PROJECT	**Rail Baltica** SBS-Study
PURPOSE	**Prefabrication connection types**
ANNEX 3	**Connections for prefabricated elements**
PERFORMANCE PERIOD	05/2019 until 09/2019
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PROJECT NUMBER INTERNAL	04119
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INDEX	a

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Technical and additional documents

Basis of assignment

[U1] Assignment order (contract) No 8/2017-120-X/X for the provision of expert services, Riga

[U2] Mini competition_SBS-Cases-R0.2

[U3] Bridge Inventory; Rail Baltica; 02.04.2019

Additional documents

[U4] Gabler, Markus; Fakhouri, Abdalla; Baumann, Katrin: “Zur Gestaltung von Fertigteilbrücken”, in: Bautechnik 96 (2019), Heft 2

[U5] U.S. Department of Transpotation, Federal Hghway Administration (2009): “Connection Details for Prefabricated Elements and Systems”, Publication No. FHWA-IF-09-010

[U6] CRC-Technology: “High strength joints for precast bridge slabs”, Summary report

[U7] Seidl, Günter (SSF Ingenieure AG): “Rahmenbrücken”

[U8] Skanska Norge AS: “Bridge Construction Using Precast Concrete Elements”

[U9] State of Florida, DOT: “Prefabricated Bridge Elements and Systems (PBES) Conceptual Drawings”

[U10] Zement + Beton Handels- und Werbeges.m.b.H: „Brückenbau – Fertigteile auf neuen Wegen“, Expertenforum Beton 2005

Table of content

1 Introduction

1.1 Propose of this document

This document presents different connection types for prefabricated elements.

This document is a library of possible connections for prefabricated elements. It lists different solutions to show possibilities. It should not be seen as ready solutions for our connection types but ideas of potential solutions.

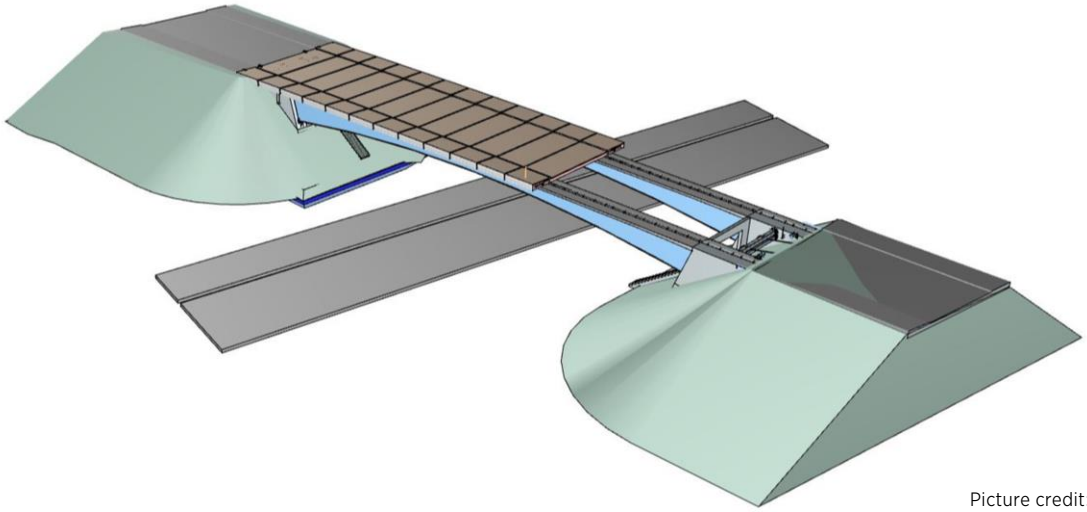
2 Superstructure connections

2.1 Deck systems

Deck systems are the most common systems for prefabrication. Therefore, there are many well tested connections and there is much experience to rely on. Most prefabricated bridges have beams that run parallel to the roadway centreline. In a concrete deck system, the primary reinforcement bars run in transverse direction. The bars in longitudinal direction are used for distribution of strength.

2.2 Full depth precast concrete deck slabs

This system is designed as a one-way slab between supporting beams (e.g. steel beams or precast concrete beams).



Picture credit: © Max Bögl

Figure 1 Composite bridge with bridge deck of precast slabs

There are two different types of connections used between the slab elements: One in strength direction and one in distribute direction:

Strength Direction (Longitudinal)

This connection is used for example between construction stages and to provide a cross slope change in the deck. It has to transfer primary deck moment and shear from one element to another. The easiest way to do is a small cast-in-place closure between the elements with post tensioning. [U5]

Distribution Direction (Transversal)

This connection has to transfer primarily shear and minor distribution moments. The most common form is a grouted shear key with or without longitudinal post-tensioning. [U5]

Examples

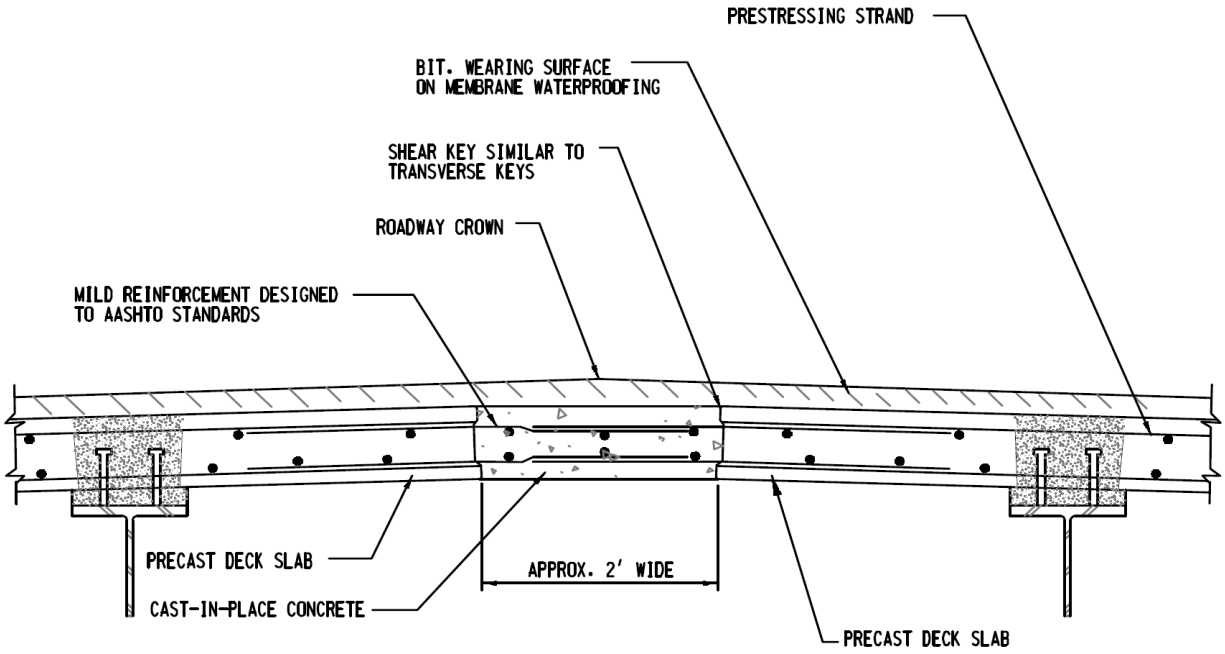


Figure 2 Longitudinal Connection (Roadway Crown) [U5]

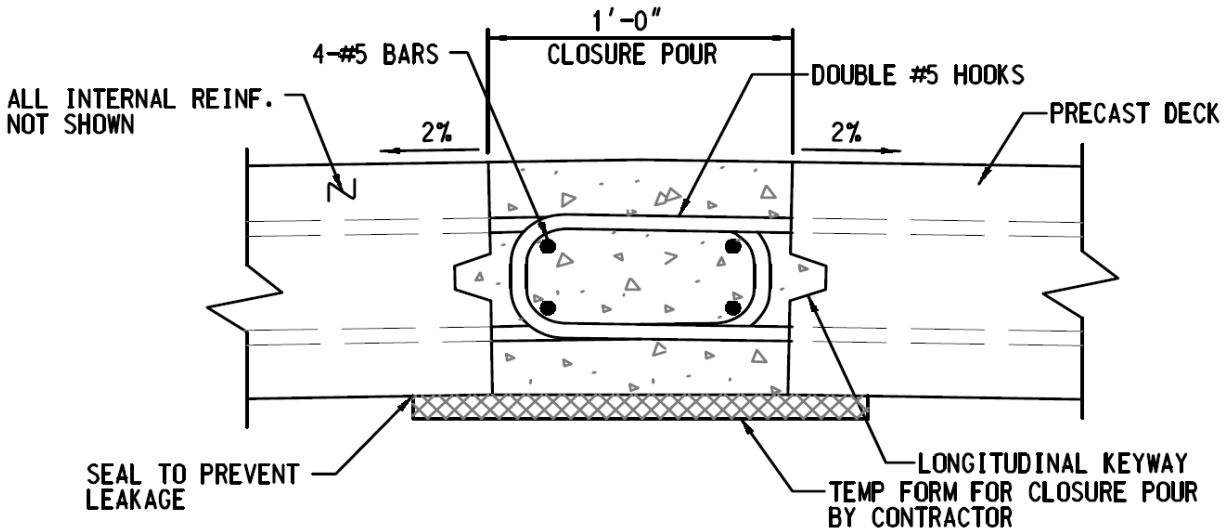


Figure 3 Longitudinal Connection (Roadway Crown) [U5]

