORDING TO ASTM A123 OR A153 AS APPLICABLE.



Editor's Notes

This detail is used in South Carolina. It is not known if the blockouts meet current crash testing criteria for snagging. Designers should consider filling the blockouts with grout.

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

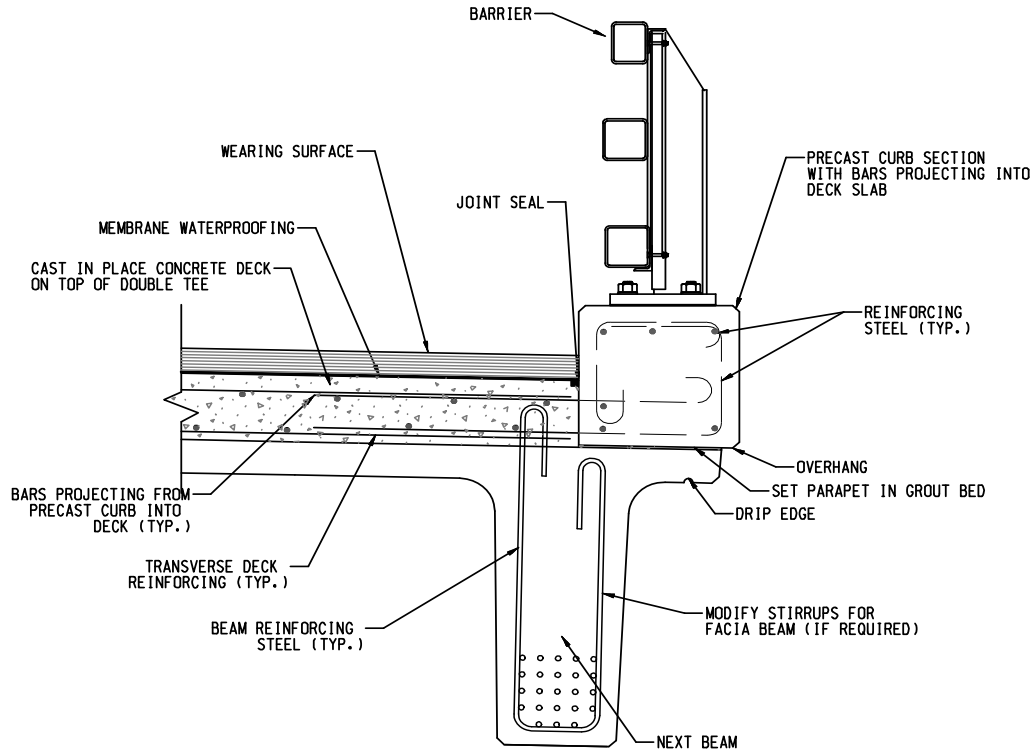
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **2.6.2 C**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 3**

Components Connected: **Precast Parapet** to **CIP Deck on Double Tee**

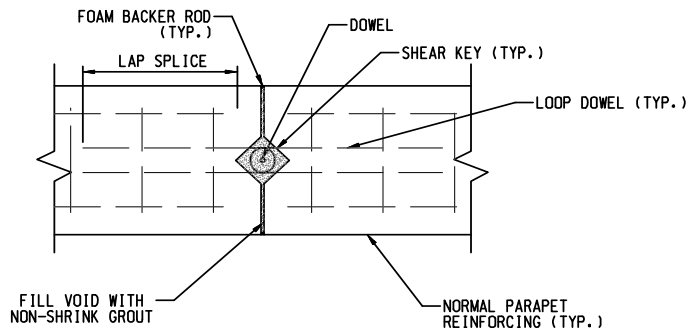
Name of Project where the detail was used: **Conceptual**

Connection Details: **Manual Reference Section 2.6.2** See Reverse side for more information on this connection



**PRECAST PARAPET OR RAILING ON PRECAST DOUBLE TEE
 TYPICAL SECTION**

NOTE: RAILING SHOWN, PARAPET SIMILAR



**PRECAST PARAPET JOINTS
 PLAN**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the Bridge Technical Committee of the Northeast Region of the PCI. The detail is part of the development of a new bridge beam called the Next Beam (Northeast Extreme Tee). The intent of this new beam is to eliminate the need for deck forming, thereby saving construction time. The top flange of the beam is intended as a form only. The cast-in-place deck is designed like a stringer bridge. The tees can vary in width from 8 feet to 12 feet. The wearing surface can wither be bituminous or sacrificial concrete.

The overhang of the fascia tee allows the use of precast parapets. Any cast-in-place standard parapet can now be detailed as a precast parapet. The typical horizontal construction joint in most parapets is replaced with a vertical construction joint. If standard shapes and reinforcing are used, there should be no need for crash testing of this connection.

The following notes outline the typical construction sequence for this detail.

1. Erect the NEXT Beams
2. Place the precast parapet in a grout bed. Use plastic shims to adjust grade.
3. Grout keyway voids between parapet pieces.
4. place deck reinforcing and cast the deck using the parapet as a side form.
5. Seal the joint between the parapet and the deck pour.
6. Place wearing surface (is required)

Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? 0 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 8 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

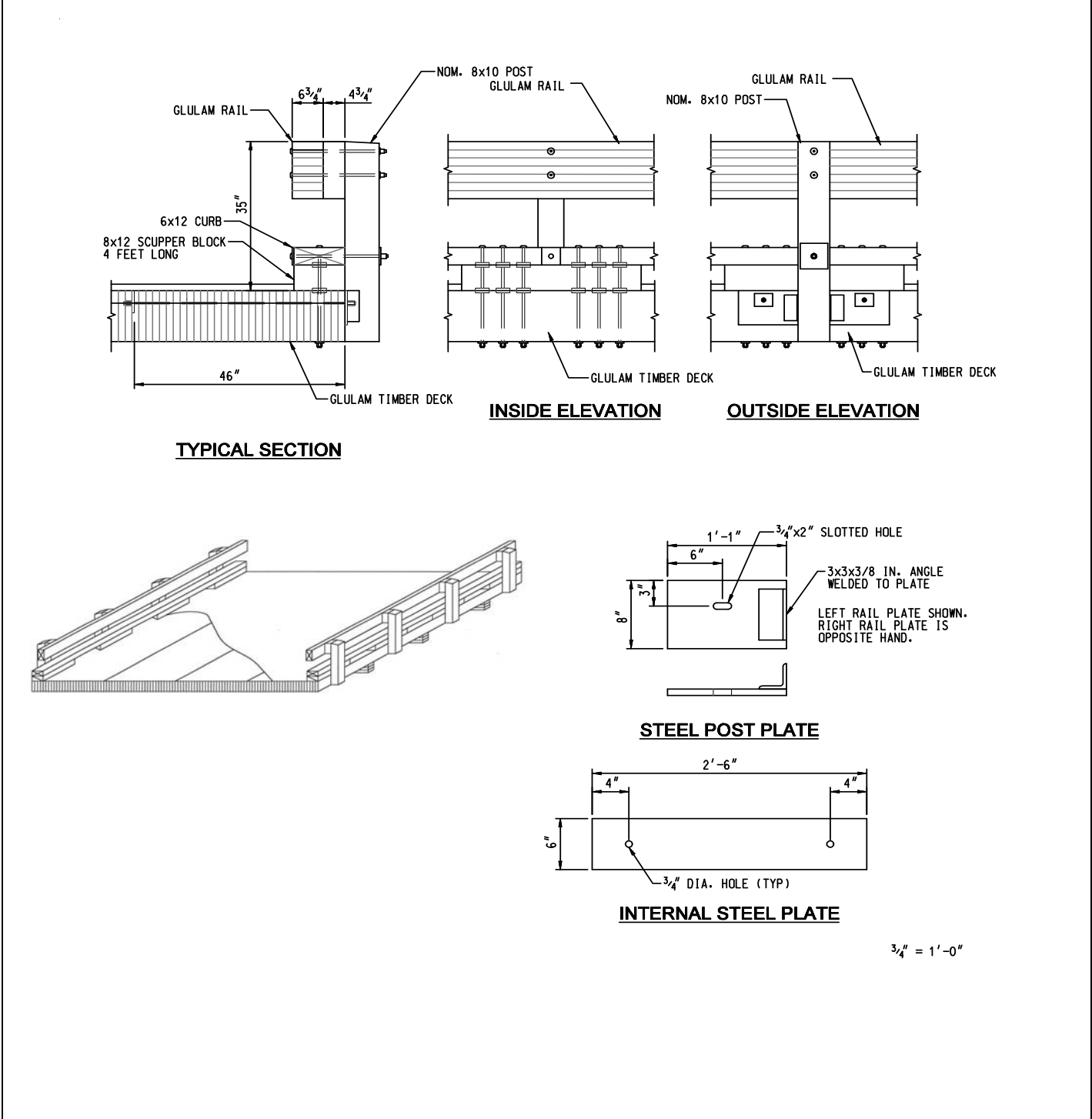
Organization: **USDA Forest Products Laboratory**
 Contact Name: **Jim Wacker**
 Address: **One Gifford Pinchot Drive
 Madison, WI 53726**

Detail Number: **2.6.2 D**
 Phone Number: **608-231-9224**
 E-mail: jwacker@fs.fed.us
 Detail Classification: **Level 2**

Components Connected: **Glulam wood railing** to **Glulam wood deck**

Name of Project where the detail was used: **Standard**

Connection Details: **Manual Reference Section 2.6.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The details provide the connection between the bridge railing and the glue laminated wood deck. This railing is has been crash tested to Test Level 4. Other railings are available on line. For more information on this bridge type and this connection, see the Manual entitled "Standard Plans for Timber Bridge Superstructures - General Technical Report FPL-GTR-125" published by the United States Department of Agriculture Forest Products Laboratory. It can be obtained at: www.fpl.fs.fed.us.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 7 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 7 (0 difficulty making connection, 10 went together easily)

Cost 7 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 8 (0 not durable, 10 very durable)

Inspection Access 10 (0 not visible, 10 easily inspected)

Future Maintenance 8 (0 will need maintenance, 10 no maintenance anticipated)

Chapter 3 – Substructure Connections

This chapter is devoted to connections in substructure systems. The chapter has been broken out into typical substructure systems that are used on most bridges. These systems include piers, abutments, and walls. The connections between substructure elements that are directly connected to foundation elements (pile bents) will also be covered in this chapter.

3.1 Pier Elements

Prefabricated pier elements have been used by many state agencies. This is due to the difficulty of forming and pouring concrete high above the ground and the fact that substructures offer opportunities for repetition. There can also be significant savings by reducing construction time for substructure work over bodies of water or near hazards such as power lines.

3.1.1 Precast Concrete Cap Beam Connections

The most common prefabricated elements in substructures are pier cap beams. These elements are often the most difficult to construct using cast-in-place concrete, where shoring and forming can become significant.

Details presented in this manual were developed in states that are in low to moderate seismic zones. Many of the connections depicted cannot develop plastic hinges or do not include adequate confinement reinforcement. Several details developed by the Northeast States PCI Bridge Technical Committee may be appropriate for high seismic zones; however at this time research to verify their seismic performance has not been conducted and, therefore, they are still only recommended for moderate seismic zones.

There is research underway to investigate designs for prefabricated connections in high seismic zones. Users of this Manual should keep abreast of this research as it is completed. See Section 1.5 of this Manual for more information on this topic.

3.1.1.1 Connection to Cast-in-Place Concrete Columns and Piles

There have been several projects where precast concrete pier caps were connected to cast-in-place concrete columns and piles. The major issue with this approach is that the tolerance of the cast-in-place columns and piles needs to be addressed in the connection. Templates can be used to provide good fit-up in the field. Details using large blockouts in the pier cap element have been successfully built.

Texas DOT has built connections that employ standard post-tensioning ducts to create voids for projecting reinforcing steel. These ducts, when combined with additional confinement reinforcing in the pier cap and grouted, can develop significant bending moment capacity; however research to verify their performance in moderate-to-high seismic regions has not been completed [5]. More information on this connection can be found in the Texas DOT research report

Number 1748-1 entitled “*Development of a Precast Bent Cap System*” [49]. Other states have used recessed grouted cap pockets to develop semi-moment connections, or simple bolted connections that would be considered a pinned connection.

3.1.1.2 Connection to Precast Columns

At least one state has constructed a pier bent using both precast concrete pier caps with precast concrete columns. Florida DOT built a large bridge called the Edison Bridge in Lee County. Figure 3.1.1.2-1 shows the completed structure.



Figure 3.1.1.2-1 Edison Bridge
(Photo courtesy of Florida DOT)

The Edison bridge pier connections used proprietary grouted splice couplers to create moment connections between the pieces. The couplers were embedded in the precast components and filled with grout after installation. The couplers used are proprietary; however there are multiple manufacturers of this type of coupler. This means that they can be used on federally funded projects. See section 1.4.2.1 for more information on these couplers.

The columns and pier caps had unique shapes that were developed to reduce shipping and lifting weight of the elements. The columns were cast in an H shape, and the cap an inverted U shape. Figure 3.1.1.2-2 shows the column section during casting.



Figure 3.1.1.2-2 Pier Column Section
(Photo courtesy of Florida DOT)

3.1.1.3 Connection to Steel Piles (pile bents)

Many states build simple pier structures that consist of driven steel piles supporting a reinforced concrete pile cap. These piers are referred to as pile bents.

Several states have developed details for prefabricated reinforced concrete bent caps. One option for the connection of the bent cap to the steel piles is a welded connection. The precast bent cap is built with embedded steel plates that are anchored in the precast bent with welded studs. After pile driving is complete, the steel piles are cut off to the proper elevation. The bent cap is placed over the piles and welded in place.

Some pile bents are constructed with hollow pipe piles. In this case, the connection of the pipe pile to the cap can be made by inserting reinforcing steel or an anchor rod into a void in the precast pile cap and the void in the pipe pile. A cast-in-place concrete closure pour in the pier cap void and the top of the hollow steel pile completes the connection.

3.1.1.4 Connection to Precast Concrete Piles (pile bents)

There are several details for connections of precast concrete pile caps to precast concrete piles. Most of these connections involve grouting the pile into a void in the pier cap. Some states use reinforcing in this connection.

Florida DOT uses large hollow precast piles for viaduct structures. The connection of these piles to the precast pier cap is similar to the connection of a precast pier cap to a hollow steel pile. A reinforced closure pour is used to connect the two elements.

3.1.1.5 Connection of Precast Concrete Cap to Precast Concrete Cap

There are several reasons to construct precast pier caps in several pieces and connect them in the field. On wide bridges, it may be desirable to have a very wide pier cap. Shipping limitations (dimensions) may require that the cap be manufactured in multiple pieces. Also, if the cap pieces are very heavy, it may be desirable to build the cap in multiple pieces to limit the size of cranes on site. Another reason to use multiple cap pieces is to facilitate fit up in the field. Connecting a precast cap to three or more columns is not impossible, but it is easier to connect to two columns. Designers should consider incorporating open joints in pier cap designs. This will facilitate the erection of caps and reduce the thermal forces in the pier bents.

One of the details submitted by the Northeast PCI Bridge Technical Committee shows a cast-in-place closure pour. This is done because it is very difficult to erect two components with a horizontal connection using grouted reinforcing bar couplers. The time to cure a closure pour might seem to be a problem with accelerated construction

methods; however if detailed properly, this connection can be designed to support only loads placed on the structure after erection of the beams. This means that the erection process can proceed while this connection is formed, poured and cured.

3.1.2 Precast Concrete Column Connections

3.1.2.1 Connection of Column to Column

Few states have designed bridges with prefabricated pier column connections. The connections were made by using the match cast method of construction combined with post-tensioning. The joints are epoxy bonded together and the post-tensioning completes the joint.

The details for column connections that are proposed by the Northeast States PCI Bridge Technical Committee could also be used for this connection. This type of connection uses grouted reinforcing splice couplers to connect the reinforcing from one element to the next. This type of connection has been used in stadium construction projects. See Section 3.1.1.2 for more information on this type of connection.

3.1.3 Wall Pier Connections

3.1.3.1 Connection of Precast Wall to Precast Footing

The Northeast States PCI Bridge Technical Committee has developed details for a precast concrete wall pier. While this type of structure has not been constructed yet, a precast cantilever wall abutment has been successfully built. The details are essentially the same except the structure does not support unbalanced soil loads. The pier elements can be connected using grouted shear keys or simply sealed to prevent moisture infiltration. See Section 3.2.1 for more information on these connections.

Other connections described in this section for precast pier columns can easily be applied to wall piers. For instance, a precast wall pier element can be connected to a cast-in-place concrete footing as described in Section 3.1.4.1 below.

3.1.4 Precast Concrete Column to Footing Connections

3.1.4.1 Connection to Cast-in-Place Concrete Footing

The connection of a precast pier column element to a cast-in-place concrete footing can be made using two approaches. The state of Washington developed a detail that involved casting the footing under the precast column element, which had reinforcing projecting from the base. The column was braced in position on top of a temporary support in the middle of the column. The footing was simply formed and poured around the projecting column reinforcement.

The second method of making this connection is by the use of mechanical connectors or post-tensioning. In this case, the location of the mechanical devices and/or post-tensioning needs to be carefully coordinated. Tolerances need to be established and

specified so that the field fit-up is successful. See Section 1.7 for more discussion on tolerances.

3.1.4.2 Connection to Precast Concrete Footing

To the knowledge of the authors of this manual, the connection of a precast column element to a precast footing element has not been used on a bridge project in the United States. Section 3.2.1.1 will discuss the connection of cantilever wall elements to precast footings (which has been used on at least one bridge project). This type of connection is essentially the same as a pier column connection, since it is called on to provide a moment splice.

The Northeast States PCI Bridge Technical Committee has developed standard details for this connection that use grouted reinforcing splice couplers. These connections are based on details used in building and parking garage construction, where they have been used successfully. The detail has been classified as conceptual in this manual; however, based on the performance of abutment connections and its use in other industries; it should be a reliable and useful connection for piers.

As with any mechanical splice connection, the tolerances of the mechanical connectors need to be specified. See Section 1.7 for more discussion on tolerances.

3.1.5 Grade Control and Tolerances

The construction of prefabricated pier elements can lead to problems with grade and horizontal control. Minor grade and alignment problems can be corrected in other connections above the pier (haunches in deck pour forming for example); however it is always desirable to make adjustment for grade as the construction progresses. All of the connections shown in the manual have grout beds or cast-in-place closer pours which can be used to make minor adjustment to grade. This is commonly done by means of small shim packs that are placed between the elements being connected. Often these shims are made of polymer sheets and are left in place in the finished structure. Steel shims should be avoided because they would represent a hard point that may attract stresses as the structure is loaded, which could lead to spalling of the precast elements.

The use of mechanical connectors or post-tensioning requires more careful attention to tolerances in the precast process. Two things can be done to ensure proper fit-up in the field. If post-tensioning is specified, the connections can be match cast to minimize field fit-up problems. If grouted reinforcing splice couplers are used between two precast elements, the designer can specify that the connections be dry connected in the shop to ensure proper fit.

See Section 1.7 for more discussion on tolerances.

3.1.6 Evaluation of Performance and Long Term Durability of Prefabricated Pier Systems

The connections shown in the manual have proven to be quite durable. During the collection of data for this manual, several precast pier projects were identified that did not perform well. These involved the use of steel plate connectors in high corrosion environments.

To date, connections using grouted joints have performed very well. For example, the Edison Bridge in Lee County Florida has been in service for over 15 years and is in very good condition. The connections on this bridge are in one of the most severe environments in the country.

Several details included in this manual consist of exposed welded plate connections. These connections should either be used in non-corrosive environments, or coated after welding to prevent future corrosion.

3.1.7 Estimated Construction Time for Connections

Exact timelines for construction are dependent on a number of factors including site access, traffic control, weather, crane locations and storage areas. It is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Table 3.1.7-1 contains approximate installation times for the various pier systems included in this section:

System	Minimum Installation Time	Comments
Grouted Duct or Reinforcing Splice Coupler Connections	1 Day or less	This includes bracing and grouting.
Blockout closure pour connections	2 Days	Two days are required for the closure pour concrete (high early strength) to attain at least enough strength to allow for construction to progress.
Post-Tensioning Systems	3 Days	This includes connecting the elements with epoxy, placement of the post-tensioning strand or rod, and grouting of the ducts.

Table 3.1.7-1 Approximate Minimum Installation Times for Pier Connection Systems

3.1.8 Recommendations for Improvements to Current Practices

To date, grouted connections and closure pour systems on precast piers have been very successful and durable. The one major hurdle that needs to be addressed is the development of pier connections in high seismic regions. Most of the connections presented in this manual are only applicable to low to moderate seismic regions where plastic hinging of

column elements in not required until research proves otherwise. Research is underway to develop connections that can be used in high seismic regions.

3.1.9 Connection Detail Data Sheets for Pier Systems

The following pages contain data sheets for the various prefabricated pier systems. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected
- Name of project where the detail was used
- Manual Reference Section

The section(s) of this Manual applicable to the particular detail shown.

- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

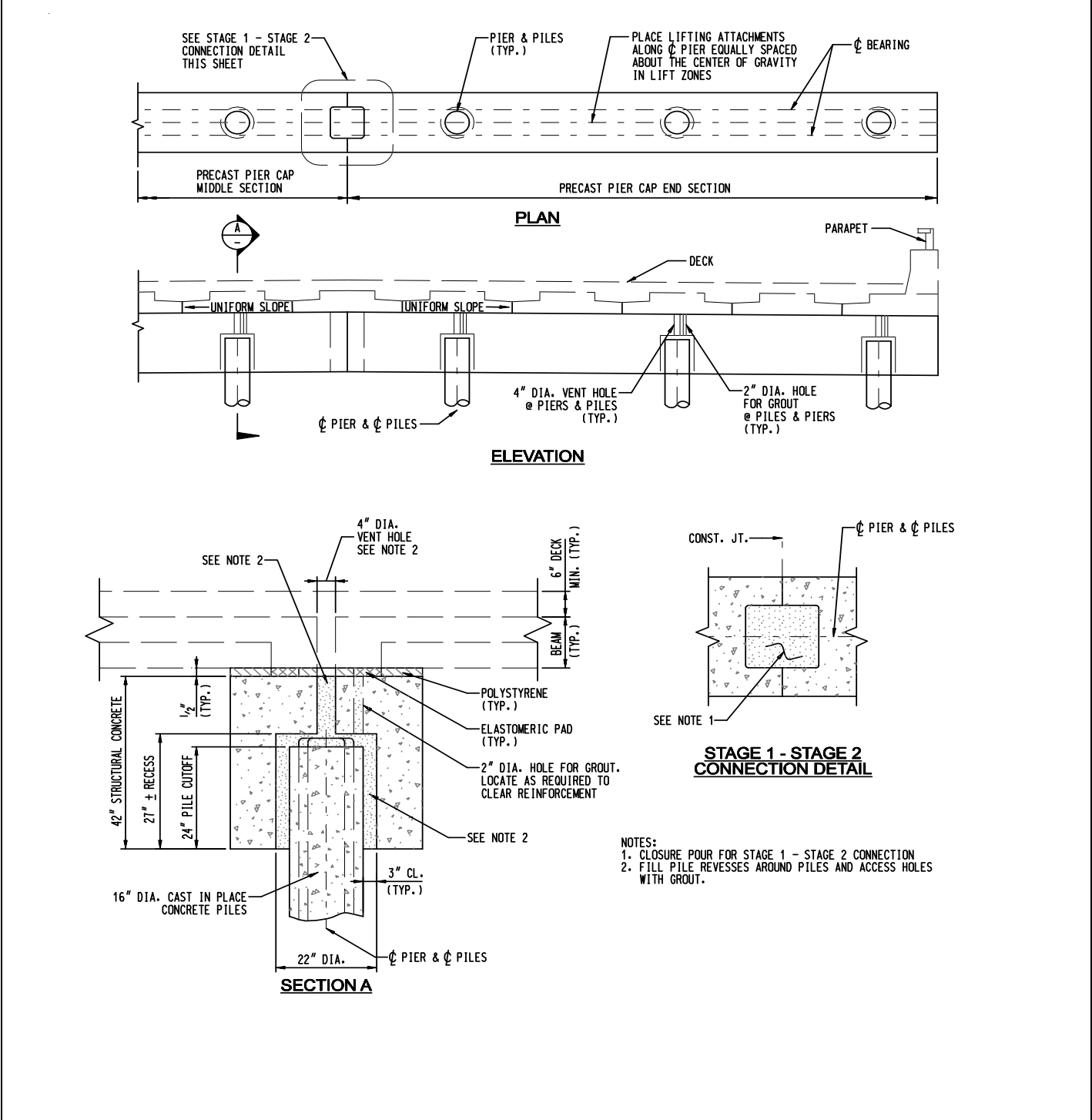
Organization: **MnDOT Bridge Office**
 Contact Name: **Joseph M. Fishbein, P.E.**
 Address: **3485 Hadley Avenue N.
 Oakdale, MN 55128**

Detail Number: **3.1.1.1 A**
 Phone Number: **651-747-2196**
 E-mail: **joefishbein@dot.state.mn.us**
 Detail Classification: **Level 2**

Components Connected: **Precast pier cap** to **Round CIP piles**

Name of Project where the detail was used: **Bridge 13004, TH 8 over Center Lake Channel, Center City, MN**

Connection Details: **Manual Reference: Section 3.1.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between precast pier cap and round CIP piles for pile-bent pier. Cap was precast with oversized holes for piles, and smaller holes between pile blockouts and top of cap were included for grouting. After piles were installed, the cap was placed over piles, leveled into position, and high-strength grout injected from top of cap through grouting holes. Rebar inside the CIP piles projected into the pier cap for additional bonding. Few problems were reported from the field. This approach required careful control of pile locations, which was accomplished by using a template, as well as waiting to excavate final slope contour until after piles were driven.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

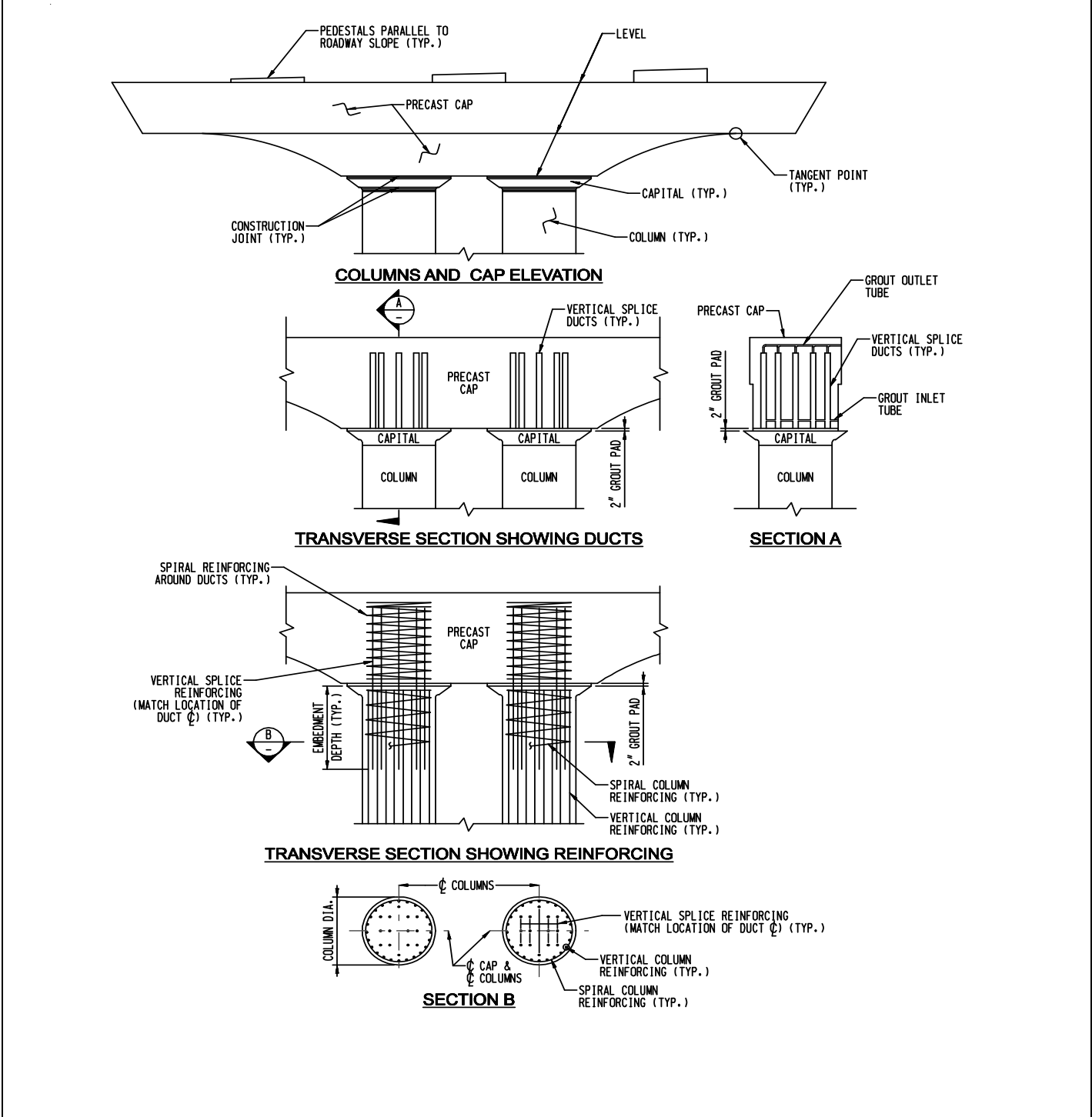
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **3.1.1.1 B**
 Phone Number: **512-416-2279**
 E-mail: **lwolf@dot.state.tx.us**
 Detail Classification: **Level 1**

Components Connected: **Precast Pier Cap** to **Cast-in-place Concrete Column**

Name of Project where the detail was used: **Lake Belton**

Connection Details: **Manual Reference Section 3.1.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The photo shown below was taken during construction. The photo shows the pier cap being lowered onto the cast-in-place concrete columns. The contractor used shims to set the grades of the caps. The ducts run from the bottom to a point near the top of the cap. This was done to avoid interference with the large amount of top reinforcing in the cap. The ducts are standard post tensioning ducts.

The contractor used a man-lift (just off the photo to the left) to facilitate this installation. A worker guided the bars into the duct openings.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

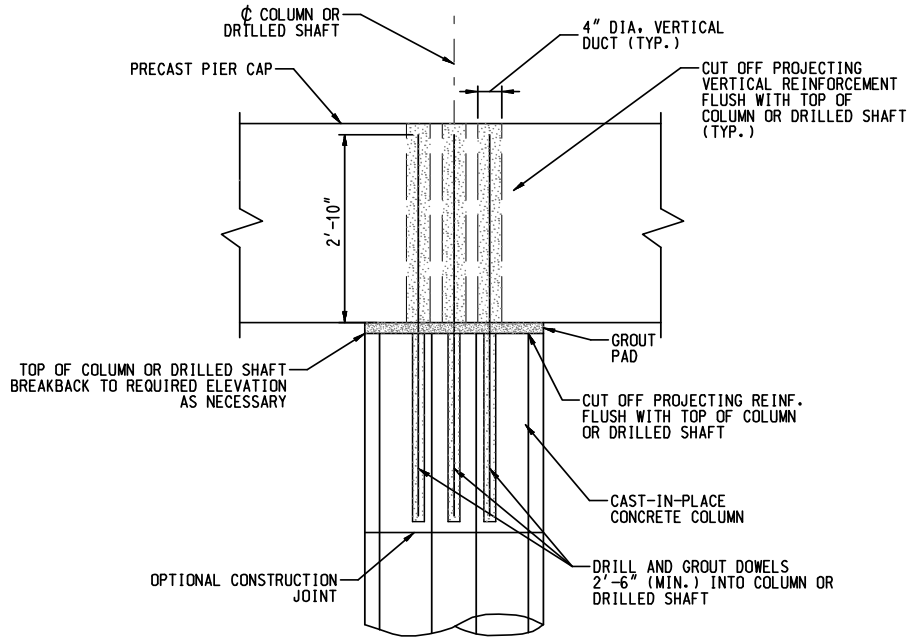
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **3.1.1.1 C**
 Phone Number: **512-416-2279**
 E-mail: **lwolf@dot.state.tx.us**
 Detail Classification: **Level 1**

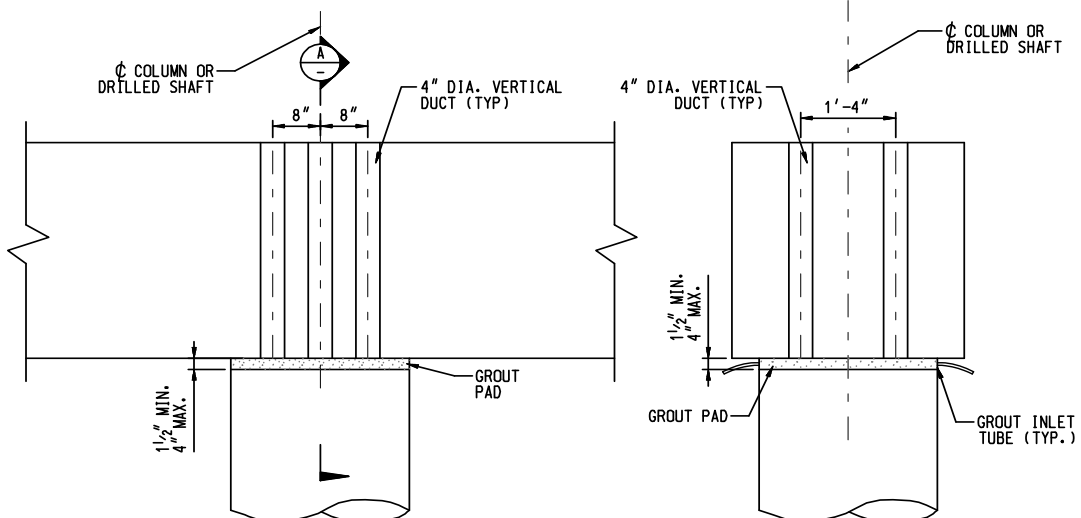
Components Connected: **Precast Pier Cap** to **Cast-in-place Concrete Column**

Name of Project where the detail was used: **Lake Ray Hubbard**

Connection Details: **Manual Reference Section 3.1.1.1** See Reverse side for more information on this connection



SECTION THROUGH PIER CAP AND COLUMN



SECTION SHOWING VERTICAL DUCTS

SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The photos shown below were taken during construction. The photo on the left shows the pier cap being lowered onto the cast-in-place concrete columns. The contractor used a cap leveling system that was strapped to the outside columns (green jacket and jacks) that was used to set the cap grades.

The photo on the right is the cap pocket during fabrication. The ducts run from the bottom to the top of the cap. The ducts are standard post tensioning ducts.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used?

Condition at last inspection (if known)

How many times has this detail been used?

Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

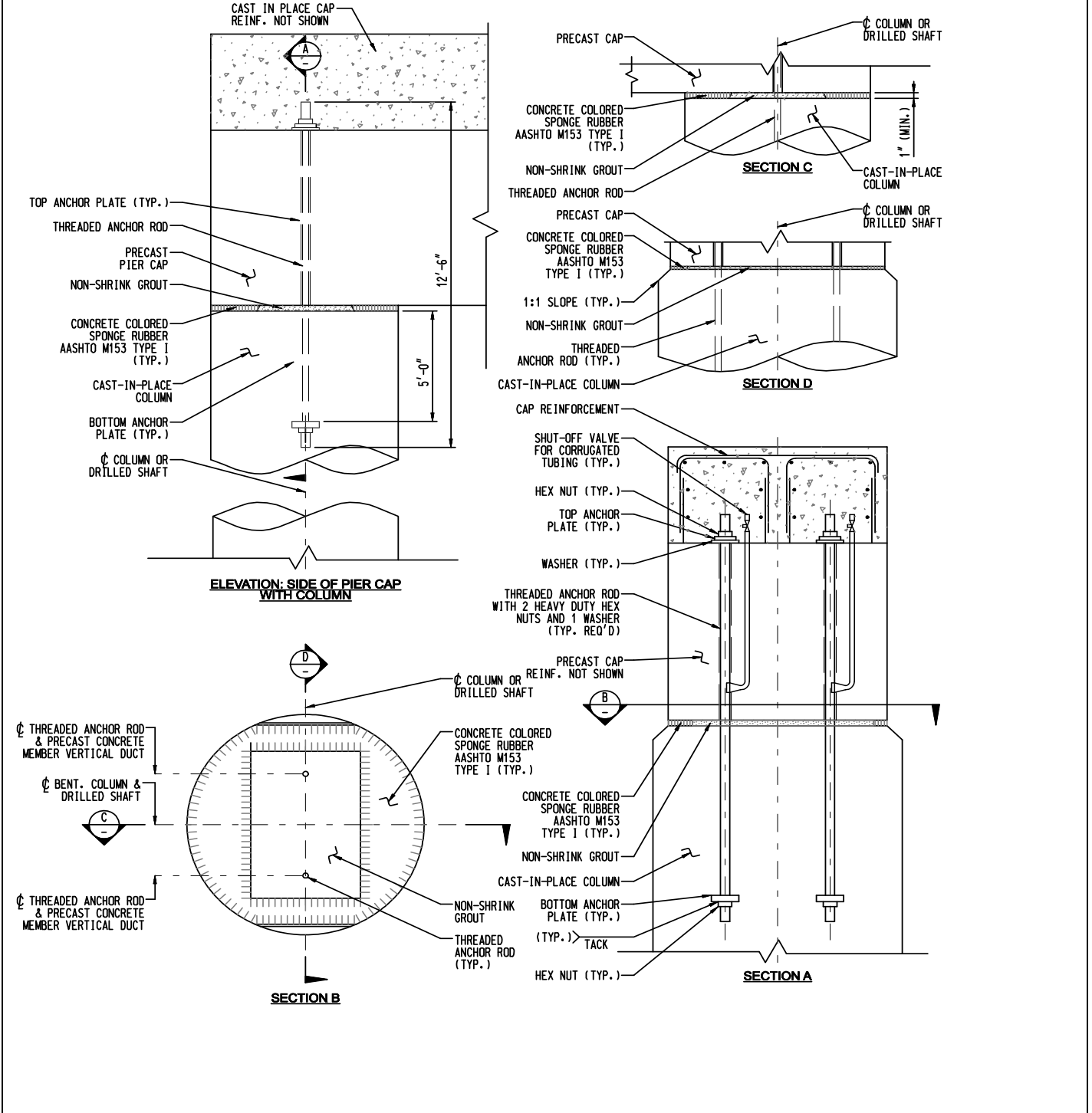
Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

Detail Number: 3.1.1.1 D
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us
 Detail Classification: Level 2

Components Connected: Precast Concrete Bent Cap to Cast in Place Concrete Column

Name of Project where the detail was used: Bridge over BNSF Railroad (Wyoming Drawing Number 7024)

Connection Details: Manual Reference Section 3.1.1.1 See Reverse side for more information on this connection



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

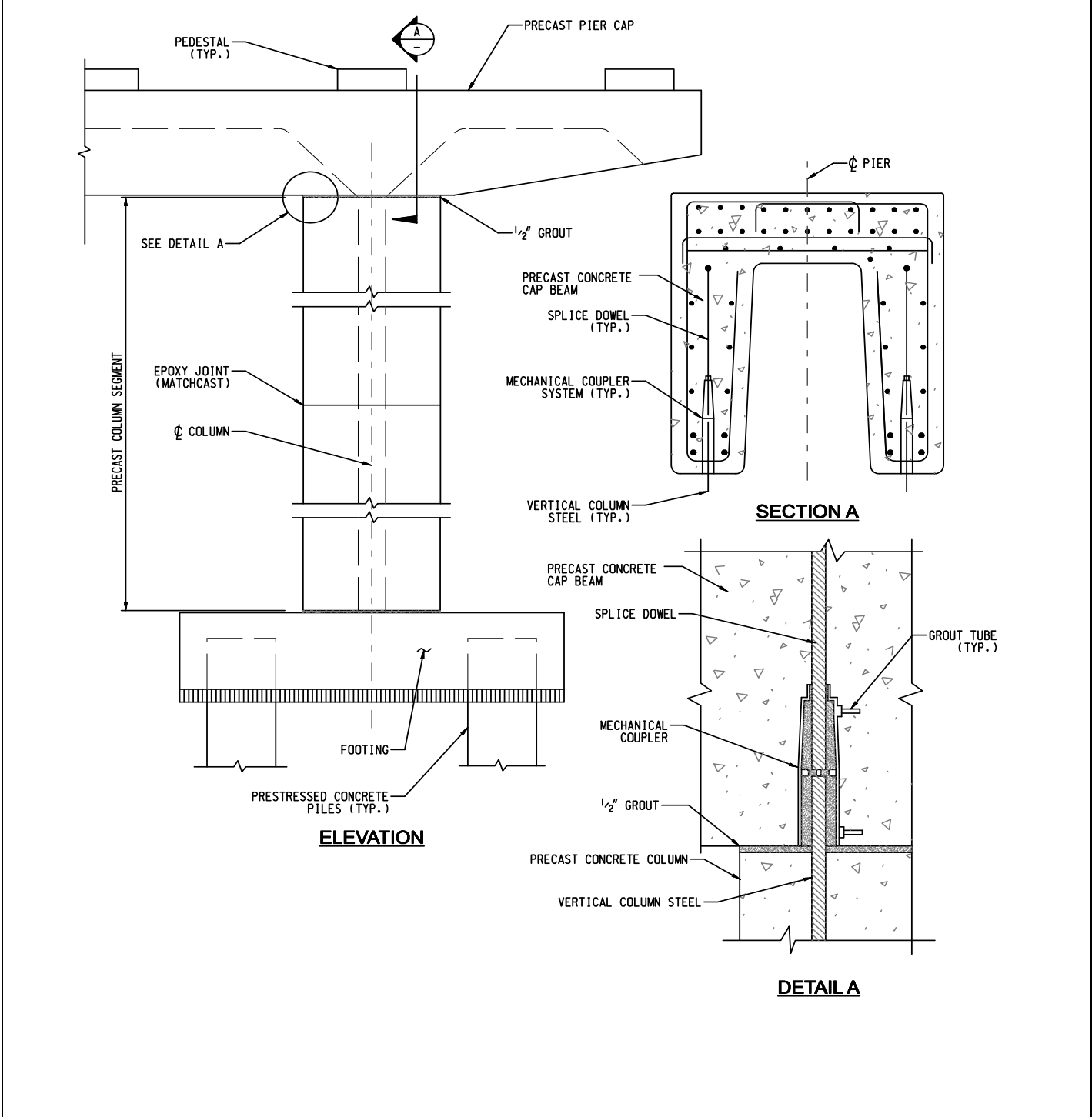
Organization: **Florida DOT**
 Contact Name: **Thomas Andres**
 Address: **605 Suwannee Street, MS 33
 Tallahassee, FL 32399-0450**

Detail Number: **3.1.1.2 A**
 Phone Number: **850-414-4269**
 E-mail: thomas.andres@dot.state.fl.us
 Detail Classification: **Level 2**

Components Connected: **Precast Pier Column** to **Precast Pier Cap**

Name of Project where the detail was used: **Edison Bridge**

Connection Details: **Manual Reference Section 3.1.1.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This Connection was made with a steel grouted reinforcing bar splicer system.

The grouted splicers can develop over 150% of bar yield. Quality control on bar and splicer locations are critical. The splicers can be oversized to accommodate approximately 1/2" of tolerance. The only design effect is that the bars must be moved closer to the center of the members in order to maintain cover around the splicers (approx. 1"). This design incorporates an H shaped column section and a U shaped cap section to reduce weight. Weight of cap did not control crane requirements (approx. same weight as beams). Contractor's labor and insurance costs less due to reduced time on the water.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

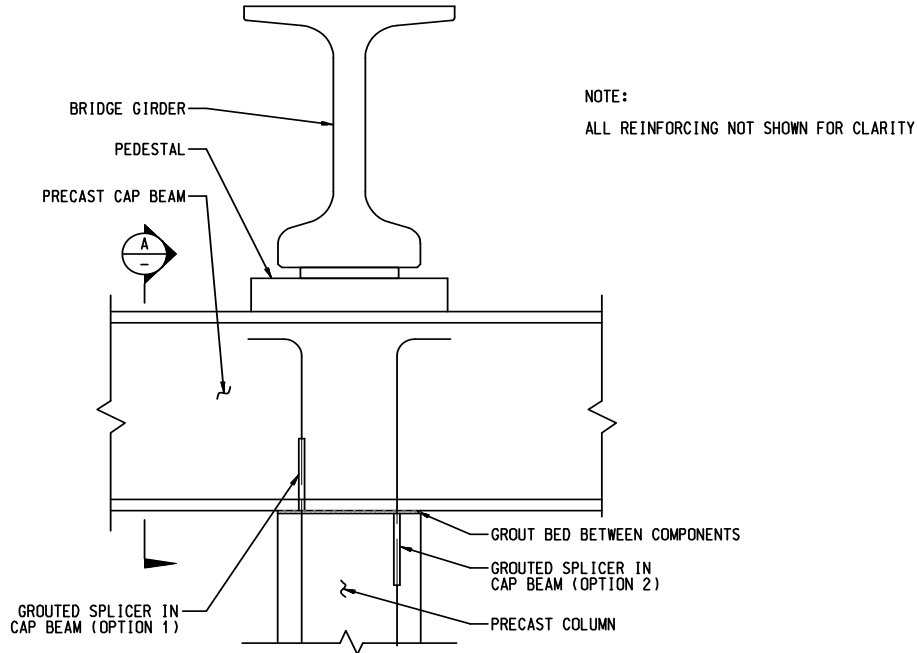
Organization: **PCI Northeast Bridge Tech Committee**
Contact Name: **Rita Seraderian**
Address: **116 Radcliffe Road
Belmont, MA 02478**

Detail Number: **3.1.1.2 B**
Phone Number: **888-700-5670**
E-mail: **contact@pcine.org**
Detail Classification: **Level 3**

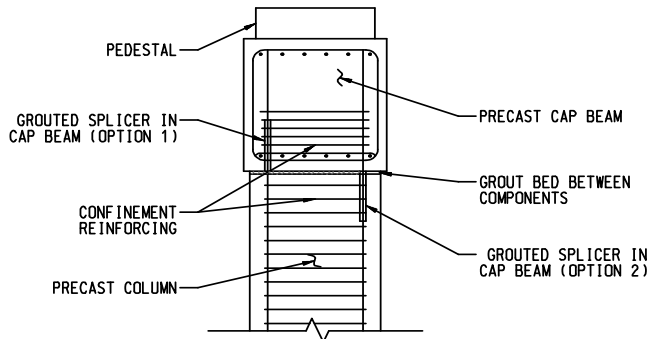
Components Connected: **Precast Cap Beam** to **Precast column**

Name of Project where the detail was used: **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 3.1.1.2** See Reverse side for more information on this connection



**ELEVATION:
PRECAST COLUMN/CAP CONNECTION**



SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges with multi-column bent piers. Details similar to these have been used in precast parking garage and stadium projects. The performance information listed below is based on these structures. The grouted spicers can be placed in the column or the cap beam. The cap beam is shimmed to grade and grouted. Square, hexagonal and octagonal columns are preferred over round columns because they can be cast in the flat position. Long cap beams may require a joint. This joint can be left open in order to control thermal forces, or can be connected with a small closure pour after placement. The closure pour is shown.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

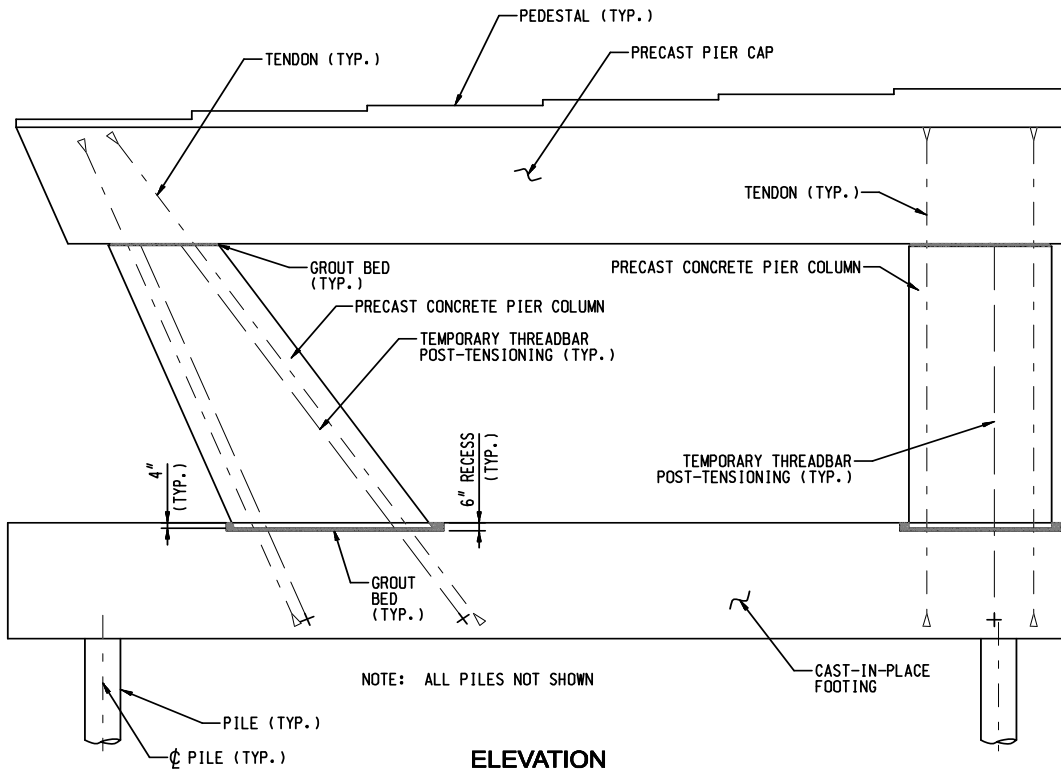
Organization: Arora & Associates, P.C.
 Contact Name: Alan Haring, P.E.
 Address: 3120 Princeton Pike
Lawrenceville, NJ 08648

Detail Number: 3.1.1.2 C
 Phone Number: (609)219-6785
 E-mail: aharing@arorapc.com
 Detail Classification: Level 2

Components Connected: Precast Pier Column to Cast in place footing

Name of Project where the detail was used: Route 70 over Manasquan River, Brielle, NJ

Connection Details: Manual Reference Section 3.1.1.2 See Reverse side for more information on this connection



NOTE: ALL PILES NOT SHOWN

ELEVATION

NOTE: THE PIER WAS CONSTRUCTED IN TWO STAGES. STAGE 1 IS SHOWN

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection provides a means of connecting the precast column segments to precast cap beams. This allows for the accelerated construction of the piers above the footing level using precast concrete construction. The anchorage devices specified in the contract plans were proprietary. The project was designed with Inclined columns with a trumpet shaped anchorages, which allowed strand to be placed and grouted after the column has been erected. Temporary threaded PT bars were used to support the columns until the cap beams were placed.

The Contractor substituted alternative details, which eliminated temporary column post-tensioning. A single full-height column section was used. All post tensioning was accomplished with threaded PT bars in place of the strand tendons. Once the precast cap beam was installed, the cap was sealed with a cast-in-place concrete cap.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

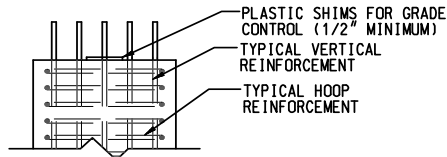
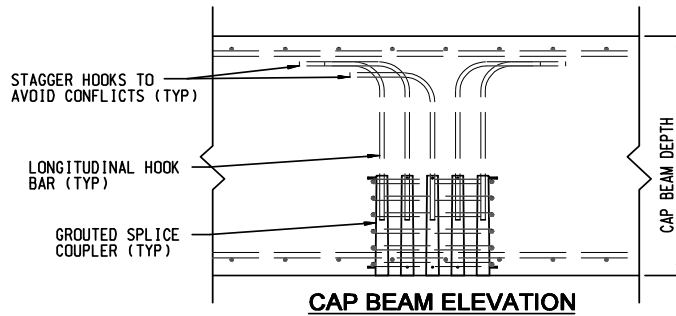
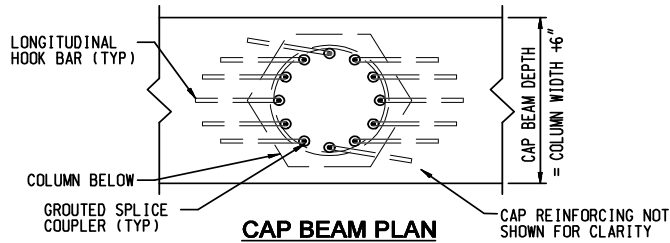
Organization: **Utah DOT via CME Associates, Inc.**
 Contact Name: **Michael P. Culmo, P.E.**
 Address: **333 East River Drive, Suite 400
 East Hartford, CT 06108**

Detail Number: **3.1.1.2.D**
 Phone Number: **860-290-4100**
 E-mail: **culmo@cmeengineering.com**
 Detail Classification: **1**

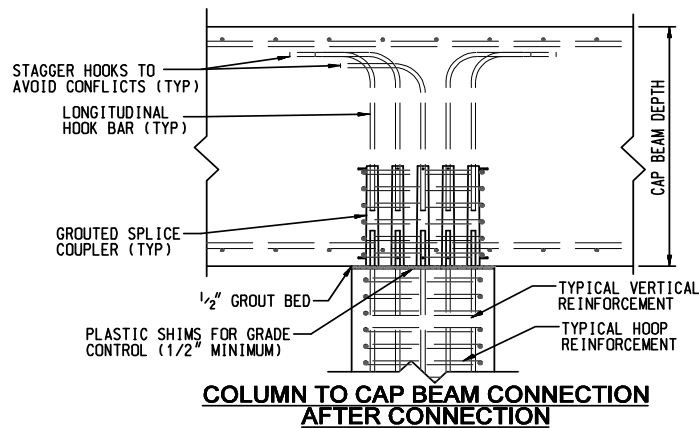
Components Connected: **Precast Pier Column** to **Precast Cap Beam**

Name of Project where the detail was used: **Under Development**

Connection Details: **Manual Reference Section 3.1.1.2** See Reverse side for more information on this connection



COLUMN TO CAP BEAM CONNECTION PRIOR TO CONNECTION

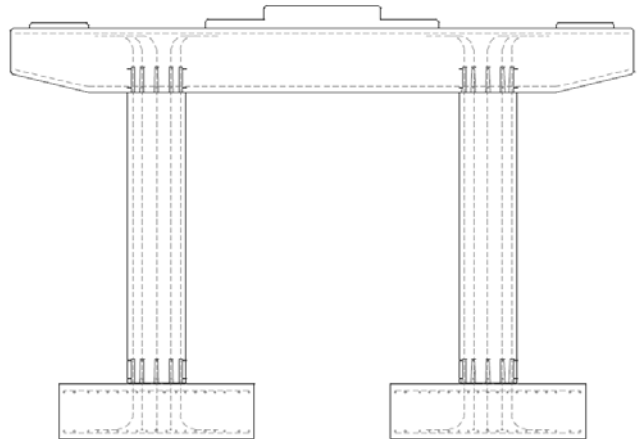
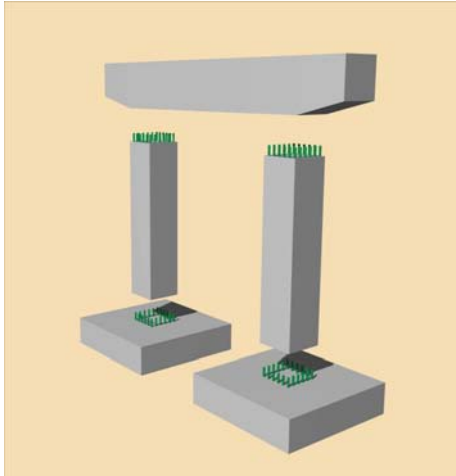


Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The UTAH DOT is currently in the process of developing standard details for prefabricated bridge elements. The detail depicted is based on several successful details that are included in the manual. The success of the other projects warranted the Level 1 detail classification. The details below depict one of the preliminary pier configurations. Others are also being developed.