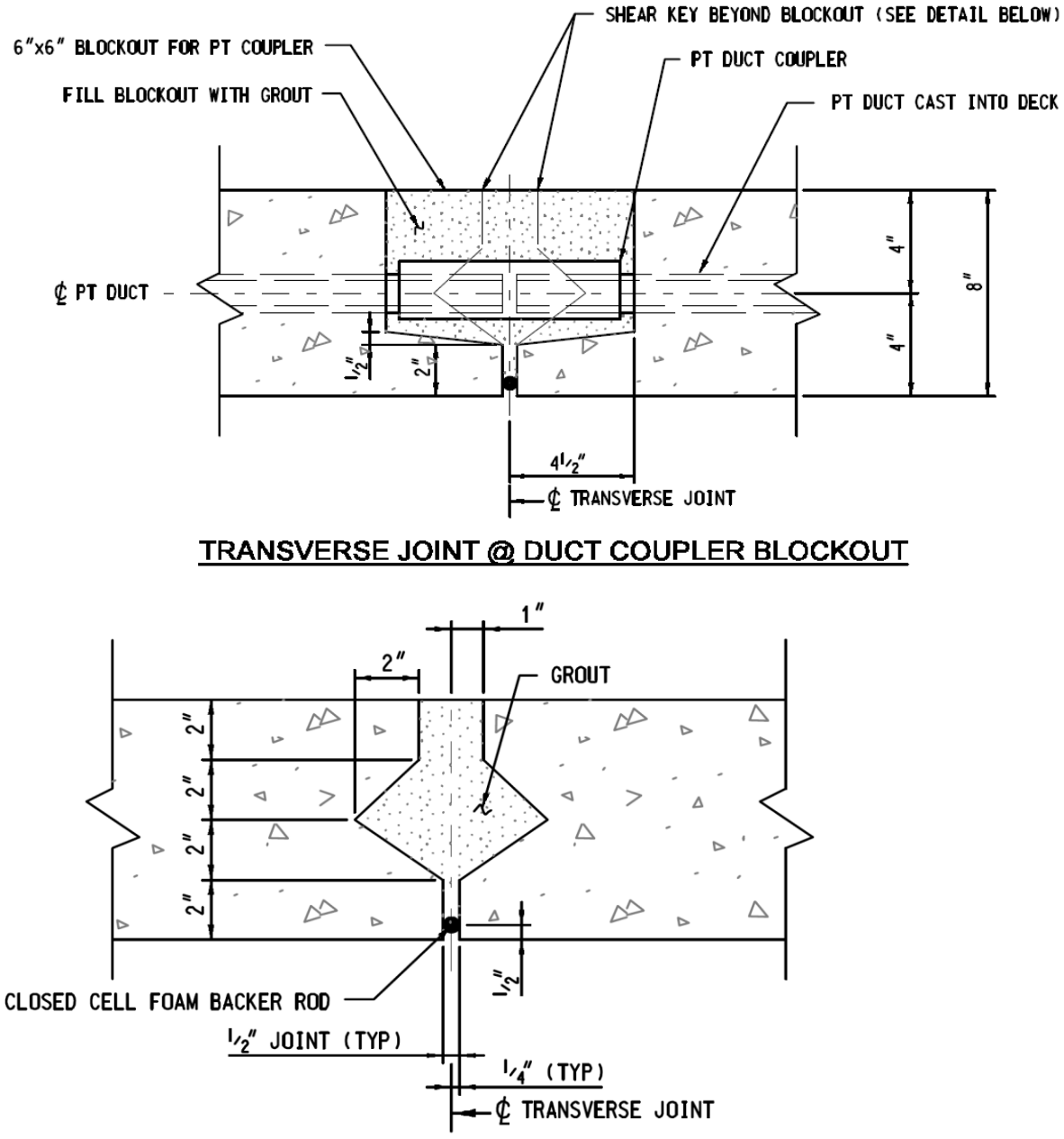
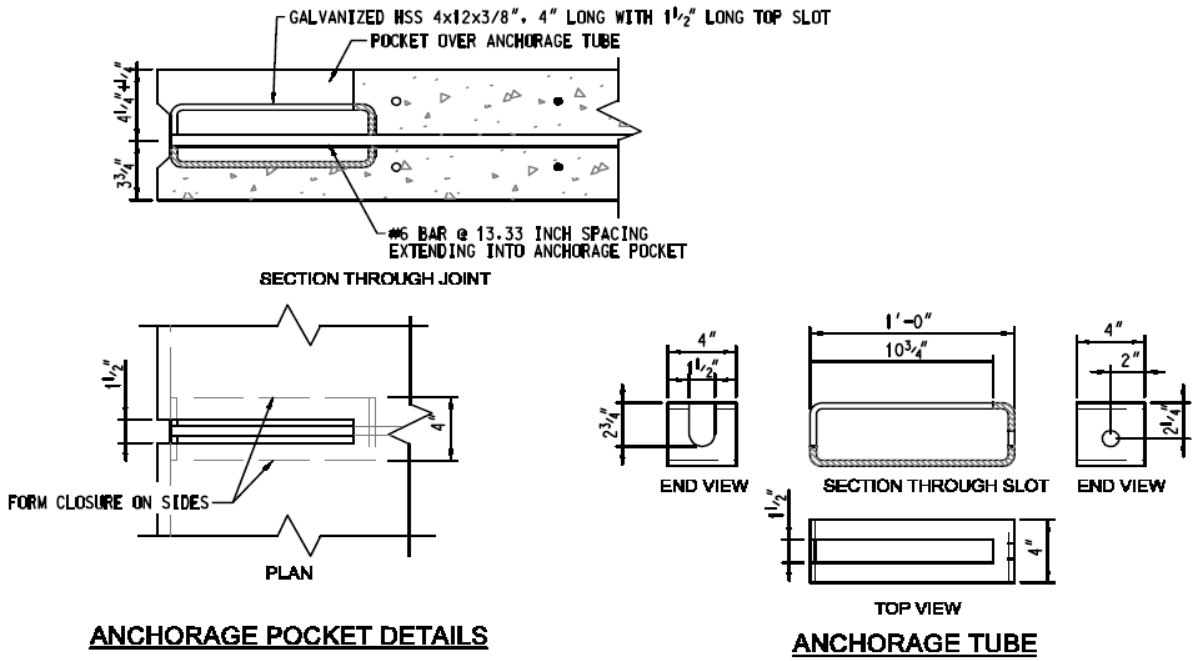


Figure 4 Transverse Connection 1 [U5]



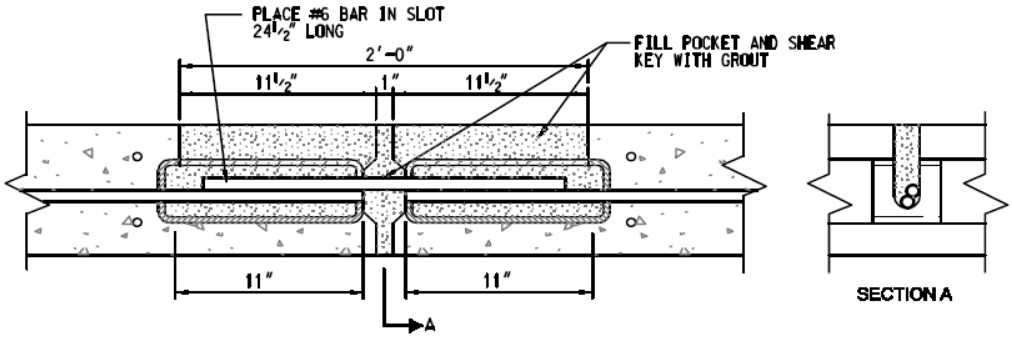


Figure 5 Transverse Connection [U5]

2.2.1 Partial-depth precast concrete deck panels

These panels are about 5 to 10 cm thick with reinforcement bars in both directions in it. Once placed on the beams, a top layer of conventional reinforcing is placed over the panels and cast-in-place concrete finishes the composite deck. Normally the elements are not continuous, but end on the beams so that a connection between the beam and the deck can be made. [U5]

Figure 6 Partial-Depth Precast Concrete Deck Panels

Decks made from these partial-depth precast panels are stiffer than full-depth precast panels but the placing of the conventional reinforcing and the cast-in-place concrete is more time-consuming. [U5]

Example

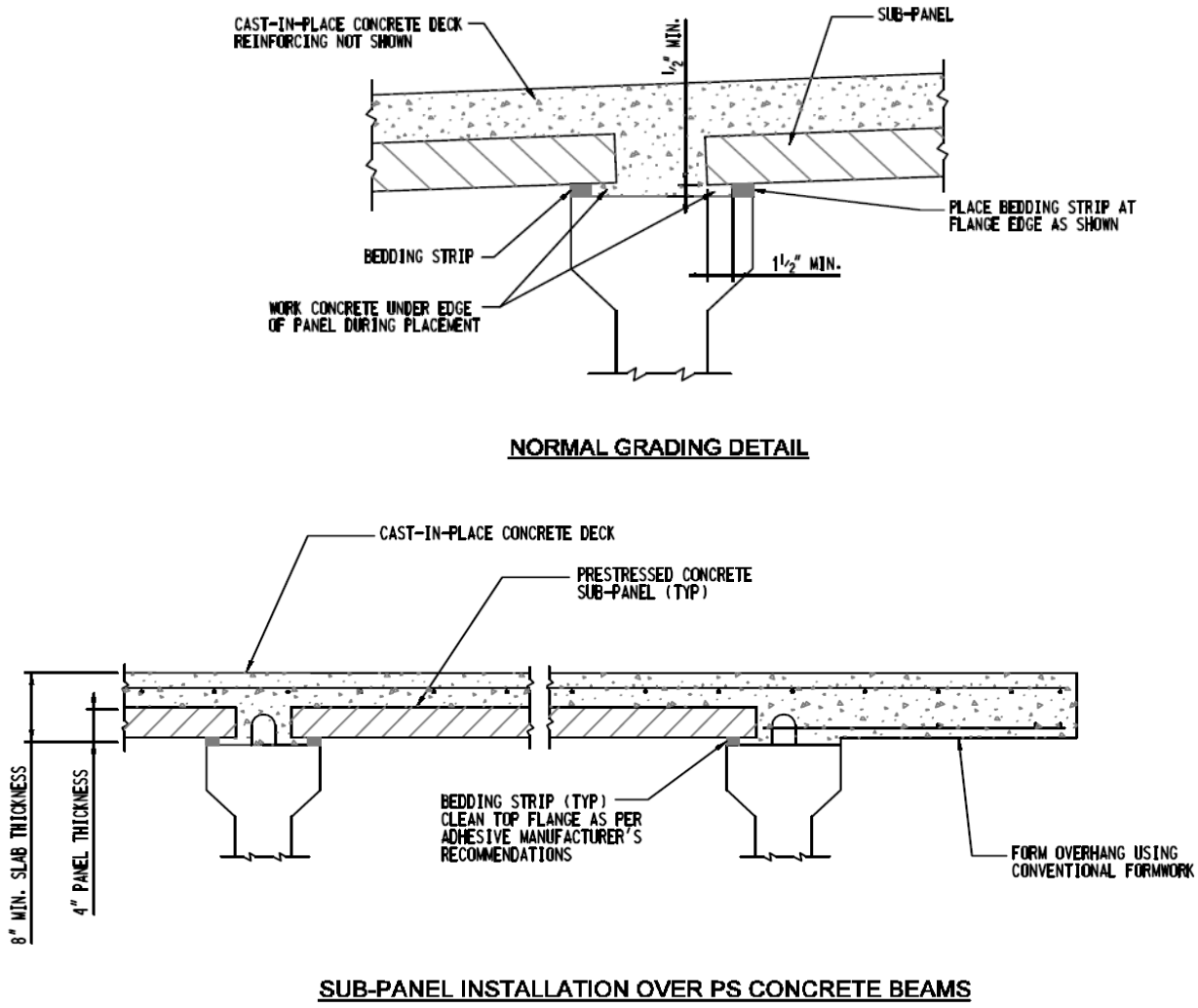


Figure 7 Connection over Beams [U5]

2.2.2 Connections to beams

Full depth precast concrete deck panels have to be connected to the beams. The most common way to do so is to use blockouts in the deck which can be placed over shear connectors on the beam and filled with cast-in-place concrete.

Examples

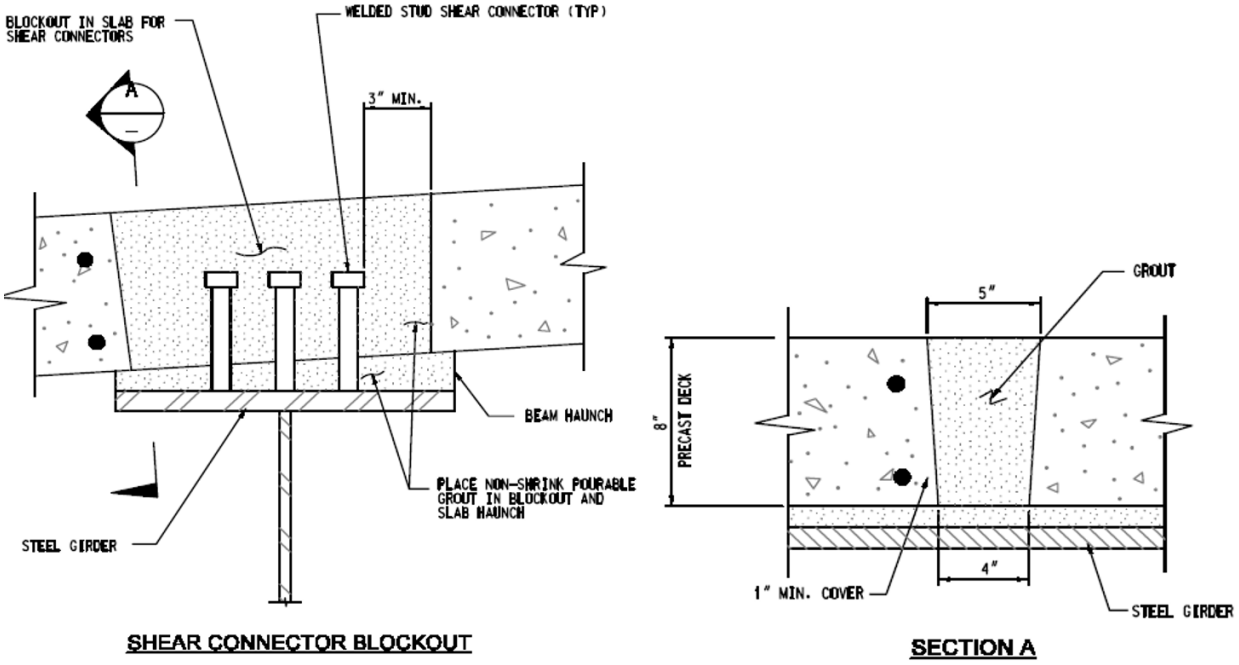


Figure 8 Deck to Steel Beam Connection [U5]

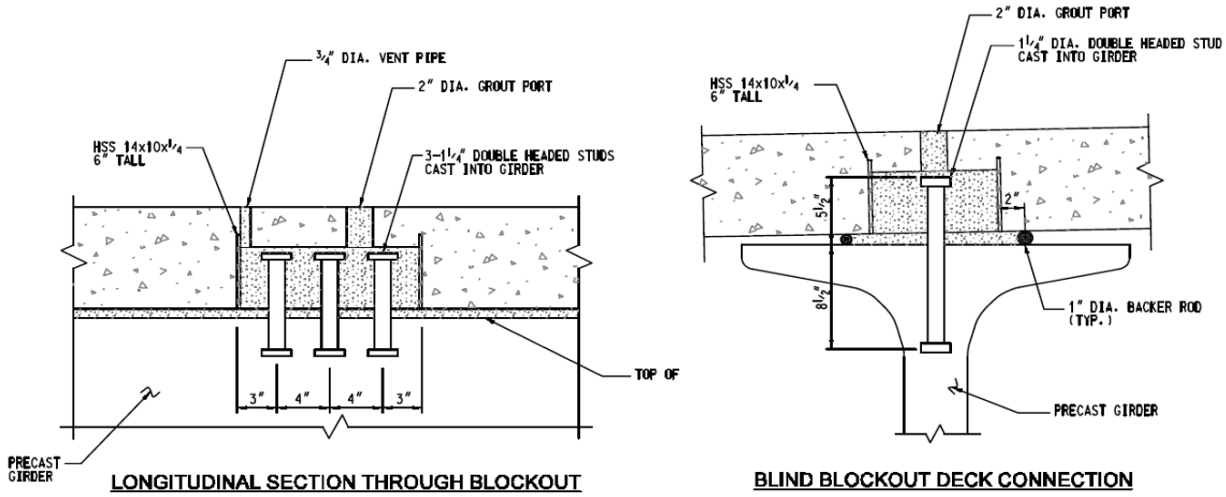


Figure 9 Deck to Concrete Beam Connection [U5]

2.3 Beam systems

Decked stringer systems

Decked stringer systems are a common form of bridge in which the deck elements are placed on longitudinal beams. The beams for example can be tee beams, I-shaped beams, U-shaped beams or box beams. Also, systems with steel beams are common.

Figure 10 U-shaped Beams in a Decked Stringer System

The beams can be connected in transverse or in longitudinal direction. For steel beams there are many possibilities of connections with screws, bolts or welds which will not be discussed here. Concrete beams are most often connected with cast-in-place concrete closure pours.

Adjacent butted beam systems

In this system, parallel beams running in the longitudinal direction are pushed directly against one another. The advantage is, that there is no need for deck forming and, in some instances, no need for deck placement. Tee Systems can be divided into standard Tee Systems, Double Tee Systems and even Triple Tee Systems. A special Tee System are Bulb Tees, which are precast prestressed concrete I-shaped beams with a large bottom flange and a wide top flange. So, there can be many strands placed in the bottom and the thin top flange can be used as formwork for a cast-in-place deck. [U5]

Figure 11 Adjacent Butted Tee Beams

2.3.1 Longitudinal connections

Each beam is designed as an independent system so that there is no need to transfer moments from one to another. A shear only connection is the most common connection used for every type of Beam.

Examples

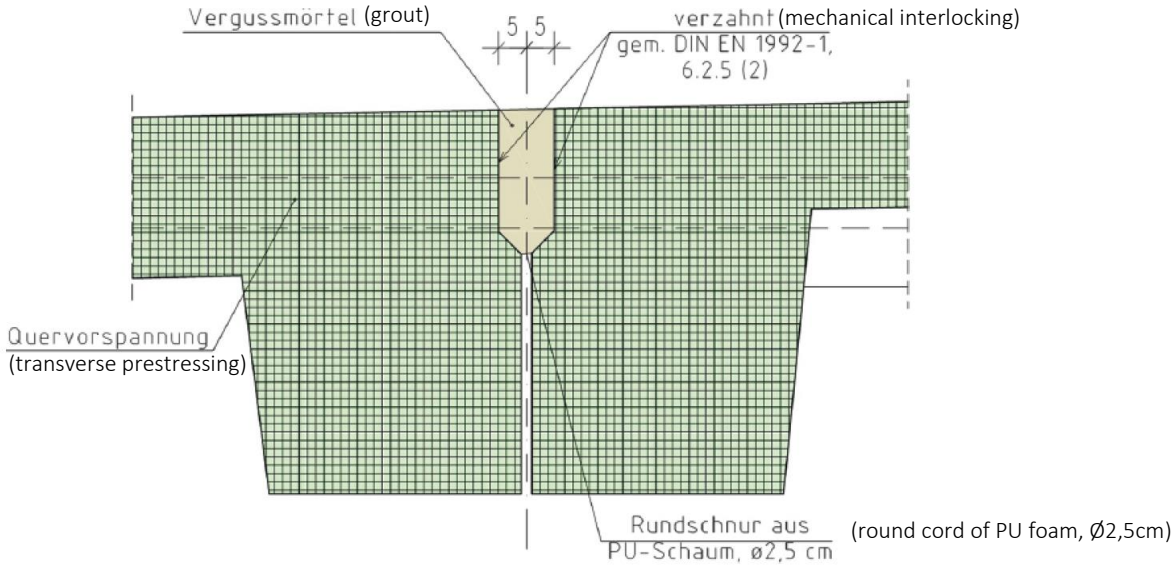


Figure 12 Longitudinal Connection between beams [U4]

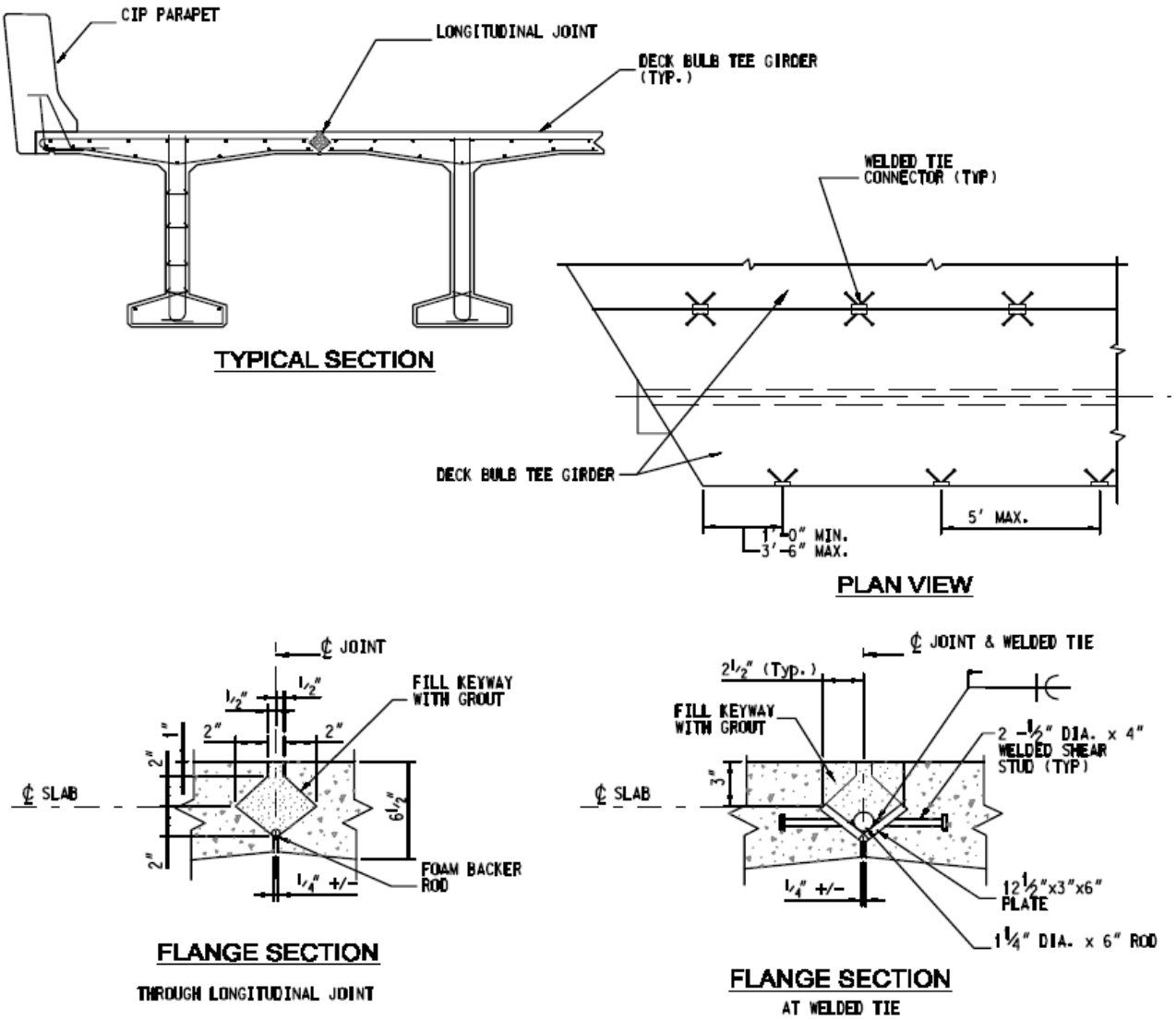


Figure 13 Longitudinal Connection between Bulb Tee Beams [U5]