CME Associates is developing the standard details; therefore they are listed as the contact.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

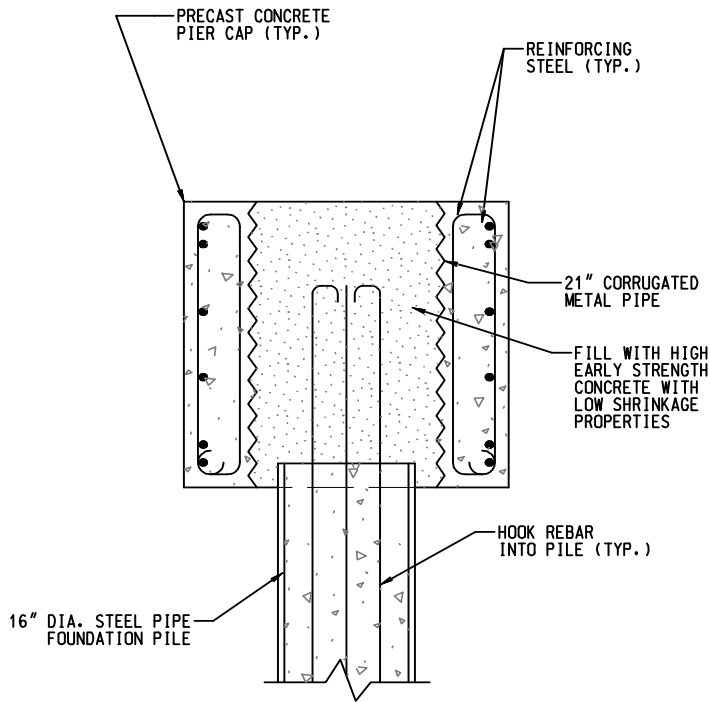
Organization: Iowa Department of Transportation
Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
Address: Office of Bridge and Structures
800 Lincoln Way
Ames, IA 50010

Detail Number: 3.1.1.3 A
Phone Number: (515-239-1393
E-mail: ahmad.abu-hawash@dot.iowa.gov
Detail Classification: Level 2

Components Connected: Precast concrete pier cap to Steel Pipe foundation pile

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek

Connection Details: Manual Reference Section 3.1.1.3 See Reverse side for more information on this connection



**SECTION THROUGH
CORRUGATED METAL PIPE
(CMP)**

PRECAST CONCRETE PIER CAP SECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The three span Boone County IBRC Project included two piers that consisted of 16" diameter steel pipe pile filled with concrete with a precast concrete pier cap. The connection between the pipe pile and the precast cap was made with hooked #8 bars cast into the pipe pile concrete and extending into the void created in the pier cap by the 21" diameter corrugated metal pipe. The pile were driven with a plan end tolerance of 2" in any horizontal direction to ensure that the pile-cap connection would fit together. The voids were filled with a early high strength concrete that exhibited low shrinkage properties.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

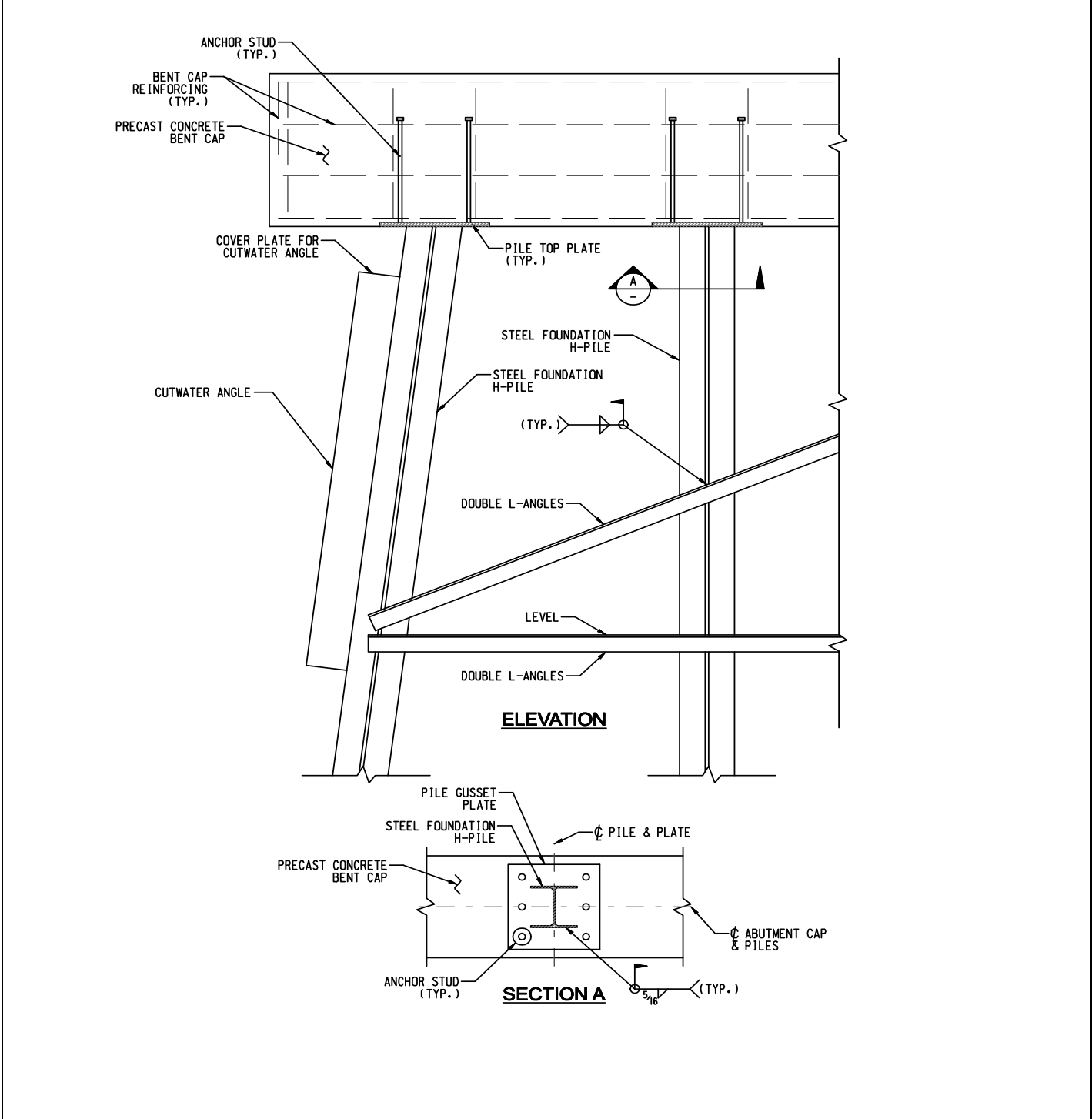
Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

Detail Number: 3.1.1.3 B
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us
 Detail Classification: Level 1

Components Connected: Precast Concrete Bent Cap to Driven Steel H Piling

Name of Project where the detail was used: Bridge over Crow Creek (Wyoming Drawing Number 6291)

Connection Details: Manual Reference Section 3.1.1.3 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Steel plates with shear studs are cast at the pile locations in the bottom of the pier cap. In the field the steel H piles are driven and then cut off level at the elevation of the bottom of the cap. The cap is set on the H piles and then the H piles are field welded to the bottom of the steel plates.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

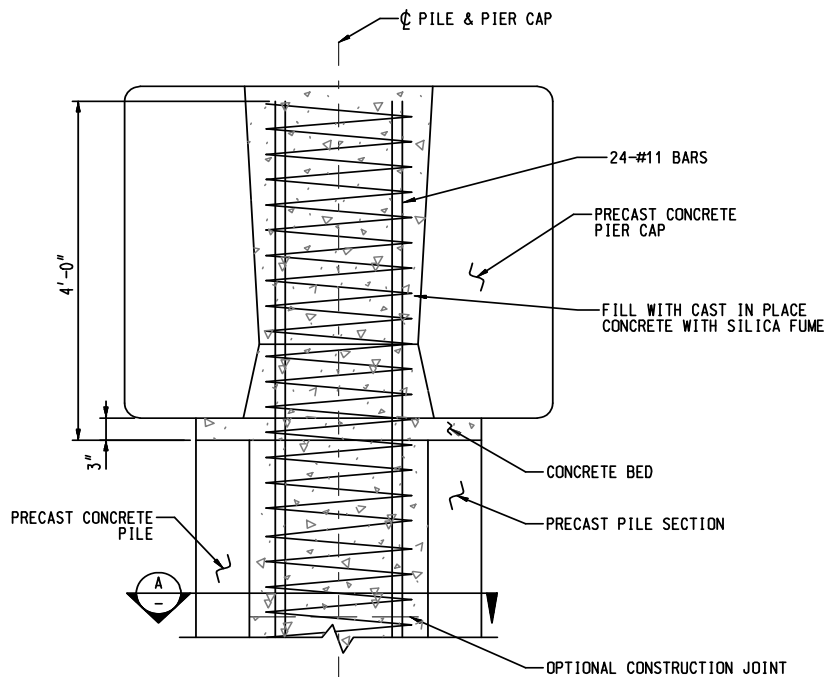
Organization: Florida DOT
 Contact Name: Thomas Andres
 Address: 605 Suwannee Street, MS 33 Tallahassee, FL 32399-0450

Detail Number: 3.1.1.4 A
 Phone Number: 850-414-4269
 E-mail: thomas.andres@dot.state.fl.us
 Detail Classification: Level 2

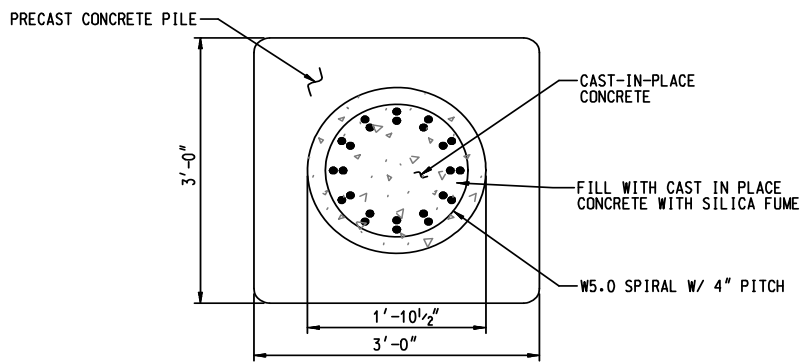
Components Connected: pile cap to Hollow P/S concrete square pile

Name of Project where the detail was used: I-10 Escambia Bay Bridge

Connection Details: Manual Reference Section 3.1.1.4 See Reverse side for more information on this connection



ELEVATION



SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Fit-up issue: pile placement tolerance is important. In order to fit prefabricated pile cap, only 3" lateral tolerance is allowed for each pile.

Design Issue: Consider lateral confining pressure of confined hole; and connection rebar development length for confined concrete.

Durability issues: Shrinkage cracks at pile cap/pile interface especially at top surface of pile cap. Corrosion concern due to shrinkage cracks. Precast element has a tendency to pull water from fresh concrete grout. There are quite a few vertical cracks observed around top of piles after concrete placement. Possible cause: Thermal expansion of concrete.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **Florida DOT**
 Contact Name: **Thomas Andres**
 Address: **605 Suwannee Street, MS 33
 Tallahassee, FL 32399-0450**

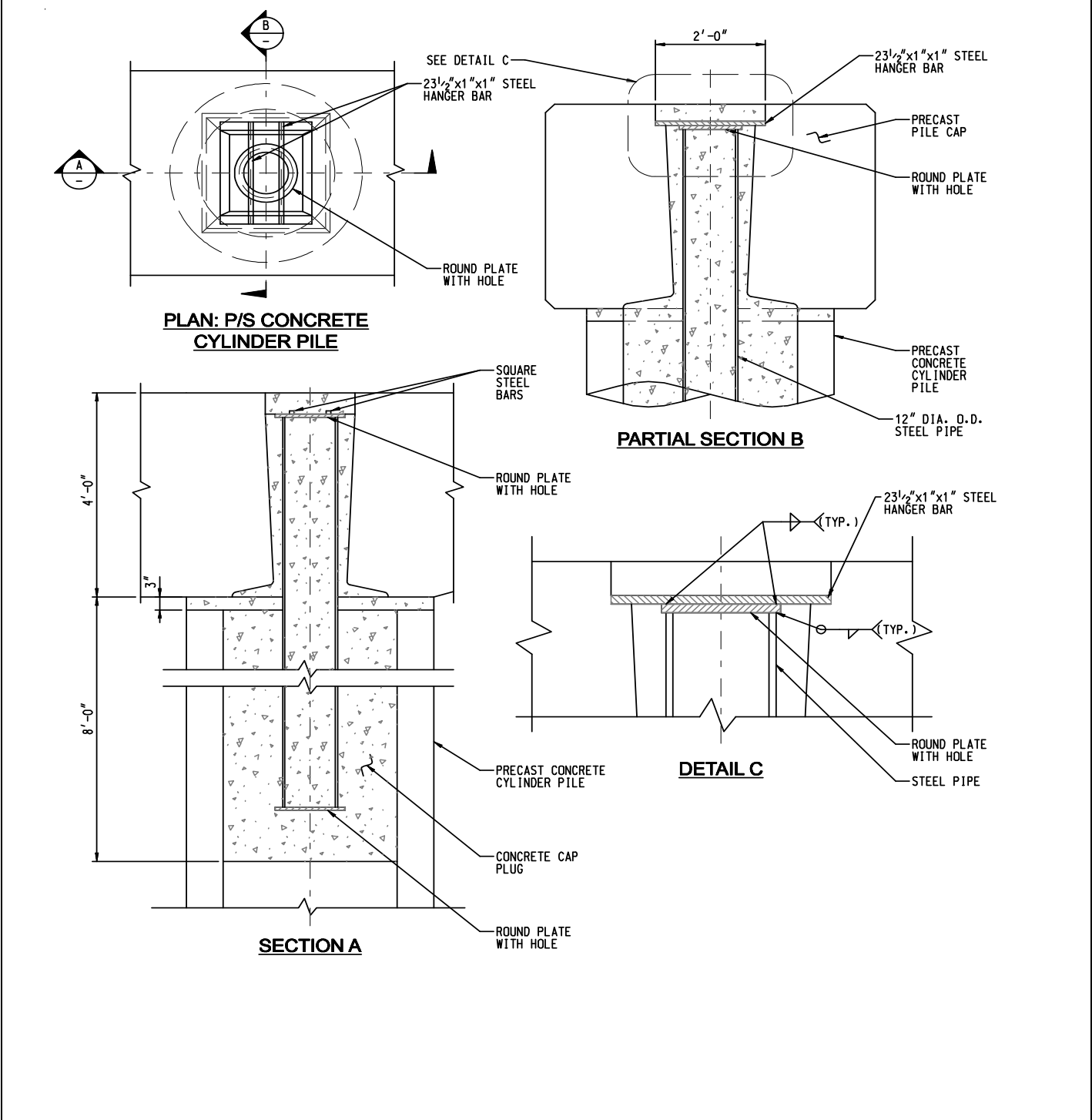
Detail Number: **3.1.1.4 B**
 Phone Number: **850-414-4269**
 E-mail: thomas.andres@dot.state.fl.us

Detail Classification **Level 1**

Components Connected **P/S concrete cylinder pile** to **Precast pile cap**

Name of Project where the detail was used **St George Island Bridge, Florida**

Connection Details: **Manual Reference Section 3.1.1.4** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Water hammer problem on cylinder piles.

Concrete spalling at joints between cylinder segments

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

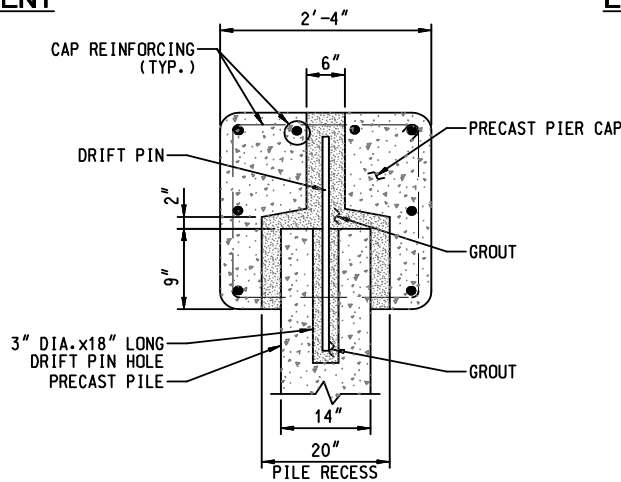
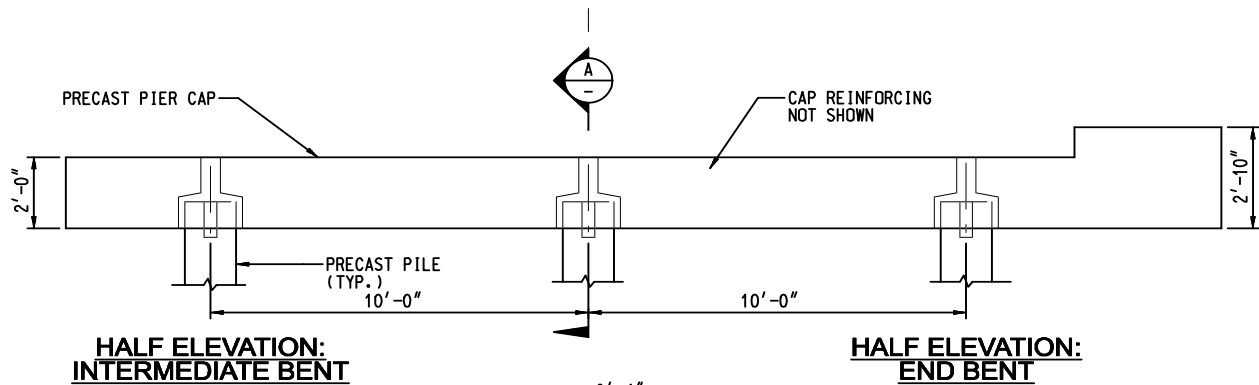
Organization: Louisiana DOT
 Contact Name: Paul Fossier
 Address: Louisiana Department of Transportation
 1201 Capitol Access RD
 Baton Rouge, LA 70804-9245

Detail Number: 3.1.1.4 C
 Phone Number: (225) 379-1323
 E-mail: PaulFossier@dotd.louisiana.gov
 Detail Classification: Level 2

Components Connected: Precast Pier Cap to Precast Piles

Name of Project where the detail was used: Louisiana Forest Highway Kisatchie National Forest Clear Creek Bridge

Connection Details: Manual Reference Section 3.1.1.4 See Reverse side for more information on this connection



**SECTION A:
CAP TO PILE CONNECTION**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The pier to pile connection is designed as a pinned connection that transfers lateral forces and axial compression.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 10 (0 not durable, 10 very durable)

Inspection Access 9 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: South Carolina DOT
 Contact Name: Barry Bowers
 Address: Post Office Box 191
Columbia, South Carolina 29202

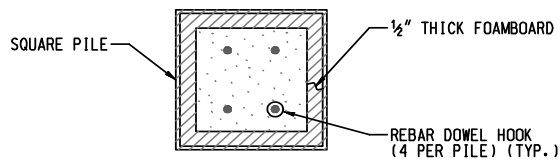
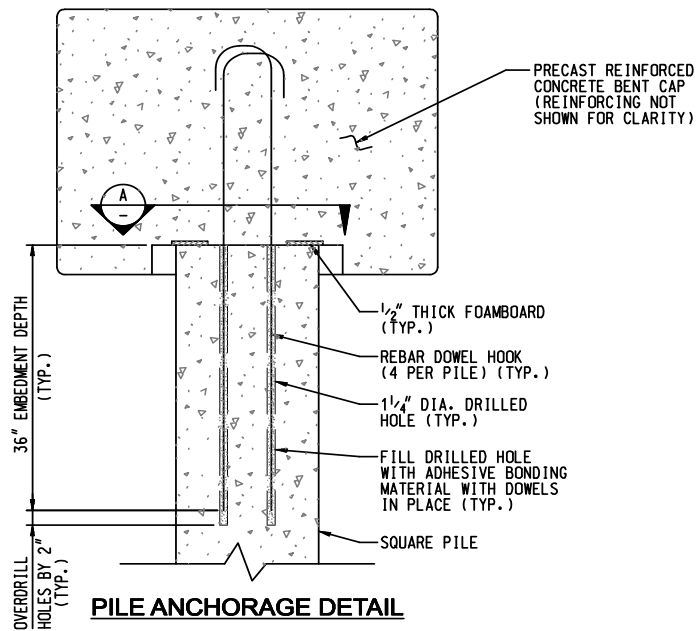
Detail Number: 3.1.1.4 D
 Phone Number: 803-737-4814
 E-mail: bowersbw@scdot.org

Detail Classification Level 2

Components Connected Precast R. C. Bent Cap to Prestressed Concrete Pile

Name of Project where the detail was used Carolina Bays Parkway

Connection Details: Manual Reference Section 3.1.1.4 See Reverse side for more information on this connection



VIEW A: TOP OF PILE DETAIL



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
 Contact Name:
 Address:

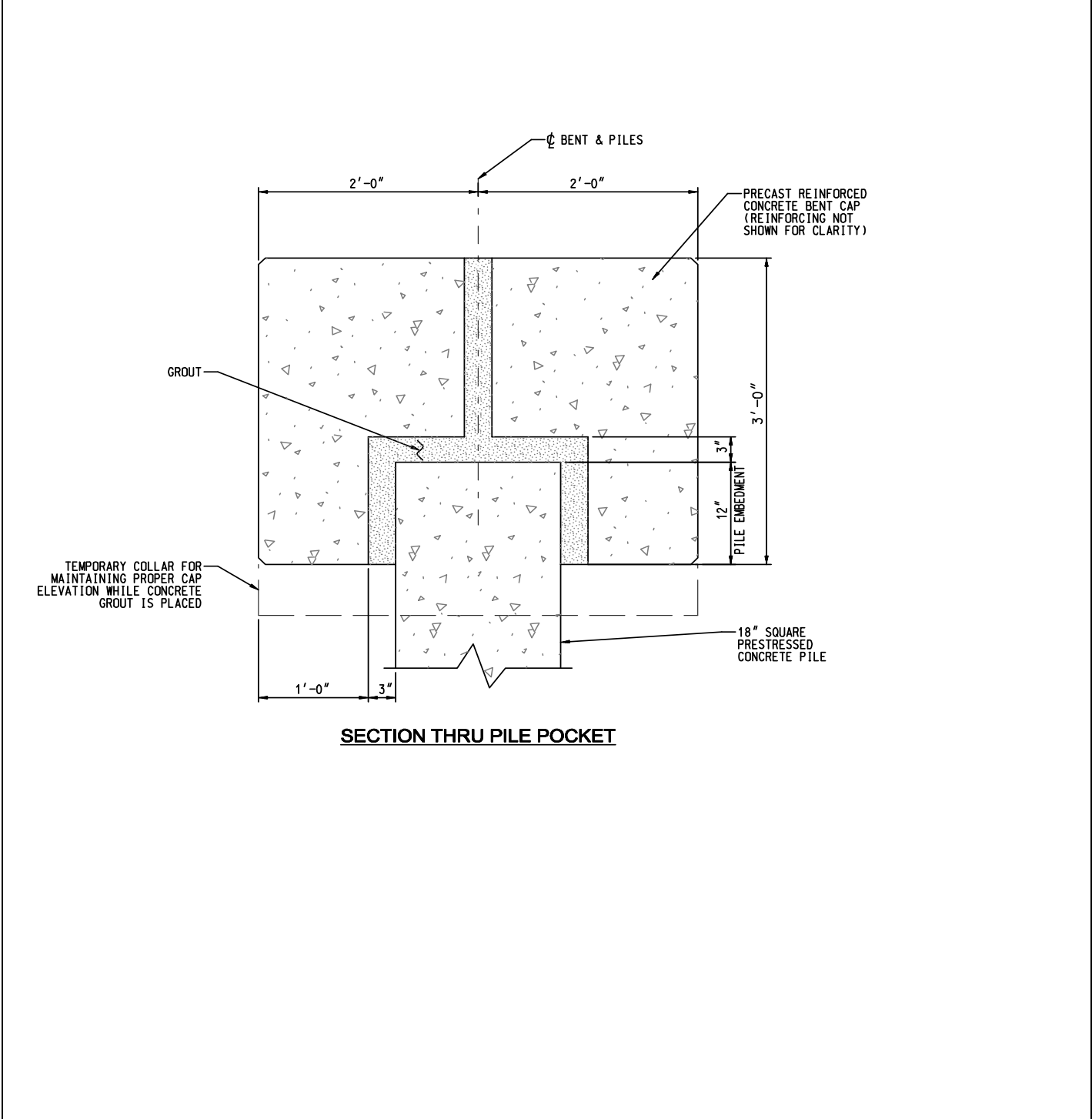
Detail Number:
 Phone Number:
 E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection





Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

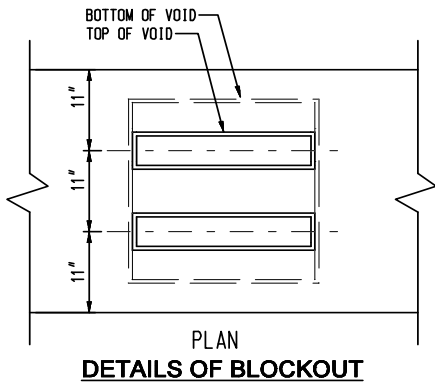
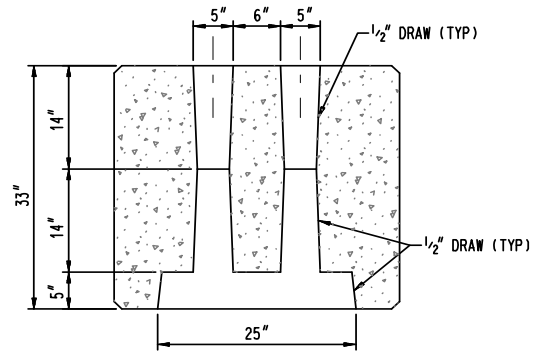
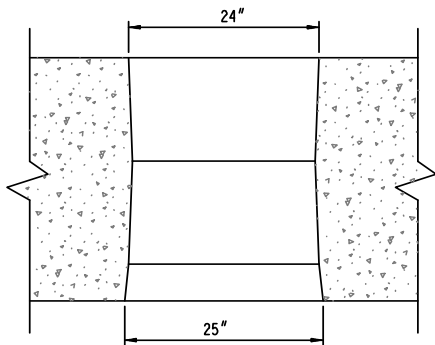
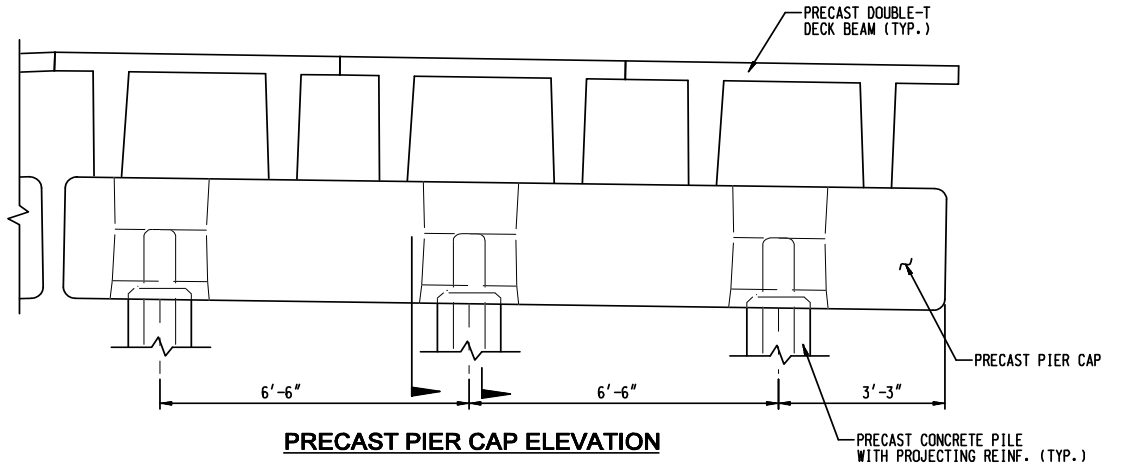
Detail Number: **3.1.1.4 F**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us

Detail Classification **Level 1**

Components Connected **Precast Pier Cap** to **Precast Concrete Pile**

Name of Project where the detail was used **Redfish Bay**

Connection Details: **Manual Reference Section 3.1.1.4** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Editor's Note: The photos shown below were taken during construction. The photo on the left shows the pier cap after being set into positioning on the precast concrete piles. The contractor used a cap leveling system that was strapped to the outside columns (right photo) that was used to set the cap grades.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

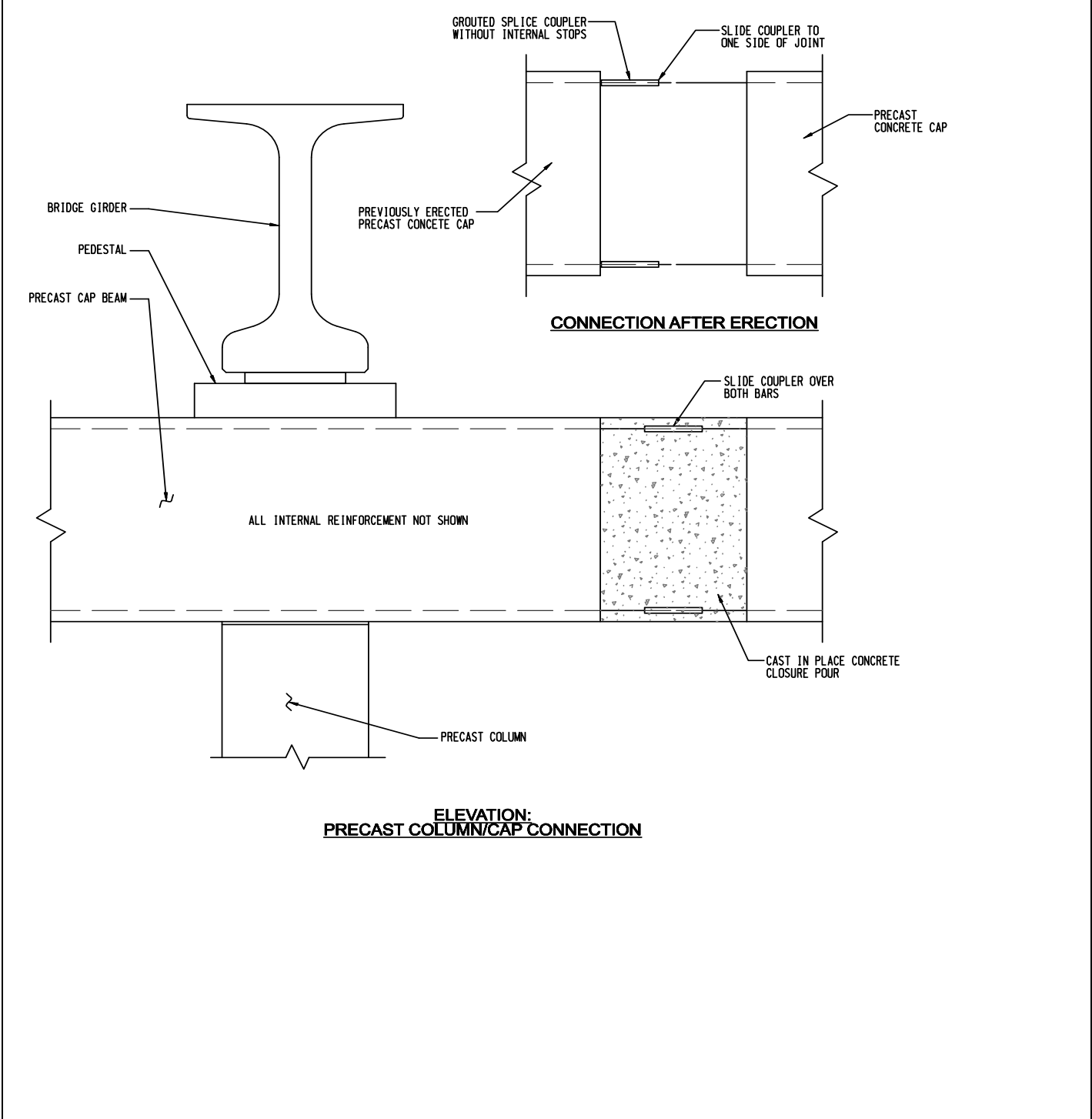
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **3.1.1.5 A**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 3**

Components Connected: **Precast Cap Beam** to **Precast Cap Beam**

Name of Project where the detail was used: **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 3.1.1.5** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges with multi-column bent piers. Details similar to these have been used in precast parking garage and stadium projects. The performance information listed below is based on these structures. The grouted spicers can be placed in the cap beam. The cap beam is shimmed to grade and grouted. Long cap beams may require a joint due to shipping and weight limitations.

This connection has never been used on a bridge; however it is quite common in the vertical construction industry.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? never Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 7 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 8 (0 difficulty making connection, 10 went together easily)

Cost 7 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 8 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

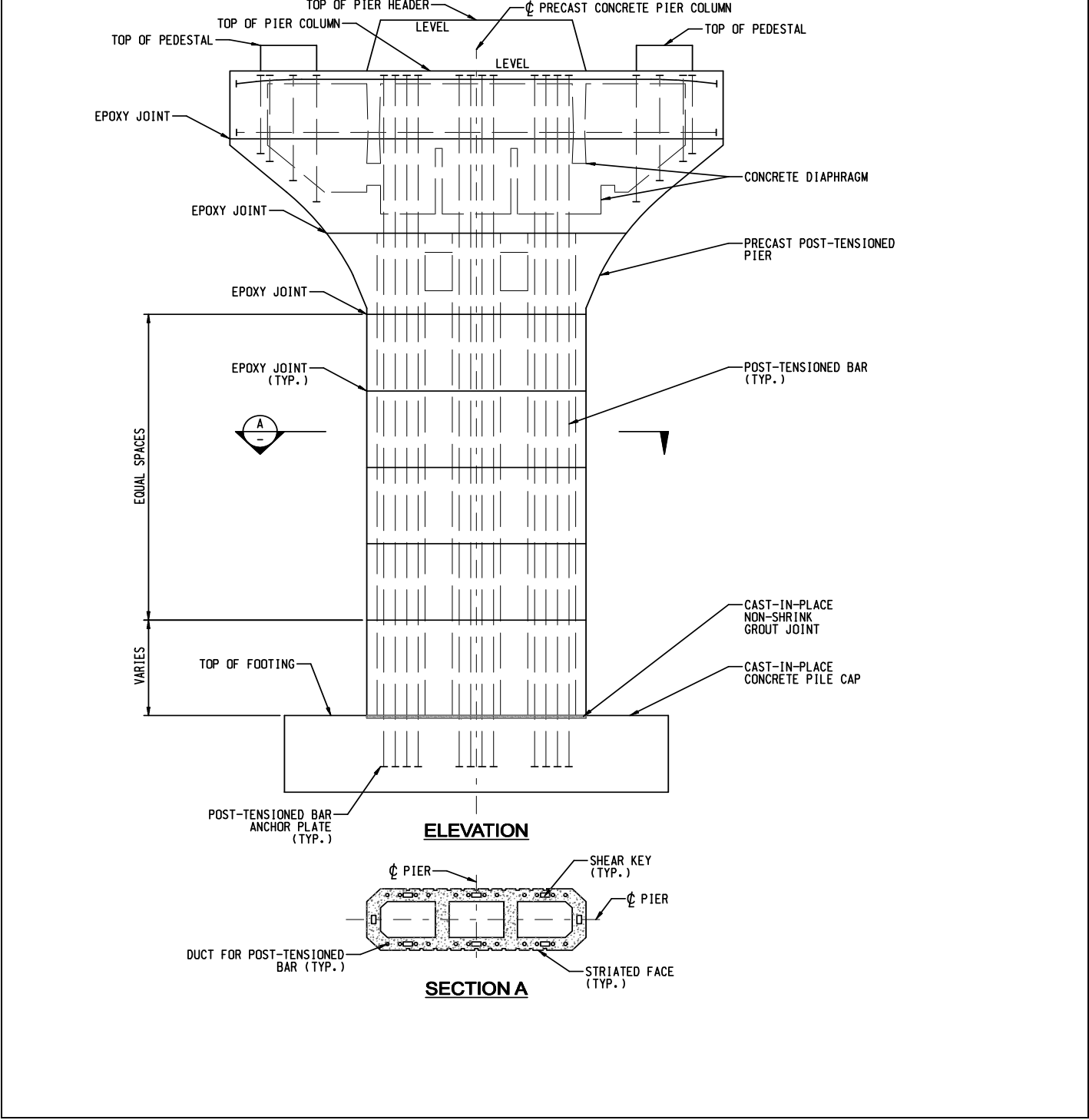
Organization: **New York State DOT**
 Contact Name: **Nicolas A. Choubah**
 Address: **Regional Structures Group
 4 Burnett Blvd.
 Poughkeepsie, NY 12603**

Detail Number: **3.1.2.1 A**
 Phone Number: **(845) 431-7924**
 E-mail: **nchoubah@dot.state.ny.us**
 Detail Classification: **Level 1**

Components Connected: **Precast Concrete Pier Column** to **Precast Concrete Pier Column**

Name of Project where the detail was used: **Replacement of I-287 Viaduct over the Saw Mill River Parkway**

Connection Details: **Manual Reference Section 3.1.2.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast post-tensioned piers were used to speed up the construction. Due to smaller footprint at bottom, this type of pier can be used for viaducts or for elevated rail or expressways in the median of an existing roadway section. This approach is expensive for a small bridge, but it is fast and economical for multiple span bridges with heavy traffic. The subject bridge had 8 bents with 3 piers each = 24 piers.

The detail shown is the connection between adjacent pier segments. Joints were sealed and bonded with epoxy adhesive. Shear was transferred between pieces by means of shear keys in the precast pieces.

PT rods were embedded in the cast in place footing and spliced with couplers at several levels. Upon the completion of the installation of all segments, the entire pier was post tensioned.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

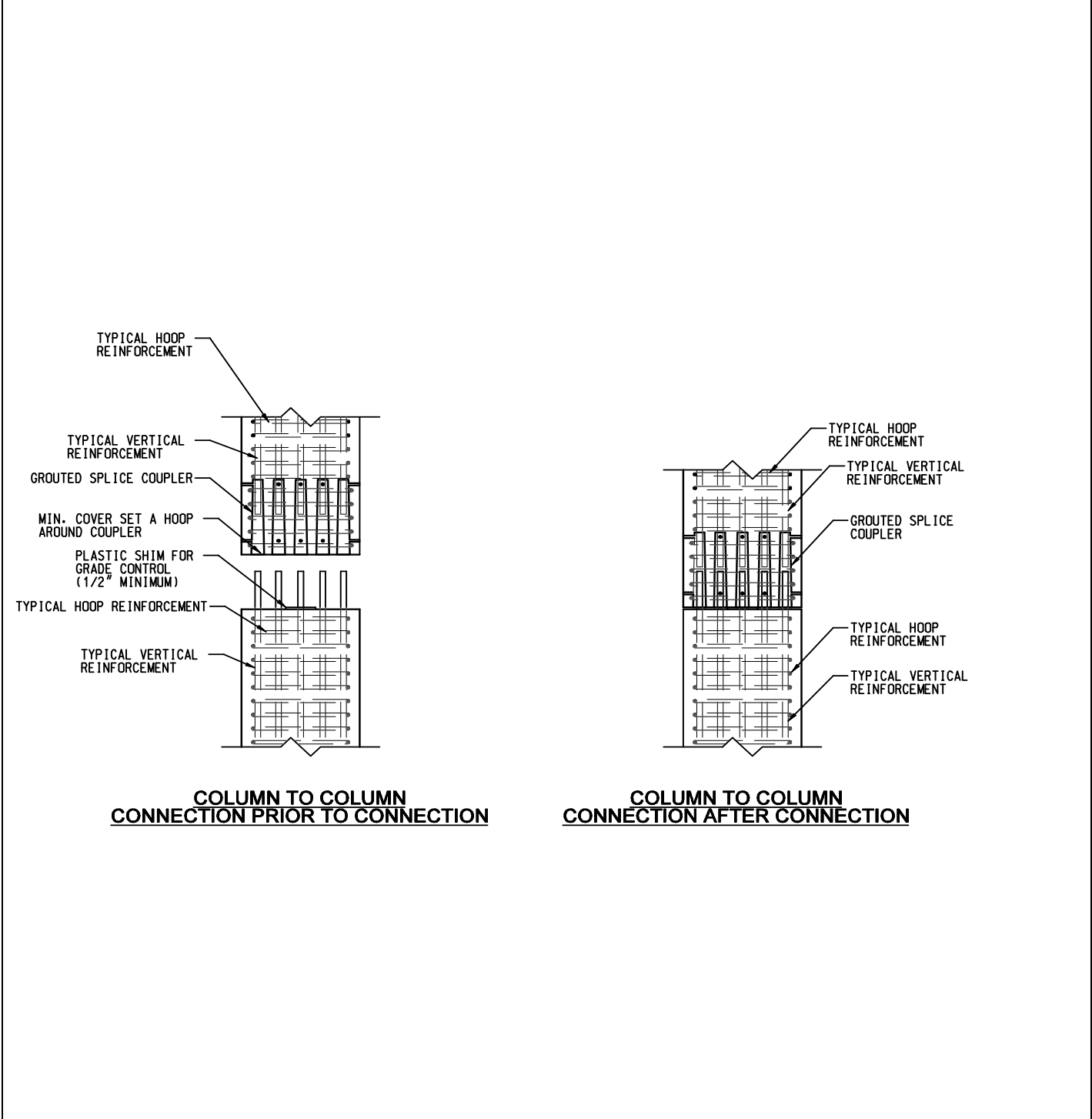
Organization: **Utah DOT via CME Associates, Inc.**
 Contact Name: **Michael P. Culmo, P.E.**
 Address: **333 East River Drive, Suite 400
 East Hartford, CT 06108**

Detail Number: **3.1.2.1.B**
 Phone Number: **860-290-4100**
 E-mail: **culmo@cmeengineering.com**
 Detail Classification: **Level 1**

Components Connected **Precast Pier Column Section** to **Precast Pier Column Section**

Name of Project where the detail was used **Under Development**

Connection Details: **Manual Reference Section 3.1.2.1** See Reverse side for more information on this connection

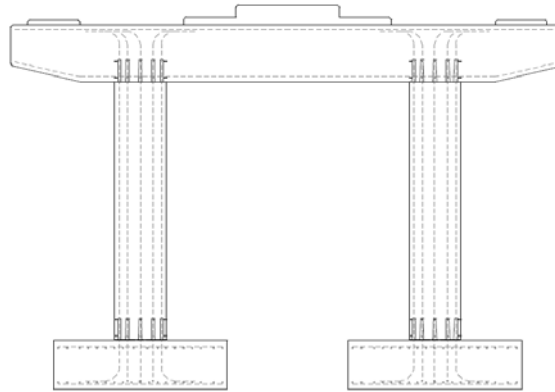
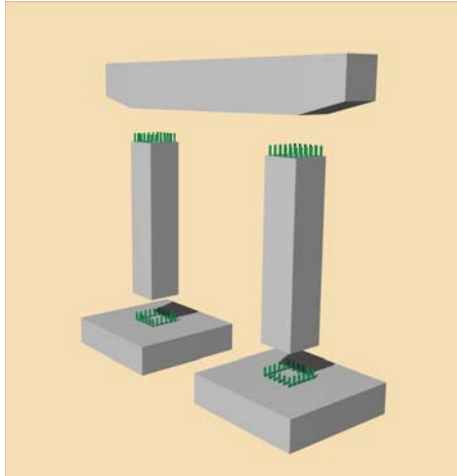


Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The UTAH DOT is currently in the process of developing standard details for prefabricated bridge elements. The detail depicted is based on several successful details that are included in the manual. The success of the other projects warranted the Level 1 detail classification. The details below depict one of the preliminary pier configurations. Others are also being developed.

CME Associates is developing the standard details; therefore they are listed as the contact.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment x Compression x Tension x Torsion x

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? 0 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 7 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

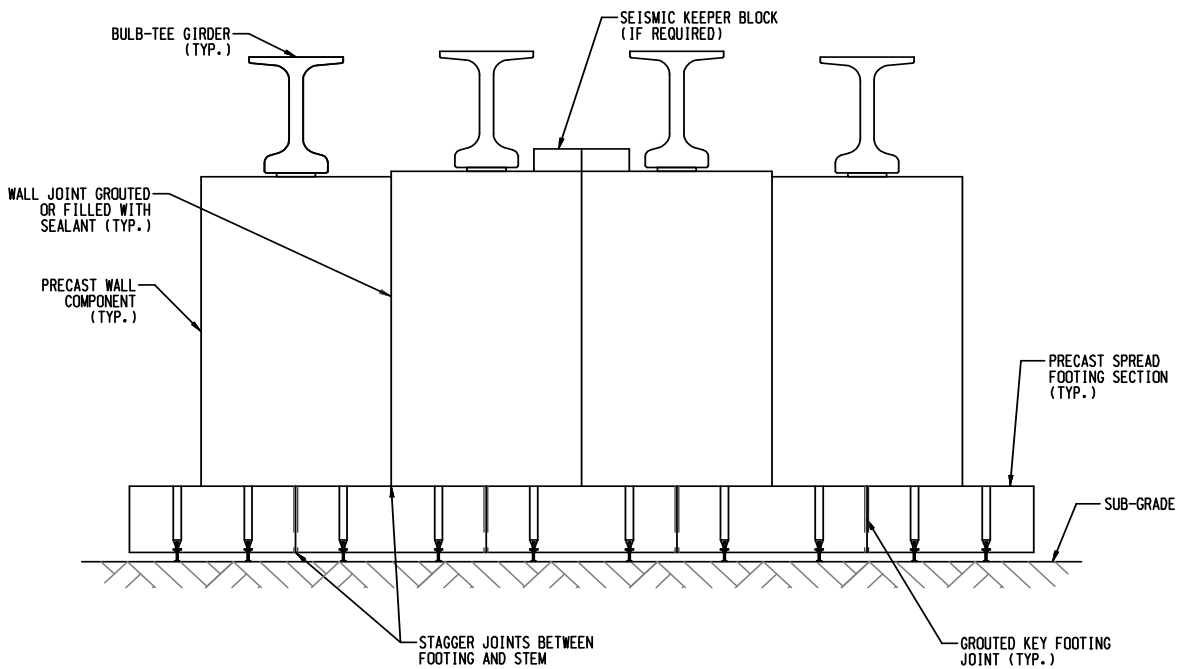
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **3.1.3.1 A**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 3**

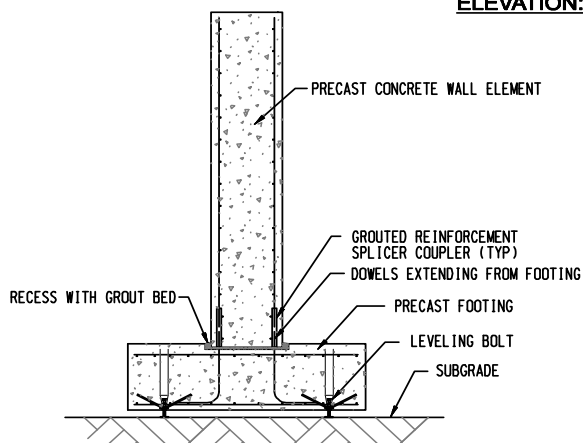
Components Connected: **Precast spread footing** to **Precast Wall Pier Stem**

Name of Project where the detail was used: **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 3.1.3.1** See Reverse side for more information on this connection



ELEVATION: WALL PIER



TYPICAL SECTION - WALL PIER

NOTE: GROUDED SPLICERS MAY BE PLACED IN THE FOOTING IF SPACE PERMITS

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges with wall piers. This detail is very similar to an abutment detail that was successfully built in Epping, New Hampshire. The performance information listed below is based on the Epping Bridge Abutment. Leveling bolts are used in the corners to set grade, and a small aggregate concrete is poured through ports to fill the void under the footing. The design of the footings and walls are the same as cast-in-place concrete construction. Wall pier footings and stems are designed as one-way cantilevers; therefore the joints between the pieces need not be reinforced. Grouted keys or foam filled joints are acceptable.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

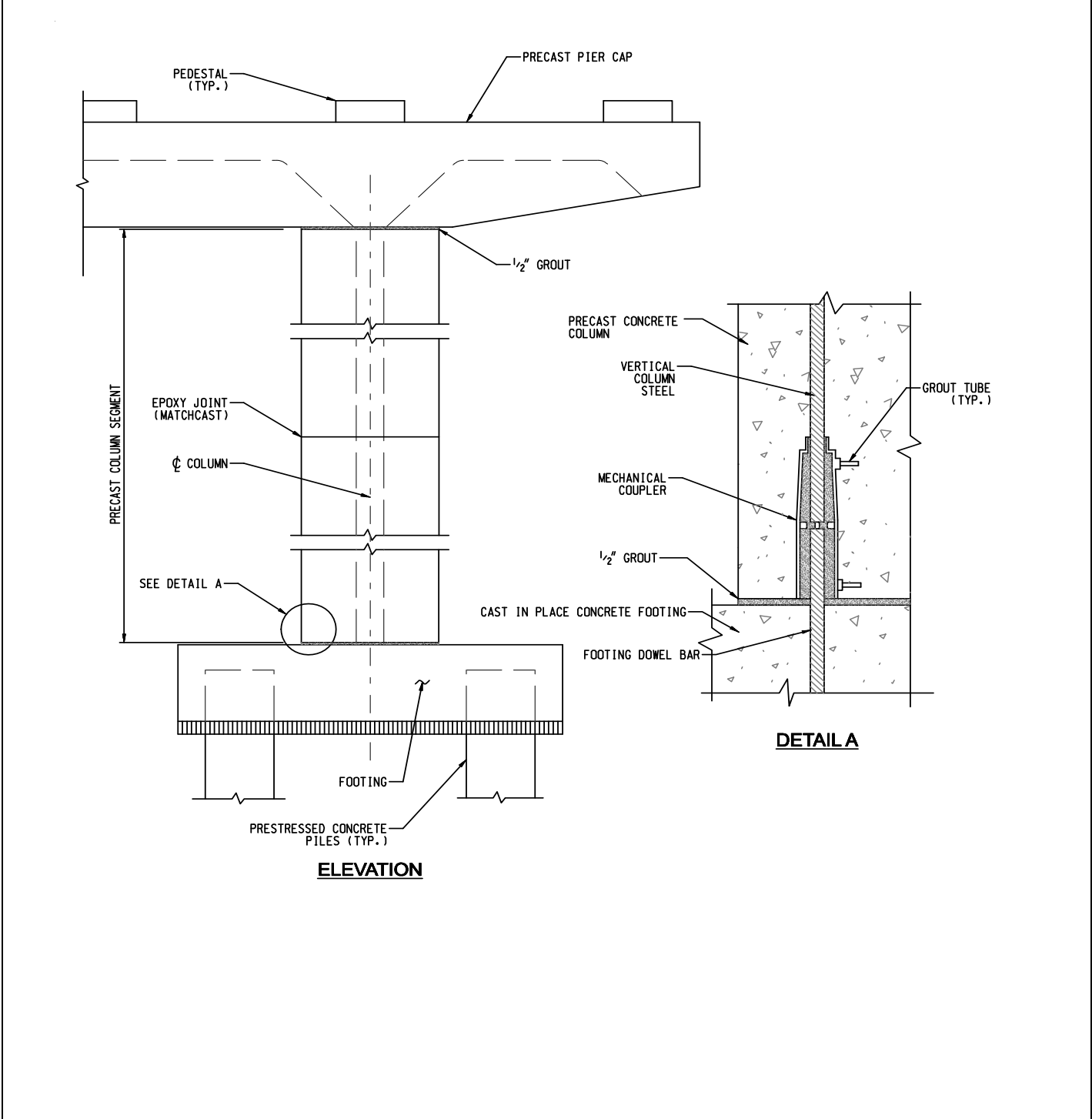
Organization: Florida DOT
 Contact Name: Thomas Andres
 Address: 605 Suwannee Street, MS 33
 Tallahassee, FL 32399-0450

Detail Number: 3.1.4.1 A
 Phone Number: 850-414-4269
 E-mail: thomas.andres@dot.state.fl.us
 Detail Classification: Level 2

Components Connected: Cast-in-place footing to Precast Pier Column

Name of Project where the detail was used: Edison Bridge

Connection Details: Manual Reference Section 3.1.4.1 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This Connection was made with a steel grouted reinforcing bar splicer system. The grouted splicers can develop over 150% of bar yield.

Quality control on bar and splicer locations are critical. The splicers can be oversized to accommodate approximately 1/2" of tolerance.

The only design effect is that the bars must be moved closer to the center of the members in order to maintain cover around the splicers (approx. 1").

This design incorporates an H shaped column section to reduce weight. Contractor's labor and insurance costs less due to reduced time on the water.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

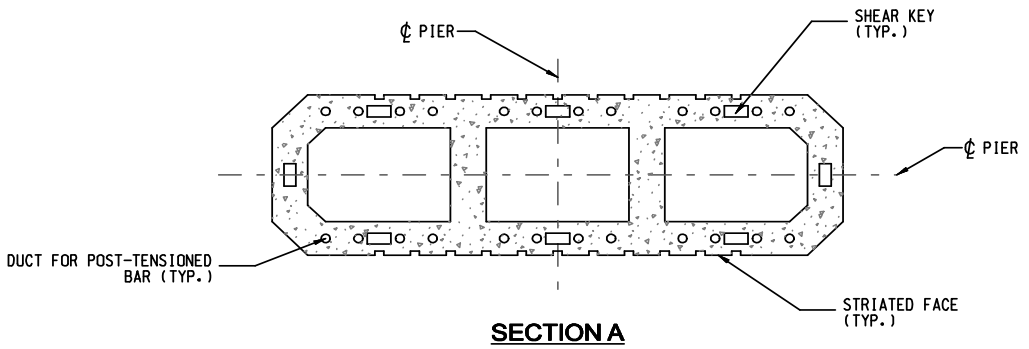
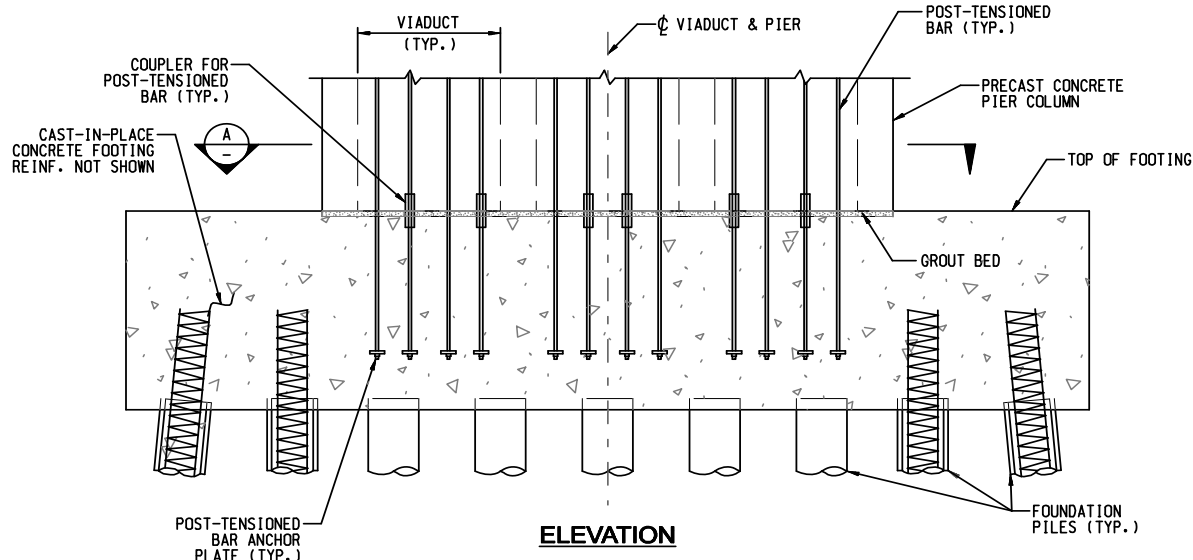
Organization: **New York State DOT**
 Contact Name: **Nicolas A. Choubah**
 Address: **Regional Structures Group
 4 Burnett Blvd.
 Poughkeepsie, NY 12603**

Detail Number: **3.1.4.1 B**
 Phone Number: **(845) 431-7924**
 E-mail: **nchoubah@dot.state.ny.us**
 Detail Classification: **Level 1**

Components Connected: **Precast Concrete Pier Column** to **CIP Concrete Footing**

Name of Project where the detail was used: **Replacement of I-287 Viaduct over the Saw Mill River Parkway**

Connection Details: **Manual Reference Section 3.1.4.1** See Reverse side for more information on this connection



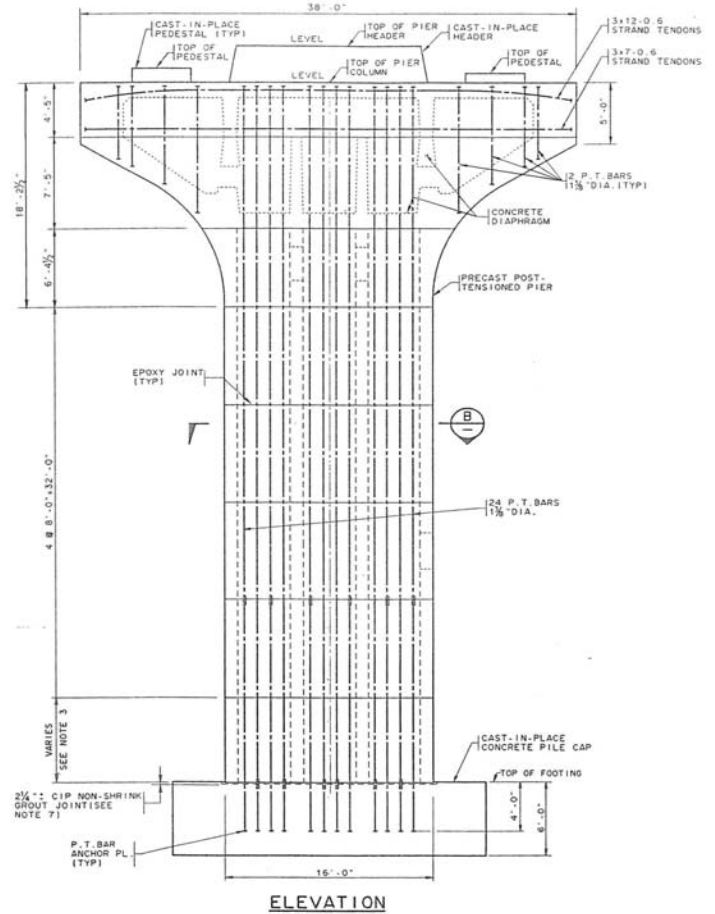
Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Precast post-tensioned pier were used to speed up the construction. Due to smaller footprint at bottom, this type of pier can be used for viaducts or for elevated rail or expressways in the median of an existing roadway section. This approach is expensive for a small bridge, but it is fast and economical for multiple span bridges with heavy traffic. The subject bridge had 8 bents with 3 piers each = 24 piers.

The detail shown is the connection between the bottom pier segment and the footing. The piece was placed in a grout bed. Intermediate joints were connected sealed and bonded with epoxy adhesive. Shear was transferred between pieces by means of shear keys in the precast pieces.

PT rods were embedded in the cast in place footing and spliced with couplers at several levels. Upon the completion of the installation of all segments, the entire pier was post tensioned.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

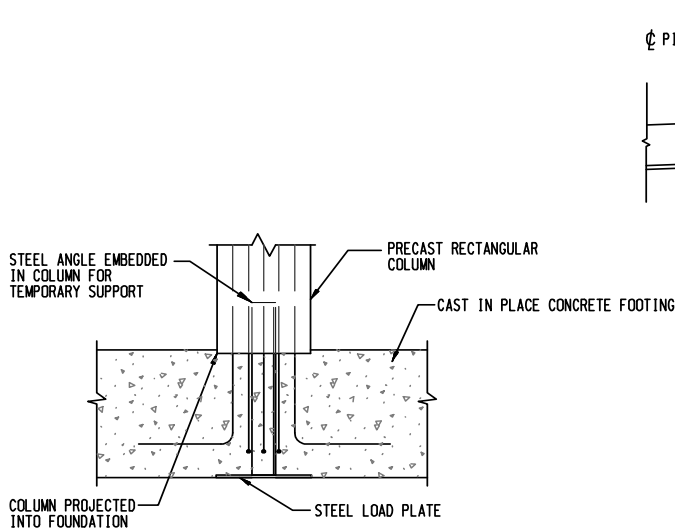
Organization: **WSDOT - Bridge Office**
 Contact Name: **John Olk, P.E.**
 Address: **P O Box 47340
 Olympia, WA 98504**

Detail Number: **3.1.4.1 C**
 Phone Number: **360-705-7395**
 E-mail: **olkj@wsdot.wa.gov**
 Detail Classification: **Level 2**

Components Connected: **Precast Rectangular Column** to **Cast in Place Footing**

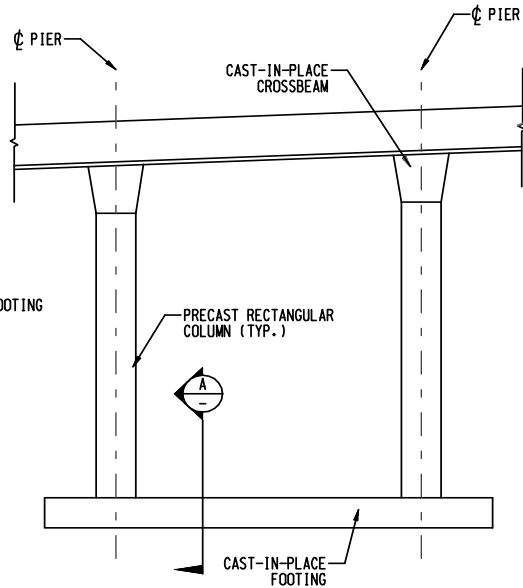
Name of Project where the detail was used: **I-405, Bellevue Access Transit NE 4th / NE 6th**

Connection Details: **Manual Reference Section 3.1.4.1** See Reverse side for more information on this connection

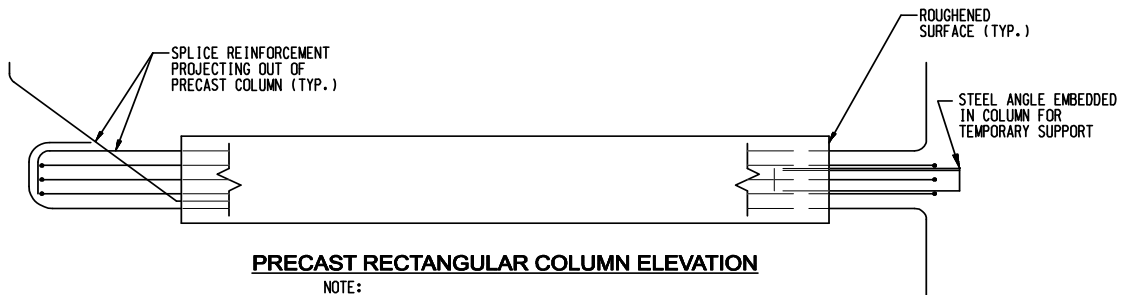


SECTION A

NOTE: COLUMN STIRRUPS AND FOOTING REINFORCING NOT SHOWN FOR CLARITY



PIER ELEVATION



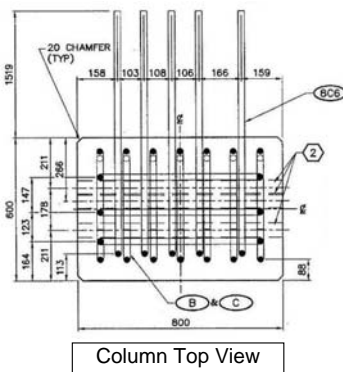
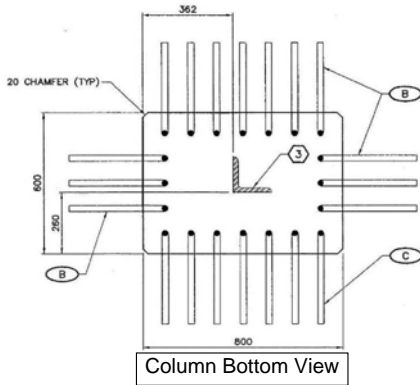
PRECAST RECTANGULAR COLUMN ELEVATION

NOTE: MAIN COLUMN REINFORCEMENT NOT SHOWN FOR CLARITY.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection of a precast concrete column, temporarily supported, to a cast in place footing. This details can be used for any type of cast in place column. The column is precast with an embedded 6x6x3/4 steel angle that is used to support the column temporarily. The angle bears on a 4 by 4 foot, 8 inch concrete pad. The photo below shows the columns in the field, with a temporary concrete pad in the lower left.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

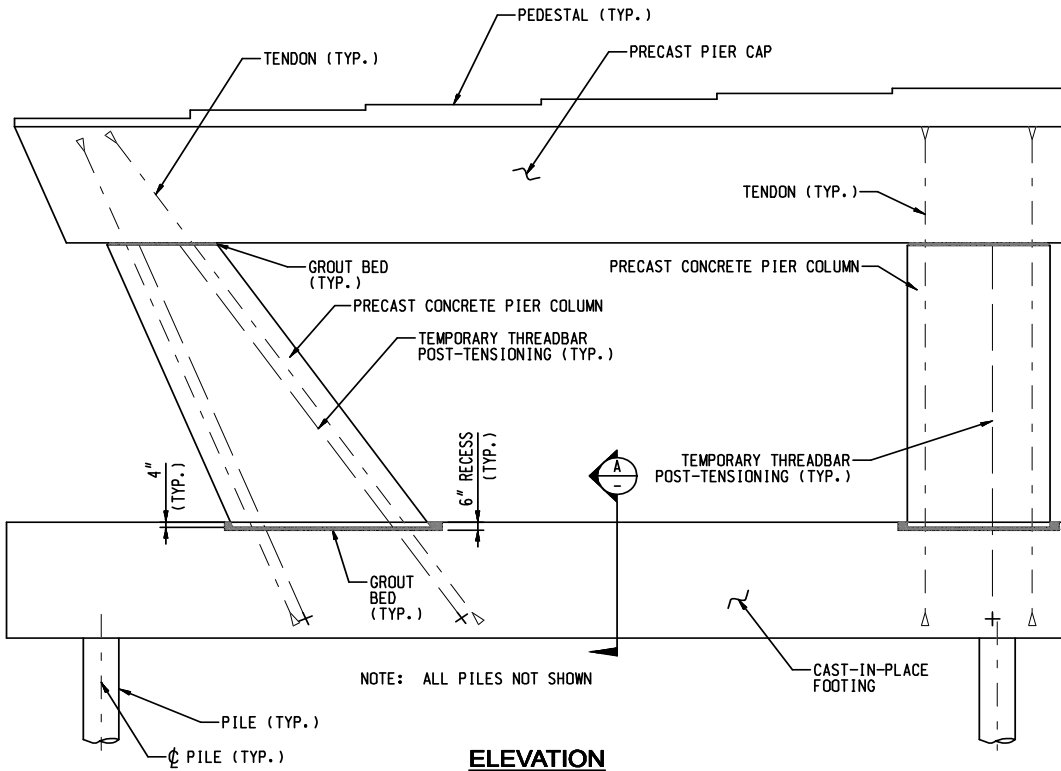
Organization: **Arora & Associates, P.C.**
 Contact Name: **Alan Haring, P.E.**
 Address: **3120 Princeton Pike
 Lawrenceville, NJ 08648**

Detail Number: **3.1.4.1 D**
 Phone Number: **(609)219-6785**
 E-mail: **aharing@arorapc.com**
 Detail Classification: **Level 2**

Components Connected **Precast Pier Column** to **Cast in place footing**

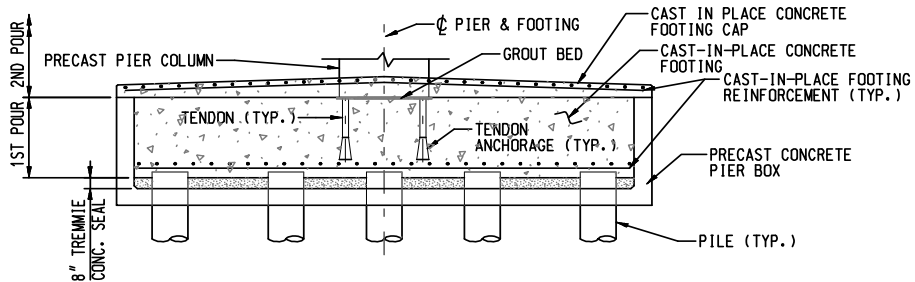
Name of Project where the detail was used **Route 70 over Manasquan River, Brielle, NJ**

Connection Details: **Manual Reference Section 3.1.4.1** See Reverse side for more information on this connection



ELEVATION

NOTE: THE PIER WAS CONSTRUCTED IN TWO STAGES. STAGE 1 IS SHOWN



SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection provides a means of connecting the precast column segments to the cast-in-place footing. This allows for the accelerated construction of the piers above the footing level using precast concrete construction. The anchorage devices specified in the contract plans are proprietary. The project was designed with Inclined columns with a trumpet shaped anchorages, which allowed strand to be placed and grouted after the column has been erected. Temporary threaded PT bars were used to support the columns until the cap beams were placed.