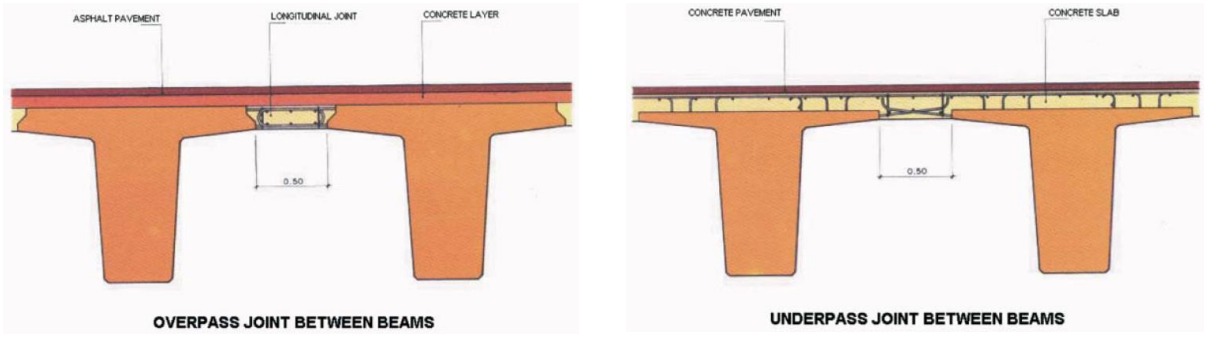


Figure 14 Longitudinal Joints between Beams [U10]

2.3.2 Transverse connections

Transverse connections between precast concrete beams are often made using cast-in-place concrete. The connection is mostly made by piers, but it is also possible to connect the girders in the field.

Examples

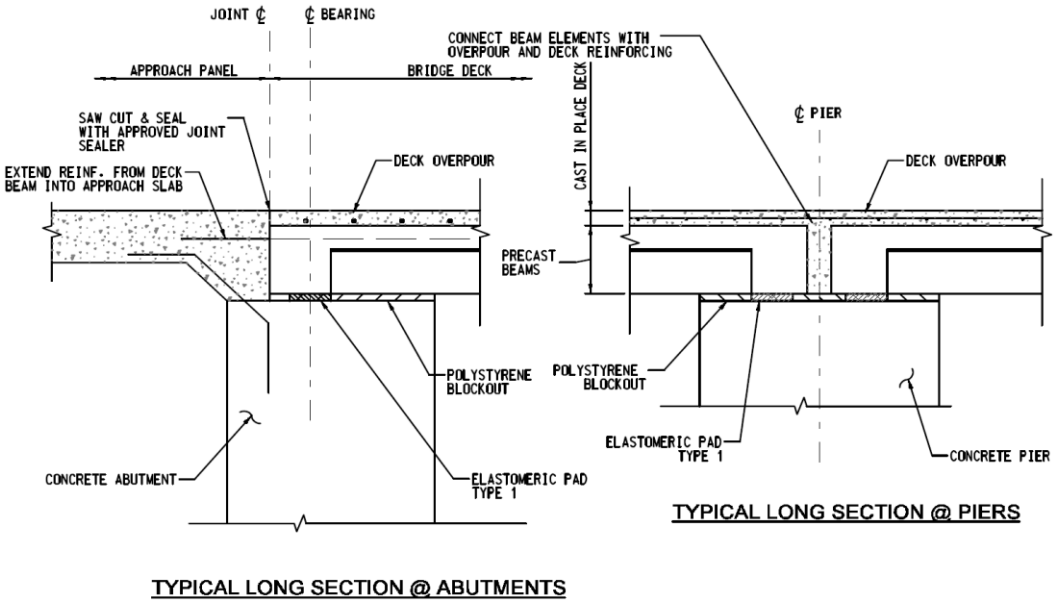


Figure 15 Transverse Connection between Beams over Pier and Abutment [U5]

Figure 16 Transverse Connection between Beams in Field

3 Connections between superstructures and substructures

Integral or semi-integral connections between superstructure and substructure are the most complicated ones. Integral connections have to transfer shear as well as moments between the piers, abutments and the superstructure. Only shear transferring semi-integral connections are less complicated but reduce the stiffness of the construction.

The most common form of connections between superstructure and substructure is a cast-in-place closure pour. Reinforcing extended from the precast elements forms the connection.

Examples

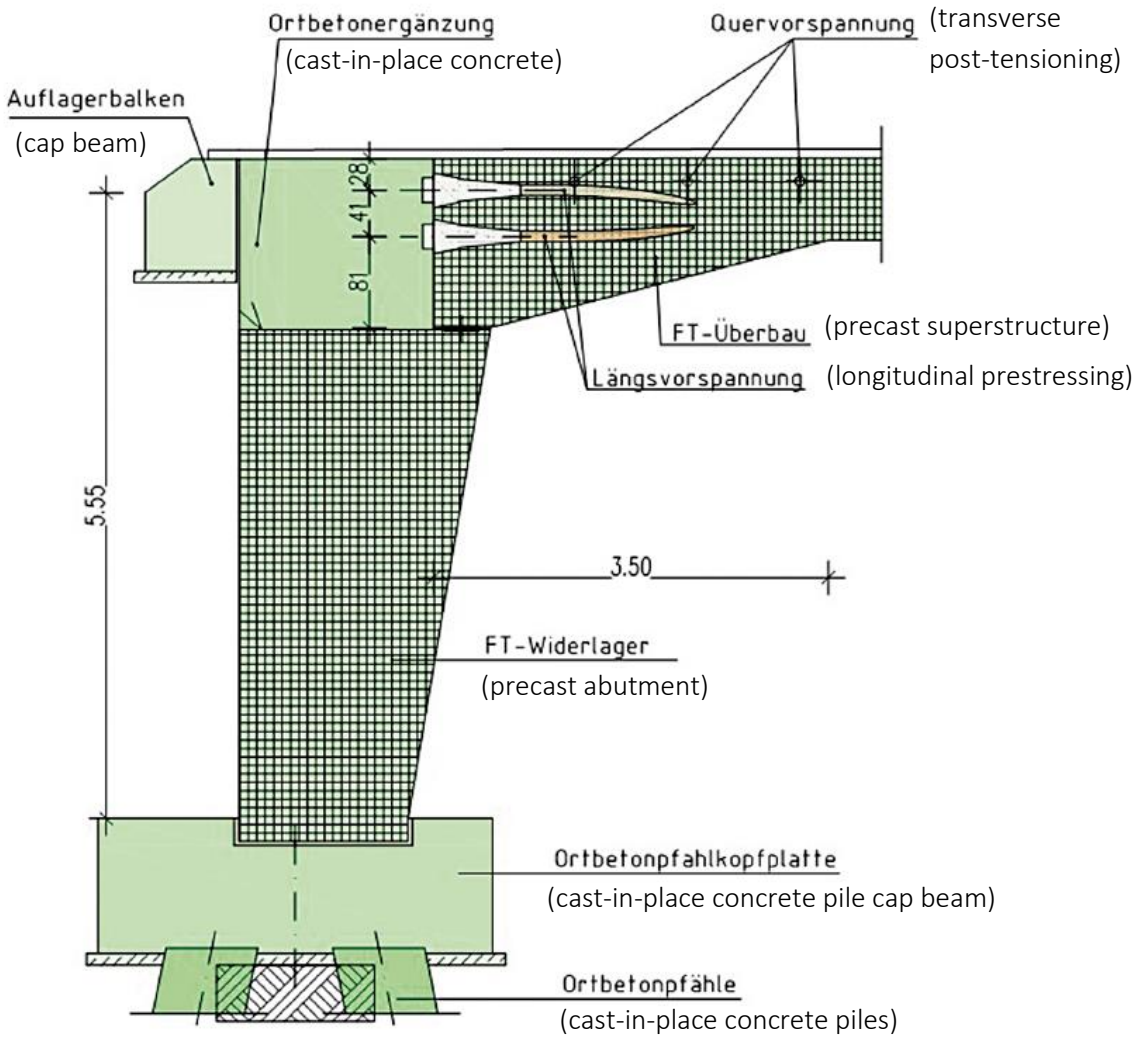


Figure 17 Integral Connection between Stringer and Abutment [U4]

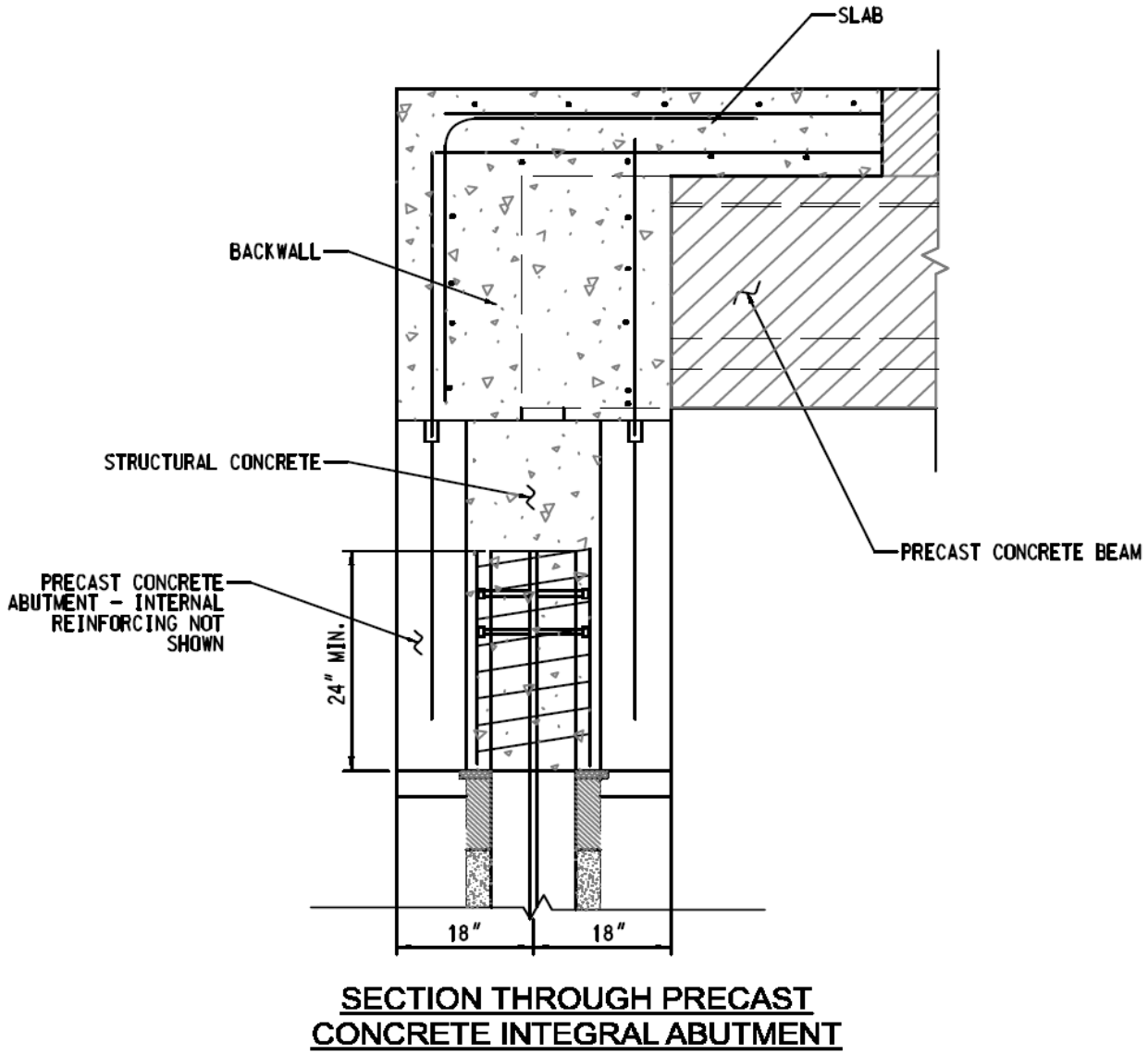


Figure 18 Integral Connection between Beam and Abutment [U5]

Figure 19 Integral Connection between Superstructure and Abutment

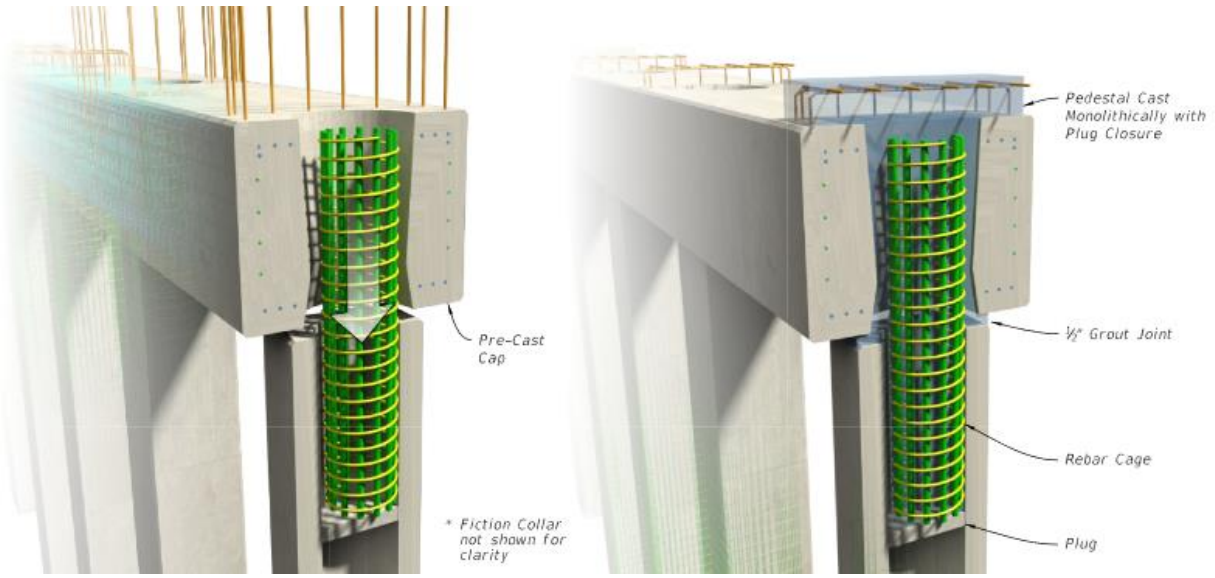


Figure 20 Connection between Cap and Pier [U9]

Figure 21 Connection between Column and Bridge Deck [U8]

4 Substructure connections

4.1 Pier elements

In the following the connections of the pier elements are treated. The pier elements are:

- Columns
- Cap Beams
- Wall Piers

Cap Beams are only needed if the bridge is built on columns. Wall piers can be connected to the superstructure without the use of cap beams.

4.1.1 Connections between columns and cap beam

For the connection between columns and cap beams extended reinforcing in the precast concrete piers is a common method. The reinforcing bars are inserted in pre-drilled holes in the cap beams and then potted. Additional post tensioning can be necessary.

Examples

Figure 22 Connection between Columns and Cap Beam

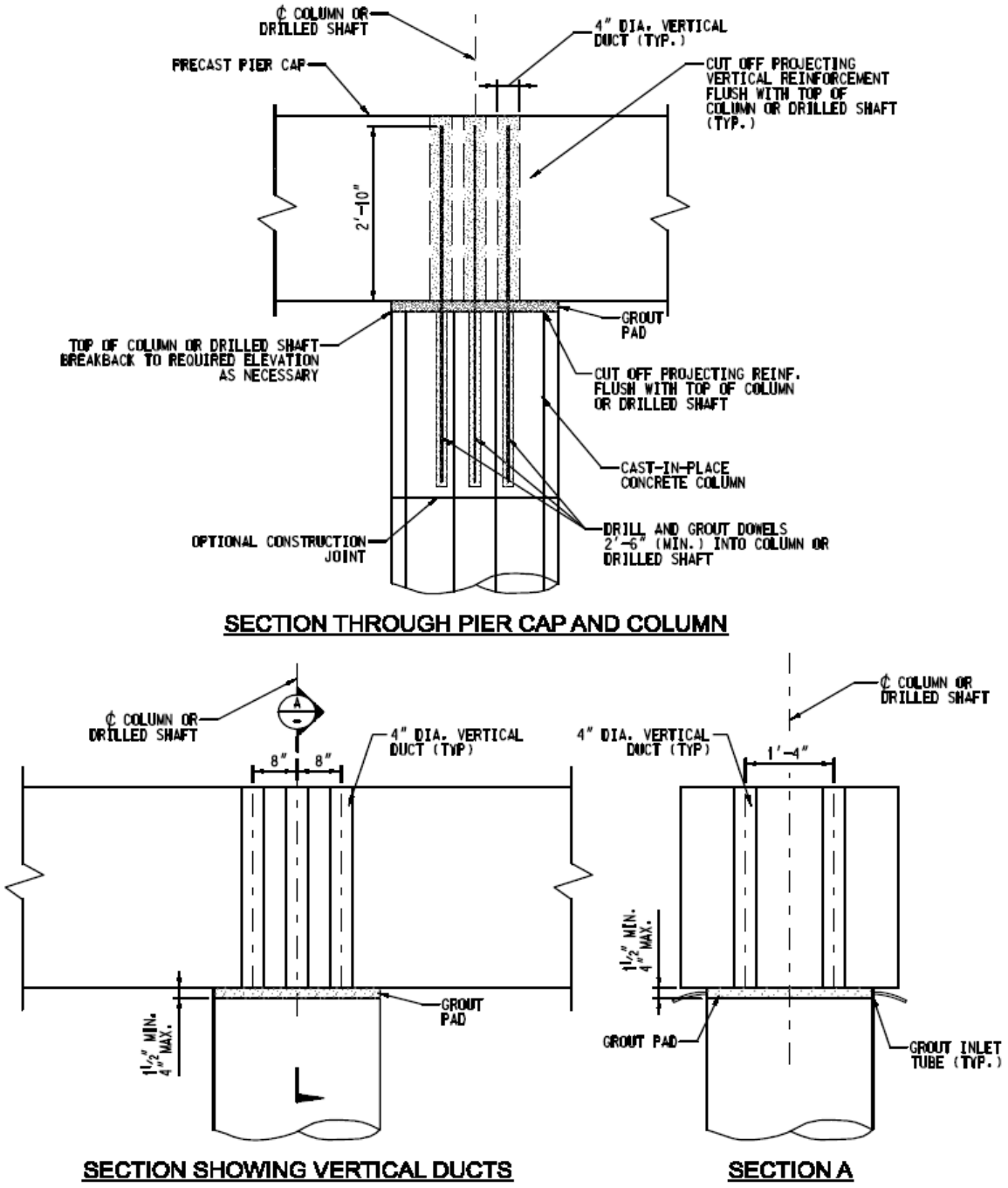


Figure 23 Connection between Columns and Beam Cap [U5]