The Contractor substituted alternative details, which eliminated temporary column post-tensioning. A single full-height column section was used. All post tensioning was accomplished with threaded PT bars in place of the strand tendons.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization:
Contact Name:
Address:

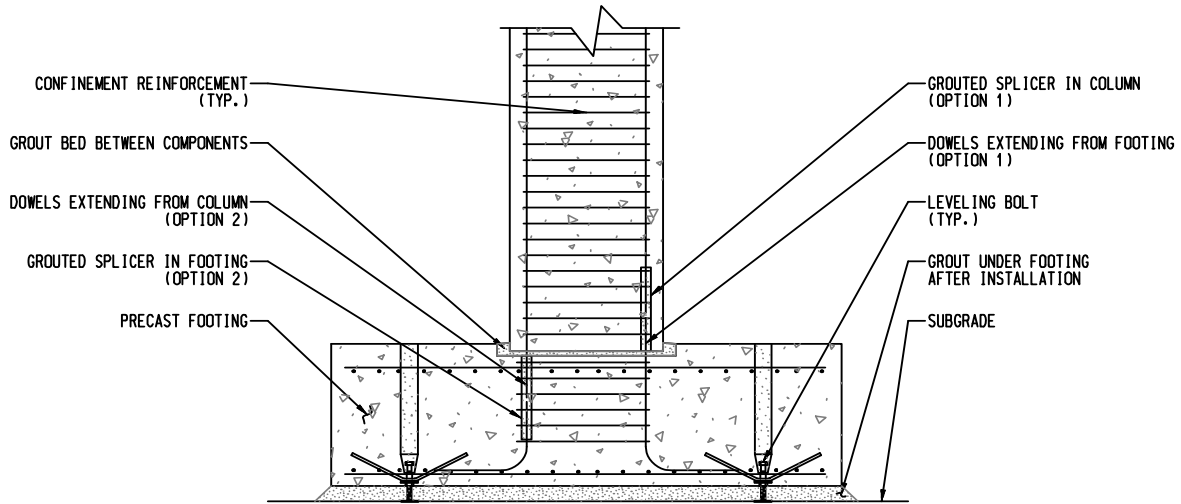
Detail Number:
Phone Number:
E-mail:

Detail Classification:

Components Connected: to

Name of Project where the detail was used:

Connection Details: See Reverse side for more information on this connection



PRECAST FOOTING/COLUMN CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges with multi-column bent piers. This detail is very similar to an abutment detail that was successfully built in Epping, New Hampshire. The performance information listed below is based on the Epping Bridge Abutment. The leveling bolts are used to set grade. After placement, the void under the footing is grouted through ports in the footing. The leveling bolt access holes are also grouted. The grouted splicers can be placed in the column or the footing. The columns are shimmed to grade and grouted. Square, hexagonal and octagonal columns are preferred over round columns because they can be cast in the flat position.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

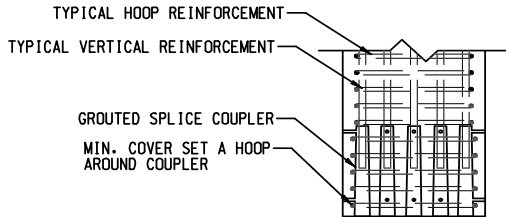
Organization: **Utah DOT via CME Associates, Inc.**
 Contact Name: **Michael P. Culmo, P.E.**
 Address: **333 East River Drive, Suite 400
 East Hartford, CT 06108**

Detail Number: **3.1.4.2 B**
 Phone Number: **860-290-4100**
 E-mail: **culmo@cmeengineering.com**
 Detail Classification: **1**

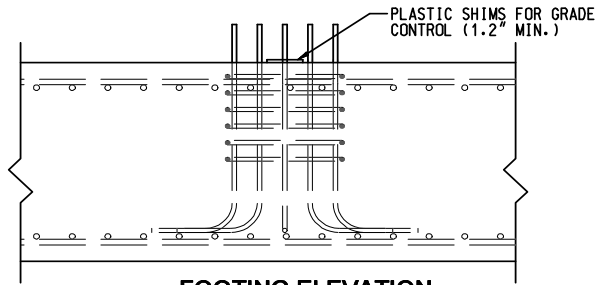
Components Connected **Precast Column** to **Precast spread footing**

Name of Project where the detail was used

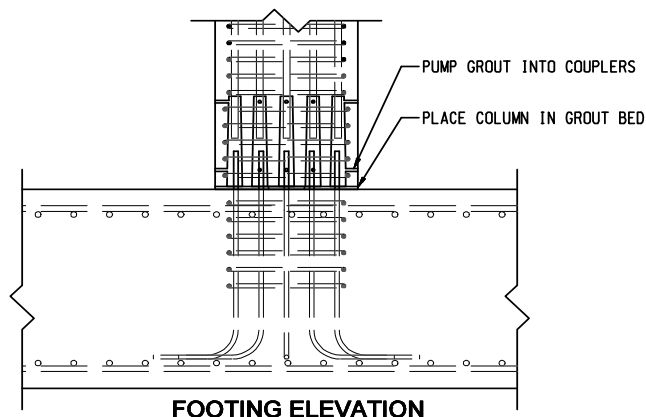
Connection Details: **Manual Reference Section 3.1.4.2** See Reverse side for more information on this connection



COLUMN ELEVATION



**FOOTING ELEVATION
 COLUMN TO FOOTING CONNECTION
 PRIOR TO CONNECTION**



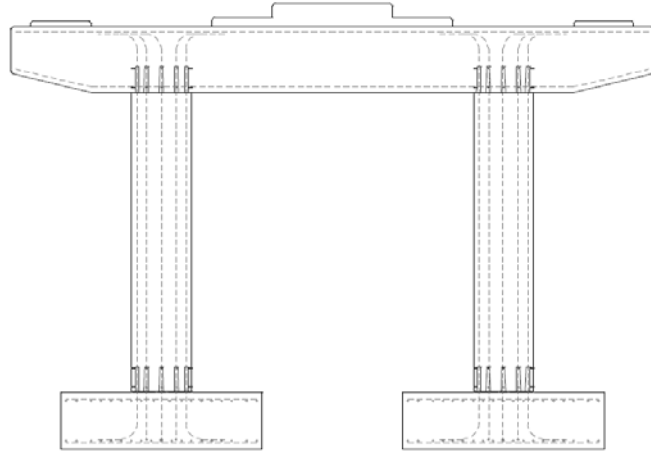
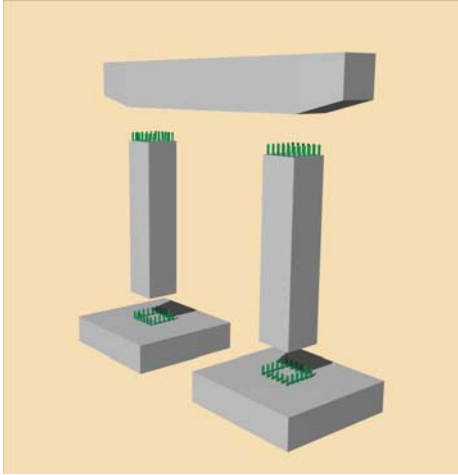
**FOOTING ELEVATION
 COLUMN TO FOOTING CONNECTION
 AFTER CONNECTION**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

The UTAH DOT is currently in the process of developing standard details for prefabricated bridge elements. The detail depicted is based on several successful details that are included in the manual. The success of the other projects warranted the Level 1 detail classification. The details below depict one of the preliminary pier configurations. Others are also being developed.

CME Associates is developing the standard details; therefore they are listed as the contact.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear x Moment x Compression x Tension x Torsion x

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? 0 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 9 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 7 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

3.2 Abutment Systems

Most states have not attempted prefabricated abutment designs; however several have had very successful projects. Abutment construction can be a slow process; therefore prefabrication offers an opportunity to greatly reduce the overall project time. There are different types of abutments in use today in the United States. Integral and semi-integral abutments are gaining popularity over conventional free standing wall abutments. Both types of abutments have been built using prefabricated elements; therefore designers can detail prefabricated abutments for virtually any abutment configuration that is in use today.

The spread footings and other substructure components for the Epping Bridge in New Hampshire were fabricated in segments as determined by the contractor and precaster to facilitate shipping and handling, and were standardized to reduce fabrication costs. The precaster used a template in the plant fabrication to ensure adequate tolerances between the abutments, wingwalls, and footing segments. The contractor developed the assembly plan.

Backfilling Options:

All abutments require some level of filling. Earth placement can be time consuming; however there are some methods that can be employed to reduce filling times.

One method is to use flowable fill for the backfill soils. Flowable fill is a mixture of sand, water and minor amounts of cement. It can be installed without compaction since it is in a semi-liquid state when placed. Therefore, flowable fill can dramatically reduce the amount of time to complete the backfilling. The only disadvantages are that the backfill area needs to be contained or formed so the fill does not spill out, and the material cost is somewhat higher than granular backfills. Designers should also note that flowable fills have different soil properties than compacted fill, which will affect the design of the abutments. The fill generally has a slightly higher unit weight when placed (approximately 125 pcf). Once set, the fill has very high passive pressure resistance since it is essentially a concrete product. For this reason, it should not be used behind integral abutments where abutment movement could generate large passive pressures against the fill.

Another method for reducing backfilling times is to use foam block fill materials. These blocks are normally made with expanded polystyrene. They are very lightweight and easy to install. The blocks are simply stacked behind the abutment. This system can greatly reduce the forces acting on the abutment stems; however there is also a reduction in overturning resistance on the top of the footings. The disadvantages to this system is that there needs to be a certain amount of fill placed over the blocks to support wheel loads, the system can float out of the ground if there is a high water table, the system needs to be waterproofed against certain types of spills, and they can be expensive when compared to conventional granular fills.

On an accelerated construction project, it may be preferable to allow one or both of these backfilling methods in combination with conventional

granular backfill. The contractor can then choose whether or not to use the compacted granular fill or one of these methods.

3.2.1 Cantilever Wall Abutments

Cantilever abutments serve two purposes. They need to retain the soils behind the ends of the bridge and they need to support the bridge superstructure. Some wall abutments are referred to as stub abutments. These abutments are made as short as possible and are installed at the top of fill embankments. Stub abutments usually only retain soils that are slightly higher than the superstructure thickness. Stub abutments can be very economical; however they tend to increase the length of the end spans. Other wall abutments can be much taller and are often constructed to the full height of the crossing. Full height abutments are more difficult to build; however they tend to reduce the length of the end spans.

The New Hampshire DOT has constructed one prefabricated bridge in Epping, New Hampshire, using precast concrete wall abutments. The abutments were designed as conventional cast-in-place concrete abutments; however the construction joints were replaced with connections that used grouted reinforcing splice couplers. Full height abutments were used to reduce the main span length. Both abutments were constructed in less than three (3) days once the excavation was complete. The details on the Epping Bridge can easily be used for any bridge since the connections simply emulate a cast-in-place concrete construction joint. See the Case Study of this bridge in Appendix D for more information on this bridge.

3.2.1.1 Precast Abutment Stem to Precast Footing Connection

Spread footings provide significant speed and simplicity to bridge construction when soil conditions permit their use. At least one state has built a prefabricated abutment wall structure that was supported on precast concrete footings. This was the Epping Bridge in New Hampshire. The connection was made using grouted reinforcing splice couplers. The splice was set in a recessed pocket in the footing. This pocket may not be necessary for shear; however it was used to provide head for flowing the grout into the joint. The same precast producer constructed both elements; therefore the fit-up of the couplers was not a problem.

3.2.1.2 Precast Backwall to Abutment Stem Connection

Backwalls are primarily used to support the soil directly behind the beam ends. Often they are also used to support concrete approach slabs.

The connection of a precast concrete backwall to a precast concrete abutment stem can be made in a similar fashion as the stem to footing connection described in Section 3.2.1.1 above. Grouted reinforcing splice couplers can be used to provide a moment connection for these elements. Other typical connection methods can also be used for this element. See Section 1.4 for more information on connection options.

3.2.1.3 Precast Breastwall (cheekwall) to Abutment Stem Connections

Breastwalls or cheekwalls are often used as a decorative element to conceal the ends of the beams at the corners of the abutments. Some states used these elements to restrain the superstructure from seismic forces.

The connection of a precast concrete breastwall to a precast concrete abutment stem can be made in a similar fashion as the stem to footing connection described in Section 3.2.1.1 above. Grouted reinforcing splice couplers can be used to provide a moment connection for these elements. Other typical connection methods can also be used for this element. See Section 1.4 for more information on connection options.

3.2.2 Spill-through Abutments

The intent of spill-through abutments is to reduce the amount of soil pressure on the abutment by installing large voids in the stem. Spill-through abutments are similar to piers except the majority of the structure is below grade. Information in Section 3.1 can be used for prefabricated bridges with spill-through abutments.

3.2.3 Precast Concrete Integral Abutments

Integral abutments get their name because the abutment structure is made integral with the superstructure elements. There are two major advantages for the use of integral abutments:

- Integral abutments do not normally have deck joints. This eliminates one of the most common deterioration areas on bridges.
- Integral abutments transfer the soil forces into the bridge superstructure. The superstructure has tremendous available capacity; therefore this usually has no affect on the superstructure design. Integral abutments are normally supported on a single row of piles that are designed to move with the bridge during thermal cycles. The result of this approach is that the abutment does not need a spread footing or multiple rows of piles to resist the overturning soil forces.

There are two types of integral abutments. The most common is a fully integral abutment where the connection to the superstructure is a full moment connection. The second type of integral abutment is a semi-integral abutment where the moment connection is replaced with a pinned connection that allows rotation of the superstructure with respect to the substructure. See Section 2.5 for information on the connection of the superstructure to integral abutments.

3.2.3.1 Connection Between Abutment Stem or Cap and Steel Piles

There are several options for connecting precast concrete abutment stems or caps to steel piles. Several states have cast the abutment caps with anchored steel plates that can be field welded to the piles after they are cut off to the proper elevation.

Other states embed the piles in large pockets in the precast abutment stem element. After placement over the piles, the void is filled with non-shrink grout or concrete.

3.2.3.2 Connection Between Abutment Stem or Cap and Concrete Piles

There are several options for connecting a precast concrete abutment stem or cap to concrete piles. The first method is to drill and grout reinforcing bars into the top of the pile, and insert these bars into grouted tube couplers in the abutment stem element.

Another option is to embed the piles into large pockets in the precast abutment stem element. After placement over the piles, the void is filled with non-shrink grout or concrete.

3.2.3.3 Connection Between Adjacent Abutment Stems or Caps

In some cases, the integral abutment stem or cap will need to be manufactured in several pieces due to shipping and crane limitations. The Maine DOT built several prefabricated integral abutment bridges with two abutment pieces that were match cast and post-tensioned in the field.

Small closure pours could also be used for this connection since the curing of the closure pour concrete would most likely not restrict the continuation of the bridge construction.

3.2.4 Miscellaneous Abutment Connections

3.2.4.1 Flying Wingwalls

Flying wingwalls are small retaining walls that project from abutment stems. These walls do not have footings or any vertical support. The soil forces are transferred to the abutment stem by means of a vertical moment connection.

Several states have used prefabricated flying wingwalls. Wyoming DOT has used welded plate connection. Plates were embedded and anchored in the elements. During installation, the plates were field welded together. Maine DOT used a match cast piece combined with post-tensioning. This was done because the abutments were constructed with two abutment stem elements in order to reduce shipping and lifting weight. The addition of the flying wingwall pieces to the process of constructing the abutments was not significant.

3.2.4.2 Approach Slabs

Approach slabs are used to prevent the “bump at the end of the bridge” that results from settlement of the approach roadway fills directly behind the abutments. The size of approach slabs vary from state to state. Many states use nominal length approach slabs of approximately 10 to 15 feet in length. These slabs are designed to span from the rear face of the abutment to the roadway approach embankment.

The connection of the approach slab to the abutment is often detailed as pinned connection with minimal reinforcing steel. Maine DOT has prefabricated approach slabs for several bridges. The Maine details are similar to the details shown in this manual from the New Hampshire DOT. The slabs were simply pinned to the abutments by means of simple dowel bars. The other end of the slab was simply set on compacted fill.

3.2.5 Grade Control and Tolerances

As with pier systems, the construction of prefabricated abutment elements can lead to problems with grade and horizontal control. Minor grade and alignment problems can be corrected in other connections above the abutment (haunches in deck pour forming for example); however it is always desirable to make adjustment for grade as the construction progresses. Some of the connections shown in the manual have grout beds or cast-in-place closure pours which can be used to make minor adjustment to grade. This is commonly done by means of small shim packs that are placed between the elements being connected. Often these shims are made of polymer sheets, and are left in place in the finished structure. Steel shims should be avoided because they would represent a hard point that may attract stresses as the structure is loaded, which could lead to spalling of the precast elements.

The use of mechanical connectors requires more careful attention to tolerances in the precast process. If grouted reinforcing splice couplers are used between two precast elements, the designer can specify that the connections be dry connected in the shop to ensure proper fit.

See Section 1.7 for more discussion on tolerances.

3.2.6 Evaluation of Performance and Long Term Durability of Prefabricated Abutment Systems

Generally the abutment connections shown in the manual are relatively new; therefore do not have a significant record of performance. The details used in the New Hampshire Epping Bridge are essentially the same as the Florida Edison Bridge, which has performed very well. It is expected that all of these details will perform very well over time.

Several details included in this manual consist of exposed welded plate connections. These connections should either be used in non-corrosive environments, or made with stainless steel plates. The use of stainless steel connection plates has become common in precast parking garage structures.

Owners should consider how aggressive the environment will be where these connections will be used and select the materials accordingly like stainless steel, galvanized connections, or coated connections. After welding, proper repair of corrosion protection is required. Galvanized or coated elements will require future periodic maintenance.

3.2.7 Estimated Construction Time for Connections

Exact timelines for construction are dependent on a number of factors including site access, traffic control, weather, crane locations and storage areas. It is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Table 3.2.7-1 contains approximate installation times for the various abutment systems included in this section:

System	Minimum Installation Time	Comments
Grouted Reinforcing Splice Coupler Connections	1 Day or less	This includes bracing and grouting.
Blockout closure pour connections	1-2 Days	Two days are required for the closure pour concrete (high early strength) to attain at least enough strength to allow for construction to progress.
Post-Tensioning Systems	3 Days	This includes connecting the elements with epoxy, placement of the post-tensioning strand or rod, and grouting of the ducts.

Table 3.2.7-1 Approximate Minimum Installation Times for Abutment Connection Systems

3.2.8 Recommendations for Improvements to Current Practices

To date, grouted connections and closure pour systems on precast abutments have been very successful. Based on the performance of pier systems using similar connections, it can be assumed that prefabricated abutment connection will also be durable.

3.2.9 Connection Detail Data Sheets for Abutment Systems

The following pages contain data sheets for the various prefabricated abutment systems. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further,

consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected
- Name of project where the detail was used
- Manual Reference Section
The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

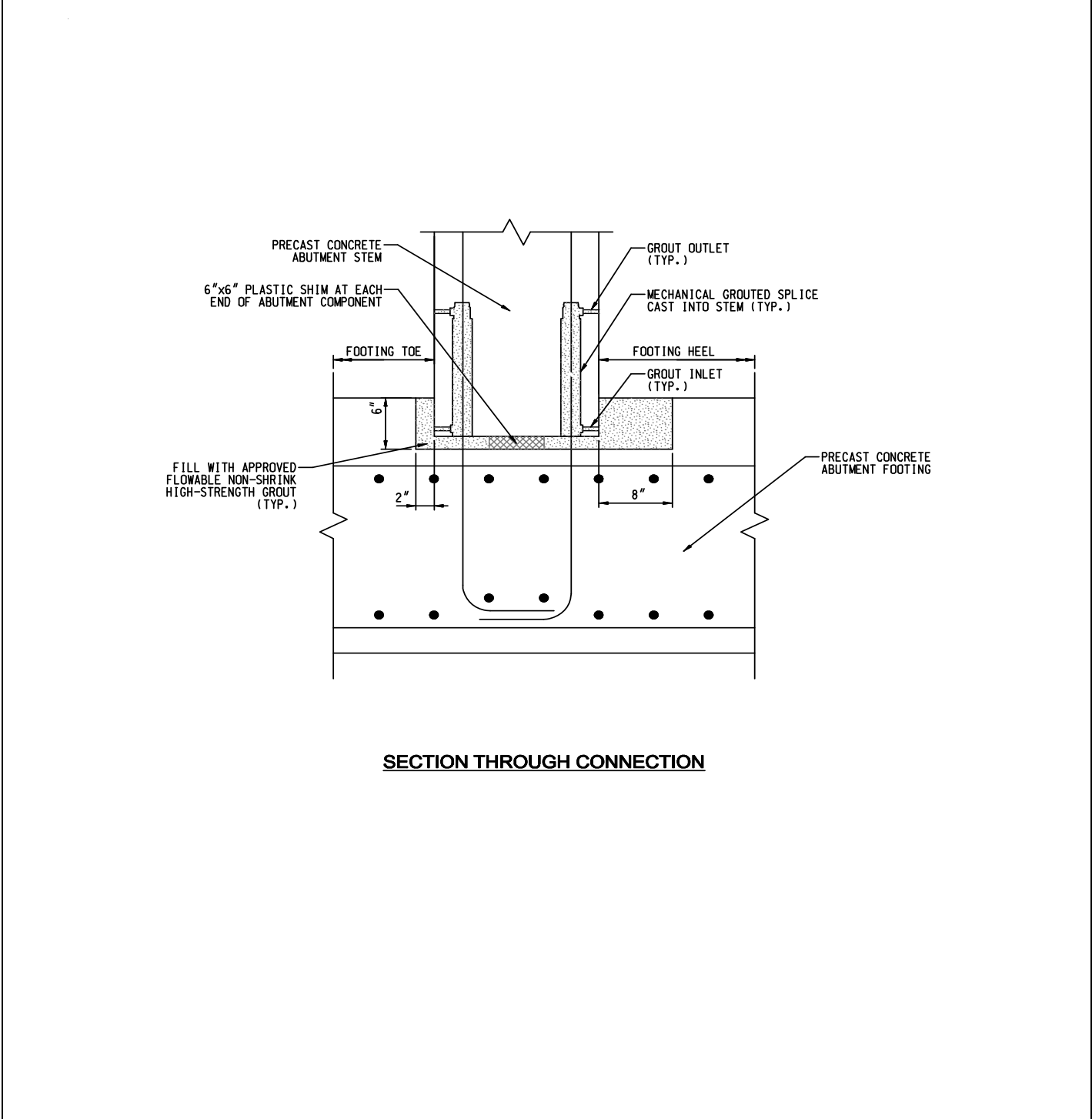
Organization: **NHDOT - Bureau of Bridge Design**
Contact Name: **David L. Scott, P.E.**
Address: **PO Box 483
7 Hazen Drive
Concord, NH 03302-0483**

Detail Number: **3.2.1.1 A**
Phone Number: **(603) 271-2731**
E-mail: **dscott@dot.state.nh.us**
Detail Classification: **Level 2**

Components Connected: **Precast concrete abutment stem** to **Precast concrete footing**

Name of Project where the detail was used: **Epping, New Hampshire**

Connection Details: **Manual Reference Section 3.2.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to connect a precast concrete footing to abutment and wingwall wall stems. The key feature with the connection is the embedded grouted splice sleeve connectors. Care needs to be taken with the casting of the footings and panels within tolerance (about 1/2") so that the splice sleeves line up with the extended bars. This was not a problem during construction. The design of the connection was according to ACI Manual on Emulation Design. The wall stem was placed in a pocket to facilitate grouting and provide shear resistance.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **NHDOT - Bureau of Bridge Design**
Contact Name: **David L. Scott, P.E.**
Address: **PO Box 483
7 Hazen Drive
Concord, NH 03302-0483**

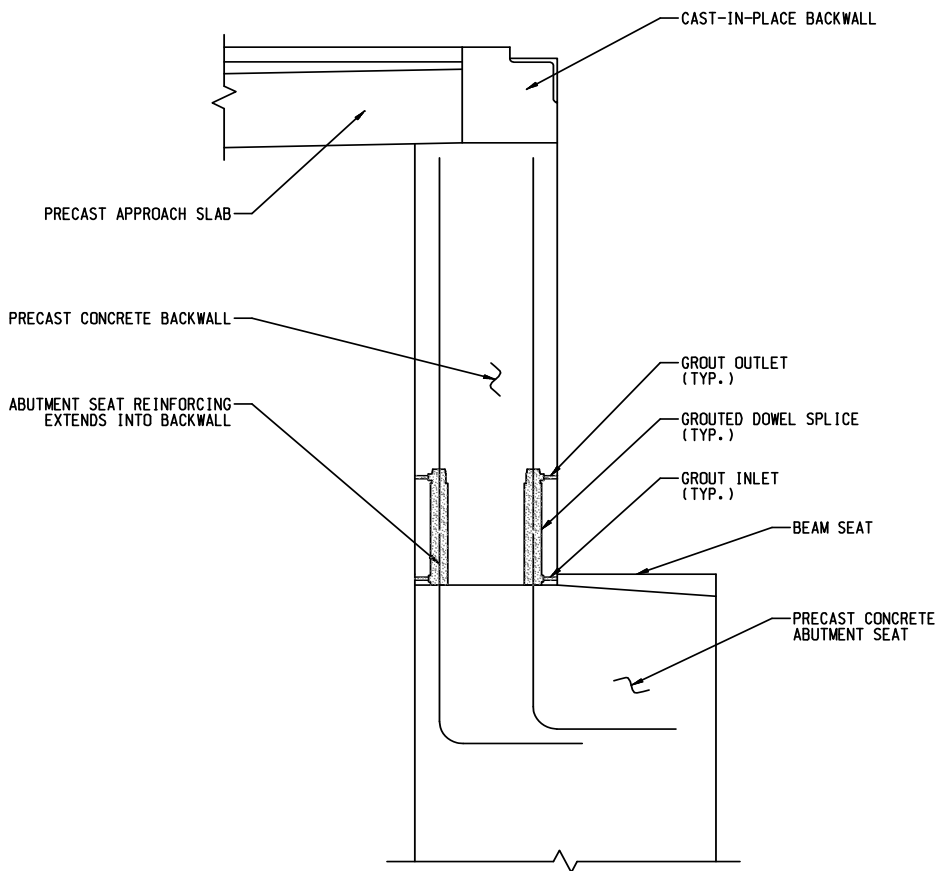
Detail Number: **3.2.1.2 A**
Phone Number: **(603) 271-2731**
E-mail: dscott@dot.state.nh.us

Detail Classification **Level 2**

Components Connected **Precast concrete backwall** to **Precast concrete abutment seat**

Name of Project where the detail was used **Epping, New Hampshire**

Connection Details: **Manual Reference Section 3.2.1.2** See Reverse side for more information on this connection

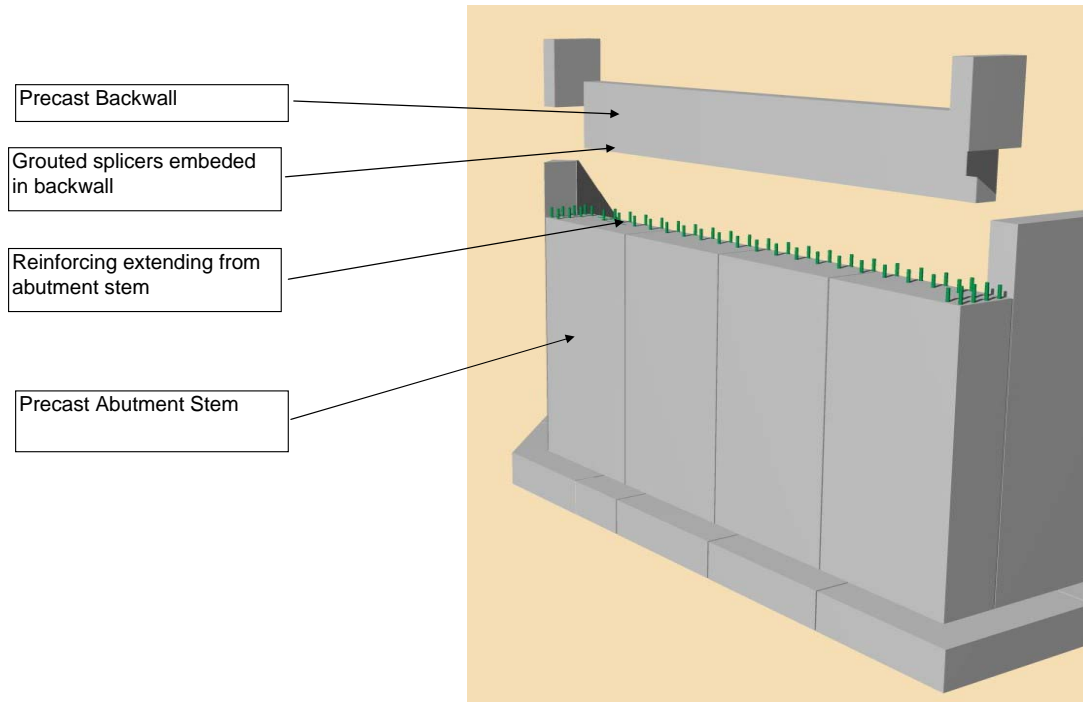


SECTION THROUGH CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is similar to the NH wall stem to footing detail. The connection is made with grouted splice sleeves. Care needs to be taken with the casting elements within tolerance (about 1/2") so that the splice sleeves line up with the extended bars. This was not a problem during construction. The design of the connection was according to ACI Manual on Emulation Design. This connection is also used to transfer longitudinal seismic forces from the superstructure to the substructure.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

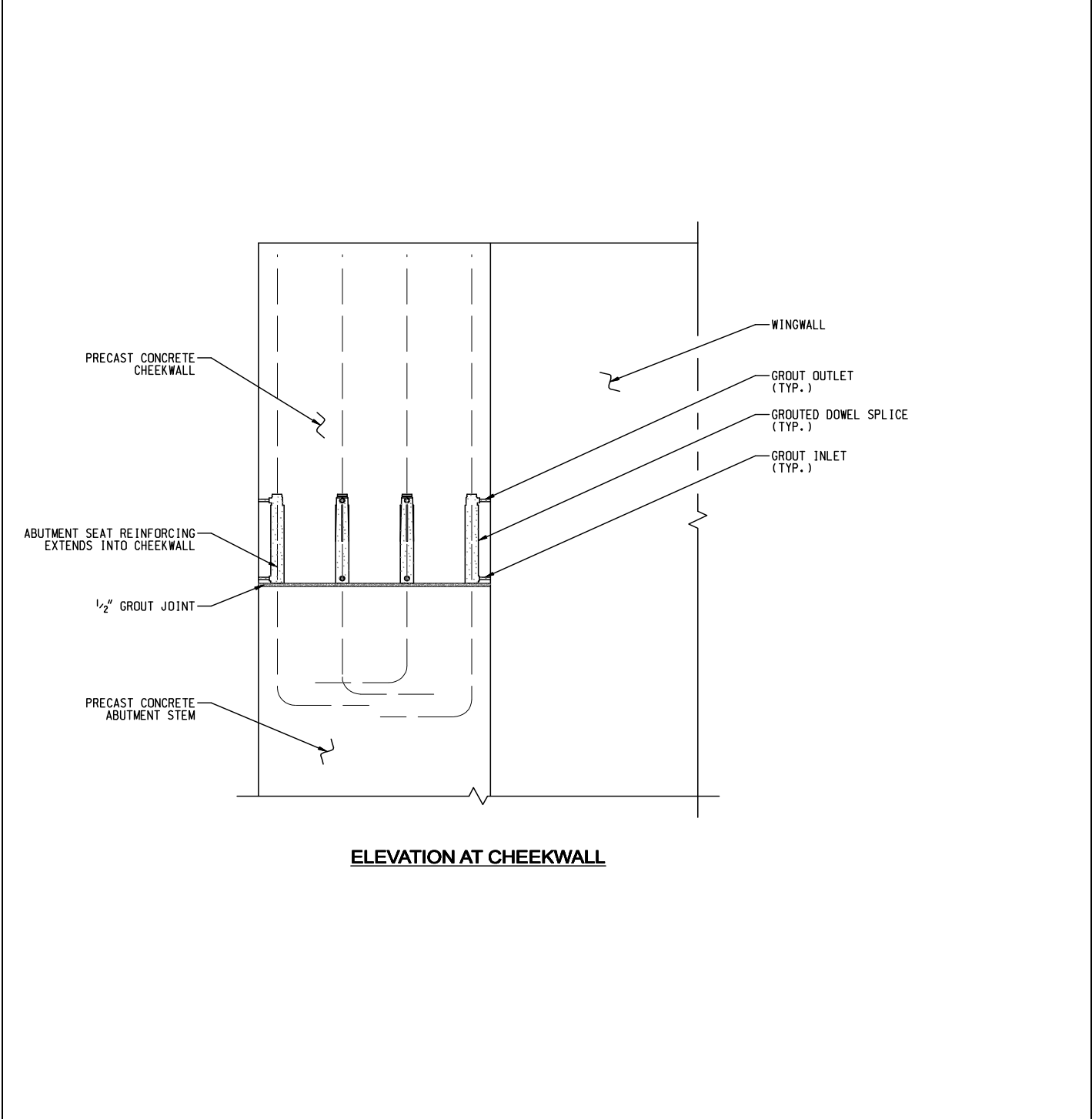
Organization: **NHDOT - Bureau of Bridge Design**
Contact Name: **David L. Scott, P.E.**
Address: **PO Box 483
7 Hazen Drive
Concord, NH 03302-0483**

Detail Number: **3.2.1.3 A**
Phone Number: **(603) 271-2731**
E-mail: dscott@dot.state.nh.us
Detail Classification: **Level 2**

Components Connected: **Precast concrete abutment stem** to **Precast concrete cheekwall**

Name of Project where the detail was used: **Epping, New Hampshire**

Connection Details: **Manual Reference Section 3.2.1.3** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

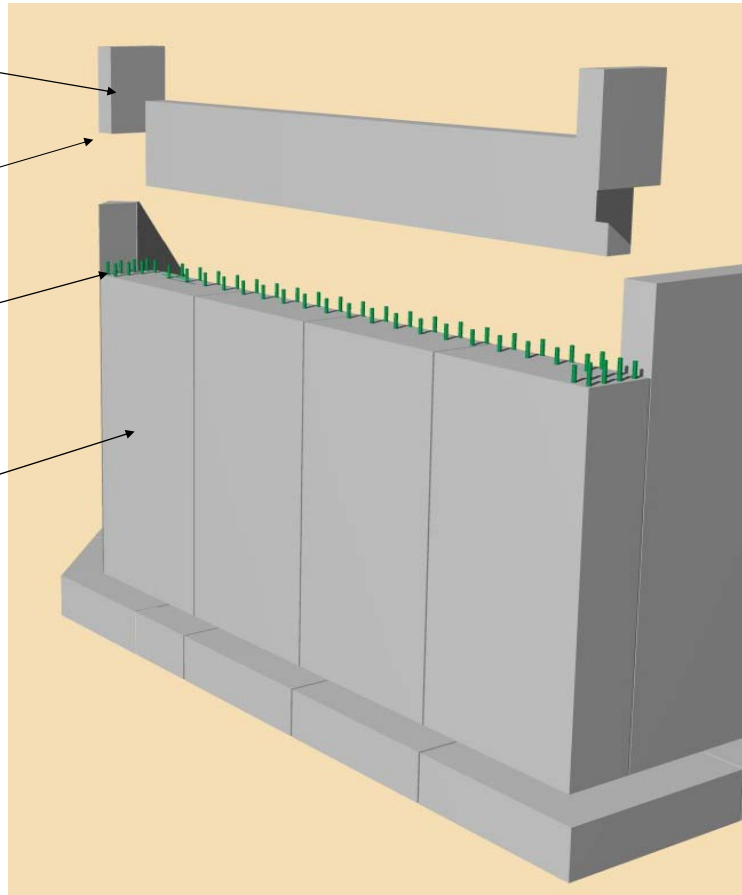
This detail is similar to the NH wall stem to footing detail. The connection is made with grouted splice sleeves. Care needs to be taken with the elements within tolerance (about 1/2") so that the splice sleeves line up with the extended bars. This was not a problem during construction. The design of the connection was according to ACI Manual on Emulation Design. This connection is also used to transfer longitudinal seismic forces from the superstructure to the substructure.

Precast Cheekwall

Grouted splicers embedded in cheekwall

Reinforcing extending from abutment stem

Precast Abutment Stem



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

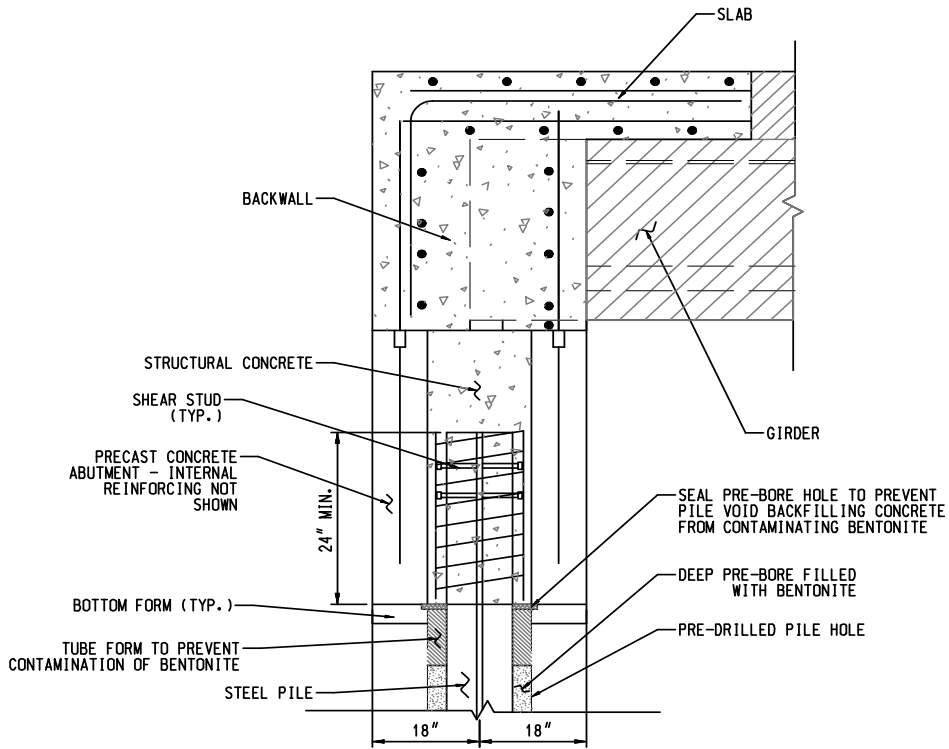
Organization: Iowa Department of Transportation
 Contact Name: Ahmad Abu-Hawash, Chief Structural Eng.
 Address: Office of Bridge and Structures
 800 Lincoln Way
 Ames, IA 50010

Detail Number: 3.2.3.1 A
 Phone Number: (515-239-1393
 E-mail: ahmad.abu-hawash@dot.iowa.gov
 Detail Classification: Level 1

Components Connected: Precast concrete integral abutment to Steel Pile

Name of Project where the detail was used: Boone County IBRC Project over Squaw Creek, Madison County IBRC Project

Connection Details: Manual Reference Section 3.2.3.1 See Reverse side for more information on this connection



SECTION THROUGH PRECAST CONCRETE INTEGRAL ABUTMENT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This connection connected steel HP 10x57 pile to the precast concrete abutment footing on an integral abutment bridge. The piles were driven to design bearing in soil and two feet of pile were left above grade for embedment into the precast footing. The integral abutment utilized 5 feet of prebore filled with bentonite. The precast concrete footing was cast with 21 inch diameter galvanized corrugated metal pipe that acted as wells for the steel pile. Two 7/8 inch by 5 inch shear studs were welded to each side of the pile web to aid in connection. The footing was placed over the pile and the voids (corrugated metal pipe) were filled with a special concrete mix designed for rapid cure.

Plan notes were needed to specify a final pile driving tolerance of 3 inches in any horizontal direction. Iowa Specifications are currently written with a starting pile tolerance, but not an end tolerance. This tight tolerance was to insure that the piles would fit into the wells created by the corrugated metal pipe. The precast abutment footing was leveled using steel channel sections welded to the steel pile. The void under the precast abutment footing created by this method of construction was filled with flowable mortar. This connection enabled pile to be driven, abutment footing placed, and flowable mortar placed in one day. The concrete in the footing voids were placed the next day.

This connection was also laboratory tested by Iowa State University as part of the evaluation of the IBRC project. The results of ISU's study will be published at a future date.

Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? Yes (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **PCI Northeast Bridge Tech Committee**
Contact Name: **Rita Seraderian**
Address: **116 Radcliffe Road
Belmont, MA 02478**

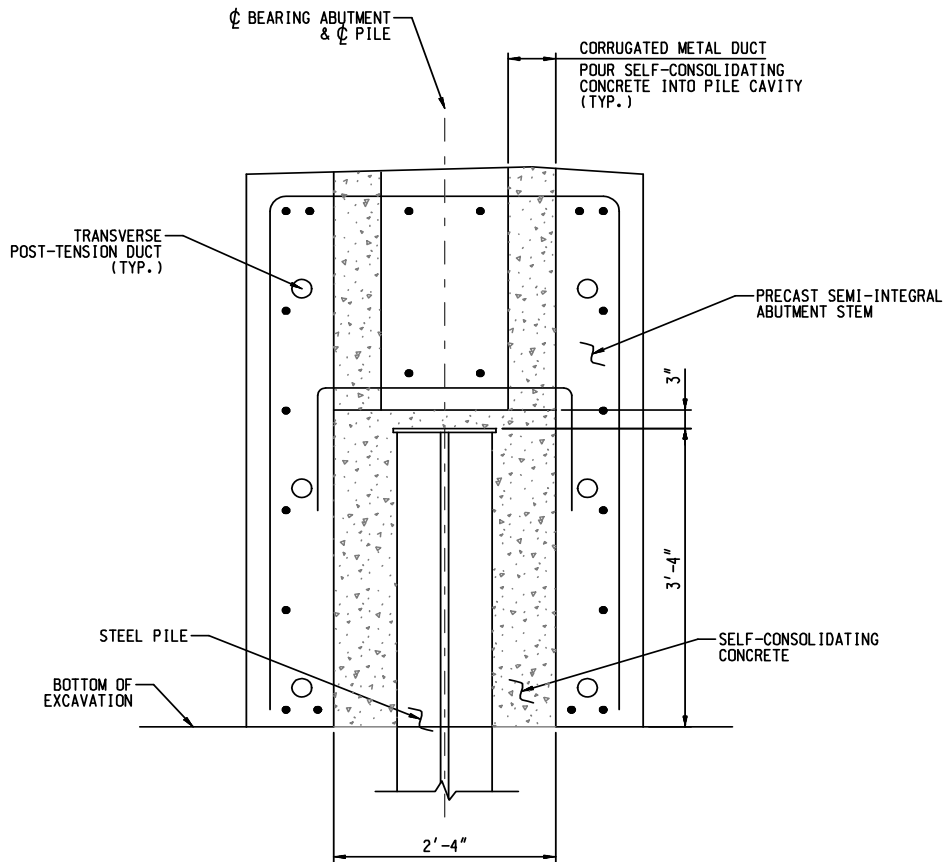
Detail Number: **3.2.3.1 B**
Phone Number: **888-700-5670**
E-mail: **contact@pcine.org**

Detail Classification **Level 1**

Components Connected **Precast semi-integral abutment stem** to **steel piles**

Name of Project where the detail was used **Upton Maine Bridge**

Connection Details: **Manual Reference Section 3.2.3.1** See Reverse side for more information on this connection



BREASTWALL SECTION THROUGH PILE CAVITY

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the Maine DOT and adopted by the committee for bridges for integral abutment bridges. The pieces were match cast with shear keys in the fabrication plant. The piles were standard steel H piles that were driven ahead of time through the roadway behind the existing abutments. The precast wall segments were epoxy bonded in the field and post tensioned. The pockets for the piles were then filled with self consolidating concrete from ports on the top face of the abutment. Installation took approximately 1 day.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

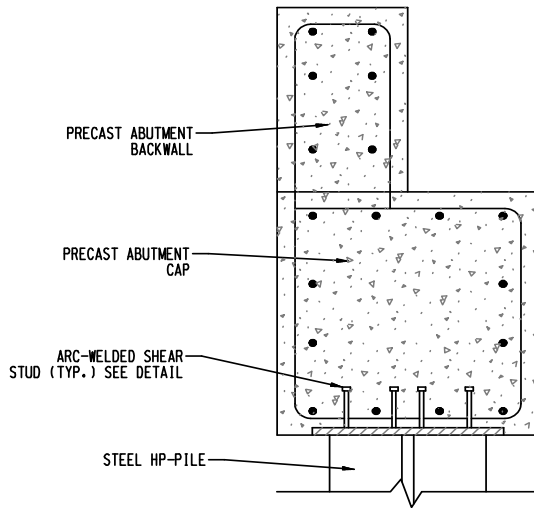
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **3.2.3.1 C**
 Phone Number: **512-416-2279**
 E-mail: **lwolf@dot.state.tx.us**
 Detail Classification: **Level 2**

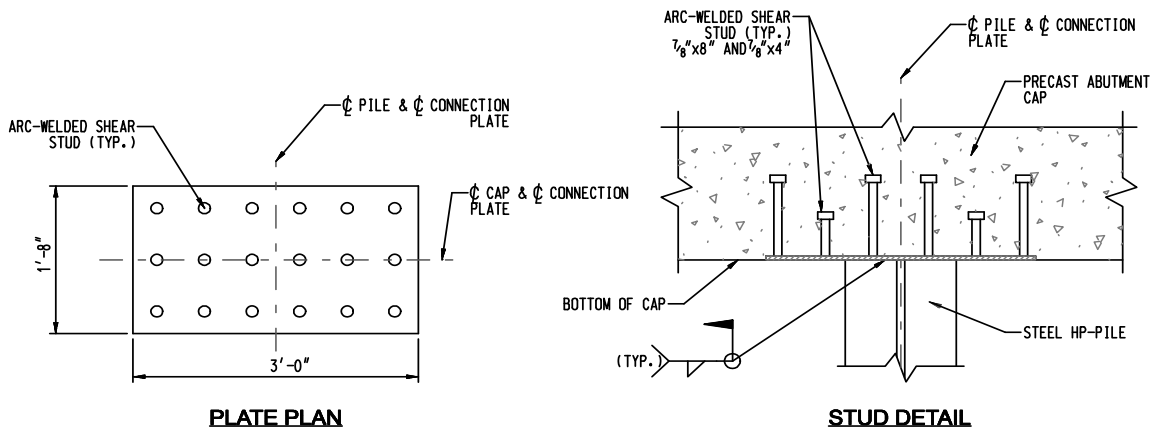
Components Connected: **Precast Abutment Cap** to **Steel H-Pile**

Name of Project where the detail was used: **Battleground Creek**

Connection Details: **Manual Reference Section 3.2.3.1** See Reverse side for more information on this connection



SECTION THROUGH PILE CAP



PILE CONNECTION PLATE DETAIL

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Steel plates with shear studs are cast at the pile locations in the bottom of the abutment seat. In the field the steel H piles are driven and then cut off level at the elevation of the bottom of the cap. The cap is set on the H piles and then the H piles are field welded to the bottom of the steel plates. Following this procedure, fill is placed under the abutment seat and behind the abutment seat.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

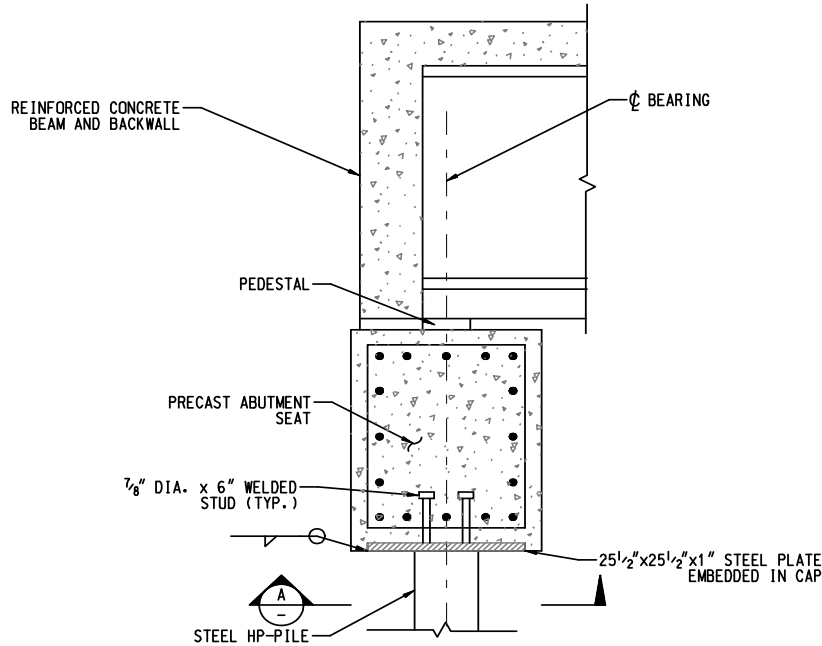
Detail Number: 3.2.3.1 D
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us

Detail Classification: Level 1

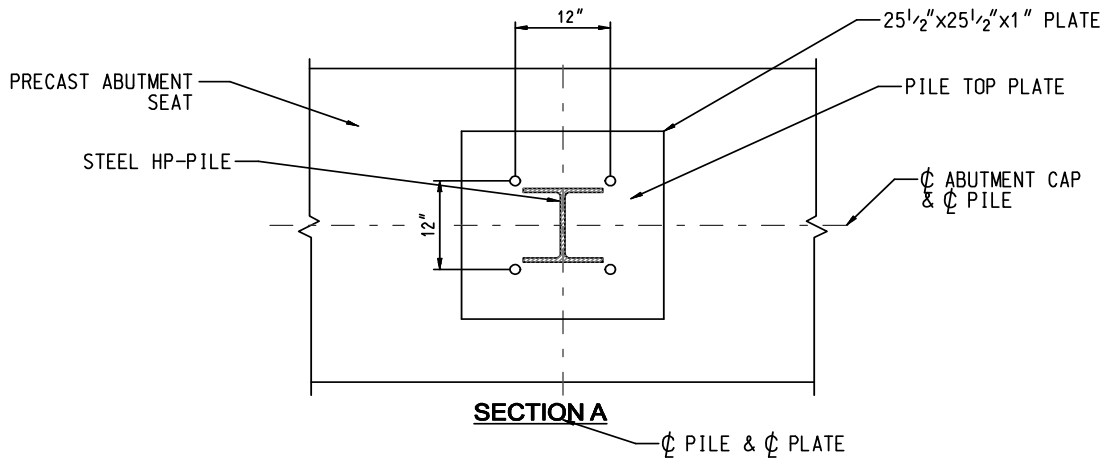
Components Connected: Precast Concrete Abutment Seat to Driven Steel H Piling

Name of Project where the detail was used: Bridge over Middle Fork Crazy Woman Creek (Wyoming Drawing Number 6635)

Connection Details: Manual Reference Section 3.2.3.1 See Reverse side for more information on this connection



SECTION THROUGH PRECAST ABUTMENT SEAT



SECTION A

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Steel plates with shear studs are cast at the pile locations in the bottom of the abutment seat. In the field the steel H piles are driven and then cut off level at the elevation of the bottom of the cap. The cap is set on the H piles and then the H piles are field welded to the bottom of the steel plates. Following this procedure, fill is placed under the abutment seat and behind the abutment seat.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

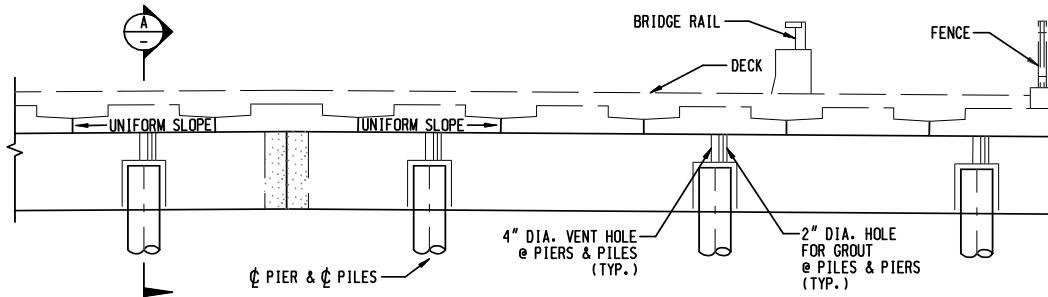
Organization: MnDOT Bridge Office
 Contact Name: Joseph M. Fishbein, P.E.
 Address: 3485 Hadley Avenue N.
 Oakdale, MN 55128

Detail Number: 3.2.3.2 A
 Phone Number: 651-747-2196
 E-mail: joe.fishbein@dot.state.mn.us
 Detail Classification: Level 2

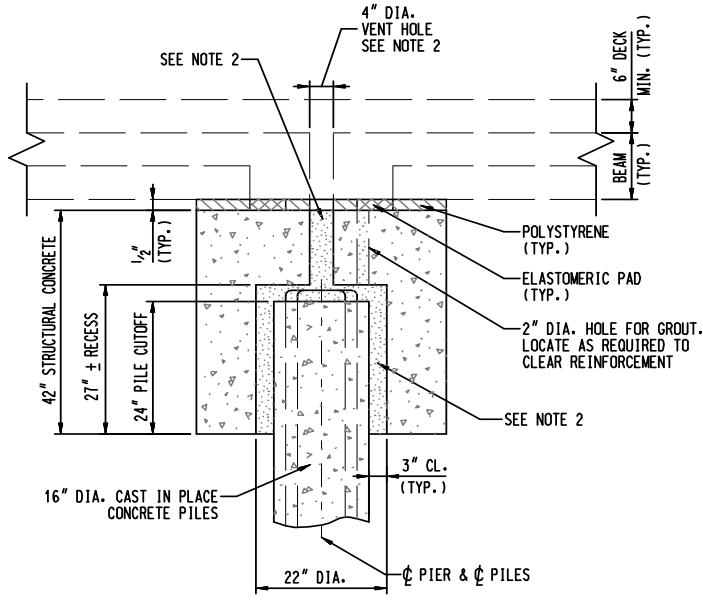
Components Connected: Precast Abutment to Round CIP piles

Name of Project where the detail was used: Bridge 13004, TH 8 over Center Lake Channel, Center City, MN

Connection Details: Manual Reference: Section 3.2.3.2 See Reverse side for more information on this connection



ELEVATION



SECTION A

- NOTES:**
1. CLOSURE POUR FOR STAGE 1 - STAGE 2 CONNECTION. VOLUMEN OF CONCRETE IS APPROXIMATELY 1 CU.YD.
 2. FILL PILE RECESSES AROUND PILES AND ACCESS HOLES WITH GROUT. VOLUME IS APPROXIMATELY 2 CU.YDS.