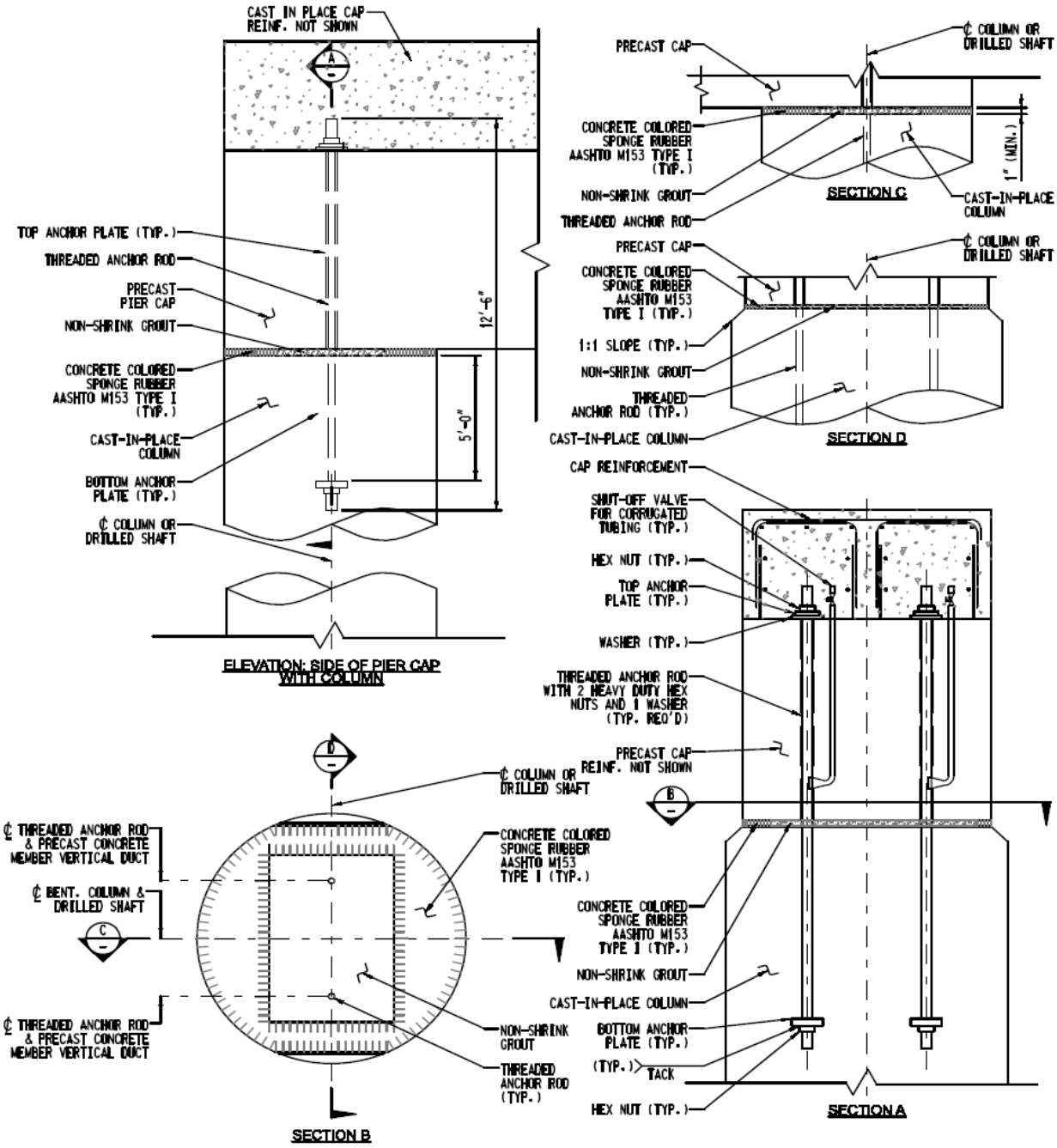


Figure 24 Connection between Bent Cap and Column [U5]

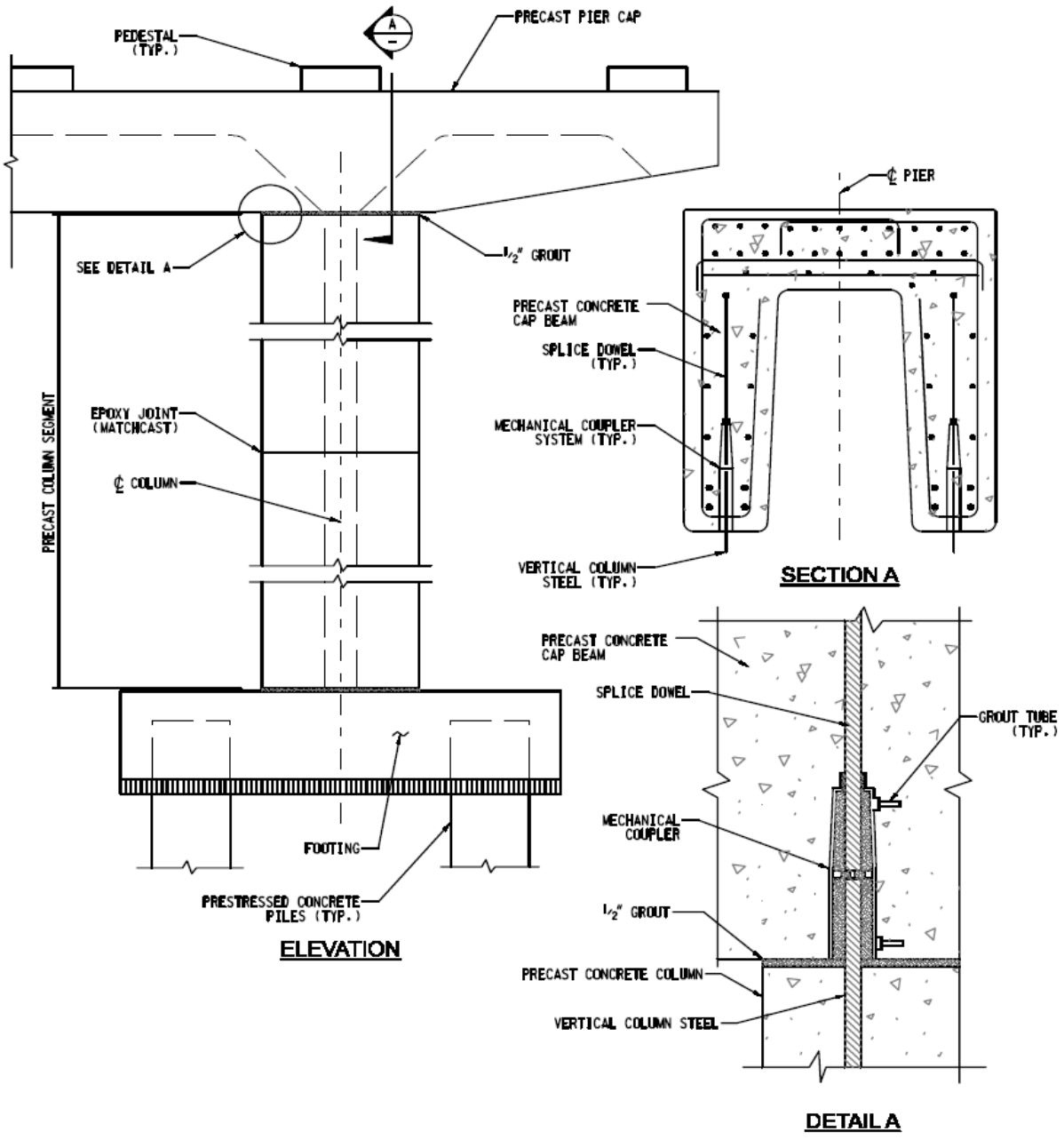


Figure 25 Connection between Cap Beam and Coloumn

4.1.2 Connections of pier element to pier element

Columns and Pier Walls often can't be prefabricated in one piece, so connections between pier elements are necessary. Similar to the connections between cap beam and column predrilled holes for inserting reinforcing bars can be used. The joints are epoxy bonded together and the whole pier gets post-tensioned.

Examples

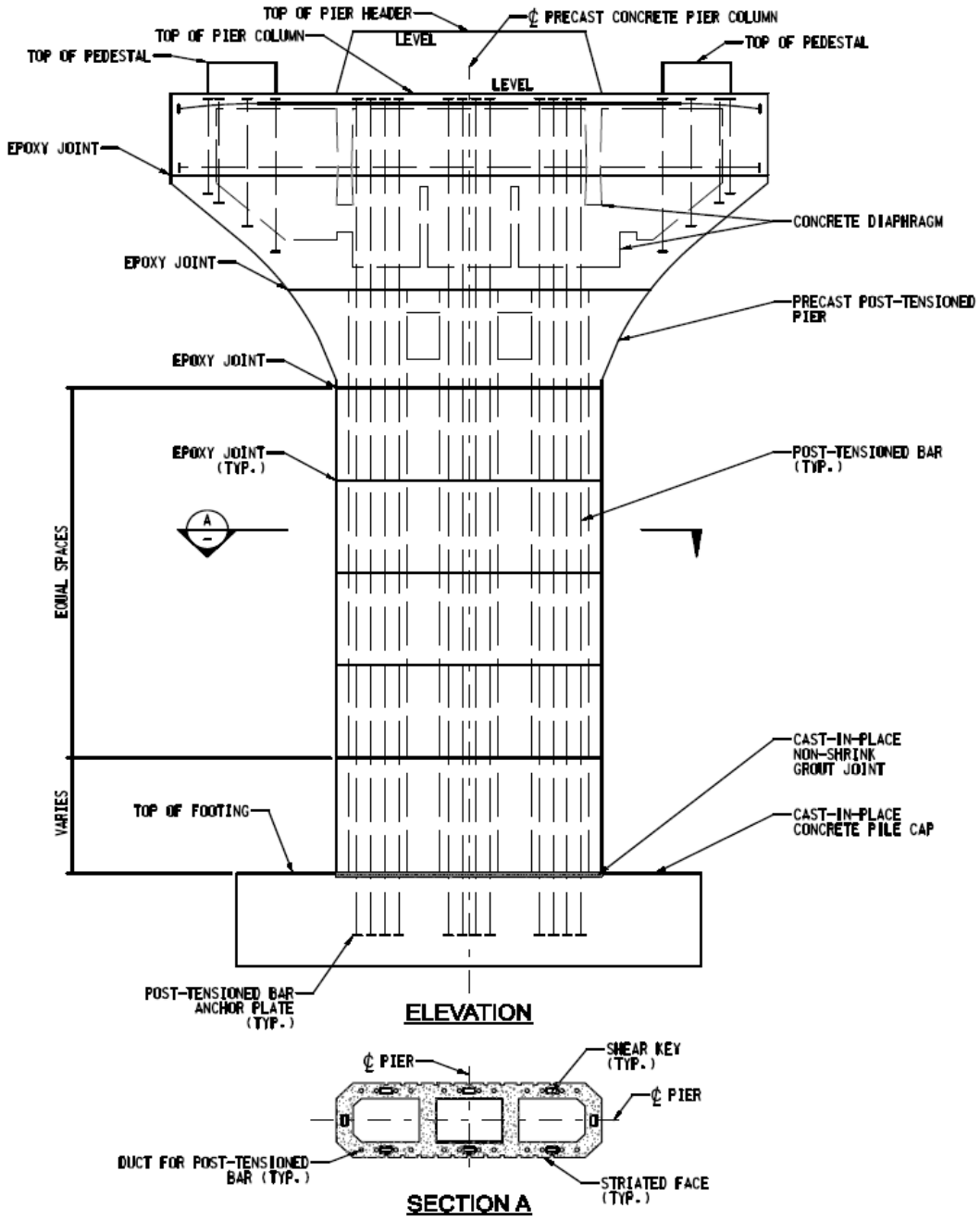


Figure 26 Connection of Pier Wall to Pier Wall [U5]