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Connection between precast abutment and round CIP piles. Abutment was precast with oversized holes for piles, and smaller holes between pile blockouts and top of abutment were included for grouting. After piles were installed, abutment was placed over piles, leveled into position, and high-strength grout injected from top of abutment through grout holes. Rebar inside the CIP piles projected into the abutment for additional bonding. The main problem was the difficulty in handling the precast abutments, due to their weight (72 tons for the stage I segments) and non-symmetric shape. For phase II of the project, conventional CIP abutments were used.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

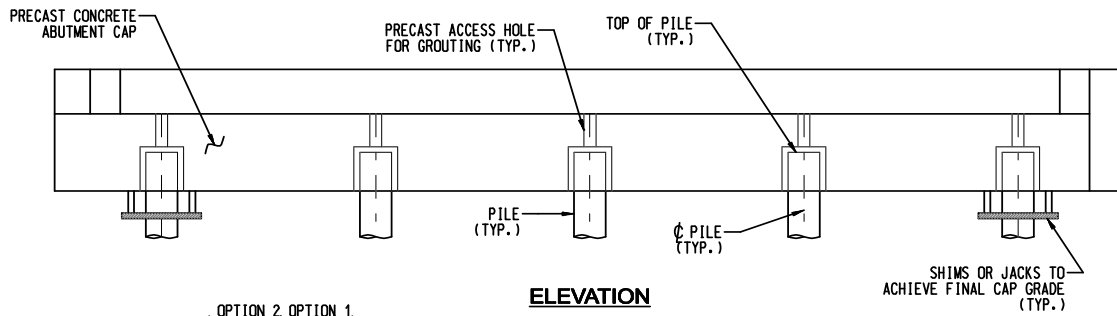
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **3.2.3.2 B**
 Phone Number: **512-416-2279**
 E-mail: lwolf@dot.state.tx.us
 Detail Classification: **Level 2**

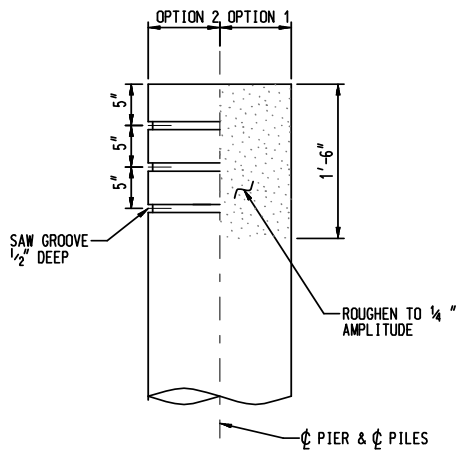
Components Connected: **Precast Abutment Cap** to **Prestressed Concrete Pile**

Name of Project where the detail was used: **Tanglewood**

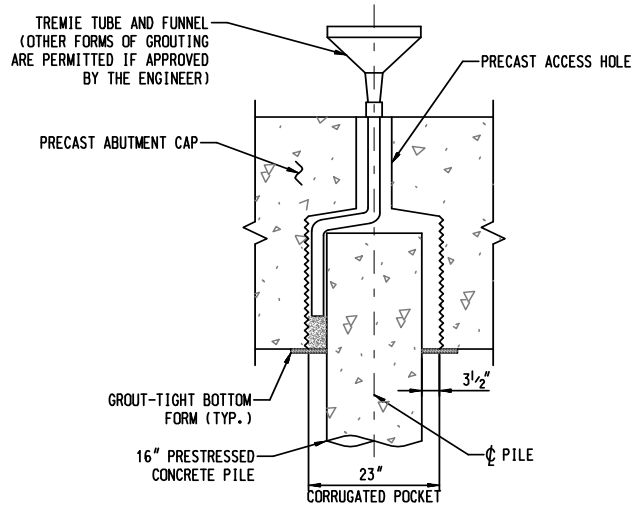
Connection Details: **Manual Reference Section 3.2.3.2** See Reverse side for more information on this connection



ELEVATION



SECTION TOP OF PILE DETAIL



SECTION CONNECTION GROUTING

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

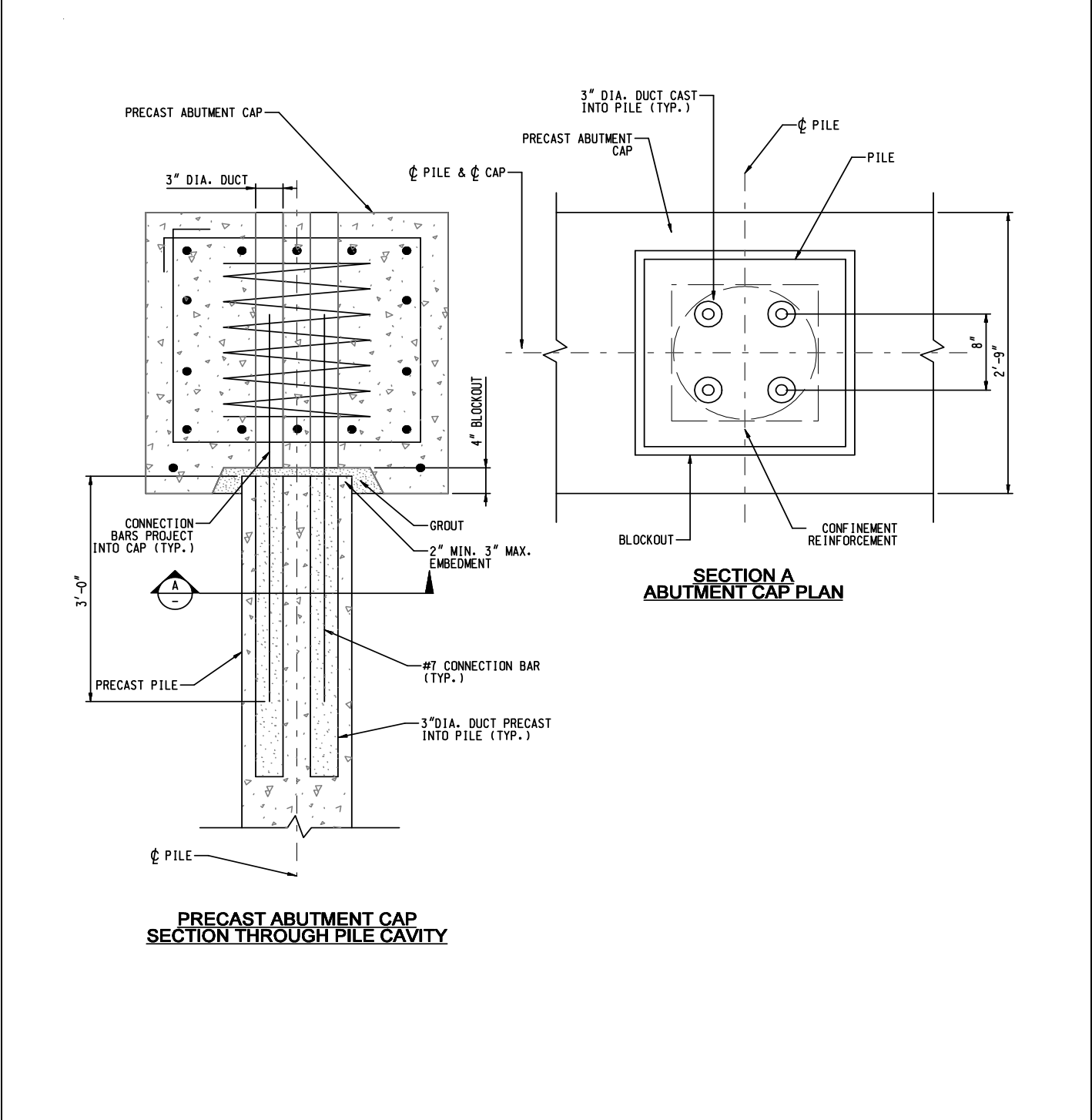
Organization: **Texas Department of Transportation**
 Contact Name: **Lloyd M. Wolf, PE**
 Address: **Bridge Division
 112 E. 11th Street
 Austin, TX 78704**

Detail Number: **3.2.3.2 C**
 Phone Number: **512-416-2279**
 E-mail: **lwolf@dot.state.tx.us**
 Detail Classification: **Level 2**

Components Connected **Precast Abutment Cap** to **Prestressed Concrete Pile**

Name of Project where the detail was used **Dry Creek Bridge**

Connection Details: **Manual Reference Section 3.2.3.2** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Editor's Note: The photos shown below were taken during construction. The photo on the left shows the pier cap being lowered onto the prestressed concrete piles.

The photo on the right is the top of the cap during the grouting procedure for the reinforcing bars. The ducts run from the bottom to the top of the cap. The ducts are standard post tensioning ducts.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used?

Condition at last inspection (if known)

How many times has this detail been used?

Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

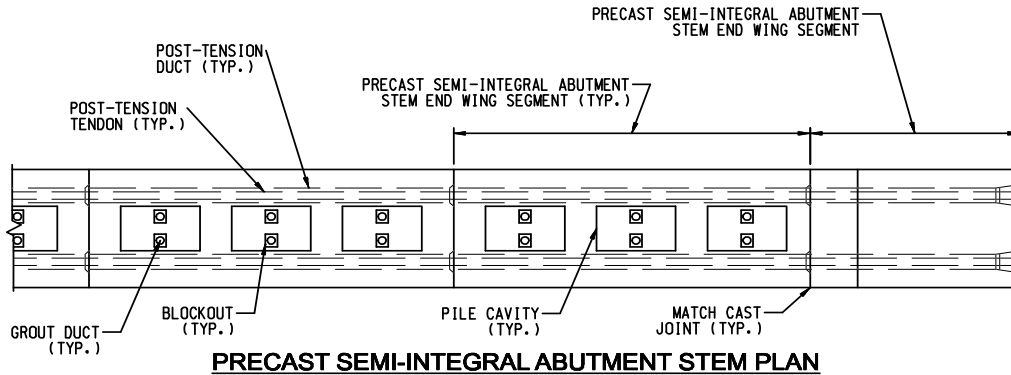
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **3.2.3.3 A**
 Phone Number: **888-700-5670**
 E-mail: **contact@pcine.org**
 Detail Classification: **Level 1**

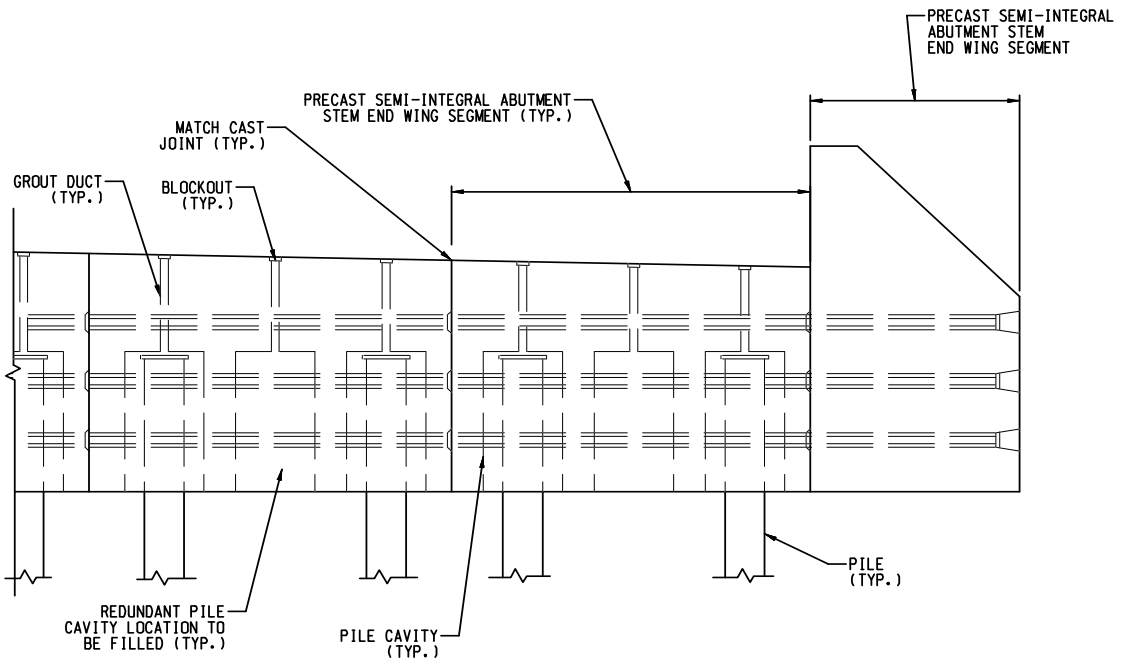
Components Connected: **Precast semi-integral abutment stem** to **Precast semi-integral abutment stem**

Name of Project where the detail was used: **Upton Maine Bridge**

Connection Details: **Manual Reference Section 3.2.3.3** See Reverse side for more information on this connection



PRECAST SEMI-INTEGRAL ABUTMENT STEM PLAN



PRECAST SEMI-INTEGRAL ABUTMENT STEM ELEVATION



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the Maine DOT and adopted by the committee for bridges for integral abutment bridges. The pieces were match cast with shear keys in the fabrication plant. The precast components were epoxy bonded in the field and post tensioned. Installation took approximately 1 day.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)
 Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

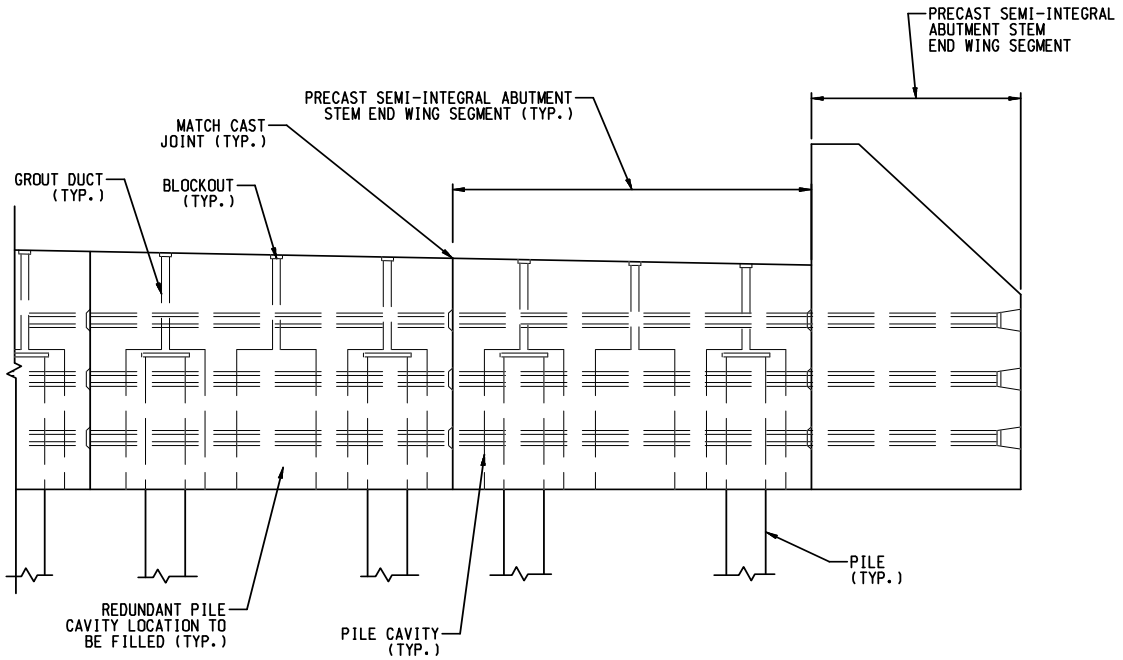
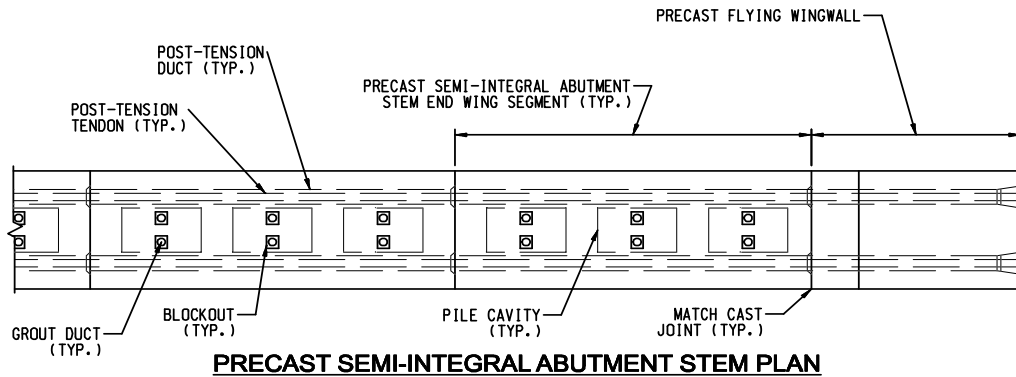
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **3.2.4.1 A**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 1**

Components Connected **Precast flying wingwall** to **Precast semi-integral abutment stem**

Name of Project where the detail was used **Upton Maine Bridge**

Connection Details: **Manual Reference Section 3.2.4.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the Maine DOT and adopted by the committee for bridges for integral abutment bridges. The pieces were match cast with shear keys in the fabrication plant. The precast components were epoxy bonded in the field and post tensioned. Installation took approximately 1 day.



Editor's Notes

[Empty box for Editor's Notes]

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: Wyoming DOT
 Contact Name: Gregg Fredrick
 Address: 5300 Bishop Blvd
 Cheyenne, Wyoming 82009

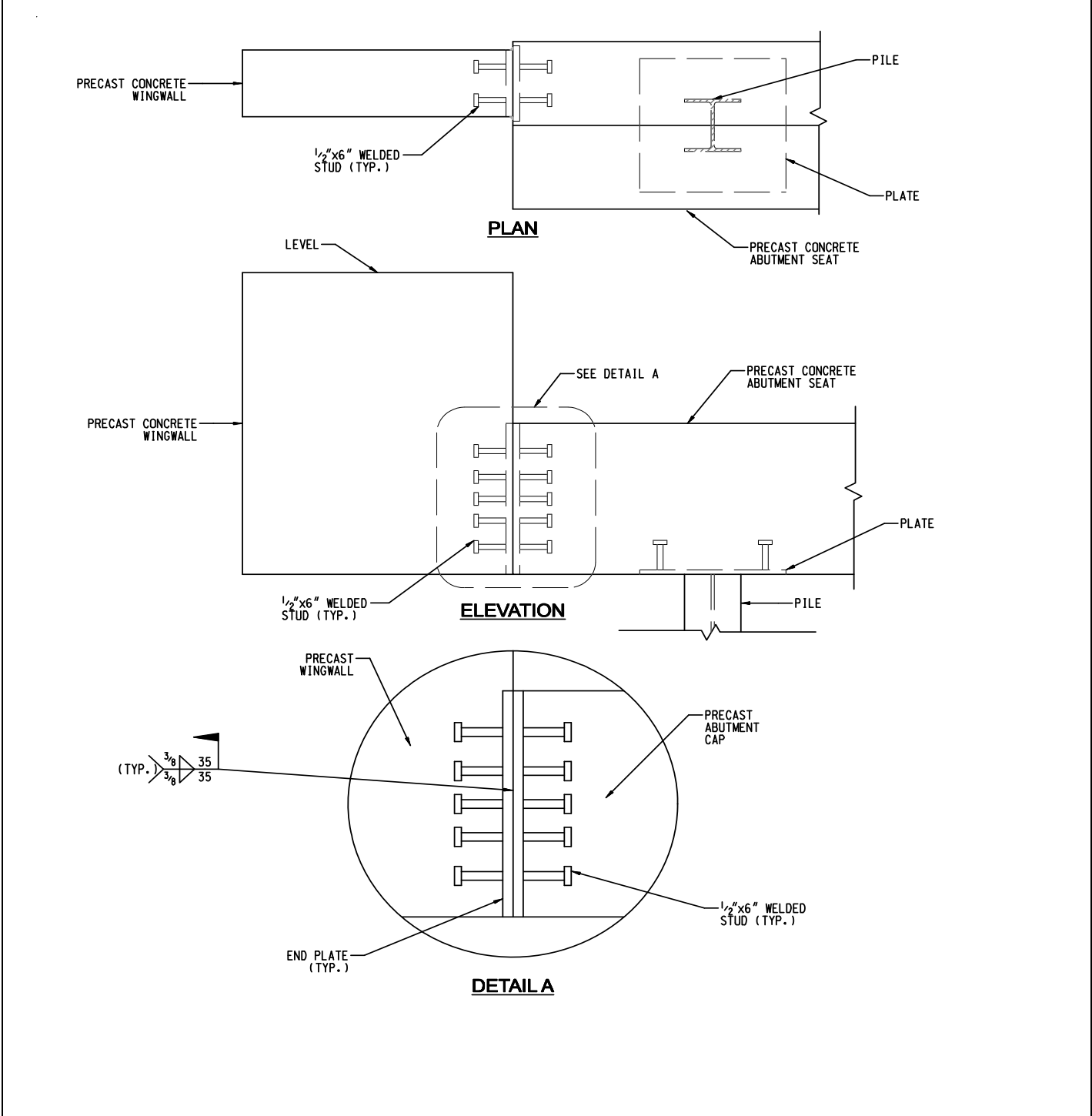
Detail Number: 3.2.4.1 B
 Phone Number: 307 777 4427
 E-mail: gregg.fredrick@dot.state.wy.us

Detail Classification: Level 2

Components Connected: Precast Concrete Wingwall to Precast Concrete Abutment Seat

Name of Project where the detail was used: Bridge over Middle Fork Crazy Woman Creek (Wyoming Drawing Number 6635)

Connection Details: Manual Reference Section 3.2.4.1 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Editor's Note: The welded steel plates are somewhat exposed after construction is complete. It is recommended that stainless steel plates and welds be used for this connection.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

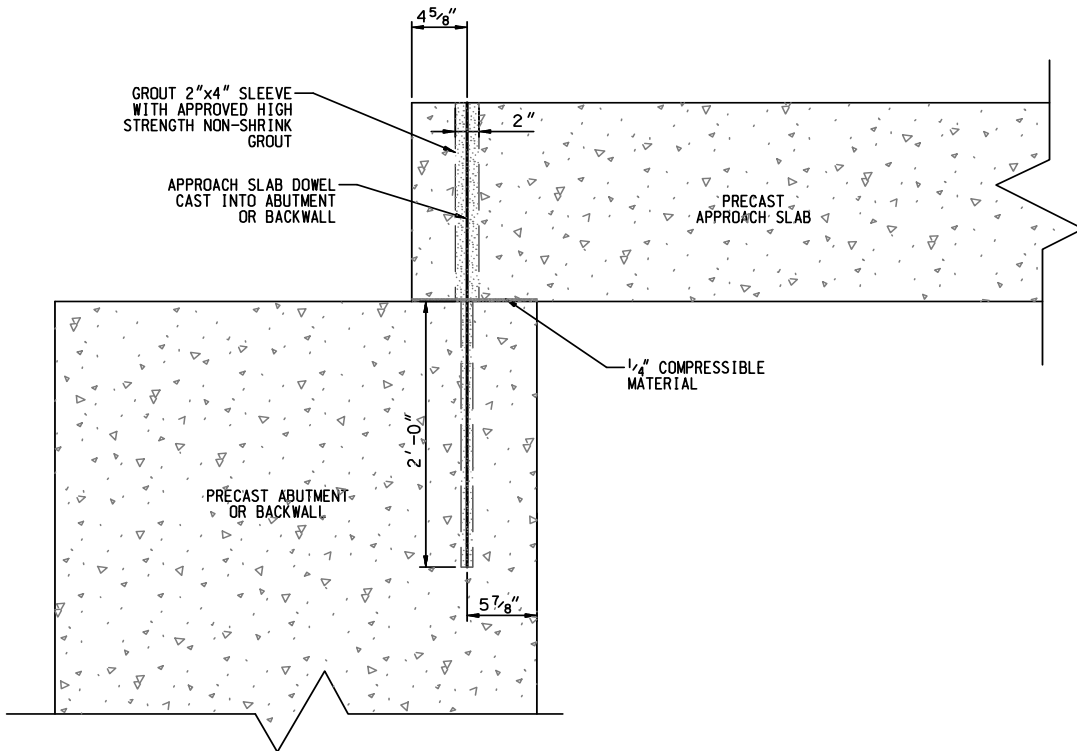
Organization: **NHDOT - Bureau of Bridge Design**
 Contact Name: **David L. Scott, P.E.**
 Address: **PO Box 483
 7 Hazen Drive
 Concord, NH 03302-0483**

Detail Number: **3.2.4.2 A**
 Phone Number: **(603) 271-2731**
 E-mail: **dscott@dot.state.nh.us**
 Detail Classification: **Level 3**

Components Connected **Precast concrete abutment or backwall** to **Precast concrete approach slab**

Name of Project where the detail was used **Conceptual detail**

Connection Details: **Manual Reference Section 3.2.4.2** See Reverse side for more information on this connection



APPROACH SLAB SECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail is a conceptual detail that may be used on future accelerated bridge projects in New Hampshire. The approach slab will be doweled to the abutment stem and set on the approach backfill.

A similar detail has been used by the Maine DOT on several projects.

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? 0 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 10 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 10 (0 difficulty making connection, 10 went together easily)

Cost 10 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 0 (0 not visible, 10 easily inspected)

Future Maintenance 10 (0 will need maintenance, 10 no maintenance anticipated)

3.3 Wingwall and Retaining Wall Systems

Wingwalls and retaining walls are sometimes referred to as earth retaining systems. There are many different types of systems for constructing earth retaining walls. The most common types of walls include:

- Concrete Cantilever
- Concrete Gravity
- Mechanically Stabilized Earth
- Prefabricated Modular
- Anchored
- Cantilever Sheet Piling and Soldier Pile

The AASHTO LRFD Specifications [1] includes details about each one of these walls. This section will include information on prefabrication of retaining wall systems and how they can be used in accelerated construction projects.

Some of the systems shown in this section are proprietary; however in most cases, there are multiple manufacturers that can produce similar walls. Some states allow multiple wall systems for larger wall projects by bidding the walls as a design-build product, where the manufacturer designs the wall based on the constraints of the site.

3.3.1 Cantilever Walls

Conventional cantilever walls are normally comprised of a reinforced concrete footing connected to a reinforced concrete stem. These wall types are common for wingwalls on bridges that are relatively short in both length and height.

3.3.1.1 Precast Wall Stem to Precast Footing Connection

The state of New Hampshire has developed a prefabricated version of a conventional cantilever wall system by using emulation techniques (see Section 1.4.2.1 for more information on emulation). The typical construction joint between the wall stem and the footing is replaced by a grouted reinforcing splice coupler connection. The New Hampshire system also includes precast concrete footings (see Section 3.2.1.1 and Chapter 4 for more information on precast footings).

This system was used on a bridge in Epping, New Hampshire, where the entire bridge was constructed in only eight days. The wingwall construction took approximately one (1) day. The data sheet detail in this section is for the Epping precast abutment stem to precast footing connection, which also works for a precast cantilever wall to precast footing connection.

3.3.1.2 Precast Wall Stem to Precast Wall Stem Connection

The AASHTO LRFD Specifications [1] require that retaining walls be constructed with contraction joints spaced at a maximum of 30 feet and expansion joints spaced at no more than 90 feet. The specification goes on to require that the joints be filled with an approved filler material to ensure the proper function of the joint.

Contraction joints are used to allow the concrete to shrink during curing and to contract with temperature changes. Contraction joints differ from construction joints in that they do not have reinforcing passing through the joint. Expansion joints are used to allow the concrete to shrink and to allow thermal expansion of the wall. Expansion joints also do not have reinforcing passing through them; however the joint must be filled with a compressible material.

Some states detail the contraction joints with shear keys to provide interaction with adjacent wall panels. Other states simply have a flat joint without shear keys. The New Hampshire DOT details include shear keys; therefore a grouted shear key configuration was used. The grout was placed after the wall panels were set and connected to the footings. The Epping Bridge did not require expansion joints due to the length of the walls; however they have developed details for longer walls where the expansion joints would be filled with expanded foam to allow for thermal expansion. Information on this detail can be found in the PCI Northeast document entitled “*Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components*” [44].

3.3.2 Modular Precast Wall Systems

Modular precast concrete wall systems are walls that are made up of prefabricated elements that are joined in different ways to create a wall system.

There are two distinct types of prefabricated wall systems that are primarily in use today. There are other systems in use and more in development. All of these wall systems include prefabricated elements; therefore they are well suited for prefabricated bridge projects.

3.3.2.1 Mechanically Stabilized Earth Systems (MSE)

MSE systems use thin prefabricated wall panels that are connected to earth anchoring devices. These devices engage the soil mass behind the wall face to create a soil mass gravity wall. The construction of these walls can progress rapidly because the system is built while the soil is being placed behind the wall; thereby combining two processes into one.

MSE walls are proprietary; however there are several manufacturers that make this type of system. Most states have standard details or approved wall products; therefore individual details from each state are not presented in this manual. Figure 3.3.2.1-1 depicts a typical wall section for a mechanically stabilized earth wall. Designers should contact each state to determine which wall systems are allowed for use.

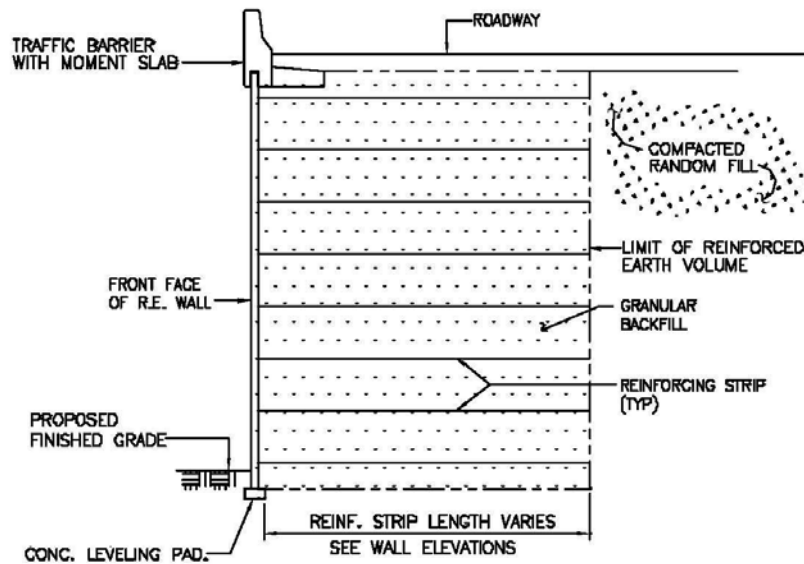


Figure 3.3.2.1-1 Typical MSE Wall Details

3.3.2.2 Modular Block Systems

Modular block retaining walls are a form of gravity retaining wall in which the cast-in-place concrete is replaced by modular reinforced concrete modules that interlock to form a wall system. The system resists soil forces by the mass of the wall and sometimes by the mass of soil placed within voids in the blocks.

As with MSE systems, modular block walls are normally proprietary. Many states have approved product lists for these wall systems; therefore individual details from each state are not presented in this manual. Figure 3.3.2.2-1 depicts a typical wall section for a modular block wall. Designers should contact each state to determine which wall systems are allowed for use.

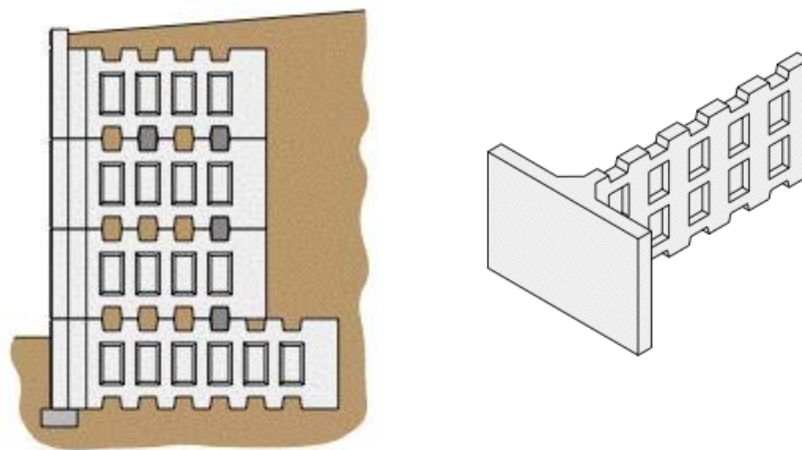


Figure 3.3.2.2-1 Modular Block Wall Example (T-WALL®, Courtesy of the Neel Company)

3.3.3 Tolerances

In cases where wingwalls are directly attached to the bridge structure the same tolerances for the bridge should be followed for the wingwall.

Most retaining walls are constructed away from the roadway and therefore do not need to be constructed to a tight tolerance. Each individual wall manufacturer has developed wall construction tolerances that should be followed during the installation. These tolerances ensure the proper fit of the individual elements.

3.3.4 Evaluation of Performance and Long Term Durability of Prefabricated Wall Systems

There is a long history of prefabricated wall systems in the United States. The modular retaining wall systems that are constructed with high quality precast concrete have performed very well. Most performance issues with wall systems can be attributed to problems with either the supporting soils or the backfill soils. The use of proper drainage systems for backfill soils is also critical for the long term performance of any wall system. Proper compaction of backfill soils also plays an important role in performance.

3.3.5 Estimated Construction Time for Connections

Exact timelines for construction are dependent on a number of factors including site access, traffic control, weather, crane locations and storage areas. It is possible to make reasonable estimates on construction time for the various systems discussed in this section. Since retaining walls and wingwalls can vary in size, the values given are for a typical bridge wingwall that is approximately 50 feet long and approximately 15 feet tall.

Table 3.3.5-1 contains approximate installation times for the various wall systems included in this section:

System	Minimum Installation Time	Comments
Precast Cantilever Wall	3 Days	This includes bracing, grouting and backfilling.
MSE Wall System	4-Days	This includes a concrete leveling pad, placement and backfilling.
Modular Block Systems	4 Days	This includes a concrete leveling pad, placement and backfilling.

Table 3.3.5-1 Approximate Minimum Installation Times for Retaining Wall Systems (approximately 50 feet long)

3.3.6 Recommendations for Improvements to Current Practices

Many states use prefabricated wall systems. The construction of retaining walls can be the critical path to an accelerated construction project. With many highways being widened within limited right of way, it

is common for designers to detail long retaining walls along the edge of roadway where earth embankments exist. These walls can be over a mile long and therefore represent the most significant structure on the project.

Designers often detail only one wall system for a given site. An option that could be considered is to allow multiple wall types at a given location so contractors can choose the most efficient system for construction. In this case the wall is bid as a lump sum item. Designers need to carefully detail the limits of payment for a lump sum wall bid, which should include the backfill soils. This is required because the backfill soils are an integral portion of any wall system (see Section 3.2 for backfilling options).

3.3.7 Connection Detail Data Sheets for Wingwall and Retaining Wall Systems

The following pages contain data sheets for various prefabricated wingwall and retaining wall systems. This information was primarily gathered from agencies that have developed and used the systems. Some systems were obtained from manufacturers and industry groups. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further, consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that

have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components connected
- Name of project where the detail was used
- Manual Reference Section
The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

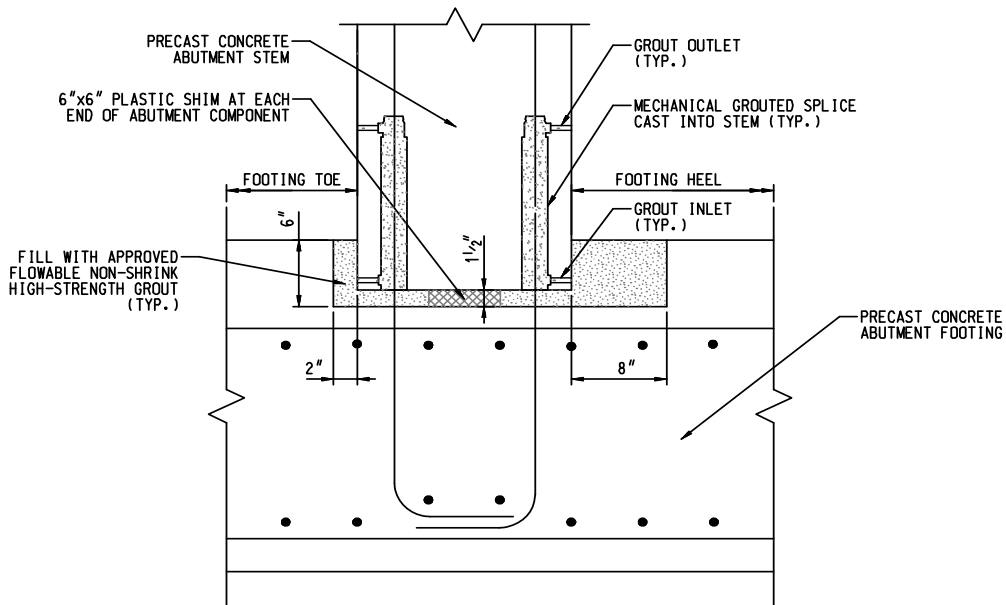
Organization: **NHDOT - Bureau of Bridge Design**
 Contact Name: **David L. Scott, P.E.**
 Address: **PO Box 483
 7 Hazen Drive
 Concord, NH 03302-0483**

Detail Number: **3.3.1.1 A**
 Phone Number: **(603) 271-2731**
 E-mail: **dscott@dot.state.nh.us**
 Detail Classification: **Level 2**

Components Connected: **Precast concrete wall stem** to **Precast concrete footing**

Name of Project where the detail was used: **Epping, New Hampshire**

Connection Details: **Manual Reference Section 3.3.1.1** See Reverse side for more information on this connection



SECTION THROUGH CONNECTION

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to connect a precast concrete footing to abutment and wingwall wall stems. The key feature with the connection is the embedded grouted splice sleeve connectors. Care needs to be taken with the casting of the footings and panels within tolerance (about 1/2") so that the splice sleeves line up with the extended bars. This was not a problem during construction. The design of the connection was according to ACI Manual on Emulation Design. The wall stem was placed in a pocket to facilitate grouting and provide shear resistance.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

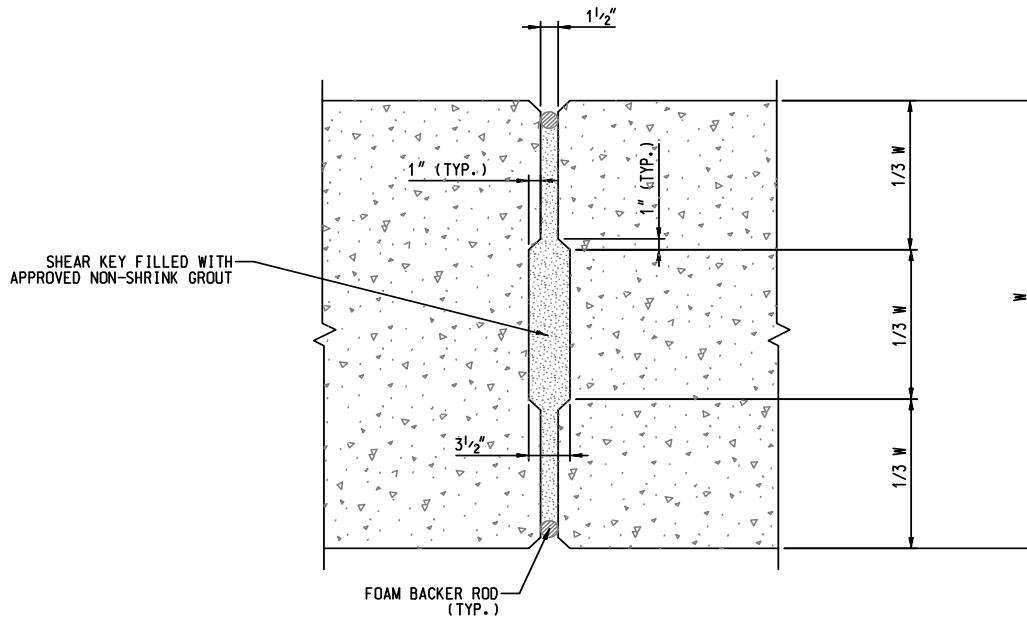
Organization: **NHDOT - Bureau of Bridge Design**
 Contact Name: **David L. Scott, P.E.**
 Address: **PO Box 483
 7 Hazen Drive
 Concord, NH 03302-0483**

Detail Number: **3.3.1.2 A**
 Phone Number: **(603) 271-2731**
 E-mail: **dscott@dot.state.nh.us**
 Detail Classification: **Level 2**

Components Connected **Precast concrete wall stem** to **Precast concrete wall stem**

Name of Project where the detail was used **Epping, New Hampshire**

Connection Details: **Manual Reference Section 3.3.1.2** See Reverse side for more information on this connection



PLAN VIEW OF WALL STEM JOINT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to connect two adjacent wall stem section. New Hampshire typically keys wall stem joint; therefore a grouted key joint was used. The contractor did have problems with the forming of the keyways. Foam backer rods were initially used, however the pressure head of the grout overcame the strength of the rod and the form failed. Subsequent forms were strengthened and performed well.



Construction Photo

Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)
Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Chapter 4 – Foundation Connections

This chapter is devoted to connections in foundation systems. The chapter has been broken out into typical foundation elements that are used on most bridges. The AASHTO LRFD design specifications [1] define constructed foundations as spread footings, driven piles and drilled shafts.

4.1: Footing and Pile Systems

Few states have designed and constructed prefabricated footings for bridges, while most states use prefabricated piles. The New Hampshire DOT has had success with prefabricated footings. The Northeast PCI Bridge Technical Committee has adopted these details as a standard for the northeast region.

4.1.1 Precast Footing to Subgrade Connections

One of the primary difficulties with using precast concrete footings is the ability to properly seat the footing on the subgrade. Inadequate seating will result in rocking of the footings and settlement of the foundation.

In order to eliminate this problem, it is necessary to place a flowable concrete or grout under the footing. The New Hampshire DOT has developed a detail that includes leveling bolts that lift the footing above the subgrade material and allows for the installation of flowable grout. The flowable grout can either be a low grade concrete, or even flowable fill. High strength material is not required for the fill because the material is simply a filler, and the footing bearing pressures are normally in the order of 50 psi.

For footings constructed on bedrock, it is recommended that a sub-footing be poured to provide a relatively level area for setting the footings. When a footing is placed on soil, the footings can be placed on steel plates under the leveling bolts.

4.1.2 Precast Footing to Precast Footing Connections

Depending on the design of the footing, the connection between adjacent footing elements may or may not need to be a structural connection. Abutment and wall footings are primarily designed as one way slabs. This means that discrete footing elements can be placed without a significant connection. The New Hampshire DOT has developed a detail where the footings are connected with a simple grouted shear key.

If a more substantial moment connection is desired, a small closure pour is recommended. Reinforcing steel can be projected from each footing elements with a simple lap splice between the bars. This closure pour is easy to form and pour because the two footing elements and the subgrade can be used for most of the formed area.

4.1.3 Precast Footing to Steel Pile Connection

Several states have developed details for connecting precast concrete pier caps to steel pile when used as a pier bent (see Section 3.1.1.3). Some of these details could be used for footing connections also. There

has also been steel pile connection details developed for integral abutment bridges (see Section 3.2.3).

The Northeast PCI Bridge Technical Committee has developed conceptual details for the connection of a spread footing to steel piles. While these details are conceptual, they are based on details that are similar to the pier cap connections.

The major issues with a pile to footing connection are whether or not there is anticipated uplift on the piles or if there is a need to provide moment capacity in the pile connection. Uplift capacity can be achieved by welding reinforcing steel to the pile end and embedding the reinforcing in a closure pour (note that weldable reinforcing steel will be required for this connection). Moment capacity is achieved by embedding the pile top at least 12 inches into the footing.

4.1.4 Precast Footing to Precast Concrete Piles

As with the steel pile connections described above, several states have developed connection details for precast concrete piles connected to precast concrete pier bents. There have also been concrete pile connection details developed for integral abutment bridges (see Section 3.2.3).

The Florida DOT has developed a connection of a hollow precast concrete pile to a precast footing. This connection consists of a large breakout in the footing where a reinforcing steel cage can be installed between the pile top and the breakout. This connection can develop the full moment capacity of the pile. The Northeast PCI Bridge Technical Committee has also developed conceptual details for the connection of a spread footing to precast concrete piles.

4.1.5 Precast Footing to Cast-in-place Pile or Drilled Shaft Connections

To the knowledge of the authors, no state has developed a connection detail for cast-in-place piles or drilled shafts connected to precast concrete footings. The details discussed in Section 4.1.4 could easily be adapted for use with cast-in-place concrete piles or drilled shafts.

4.1.6 Precast Pile to Precast Pile Connection

Most precast concrete driven piles are square, round, or octagonal solid piles. Many states used this pile and have standard details for connecting piles that need to be spliced. The precast concrete pile industry has developed standard pile splicing details. The PCI manual entitled "Precast Prestressed Concrete Piles (BM-20-04)"[50] is recommended for more information on this subject.

The Florida DOT has developed a detail for splicing hollow square prestressed concrete piles. This detail consists of a reinforced concrete closure pour between pile elements.

4.1.7 Precast Pier Box Cofferdams

One of the most difficult processes for construction of piers over water involves the construction of the pier footings on piles. This can involve complicated sheeting systems and cofferdams. The advent of larger diameter drilled shaft technology has brought about new methods for supporting bridge structures over water. With large diameter drilled shafts, it is possible to support large bridges with a few or even one drilled shaft per pier column.

Several projects have been designed where a precast concrete pier box was used to dewater the area where the drilled shaft connects to the bridge footing. For example, the new Providence River Bridge in Providence, Rhode Island, has precast concrete pier boxes that were hung from the 8 foot diameter drilled shafts that allowed the construction of the footings in the dry. The precast box was set over the drilled shaft and sealed with a small tremie pour around the drilled shaft. These systems can eliminate the need for complicated deep cofferdams and dewatering systems, especially in deep water. When built using HPC, the precast box forms can serve as an additional corrosion protection system for the new pier footing.



Figure 4.1.7-1 Providence River Bridge Pier Box



Figure 4.1.7-2 Providence River Bridge Pier Box Preparation for Footing Reinforcing Placement

Figures 4.1.7-1 and 2 show the construction of the Providence River Bridge. The use of the precast concrete pier boxes saved the contractor significant time in the construction of the foundations.

4.1.8 Grade Control and Tolerances

The grade and alignment of prefabricated foundation elements should be controlled as much as possible, since it may be difficult to make significant adjustments in other parts of the structure.

The placement of precast footing elements can be adjusted by shims during placement. The New Hampshire DOT installed leveling bolts in the footings that allow precise adjustment of the footing during installation. This system worked well, although there was some difficulty in turning the leveling bolts. This was attributed to corrosion of the bolt threads. They corrected this by greasing the bolts and by adjusting the bolts prior to full release of the footing from the crane.

4.1.9 Evaluation of Performance and Long Term Durability of Prefabricated Footing and Pile Systems

To date, very few prefabricated footing systems have been constructed. The oldest installation is on the Escambia Bay Bridge in Florida. This footing is in a severe corrosion environment and is still in good condition.

Based on the performance of other precast foundation systems (piers, abutments) which have similar details, it is likely that the precast footing systems will be very durable.

4.1.10 Estimated Construction Time for Connections

Exact timelines for construction are dependent on a number of factors including site access, traffic control, weather, crane locations and storage

areas. It is possible to make reasonable estimates on construction time for the various systems discussed in this section.

Table 4.1.10-1 contains approximate installation times for the various foundation connection systems included in this section:

System	Minimum Installation Time	Comments
Precast footing to subgrade	1-2 Days	This includes installation leveling and grouting.
Precast footing to precast footing	1-2 Days	One day for a grouted shear key, 2 days for a concrete closure pour.
Precast footings to various piles	1-3 Days	This includes placement and grouting.
Precast Pile to Precast Pile	1 day	
Precast concrete pier boxes	1-4 weeks	This includes the installation of the box and dewatering (not footing placement). This depends greatly on the size of the pier and the complexity of the footing.

Table 4.1.10-1 Approximate Minimum Installation Times for Foundation Connection Systems

4.1.11 Recommendations for Improvements to Current Practices

Prefabricated footings have not been used by many states. This is probably because of concerns about obtaining a proper connection to the subgrade materials. The work completed by several states should be expanded to more projects so that a more substantial knowledge base will be developed.

4.1.12 Connection Detail Data Sheets for Footing and Pile Systems

The following pages contain data sheets for the various prefabricated foundation systems. This information was primarily gathered from agencies that have developed and used the systems. Most data in the sheets were provided by the owner agency; the authors added text when an agency did not supply all requested information. The owner agencies also provide a comparative classification rating.

Each connection detail data sheet is presented in a two-page format. Users of this Manual can simply remove and copy a data sheet for use in developing a system for a particular project. These sheets are meant to give users a basic understanding of each connection that can be used during the type study phase of a project. The data sheets are not meant to be comprehensive, but do convey the component make-up of the detail, how it is meant to function, and provide some background on its field application. Users will need to investigate each connection further,

consider site-specific conditions, and apply sound engineering judgment during design.

The key information provided for each connection is as follows:

- Name of the organization that supplied the detail
- Contact person at the organization
- Detail Classification Level

Level 1

This is the highest classification level that is generally assigned to connections that have either been used on multiple projects or have become standard practice by at least one owner agency. It typically represents details that are practical to build and will perform adequately.

Level 2

This classification is for details that have been used only once and were found to be practical to build and have performed adequately.

Level 3

This classification is for details that are either experimental or conceptual. Details are included in this Manual that have been researched in laboratories, but to the knowledge of the authors, have not been put into practical use on a bridge. Also included in this classification are conceptual details that have not been studied in the laboratory, but are thought to be practical and useful.

- Components Connected
- Name of Project where the detail was used
- Manual Reference Section
The section(s) of this Manual applicable to the particular detail shown.
- Connection Details
- Description, comments, specifications and special design procedures
- Forces that the connection is designed to transmit
- Information on the use of the connection (including inspection ratings)
- A performance evaluation of the connection rated by the submitting agency

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

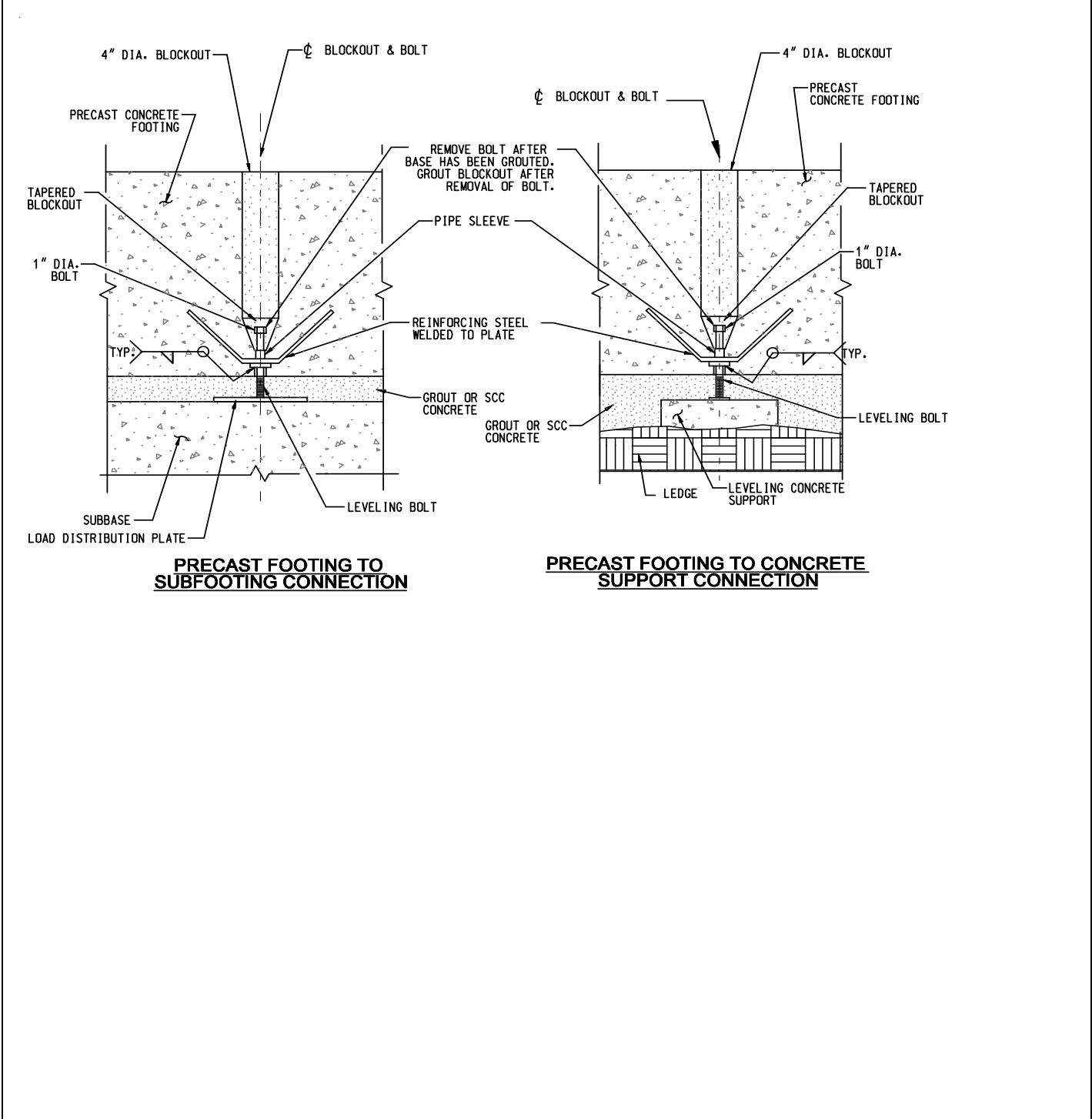
Organization: **NHDOT - Bureau of Bridge Design**
 Contact Name: **David L. Scott, P.E.**
 Address: **PO Box 483
 7 Hazen Drive
 Concord, NH 03302-0483**

Detail Number: **4.1.1 A**
 Phone Number: **(603) 271-2731**
 E-mail: **dscott@dot.state.nh.us**
 Detail Classification: **Level 1**

Components Connected: **Precast concrete footing** to **Subgrade**

Name of Project where the detail was used: **Epping, New Hampshire**

Connection Details: **Manual Reference Section 4.1.1** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to place a precast footing on the native subgrade. A lean concrete sub-footing was used to provide a level work area over blasted bedrock. In addition, details have been developed for placement over compacted gravel. The key feature is that concrete grout is placed between the footing and subgrade to provide even bearing. Leveling bolts are also incorporated so that the grade of the footing can be adjusted easily. This was found to be an easy adjustment as long as the bolts were lubricated and the leveling took place before the crane released the piece.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **NHDOT - Bureau of Bridge Design**
Contact Name: **David L. Scott, P.E.**
Address: **PO Box 483
7 Hazen Drive
Concord, NH 03302-0483**

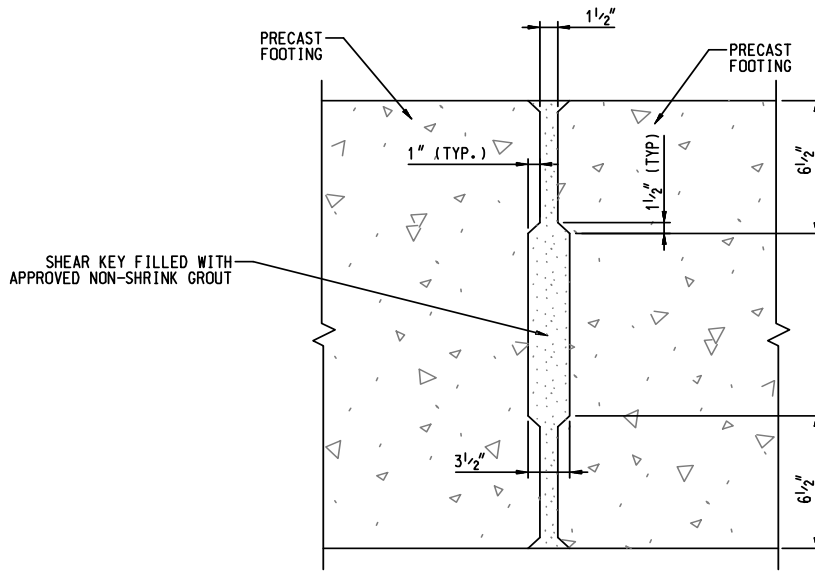
Detail Number: **4.1.2 A**
Phone Number: **(603) 271-2731**
E-mail: **dscott@dot.state.nh.us**

Detail Classification **Level 2**

Components Connected **Precast concrete footing** to **Precast concrete footing**

Name of Project where the detail was used **Epping, New Hampshire**

Connection Details: **Manual Reference Section 4.1.2** See Reverse side for more information on this connection



PRECAST FOOTING JOINT

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was used to connect two adjacent footing components. The footing reinforcing was designed with one way action and only distribution reinforcing in the other direction. This allowed for a simple grouted shear connection. The joints in the footing were offset from the wall stem joint. The shear keys were grouted at the same time as the under footing grouting procedure. The photo shows the footing being installed. A concrete sub-footing was used due to the presence of fractured bedrock on the site. This detail can also be used on compacted fill.



Editor's Notes

The submitting agency did not submit the data shown below. The authors have inserted the data based on a review of the details.

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

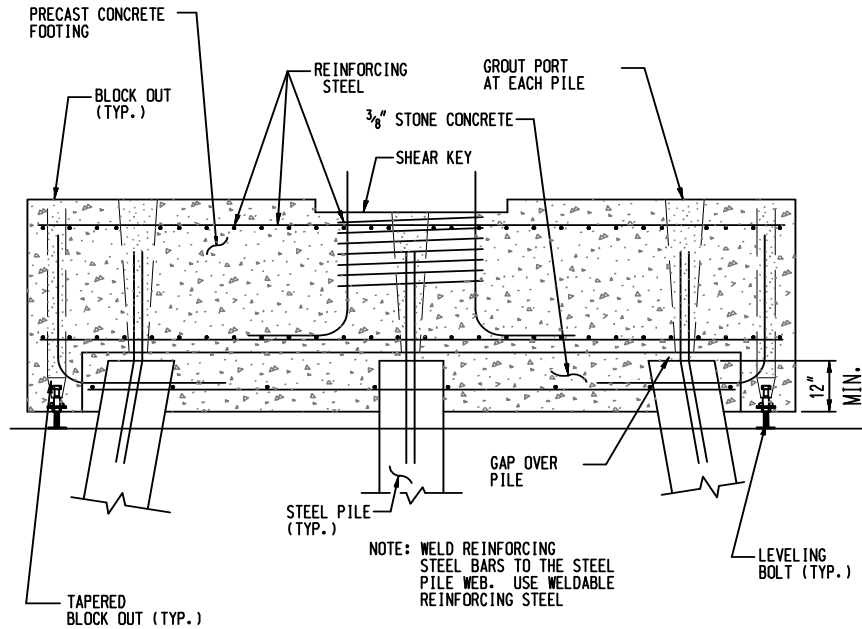
Organization: **PCI Northeast Bridge Tech Committee**
 Contact Name: **Rita Seraderian**
 Address: **116 Radcliffe Road
 Belmont, MA 02478**

Detail Number: **4.1.3 A**
 Phone Number: **888-700-5670**
 E-mail: contact@pcine.org
 Detail Classification: **Level 3**

Components Connected: **Precast spread footing** to **Steel Pile with uplift**

Name of Project where the detail was used: **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 4.1.3** See Reverse side for more information on this connection



**ELEVATION
 PILE SUPPORTED PRECAST FOOTING
 WITH UPLIFT ON STEEL PILES**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges as a conceptual detail. This has not yet been built; however similar configurations have been built in other states. Leveling bolts are used in the corners to set grade, and a small aggregate concrete is poured through ports to fill the voids around the piles. The reinforcing around the piles is to control shrinkage of the poured concrete and can be placed prior to setting the footing. The design of the footing is the same as a conventional cast-in-place concrete footing design. A corrugated steel duct pocket could be substituted for the tapered pocket.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

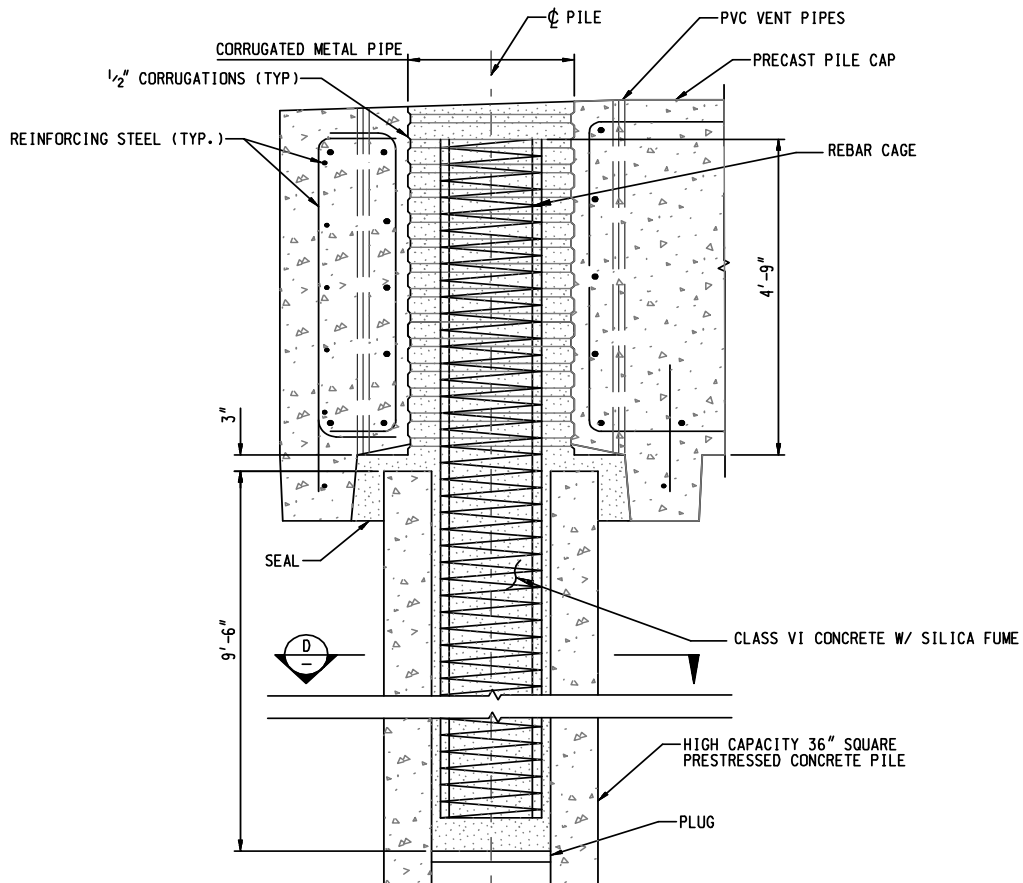
Organization: Florida DOT
 Contact Name: Thomas Andres
 Address: 605 Suwannee Street, MS 33 Tallahassee, FL 32399-0450

Detail Number: 4.1.4 A
 Phone Number: 850-414-4269
 E-mail: thomas.andres@dot.state.fl.us
 Detail Classification: Level 2

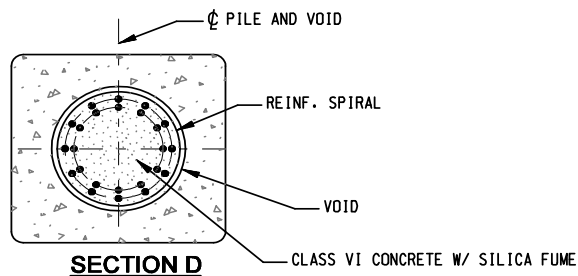
Components Connected: P/S concrete square pile to Pile Footing

Name of Project where the detail was used: I-10 Escambia Bay Bridge

Connection Details: Manual Reference Section 4.1.4 See Reverse side for more information on this connection



PILE CONNECTION DETAIL



SECTION D

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Fit-up issue: pile placement tolerance is important. In order to fit prefabricated pile footing, only 3" lateral tolerance is allowed for each pile.

Design Issue: Evaluate the effect of eccentricity load from column due to pile placement tolerance; consider lateral confining pressure of confined hole; and connection rebar development length for confined concrete.

Durability issues: Shrinkage cracks at pile footing/pile interface especially at top surface of pile footing. Corrosion concern due to shrinkage cracks. Precast element has a tendency to pull water from fresh concrete placement.

Shape of the underside of the grout cavity is important to prevent hollow areas. The contractor was required to do a test pour to ensure proper concrete placement. This process is recommended for all complex void filling operations.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

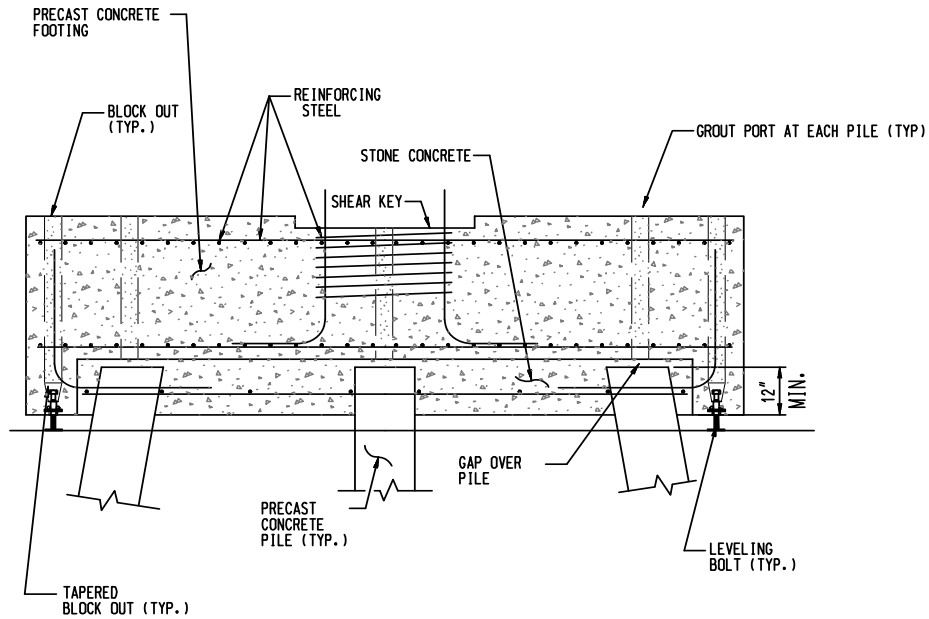
Organization: PCI Northeast Bridge Tech Committee
Contact Name: Rita Seraderian
Address: 116 Radcliffe Road
Belmont, MA 02478

Detail Number: 4.1.4 B
Phone Number: 888-700-5670
E-mail: contact@pcine.org
Detail Classification: Level 3

Components Connected: Precast spread footing to Precast concrete piles

Name of Project where the detail was used: Never used: CONCEPTUAL

Connection Details: Manual Reference Section 4.1.4 See Reverse side for more information on this connection



**ELEVATION
PILE SUPPORTED PRECAST FOOTING
WITHOUT UPLIFT ON PILES**

Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges as a conceptual detail. This has not yet been built; however similar configurations have been built in other states. Leveling bolts are used in the corners to set grade, and a small aggregate concrete is poured through ports to fill the voids around the piles. The reinforcing around the piles is to control shrinkage of the poured concrete and can be placed prior to setting the footing. The design of the footing is the same as a conventional cast-in-place concrete footing design.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear x Moment x Compression X Tension Torsion

What year was this detail first used? NA Condition at last inspection (if known)

How many times has this detail been used? 0 Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction 9 (0 very slow, 10 very fast) When compared to conventional construction

Constructability 9 (0 difficulty making connection, 10 went together easily)

Cost 7 (0 expensive, 10 cost effective) When compared to other connection methods

Durability 9 (0 not durable, 10 very durable)

Inspection Access 0 (0 not visible, 10 easily inspected)

Future Maintenance 0 (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

Organization: **PCI Northeast Bridge Tech Committee**
Contact Name: **Rita Seraderian**
Address: **116 Radcliffe Road
Belmont, MA 02478**

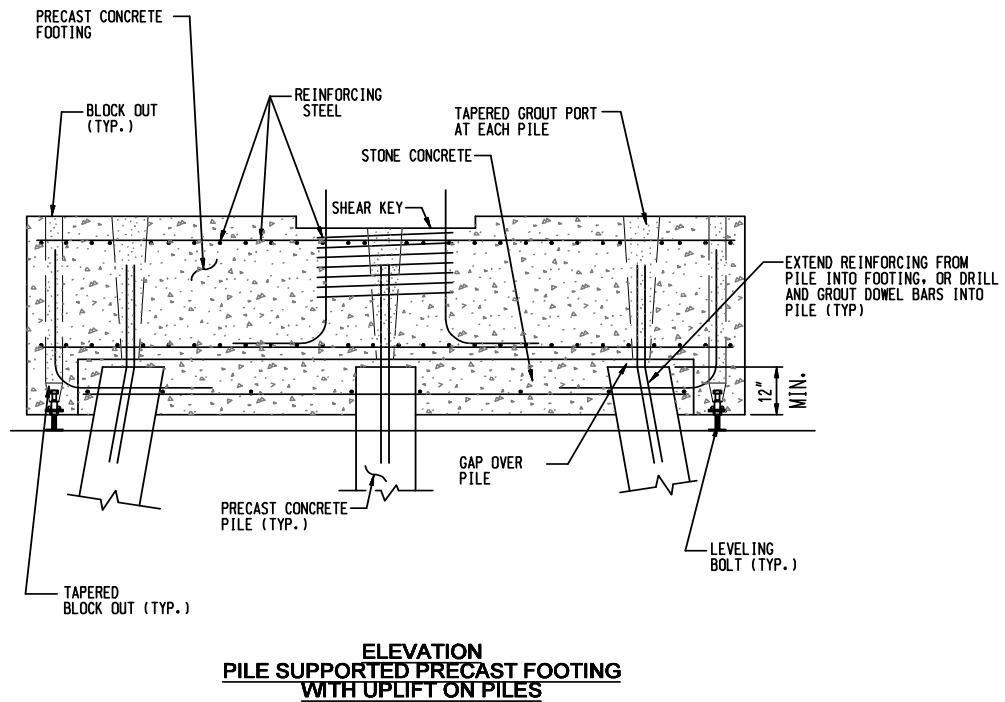
Detail Number: **4.1.4 C**
Phone Number: **888-700-5670**
E-mail: contact@pcine.org

Detail Classification **Level 3**

Components Connected **Precast spread footing** to **Precast Concrete Pile with uplift**

Name of Project where the detail was used **Never used: CONCEPTUAL**

Connection Details: **Manual Reference Section 4.1.4** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

This detail was developed by the committee for bridges as a conceptual detail. This has not yet been built; however similar configurations have been built in other states. Leveling bolts are used in the corners to set grade, and a small aggregate concrete is poured through ports to fill the voids around the piles. The reinforcing around the piles is to control shrinkage of the poured concrete and can be placed prior to setting the footing. The design of the footing is the same as a conventional cast-in-place concrete footing design. A corrugated steel duct pocket could be substituted for the tapered pocket.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

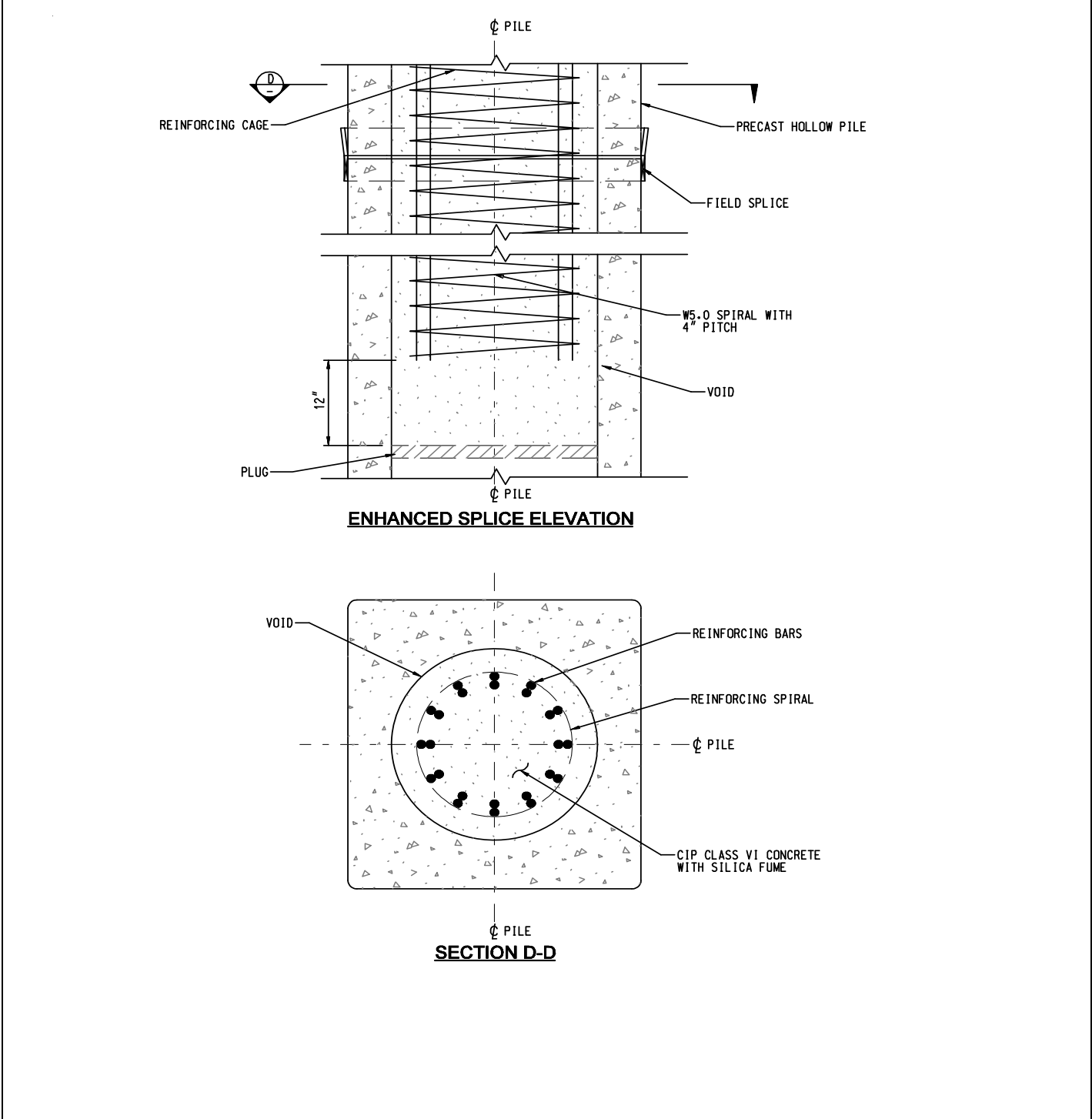
Organization: Florida DOT
 Contact Name: Thomas Andres
 Address: 605 Suwannee Street, MS 33
 Tallahassee, FL 32399-0450

Detail Number: 4.1.6 A
 Phone Number: 850-414-4269
 E-mail: thomas.andres@dot.state.fl.us
 Detail Classification: Level 2

Components Connected: Hollow P/S concrete square pile to Hollow P/S concrete square pile

Name of Project where the detail was used: I-10 Escambia Bay Bridge

Connection Details: Manual Reference Section 4.1.6 See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

See discussion on pile to pier cap detail.

Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used? Condition at last inspection (if known)

How many times has this detail been used? Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Connection Details for Prefabricated Bridge Elements

Federal Highway Administration

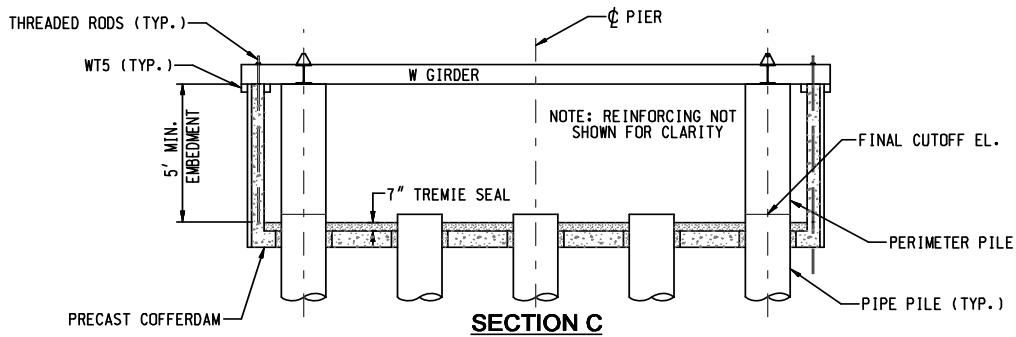
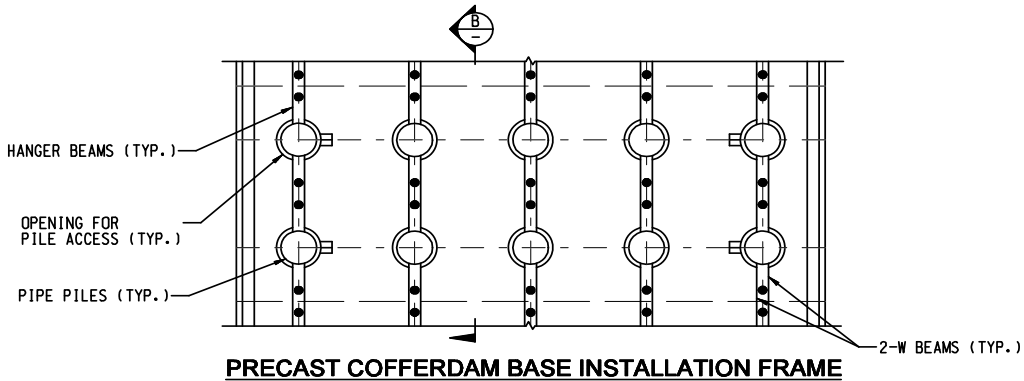
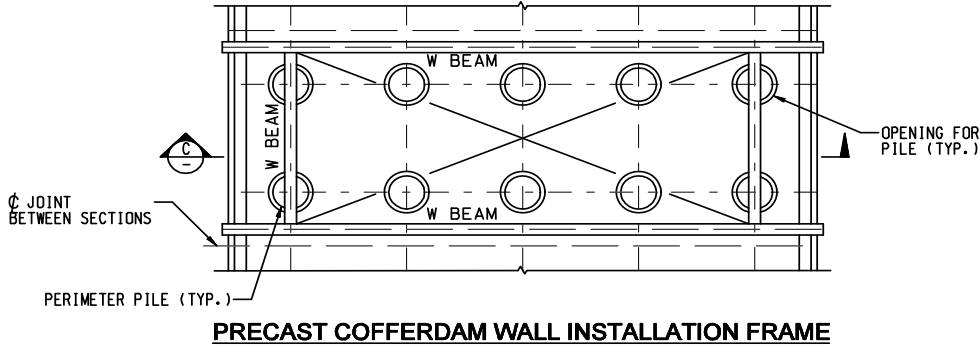
Organization: **Arora & Associates, P.C.**
 Contact Name: **Alan Haring, P.E.**
 Address: **3120 Princeton Pike
 Lawrenceville, NJ 08648**

Detail Number: **4.1.7 A**
 Phone Number: **(609)219-6785**
 E-mail: **aharing@arorapc.com**
 Detail Classification: **Level 2**

Components Connected: **Precast Pier Box Cofferdam** to **Steel Pipe Pile**

Name of Project where the detail was used: **Route 70 over Manasquan River, Brielle, NJ**

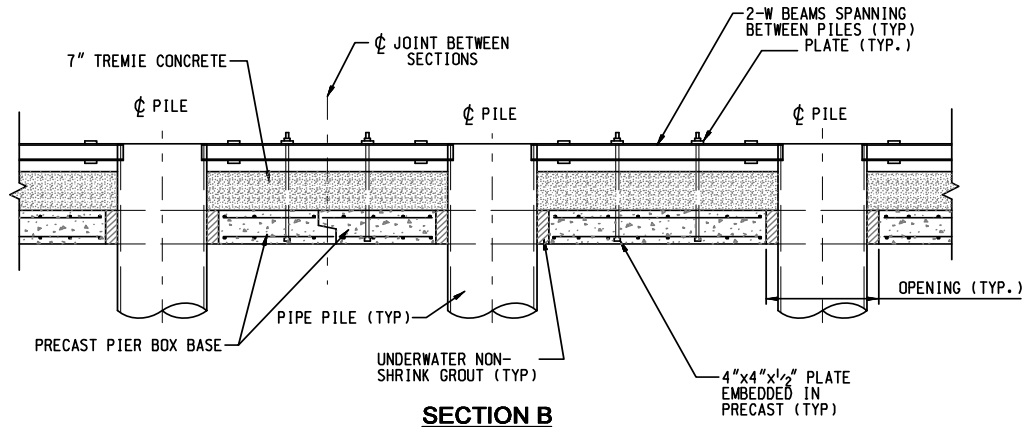
Connection Details: **Manual Reference Section 4.1.7** See Reverse side for more information on this connection



Description, comments, specifications, and special design procedures

See Reverse side for more information on this connection

Temporary support systems for supporting segmental precast cofferdam sections used as a pile-driving frame and as formwork of the cast-in-place footing. Stage 1 shows a plan of the first framing system used to lift the precast cofferdam sections. The system is supported on the outside rows of piles temporarily. After driving the remaining piles through the openings in the bottom of the cofferdam, the Stage 2 support system is installed above the top of the cutoff piles and the first framing system is removed. The annulus between the piles and the cofferdam openings are sealed with grout and a tremie seal is installed. The footing concrete can now be placed in the dry.



Editor's Notes

What forces are the connection designed to transmit? (place x in appropriate boxes)

Shear Moment Compression Tension Torsion

What year was this detail first used?

Condition at last inspection (if known)

How many times has this detail been used?

Year of last inspection

Would you use it again? (yes/no/maybe)

On a scale of 1 to 10, how would you rate the performance of this connection in the following categories?

Speed of Construction (0 very slow, 10 very fast) When compared to conventional construction

Constructability (0 difficulty making connection, 10 went together easily)

Cost (0 expensive, 10 cost effective) When compared to other connection methods

Durability (0 not durable, 10 very durable)

Inspection Access (0 not visible, 10 easily inspected)

Future Maintenance (0 will need maintenance, 10 no maintenance anticipated)

Appendix A: Connection Design Examples

Example	Title	Page
1	Full Depth Precast Concrete Deck Slabs	A-3
2	Precast Column Connections: Column to Cap Connection using mild reinforcement embedded in grouted post-tensioning duct	A-9
3	Precast Column Connections: Precast Column Connections using Grouted Reinforcing Splice Couplers	A-11

Example 1

Full Depth Precast Concrete Deck Slabs

The design of full depth precast concrete deck slabs is similar to the design of a cast-in-place concrete deck with a few exceptions. The AASHTO LRFD Bridge Design Specifications [1] contain provisions for precast full depth deck slabs. Portions of those provisions will be covered in this example.

This example will be for a full depth precast concrete deck slab placed on girders that run parallel to the span. The connections that will be highlighted include the transverse connection between adjacent deck panels and the connection between the slab and the beam. There will also be discussion regarding the design of the actual deck.

Design of Main Reinforcing in the Deck

The design of the main deck reinforcing can be based on the standard design provisions for cast-in-place concrete decks as outlined in the AASHTO LRFD Bridge Design Specifications [1]. The one exception to this is that the empirical design method as specified in Article 9.7.2 is not applicable to precast decks.

The reinforcing in the deck can be mild reinforcing, prestressing (pretensioned or post-tensioned), or a combinations of each. The AASHTO specifications cover the design of all of these approaches; therefore a detailed design example is not presented here.

The design of the overhang requires special attention. The maximum moment in the overhang deck can be at the base of the bridge parapet or railing post. This location is often very close to the end of the deck slab. It may not be possible to design this connection using prestressing strand since the moment is normally applied within the development length of the strand and sometimes within the transfer length of the strand. In this case, the overhang slab will need to be supplemented with mild reinforcement.

Design of the connection to the steel beams

The design of this connection is critical to the performance of the superstructure if the design of the girders is based on composite action. Standard shear connectors can be used that are placed in pockets that are cast in the precast deck slab. The pocket shape is normally rectangular with either square or rounded corners. The sides of the pockets can be vertical; however it is recommended that the pockets be tapered from top to bottom for several reasons. It is easier to remove a tapered pocket form in the deck after casting, and a tapered pocket will develop a mechanical connection to the beam.

The design of the shear connectors is according to the AASHTO specifications. Instead of varying the spacing of the connectors across the beam, the spacing is kept constant and the number of connectors in each pocket is varied as the shear demand changes.

Design of the connection to concrete beams

The design of this connection is similar to the steel beam connection above. The AASHTO provisions for horizontal shear design can be followed. If projecting reinforcing is used, the bars need to be spaced in cadence with the proposed slab pocket spacing. Research has shown that embedded headed studs can also be used for this connection [22]. Other research has shown that this connection can be made using embedded steel

plates cast into the precast beams [33]. These plates are attached to the beam using shear studs. In the field, the deck is connected in a similar manner as a steel beam.

Transverse Connection with Post-tensioning (PT)

The AASHTO LRFD Bridge Design Specifications [1] contain several provisions that cover the design of post-tensioning systems. This example will cover the sections that are applicable to the design of a post-tensioning for the connection between full depth precast concrete deck slabs.

Givens:

- 200 foot long single span bridge
- Deck information
 - 8 inches thick
 - 50 feet wide
 - $f'c = 4000$ psi
- PT duct information
 - Use 1"x3" Oval polyethylene duct placed flat (inside dimensions)
 - Use a maximum of 4-0.5" diameter grade 270 strand for PT
 - $f_{pu} = 270$ ksi
 - $f_{py} = 0.9 * f_{pu} = 243$ ksi

1. Article 9.7.5.3 Longitudinally Post-Tensioned Precast Decks

- a. The average effective prestress shall not be less than 0.25 ksi.
 - i. This will be the basis of this design example. The prestress is placed at mid-depth of the slab to provide uniform pre-compression across a grouted shear key joint.
 - ii. Article 9.7.5.3 specifies a minimum average effective prestress of 0.250 ksi. Most designers assume this prestress is taken at release and do not account for long term losses due to creep, shrinkage and elastic shortening of the strand. The interaction of the composite prestressed deck with the supporting framing is a very complex situation. Some prestress will be lost due to these effects; however the beam framing will resist these losses. There is not a recognized method for calculating these losses in a composite deck. Most designers assume that 0.250 ksi prestress is conservative enough to cover any minor loss of prestress. For this example, it will be assumed that the effective prestress is taken at release. Losses will be calculated for friction between the duct and the PT strand, anchorage set, and elastic shortening.

2. Article 5.4.6.2 Size of Ducts

- a. For multiple strand tendons: Required Area $\geq 2.5 * A_s$
 $A_s = \text{Net area of prestressing steel} = 4 * 0.153 = 0.612 \text{ in}^2$
Duct Area = 2.79 in² (from manufacturer)

Therefore: $2.79 \text{ in}^2 \geq 0.612 \text{ in}^2$ **ok**

- b. Inside diameter $\geq d + 0.25$ in.

d = strand diameter = 0.5 in.

Therefore: $1" \geq 0.5 + 0.25 = 0.75$ **ok**

c. Duct size ≤ 0.4 * least gross concrete thickness

Therefore: $1" \leq 0.4 * 8" = 3.2"$ **ok**

3. Article 5.9.3 Stress limitations for prestressing tendons

Prior to seating = $0.9f_{py} = 219$ ksi

At anchorages immediately after anchor set = $0.7f_{pu} = 189$ ksi

4. Article 5.9.5.1 Total Loss of Prestress

a. For post-tensioned members:

$$\Delta f_{pT} = \Delta f_{pF} + \Delta f_{pA} + \Delta f_{pES} + \Delta f_{pLT}$$

Δf_{pT} = total loss (ksi)

Δf_{pF} = Loss due to friction (ksi)

Δf_{pA} = Loss due to anchorage set (ksi)

Δf_{pES} = sum of all losses due to elastic shortening (ksi)

Δf_{pLT} = losses due to long-term shrinkage and creep of concrete and relaxation of the steel (ksi)

i. Loss due to anchorage set

Elongation = $\Delta = PL/AE_p$

In terms of stress = $\sigma = f_{pA} = P/A = \Delta E_p/L$

Δ = anchorage set dimension = 0.375 (C5.9.5.2.1)

L = 200 feet = 2400 inches

E_p = Modulus of elasticity of strand = 28500 ksi (5.4.4.2)

$f_{pA} = 0.375 * 28500 / 2400 = 4.45$ ksi

ii. Loss Due to friction

$$\Delta f_{pF} = f_{pj} (1 - e^{-(Kx + \mu\alpha)})$$

f_{pj} = stress in prestressing steel at jacking (ksi)

Controlling stress after anchor set = 189 ksi
(see above)

Anchorage set stress = $f_{pA} = 4.5$ ksi (see above)

Therefore: $f_{pj} = f_{pj} + f_{pA} = 189 + 4.5 = 193.5$

x = length of prestressing tendon from jacking end to any point under consideration (ft)

Assume that jacking will be done from one end;
 therefore the point under consideration will be the
 far end of the slab
 Therefore: $x = 200$ ft

K = wobble coefficient (per foot of tendon)
 = 0.0002 (Table 5.9.5.2.2b-1)

μ = coefficient of friction
 = 0.23 (Table 5.9.5.2.2b-1)

α = sum of angular change of prestressing steel path
 = 0 (straight bridge)

e = base of Napierian logarithms = 2.718

Therefore: $\Delta f_{pF} = 193.5 (1 - e^{-(0.0002*200 + 0.23*0)}) = 7.59$ ksi

iii. Article 5.9.5.2.3 Elastic shortening

There are two portions of this section. One for pretensioned members and one for post-tensioned members. The equations are as follows:

Pretensioned members

$$\Delta f_{pES} = (E_p / E_{ct}) * f_{cgp}$$

Post-tensioned members

$$\Delta f_{pES} = ((N-1)/2N) * (E_p / E_{ct}) * f_{cgp}$$

The equations are very similar. The PT equation has an additional multiplier term $(N-1)/2N$. This term will always be less than 1. The notes also state that this value can be multiplied by 0.25 for slab systems. A precast deck system is more similar to a pretensioned beam since the prestressing is concentric and uniform. For this reason, it is recommended that the equation for pretensioned members be used. This is significantly more conservative than equation for PT members.

$$\Delta f_{pES} = (E_p / E_{ct}) * f_{cgp}$$

E_p = modulus of elasticity of prestressing steel (ksi)
 = 28500 ksi (5.4.4.2)

E_{ct} = modulus of elasticity of concrete at transfer (ksi)
 = $33,000 K_1 w_c^{1.5} \sqrt{f'_c}$ (5.4.2.4-1)

K_1 = correction factor for aggregate
 = 1.0 (5.4.2.4)

w_c = unit weight of concrete (kcf)
 = 0.145 (Table 3.5.1-1)

f'_c = 4.0 ksi (given)

Therefore $E_{ct} = 3644$ ksi

$$\begin{aligned} f_{cgp} &= \text{the concrete stress at release (ksi)} \\ &= 0.250 \text{ ksi} \quad (9.7.5.3) \end{aligned}$$

Therefore $\Delta f_{pES} = 1.96$ ksi

$$\begin{aligned} \text{Therefore the total losses} &= \Delta f_{pT} = \Delta f_{pF} + \Delta f_{pA} + \Delta f_{pES} + \Delta f_{pLT} \\ &= 7.59 + 4.45 + 1.96 + 0 \\ &= 14.0 \text{ ksi} \end{aligned}$$

5. Required number of Post-tensioning Ducts

a. Area of bridge deck

Width = 50 feet = 600 in. (given)

Thickness of deck = 8 in. (given)

Therefore deck area = 4800 in²

b. Required Prestress force

Effective Prestress = $f_{cgp} = 0.250$ ksi (see Step 1 above)

Therefore the required prestress force = $0.250 * 4800 = 1200$ kips

c. Number of PT strand required

Prestress after anchorage set = 189 ksi (see Step 3 above)

Anchorage set = 4.45 ksi

Therefore stress prior to anchorage set = $189 + 4.45 = 193.45$ ksi

$$\begin{aligned} \text{Prestress after losses} &= \text{Effective prestress} \\ &= 193.45 - 14.0 = 179.45 \text{ ksi} \end{aligned}$$

$$\begin{aligned} \text{Area of strand req.} &= A_{sreq} \\ &= \text{Req. Prestress force} / \text{Prestress after losses} \\ &= 1200 / 179.45 \\ &= 6.69 \text{ in}^2 \end{aligned}$$

Area of strand per duct = 0.612 in²

Number of Ducts required = $6.69 / 0.612 = 10.9$

Therefore use 11 Ducts with 4 – ½ in. diameter grade 270 strand

Example 2 Precast Column Connections

Column to Cap Connection using mild reinforcement embedded in grouted post-tensioning duct

Post-tensioning ducts embedded in precast concrete components offer a means to connect two concrete elements. There are proprietary connectors that are available for this connection (see next section). There is one proprietary option that can be used for several types of connections.

This connection was developed through research undertaken by the Texas Department of Transportation and put into practice on the Lake Belton Bridge (see photo to the left).



Figure EX2-1 Lake Belton Bridge Pier

Design of the connection and connected components

The design of this connection is currently not covered in the AASHTO LRFD Bridge Design Specifications [1]. The Texas Research project included the development of a design methodology for this connection. The research report for this work is as follows:

Development of a Precast Bent Cap System [49]

Authors: E.E. Matsumoto, M.C. Waggoner, M.E. Kreger, S.L. Wood and J.E. Breen

The University of Texas at Austin, Center for Transportation Research

Published: January 2001

Design Methodology: Pages 251-309

This methodology is well developed and is quite lengthy. In order to keep the size of this manual reasonable, it was decided to not include this detailed design methodology in this appendix. The full research document and design methodology is available at the following website:

http://www.utexas.edu/research/ctr/pdf_reports/0_1748_2.pdf

Seismic Issues

At this time, this connection does not meet the requirements for high seismic applications. Future research may lead to a similar connection that can be used in high seismic areas.

Example 3 Precast Column Connections

Precast Column Connections using Grouted Reinforcing Splice Couplers

Several states have designed and built bridges using grouted reinforcing splice couplers. These couplers are mechanical couplers that take the place of a reinforcing lap splice. There is no requirement for the design of the coupler. They are an off-the-shelf item that is normally handled through a performance specification. They are particularly suited for prefabrication because the connector is embedded in the precast concrete component. The connection is made by injecting grout into the cast steel connector.

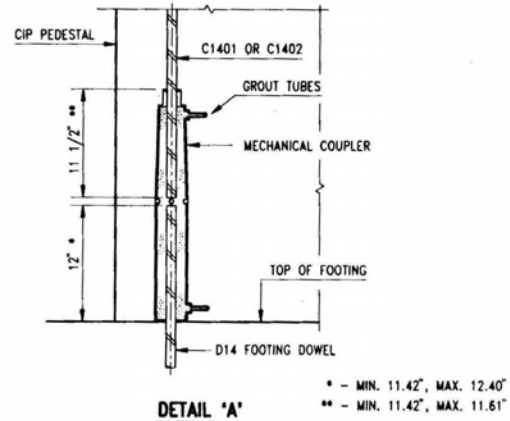


Figure EX3-1 Grouted Reinforcing Splice Coupler



Figure EX3-2 Edison Bridge

These couplers have been in the building market for many years; however, they are relatively new to the bridge market. One of the first agencies to use these couplers on a bridge project was the Florida Department of Transportation. The Edison Bridge was built using couplers for the column to footing connection and the column to cap connection. The detail above and the photo to the left are from the Edison Bridge Project.

Design of the Grouted Splice Coupler

The AASHTO LRFD Bridge Design Specifications require that all mechanical reinforcing splices develop 125% of the specified yield strength of the bar (Article 5.11.5.2.2) [1]. Several manufacturers make grouted splice couplers that can meet and exceed this requirement.

Design of the Connecting Components

The design of the components is the same as the design of a standard reinforced concrete component with one minor change. The couplers are larger than the connecting bars; therefore in order to obtain proper cover over the coupler, the reinforcing cage needs to be moved toward the interior of the component. This may have an effect on the design of the component since the effective structural depth of the member is reduced when compared to cast-in-place concrete construction. The resulting change will be larger or more closely spaced bars.

Seismic Issues

At this time, this connection has been approved for use on seismic connection designed for Seismic Zones 1 and 2. There is concern that this connection will meet the stringent demands of ductile plastic hinging. Research has been completed in Japan in the past that investigated plastic hinging capabilities of these connections [7]. The following two plots show the results of this limited research. The upper plot is a plot of a control sample column connection built without couplers. The lower plot is a plot of a column connection built with couplers.

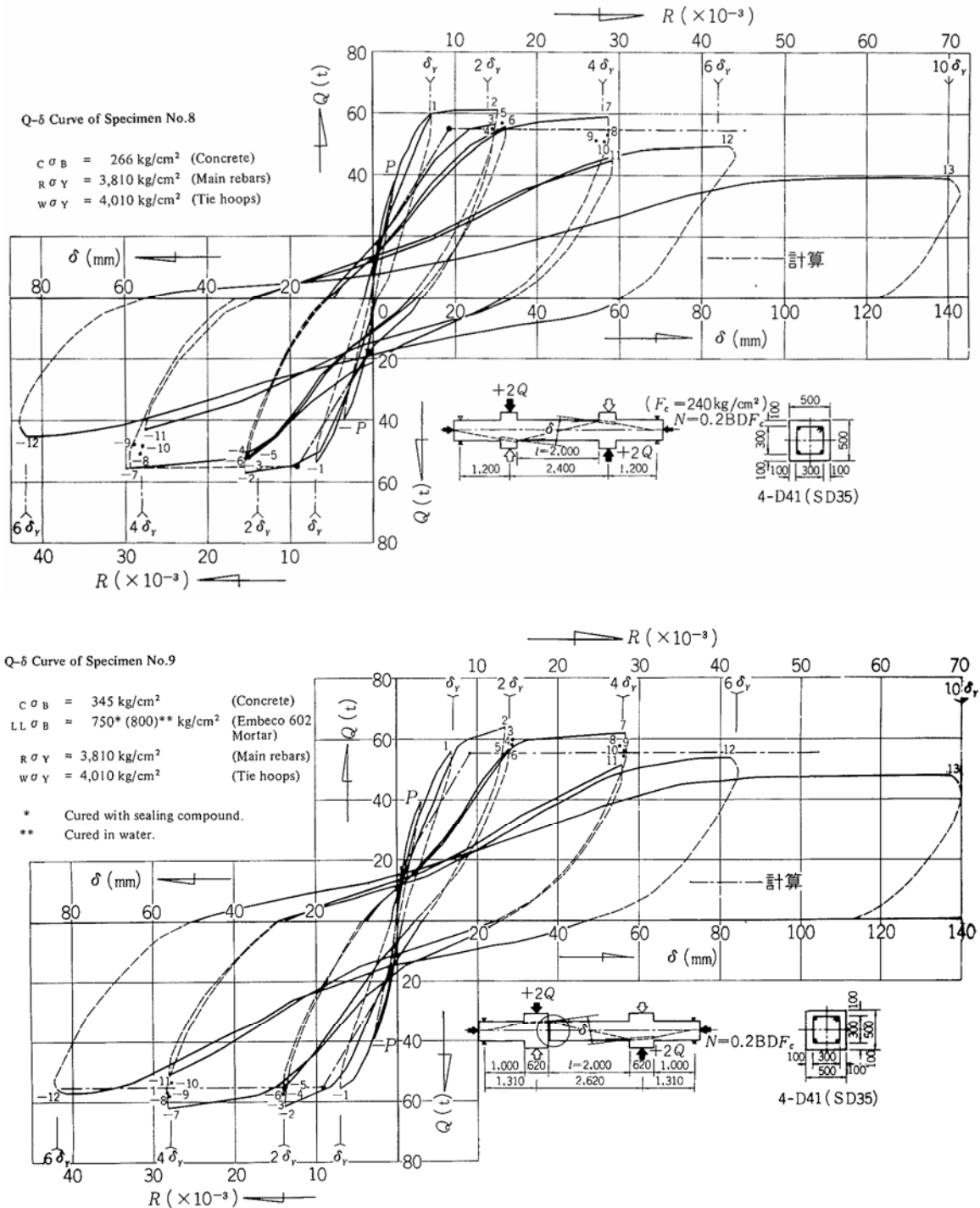


Figure EX3-3 Grouted Reinforcing Splice Coupler Test Results

A review of these two plots indicate that the column with the couplers behave essentially the same as the control column and the plastic deformations are well above what is normally required for ductile column behavior. There is concern that this research was not broad enough for acceptance in the US bridge market. Future research may be undertaken to confirm the behavior of these couplers on bridge.

Appendix B: Proprietary Products

The following is a listing of proprietary products and systems that can be used for prefabricated bridges. The list is based on the information contained in this document. There are other products and systems available in the United States. Designers should keep apprised of systems that may be available.

Description	Page
Prefabricated Superstructure Systems	B-3
Inverset	
Effideck™	
CON/SPAN® Bridge Systems	
BEBO® Concrete Arch System	
HY-SPAN® Bridge System	
Grouted Reinforcing Splice Couplers	B-5
NMB Splice Sleeve	
Dayton Superior DB Grout Sleeve	
Erico Lenton Interlok Rebar Splicing System	
Proprietary Retaining Wall Systems	B-6
Reinforced Earth® and Retained Earth™ Retaining Walls	
Doublewal Retaining Wall	
T-WALL® Retaining Wall System	
Post-tensioning Systems	B-7
Dydiwag Systems	
VSL Post-tensioning Systems	
Williams Threadbar Systems	

Prefabricated Superstructure Systems

1. Inverset

A precast concrete steel composite superstructure unit that is fabricated in the inverted (up side down) position. When flipped right side up, the deck is pre-compressed by the weight of the unit. The units are placed on the substructure and narrow reinforced longitudinal closure pours complete the superstructure. The additional compression due to the inverted casting increases the quality and durability of the deck. The system was at one time patented. It is the understanding of the authors that patent has run out; therefore it can be manufactured by any precast fabricators.

Contact Information:

The Fort Miller Co, Inc.
P.O. Box 98
Schuylerville, NY 12871
Phone: (518) 695-5000
www.fortmiller.com

2. Effideck™

Effideck™ is a lightweight, precast concrete bolt down deck replacement system. The system consists of a lightweight concrete deck slab and closely spaced structural steel members cast integrally.

Contact Information:

The Fort Miller Co, Inc.
P.O. Box 98
Schuylerville, NY 12871
Phone: (518) 695-5000
www.fortmiller.com

3. CON/SPAN® Bridge Systems

CON/SPAN® is a patented modular precast concrete system for the construction of bridges, culverts, underground structures and environmentally acceptable alternatives for underground containment. The structures are arch type spans with spandrel walls. Precast wingwalls are also included in this system.

Contact Information:

CON/SPAN®
3100 Research Blvd.
P.O. Box 20266
Dayton, Ohio 45420-0266
Phone: 937-254-2233
www.con-span.com

4. BEBO® Concrete Arch System

The BEBO® Concrete Arch System is a combination of cast-in-place concrete footings, precast arch elements, headwalls, and wingwalls. The arch segments can be supplied in one or two piece configurations.

Contact Information:

CONTECH Construction Products Inc.

9025 Centre Pointe Dr.
Suite 400
West Chester, OH 45069
Phone: 800-338-1122
www.contech-cpi.com

5. HY-SPAN® Bridge System

The HY-SPAN® Bridge System is a precast concrete rigid frame system with a flat top. It can span from six to forty feet.

Contact Information:

HY-SPAN® Systems, Inc.
2050 South Harding
Indianapolis, Indiana 46221
Phone: 800-875-4920
www.hyspan.com

Grouted Reinforcing Splice Couplers

1. NMB Splice Sleeve

The NMB Splice Sleeve is a mechanical coupler for splicing reinforcing bars which uses a cylindrical shaped casting filled with a Portland cement based non-shrink high early strength grout. Reinforcing bars being spliced are inserted into the sleeve to meet approximately at the center of the sleeve. This allows for the structural connection of precast sections that will develop connections beyond the tensile strength of the bar.

Contact Information:

Splice Sleeve North America, Inc.
192 Technology Drive, Suite J,
Irvine, California 92618-2409
Phone: (949)861-8393
www.splicesleeve.com

2. Dayton Superior DB Grout Sleeve

The Dayton Superior DB Grout Sleeve provides a two-piece splicing technique for splicing rebar. Typical applications include splicing rebar in precast concrete construction and cast-in-place concrete structures. The DB Grout Sleeve is a steel casting filled with special non-shrink grout that splices reinforcing after elements are erected.

Contact Information:

Dayton Superior
Corporate Headquarters
7777 Washington Village Dr., Ste. 130
Dayton, OH 45459
Phone: 937-428-6360
www.daytonsuperior.com

3. Erico Lenton Interlok

The Erico Lenton Interlok rebar splicing system is a coupler using for connecting precast elements using the patented Lenton tapered thread system along with a specially formulated cementitious grout placed in a steel casting sleeve.

Contact Information:

ERICO United States
34600 Solon Road
Solon, Ohio 44139
Phone: 440-248-0100
www.erico.com

Proprietary Retaining Wall Systems

There are numerous prefabricated retaining wall companies in the United States. Most agencies have approved product lists for proprietary retaining walls. Designers are encouraged to contact the local agencies for walls that are approved for use.

1. Reinforced Earth

Reinforced Earth® and Retained Earth™ Retaining Walls are mechanically stabilized earth (MSE) gravity structures consisting of alternating layers of granular backfill and reinforcing strips with a modular precast concrete facing.

Contact Information:

The Reinforced Earth Company
8614 Westwood Center Drive, Suite 1100
Vienna, VA 22182-2233
Phone: 1-800-446-5700
www.reinforcedearth.com

2. Doublewal

Doublewal is an interlocking precast retaining wall system. Each Doublewal unit consist of two concrete panels connected by cross beams to form a soil bin. The units are keyed together and filled with granular materials.

Contact Information:

Doublewal Corporation
7 West Main Street Plainville, CT 06062
Phone: 860-793-0295
www.doublewal.com

3. T-Wall

The T-WALL® Retaining Wall System is a precast reinforced concrete modular wall system. The precast unit is comprised of a rectangular face panel and a stem that extends into the backfill. The units are fabricated with a stem length designed to suit the application. The units are then stacked and backfilled to suit site conditions.

Contact Information:

The Neel Company
8328-D Traford Lane
Springfield, VA 22152
Phone: 703-913-7858
www.info@neelco.com

Post-tensioning Systems

1. Dywidag Systems

Dywidag Systems supplies both multi-strand and threaded bar post-tensioning systems.

Contact Information:

DYWIDAG Systems International USA, Inc.
320 Marmon Drive
Bolingbrook, IL 60440
Phone: 630-739-1100
www.dsiamerica.com

2. VSL Post-tensioning Systems

VSL supplies all types of multi-strand post-tensioning systems.

Contact Information:

VSL Corporate Headquarters
7455 New Ridge Road, Suite T
Hanover, MD 21076
Phone: 410-850-7000
www.vsl.net

3. Williams Threadbar

Williams supplies threaded bar post-tensioning systems.

Contact Information:

Williams Form Engineering Corp.
8165 Graphic Drive
Belmont, MI 49306
Phone: 616-866-1890
www.williamsform.com

Appendix C: Sample Construction Specifications

The following is a listing of sample specifications from several state agencies. These specifications are written in the format of the particular agency; therefore the formats are not similar. These specifications are presented for reference only. Designers can use the information contained in this appendix; however the specifications should be carefully reviewed and modified as needed.

Example	Title	Page
1	New Hampshire DOT – Prefabricated Substructures	C-3
2	New Hampshire DOT - Full Depth Precast Concrete Deck Slabs	C-11
3	Maine DOT – Prefabricated Integral abutments and piers	C-27
3	Texas DOT Precast Column Connections: Column to Cap Connection using mild reinforcement embedded in grouted post-tensioning duct	C-41

Example 1: New Hampshire DOT Prefabricated Substructures

The following specification was taken from a project that involved the reconstruction of a portion of Interstate 93. In this project, the design was based on conventional cast-in-place concrete construction for the substructure elements. Typical details for prefabricated substructure elements were also included in the contract. Contractors were given the option to use either conventional construction or prefabricated construction. Two specifications are included. One supplements the standards concrete specification, and the other supplements the standard prestressed concrete specifications.

**SALEM TO MANCHESTER
13933C**

June 6, 2007

SPECIAL PROVISION

AMENDMENT TO SECTION 520 -- PORTLAND CEMENT CONCRETE

Item 520.01027 - Concrete Class AA (QC/QA) (Precast Option) (F)

Item 520.03007 – Concrete Class AA (Precast Option)

Item 520.03027 - Concrete Class AA, Approach Slabs (QC/QA) (Precast Option) (F)

Item 520.12007 - Concrete Class A, Above Footings (Precast Option) (F)

Item 520.21307 - Concrete Class B, Footings (On Soil) (Precast Option) (F)

This special provision allows the optional substitution of precast elements to construct subabutments, approach slabs, and piers for the cast-in-place elements detailed on the plans. All applicable provisions of 520 shall apply to cast-in-place concrete except as amended or modified below. All applicable provisions of 528 and any special provisions to 528 shall apply to precast concrete. The QC/QA provisions of this section shall not apply if the precast option is selected.

Add to 520.1.1 the following:

1.1.2 This work shall consist of manufacturing, storing, transporting, and assembling precast concrete substructure elements including subabutments, approach slabs, and piers, herein referred to as “members”, in accordance with the contract plans. The relevant provisions of the design method specified on the contract plans shall be adhered to unless such provisions are in conflict with this specification, in which case this specification shall govern.

1.1.3 This work shall also include the installation of approved cementitious grout where indicated on the plans, and/or assembly plans and shop drawings.

Add to 520.1 the following:

1.3 Design Criteria. Precast substitutions requiring a re-design shall meet all the applicable requirements from the current AASHTO Standard Specifications for Highway Bridges, including both seismic and non-seismic loading.

1.3.1 Design loads used for the development of contract plans and required for the re-design of the optional precast members may be obtained from the Department upon request.

1.3.2 Details of the precast options are provided as an attachment to this specification.

Add to 520.3 the following:

3.13 Special Contract Requirements for Precast Members

3.13.1 Assembly Plan for Precast Concrete Members.

3.13.1.1 One assembly plan shall document all aspects of the precast element substitution. The plan shall include but shall not be limited to:

- a) shop drawings of all products
- b) material requirements for other grout products proposed for use
- c) method of erection proposed and the amount and character of equipment to be utilized
- d) temporary support requirements including leveling screws and/or shims for footings and lateral load and moment resistance for stems
- e) member placement sequence
- f) tolerance requirements for assembly
- g) grouting plan

3.13.1.2 The plan shall be submitted for approval 60 days prior to the start of fabrication and shall be stamped by a Professional Engineer, licensed in the State of NH. Multiple PE stamps may be included on the various portions of the plan, but only **ONE** engineer with PE stamp shall be clearly identified as the Engineer of Record for the entire assembly plan. All questions, comments, and revisions shall be coordinated with the Engineer of Record.

3.13.1.3 The Engineer of Record for the assembly plan is responsible for the precast system and its ability to resist the minimum design loads detailed on the contract drawings or provided in the specifications. The design loads detailed are specified to a particular location for a cast-in-place solution. Loadings specific to a precast system are not addressed and their inclusion and application shall be the sole responsibility of the assembly plan Engineer of Record.

3.13.2 Pre-Placement Meeting. A pre-placement meeting will be held to review the specifications, schedule, and assembly plan, and to discuss any special requirements. The meeting will be held at least forty-five (45) days prior to the scheduled casting of any

member. The Contract Administrator shall schedule the meeting and invite representatives of the Contractor, Fabricator, and the Bureau of Bridge Design and Materials and Research, along with any other party the Engineer deems appropriate.

3.13.3 All precast products used in the bridge system shall be fabricated by the same precast plant.

Add to 520.4 the following:

4.4 The furnishing and placing of precast members substituted for cast-in-place elements will not be measured.

Add to 520.5 the following:

5.10 Precast Option

5.10.1 No additional payment will be made for use of the precast construction method. Payment will be made on plan quantities only.

5.10.2 The Contract final pay quantity will not be adjusted by the volume of the precast concrete or by any additional concrete thickness required for the precast concrete option.

5.10.3 The Contract estimated quantity for reinforcing steel will not be adjusted by the quantity of reinforcement included in the precast concrete element.

5.10.4 All costs for preparing and following the assembly plan shall be subsidiary.

5.10.5 The furnishing and placing of precast concrete members shall be subsidiary.

5.10.6 All costs for materials used in the assembly of the precast members and/or detailed in the assembly plan shall be subsidiary.

Add to Pay items and units:

520.01027	Concrete Class AA (QC/QA) (Precast Option) (F)	Cubic	Yard
520.03007	Concrete Class AA (Precast Option)		Cubic Yard
520.03027	Concrete Class AA, Approach Slabs (QC/QA) (Precast Option) (F)	Cubic	Yard
520.12007	Concrete Class A, Above Footings (Precast Option) (F)	Cubic	Yard
520.21307	Concrete Class B, Footings (On Soil) (Precast Option) (F)	Cubic	Yard

June 6, 2007

SPECIAL PROVISION

AMENDMENT TO SECTION 528 -- PRESTRESSED CONCRETE MEMBERS

This special provision allows the optional substitution of precast elements to construct stub abutments, approach slabs, and piers for the cast-in-place elements detailed on the plans. All applicable provisions of 528 shall apply to precast concrete except as amended or modified below. Refer to PCINER-06-ABC "Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components" (www.pcine.org) for more information and additional guidelines. This specification includes provisions for self-consolidating concrete.

Replace 528.2.8.2 with the following:

2.8.2 Mix Design for Precast Substitution. The fabricator shall design and submit for approval the proportions and test results for a concrete mix which shall attain the minimum properties in 520 Table 1A. Compressive strength test cylinders shall be sampled in accordance with the requirements of AASHTO T 141, molded and cured in accordance with the requirements of AASHTO T 23, and tested in accordance with the requirements of AASHTO T 22. The permeability shall be measured at 56 days using AASHTO T 277. Air entrainment testing shall be in accordance with AASHTO T 119 and T 152. The minimum average compressive strength of the proposed mix shall be determined using the procedure in Appendix D of 528.

Add to 528.2.8 the following:

2.8.4 Mix designs for Self Consolidating Concrete shall be submitted for approval to the Bureau of Materials and Research. Mix designs and material testing shall conform to the Interim Guidelines for the use of Self-Consolidating Concrete in Precast/Prestressed Concrete Institute Member Plants, PCI Report TR-6-03 (www.pci.org). Submittals shall be approved by the admixture manufacturer. Results of trial mixes shall be included with the mix design submittal and shall include all test results. Test results shall include: compressive strength; air content; permeability; slump flow; and U-tube test. Test results for the slump flow shall show that the mix meets the requirements for flow and that the aggregate distribution and mortar halo shall show no segregation or bleeding. Test results for the U-tube test shall show that the mix is capable of flowing around the reinforcing. Compression testing and permeability testing shall be done on rodded and non-rodded specimens to show that the material performs satisfactorily without consolidation.

Amend 528.2.9 to read:

2.9 Shear Key Grout for Butted Box Beams, Shear Keys, Joints and Blockouts

Amend 528.2.9.1 to read:

2.9.1 Grout for shear keys, joints, and blockouts shall be an approved grout as listed under Section 529A of the Qualified Products List. Additional aggregates and/or materials shall not be added to the material during field mixing. Grout shall have a minimum strength of the cast-in-place concrete that is being replaced.

Add to 528.2.10 the following:

2.10.1 Temporary supports, leveling screws, and shims shall be approved prior to use.

Amend 528.3.1.4.3.1 with the following:

3.1.4.3.1 At least thirty (30) days prior to fabrication of the precast members, a test placement [10 feet (3 meters) in length] of the actual member section (unreinforced) shall be poured utilizing the proposed methods of concrete placement and curing. The minimum air entrainment value shown in 520 Table 1A shall be held as the absolute minimum value for the test section. Concrete that does not meet this value shall not be used in the test section.

Add to 528.3.4 the following:

3.4.5 Upon approval, the shop drawings shall be transferred to permanent, archival quality, 22 inches by 34 inches (559 by 838 mm) double matte mylar and submitted to the Department.

3.4.6 The shop drawings shall be properly titled as to project location and bridge components similar to the Contract Plans title box. The shop drawings shall include but not necessarily be limited to the following:

- a. Fully and accurately dimensioned views clearly showing the geometry of the members including all projections, recesses, notches, openings, blockouts, connections, etc.
- b. Details and bending schedules of steel reinforcing clearly showing the size, spacing, and location including any special reinforcing items required but not shown on the contract plans. Reinforcing or ties provided under lifting devices shall be shown in detail.
- c. Details and locations of all items to be embedded in the members such as inserts, lifting devices, leveling screws, temporary supports, etc.
- d. Quantities for each member (concrete volume, reinforcing steel weight, and total section weight).
- e. Description of methods for curing, handling, storing, transporting, and erecting the members.

Add to 528.3.17 the following:

3.17.3 Rejection of precast members. The Engineer will inspect the first group of members cast (not to exceed three members) upon removal from the casting bed. Defects will be identified and the Contractor shall propose to the Engineer in writing the preventative measures to be taken to eliminate those defects in the second group of members to be cast. Defects in members cast in the first group may be cause for rejection. After the second group is cast, the members again will be inspected and the Contractor shall again propose preventative measures as may be necessary. If other defects occur during subsequent casting of members, the above procedure shall be repeated. Any defect occurring a second time will be cause for rejection of the member in which it occurs.

3.17.3.1 The following are considered defects that may constitute cause for rejection:

1. Individual rock pockets or honeycomb over 6 square inches (3750 square mm) in area or over 1 inch (25 mm) deep.
2. Any member having more than one honeycomb area per side or surface even though of smaller scope than defined above.
3. Any discontinuity or crack in the concrete that would permit moisture to reach the reinforcing steel.
4. Edge or corner breakage exceeding 12 inches (300 mm) in length or over 1 inch (25 mm) in depth, and damaged ends where such damage would prevent making a satisfactory joint.
5. Extensive fine cracks or checks.
6. Precast sections produced by racked or otherwise distorted forms.

3.17.3.2 The Engineer may approve repairs to occasional, non-recurring, and isolated defects. The Contractor shall submit procedures and materials for repairs to the Engineer for approval.

Add to 528.3.19 the following:

3.19.4 Dimensional Tolerances of Precast Concrete Members.

3.19.4.1 All tolerances not specified otherwise, shall be in accordance with PCI MNL-135-00 "Tolerance Manual for Precast and Prestressed Concrete Construction" except as modified herein.

3.19.4.2 Tolerances for all substructure elements shall meet or exceed those listed for Flat Structural Wall Panels except for the following items:

d, variation from specified plan end squareness or skew = +/- 1/8"
f, sweep = +/- 1/8"

3.19.4.3 Vertical joints between adjacent wall members shall be adequately filled and sealed. Grouted shear keys may be introduced, as required, to meet fabrication and

assembly tolerances. All shear keys introduced for fabrication and assembly convenience shall be detailed on the shop drawings.

Amend 528.3.20.2 to read:

3.20.2 Members shall be lifted only at the designated points by approved lifting devices embedded in the concrete and by following proper hoisting procedures. The Contractor is responsible for not exceeding allowable stresses in the precast members during handling and shall include all necessary member modifications on the shop drawings that are required to accommodate lifting and assembly loads and methods.

Example 2: New Hampshire DOT Full Depth Precast Concrete Deck Slabs

The following specification was taken from a project that involved the replacement of a bridge deck on a multi-span bridge. The prefabricated bridge elements were Full Depth Precast Concrete Deck Slabs. This specification is a supplement to the New Hampshire DOT Standard Specifications.

**HAVERHILL, NH – NEWBURY, VT
14435**

September 11, 2007

SPECIAL PROVISION

AMENDMENT TO SECTION 528 – PRESTRESSED CONCRETE MEMBERS

Item 528.62– Precast Concrete Deck Panels, Post-Tensioned (F)

Description

This special provision provides for full depth precast concrete deck panels with bonded longitudinal post-tensioning and contents of this special provision apply to this item only. All provisions of 528 shall apply except as amended or modified below.

Add to 1.1

1.1.2 This work shall also include the design, detailing, furnishing, post-tensioning and grouting of tendons and all appurtenances required to complete a longitudinally post-tensioned system where indicated on the plans.

1.1.3 Terms. Wherever in this specification or in other contract documents the following terms are used, the intent and meaning shall be interpreted as follows:

POST-TENSIONING- The application of compressive force to the concrete by stressing tendons after the concrete has been cast and cured. The force in the stressed tendons is transferred to the concrete by means of anchorages.

POST-TENSIONING LAYOUT- The pattern, size, and locations of post-tensioning tendons provided in the plans.

POST-TENSIONING SYSTEMS- A proprietary system where the necessary hardware (anchorages, confining reinforcing, wedges, strands) is supplied by a particular manufacturer or manufacturers of post-tensioning components.

TENDONS- A high strength steel member made up of a number of prestressing strands or wires in a metal or plastic duct.

STRAND- an assembly of several high strength steel wires wound together. Strands usually have six outer wires helically wound around a single straight wire of similar diameter.

WIRE- A single, small diameter, high strength steel element and, normally, the basic component of strand, although some proprietary post-tensioning systems are made up of individual or group of single wires.

ANCHORAGE- An assembly of various hardware components, including confining reinforcement, which secure a tendon and its ends after it has been stressed and imparts the tendon force into the concrete.

WEDGES- A small conically shaped steel component placed around a strand to grip and secure it by wedge action in a tapered hole through a wedge plate.

WEDGE PLATE- A steel component of the anchorage containing a number of tapered holes through which the strands pass and are secured by conical wedges.

SET (ALSO ANCHOR SET OR WEDGE SET)- Set is the total movement of a point on the strand just behind the anchoring wedges during load transfer from the jack to the permanent anchorages. Set movement is the sum of slippage of the wedges with respect to the anchorage head and elastic deformation of the anchor components.

ANTICIPATED SET- Anticipated set is that set which was assumed to occur in the design calculation of the post-tensioning forces immediately after load transfer.

MEMBER- Member shall be considered to mean the concrete which is to be post-tensioned.

Revise 2.9 to read:

2.9 Grout for Transverse Shear Keys

Revise 2.10 to read:

2.10 Post-tensioned systems

2.10.1 Post-Tensioning Strands shall conform to 2.4.

2.10.2 Post-Tensioning Bars shall conform to the requirements of AASHTO M 275M/M 275-00 (ASTM A722/A 722M-98).

2.10.3 Anchorages. All anchorage devices shall meet the requirements of Section 10 of AASHTO Specifications for Highway Bridges Division II, 2002, and latest interims.

2.10.4 Post-Tensioning ducts. All post-tensioning ducts shall meet the requirements of Section 10.8.2 of AASHTO Specifications for Highway Bridges Division II, 2002, and latest interims.

2.10.5 Grout for Bonded Post-Tensioning. Grout shall be prebagged and of a variety specifically detailed for use in the grouting of post-tensioning ducts. The grout shall meet or exceed the specified physical properties stated herein as determined by the following standard and modified test methods. Grouts shall contain no aluminum powder.

Property	Test Value	Test Method
Total Chloride Ions	Max. 0.08% by weight of cementitious material	ASTM C 1152
Fine Aggregate (if utilized)	Max Size < No. 50 Sieve (300 micron)	ASTM C 33
Volume Change @ 24 hrs and 28 days	0.0% Shrinkage @ 24 hours <= 0.3 % Expansion @ 28 days	ASTM C 1090 *
Expansion	<= 2.0% for up to 3 hours	ASTM C 940
Compressive Strength @ 28 days (Average of 3 cubes)	>= 5000 psi	ASTM C 942
Initial Set of Grout	Min. 3 hours Max. 12 hours	ASTM C 953
Fluidity Test** Efflux Time from Flow Cone		
(a) Immediately after mixing	Min. 20 sec. Max. 30 sec.	ASTM C 939
or	Min. 9 sec. Max. 20 sec.	ASTM C 939***
(b) 30 minutes after mixing with remixing for 30 sec.	Max. 30 sec.	ASTM C 939
or	Max. 30 sec.	ASTM C 939***
Bleeding @3 hours	Max. 0%	ASTM C 940****
Permeability @ 28 days	Max. 2500 coulombs at 30V for 6 hours	ASTM C 1202
Freeze/Thaw durability	Relative dynamic E > 95%	AASHTO T 161 Procedure A

* Modify ASTM C 1090 to include verification at both 24 hours and 28 days.