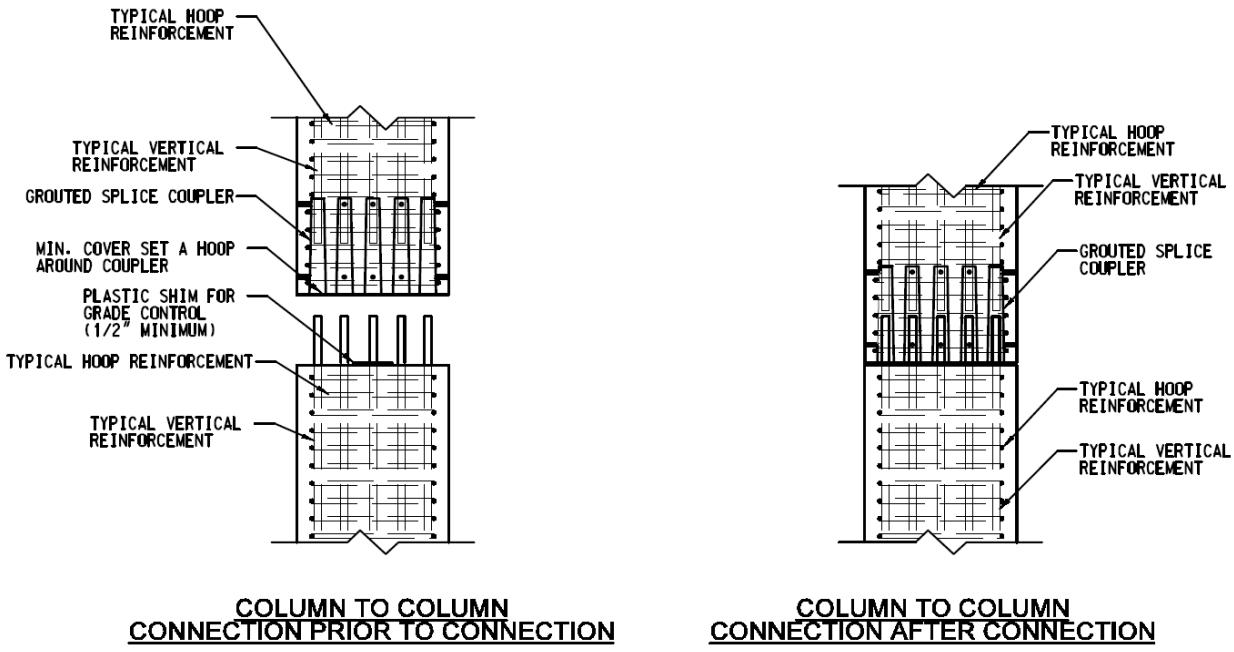


Figure 27 Connection of Column to Column [U5]

Figure 28: Reinforcement cage for prefabricated elements, to ensure the right position

Figure 29 prefabricated element drilled part; connection prior to connection

Figure 30 prefabricated element reinforcement part, connection prior to connection

Figure 31 connection after connection, before grinding

Figure 32 connection after connection, after grinding

4.1.3 Connection of pier elements to footing

The Connection between pier elements and footing is pretty much the same as between pier elements. Because footings are mostly made of cast-in-place concrete there are two ways to connect a precast pier element to the footing:

One opportunity is to bring the pier element with extended reinforcing bars in place, using temporary support and to form the footing around it.

Second opportunity is to connect both elements through reinforcing bars inserted in predrilled holes like shown before. This system needs to be post-tensioned.

Examples

Figure 33 Connection of Column to Footing

Figure 34 Connection of Column to Footing

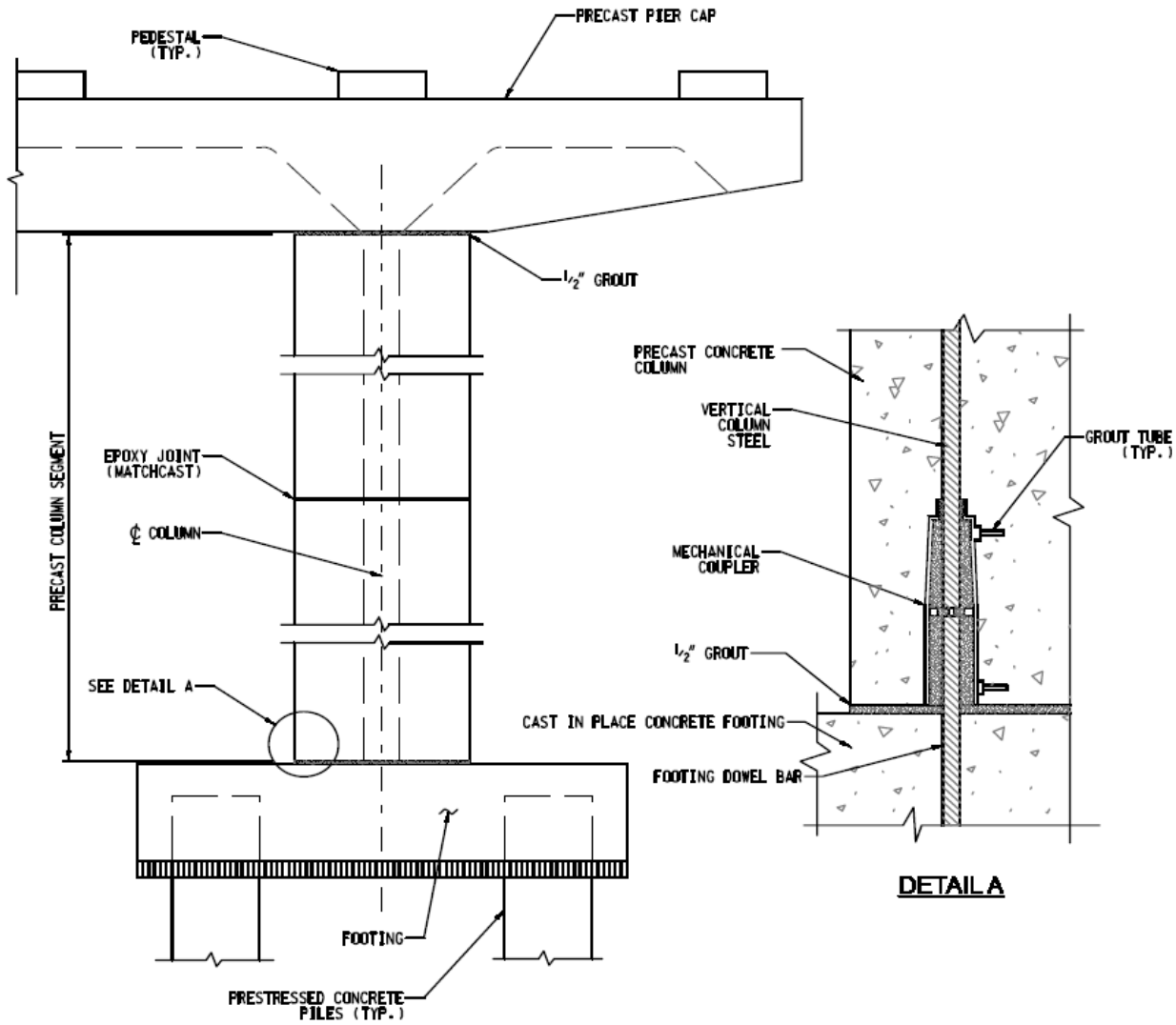


Figure 35 Connection of Column to Footing [U5]

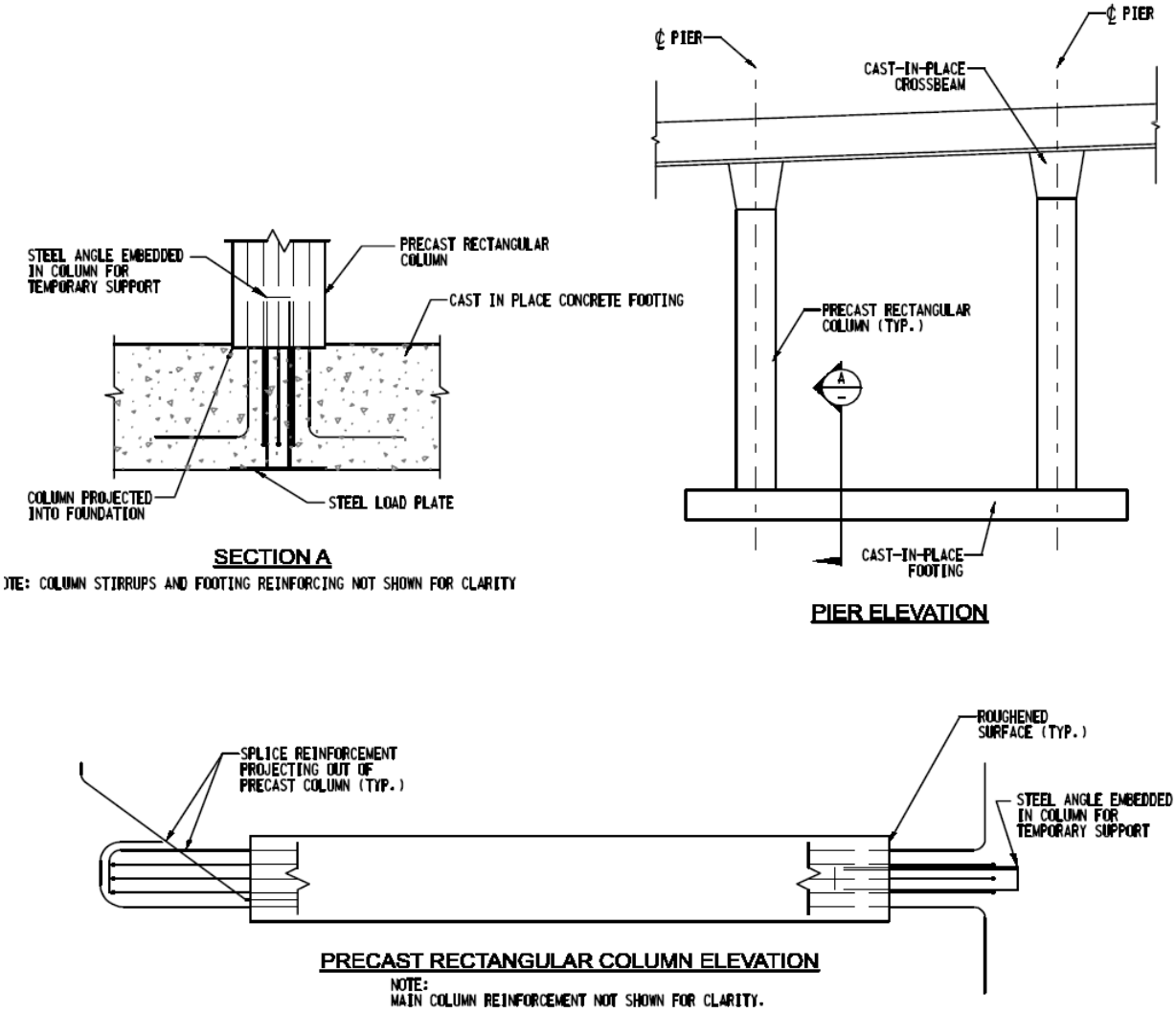


Figure 36 Connection of Column to Footing [U5]

4.2 Abutment systems

Integral abutments are connected to the superstructure, so the soil forces can be transferred to it and the abutment doesn't have to resist it. Therefore, it can be supported on a single or double row of piles and is designed to move with the bridge due to thermal cycles.