** Adjustments to flow rates will be achieved by strict compliance with the manufacturer's recommendations.

*** Grout fluidity shall meet either the standard ASTM C 939 flow cone test or the modified test described herein. Modify the ASTM C 939 test by filling the cone to the top instead of the standard level. The efflux time is the time to fill a one-liter container placed directly under the flow cone.

**** Modify ASTM C 940 to conform to the wick induced bleed test described below.

- a) Condition dry ingredients, mixing water, prestressing strand and test apparatus overnight at 75 to 80° F.
- b) Insert 800 ml of mixed conditioned grout with conditioned water into the 1,000 ml graduated cylinder. Mark the level of the top of the grout.
- c) Wrap the strand with 2-inches wide duct or electrical tape at each end prior to cutting to avoid splaying of the wires when it is cut. Degrease (with acetone or hexane solvent) and wire brush to remove any surface rust on the strand before temperature conditioning. Insert completely a 20-inch length of conditioned, cleaned, ASTM A 416 seven wire strand (0.5 inch diameter) into the 1,000 ml graduated cylinder (possibly using a centralizer). Mark the level of the top of the grout.
- d) Store the mixed grout at the temperature range listed above in (a).
- e) Measure the level of the bleed water every 15 minutes for the first hour and hourly afterward for three hours.
- f) Calculate the bleed water, if any, at the end of the three hour test period and the resulting expansion per the procedures outlined in ASTM C 940, with the quantity of bleed water expressed as a percent of the initial grout volume. Note if the bleed water remains above or below the top of the grout.

2.10.5.1 Grouts shall be prebagged in plastic lined or coated bags. Stamp grout bags with date of manufacture, lot number and mixing instructions. Any change of materials or material sources requires retesting and certification of the conformance of the grout with the physical properties requirements. A copy of the Quality Control Data Sheet for each lot number and shipment sent to the job site shall be provided to the contractor by the grout supplier and furnished to the Engineer. Prebagged grout with clumps will be rejected.

2.10.5.2 Materials with a total time from manufacture to usage in excess of six months shall be retested and certified by the supplier before use or shall be removed and replaced.

2.10.5.3 Manufacturers of post-tensioning grout seeking qualification of their product shall provide certified test reports from an audited and independent Cement Research Laboratory (CCRL) which shows the material meets all the requirements specified herein.

Add to Construction Requirements:

3.1.7 Post-Tensioning

3.1.7.1 The post-tensioning system shall provide a minimum compressive force of 350 psi at transverse joints between panels or force detailed in the plans. Any 7-wire strand post-tensioning system that conforms to this specification can be considered for use. The requirements of a system shall include the furnishing and installing of all appurtenant items necessary for the particular stressing system used, including but not limited to ducts, anchorage assemblies, grout, and supplementary steel reinforcing bars for bursting and crack control behind anchorage assemblies and for duct support.

3.1.7.2 Shop Drawings: Shop drawings shall conform to the requirements in 3.4 and additional requirements below.

1. Show fully and accurately detailed blockouts, notches, recesses, projections, and the like that might be required by the Contractor's construction scheme.
2. Details of mild steel reinforcing shall be clearly shown as to size, spacing, and location including all special reinforcing required but not shown on the Contract Plans. No separate payment will be made for special reinforcement required to accommodate the Contractor's method of construction.
3. Show size and type of ducts for all post-tensioning tendons with their horizontal and vertical profiles clearly detailed. Duct supports, grout tubes, and vents shall be shown including type, size, and location, including the elements to be installed in the cast-in-place pier diaphragms.
4. Details and locations of all other items to be embedded in the girder such as inserts, post-tensioning hardware, conduit penetrations, and the like shall be shown.
5. Details of the anchorage system including confinement reinforcement required for the post-tensioning system shall be shown.
6. A table giving jacking sequence, jacking forces, and initial elongation of each tendon for all post-tensioning shall be provided to Engineer at least 10 days prior to stressing operation.
7. The Contractor shall prepare and submit integrated drawings showing all embedded items such as post-tensioning ducts, anchorages, anchorage reinforcement, blockouts, reinforcing steel. These drawings shall be to scale, shall be accurate, and shall have sufficient detail to show the relative positions of all items and their embedded depth. The drawings shall be adequate to ensure that there will be no conflict between the planned positions of the embedded items and that the concrete cover will be adequate. In the event of conflicts between post-tensioning hardware and reinforcement, the location and details of post-tensioning hardware takes precedence over the location of mild steel reinforcement. The Engineer shall review such revisions before work on any affected item is started.
8. Provide details and a complete description of the post-tensioning system to be used. Stressing details shall include method, sequence, and procedure of prestressing and securing tendons; release procedures and equipment; and

sizes and properties of tendons, anchor plate, anchor plates, anchorage assemblies, reinforcement, and equipment.

9. Data sheets for prebagged grout for post-tensioning tendons, method of mixing and detailed grouting procedure, equipment description and capacity (including standby flushing equipment). Details to be included in grouting procedures shall include, but is not limited to, intended direction of grouting, low point from which grouting will be injected, and sequence of closing vents.
10. Qualifications of the post-tensioning and grouting personnel. One member of the crew completing the work (superintendent or foreman) shall have attended the American Segmental Bridge Institute (ASBI) Grouting Certification Training Program and shall be ASBE Certified Grouting Technicians.
11. Furnish test and verification data as called for elsewhere in this Section.
12. Certified Reports: Submit the following certified test reports prepared by a reputable nationally recognized independent testing laboratory:
 - a) Test reports on static pullout bonding strength of the corrugated ducts.
 - b) Certified calibration charts shall be furnished with each jack and gauge used.
 - c) Certified copies of test results for the post-tensioning anchorage. Anchorage shall be so arranged that the jacking force in the tendon may be verified prior to removal of the stressing equipment.
 - d) Test reports of tendon modulus of elasticity, ultimate tensile strength, yield strength, elongation, composition, and in place friction tests if required.
13. Stressing Records: The Contractor is responsible for all stressing records including gauge pressure and elongation for each tendon stressed. The stressing logs shall be submitted to the Engineer daily for review and the Contractor shall reconcile the differences with calculated values of all individual tendons and groups of tendons, prior to next load transfer erection operation or on a weekly basis. The Contractor shall submit a system of tendon identification, individually and in groups, to expedite the tasks of the Contractor and the Engineer in mutual pursuit of the installation and acceptance of the post-tensioning process. Grout logs as called for elsewhere in this Section.

3.1.7.3 Design Computations: Four (4) sets of design computations for the proposed method of post-tensioning shall be submitted for approval with the shop drawings. The design computations shall be signed and sealed by a licensed professional engineer, registered in the State of New Hampshire, and shall include but not be limited to the following information:

1. Computed losses for each tendon such as creep and shrinkage of concrete, elastic shortening, relaxation of steel, losses in post-tensioned prestressing steel due to sequence of stressing, friction and take up of anchorages, and

other losses peculiar to the method or system of prestressing that may take place or have been provided for.

2. Jacking force for each tendon.
3. Effective force for each tendon.
4. Anchorage bearing stress at service load.
5. All other computations required for the system of stressing being used, including all reinforcing required to resist bursting stresses. Post-tensioned anchorage zones shall conform to the requirements of Section 9.21 of the AASHTO Standard Specifications for Highway Bridges.

3.1.7.4 Post-Tensioning Anchorages: All prestressing steel shall be secured at the ends by means of permanent type anchoring devices that have been reviewed and accepted by the Engineer. The anchorages shall meet or exceed the following requirements:

1. The anchorages shall develop at least 95 percent of the minimum specified ultimate tensile strength of the prestressing steel, tested in an unbonded state without exceeding anticipated set. Certified copies of test results for the anchorage system to be used shall be supplied to the Engineer at no additional cost. The anchorage shall be so arranged that the prestressing force in the tendon may be verified prior to removal of the stressing equipment.
2. The load from the anchoring device shall be distributed to the concrete by means of approved devices that will effectively distribute the load to the concrete. Such devices shall conform to the following requirements:
 - a) The average bearing stress in the concrete created by the anchorage plates shall not exceed the values in Section 9.2.1 and 14.0 of Division I and Section 4.2 of Division II of the 1999 AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges.
 - b) Bending stresses in the plates or assemblies induced by the jacking of the prestressing steel shall not exceed the yield point of the material in the anchorage plate when 95 percent of the ultimate strength of the tendon is applied or cause visible distortion of the anchorage plate, as determined by the Engineer.
3. Should the Contractor elect to furnish an anchoring device of a type which is sufficiently large and which is used in conjunction with a steel grillage embedded in the concrete that effectively distributes the compressive stresses to the concrete, the steel distribution plates or assemblies may be omitted.
4. Anchorages must be set in a plane normal to the axis of the tendons such that uniform bearing on the concrete is assured. Wedge-type anchors shall not be used in inaccessible locations.
Anchorages shall be supplied with a steel reinforcing spiral for those tendons having a prestressing force greater than 300 kips.
5. Anchorages shall be protected as follows:

- a) The anchoring devices shall be recessed so the ends of the post-tensioning steel and all parts of the anchorage will have at least two inches of cover from the panel's surface. The recess shall be filled with a qualified non-shrink grout following post-tensioning.
 - b) Anchorage blisters may be required to accommodate the anchorage assemblies and the clear cover requirement. The Contractor can fabricate the end panels with the anchorage assemblies and anchor blocks already installed or can install the anchorage assemblies and fill the anchorage blisters with non-shrink grout, on-site, after the panels have been erected.
 - c) As soon as possible, but not exceeding 14 days after post-tensioning is complete, exposed end anchorages, strands and other metal accessories shall be cleaned of rust, displaced mortar, grout and other deleterious materials. Immediately following the cleaning operation, the entire surface of the anchorage recesses (all metal and concrete) shall be thoroughly dried and uniformly painted with an epoxy bonding compound conforming to AASHTO M235, Type II, in accordance with the manufacturer's recommendations. The anchorage recesses shall be filled with a non-shrink cement based grout immediately following the application of the epoxy-bonding compound.
6. Local zone reinforcement, required for the performance of the anchorage (based on previous tests and history of successful performance on other projects) shall be provided by the Contractor incidental to the proprietary anchorage system selected.
 7. All anchorages shall be provided with a permanent non-metallic grout cap with gasket that fully encapsulates the wedge plate. The grout cap shall be durable and impervious, and shall protect the strands from corrosion. Temporary grout caps will not be permitted.

3.1.7.5 Samples for Testing:

1. The following samples of materials and devices selected at locations designated by the Engineer shall be furnished by the Contractor at Contractor's expense. The Engineer shall be present at the time of sampling. The Contractor shall notify the Engineer at least 24 hours in advance of when samples will be taken from stored materials.
 - a) Three 7-foot long samples of prestressing wire or bar for each size from each heat number or production lot.
 - b) Three 7-foot long samples of prestressing strand for each size from each heat number or production lot.
 - c) If bar couplers are to be used, three samples with two specimens each consisting of four foot lengths of the specific prestressing bar coupled with a bar coupler from the materials to be used on the project.
 - d) One unit of each prestress anchorage to be used on the project.

- e) Samples shall be taken at least 30 days in advance of the time they are to be incorporated into the Work.
- 2. All strands from each manufactured reel to be shipped to the site shall be assigned an individual lot number and shall be tagged in such a manner that each such lot can be accurately identified at the job site. Each lot of anchorage assemblies to be installed at the job site shall also be identified in a similar manner. All unidentified prestressing steel and anchorage assemblies received at the site will be rejected and loss of positive identification of these items at any time will be cause for rejection of their use as intended.
- 3. The release of any material by the Engineer shall not preclude subsequent rejection if the material is damaged in transit or later damaged or found to be defective.

3.1.7.6 Testing by Contractor:

- 1. The Contractor shall furnish manufacturer's certified reports covering the tests required by these specifications. A certified test report stating the guaranteed minimum ultimate tensile strength, yield strength, elongation, and composition shall be furnished for each lot of prestressing steel. Typical stress-strain curves for prestressing steel shall be furnished. A certified test report stating strength when tested using the type prestressing steel to be used in the Work shall be furnished for each lot of prestress anchorage devices.

3.1.7.7 Protection of Prestressing Steel:

- 1. During and after prestressing steel installation the Contractor shall prevent all water, rain, snow and/or ice from entering the post-tensioning ducts.
- 2. When acceptable prestressing steel for post-tensioning is installed in the ducts after completion of concrete curing, and if stressing and grouting are completed within ten calendar days after the installation of the prestressing steel, rust which may form during said ten days will not be cause for rejection of the steel, provided no pitting has developed over this period. Prestressing steel installed, tensioned and grouted in the manner, all within ten calendar days, will not require the use of corrosion inhibitor in the duct following installation of the prestressing steel. Post-tensioning steel installed as above but not grouted within ten calendar days shall be subject to all the requirements in this section pertaining to corrosion protection, which includes an accepted water soluble corrosion inhibitor and may include rejection because of rust. The corrosion protection system shall be submitted for review and approval prior to the start of any post-tensioning work. Vapor Phase Inhibitor (VPI) is not an acceptable corrosion protection system. The submission for approval shall include certified test reports from an audited and independent research laboratory which indicates the proposed corrosion inhibitor will provide corrosion protection in accordance with the provisions of Federal Specifications MIL-P-3420. Bond testing shall be also performed to prove that the proposed corrosion inhibitor does not impair the bond strength between the cement grout and prestressing steel. Appropriate ventilation is required to avoid toxic effects.

3.1.7.8 Post-tensioning ducts:

1. The inside diameter of the ducts shall be at least ¼" larger than the nominal diameter of single wire, bar, or strand tendons, or in the case of multiple wire, bar, or multiple strand tendons, the inside cross-sectional area of the sheathing shall be at least two times the net area of the prestressing steel. When tendons are to be placed by the pull through method, the duct area shall be at least 2 ½ time the net area of the prestressing steel.
2. Transition couplings connecting ducts to anchoring devices shall be galvanized ferrous metal and shall be capable of positively preventing the entrance of cement paste and water from concrete and of sufficient strength to prevent distortion or displacement of the ducts during concrete placement.
3. Splices in ducts used at the cast-in-place concrete diaphragms shall be the same material as used in the members. Joints between the portion of duct protruding from the end of the members and the splice section shall be capable of positively preventing the entrance of cement paste and water from concrete and of sufficient strength to prevent distortion or displacement of the ducts during concrete placement. Duct tape is not considered adequate.
4. Ducts shall be securely tied in position, carefully inspected, and repaired before placing of the concrete is started, and care shall be exercised during the placing of the concrete to avoid displacing or damaging the ducts. Metal ducts shall be supported at intervals of not more than 4 feet. Plastic ducts shall be supported at intervals of not more than 2 feet. The tolerance on the location of the tendons shall be plus or minus 0.25 inches at any point and in any direction. Visual inspection shall be used to confirm a smooth profile with no kinks prior to closing forms.
5. After installation in the forms and bulkheads, the ends of the ducts shall be sealed at all times to prevent entry of water and debris. Following concrete placement, the Contractor shall demonstrate to the Engineer that all empty ducts are free of water and are unobstructed and undamaged. Immediately prior to installation of the prestressing steel, the Contractor shall again demonstrate to the Engineer that all ducts are unobstructed and that they are free of water and debris. An acceptable method of demonstrating that the ducts are unobstructed and free of water and debris is to blow oil-free compressed air through the full length of each duct.

3.1.7.9 Vent and Grout Injection Pipes:

1. All ducts and anchorage assemblies for permanent prestressing shall be provided with pipes or other suitable connections at each end and each side of couplers for injection of grout after post-tensioning. In addition all ducts having a tendon profile varying in elevation by more than six inches shall be vented at all high points of the tendon profile and drained at all low points in the tendon profile. In addition, grout vents shall be placed from 3'-6' either side of the high point of the tendon. Any segment of the tendon profile that is horizontal at a high point will have a grout vent placed at no greater than 50 ft

increments. Vents and drains shall be 3/4" minimum diameter standard pipe or suitable plastic pipe. Waterproof tape shall be used at all connections including vent and grouting pipes. Plastic components shall not react with the concrete or enhance corrosion of the prestressing steel, and shall be free of water-soluble chlorides. The vents shall be mortar tight, taped as necessary, and shall provide means for injection of grout through the vents and for sealing the vents. At all times, pipes shall be capped with water tight plastic caps specifically provided by the post-tensioning supplier, and shall be protected from damage by pedestrian, vehicle and equipment traffic. Any damage to the pipe or cap shall be immediately repaired and misplaced caps shall be immediately replaced.

2. Grout injection pipes shall be fitted with positive mechanical shut-off valves. Vents and injection pipes shall be fitted with valves, caps, or other devices capable of withstanding the pumping pressures specified herein.

3.1.7.10 Strand Installation

1. Strands shall be installed in the ducts so as to avoid entanglement and excessive slack. The placement should be such that would allow a linear elongation of the tendons when jacking from 20% to 100% of the jacking force.
2. During and after prestressing steel installation, the Contractor shall prevent all water, rain, snow, and ice from entering the prestressing ducts.

3.1.7.11 Post-Tensioning

3.1.7.11.1 Stressing Tendons:

1. All post-tensioning steel shall be tensioned by means of hydraulic jacks so that the force of the prestressing steel shall not be less than the value shown on the approved working drawings. The maximum temporary tensile stress (jacking stress) in prestressing steel shall not exceed 80 percent of the specified minimum ultimate tensile strength of the prestressing steel. The prestressing steel shall be anchored at stresses (initial stresses) that will result in the ultimate retention of permanent forces of not less than those shown on the approved drawings, but in no case shall the initial stress, after anchor set, exceed 70 percent of the specified minimum ultimate tensile strength of the prestressing steel. Permanent force and permanent stress will be considered as the force and stress remaining in the prestressing steel after all losses, including creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, losses in post-tensioned prestressing steel due to sequence of stressing, friction and take-up of anchorages, and all other losses peculiar to the method or system of prestressing have taken place or have been provided.
2. A qualified representative of the post-tensioning manufacturer who is skilled and experienced in the proposed work shall be on site during all stressing operations. The representative shall be available for (a) inspecting and

approving all post-tensioning hardware installation prior to concrete placement; (b) stressing and anchoring tendons; (c) grouting operations.

3. Each jack used to stress tendons shall be equipped with a pressure gauge for determining the jacking pressure. The pressure gauge shall have an accurately reading dial at least six inches in diameter and each jack and its gauge shall be calibrated as a unit with the cylinder extension in the approximate position that it will be at final jacking force prior to stressing the initial tendon. Certified calibration charts shall be furnished by an independent laboratory with each jack and gauge used on the project. Certified calibration shall be made at the start of the work and every six months thereafter, or as requested by the Engineer. The calibration shall be done while the jack is in the identical configuration as will be used on the site, e.g., same length hydraulic lines. At the option of the Contractor, calibrations subsequent to the initial ram calibration by the load cell may be accomplished by the use of a master gauge. The master gauge shall be supplied by the Contractor in a protective waterproof container capable of protecting the calibration of the master gauge during shipment to a laboratory. The Contractor shall provide a quick-attach coupler next to the permanent gauge in the hydraulic line, which enables the quick and easy installation of the master gauge to verify the permanent gauge readings. The master gauge shall remain in the possession of and be calibrated by the Engineer for the duration of the project. Any repair of the rams, such as replacing the seals or changing the length of the hydraulic lines, is cause for recalibration of the ram with a load cell. No extra compensation will be allowed for the initial or subsequent ram calibrations or for the use and required calibrations of a master gauge.
4. Post-tensioning forces shall not be applied until the concrete has attained the compressive strength specified as determined by the cylinder tests.
5. The tensioning process shall be so conducted that tension being applied and the elongation of the post-tensioning steel may be measured at all times. A record shall be kept of gauge pressures and elongations at all times and shall be submitted to the Engineer. The post-tensioning force may be verified as deemed necessary by the Engineer. The tendon force measured by gauge pressure shall agree within seven percent of the theoretical elongation. The entire operation shall be checked and the source of error determined and remedied to the satisfaction of the Engineer before proceeding with the work. Elongations shall be measured to the nearest 1/8 in. Equipment for tensioning the tendons must be furnished by the manufacturer of the system (tendons and Contractor, may require additional bench tests and/or friction tests, should the agreement between pressure gauge readings and measured elongations fall outside the acceptable tolerances.
6. The Contractor shall submit computations showing tendon forces and elongations after friction, wobble, and anchor set losses. Losses shall be based on expected modulus of elasticity and actual friction and wobble coefficients and anchor set losses for the system to be used. These parameters shall also appear on the shop plans for all different tendon types.

7. Tendons shall be stressed in the sequence shown on the approved shop drawings. The stressing sequence shall be such that not more than one tendon will be eccentric about the centerline of a member at any time.
8. The Contractor shall take all necessary provisions to avoid crushing of vacant adjacent ducts during the stressing operations.
9. Prestressing steel shall be cut by an abrasive saw within 0.75 to 1.5 inches away from anchoring device. Flame cutting of prestressing steel is not allowed.
10. Within four hours after stressing, protect tendons against corrosion or harmful effects of debris, by temporarily plugging or sealing all opening and vents. Clean rust and other debris from all metal surfaces, which will be covered by the grout cap, and place the permanent nonmetallic grout cap with gasket over the wedge plate.

3.1.7.11.2 Grouting post-tensioning ducts:

1. After the tensioning of all tendons has been completed and the prestressing steel has been anchored, the annular space between the duct and the tendons shall be completely filled with grout. The tendons shall be protected against corrosion by a plug at each end to prevent the passage of air, and such plugs shall be left in place until the tendon is grouted. A pressure test on the duct shall be performed prior to the grout procedure. Duct should be able to achieve 30 psi pressure. Test should not raise pressure greater than 40 psi with closed vents and temporary grout caps.
2. The grouting equipment shall include a colloidal grout mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement. The equipment shall be able to pump the mixed grout in a manner which will comply with all provisions hereinafter specified. Graduated measuring equipment shall be used for accurate liquid measurement. The pumps shall be positive displacement type and be able to produce an outlet pressure of at least 150 psi. The pump shall have seals adequate to prevent introduction of oil, air, or other foreign substance into the grout, and to prevent loss of grout or water. A pressure gauge having a full-scale reading of no greater than 300 psi shall be placed at some point in the grout line between the pumping outlet and the duct inlet. The grouting equipment shall contain a screen having clear openings of 0.125-inch maximum size to screen the grout prior to its introduction into the grout pump. If a grout with an additive is used, a screen opening of 0.188 inch is satisfactory. This screen shall be easily accessible for inspection and cleaning. The grouting equipment shall utilize gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct. Under normal conditions, the grout equipment shall be capable of continuously grouting the longest tendon on the project in not more than twenty minutes.

3. Provide back up grouting equipment and independent back up power supply to ensure that grout placement can continue if primary equipment or power supply fails.
4. Mix the grout in accordance with the manufacturer's instructions using a colloidal mixer to obtain a homogenous mixture. Perform a fluidity test on the mixed grout, in accordance with the grout material specifications, prior to beginning the injection process. Obtain target flow rates as a function of mixer type used and ambient temperature from the grout manufacturer. Do not begin the grouting process until the proper grout properties have been obtained.
5. Batches shall be placed within 30 minutes of mixing.
6. All grout openings and high point vent openings shall be open when grouting starts. Grout shall be allowed to flow from the first vent after the inlet pipe until all residual flushing water and entrapped air has been removed, at which time the vent shall be capped or otherwise closed. Remaining vents shall be closed in sequence in the same manner. Maintain a continuous flow of grout at a rate not to exceed 30 feet of duct per minute. The pumping pressure at the tendon inlet shall not exceed 250 psi. Normal operations shall be performed at 75 psi. If the actual grouting pressure exceeds the maximum allowable pumping pressure, close the injection vent and inject the grout at the next vent, which has been, or is ready to be, closed as long as one-way flow is maintained. Do not inject grout into a succeeding vent from which grout has not yet flowed. If a one-way flow of grout cannot be maintained as outlined above, the grout shall be immediately flushed out of the duct with water.
7. Grout shall be pumped through the duct and continuously wasted at the outlet pipe until no visible slugs of water or air are ejected and efflux time of ejected grout is not less than the injected grout. Perform a fluidity test, in accordance with the grout material specifications, on each tendon measuring the grout discharged from the discharge outlet. The measured grout efflux time shall meet the requirements of the Fluidity Test listed in the grout material specifications. If the grout efflux time is not acceptable, discharge additional grout from the discharge outlet. Test grout efflux time. Continue this cycle until acceptable grout fluidity is achieved. Ensure that the tendon remains filled with grout, by closing the ejection and injection vents in sequence, respectively, under pressure when the tendon duct is completely filled with grout. Do not remove the positive shut-offs at the injection and ejection vents or open until the grout has set. At all times, the ducts shall be free of water to avoid damage due to freezing. The temperature of the concrete or air surrounding the tendon shall be 40 degrees F or higher from the time grout is placed until the minimum compressive strength of 800 psi, as determined from tests on 2 inch cubes cured under the same condition as the in-place grout, is obtained. Grout shall not be above 90 degrees F during mixing or pumping. If necessary, the mixing water shall be cooled. The waste fluid that is flushed from the duct shall be captured and disposed of in compliance with applicable laws. All grout that spills shall be collected and disposed of in compliance with applicable laws.

8. 24-hours after grouting, the level of grout in the grout inlet pipes, vent pipes, and grout caps shall be inspected and topped off as necessary with freshly mixed grout. Vacuum grouting or other remedial action may be required by Engineer based on size and extent of voids found.
9. Do not remove or open valves, caps or vent pipes until the grout has set. Ends of steel vents shall be removed at least 1 inch below the concrete surface after the grout has set. Ends of plastic vents shall be removed to 1 inch below surface of the concrete, or 1 inch below deck grade, after the grout has set. Remove all miscellaneous material used for sealing grout caps before carrying out further work to protect end anchorages or filling in anchorage pourbacks and the like. A shrinkage compensating polymer modified grout applicable for vertical patching shall be used to patch holes left from grouting procedures.
10. Daily grouting logs and cumulative record books shall be submitted to the Engineer for review and record within 72 hours of grouting. Information to be provided in the records shall include but shall not necessarily be limited to the following: tendon number, date grouted, number of days between stressing and grouting, brand of prebagged grout, tendon end used for injection, grout flow test results, grouting pressure, and summary of problems encountered and corrective action taken.

3.2.1.1.1 For precast concrete deck panels that are not prestressed, proof shall be given by the Contractor that the Fabricator is capable of and has the organization and plant for performing the work in manufacturing the panels. The fabricator shall cast a trial panel, as required by the Engineer. All costs to manufacture the trial piece shall be subsidiary to Item 528.62.

Revise 3.22.6 to read:

3.22.6 Installation of Partial Depth Deck Panels

Add to 3.22

3.22.7 Installation of Full Depth Deck Panels

3.22.7.1 The full depth panels shall be set to the elevations detailed on the plans. Final panel elevations shall be attained by adjusting the torque on leveling screws to promote an equal distribution of panel dead load to all girders. The torque schedule shall be submitted with the shop drawings for the panels. The torque tolerance shall be +/- 15%.

3.22.7.2 Panels shall not be used to support construction loads until the bedding concrete has attained a minimum compressive strength equal to the design compressive strength of the panels.

3.22.7.3 The transverse shear keys and recesses between the precast slabs shall be thoroughly cleaned prior to delivery by means of high pressure washing using a pressure of at least 1000 psi and a delivery rate of not less than 4 gallons per minute. The shear key surface shall be cleaned on site by air blasting prior to placing the grout. If a pre-bagged non-shrink grout is used, the shear keys and recesses shall be prepared and the grout shall be placed according to the grout manufacturer's recommendations. If a

cement based, non-shrink grout is used (not pre-bagged) the key areas shall be wet thoroughly prior to grout placement. The grout shall attain a minimum compressive strength of 1500 psi (or minimum strength detailed on the plans) prior to post-tensioning the panels longitudinally.

3.22.7.4 The deck panels shall be post-tensioned prior to making them composite with the girders unless specific direction to the contrary is detailed on the plans. See post-tensioning requirements elsewhere in this special provision. Panels shall not be post-tensioned until they have aged a minimum of 45 days.

3.22.7.5 After the shear studs have been installed, bedding concrete shall be placed through the shear connector pockets in the deck panels to completely fill the area under the panels and over the flanges. Compressible foam grout dams or temporary formwork shall be used to maintain the concrete within the haunch. All leveling screws and other supplemental supports shall be removed after the bedding concrete has attained strength. Holes left by the removal of the leveling screws shall be filled with an approved non-shrink grout.

Add to Basis of Payment Pay items and unit:

528.62X	Precast Concrete Deck Panels, Post-Tensioned (F)	Square Foot
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Example 3: Maine DOT Precast Integral Abutments and Piers

The following specifications were taken from a project that involved the reconstruction of a bridge in Maine. This project included prefabricated integral abutments, piers and approach slabs.

The following pages include:

- Prosecution of Work
- Incentive-Disincentive Specification
- Modifications to the standard precast concrete specifications

SPECIAL PROVISION
SECTION 107
TIME

(PROSECUTION OF WORK)

To subsection 107.4.2 Schedule of Work Required, add the following:

“The Contractor shall plan and conduct his operations such that the Boom Birch Bridge will be closed for only a single period of time of up to 45 days between **July 9th, 2007** and **September 1st, 2007**. While exact sequence of operations may vary from those found herein the following activities must be completed prior to opening both lanes to traffic:

Existing bridge must be completely removed.

All piles must be driven to meet the approval of the Resident.

Abutment and pier caps must be erected, post-tensioned, and the socket fill placed prior to loading them.

Superstructure must be erected and shear keys grouted.

Shear key grout must be cured to a minimum strength of 3 ksi.

Superstructure must be post-tensioned.

Approach slabs must be placed.

Curbs must be cast

Bridge rail must be installed

Permanent or temporary approach road guardrail must be installed

Approach roadway gravel must be compacted and graded to a passable condition

The post-tensioning ducts in the abutments may be grouted under traffic. Fine grading of approaches, membrane, pavement, and permanent approach road guardrail may take place under single lane closures with traffic controlled through the work zone with flaggers.

A minimum of 30 days prior to the road closure, the Contractor shall provide the Department a Schedule of Work covering specifically each activity to take place during the closure in a Critical Path Method (CPM). In addition to either an activity on node or an activity on arrow diagram the contractor shall also provide the output from the CPM schedules in the form of a bar chart. At a minimum, the Schedule of Work shall show the major Work activities, milestones, durations, and a timeline. Durations within the schedule should be in hours.

The Department will review the Schedule of Work and provide comments to the Contractor within 7 days of receipt of the schedule. The Contractor will make the requested changes to the schedule and issue the finalized version to the Department.

SPECIAL PROVISION

SECTION 108

PAYMENT

(Incentive – Disincentive)

The Contractor shall plan and conduct operations in such a manner that the Route 116 in the vicinity of Boom Birch Bridge is closed to traffic for no more than forty-five (45) consecutive calendar days. The said road closure may only occur between Monday July 9th, 2007 and Saturday September 1st, 2007.

Once the Contractor commences work on this project, the work shall be continuous through completion. During the closure the Contractor shall maintain traffic on the detour route indicated in the Special Provision, Section 105, Use of Roads as Detours.

The closure period starts the moment the road is closed to through traffic for both lanes and ends the moment the road is opened to through traffic for both lanes. For the purposes of establishing incentive and disincentives the total closure period shall be the number of days both lanes of the road are closed to traffic.

Failure to open Route 116 to traffic across Boom Birch Bridge after a total closure period of 45 days will result in a disincentive of \$1000/day. Opening Route 116 to traffic across Boom Birch Bridge within the forty-five (45) days total closure period will result in a daily incentive of \$1000 per day for the number of days the road is open to traffic before the total closure period has elapsed.

The assessment of any disincentive charges to the Contractor will be in addition to the liquidated damages specified in Section 107 - Time, of the Maine Department of Transportation Standard Specifications.

SPECIAL PROVISION
SECTION 534

Section 534, Precast Structural Concrete of the Standard Specifications is added as follows:

534.01 Description: This work shall consist of fabricating, delivering, and erecting the precast approach slabs, the precast/post-tensioned abutments and piers, and related material. Materials, work, inspection and documentation not specifically addressed by this Specification shall be done in accordance with the applicable sections of the PRECAST/PRESTRESSED CONCRETE INSTITUTE (PCI), *Manual for QUALITY CONTROL for Plants and Production of PRECAST AND PRESTRESSED CONCRETE PRODUCTS* (MNL 116), including Commentary.

534.02 Materials. Materials for precast and prestressed concrete products shall meet the requirements of the following Sections:

Water	701.02	
Air Entraining Admixtures	701.03	
Water Reducing Admixtures		701.04
High Range Water Reducing Admixture (HRWR)		701.0401
Set-Retarding Admixtures	701.05	
Fly Ash	701.10	
Calcium Nitrite Solution	701.11	
Silica Fume	701.12	
Ground Granulated Blast Furnace Slag		701.13
Fine Aggregate for Concrete	703.01	
Coarse Aggregate for Concrete	703.02	
Reinforcing Steel	709.01	
Welded Steel Wire Fabric	709.02	
Steel Strand for Concrete Reinforcement		709.03
Post-tensioning Bar		see below

The precast abutments and piers shall be post-tensioned with galvanized bars conforming to ASTM A722, Type II. Ducts for post-tensioning bars shall be galvanized, metal duct suitable for the intended purpose.

Portland cement shall conform to the requirements of AASHTO M85 (ASTM C150), Type I, Type II, or Type III. The Contractor shall supply the Department with copies of certified mill tests of the cement. The mill tests shall show the name of the manufacturer, location where produced, silo number and the person or agency conducting the test.

Coarse aggregate shall conform to the requirements of Section 703.02 - Coarse Aggregate for Concrete, Class A, Class AA or Latex.

Concrete that is to be placed in voids around the piling shall be self-consolidating with the addition of an approved high-range water-reducing admixture. The concrete shall also have an approved expansion agent such as intraplast-n or an approved

shrinkage compensating admixture, to ensure a tight bond between the fresh concrete and the inside of the void. At the time of placement in the abutment voids, this concrete shall have a spread of between 20 inches and 25 inches with a Visual Stability Index of 1.5. Mix designs for all self-consolidating concrete shall be trial batched to: certify the standard specification requirements, including 28 day compressive strength; assure flowability considering reasonable transit time; and determine the curing time to reach intermediate compressive strengths of 1 ksi and 2.5 ksi. These curing times shall be reported to both the Department and the Contractor. Trial batch results must be acceptable to the Resident prior to the closure of the bridge to traffic. A technical representative from the admixture supplier must be at the production plant for trial and production batching.

534.03. Drawings : The Contractor shall prepare shop detail, erection and other necessary working drawings in accordance with Section 105.7 - Working Drawings. The drawings will be reviewed and approved in accordance with the applicable requirements of Section 105.7. Changes and revisions to the approved working drawings shall require further approval by the Fabrication Engineer.

Concrete mix designs shall be part of the shop drawing submittal. Mix designs shall include aggregate specific gravity, absorption, percent fracture, fineness modulus and gradation.

A copy of the Contractor's Quality System Manual (Q.S.M.) shall be submitted when requested by the Fabrication Engineer.

534.04 Plant : Precast, prestressed or post-tensioned concrete products shall be manufactured in a Precast/Prestressed Concrete Institute (PCI) Certified facility. An alternate facility certificate may be used at the discretion of the Engineer.

534.05 Inspection Facilities : The Contractor shall provide a private office at the fabrication plant for inspection personnel authorized by the Department. The office shall have an area not less than 9.3 m² [100 ft²] and shall be in close proximity to the work. The office shall be climate controlled to maintain the temperature between 18°C [65°F] and 30°C [85°F], lighted and have the exit(s) closed by a door(s) equipped with a lock and 2 keys which shall be furnished to the Inspector(s). The office shall be equipped with a desk or table having a minimum size of 1200 mm by 760 mm [48 in by 30 in], 2 chairs, a telephone, telephone answering machine, line data port, plan rack and 2-drawer letter size file cabinet with a lock and 2 keys which shall be furnished to the Inspector(s).

The facilities and all furnishings shall remain the property of the Contractor upon completion of the work. Payment for the facilities, heating, lighting, telephone installation, basic monthly telephone charges and all furnishings shall be incidental to the contract.

534.06 Notice of Beginning Work: The Contractor shall give the Fabrication Engineer a minimum of two weeks notice prior to beginning work. The Contractor shall advise the Fabrication Engineer of the production schedule and any changes to it. If the Contractor suspends work on a project, the Fabrication Engineer will require 48 hours notice prior to the resumption of work.

534.07 Inspection: Quality Control (Q.C.) is the responsibility of the Contractor. Quality Control Inspectors (QCIs) shall have a valid PCI Quality Control Certification Level I, Level II or Level III. Personnel performing concrete testing shall hold a current ACI Field Testing Technician Grade I Certification or equivalent, or work under the direct supervision of an ACI certified technician.

The QCI shall inspect all aspects of the work in accordance with the Contractor's QSM. The QCI shall record measurements and test results on the appropriate forms from APPENDIX E of MNL 116 or an equivalent form prepared by the user. Copies of measurements and test results shall be provided to the Quality Assurance Inspector (QAI) as follows:

Type of Report	When Provided to Q.A.I.*
Material certifications/stressing calculations/calibration certifications	Prior to beginning work (anticipate adequate time for review by QAI)
Pre-pour inspection report	Prior to the concrete placement
Concrete Batch Slips	The morning of the next work day
Results of concrete testing	The morning of the next work day
Results of compressive testing (for release)	The same work day
Concrete temperature records	Provide with compressive testing (for Release)
Non-conformance reports/repair procedures	Within 24 hours of discovery
Results of compressive testing (for design strength)	Prior to stopping curing/Prior to final Acceptance
Post-pour inspection report	Prior to final acceptance

*The Contractor and QAI, by mutual agreement, may modify any part of the schedule; however, failure to provide the documentation when required will result in the product being deemed unacceptable.

The QCIs shall reject materials and workmanship that do not meet contract requirements. The Contractor may perform testing in addition to the minimum required. The results of all testing shall be made available to the (QAI).

Quality Assurance (Q.A.) is the prerogative of the Fabrication Engineer. The QAI will verify documentation, periodically inspect workmanship, and witness testing. Testing deemed necessary by the Fabrication Engineer in addition to the minimum testing requirements shall be scheduled to minimize interference with the production schedule.

534.08 Inspector's Authority: The QAI will have the authority to reject material or workmanship that does not meet the contract requirements. The acceptance of material or workmanship by the QAI will not prevent subsequent rejection, if found unacceptable.

534.09 Rejections: Rejected material and workmanship shall be corrected or replaced by the Contractor. In the event that an item fabricated under this Specification does not meet the contract requirements but is deemed suitable for use by the Fabrication Engineer, said item will be paid for in accordance with Section 108.8.1 - Substantially Conforming Work.

534.10 Forms and Casting Beds: Form dimensions shall conform to the approved shop drawings. Forms shall be well constructed, carefully aligned and sufficiently tight to prevent leakage of mortar. Forms that do not maintain the plan dimensions within allowable tolerances during concrete placement shall be rejected.

Each abutment segment and each pier segment shall be match cast against the pieces to which they will be erected in their final position to ensure a precise fit up in the field.

Wood forms, if used, shall be sealed with a material to prevent absorption. The sealer shall be applied and cured in accordance with the manufacturer's recommendations.

Forms shall be cleaned of adherent material before each use. Forms shall be cleaned of all foreign matter and debris immediately prior to placing concrete. New forms shall be free from paint or other protective coatings.

Forms shall be treated with a non-staining bond breaking compound applied in accordance with the manufacturer's recommendations.

If the reinforcing steel or post-tensioning ducts have been contaminated with the bond-breaking compound, it shall be cleaned with solvent. No concrete shall be placed until the reinforcing steel and post-tensioning ducts has been inspected and accepted by the QCI.

534.11 Reinforcing Steel: Reinforcing steel shall be fabricated, packaged, handled, stored, placed, spliced, and repaired in accordance with Section 503 - Reinforcing Steel.

Reinforcing steel shall be accurately located and securely anchored to prevent displacement during concrete placement. All reinforcing steel shall be installed and secured before beginning the concrete placement.

The concrete cover shown on the approved shop drawings shall be the minimum allowable cover. The contractor shall use bar supports and spacers to maintain the minimum concrete cover. The bar supports and spacers shall be made of a dielectric material or other material approved by the Fabrication Engineer.

534.12 Voids and Inserts: Voids shall be non-absorbent. The out-to-out dimensions of the voids shall be within 2% of plan dimensions. Damaged voids shall be repaired in manner acceptable to the QAI. Voids shall be stored, handled and placed in a manner that prevents damage. Residue from void placement shall be entirely removed from the forms before beginning or continuing the concrete placement.

Voids shall be located accurately, anchored securely, capped and vented. Any portion of a void that is displaced beyond the allowable dimensional tolerances shall be cause for rejection of the abutment segment.

534.13 Conventional Concrete: Concrete mix designs shall be submitted to the Fabrication Engineer for approval a minimum of 30 days prior to beginning work. Mix designs previously approved for use shall not require qualification by trial batch if the

mix design meets all the requirements of this Section. Only conventional concrete meeting this subsection shall be used for precast concrete.

New concrete mix designs shall be qualified by trial batches prepared in accordance with AASHTO T126 (ASTM C192). The test results shall demonstrate that the concrete meets the requirements of the Plans and this Section. If accelerated curing is to be used in production, the test specimens shall be similarly cured.

No concrete shall be placed until the mix design has been approved. Approval of the mix design does not relieve the Contractor of the responsibility of meeting the requirements of this Section during production.

The concrete mix design shall meet the following requirements:

Table 1

Maximum cement content	660 lb/yd ³
Maximum cementitious material	685 lb/yd ³
Water-cement ratio	0.42 maximum
Air entrainment	5½ % - 7½ %
Allowable slump	5 inch to 10 inch
Calcium Nitrite*	3 gal/yd ³
Silica Fume (when required)	5% - 10% of cement content by weight
Fly Ash	40% of cementitious material maximum
Slag	50% of cementitious material maximum

*The water in the Calcium Nitrite solution shall be included when calculating the water/cement ratio

The batching equipment, mixers and delivery equipment shall meet the requirements of MNL 116. Concrete shall be batched, mixed and handled in accordance with MNL 116.

534.135 Self-Consolidating Concrete: Self-consolidating concrete shall be trial batched to achieve the desired properties as discussed in 534.02 Materials.

534.14 Concrete Placement: The first two loads of concrete from each placement shall be tested by the QCI for temperature, air entrainment, and slump. If the first load is unacceptable, the second load shall be tested as the first. This process shall continue until two consecutive loads are found acceptable. After two consecutive loads are found acceptable, the frequency of testing shall be at the discretion of the QAI.

Concrete shall be tested if there is a change in the dosage rate of any admixture, a change of 2 inches or more in slump or a change of more than 5 °F [3 °C] in mix temperature.

Any load of 1 yd³ or less from a stationary mixer or 2 yd³ or less from a transit mixer shall be tested for air entrainment, slump, and temperature prior to being placed in the form.

Concrete shall be placed as nearly as possible to its final location. The depth of a lift shall be controlled in order to minimize entrapped air voids in conventional concrete castings. The maximum depth of an unconsolidated lift shall be 18 inches in conventional concrete castings. Concrete shall be vibrated with internal or external and external vibrators in conventional concrete castings. External vibrators shall not be used alone. Internal vibrators shall be inserted vertically and penetrate the lower layer of concrete by at least 4 inches. The vibrators shall be inserted to assure that the radius of action of the vibrators overlap. The vibrators shall be held in position from 5 to 15 seconds. Vibrators shall not be used to move concrete horizontally. In concrete that is made self-consolidating, the amount of vibration and maximum depth of lifts shall be determined during the trial batching process with input from the Department, the Manufacturer's Technical Representative, and the Contractor.

When concrete placements are interrupted, no more than 60 minutes shall elapse from the time of the beginning of the placement and the resumption of the concrete placement when the concrete temperature is below 75 °F. When the concrete temperature is above 75°F, the elapsed time shall be reduced to 30 minutes. Cold joints shall make the unit subject to rejection.

No water shall be added to the concrete after batching. HRWR may be added to the concrete after batching if that practice conforms to the manufacturer's published recommendations. Concrete that becomes unworkable shall be discarded.

534.15 Process Control Test Cylinders: All process control test cylinders shall be made and tested in accordance with the following Standards:

- AASHTO T23 (ASTM C31/C31M) Practice for Making and Curing Concrete Test Specimens in Field
- AASHTO T22 (ASTM C39) Test Method for Compressive Strength of Cylindrical Concrete Specimens
- AASHTO T119 (ASTM C143) Test Method for Slump of Hydraulic Cement Concrete
- AASHTO T141 (ASTM C172) Practice for Sampling Freshly Mixed Concrete
- AASHTO T152 (ASTM C231) Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
- ASTM C1064 - Test Method for Temperature of Freshly mixed Portland Cement Concrete

A minimum of 8 concrete test cylinders shall be cast to represent each continuous concrete placement. Six of the cylinders from each test shall be cured under the same conditions as the units. Unit identification, entrained air content, water-cement ratio, slump and temperature of the sampled concrete shall be recorded by the Contractor at the time of cylinder casting. Testing shall be done in the presence of the QAI. The QAI will designate the loads to be tested. Cylinders made to determine handling strength shall be made during the last 1/3 of the placement.

At least once a week, the Contractor shall make four cylinders for use by the Department. They shall be cured in accordance with AASHTO T23 (ASTM C31/C31M).

If the Contractor fails to make enough cylinders to demonstrate that the product meets the contract requirements, the product will be considered unacceptable.

The standard size test cylinder for acceptance shall be 6 inches by 12 inches. If 4 inch by 8 inch cylinders are used for acceptance, the compressive strength values shall be reduced by 5%. The compressive strength of the concrete shall be determined by averaging the compressive strength of two test cylinders made from the same load.

For the purpose of acceptance, the average of two cylinders shall meet or exceed the design strength, and, neither cylinder shall be more than 500 psi. below the required strength.

534.16 Abutment and Pier Segment Curing: Immediately after the concrete has been finished, the product shall be covered with an impermeable barrier to prevent moisture loss. The barrier shall be tight to the form and securely fastened. The exposed surface of the concrete shall be kept moist. The Contractor shall monitor and record the concrete temperature during the initial curing cycle.

After the product has been removed from the form, moist curing shall continue until it has reached design strength. All surfaces of the product shall be kept moist and the product shall be placed in a moisture retention enclosure with a relative humidity not less than 80%. The product shall not be exposed to temperatures below 50 °F until design strength is achieved.

Membrane curing compounds shall not be used without the approval of the Fabrication Engineer. If approved, the compound shall be applied in strict accordance with the manufacturer's published instructions. The Contractor shall provide the QAI with the product data sheet for the compound prior to application. The compound shall be applied immediately after stripping. Concrete shall have reached stripping strength prior to handling abutment and pier segments.

534.165 Curing Self-consolidated concrete placed within voids, around piling: An approved membrane curing compound shall be applied in strict accordance with the manufacturer's published instructions.

534.17 Accelerated Curing (Optional): Accelerated curing shall begin after the concrete has attained its initial set. Initial set shall be determined in accordance with ASTM C403, Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance. A strength gain of 500 psi. indicates initial set. The Contractor shall provide documentation that the mix design being used has been tested in accordance with ASTM C403. Accelerated curing shall begin after the concrete has attained initial set. Application of heat more than 8 hours after initial set will not be considered accelerated curing.

The enclosure temperature may be increased by a maximum of 10 °F/hour prior to initial set. The total temperature gain prior to initial set shall not exceed 40°F.

After initial set, the temperature gain of the concrete shall not exceed 40°F/hour. The concrete temperature shall attain a minimum temperature of 120°F and that temperature shall be maintained for a minimum of 8 hours. The maximum allowable concrete temperature shall be 180°F. Concrete temperature shall be measured near each end of the casting bed and at intervals not to exceed 100 feet.

The cooling rate from maximum accelerated curing temperature shall not exceed 40°F/hour. The cooling rate shall continue until the concrete temperature is within 40°F of the ambient air temperature.

Steam curing shall take place in an enclosure that allows the free circulation of steam. Steam jets shall provide a uniform distribution of steam without discharging directly on the product or the test cylinders.

When radiant heat is used, the Contractor shall take measures to assure that there is no moisture loss from the product. Free water shall be present on all exposed surfaces at all times.

Recording thermometers that indicate the time/temperature relationship shall be used by the Contractor until transfer/stripping strength has been achieved. Copies of the time/temperature records shall be made available to the QAI.

If the units have achieved 80% of design strength during the curing cycle, no further curing will be required.

534.20 Finishing Concrete and Repairing Defects Products fabricated under this Section shall meet Standard Grade finish requirements as defined in MNL 116 when they are hidden from view in their final position by backfill or riprap, all other surfaces will be considered exposed to view and will require a special architectural finish.

For portions of product not exposed to view in their final position the recommendations of Standard Grade finish requirements shall be mandatory.

Portions requiring an architectural finish shall meet the following standards. No projections from the surface along the length of each piece will be allowed, uniform color and texture, no visible form tie holes patched or otherwise, all surface voids filled. In order to assure uniformity in appearance of the exposed abutment face, prior to any production work the Precaster shall prepare a sample measuring 24 inch by 24 inch by 6 inch for acceptance by the Department on an aesthetic and cosmetic basis; this piece shall be used throughout production as the standard by which all abutment surfaces exposed to view in their final position are compared for acceptance of the finish.

Structural defects shall be repaired by a method approved by the Fabrication Engineer. Structural defects shall include, but not be limited to exposed reinforcing steel or strand, cracks in bearing areas, through cracks and cracks 0.0125 inches or more in width that extend more than 12 inches. The Contractor shall submit a proposed repair procedure for structural repairs to the Fabrication Engineer. No structural repairs shall be made without the QAI being present. The QAI shall be given adequate notice before beginning repairs.

Chamfers and drip notches shall be made smooth and uniform. Keyways shall be sandblasted to remove mortar paste.

On surfaces not exposed to view in their final position honeycombing, ragged or irregular edges and other cosmetic defects shall be repaired using a product from the MDOT Prequalified List for Patching Materials. The repair, including preparation of the repair area, mixing, application, and curing of the patching material shall be in accordance with the manufacturer's published instructions. Edges not exposed in the final product may be ground smooth with no further repair necessary if the depth of the defect does not exceed one-half inch. Form ties shall be removed to a depth of not less than 1 inch from the face of the concrete and patched using a cementitious mortar or patching compound.

534.22 Tolerances: Tolerances for precast units shall be in conformance with the latest edition of MNL 116, as applicable.

534.23 Transportation and Storage: The precast products may only be handled, moved or transported after the 28 day design strength has been attained.

Prestressed products shall be stored and transported so that the reactions with respect to the unit shall be approximately the same during transportation and storage as the product in its final position. The product shall be handled so that only a vertical force is applied to the lifting devices.

Stored products shall be supported above the ground on dunnage in a manner to prevent twisting or distortion. Products shall be protected from discoloration and aesthetic damage.

Units damaged by improper storing, hoisting or handling shall be replaced by the Contractor.

534.26 Post-Tensioning and Pile Socket Filling: Immediately before post-tensioning abutment segments and pier segments, the match cast joint shall be coated with an adhesive epoxy, Sikadur 32 or approved equal, in accordance with the manufacturer's published recommendations. A lockoff tension of 166,000 pounds per bar shall be applied to lateral post-tensioning bars.

Recesses at ends of lateral post-tensioning ducts shall be filled with grout using the same type cement as that in the abutment segments. Prior to installing the grout, the stressing pockets shall be clean of any dirt, grease, oil, or other material that may prevent bonding. Grouting shall be completed within 10 days of lateral post-tensioning. Backfill of abutments and erection of precast superstructure shall not be allowed until post-tensioning of all substructure caps is complete.

After the post-tensioning of a precast unit is complete, fill the socket for the tops of the piles with self-consolidating concrete. Test cylinders cured in the same environment as the socket fill concrete must demonstrate that the fill concrete has reached 2.5 ksi prior the application of any gravity loads on the precast segments. Backfilling of abutments may proceed once the abutment socket fill concrete has reached 1.0 ksi.

534.27 End anchorage, Ducts & Grout: End anchorage shall be the plate anchorage detail as manufactured by Dywidag-Systems International or approved equal. They shall be shown in detail on the working drawings, and shall be formed in such a manner that 2 inches of cover is provided to the ends of the post-tensioning bar in the final product. Grout tubes shall be installed at each duct in each end of each segment for a total of: **8 grout tubes** required for each abutment post-tensioning duct; and **6 grout tubes** required for each pier post-tensioning duct. Ducts shall be galvanized corrugated metal ducts. Grout for post-tensioning ducts shall be either **Five Star Special Grout 400** or **Masterflow 1205**. Alternate high strength specially graded pumpable cable grouts will be considered for approved by the engineer upon request.

534.28 Method of Measurement: Precast structural concrete will be measured by the lump sum.

534.29 Basis of Payment: All work done under Precast Structural Concrete will be paid for at the contract lump sum price. Payment will be full compensation for furnishing all materials in the precast unit including, precast concrete, reinforcing steel, post-tensioning bars, ducts and related materials and work. Related materials and work will include, but not be limited to, erecting the products, grouting of ducts, post-tensioning operations, providing and applying adhesive epoxy, providing and placement of socket filling, and any concrete admixtures used. The quantity shown on the Plans for estimating purposes is both the precast concrete and the socket filling concrete.

Payment will be made under:

<u>Pay Item</u>		<u>Pay Unit</u>
534.76	Precast Abutment	Lump Sum
534.7601	Precast Approach Slab	Lump Sum
534.7602	Precast Pier	Lump Sum

Example 4: Texas DOT Precast Column Connections

The following pages contain portions of a Texas DOT research project for the connection of precast bent caps using grouted post-tensioning sleeves. The research report for this work is as follows:

Development of a Precast Bent Cap System [49]

Authors: E.E. Matsumoto, M.C. Waggoner, M.E. Kreger, S.L. Wood and J.E. Breen

The University of Texas at Austin, Center for Transportation Research

Published: January 2001

Design Methodology: Pages 251-309

The following pages include:

- Chapter 7 – Development of a Precast Connection Specification
- A sample specification for this connection

CHAPTER 7:

DEVELOPMENT OF A PRECAST CONNECTION SPECIFICATION

7.1 INTRODUCTION

This chapter summarizes the development of a connection specification for a precast bent cap system, referred to as a precast connection specification. Major components of the specification are developed based on results from Phases 1-3. The following areas are addressed: 1) materials, 2) precast bent cap placement plan, 3) grouting operations, and 4) additional items.

7.2 MATERIALS

To ensure selection of a proper grout, the connection specification should include a grout specification. In addition, properties of connectors and connection hardware should be carefully specified.

7.2.1 Non-Shrink Grout

Table 7.1 is a modified version of Table 2.6, the grout specification for a precast bent cap system. Based on Phase 1-3 tests, the properties specified in Table 2.6 were modified to address mechanical, compatibility, constructability, and durability properties. The reader is referred to Chapters 2 through 5 for background information on construction and grouting issues.

7.2.1.1 Mechanical Properties

The compressive strength requirement for grout is intended to: 1) provide for transfer of forces between connectors, grout, ducts, and/or concrete, 2) provide timely strength gain for rapid construction, and 3) ensure the grout is not the weak link in the connection system. Phase 1-3 tests indicated adequate grout strength for transfer of connection forces, even for the majority of cases in which the grout strength was less than that of the surrounding concrete. All of the tested grouts were expected to satisfy the strength gain requirements of Table 2.6, although this did not always occur. Masterflow 928 (MF928) exhibited the most consistency in achieving strength gain. Although the grout specification provides a reasonable minimum requirement for strength gain, project-specific requirements may be more or less stringent. Thus, the engineer should not rely solely on the grout specification, but should specify in the plans the required minimum grout strength for beam placement and the final grout strength. The contractor, in turn, is required to select a grout that achieves the necessary strength at the critical stages.

Only in one test was the grout considered to be the weak link in the system (Phase 2, VD04, Euclid Hi-Flow [EHF]). In the VD04 pullout tests, the grout strength was just 55% of the strength of the surrounding concrete (3.1 ksi, modified grout cube strength compared to a concrete strength of 5.6 ksi). As mentioned in Chapter 1, others have reported excellent anchorage and response for grouted vertical duct connections when the grout strength was approximately equal to or as much as 1.4 ksi greater than the concrete strength [1.30,1.31].

Based on the previous discussion, it is recommended that: 1) the grout cube compressive strength satisfy the requirements of Table 7.1, and 2) the modified grout cube strength at 28-days, based on a 0.8 factor, exceed the specified 28-day concrete compressive strength by a minimum of 1000 psi. Many prepackaged grouts satisfy these two requirements. A 1000-psi margin accounts for the likelihood that the actual concrete strength will exceed the specified strength as well as the possibility of a low grout strength. The 28-day grout cube strength was increased to 5800 psi in Table 7.1 to provide a 1000-psi margin for Class C concrete.

If a bent cap uses 5000-psi concrete, then grout with a 28-day (unmodified) cube strength of at least 7500 psi is required. A number of such grouts are available. Engineers should be careful to ensure that they select a grout with a compressive strength based on the water required for fluid consistency. Grouts mixed to a flowable or plastic consistency in accordance with ASTM C 230 achieve a higher compressive strength but inadequate fluidity for grouting voids in a precast bent cap system. Manufacturers' data sheets typically list compressive strengths for all three consistencies.

7.2.1.2 Compatibility

Compatibility requirements are related to volume stability, modulus of elasticity, and coefficient of thermal expansion. Table 7.1 uses the same values as those defined in Table 2.6. The values for the modulus of elasticity and coefficient of thermal expansion provide a fairly close match for grout and the surrounding concrete. As mentioned in Chapter 2, ASTM C 1107 allows three grades of shrinkage-compensating grouts (Table 2.5): Grade A—prehardening volume-controlled type, Grade B—post-hardening volume-controlled type, and Grade C—combination volume-controlled type. MF928 is a Grade B grout, whereas EHF and Sika 212 are Grade C. Tests confirmed that for connections using Grade B and Grade C grouts, cracking did not develop in the connection region prior to loading. No deficiencies in behavior were attributed to Grade type. Thus, Table 7.1 lists either Grade B or Grade C as acceptable grout types. Grade A grouts were eliminated because they can produce as much as a 4-percent volume expansion before the grout hardens, possibly causing a reduction in density of the hardened grout, as well as larger shrinkage stresses.

7.2.1.3 Constructability

Proper grout flowability is a key to successful construction of a precast bent cap system. Table 7.1 specifies a fluid consistency for grout, with an efflux time, or flow, between 20 and 30 seconds as determined by the Flow Cone Method per CRD-C 611 and ASTM C 939. The lower limit has been changed from Table 2.6, which specified a flow between 10 and 30 seconds.

In tests that used grouts with a flow that longer than 30 seconds, the greater grout viscosity slowed down the venting of air bubbles from the grout, often resulting in an air void at the top of the pocket. This could provide a moisture path into the connection and threaten durability. On the other hand, a grout with too short of a flow time may be indicative of segregation. This was observed particularly with Sika 212 grout in Phases 2 and 3. Segregation resulted in a denser grout at the bottom of connections, but pasty, weak material near the top surface. To prevent segregation, the lower range has been increased to 20 seconds. When needed, ice or warm water may be used in grout mixing to help adjust the flow. For some temperature ranges, this will also increase the working time. No problems with set time were observed in the test program. Thus, the range was not changed from Table 2.6.

The working time, or pot life, of the grout is a crucial consideration in grout selection. Based on Phase 2 and 3 grouting, it is expected that a contractor will require approximately 15 minutes to gravity-flow grout a 30-in. deep cap with a double line grout pocket connection or a connection with four ducts. Although longer times should be estimated for deeper caps or additional ducts, grouting of an individual connection is not expected to require more than 30 minutes. Pumping of grout is expected to reduce grouting time. It is important that the estimate of the total grouting time account for: 1) conducting the flow cone test, 2) transferring grout from the mixer to dispensers, 3) transporting grout to point of placement, and 4) grouting one or more connections. Water and air temperatures at the jobsite must also be considered.

Table 7.1 Precast Bent Cap Grout Specification

Property	Values	
<p>Mechanical</p> <p>Compressive strength (ASTM C-109, 2” cubes)</p>	<p>Age</p> <p>1 day 3 days 7 days 28 days</p>	<p>Compressive strength (psi)</p> <p>2500 4000 5000 max[5800, 1.25($f_{c_{cap}}+1000$)]</p>
<p>Compatibility</p> <p>Expansion requirements (ASTM C 827 & ASTM C 1090)</p> <p>Modulus of elasticity (ASTM C-469)</p> <p>Coefficient of thermal expansion (ASTM C-531)</p>	<p>Grade B or C—expansion per ASTM C 1107</p> <p>3.0-5.0×10⁶ psi</p> <p>3.0-10.0×10⁻⁶/deg F</p>	
<p>Constructability</p> <p>Flowability (CRD-C 621/ASTM C-939)</p> <p>Set Time (ASTM C-191) Initial Final</p>	<p>fluid consistency efflux time: 20-30 seconds</p> <p>3-5 hrs 5-8 hrs</p>	
<p>Durability</p> <p>Freeze Thaw (ASTM C-666)</p> <p>Sulfate Resistance (ASTM C-1012)</p>	<p>300 cycles, RDF 80%</p> <p>expansion at 26 weeks < 0.1%</p>	

7.2.1.4 Durability

As mentioned in Chapter 2, grout durability should be at least equal to that of the surrounding concrete, and proprietary grouts are often formulated to achieve this. Because examination of grout durability was beyond the scope of this research, specific properties of proprietary grouts were not investigated. Requirements listed in Table 7.1 should be checked against project-specific requirements. In addition, manufacturers should be consulted for available properties, such as resistance to freeze-thaw, chlorides, sulfates, and scaling.

In some cases, specially-modified grouts such as latex-modified grouts may be useful. Such grouts cannot be recommended based on the scope of this research. However, future research may show other alternatives to be viable. Specifying durability requirements for a cementitious grout is generally expected to eliminate lesser quality grouts. However, engineers should be careful that grouts do not satisfy durability requirements at the expense of other required properties.

The following minimal provisions are recommended in selecting durable grouts: 1) grouts should be chloride-free, 2) grouts should use non-metallic formulations. Bleed properties should also be reviewed, if available.

Provisions for durability enhancement of the connection region are discussed in Chapter 6.

7.2.2 Connection Hardware

Connection hardware refers to connectors, ducts, anchor plates, shims, and other similar items required for connection construction. Connector and duct requirements are discussed in Chapter 6. Connectors should conform to the requirements of the *Materials* section of the Precast Connection Specification.

The engineer should specify in the plans any requirements for plates and other items necessary for anchorage of bolted connections. These items were not addressed in a detailed way in Phases 2 and 3.

7.2.2.1 Shims

Shims were found to be a reliable means for cap support. In Phase 2, both steel and plastic shims were effective for cap placement. Shims were glued together and to the column or pile surface to prevent movement. In Phase 3 the contractor did not glue individual shims together or glue shimpaks in place. Workers thus found steel shims to provide better stability than plastic shims.

It is recommended that both steel and plastic shims be permitted. Plastic shims should be an engineered multipolymer high-strength plastic. Specific measures to prevent movement of shims during cap placement should be detailed in the plan sheets. Prior to cap placement, the underside of the cap should be checked to ensure a flat bearing surface. Two shims may be used at exterior columns or piles to ensure bearing on at least three of the four shims. To facilitate complete grouting of the bedding layer, the total shim plan area should be limited to approximately 10% of the pile or column top area. Limiting individual shims to an aspect ratio of two may also help. Shims should be sized to ensure the allowable bearing stress at both concrete surfaces is not exceeded. In addition, shims should be placed at least 2 in. away from surface edges to help ensure grout completely surrounds shims. Additional cover may be required for corrosion protection of steel shims.

7.3 PRECAST BENT CAP PLACEMENT PLAN

To ensure the contractor uses an appropriate construction sequence and carefully plans all operations associated with cap placement, the contractor should submit a Precast Bent Cap Placement Plan to the engineer for approval prior to mixing a trial batch of grout. This plan should include: 1) a step-by-step description of the construction sequence, 2) a step-by-step description of grouting operations, 3) the method for cap support prior to and during grouting, 4) manufacturer's literature for a minimum of two candidate connection grouts, and 5) manufacturer's literature for connection hardware.

7.3.1 Construction Sequence

Example construction sequences for a precast bent cap system are discussed in Section 2.2. The contractor should completely describe the proposed construction sequence. In addition, a description of other pertinent information should be outlined, such as the method to provide anchorage holes in the piles or columns (i.e., embedded sleeves vs. drilled holes) or the use of special devices to assist in threading the cap over connectors.

7.3.2 Grouting Operations

A detailed description of grouting operations should address formwork, air venting, grouting method, and sequence of steps. These issues are discussed in Section 7.4.

7.3.3 Cap Support

The contractor should indicate the method and hardware for cap support prior to and during grouting. Hardware will likely consist of shims, friction collars, bearing plates and leveling nuts, shoring or other systems. The contractor should define the support systems and provide product information, material descriptions, and drawings, as appropriate.

7.3.4 Manufacturer's Literature for Candidate Grouts

The contractor should identify two candidate grouts for connections and provide the manufacturers' literature. Selected grouts should satisfy the grout criteria listed in Table 7.1. In addition, literature should indicate mixing requirements, working time, curing requirements, and other pertinent information. Two grouts should be selected in the event that the first grout is found unacceptable during the trial batch.

7.3.5 Manufacturer's Literature for Connection Hardware

The contractor should also provide manufacturers' literature for all connection hardware to be used.

7.4 GROUTING

The precast connection specification should include specific requirements for all grouting operations, including: 1) a trial batch, 2) formwork, 3) presoaking, 4) pre-grouting meeting, and 5) grouting methods. The following sections discuss these requirements.

7.4.1 Trial Batch

The trial batch of grout should be prepared a minimum of two to four weeks prior to connection grouting. The requirement for a trial batch is especially important because a trial batch enables contractor personnel to assess the suitability of a grout for constructability and strength, and also provides the contractor valuable experience. During Phase 3, the contractor confirmed the importance of a trial batch. As mentioned in Section 5.2.5.1, the specific purposes of a trial batch are:

1. To determine the required amount of water to be added to a particular grout brand to achieve acceptable flowability using the CRD-C 611/ASTM C 939 Flow Cone Method under the temperature conditions expected in the field
2. To determine the grout cube strength corresponding to the flow achieved
3. To examine grout for undesirable properties such as segregation
4. To establish the adequacy of proposed grouting equipment such as the mixer, tremie tubes, funnels, buckets, and vent tubes
5. To provide jobsite personnel experience in mixing and handling grout prior to connection grouting
6. To help the contractor to make a judicious decision regarding grout brand

The following sections highlight important lessons learned during Phase 1-3 grouting, which should be applied in trial batches.

7.4.1.1 Equipment

The contractor should use the proposed grouting equipment in all mixing and grouting operations. Equipment such as a mortar mixer, tremie tubes, funnels, buckets, and vent tubes should be carefully selected. The proposed mixer for actual grouting should be used for mixing trial batches. High-speed hand drills mix grout more thoroughly, but cannot produce a sufficient volume for connection grouting. The inside diameter of the tremie tube should be large enough for grouting in a timely manner, but small

enough to drain the funnel volume gradually so that a continuous grout flow is maintained. In addition, the outside diameter of the tube should be small enough to fit between the duct walls and connectors. Funnels should be large enough to ensure a continuous flow of grout within the tube. A minimum funnel size of 4 quarts is recommended. A pinch valve in the tube is recommended and should be required for cases in which an interruption in grouting operations may occur. Bucket volume should be at least 5 gallons. The inner diameter of air vent tubes should be at least 0.5 in. Transparent vent tubes will accommodate visual inspection of air venting better than opaque tubes or vent holes. A 0.5-in. minimum wire mesh (hardware cloth) should be used as a filter to remove potential clumps when dispensing grout from the mixer.

7.4.1.2 Grout Flowability

A main purpose of the trial batch is to determine the required amount of water to be added to a prepackaged grout to achieve acceptable flowability in the field. The trial batch of grout should be mixed using water at a temperature corresponding to that expected for field grouting, and also at the expected ambient air temperature. This is important, as some grouts only achieve the fluidity and strength stated in the literature when mixed at an ideal temperature of 70 degrees Fahrenheit. The manufacturer's recommended amount of water to achieve fluid consistency may be used in the first batch.

After mixing in accordance with manufacturer's recommendations, the grout should be inspected for undesirable properties such as segregation or clumps. A minor amount of settlement of grout solids during mixing is acceptable, but grouts exhibiting significant segregation (e.g., clear separation between mix water and fine aggregate) should not be used. Grout segregation may lead to the formation of gaps at the bedding layer or produce cavities at the top of the cap. Gaps or cavities may threaten connection durability and/or reduce the ability of the connection to transfer forces. Clumps may result when a low-speed mortar mixer is used with a large volume of grout.

The flow time should be determined using the CRD-C 621/ASTM C 939 Flow Cone Method. When collecting grout for the flow cone test, a representative portion of the grout should be used. Grout should not be obtained by skimming the top surface of grout from a mixer, as grout tends to be more fluid at the top. A 0.5-in. mesh should be used to eliminate clumps from grout used for the flow cone test. Two flow cone tests should be conducted: one immediately after mixing and a second at the expected pot life of the grout. The second test is intended to confirm that a batch of grout will maintain a suitable flowability throughout grouting operations.

If the flow time falls outside of the 20 to 30 second range, then one of the following actions should be taken: 1) slightly change the amount of water, as long as it is still within manufacturer's recommendations, or 2) use cold or warm water to adjust the flow. If this does not produce an acceptable flow, another brand of grout should be used. In each case, a new batch of grout should be mixed. Remixing, or retempering, of grout mixtures should not be permitted, as it can change grout properties and introduce extra air into the mix. In some cases, slightly increasing the amount of water (e.g., 10%) may significantly increase the flow. However, this will also reduce the grout strength.

A TxDOT Materials representative should assist in conducting the flow cone test, and should prepare and cure a minimum of nine grout cubes for each candidate grout that achieves a suitable flow. A commercial testing laboratory approved by the engineer or a TxDOT Materials representative should test the grout cube specimens. At least two cubes should be tested at 1 day, 3 days, 7 days and 28 days.

7.4.1.3 Trial Grouting Operation

Only grouts that achieve a suitable flow should be used in a trial grouting operation. All equipment proposed for actual grouting operations should be used in a simple, mock grouting operation. Grouting operations should test the suitability of tremie tubes, funnels, vent tubes, and other equipment proposed for use. This allows the grout to be further inspected for workability, segregation and excessive bleeding.

Tamping of grout is recommended instead of vibrating. However, if a vibrator is proposed for use, it should be approved by the grout manufacturer and tested during the trial grouting operation. Care must be exercised in using vibrators because excessive agitation can entrap air in the grout.

Depending on the project requirements, grouting operations may encompass a wide range of activities, from forming and grouting a mock-up of an actual connection detail to grouting a simple box or circular form. It is left to the discretion of the engineer to judge what is reasonable and prudent. However, the trial grouting operation should closely simulate the actual field conditions, including physical constraints, temperature, etc.

7.4.1.4 Scheduling, Weather Restrictions, Admixtures

7.4.1.4.1 Scheduling of Trial Batch

It is recommended that trial batches be completed at least two weeks prior to actual grouting operations. This time is necessary to conduct the trial batch, determine grout strength and strength gain, and conduct an additional trial batch if the strength or strength gain does not satisfy the specification.

7.4.1.4.2 Weather Restrictions

Grouting should be conducted under the same limitations as casting concrete. Grouting during rainy weather may not only add water to grout mixes but may also rush workers as they conduct grouting operations. To prevent poor durability or other undesirable properties, manufacturer's recommendations for cold weather limitations should be followed. In addition, cold and warm weather practices may be necessary for flowability.

7.4.1.4.3 Admixtures

Prepackaged grouts are proprietary mixes, and thus no additives should be used in the grout. Additives may adversely affect grout properties and void manufacturer warranties.

7.4.1.5 Acceptance

Any grout conforming to the following should be acceptable for use:

1. Satisfies all of the parameters of the grout specification of Table 7.1
2. Achieves an acceptable grout flow in field conditions during the trial batch immediately after mixing and at the pot life
3. Attains compressive strength and compressive strength gain based on grout cube tests using trial batch grout
4. Possesses a working time suitable for connection grouting
5. Performs reliably in trial grouting operation
6. Possesses other properties, including durability, required for a project-specific application

7.4.2 Formwork

To ensure successful grouting, the bedding layer must be properly formed. As shown in Chapter 5, flexible fiberglass forms are readily available and may be tightly wrapped around and bolted on round columns. Wood may be used to form around the bedding of square or rectangular piles or columns. Care should be exercised to ensure forms are tight and properly sealed. Presoaking is a vital step to ensure forms are sealed. Custom-made forms may be more reliable in sealing rectangular and square sections. Formwork should accommodate air vent tubes or holes. Supplementary vents may be formed into the bent cap.

7.4.3 Presoaking

Connections should be presoaked with water for a minimum of two hours prior to grouting. Presoaking connections should be conducted for two reasons: 1) to verify tightness of forms at the bedding layer, and 2) to minimize loss of moisture from the grout into the surrounding concrete that can lead to grout shrinkage. Verification of form tightness is particularly critical to successful connection grouting. An overnight or 24-hour presoaking of the connection is preferable. Residual water left in the connection after presoaking must be drained prior to grouting. This may be accomplished with auxiliary water ports provided at the bottom of the bedding layer formwork or by vacuuming.

7.4.4 Pre-Grouting Meeting

Because of the difficulty in correcting field problems after grouting, special care and oversight should be exercised prior to and during initial grouting operations. An on-site pre-grouting meeting between the contractor and a TxDOT representative should be conducted just prior to actual grouting operations to review the details of the grouting procedure and ensure lessons learned during the trial batch are incorporated. In addition, the TxDOT representative should be available for consultation during initial grouting operations and periodically thereafter. All grouting operations should be observed by a TxDOT representative for compliance with the Precast Bent Cap Placement Plan.

7.4.5 Grouting Methods

Grout should be deposited in the connection in such a way that all voids are completely filled. Both gravity-flow and pressure grouting may achieve this objective. As mentioned in Chapter 2, gravity-flow grouting involves simpler operations overall and may be less expensive. However, additional effort may be required to ensure connection voids are completely filled. Grouting using a low pressure pump requires a higher level of skilled labor in the field, but would likely result in a connection free of voids and can expedite grouting operations, especially on large projects. Both approaches can be economical, depending on specific project constraints.

This section discusses gravity-flow grouting, which was used in Phases 1 through 3. Gravity-flow grouting should be conducted using either a bucket or tremie tube.

7.4.5.1 Bucket Approach

Placement of grout with a bucket is a viable alternative for grout pocket connections, which use relatively large openings at the cap top. As discussed in Chapters 4 and 5, five-gallon buckets are recommended for placement. After mixing the grout, buckets are filled and lifted to the cap top. The grout is poured into the pocket in lifts and tamped after each lift. A flat object such as a shovel or plywood can be used to help direct grout into the pocket with minimal agitation of the grout or air entrapment. Any grout sediments remaining at the bottom of the bucket should be removed and placed into the pocket prior to tamping.

7.4.5.2 Tremie Tube

Tremie-tube grouting should be used for grouted vertical duct and bolted connections, and may also be used for grout pocket connections. One of three variations may be used: 1) continuous-flow, 2) modified, and 3) decanting. Continuous-flow tremie-tube grouting should be conducted by lowering a flexible tube to the bottom of the bedding layer and filling the connection from the bottom upward with a continuous flow of grout. With this approach, it is crucial that grout fill the tube continuously to avoid entrapping air in the connection. This requires that a sufficient amount of grout be mixed prior to grouting and that the funnel connected to the tube have adequate capacity. A pinch valve may be used to stop the flow during grouting. This allows for refilling the funnel and tamping the voids. The tube should remain within the grout, but may be gradually withdrawn as the level of grout rises in the ducts or pockets. This approach should be used when possible, as it will likely prevent air entrapment.

The modified tremie tube and decanting approaches do not require a continuous flow of grout. The modified tremie tube approach should be used in cases where the tube cannot extend to the bottom of a connection due to small clearances or other reasons. The tremie tube should always be kept above the top of the grout, and the tube should direct the flow of grout against either a connector, sidewall, or duct. The decanting approach should be conducted by pouring grout against connectors to direct the flow to the bottom of the connection. This limits grout agitation and helps prevent air entrapment. Voids should be tamped several times during grouting.

7.4.5.3 Pressure Grouting

Pressure grouting involves pumping grout into connections under low pressure. This approach may be used for all connection types, and is required for grouted sleeve couplers. The trial batch and manufacturer's guidelines should be used to establish the pressure for grouting. To prevent entrapped air, grout should not be placed at too high a rate. Voids may be lightly tamped.

7.4.5.4 Air Venting, Plan Sheets, Grout Handling

7.4.5.4.1 Air Venting

Air should be vented at the bedding layer using a minimum of four vent tubes or holes, distributed uniformly around the perimeter of the column or pile formwork. Vent tubes or holes should be located at the top of the bedding layer. When gravity flow grouting is used, multiple grout pockets or vertical ducts should be grouted from a single pocket or from a corner duct. Vents should be plugged sequentially when a steady stream of grout flow out without air. For connections with ducts or pockets, grout will eventually flow up the ducts or pockets. After the grout level in the pocket or ducts rises near the cap top, a tremie tube should be used to top off the openings.

7.4.5.4.2 Plan Sheets

It is highly recommended that plan sheets include a step-by-step list of procedures to be followed during grouting operations. This is considered a key to successful grouting operations. The contractor involved in Phase 3 construction strongly felt that this will help ensure grouting procedures are properly conducted.

7.4.5.4.3 Grout Handling

Precautions should be taken to minimize air entrapment when pouring grout from the mixer into dispensers and when grouting connections.

7.5 OTHER ITEMS

Additional items related to the precast connection specification are discussed in this section, including recommended tolerances, grout sampling for test cubes, grout curing, post-grouting inspection, and verification of connector anchorage in columns and piles.

7.5.1 Recommended Tolerances

As discussed in Chapter 6, horizontal tolerances for grout pocket connections should be +/-1 in. in the longitudinal direction and +/-2 in. in the transverse direction. Grouted vertical duct and bolted connections using ducts should provide for a horizontal tolerance of +/-1 in. in both directions. If possible, however, the engineer should size pockets and ducts to provide tolerances of at least +/-1.5 in. in both directions. These tolerances must account for combined tolerances associated with placement of connectors in piles or columns and fabrication and placement of pockets and ducts in the bent cap. Vertical tolerances should be +/-1 in.

When specifying connections using grouted sleeve couplers, the engineer should verify the available horizontal and vertical tolerances provided by a particular coupler. Different tolerances are available for different manufacturers and for couplers housing different bar sizes. In determining the suitability of such a connection, the engineer should ensure that available tolerances are compatible with tolerances of $\pm 1/8$ in. in the horizontal direction and $\pm 3/8$ in. in the vertical direction for placement of the coupler within the bent cap.

To ensure adequate clearances are provided, ducts should be cast in the bent cap in such a way that a vertical orientation is achieved after setting of the bent cap. This must be carefully considered during bent cap fabrication, and may be especially critical when tight tolerances are necessary such as for grouted sleeve couplers. Cross slope can be achieved by use of variable depth pedestals.

7.5.2 Grout Sampling for Test Cubes

During grouting operations, a TxDOT representative should witness the flow cone test and preparation of a minimum of six grout cubes for each batch of grout. A commercial testing laboratory approved by a TxDOT representative should test the grout cube specimens. To verify grout strength, cubes should be tested at 1 day, 3 days, and for approval of beam setting and final strength.

For cases in which inadequate strength is indicated, additional grout cubes should be tested and the average strength calculated. The engineer should determine the course of action in the event of inadequate strength, including additional grout cube testing, a review of structural calculations and durability provisions, and grout removal and re-grouting of the connection.

7.5.3 Grout Curing

All exposed grout surfaces should be cured in accordance with manufacturer's recommendations. This will typically involve covering exposed grout with clean wet rags and maintaining moisture for a minimum of 6 hours, followed by the application of an approved membrane curing compound.

7.5.4 Post-Grouting Inspection

After grout curing and form removal, all exposed grout surfaces at the top and sides of the cap and at the bedding layer should be carefully examined. If voids appear at any surface, external sealants should be applied to prevent a moisture path into the connection. In extreme cases, epoxy injection or other measures may be recommended by the engineer. In addition, external sealants should be applied to all surfaces for which enhanced durability is required.

7.5.5 Verification of Anchorage

For specific projects, the engineer may require that a pullout test be conducted to verify the adequacy of connector installation in columns, drilled shafts or piles. The connector should be loaded to less than the yield force to limit potential damage. The number of connectors to be tested is left to the engineer's discretion. The minimum force required to demonstrate adequacy of connector installation should be shown in the plans. Adequate anchorage should be assumed when an applied load equal to 85% of the specified yield strength of the connector is applied without slippage or pullout of the connector.

XXXX Specifications

SPECIAL SPECIFICATION

ITEM XXXX

PRECAST CONNECTIONS

XXXX.1. Description. This item shall govern for connection of precast concrete bent caps to cast-in-place columns, drilled shafts and prestressed concrete piles.

XXXX.2. Materials. All materials shall conform to the pertinent requirements of the following Items except as otherwise required herein:

Item 420, "Concrete Structures"

Item 421, "Portland Cement Concrete"

Item 425, "Prestressed Concrete Structural Members"

Item 435, "Elastomeric Materials"

Item 440, "Reinforcing Steel"

Item 442, "Metal for Structures"

Item 447, "Structural Bolting"

Item 449, "Anchor Bolts"

(1) Hydraulic Cement Grout (Non-Shrink)

All grout for precast connections shall consist of prepackaged, cementitious, non-shrink grout in accordance with ASTM C-1107 and the additional performance requirements listed in Table 1, including mechanical properties, compatibility, constructability, and durability. Table 1 requirements shall govern over ASTM C-1107 requirements. Grout using metallic formulations will not be allowed. Grout shall be free of chlorides. No additives shall be added to prepackaged grout.

(2) Connection Hardware

All connection hardware, connectors, and ducts shall be in accordance with the requirements shown in the plans.

XXXX.3. Contractor Submittals. At least one month prior to the start of precast bent cap placement, the Contractor shall submit to the Engineer a Precast Bent Cap Placement Plan. Caps shall not be set

until the Engineer has approved all required submittals. At a minimum, the plan shall contain the following items:

- a) Step-by-step description of bent cap placement for each bent, including proposed method to form the connection and ensure grout is properly consolidated in the connection and bedding layer.
- b) Method and description of hardware used to hold bent cap in position prior to connection grouting. Hardware may consist of plastic shims, steel shims, friction collars, shoring or other support systems. Total shim area for each connection shall not exceed 10% of the cross sectional area of the column, drilled shaft or pile. Individual shims shall be limited to a ratio of length to width of 2:1. Hardware submittal shall consist of product information for plastic shims and friction collars, drawings and material description for steel shims, and shop drawings for shoring if used.
- c) Method of installing connectors. Manufacturer's literature for connector hardware and adhesives used to install the connectors in the columns, drilled shafts or piles. Literature shall include step-by-step installation instructions for adhesives used to install connectors and material properties of the adhesive. Connector hardware shall conform to the type, coating, and installation requirements shown in the plans. Submittals for connectors shall include design calculations showing that the embedment depth exceeds that required to yield connectors. Installation of anchors shall be in accordance with Item 420.11 (9) "Installation of Dowels and Anchor Bolts".
- d) Manufacturer's product information for two candidate grouts, to include a description of the performance characteristics as specified in Table 1, mixing requirements, working time, curing requirements, and other information related to grouting of precast connections utilizing ducts or grout pockets.
- e) Other required submittals shown on the plans or requested by the Engineer relating to successful installation of precast bent caps and associated hardware.

XXXX.4. Construction Methods.

(1) General.

The Contractor shall follow the Precast Bent Cap Placement Plan, including all manufacturer's recommendations for anchorage installation and grouting operations. At the request of the Engineer, a pre-grouting meeting shall be held to review grouting procedures.

When grout pocket connections are used, tolerance for placement of columns, drilled shafts and piles shall be +/-1 in. in the longitudinal direction and +/-2 in. in the transverse direction. Horizontal tolerances shall be taken with respect to the centerline of the bridge. When connectors are embedded in ducts, tolerance for placement of columns, drilled shafts and piles shall be +/-1 in. Size, type, location and orientation of ducts to account for cap slope shall be as shown in the plans. When connectors are installed in preexisting columns, drilled shafts or piles, the tolerance for connector placement shall be +/-1/4 in. with respect to plan location. All connectors shall be installed plumb. Vertical tolerance for cap placement shall be +/-1 inch. Tolerances for grouted sleeve couplers, if used, shall be as shown in the plans. Out-of-tolerance substructure elements shall be subject to structural review by the Engineer.

All form release agents and curing membranes shall be completely removed from areas of the cap that will be in contact with bearing seat and connection grout.

(2) Cap Placement.

The Contractor is solely responsible for insuring the stability of the bent cap prior to and during grouting operations.

All grades, dimensions and elevations shall be verified and/or determined before the bent cap is placed. The contractor shall verify proper alignment between the columns, drilled shafts or piles, including connectors, grout pockets, post-tensioning ducts, and other connection hardware cast into the bent cap. The precast cap may be set and used as a template for drilling anchorage holes at the Contractor's option.

All loose material, dirt and foreign matter shall be removed from the tops of columns, drilled shafts or piles before the cap is set.

(3) Anchorage.

A pullout test shall be used to verify the adequacy of the grout or adhesives used to anchor connectors into columns, drilled shafts or piles. The minimum force required to demonstrate adequacy of anchor installation shall be 85% of the nominal force required to yield the connector.

(4) Grouting of Connections.

Grout shall be used in strict accordance with manufacturer's recommendations.

Admixtures, including retarders, shall not be added to grout, but the temperature of mixing water may be adjusted or ice may be added to increase working time and pot life.

Addition of water to previously mixed grout or remixing of grout shall not be permitted. Water exceeding manufacturer's recommendations shall not be added to the grout to increase flowability.

(a) Trial Batch At least two weeks prior to grouting of connections, a trial batch of grout shall be prepared to demonstrate grout properties and adequacy of equipment and to familiarize job site personnel with grouting procedures.

A batch of grout is the amount of grout sufficient to complete an entire connection or number of connections and is limited to the amount of grout that can be placed within the pot life determined in the trial batch. Partial batches will not be allowed and shall be discarded. For continuous placement using a grout pump, a batch shall be defined as one connection or one bent cap.

The Contractor shall establish grout flowability by measuring efflux (flow) time of with a standard flow cone according to the Corps of Engineers Flow Cone Method, CRD-C 611 and ASTM C 939.

Test flow shall be determined immediately after mixing and at the expected working time to establish pot life. The ambient temperature and mixing water temperature at the time of trial batch mixing shall be the same as that expected at the time of grout placement. The Contractor shall establish that the grout flow time satisfies the limits prescribed in Table 1.

Observation of segregation or large clumps of grout in the final trial batch shall be cause for rejection of the proposed brand of grout. Samples used for testing shall be taken from the middle of the batch.

One set of six (6) grout cubes shall be prepared as specified under Section 4 (c), Grout Testing, to verify the compressive strengths shown in Table 1.

The Contractor shall validate the proposed grout placement technique by using the trial batch grout and grout equipment in a sample grouting operation similar to the proposed connection grouting. Adequacy of mixer, pump, tremie tubes, funnels, buckets, and vent tubes shall be established. The contractor shall demonstrate that the equipment provided for grouting is adequate for mixing the grout and grouting the connection within the pot life of the batch and does not introduce air into the grout or connection. A square mesh with an opening no larger than 0.5 in. shall be used to filter out potential clumps when transferring grout from the mixer to buckets.

(b) Grout Placement

Tremie tubes shall be small enough to enable grout to be placed between the connectors and corrugated ducts. Funnels shall be large enough to keep the tremie tube full at all times. The tremie tube shall be equipped with a pinch valve to stop flow in the event that grouting is interrupted.

All equipment necessary to properly perform grouting operations shall be present before actual grouting operations begin. All grouting operations shall be performed in the presence of the Engineer in accordance with the Precast Bent Cap Placement Plan. Grouting operations shall be performed under the same weather limitations as cast-in-place concrete and as required by the manufacturer. Grout pumping shall be required for connections that cannot be completed using buckets within the pot life established for the grout during the trial batch.

Forms shall be drawn tight against the existing concrete and sealed water tight to avoid grout loss or offsets at the joint. The connection shall be presoaked with water for a minimum of two hours prior to grouting. After presoaking, the connection shall be drained of all water just prior to placement of grout.

Forms for the closure pour between the cap and column shall be adequately vented to allow air to escape during grouting. Vent tubes shall have a minimum ½-in. inner diameter and shall be flush with the top of the bedding layer. Vents shall not be plugged until a steady stream of grout flows out.

Grout shall be deposited such that all voids are completely filled. Grout shall be consolidated at intervals during placement operations for all connection types. Vibrators shall not be used. All connections shall be grouted in a manner that deposits grout from the bedding layer or bottom of the connection upward. Grout shall be placed through connection ducts and/or grout ports located at the top or side of the precast cap. When grout pocket connections are used, grout may also be deposited against the side of the pocket. When insufficient pressure is available to completely fill the duct from the bottom up, the final portion of grout may be placed from the cap top.

The Contractor shall validate the proposed grout placement technique by using the trial batch grout and grout equipment in a simple grouting operation. Adequacy of tremie tubes, funnels, buckets, and vent tubes shall be established.

All equipment necessary to properly perform grouting operations shall be present before actual grouting operations begin. All grouting operations shall be performed in the presence of the Engineer in accordance with the Precast Bent Cap Placement Plan.

Forms shall be drawn tight against the existing concrete to avoid grout loss or offsets at the joint. All previously hardened concrete surfaces that will be in contact with the grout shall be pre-watered to a surface-saturated moist condition when the grout is placed. Drain ports or holes shall be provided to allow residual water from prewatering to drain prior to grouting. Forms for the closure pour between the cap and column shall be adequately vented to allow air to escape during grouting.

Grout shall be deposited such that all voids are completely filled. Grout shall be consolidated at intervals during placement operations for all connection types. All connections shall be grouted in a manner that deposits the grout from the bedding layer or bottom of connection upward. Grout shall be placed through connection ducts and/or grout ports located at the top or side of the precast cap. When insufficient pressure is available to completely fill the duct from the bottom up, the final portion of grout may be placed from the cap top. In such cases, care shall be taken to prevent introducing air into the previously placed grout.

Care shall be taken to prevent introducing air into previously placed grout by monitoring tremie tube placement, grout flow, and rate of pour.

All exposed grout surfaces shall be cured in accordance with manufacturer's recommendations.

(c) Grout Testing. The compressive strength of the grout for “Beam Setting Strength” and “Final Strength” shall be determined using grout cubes prepared and tested in accordance with ASTM C-109. The contractor will prepare a minimum of six (6) cubes per batch. A Commercial Testing Laboratory approved by the Engineer shall test the specimens for “Beam Setting Strength” and “Final Strength.” Grout failing to meet the minimum required compressive strength may be cause for rejection of the connection, grout removal, and re-grouting of the connection by means approved by the Engineer.

(5) Beam Placement.

Bearing seat build-ups, when required, shall be placed in accordance with Item 420.18. The top surface of the precast cap anchorage shall be finished in accordance with Item 420.18 or waterproofed as shown in the plans. Lifting loops shall be burned off 1 in. below the surface of surrounding concrete and patched using anchorage grout, bearing seat buildup grout or other material approved by the Engineer.

Beams shall not be set until the connection grout has reached a compressive strength equal to the “Beam Setting Strength” shown on the plans. Final acceptance of the connection shall be after the grout has reached the “Final Strength” shown in the plans and after the connection has been waterproofed, if required.

XXXX.5. Measurement. Precast connections of the type specified shall be measured by each precast connection.

XXXX.6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” shall be paid for at the unit price bid for each precast connection of the type specified. This price shall be full compensation for furnishing hardware to support the bent cap prior to grouting; for installation of the precast connection anchorage devices; for furnishing and mixing grout; for placing, finishing and curing the grout; waterproofing the connection; and for all labor, tools, equipment and incidentals necessary to complete the work.

Table 1: Grout Performance Specification

Property	Values	
<p>Mechanical Compressive strength (ASTM C-109, 2” cubes)</p>	<p>Age 1 day 3 days 7 days 28 days</p>	<p>Compressive strength (psi) 2500 4000 5000 5,800 and 1.25($f_{c_{cap}} + 1000$)</p>
<p>Compatibility Expansion requirements (ASTM C 827 & ASTM C 1090) Modulus of elasticity (ASTM C-469) Coefficient of thermal expansion (ASTM C-531)</p>	<p>Grade B or C—expansion per ASTM C 1107 3.0-5.0×10⁶ psi 3.0-10.0×10⁻⁶/deg F</p>	
<p>Constructability Flowability (ASTM C-939; CRD-C 611 Flow Cone) Set Time (ASTM C-191) Initial Final</p>	<p>fluid consistency efflux time: 20-30 seconds 3-5 hrs 5-8 hrs</p>	
<p>Durability Freeze Thaw (ASTM C-666) Sulfate Resistance (ASTM C-1012)</p>	<p>300 cycles, RDF 90% expansion at 26 weeks < 0.1%</p>	

Appendix D: Case Studies

The following pages contain brief case studies of prefabricated bridge projects. The first three are actual projects. The third is a hypothetical bridge project that demonstrates the use of this document.

Case Study Number	Title	Pages
1	New Hampshire DOT Mill Street over the Lamprey River Epping, New Hampshire	D-3
2	Texas DOT State Highway 36 over Lake Belton Belton, Texas	D-9
3	Texas DOT Short Span Local Bridges in Texas	D-15
4	Hypothetical Bridge Replacement Project using All Prefabricated Components Details taken from this document	D-21

Case Study 1: Mill Street Bridge over the Lamprey River Epping, New Hampshire

Introduction:

The New Hampshire Department of Transportation has been a lead state in the use of high performance concrete for bridges. To further extend the capabilities of high performance concrete, the state undertook the development of details for an all precast concrete bridge. The intent was to expedite construction using prefabricated components with simple yet durable connections.

A trial demonstration project was selected in the Town of Epping, New Hampshire. The project scope included the removal of two short span bridges that span split channels of the Lamprey River and combine them into one single span bridge that would span both channels. The project site was chosen for the demonstration project because there was a short detour available that would allow for full closure of the roadway.

Project Site:

The bridge is located in the Town of Epping New Hampshire. Epping is typical of many towns in New England that are home to short span bridges that are often over 100 years old. The existing river crossing consisted of two bridges that carried Mill Street over two channels of the Lamprey River. The site also included a historic mill dam that needed to be kept in place in order to minimize changes to the river and to satisfy historic preservation criteria at the site. The new bridge was designed to span both channels and the dam. The resulting span length is 115 feet. The alignment of the road is straight and there is an intersection just beyond the south end of the bridge.

Project Approach:

The New Hampshire DOT was interested in developing a rapid bridge replacement system for use on state highway projects. The Epping site was chosen as a demonstration project for several reasons. There was a reasonable detour around the site; therefore a temporary bridge could be avoided. The site had low traffic volume, therefore if problems arose on this demonstration project, there would not be significant risk associated with not completing the project on schedule.

The intent was to develop a bridge design that could be constructed in less than 2 weeks using all precast concrete elements. In order to simplify the contracting for this trial project, the existing bridge removal and excavation were excluded from the 2 week timeframe. This was done because there was bedrock at the site; which could complicate the site preparation work and lead to contracting problems with unknown foundation conditions. On future accelerated construction projects, the state would include the site preparation within the accelerated construction timeframe.

Design Details:

A decision was made in the early design phase of the project to build a bridge with traditional abutments and walls that used connections that have been used in the past on other structures. By using traditional foundations, the details could easily be transferred to other accelerated construction projects.

The state wanted to use a proven system of connecting precast elements whose behavior is known. The system chosen was taken from the vertical construction industries (parking garages, stadiums, and buildings). The connections are made using grouted reinforcing splice couplers. The use of these connectors allowed for a simplified emulation design procedure for the substructure elements (see Section 1.4.2 for more information on these connectors and emulation design).

Substructure:

The substructure is a simple cantilever abutment and cantilever wingwall system that is supported on reinforced concrete spread footings. The site constraints, hydraulics, and maximum beam span dictated that the abutments be full height abutments with the base located at the edge of the river channel. The design of the connections emulated a typical cast-in-place concrete construction joint at the base of the wall element, except the lap splices were replaced with the grouted reinforcing splice couplers. All other aspects of the design were based on conventional reinforced concrete methods.

One of the most unique aspects of this project was the use of precast concrete footing elements. At the time of the design, the state was not aware of any other bridge projects that had used precast concrete footings; therefore new details had to be developed. Conventional footings are designed using one-way slab action; which means that the transverse connection between footing elements need not transmit moment. Instead, a simple grouted shear connection was used that would transfer shear between the footing elements in case there was minor differential settlement across the length of the wall section.

Proper seating of the footings over the substrate was a concern. In order to provide uniform bearing, a grouted void was used. The footings were also cast with leveling bolts that allowed for adjustment of grade in the field. The intent was to support the footings on the leveling bolts until the grout could be placed under the footings. Grout placement was done through pipe blockouts in the footing. A flowable grout was placed from the center and allowed to flow to the edges of the footings where it was contained with a simple dam system. The strength and curing of the grout did not hinder the continuation of the construction because the bearing pressures on the grout are very low during construction. These pressures are even very low after the bridge is in service. Typical bearing pressures on spread footings are in the range of 50 pounds per square inch; therefore a high strength grout is not needed under the footings.

The wall stems were placed in a shallow trough cast in the top of the footing to facilitate grouting and to improve shear resistance in the connection. This trough could have been eliminated by checking the shear resistance of the connection using the shear friction provisions in AASHTO; however the state preferred to use the trough to facilitate the grouting and to provide extra shear resistance.

The vertical joints between wall panels were detailed with simple grouted shear keys that are similar to a typical contraction joint in New Hampshire standards for reinforced concrete cantilever walls. The original contract plans had a layout of both horizontal and vertical joints in the wall stems. The layout was shown as schematic, and the contractor was allowed to modify the joint layout within certain parameters that were defined on the contract documents. The contractor

chose to use only one horizontal joint at the wall to footing interface and run the wall elements full height. This approach is recommended because it limits the wall construction to only one moment connection over the entire height. Additional horizontal joints would require the use of more grouted reinforcing splice couplers, which would lead to higher costs.

All other connections including the abutment cheekwalls were made using the grouted reinforcing splice couplers or grouted shear keys.

Superstructure:

The New Hampshire DOT has been using precast prestressed adjacent box beam bridges for many years. These beams allow for a simple superstructure that can be built very quickly because there is no need for a reinforced concrete deck. Typical details in the northeast historically have not included a concrete over-pour on these beams. The system is overlaid with bituminous pavement after the installation of a membrane waterproofing system.

The connection between beams is made using a grouted shear key combined with an unbonded lateral post-tensioning tie. The lateral ties used in the northeast for the last ten years are monostrand post tensioning system that is commonly used in post tensioned parking garage structures. Each strand is delivered to the job site in a grease filled sheath that is run through a transverse void in the beams. The ends are anchored to an epoxy coated anchor plate and sealed with a grease filled cap. This unbonded system does not use grouted ducts; therefore the installation can be completed very quickly. A typical installation of all lateral ties in a span is less than 1 hour.

To expedite construction of the railings, the state detailed a reinforced concrete curb that was installed at the precast plant. This curb included anchor bolts for a standard New Hampshire aluminum rail system that was installed after erection of the beams.

Construction:

The contractor was given two weeks to complete the bridge installation after the existing bridges were removed and the excavation was completed. The existence of bedrock required that the bottom be over excavated so that the precast footings would fit within the excavation. A thin layer of low-density concrete fill was placed to facilitate the placement of the footings on the uneven bedrock (a layer of structural granular fill could have been used also). The timeline for construction is shown in Figure CS1-1:

Construction Item	Running Time							
	Day One	Day Two	Day Three	Day Four	Day Five	Day Six	Day Seven	Day Eight
Footing Installation	■							
Abutment stems and wall stems		■						
Backfilling of Abutment and walls			■					
Superstructure Installation					■			
Waterproofing, Paving and approaches								■

Figure CS1-1: Construction Timeline

The contractor was given options for backfilling the walls and abutments that included the use of flowable fill or standard compacted gravel fill. Flowable fill is a mixture of sand, water, and a small amount of cement that has the consistency of flowable concrete. The contractor chose the compacted gravel option due to difficulties with containing the flowable fill during placement. The area for backfill was relatively small and was accomplished with small vibratory compaction equipment.

Lessoned Learned:

The construction of the Mill Street Bridge was a great success. The construction time of eight days was faster than the specified 14 day construction window. Construction costs for the foundations were higher than conventional construction; however when factoring in the elimination of a temporary bridge crossing, the overall cost of the project was only 8% higher than conventional construction.

The following items contain concepts that should be followed on future projects using these methods and lessons learned on the Mill Street Bridge:

1. The tolerances on the placement of the grouted reinforcing splice couplers are critical, but not unattainable. The couplers have some tolerance and it is possible to oversize the couplers by two bar sizes to give even larger tolerances. For instance, a number 11 coupler can be used with a number 9 bar. The use of narrower wall elements will also help to alleviate fit-up problems with the couplers. This requires fewer couplers per piece, which which less chance for dimensional problems.
2. Specifications should indicate that the tolerable distance to each coupler be measured from a common working point as opposed to center-to-center

- spacing. This way there will be no build up of placement tolerances in the form.
3. Simple geometric layouts of abutments and walls are preferred over complex geometry. The Mill Street Bridge was designed with walls that were either 0 degrees or 90 degrees when compared to the abutment wall face. It is possible to build a precast substructure with complex geometry; however more care may need to be taken during fabrication. It may be desirable to have the structure dry fit in the shop prior to shipment to ensure the geometries are correct.
 4. The shape of pieces should be kept simple, so that basic flat slab precasting can be used.
 5. Allowing the contractor to adjust the size and number of pieces is beneficial so that the contractor can bid the project based on the available equipment.
 6. Maximum element dimensions and weights need to be specified so that shipping can be made without special permits.
 7. Grouting of vertical joints in wall elements was difficult. The contractor tried to use backer rods; however the rods pushed out during grouting. More substantial forms are required for the vertical joints. Designer should add notes to the plans warning the contractor of the pressure head of the grout.
 8. The joint widths for the vertical wall elements were detailed as 1" wide, which made grout installation difficult. On future projects, these joints should be detailed as 1 ½" wide.
 9. Some states do not use shear keys between wall sections for cantilever walls. On future projects, the state will use non-keyed joints combined with expanding foam joint filler that can be injected into the gap between the wall elements after erection.
 10. The design of the footing leveling bolts should be based on the full weight of the footing element. It is inevitable that the footing will rest on just two of the bolts, which makes it difficult to adjust. One method of overcoming this is to adjust the elevation by turning the leveling bolts prior to release of the footing element from the crane. Greasing the bolts also improves this operation.
 11. The grouting of the reinforcing bar couplers went very fast (approximately 150 sleeves per hour). Cure time prior to backfilling is approximately 12 to 16 hours. It is recommended that the contractor's workers be trained by the manufacturer prior to installation.

Case Study 2: State Highway 36 over Lake Belton Belton, Texas

Introduction:

The Texas Department of Transportation undertook a project to replace an aging bridge that carries State Route 36 over Lake Belton in Belton, Texas. The existing bridge is multi-span steel stinger bridge that is approximately 3700 feet long and is located approximately 35 feet above normal water levels. Figure CS2-1 shows the existing bridge.



Figure CS2-1 Existing Bridge

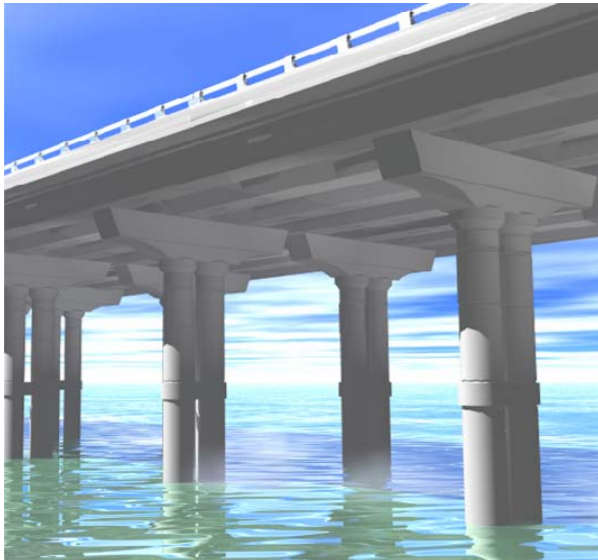


Figure CS2-2 Proposed Bridge

The new bridge is a 32 span prestressed concrete U-Beam bridge that is supported on twin column reinforced concrete pier bents with a hammerhead bent cap. The proposed bridge is a twin span with two side by side bridges that were nearly identical. There are 62 pier bents on the project. The superstructure is a standard precast prestressed U beam that is used in Texas. The beams support a standard 8" thick reinforced concrete deck. Figure CS2-2 is a computer rendering of the proposed structure.

Project Approach:

The existing bridge had a low strength rating; therefore the delivery of materials via the existing bridge not possible. In order to facilitate construction, prefabricated pier bent caps were proposed. The bent caps offer the following advantages when compared to conventional cast-in-place construction.

1. The use of a repetitive shape was ideal for prefabrication, which saved time. By using prefabricated elements, the state saved the time for setting the formwork, placing concrete and curing. Installation proceeded at a rate of two caps per week.
2. There is a cost savings by minimizing the amount of labor on site and by reducing the overall project time.
3. The quality of the caps was far superior to conventional cast-in-place concrete. High strength high quality concrete was specified that will be more durable than

conventional construction. Quality control in a precast plant typically exceeds the quality that can be attained in the field.

4. Safety was improved by reducing the amount of man-hours of labor and inspection personnel that need to be working on a high platform.
5. The repetition of the pier caps made it cost effective to build custom forms for the bent cap shape. The cost of the forms was spread out among the 62 cap pieces that needed to be cast. Since a custom form needed to be made, designers chose to incorporate architectural details into the cap shape.

Project Site:

The bridge is located near Belton Texas. The bridge is very high above the normal water line because the water surface elevation on Lake Belton can fluctuate as much as 40 feet. There is barge access to most of the project site. The low load carrying capacity of the existing bridge (13 tons) greatly limited the delivery of materials for the new bridge. Concrete delivery had to be made via barges. Figure CS2-3 is a satellite photo of the project site.



Figure CS2-3 Project Site

Project Approach:

The Texas Department of Transportation had completed several precast concrete bent cap project prior to this project. They had also complete several large research project that investigated the connection of the precast bent cap to concrete columns. The Connection details that were studied included grouted voids and grouted post tensioning duct with mild reinforcement dowels. Previous projects with grouted ducts had the ducts projecting to the top of the pier cap. The Lake Belton project did not have this detail. Instead, all but two of the ducts were capped in the core of the pier cap; thereby eliminating issues with exposure of the ducts to the environment and also eliminating interference issues between the ducts and the densely spaced reinforcement in the top of the pier cap. Grouting was done via standard grout ports and vents. The connection is enhanced by the addition of spiral reinforcement to help enhance the strength and service performance of the connection.

Design Details:

Figure CS2-4 shows an elevation view of a typical bent. The lower portion of the bent consists of two 5 foot diameter drilled shafts. There is a tie beam located approximately 12 to 15 feet above normal water levels. The tie beam was used to make up for tolerances in the drilled shaft locations. Constant height columns with reveals and column capitals were then cast above the tie beam that were aesthetically pleasing and allowed for repetitive formwork.

The bent caps were 39 ft long and 5.5 ft wide. The bottom soffit of the cantilevers has a 17 foot radius. The depth of the cantilevers varies from 3 feet to 5.5 feet. The cross slope of the roadway was accomplished by varying height beam pedestals on top of the bent caps.

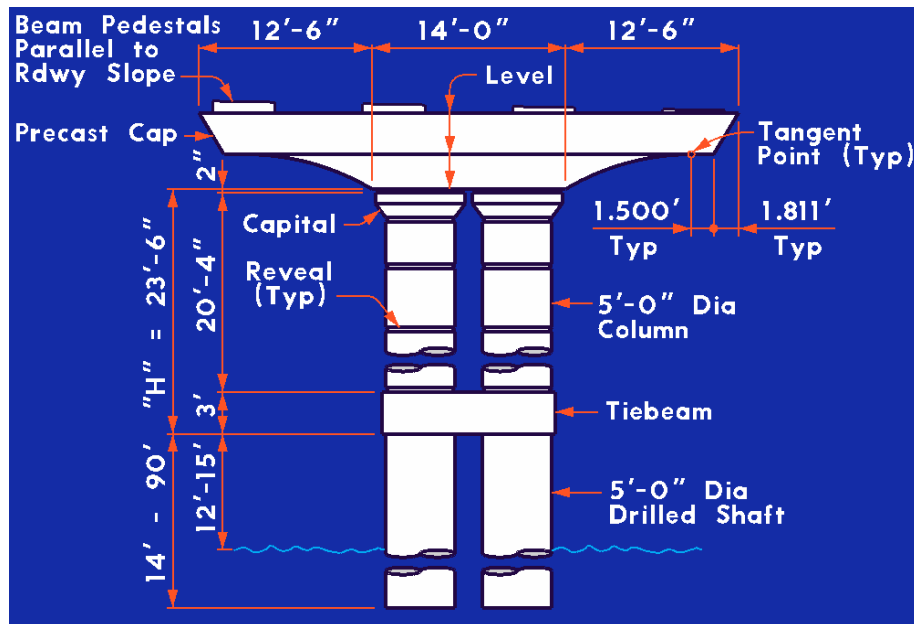


Figure CS2-4 Proposed Pier Bent

Figure CS2-5 shows the arrangement of the post tensioning ducts within the bent cap. There were a total of 14 ducts in the connection. Most were used to anchor #11 reinforcing bars that projected from the cast-in-place columns. Several were used for temporary threadbar connections. In later stages of construction the use of the temporary threadbar connections was waived because of the stability of the bent cap on the columns.

Grout tubes were used to deliver the grout to both the ducts and the interface gap between the columns and the bent cap. Elevations and the gap between the cap and the column were set by the installation of leveling shim packs (4 sets per column) that were placed prior to setting the cap. A form was used to contain the grout at the top of the column. After grouting (Figure CS2-6), the form was removed and replaced with dry pack grout (Figure CS2-7). Mock-ups of the grouting area were made and tested prior to production in order to ensure that the grout was filling all the voids.

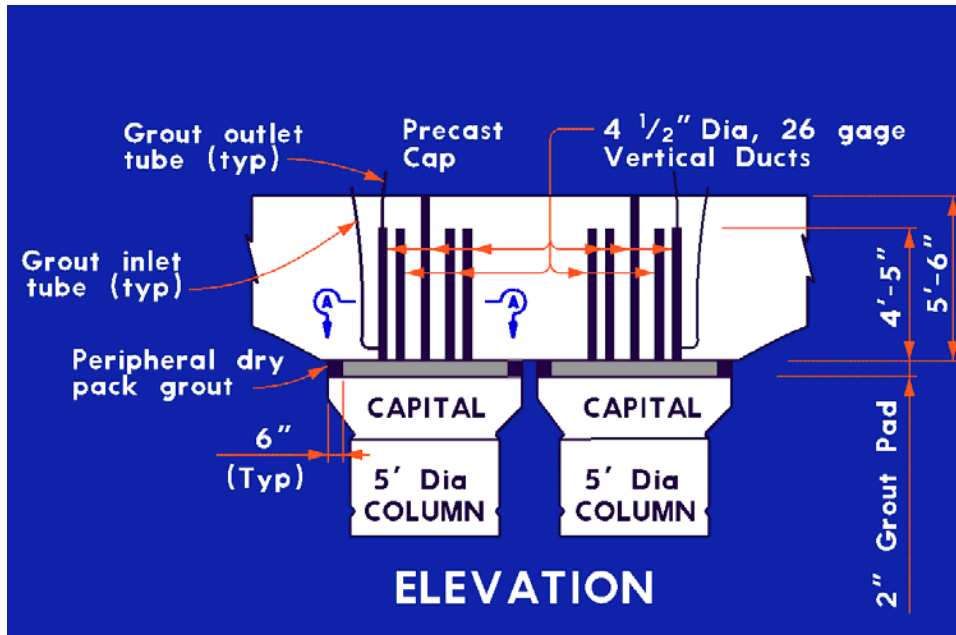


Figure CS2-5 Grouted Reinforcement PT Duct Layout

The bent caps were fabricated off site at a precast fabrication plant. Trucking the elements required the use of non-standard trailers due to the high weight. Once on site, the caps were transferred to a work barge with a crane. Once in position, the crane lowered the bent cap on top of the cast-in-place concrete columns.



Figure CS2-6 Grouted Placement



Figure CS2-7 Dry Pack Grouted Placement

Lessoned Learned:

The Lake Belton project was very successful. The construction of the bent cap was much faster than conventional cast-in-place construction. The caps were installed at a rate of 2 per week. Construction costs were slightly higher than cast-in-place construction; however the high quality concrete and improvement of worker safety made the cost increase acceptable. The state anticipates that costs will decrease as contractors become familiar with the process.

The following items contain concepts should be followed on future projects using these methods and lessons learned on the Mill Street Bridge:

1. Since a non-conventional grouted post tensioning tube connection was used, research was critical in order to determine the behavior of the connection. The research proved that the connection was viable and low cost. This connection is not recommended for high seismic zones; however there is on-going research in California to enhance this connection type for use in high seismic areas.
2. The tolerances on the vertical reinforcing projecting from the cast-in-place columns was set at $\frac{1}{2}$ " This was found to be more than adequate to make the connection.
3. The use of mock-ups for grouting procedures was a benefit for both the contractor and the inspection personnel.
4. The quality of the concrete used in the precast bent caps far exceeded the quality of normal cast-in-place concrete. This was due to the use of better concrete and better curing methods in the fabrication plans.
5. Through the use of prefabrication on several projects, the state has concluded that prefabrication has several advantages over conventional construction:
 - a. Reduced traffic disruption
 - b. Increased work zone safety
 - c. Reduction in environmental impacts
 - d. Improved constructability
 - e. Increased quality
 - f. Lower life cycle costs
6. The state plans on developing new prefabrication concepts for future projects.

Case Study 3: Short-span Local Bridges in Texas

Introduction:

The Texas Department of Transportation has been developing standard designs for short-span bridges in Texas. The state has numerous county bridges that are in need of replacement. Prefabrication of replacement bridges is a large part of this initiative.

Several different types of prefabricated bridge elements have been developed for use on this program. The intent is to minimize on-site casting and curing of concrete. A typical off-system bridge construction contract duration in Texas is approximately 6 months. The goal is to reduce this duration to one month or less.

Program Approach:

Local off-system bridges present a different set of constraints when compared to high volume highway bridges. The fact that a bridge has low traffic volume does not mean that prefabrication is not viable. Several factors can play into the need for prefabrication on local bridges:

1. Detour lengths in rural area can be significant. The cost for detours or temporary structures can be significant. The detours are also disruptive to local residents and businesses.
2. Remote bridge location can make the delivery of cast-in-place concrete difficult. The ability to precast concrete elements off site can lead to significant savings.
3. By using prefabricated butted beam elements, a bridge can be built without deck forming and casting. The beams can be overlaid with asphalt pavement, thereby reducing construction time and cost.
4. Prefabricated steel railings can be used on low volume roads, which eliminates the need for cast concrete parapets.

Several different prefabricated bridge elements have been developed for local bridges in Texas. The following are examples of these elements:

Precast concrete pier bent pile caps with steel piles:

Pile bents made with steel piles and concrete caps can be a very cost effective substructure for multi-span bridges. The piles can be driven quickly without significant disruption to the river. Upon completion of the driving operation, the piles are cut off to the proper elevation. The bent caps are made using precast concrete elements with embedded steel plates on the underside of the cap. The connection between the piles and the cap is made using overhead fillet welds. Figure CS3-1 shows a typical pile to cap connection.

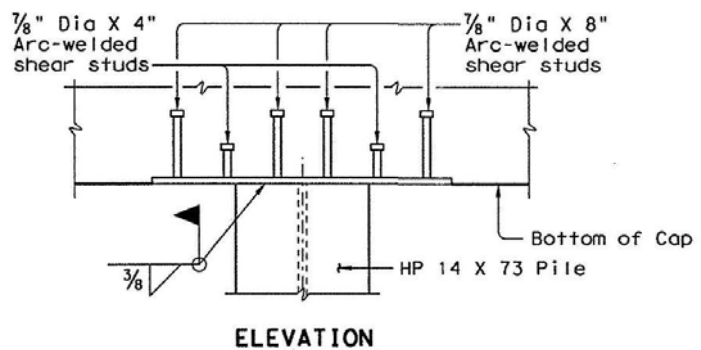


Figure CS3-1 Steel Pile to Cap Connection

The detailing of the bent cap is rather simple; therefore it can be cast near site or in a local construction yard. The caps can be cast on the ground using standard concrete forms. Figure CS3-2 shows a typical cap after fabrication. Figure CS3-3 shows the welding procedure.



Figure CS3-2 Pile Bent Cap Fabrication



Figure CS3-3 Pile to Cap Connection

Precast abutment caps are similar to the pier bents. Abutment bent caps can be constructed with backwalls and integral “flying” wingwalls. Figure CS3-4 shows a typical abutment bent cap being installed.



Figure CS3-4 Abutment Bent Installation

Winged Slab and Double Tee Beams:

A family of winged slab and double tee beams has been developed for use in adjacent beam superstructures. These beams are use instead of traditional butted slab and box beam bridges due to leakage problems and joint failures. Figure CS3-5 shows a typical cross section of a winged slab bridge. Figure CS3-6 shows a typical cross section of a butted double tee bridge.

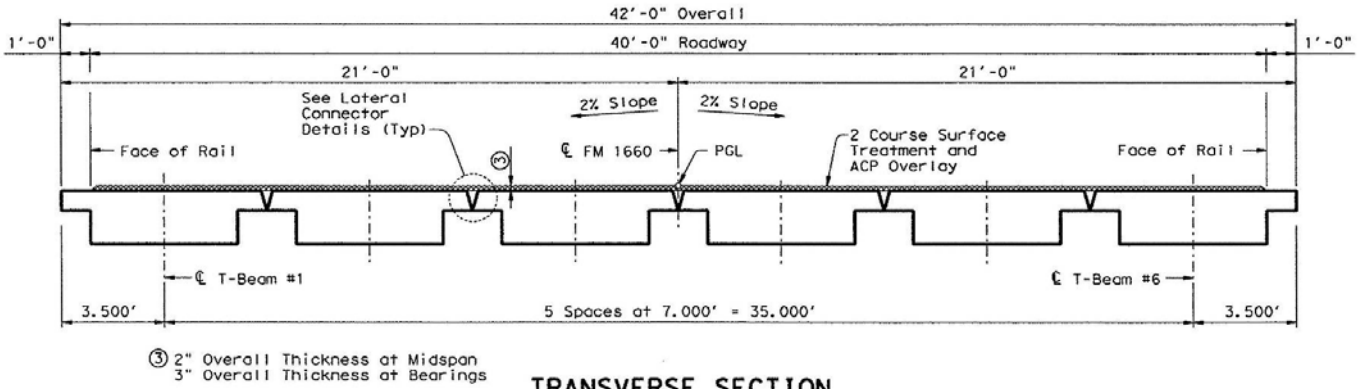


Figure CS3-5 Winged Slab Bridge Beams

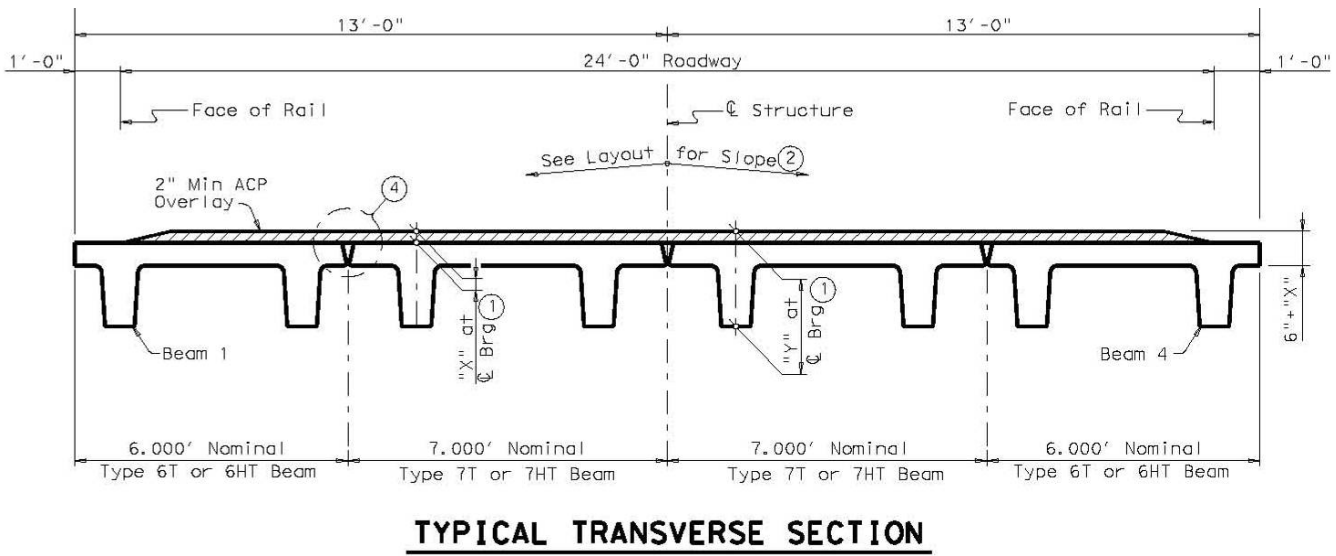
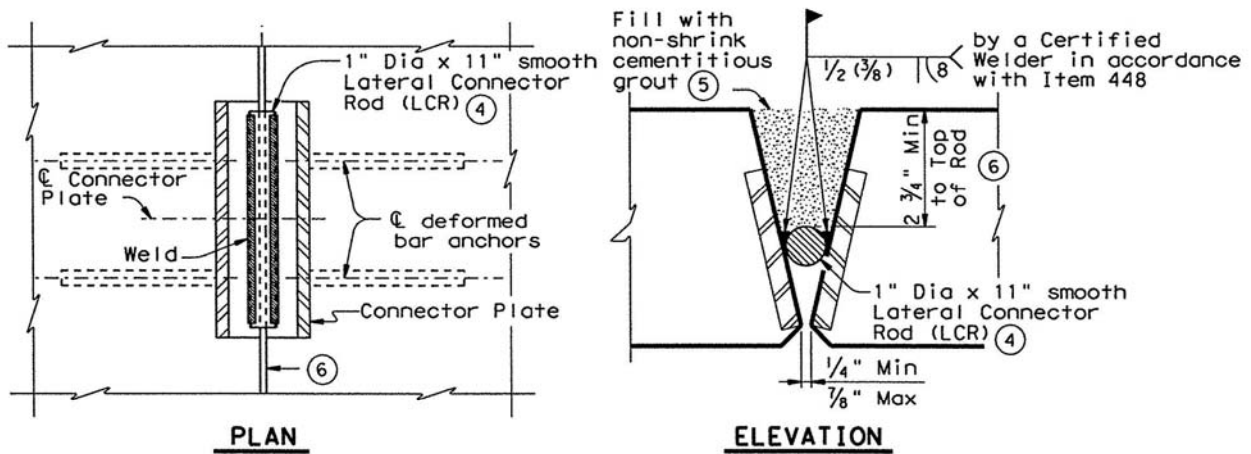


Figure CS3-6 Butted Double Tee Bridge Beams

The beams are butted together and jointed using a welded rod and non-shrink grout. Upon completion of the grouting, the slabs are given a 2 course surface treatment and then covered with an asphalt overlay wearing surface. The bridge railings are then bolted directly to the winged slab. Figure CS3-7 show the details of the welded plate connection. This connection was studied in a Texas DOT Research Project Number 1856-2 to ensure that it would provide a durable connection. The research showed that the welded plate spaced at 5 feet on center combined with a grouted shear connection between the welded plates adequately provided load transfer to adjacent beams.



LATERAL CONNECTOR DETAILS

- ④ Seat and center 1" diameter smooth Lateral Connector Rod (LCR) in the bottom of the flange connection "Vee" prior to welding.
- ⑤ It is critical to deck serviceability that the Contractor ensure complete filling and consolidation of grout in all flange connection voids.
- ⑥ Use forming material between lateral connectors. Maintain a uniform grout depth along length of beams.

Figure CS3-7 Lateral Welded Plate Beam Connection Details

Conventional Butted Slab Beams:

Texas also uses butted slab beam bridges. These beams are connected by means of a grouted shear key combined with lateral post tensioning. The lateral post tensioning consists of a single 1/2" diameter prestressing strand in a grease filled sheath. The strands are spaced a 5 foot intervals and stressed to 31,000 pounds after the grouted keys have cured. Figure CS3-8 shows a typical cross section of a butted slab bridge. Figure CS3-9 shows typical post-tensioning details.

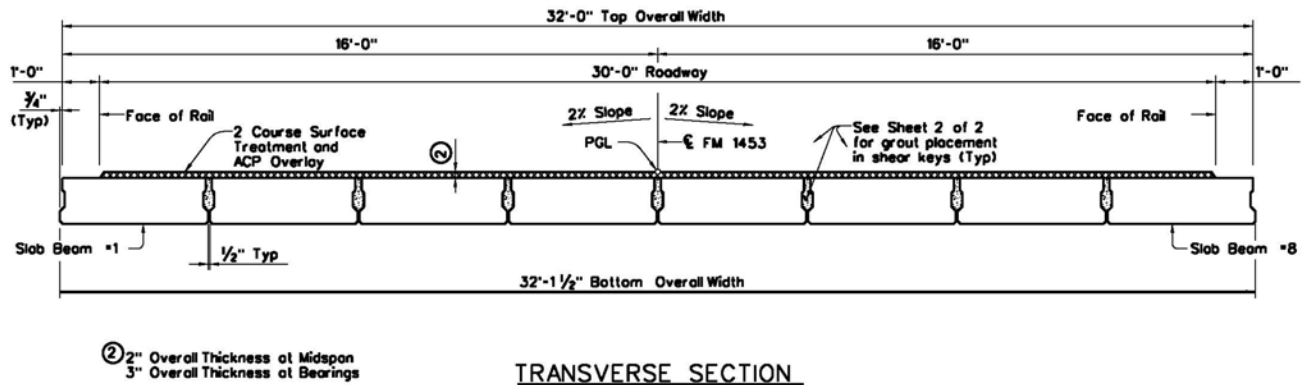
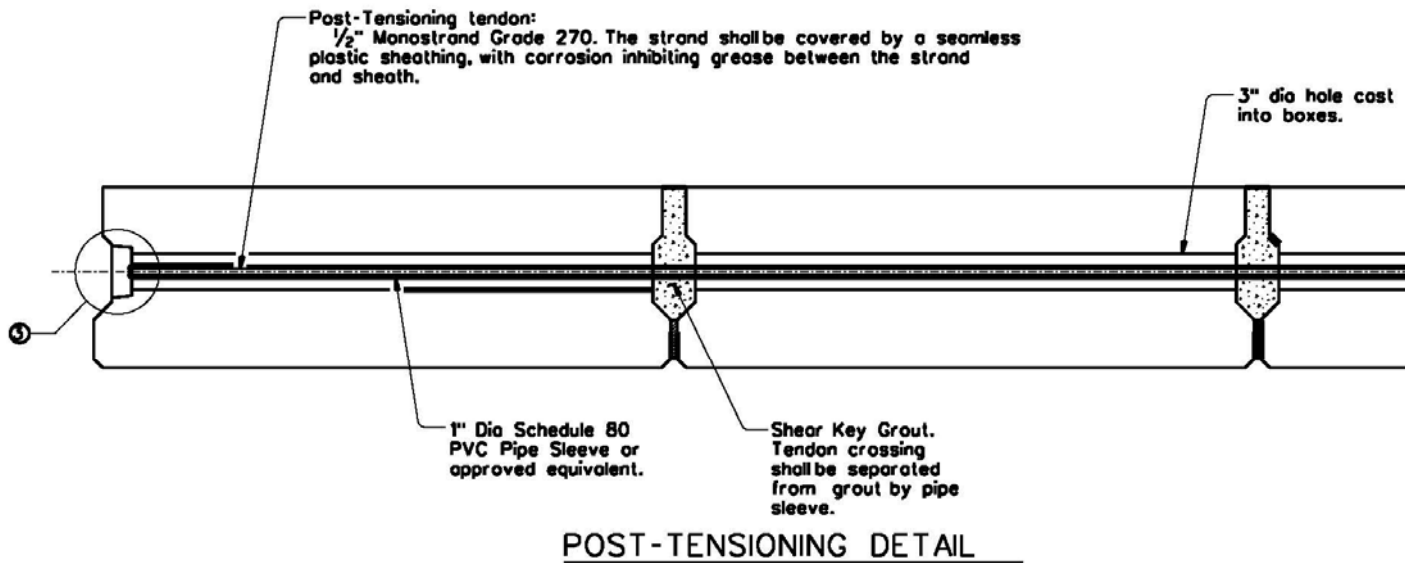


Figure CS3-8 Butted Slab Beam Bridge Beams



- ① Post Tensioned tendon pocket detail shall be supplied by Contractor and approved by the Engineer. The anchorage device shall be configured such that no portion of the tendon inside the point of anchorage is left uncovered and exposed. The end of the tendon shall be sealed by a cap that will provide a watertight seal and corrosion protection. If an anchorage recess is used, it shall be filled with grout color blended to match outside of box. Provide a smooth surface finish.

Figure CS3-9 Lateral Post-Tensioning Details

Flowable Fill Backfill:

Flowable fill is a mixture of sand water and fly ash. The fly ash content is kept low, so that the resulting material can be excavated in the future with relative ease. The intent of flowable fill is to provide a stable backfill material that does not need compaction. It can be driven on hours after placement. It has a final compressive strength of approximately 150 psi.



Figure CS3-10 Placement of Flowable Fill

Lessoned Learned:

1. It is possible to build prefabricated bridges very quickly.
2. Precast pile caps welded to steel piles is a viable option for accelerated bridge construction in Texas.
3. Transverse connections for butted beam systems have been researched and a welded plate connector was developed. This connection can be used on various types of butted beam bridges.
4. Flowable fill can be used to place backfill soils rapidly.

Case Study 4: Hypothetical Bridge Replacement Project Using All Prefabricated Components Based on Details in this Document

Introduction:

This case study is for a hypothetical bridge replacement project. The intent of this study is to demonstrate the use of this manual and how details from several different sources can be combined into an actual bridge project. The bridge chosen is a typical expressway overpass. This example is for the development of a preliminary structure type study using prefabricated components.

Project Site:

The bridge is located in a northern climate. It is exposed to snow and de-icing salts. The bridge is located in a commercial/retail area. The bridge carries the local road over an expressway. There are four lanes of traffic on the bridge (2 in each direction) and four lanes beneath the bridge (2 in each direction). There are retail establishments near the bridge that would be affected by any type of construction. Traffic volume is high on both roadways. There is a detour available for the local road; however it is approximately 2 miles long.

The structure is a three span bridge (simple spans). The structure type is a composite deck supported by steel beams. The abutments are full height cantilever type and the piers are conventional concrete multi-column bents. A sketch of the existing bridge is shown in Figure CS4-1 on the following page.

The bridge structure has deteriorated to the point where replacement is the only option. The bridge has the following deficiencies:

- Minimal under-clearance (14'-5")
- The piers and abutment are deteriorated due to close proximity to roadway (salt spray attack)
- The deck is severely deteriorated
- There are leaking deck joints at each pier and abutment
- The beams have peeling lead paint
- The beam ends are deteriorated due to deck joint leakage

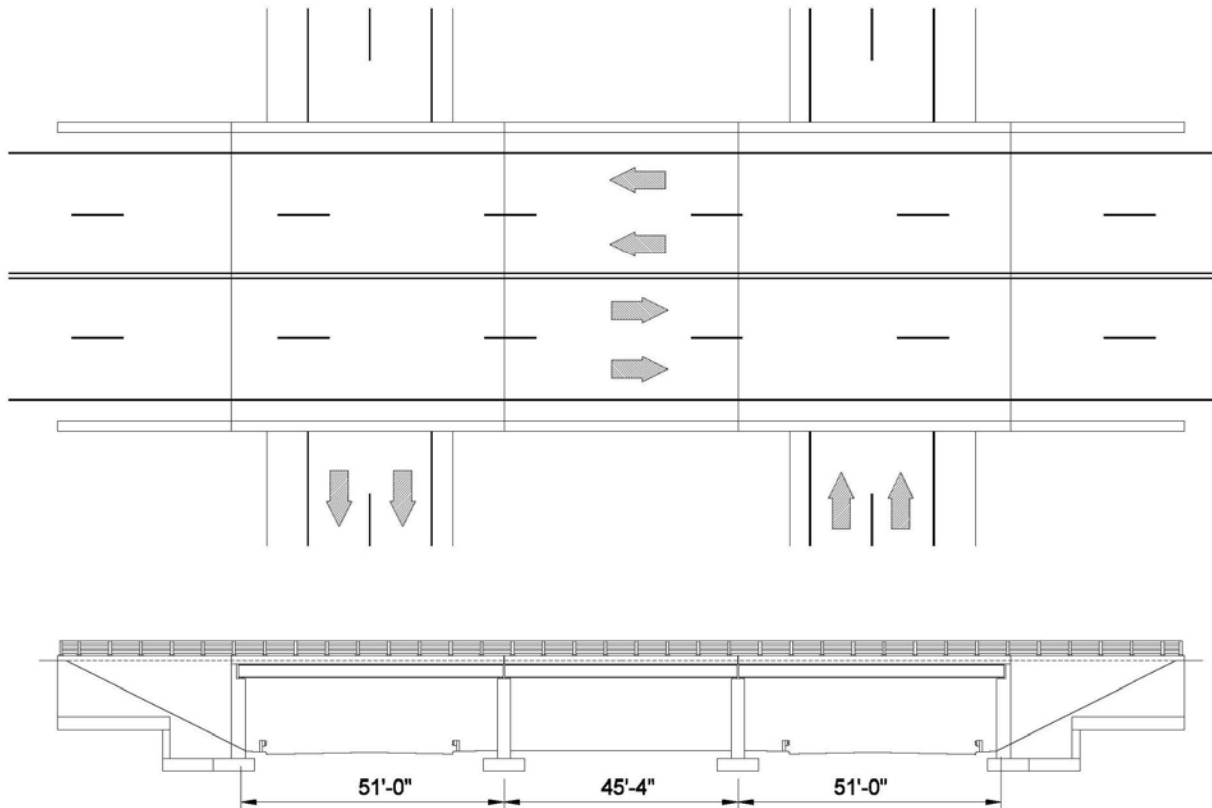


Figure CS4-1: Existing Bridge

Project Approach:

The state DOT undertook a public involvement process and presented several options to the local businesses. The primary concern of the businesses was the potential loss of income from the construction project.

The designers investigated and presented two options.

Option 1: Conventional construction using multiple stages

Under this option, both roadways would remain open to traffic for the entire duration of the project; however one lane of traffic would need to be taken out of service in each direction in order to make room for the construction activities. The bridge would need to be built in two stages, and it is estimated that construction would take approximately 18 months (with a 3 month winter shutdown).

Advantages:

The roadways will remain open to traffic at all times

Disadvantages:

Construction will take almost 2 years

Traffic will be congested during construction.

Option 2: Use prefabrication, close the road and accelerate construction

Under this option, the traffic on the bridge will be detoured around the site. The entire bridge can then be built without traffic management on site. Virtually all components will be prefabricated off site prior to roadway closure. The goal would be to replace the bridge in 30 days.

Advantages:

- The overall project can be greatly reduced
- Quality can be improved by using plant produced concrete

Disadvantages:

- The road will be closed for 30 days, which will impact the businesses.

During the public hearing, the business owners expressed that they would prefer to live with a 30 day full closure as opposed to a protracted partial closure. This is not unusual. Businesses often see a marked drop-off in customers if they are near a construction site. Two years of a 20% reduction in business is much worse than 30 days of a more significant reduction. Based on this, the design team opted for the second option with the full closure and a detour.

Design Details:

Following the public involvement process, a formal type study was completed. The use of prefabricated elements does not necessarily correspond to a significant change in the structure type. It is possible to construct typical bridge structures with prefabricated elements. In this case, the designer opted for the following design after the type study was completed:

- Structure Layout: 2 span continuous (no deck joint at the pier)
 - Place the pier in the center of the median between the existing piers
- Raise the grade of the bridge 3 feet
 - Improve under-clearance and allow for deeper beams (longer spans)
- Integral abutment design (no deck joints at the abutments)
 - Place the abutment on top of the slope to minimize the height of the stems
 - Support the abutments on steel H-Piles
- Use a typical multi-column concrete pier bent
 - Supported on spread footings
- Use a continuous steel plate girder with a composite concrete deck
 - Unpainted weathering steel
- Use a bituminous concrete wearing surface
 - Protect the deck with a waterproofing membrane
- Use open galvanized steel railings (aesthetics)
 - Placed on top of a small curb section

The layout of the bridge is shown in Figure CS4-2. The new bridge offers significant improvements over the existing bridge. The under clearance has been increased to 16'-5". All deck joints have been eliminated. By pushing the substructure elements away from the roadway, there is an improvement in roadside safety and the potential for salt spray attack is virtually eliminated.

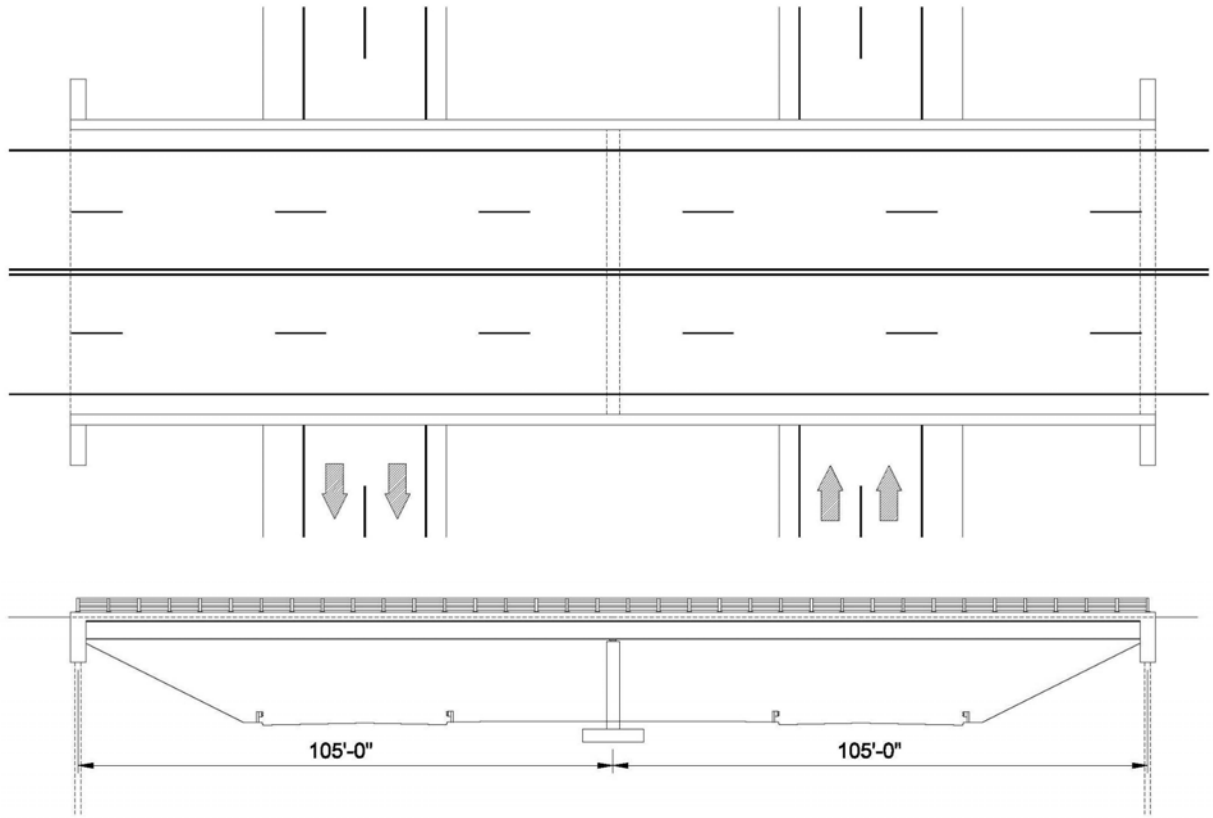


Figure CS4-2: Proposed Bridge

Use of this Manual:

The design of this bridge is no different than a typical highway overpass. The goal is to use connections that emulate traditional construction joints. The designers reviewed chapter one of this manual to become familiar with the options for connection types and the materials and tolerances that would be required. Following this, the designers searched through the applicable sections in chapters 2,3 and 4 for details that could be used on the structure type chosen.

Connection Types:

The designers chose the following connection types for this bridge:

Grouted Reinforcing Splice Couplers

These couplers are very versatile because they simply replace a traditional reinforcing lap splice at a construction joint. They can be used for the footing to column connection, and the column to cap connection as well as other connections throughout the bridge. The design of the bridge is also simplified since traditional reinforced concrete design methods can be used.

Grouted Voids

Some of the potential connections on the bridge do not require large force resistance. In this case a simple grouted void with a pin will suffice. An example of this is the connection of the approach slab to the abutment shelf.

Cast-in-place Concrete Closure Pours

There are a few connections that may require a concrete closure pour. This connection is normally limited to connections that require significant tolerance adjustment. This connection is anticipated for the connection of the superstructure to the substructure at the top of the integral abutment.

Schematic Pier Design:

The proposed pier design is a traditional multi-column concrete bent. In order to accelerate construction, all precast elements will be used (including the footings). The designer located details for this structure in chapter 4 of the manual (foundations) and chapter 3 (substructures).

Section 4.1.1 includes information on the connection of precast concrete footings to the subgrade soils. While this may not seem like a connection, the interface between the footing and the soil must transfer significant forces. The connection chosen was developed by the New Hampshire DOT (detail 4.1.1 A)

Section 3.1.4.1 includes information on the connection of precast concrete columns to precast concrete footings. The selected connection is a conceptual detail developed by the PCI Northeast Bridge Technical Committee. The detail is very similar to an abutment detail that was successfully built in Epping, New Hampshire. This connection is also used extensively in the building industry. The connection is made using grouted reinforcing splice couplers.

Section 3.1.1.2 includes information on the connection of precast concrete columns to precast concrete pier caps. The connection chosen has also been used by the states of Florida and Georgia (detail 3.1.1.2 A). The connection is made using grouted reinforcing splice couplers.

A double two column pier bent was chosen in order to simplify the connection of the pier cap to the columns and to reduce the shipping weight of the pier cap elements. Figure CS4-3 depicts a schematic exploded view rendering of the proposed pier.

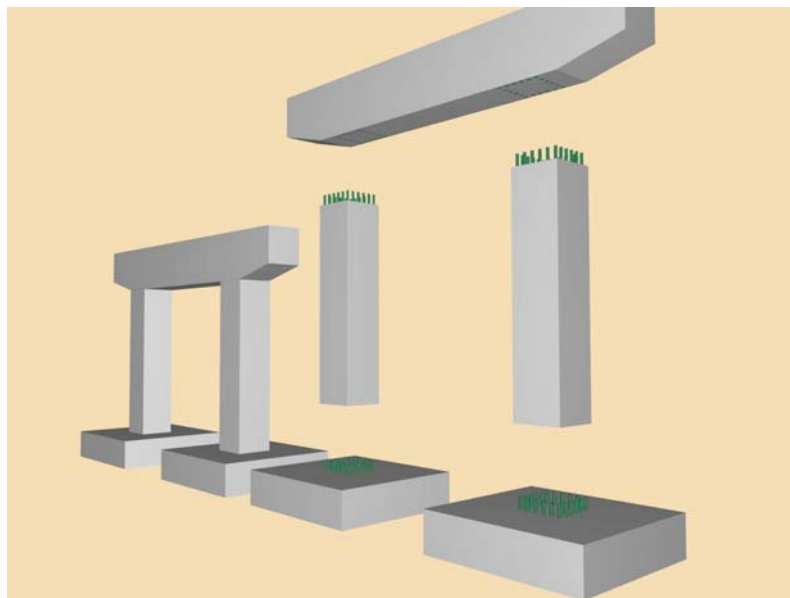


Figure CS4-3: Proposed Pier

Schematic Abutment Design:

The proposed abutment is an integral abutment supported on steel H-piles. The majority of this structure will be precast. The connection to the superstructure will be a cast-in-place closure pour. The designer located details for this structure in chapter 3 of the manual (substructures).

Section 3.2.3.1 includes information on the connection of abutment caps and steel piles. The connection chosen was developed by the Maine DOT. Similar connections have also been used in other states (detail 3.2.3.1 B).

Splices in the abutment wall are required in order to keep the shipping weights reasonable. Flying wingwalls were also chosen for this design. A flying wingwall is a short wingwall that is cantilevered off the rear or side of the integral abutment. Sections 3.2.3.3 and 3.2.4.1 cover these connections. It involves match casting the abutment components and wingwall extensions. These details were also developed by Maine DOT (details 3.2.3.3. A and 3.2.4.1.A).

The connection of the precast approach slab to the integral abutment is a simple grouted void with a reinforcing bar pin. Section 3.2.4.2 includes information on approach slab connections. The detail chosen was also developed by New Hampshire DOT based on similar work on three Maine DOT projects (detail 3.2.4.2 A).

Figure CS4-4 depicts a schematic exploded view rendering of the proposed abutment.

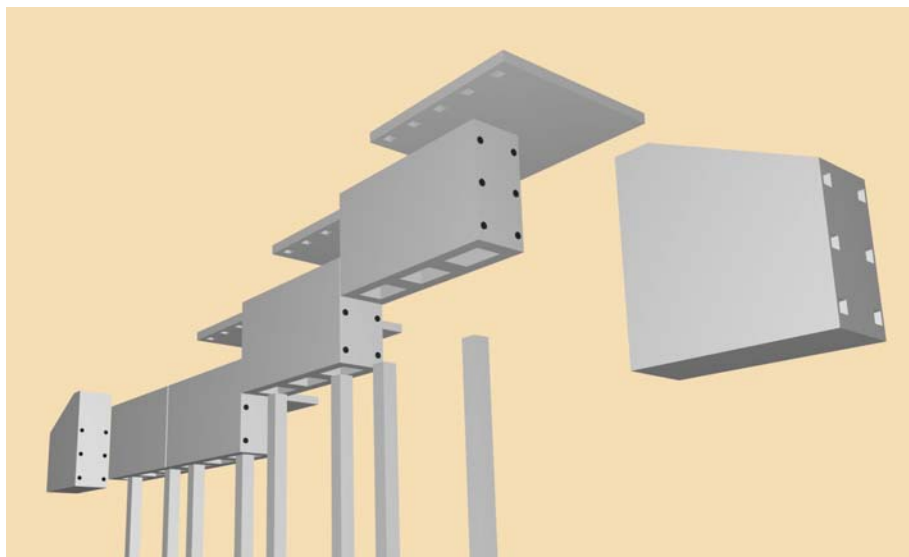


Figure CS4-4: Proposed Integral Abutment

The connection of the integral abutment to the superstructure is one of the most complicated connections on the bridge. There is a need for significant tolerance adjustment at this connection (both vertically and horizontally). For this reason, a cast-in-place concrete closure pour is proposed. The Bridge Technical Committee of the Precast Prestressed Concrete Institute (PCI) Northeast Region has developed a detail for this connection. A precast concrete backwall is connected to the abutment stems using grouted reinforcing splice couplers. This backwall serves several purposes. First

is acts as a form for the closure pour. It also supports the approach slab. It also provides the negative moment resistance for the superstructure connection. Section 2.5.2 covers this connection. The detail chosen is detail number 2.5.2 A. Figure CS4-5 depicts a schematic section of the connection.

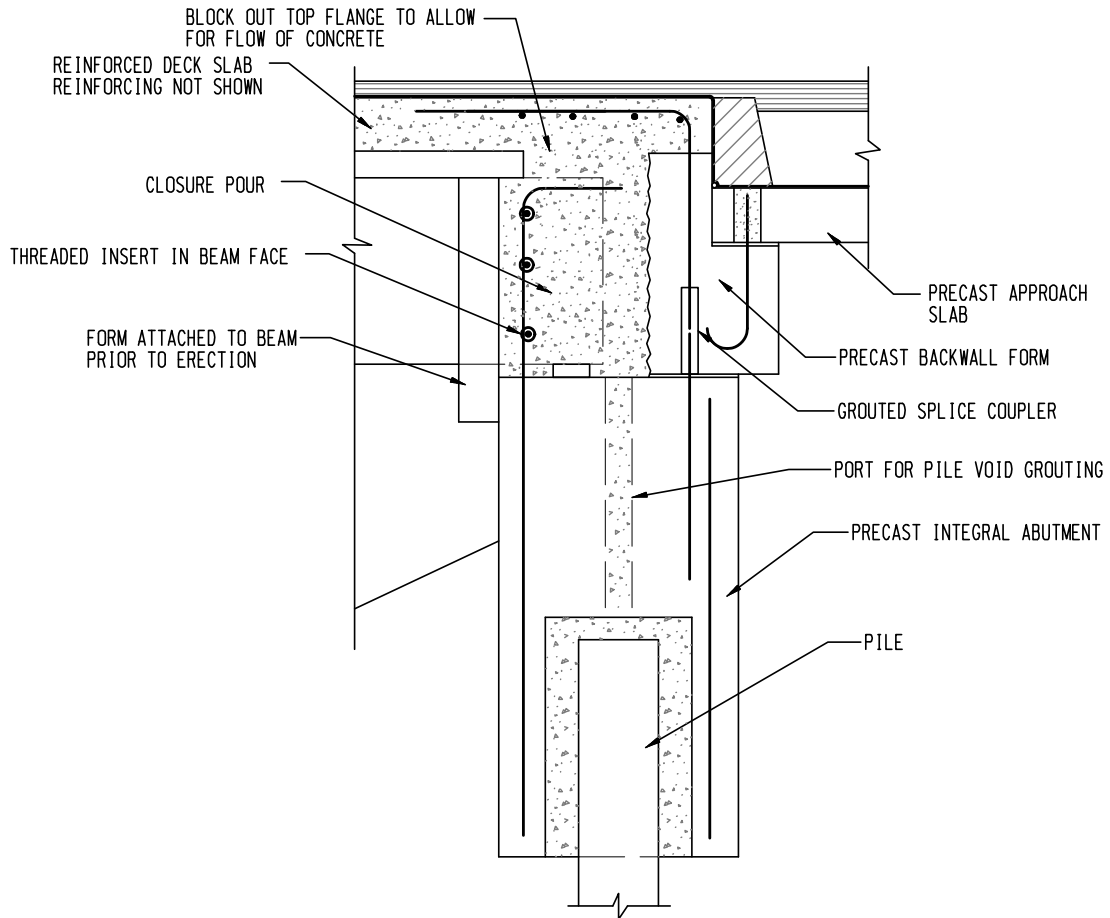


Figure CS4-5: Schematic Superstructure to Substructure Connection

Schematic Precast Deck Design:

The proposed bridge deck is a full depth precast concrete system. Many states have built full depth precast concrete decks with similar details. The system chosen is prestressed in the transverse direction and post-tensioned in the longitudinal direction. The majority of the deck will be precast. A small closure pour is required to accommodate the roadway crown. The designers located details for this portion of the structure in chapter 2 of the manual (superstructures).

Section 2.1.1.2 covers the connection of the deck to the steel girders. This detail has been used in many different states. It consists of shear studs welded to the girder through a pocket cast into the deck (detail 2.1.1.2 A). The pockets are grouted to make the deck composite with the girders. Temporary support of the deck is required during

construction. There is also a need to provide grade adjustment during construction. Detail 2.1.1.2 B is a detail that has been used many times in different states. The connection of the individual deck panels is a transverse connection that is perpendicular to the strength direction of the deck. The AASHTO LRFD Bridge Design Specifications [1] include requirements for this connection. They include the need for post-tensioning and grouted shear keys. Section 2.1.1.1 contains information on this connection. The designers chose details 2.1.1.1 B and 2.1.1.1 C for this connection.

This bridge as with most bridges requires a crown at the centerline of the deck. It is very difficult to cast a precast deck with a crown because the deck normally follows the roadway crown. Most deck panels are cast on a flat form. In order to build a crowned panel, custom forms would be required. Even if this was possible, it is impractical to cast, handle and ship a deck slab element that is as wide as this bridge deck (approximately 60 feet). For these reasons, the designers chose to use a small closure pour at the roadway crown. This connection needs to develop the full strength of the deck section. Section 2.1.1.1 has information on this connection. The designers chose detail 2.1.1.1 D for this connection.

The connection of the curb to the deck is somewhat problematic. All curbs and railings on federally funded project are required to be crash tested. There are very few crash tested prefabricated parapets or curbs. For this reason, the designers chose to use a cast-in-place concrete curb for this bridge. It should not effect the project schedule because it can be cast at the same time as the roadway crown and integral abutment connection.

Figure CS4-6 depicts the schematic deck design.

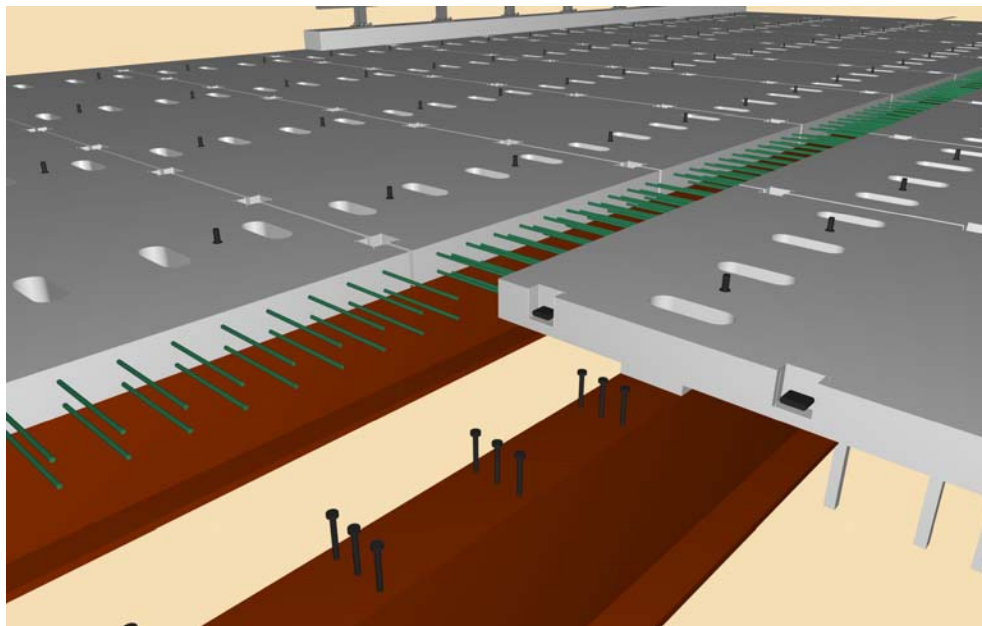


Figure CS4-6: Proposed Precast Concrete Deck

Figure CS4-7 depicts a partial view of the complete bridge structure.

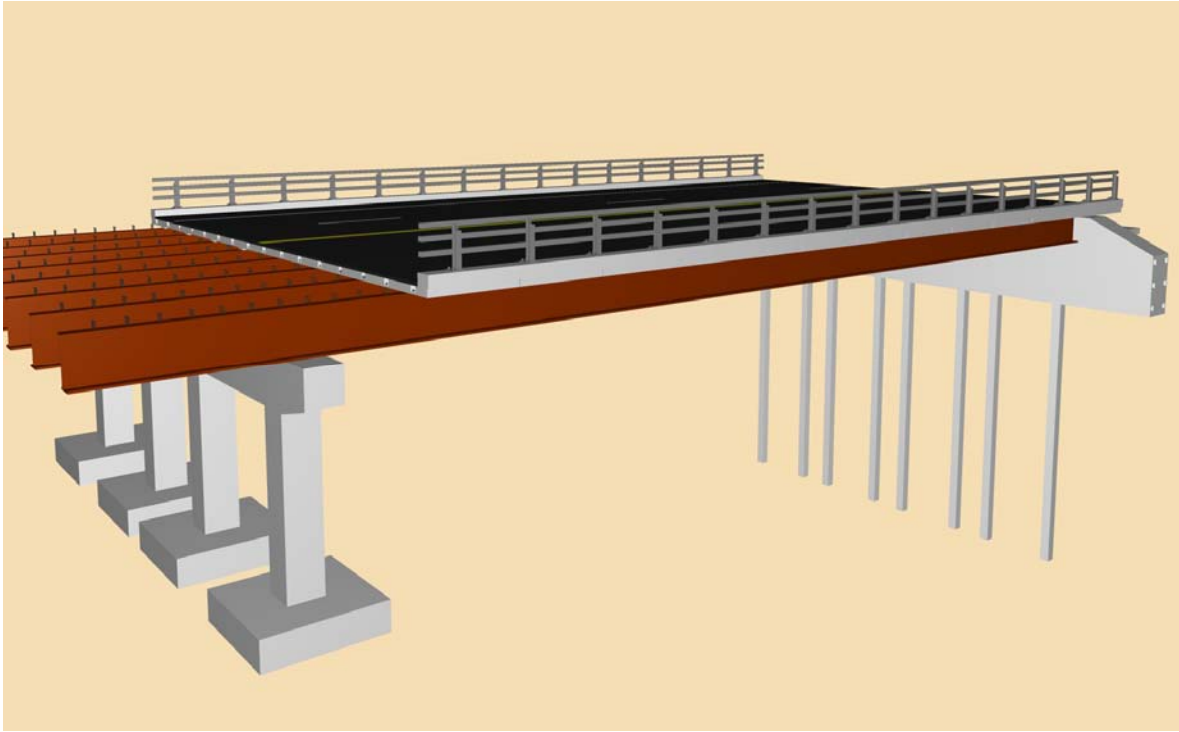


Figure CS4-7: Partial View of the Proposed Bridge

Construction:

The goal of this project is to accelerate the construction of this bridge less than 30 days. The timeline shown in Figure CS4-8 was developed based on actual projects around the country and are therefore considered to be reasonable.

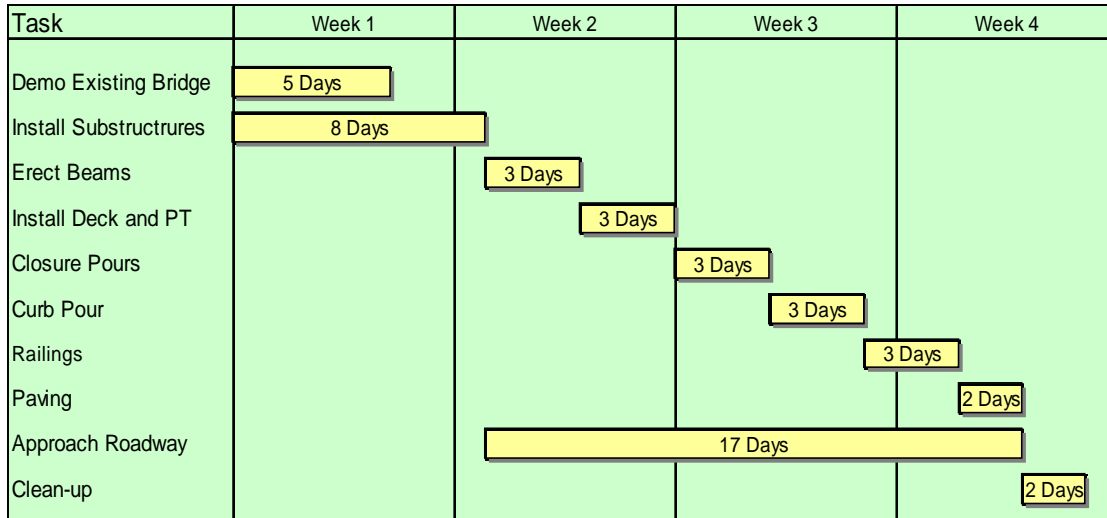


Figure CS4-8: Construction Timeline

Notes on construction timeline:

1. Utah DOT has demolished superstructures in less than 8 hours (without traffic below); therefore an estimated time of 5 days is reasonable (with traffic below).
2. The construction of the new substructures can begin on day one. This is because the new substructures are proposed to be built in a different footprint than the old substructures. This is a recommended practice for construction of accelerated bridge projects.
3. Several states have installed full depth precast concrete decks with weekend closures (including removal of the old deck); therefore 3 days for an installation is very reasonable.
4. The closure pours and curb pour are shown in series (6 days total). It will be possible to construct these in parallel.
5. The approach roadway work begins as soon as the substructures are set. The fact that the roadway is closed greatly facilitates raising the grade 3 feet for this project.

Quality and Durability:

The details chosen have a proven record of durability. The piers and pier connections are very similar to piers that were built for the Edison Bridge in Florida. Figure CS4-9 shows the completed Edison Bridge. This bridge was built in a highly corrosive environment. It has been in service since 1992 and is still in good condition.



Figure CS4-9: Edison Bridge

Full Depth Precast decks that are prestressed transversely and post tensioned longitudinally have proven to virtually crack free. History has proven that this cannot be said for cast-in-place concrete decks, which routinely have significant cracking due to shrinkage and other effects. The Connecticut DOT built a precast deck system in 1990. This deck is still in excellent condition.

The design of this hypothetical bridge also incorporated a jointless design. The bridge is continuous at the pier and the abutments are integral. This type of design eliminates potential leaking joints, which is the most problematic corrosion problem on bridges.

Costs:

This hypothetical bridge project was based on the premise of eliminating multi-stage construction. The exact cost for stage construction is difficult to estimate, but anecdotal evidence has shown that this can be a significant cost. By closing the roadway and accelerating the bridge, no costly stage construction schemes are required. The contractor will have the entire site for construction instead of constantly fighting with traffic and exposing workers to a dangerous environment. There are other ways to reduce construction costs using accelerated bridge construction, such as:

1. Standardization of prefabricated components and systematic use of accelerated bridge construction can reduce costs by building repetitive components. Contractors will become familiar with the processes and products, which normally leads to lower bid prices. The Utah DOT has seen steady decreases in bid prices as they systematically bid more accelerated bridge projects.
2. By decreasing project construction schedules, the following cost savings can be realized:
 - a. Reduces rental costs of worksites (trailers, land rental, etc.)
 - b. Reduction in construction inspection costs. This is not a cost that is carried in the bid, but is a cost that is realized by the agency.
 - c. Reduced costs of police details and flagging.
3. By reducing overall project time, the effects of inflation on construction are reduced. Contractors estimate inflationary costs in bids. Faster projects equate to lower inflation estimates.

Conclusions:

1. This hypothetical bridge demonstrates that it is possible to build a typical bridge structure using all prefabricated elements.
2. Designers do not need to change the way they layout and design prefabricated bridges. The bridge chosen is a typical highway overpass with up-to-date amenities such as continuous girders, integral abutments and weathering steel.
3. There is not sacrifice of quality on bridges built with prefabricated elements. In fact, it is possible to improve quality using this approach. Precast elements have very few shrinkage cracks because they are allowed to shrink and cure with restraint from adjoining members. This is especially true for precast decks.
4. By standardizing elements, eliminating construction staging, and reducing overall project time, it may be possible to reduce overall project costs using accelerated bridge construction.

Appendix E: Glossary

The following terms are used in this document. The description of each term is written in the context of this document.

Term	Description
additives	Substances (typically chemical) that are added to a grout mixture to counteract the natural tendency of grouts to shrink.
air release grouts	A type of grout that does not rely on a chemical reaction to achieve expansion. The additive reacts with water to release air and cause expansion of the grout.
anchor rods	Steel rods that are used to transfer loads from the superstructure to the substructure. Often referred to as “anchor bolts”, anchor rods differ in that they do not have a hexagonal head. Anchor rods are normally specified according to ASTM F1554.
approach slabs	Structural slabs that span between the bridge abutments and the approach fill. They are used to span across the potential settlement of the approach roadway fills directly behind the abutments.
backwall	A structural wall element that retains the backfill soils directly behind the beam ends on a bridge abutment
barrier	A structural wall element that is used to contain aberrant vehicles. They can be used on the bridge (parapet), or on the approach roadway.
batching	The process of combining and mixing the materials to form concrete
bearing	A structural element that connects the bridge superstructure to the substructure, while allowing for movements such as thermal expansion and contraction.
bleed water (grout)	Water that seeps out of the surface of a grout due to expansion of a grout in a confined or semi-confined area
blockouts	Voids that are cast in prefabricated concrete elements that are used in connecting the elements in the field
breastwall	A wall that is typically non-structural that covers the beam ends at the corners of the bridge abutments. Sometimes referred to as “cheekwalls” by some states.

Term	Description
bridge deck	A structural slab that spans between support elements (typically beams and girders) on a bridge. Bridge decks can be made of many materials, including reinforced concrete, steel, timber, fiber reinforced polymers, etc.
cable restrainers	Structural elements that are used to restrain a bridge superstructure from excessive lateral movement during seismic events. The goal being to prevent the superstructure from falling off the substructure, which is a very common form of failure during seismic events.
camber	A geometric adjustment of a bridge beam that is designed to compensate for the the vertical deflection of the beam when subjected to dead loads. Camber is typically built into steel beams during fabrication. Camber is an inherent side effect of prestressed girder construction.
carbon fiber	A materials that is used in fiber reinforced polymer elements (FRP) to provide the structure performance. These fibers are oriented parallel to the direction of stress.
cast-in-place concrete	Concrete that is cast on site (as opposed to cast in a fabrication plant)
cheekwall	A wall that is typically non-structural that covers the beam ends at the corners of the bridge abutments. Sometimes referred to as “breastwalls” by some states.
cofferdam	An enclosure used to retain water in order to create a dry work environment. Typically used for bridge pier construction in rivers.
composite beam action	The process of connecting the bridge deck to the beams or girders to form a combined structural element.
composites	The combining of multiple structural materials to form a structural element.
compressive strength	The value of uniaxial compressive stress reached when a material fails.
concrete	A construction material that consists of cement (commonly portland cement), coarse aggregates (such as gravel limestone or granite), fine aggregates (such as sand), and water. Often other materials are added to improve the structural properties such as chemical admixtures and other cementitious materials (such as fly ash and slag cement).

Term	Description
concrete/steel hybrid decks	A structural bridge deck system that combines structural steel elements with composite concrete to create a prefabricated deck system.
confinement steel	Reinforcing steel used to contain the concrete core of a column when subjected to plastic deformations brought on by seismic loading.
consistency	The state of a mixture of materials where the formulation is of uniform quality.
constructability	The extent to which a design of a structure provides for ease of construction yet meets the overall strength requirements.
construction joints	Joints in structures that are used to facilitate the construction of a portion of the structure. Construction joints typically have reinforcing steel passing from one side of the joint to the other.
construction stages	A process of building a bridge in segments in order to maintain traffic during construction.
continuity connection	A connection used to connect two longitudinal bridge element (beams) to form a continuous bridge system. Typically these connections are only designed to resist live load.
continuous spans	A structural system where the beams span across more than two supports without joints.
contraction joints	Joints in structures that are used to allow the concrete elements to shrink without causing excessive cracking. Contraction joints typically do not have reinforcing steel passing from one side of the joint to the other.
conventional construction	Construction methods that do not include large scale prefabrication.
cover concrete	A layer of concrete placed around reinforcing steel to prevent the corrosive attack from water and other elements.
critical path	The portion of the sequence of construction activities which represents the longest overall duration. This in turn determines the shortest time possible to complete a project.

Term	Description
cross frame	A transverse structural element connecting adjacent longitudinal flexural components used to transfer and distribute vertical and lateral loads and to provide stability during construction. Sometimes synonymous with the term “diaphragm”.
crown	The apex of the roadway cross slope.
curing compounds	Chemical compounds that are used to prevent the rapid evaporation of water from concrete during curing.
curb	A structural element that is constructed at the edge of bridge deck that is used to contain rain water runoff. Curbs are often combined with structural railings to retain vehicles.
debonding	The process of disconnecting prestressing strand from the surrounding concrete in a prestressed concrete element. This is done to control stresses in prestressed elements (typically at the at the ends).
deck	The structural portion of a bridge that is directly beneath the wheels of passing vehicles.
dewatering	The process of removing water from an excavation that is below the water table.
diaphragm	A transverse structural element connecting adjacent longitudinal flexural components used to transfer and distribute vertical and lateral loads and to provide stability during construction. Sometimes synonymous with the term “cross frame”.
differential camber	A variation on the camber of two adjacent beams. See “camber”.
dimensional growth	The phenomenon that results in the change in overall structure width or length when multiple elements are butted together. This is brought on by a build up of element side variations or tolerances that are a result of the fabrication process.
distribution direction	A direction that is normally parallel to the supporting members and is perpendicular to the direction of beam action in reinforced concrete slabs that are designed for one-way slab action.

Term	Description
drilled shafts	A deep foundation unit, wholly or partly embedded in the ground, constructed by placing fresh concrete in a drilled hole with or without steel reinforcement. Drilled shafts derive their capacity from the surrounding soil and/or from the soil or rock strata below its tip. Drilled shafts are also commonly referred to as caissons, drilled caissons, bored piles, or drilled piers.
dry pack grout	A form of grout that has very stiff consistency that is placed by packing the material into voids by hand and hand tools.
effective prestress	The stress or force remaining in the prestressing steel after all losses have occurred.
elastomeric bearing pads	A type of structural bearing that is comprised of neoprene or natural rubber. Sometimes combined with internal steel plates, fiberglass sheets, or cotton duck sheets.
emulation design	A design method where a prefabricated connection is designed and detailed to act as (or emulate) a conventional concrete construction joint.
epoxy adhesive anchoring systems	A method of embedding reinforcing steel or steel rods into hardened concrete to form a structural connection. The process involves a drilled hole and a chemical adhesive.
epoxy grouts	Grout materials with chemical adhesives used in place of cementitious materials.
ettringite expansive grout	Ettringite is crystal that forms as a result of the by product of reactive chemicals that can be interground into the cement in expansive grouts to produce non-shrink grout.
exodermic bridge deck	A bridge deck system that is composed of a steel grid deck combined with a top layer of concrete to form a composite system. This system differs from filled grid decks in that the concrete is placed above the top of the grid to maximize the composite action between the steel and the concrete.
expansion joints	Joints in structures that are used to allow the concrete elements to expand and contract with temperature variation without causing excessive cracking. Expansion joints are similar to contraction joints except they are normally wider and often include a compressible material to allow for thermal expansion. They also do not have reinforcing steel passing from one side of the joint to the other.

Term	Description
fiber reinforced polymers (FRP)	A structural matrix of materials used to produce a structural element. FRP is commonly made reinforcing fibers that are combined with polyester, epoxy or nylon, which bind and protect the fibers from damage, and transfers the stresses between fibers. FRPs are typically organized in a laminate structure, such that each lamina (or flat layer) contains an arrangement of unidirectional fibers or woven fiber fabrics embedded within a thin layer of light polymer matrix material. The fibers, typically composed of carbon or glass, provide the strength and stiffness.
filled steel grids	A bridge deck system that is composed of a steel grid deck combined that is either fully or partially filled with concrete.
flowable fill	A material used to rapidly fill a void in embankment backfills or under structures without compaction. It normally has high flow characteristics. It is commonly made up of sand, water and a minor amount of cement.
flying wingwalls	Walls used to retain embankment soils at the corners of abutments that are cantilevered from the end or rear of the abutment as opposed to being supported on a footing.
foam block fill	A material used to rapidly fill embankments where low unit weight materials are desired. This is often used over highly compressible soils such as clays.
full-depth precast concrete deck slabs	A bridge deck system that is composed of reinforced concrete elements that when placed, make up the full structural deck system.
gantry crane	A crane type that is characterized by two or more legs supporting an overhead beam with a traveling trolley hoist.
gas generating grout	A type of non-shrink grout that expands due to the production of gas during the curing process. The gas is generated by adding reactive materials to the mix (often aluminum) to produce the gas.
girder-floorbeam bridges	A bridge framing system that is composed of main girders that run parallel to the roadway combined with transverse floorbeams that support the deck. Often the system includes stringer beams that run between floorbeams (parallel to the roadway).

Term	Description
glue laminated wood	A structural framing material that consists of multiple layers of dimensional lumber glued together to form a large timber element.
grout	A material (often cementitious or epoxy) that is used to fill voids between elements.
grouted reinforcing splice couplers	A proprietary product used to join precast concrete elements by connecting reinforcing steel bars at the ends of the elements. They consist of a steel casting sleeve that is filled with grout. The reinforcing bars are inserted into the ends of the casting and developed by the interaction of the grout with the sleeve.
haunch	The material between the top of a beam element and the bottom of the bridge deck that gaps the space between the two elements (also referred to as the “web gap” in some states).
high early strength concrete	A concrete mixture that gains strength rapidly in order to accelerate construction.
integral abutment	A bridge abutment type that is made integral with the bridge superstructure through a combined shear and moment connection. They are often constructed with a single row of piles that allow for thermal movement and girder rotation. Soil forces behind the abutments are resisted through the strut action of the superstructure.
integral abutment connection	The connection between the superstructure and the integral abutment substructure that can resist both shear and moment.
integral pier connection	The connection between the superstructure and the pier substructure elements that can resist both shear and moment.
keeper assemblies	Devices that are placed on top of substructures to prevent lateral movement of the bridge superstructure. They are often used to resist lateral seismic forces. They can be constructed with structural steel or reinforced concrete.
leveling bolts	Bolt assemblies embedded in prefabricated elements that are used to make grade adjustments in the field during construction.

Term	Description
match casting	A process of joining two precast concrete elements with high precision. This is done by casting one element against the adjoining element in the fabrication yard, separating them, and then re-joining them in the field. The field connection is normally made with thin epoxy adhesives combined with post-tensioning
mechanical splices	Devices used to connect reinforcing steel through mechanical means. Examples of these systems include grouted sleeves, wedge assemblies, and threaded bar ends.
mechanically stabilized earth (MSE) retaining walls	A soil-retaining system, employing either strip or grid-type, metallic, or polymeric tensile reinforcements in the soil mass, and a facing element that is either vertical or nearly vertical. In this system, the soil mass is engaged by the strips to become a gravity type retaining wall.
mild reinforcement	Steel bars or grids within concrete elements that are used to resist tension stresses. Mild reinforcement normally consists of deformed steel bars or welded wire fabric.
modular block retaining walls	A soil-retaining system employing interlocking soil-filled timber, reinforced concrete, or steel modules or bins to resist earth pressures by acting as gravity retaining walls.
near site fabrication	A process of constructing prefabricated elements near the bridge construction site in order to minimize problems with shipping of large components.
non-shrink cementitious grout	A structural grout used for filling voids between elements that is formulated with cement, fine aggregates and admixtures. The admixtures are used to provide expansive properties of the material during curing. This expansion counteracts the natural tendency of cement grouts to shrink during curing.
one-way slab	A reinforced concrete slab system that primarily spans between two parallel support members. In this system, the majority of the reinforcing runs perpendicular to the support members.
open grid decks	A bridge deck system that is composed of an open steel grid spanning between supporting members.
parapet	A structural element that is constructed at the edge of bridge deck that is used to contain aberrant vehicles.

Term	Description
partial-depth precast concrete deck panels	A bridge deck system that consists of relatively thin precast concrete panels that span between supporting members that are made composite with a thin layer of site-cast reinforced concrete. The precast panel makes up the bottom portion of the structural slab. The site cast concrete makes up the remainder of the structural slab.
pier box	A prefabricated system that includes a precast concrete box that is placed over driven piles or drilled shafts. The box becomes the form to contain site cast reinforced concrete. Often pier boxes are used in water applications to form a cofferdam for the footing concrete.
pier cap	A structural beam spanning between pier columns.
pier column	The vertical structural element in a bridge pier
pile bent pier	A bridge pier without a footing that is comprised of driven piles or drilled shafts supporting a pier cap.
pile cap footing	A footing that is supported by driven piles or drilled shafts.
plastic hinge	A method of dissipating lateral seismic forces by allowing portions of reinforced concrete pier columns to bend beyond the yield point. Stability of the structure is maintained by providing adequate confinement reinforcement.
post-tensioning ducts	A form device used to provide a path for post-tensioning tendons or bars in hardened concrete
post-tensioning (PT)	A method of prestressing in which the tendons (strands or bars) are tensioned after the concrete has reached a specified strength.
precast concrete	Concrete elements that are cast in a location other than their final position on the bridge.
prefabrication	The process of building bridge elements prior to on-site construction in order to accelerate the construction of the bridge.
prestressed concrete	Concrete components in which force is introduced into the element during fabrication to produce internal stresses that are normally opposite of the anticipated stresses in the completed structure. Prestressing can be accomplished with pretensioning or post-tensioning.

Term	Description
pretensioning	A method of prestressing in which strands are tensioned before the concrete is placed, and released after the concrete has hardened to a specified strength.
quality assurance and quality control (QA/QC)	The process of inspection and control during fabrication to ensure that the specified quality is achieved.
reflective cracking	A crack that can form in site cast concrete that is placed over a joint between two elements below the pour.
reinforced closure pours	A method of connecting two prefabricated elements by casting a segment of reinforced concrete between two elements. The connection is often made using lap splices or mechanical reinforcing connectors.
reinforced concrete	Concrete elements with reinforcing steel cast into the concrete to form a structural element. The steel is normally used to resist tension stresses in the element.
reinforcing steel	Steel placed in concrete elements (either be mild reinforcement or prestressing steel).
saturated surface dry (SSD) condition	A condition that is normally specified for concrete surfaces that are to be grouted. Saturated Surface Dry describes the condition of the concrete surface in which the pores are filled with water; however no excess water is on the surface. This condition minimizes the absorption of water from the grout into the surrounding concrete.
segregation	A condition where the distribution of coarse or fine aggregates in the concrete or grout mix become non-uniform.
self-propelled modular transporter (SPMT)	A high capacity transport trailer that can lift and move prefabricated elements with a high degree of precision and maneuverability.
shear key	A shaped joint between two prefabricated elements that can resist shear through the geometric configuration of the joint.
shear studs	Headed steel rods that are welded to elements to provide composite action between two bridge elements. Typically used between beams and the deck slab.
sheeting	A structural system used to retain earth and water and allow for excavation during the construction of a bridge substructure.

Term	Description
shims pack	Flat plates placed between two prefabricated elements used to provide a specified separation. Shims are also used to make vertical grade adjustments. Shims are typically made of steel or polymer sheets.
shrinkage (grout)	A property of cementitious concretes and grouts that occurs during curing where the material reduces in size.
spandrel wall	A wall that is constructed on the sides of earth filled arch structures that are used to retain the fill soils.
spiral reinforcement.	Transverse reinforcement used in reinforced concrete columns to resist shear. Spirals are also used for confinement of the concrete core as a plastic hinge forms.
steel stay-in-place forms	Corrugated steel sheeting that is used to support the wet concrete in a bridge deck during construction, and left in place in the permanent structure.
strength direction	A direction that is normally perpendicular to the supporting members and is parallel to the direction of beam action in reinforced concrete slabs that are designed for one-way slab action.
stress laminated timber deck bridges	A timber bridge deck that is comprised of multiple layers of dimension lumber placed on edge and connected with transverse prestressing. Shear transfer between the laminations is accomplished through friction.
stringers	There are two common uses for this term. <ol style="list-style-type: none"> 1. Longitudinal steel beams on short span multi-beam bridges. 2. Secondary framing members on floor beam type bridges that span from floor beam to floor beam.
stub abutments	A short cantilever type abutment that is constructed near the top of the approach embankment.
substructure	The portion of the bridge that is below the beam and/or deck elements. It typically includes piers, abutments, and walls.
superstructure	The portion of the bridge that is above substructure. It typically includes beams, girders, trusses, and the bridge deck.

Term	Description
surface preparation (grout)	The process of preparing a concrete surface for grouting by cleaning or intentionally roughening the surface. This is done to improve the adhesion of the grout to the concrete. It typically includes sand blasting, water blasting, or hand tool cleaning.
sweep	The lateral curvature of a prefabricated element caused by fabrication form irregularities and/or internal stresses.
test pours and test mock-ups	A method of quality control whereas a contractor will build a model of a portion of the bridge structure that includes a void that requires grout placement. These are used to demonstrate proper grout placement in complex voids.
timber deck panels	Prefabricated timber panels that are made with glue laminated lumber.
tolerance	Specified allowable dimensional variations in prefabricated elements. The variations are a result of irregularities in formwork and minor deviations in measurements during fabrication.
transverse ties	Reinforcement used in reinforced concrete columns to resist shear. Ties, if properly detailed, can also used for confinement of the concrete core as a plastic hinge forms.
tremie concrete pour	Concrete that is placed underwater and within a cofferdam to resist the vertical pore pressure of the water below a footing during construction.
user costs	Costs that incurred by users of a highway network when they are delayed due to construction activities.
variable web gap	See "Haunch"
water content	The specified amount of water in a concrete or grout mix.
wearing surface	The top portion of the bridge deck that is directly below the vehicle tires. Often wearing surfaces are designed to be sacrificial and replaceable.
wet curing	Curing is the process of retaining sufficient moisture (water) in freshly placed grout/concrete to complete the hydration reaction which occurs when water is introduced to Portland cement. Wet curing leaves the freshly placed grout/concrete in an environment of 100 percent humidity

Term	Description
working time	The amount of time that a concrete or gout mix remains in a liquid or plastic state so it can be placed and consolidated.
yield strength	The stress at which an elastic material begins to deform in a plastic manner. Prior to yield, the material will deform elastically and will return to its original shape when the applied stress is removed. If loaded beyond yield and then unloaded, the material will not return to its original shape.

Appendix F: References

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