4.2.1 Connection between piles and abutment cap

The connection which will be treated in the following is the connection between the piles and the abutments stem. There are two main ways to connect a prefabricated abutment stem to concrete piles [U5]:

1. Extended reinforcing from the piles can be inserted in pre drilled holes in the abutment stem element. After placement, the holes are filled with non-shrink concrete.
2. The piles can also be embedded in pockets in the abutment stem element. After placement the void gets filled with non-shrink concrete as well.

Examples

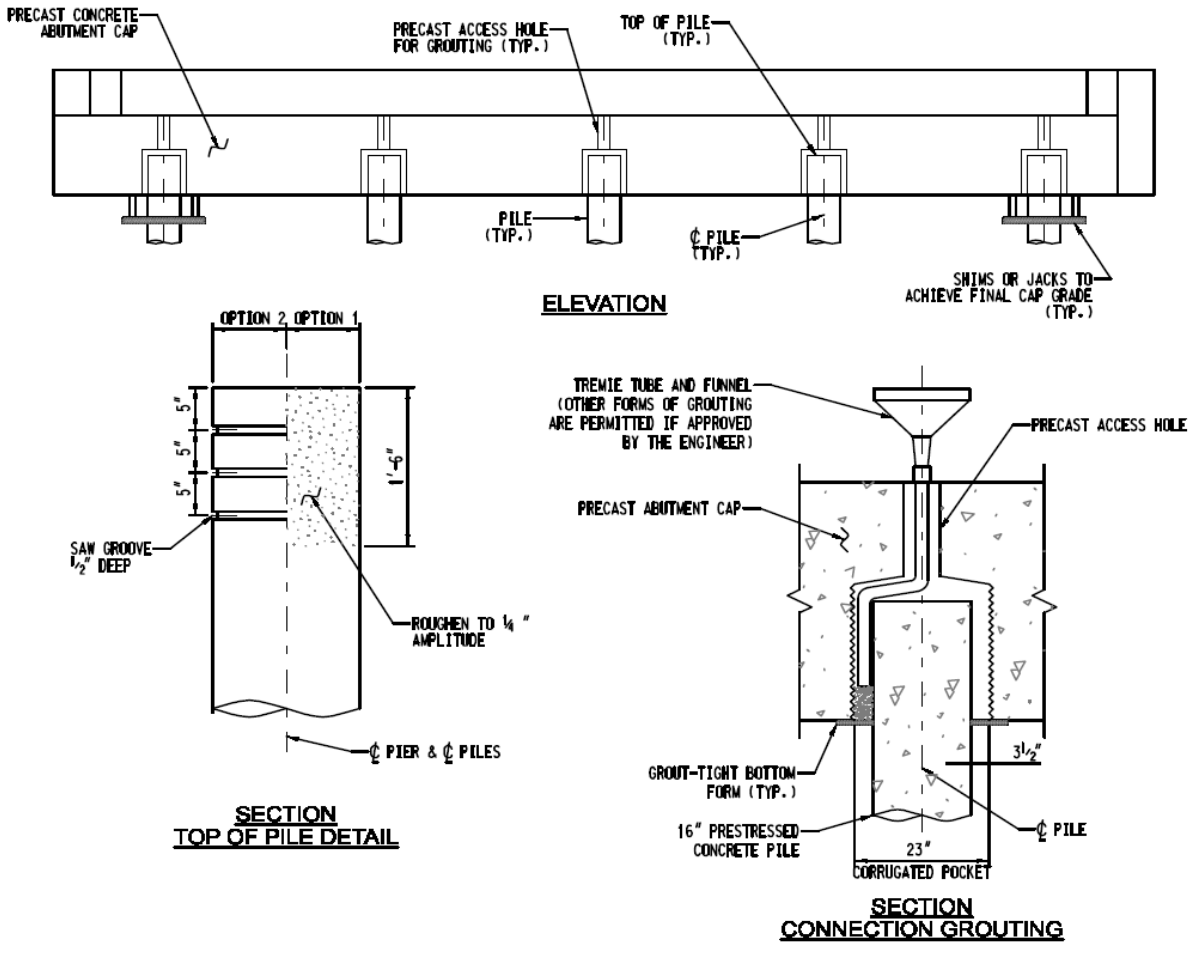


Figure 37 Connection between Abutment Cap and Piles [U5]

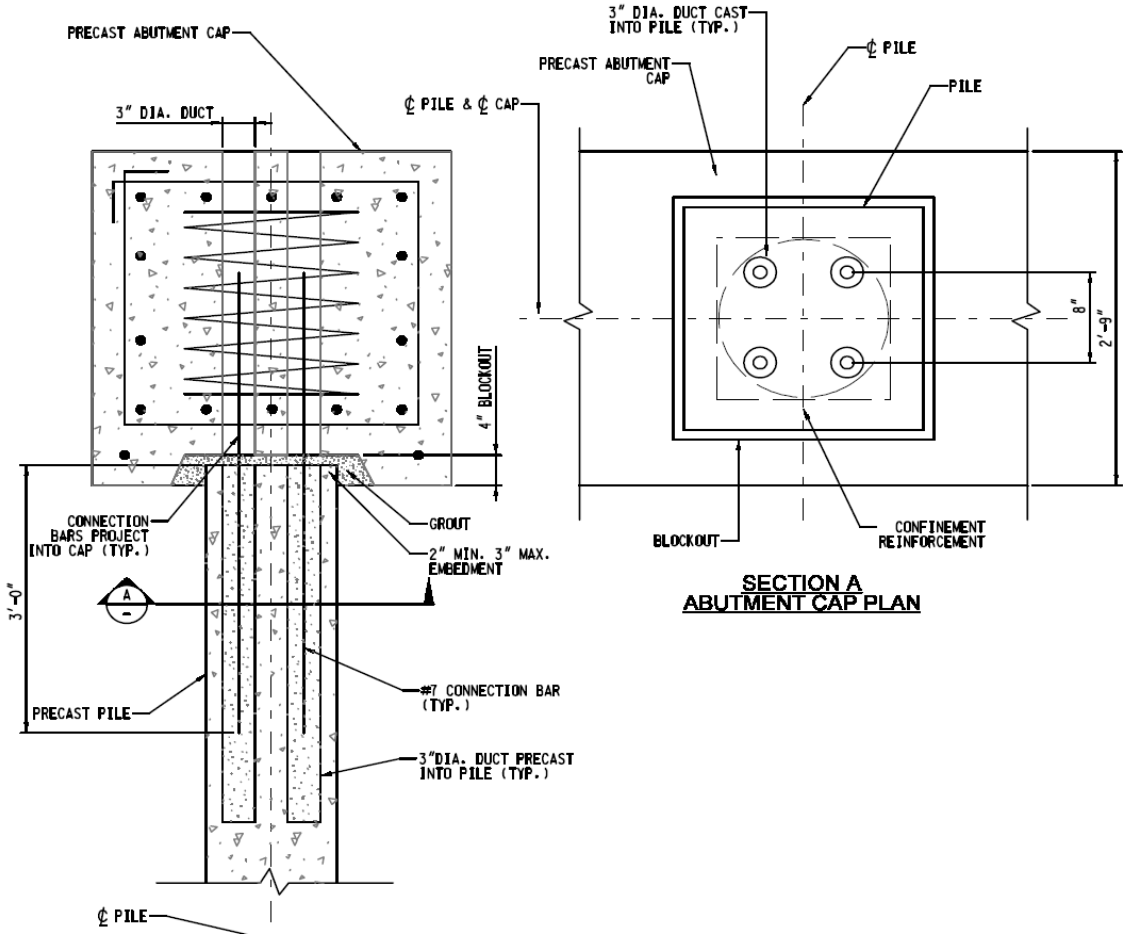


Figure 38 Connection between Abutment Cap and Pile [U5]

4.2.2 Connection between abutment stem and abutment cap

Connections between abutment stems and abutment caps can easily be made with extended reinforcing bars which are inserted in pre drilled holes. Non-shrink concrete or grout is used to complete the connection.

Example

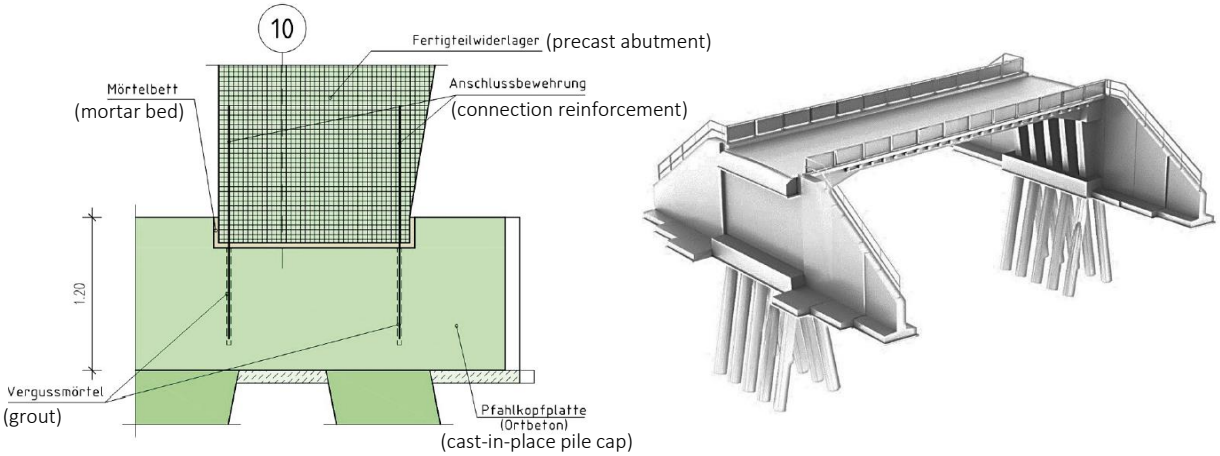


Figure 39 Connection between Abutment Cap and Abutment Stem [U4]

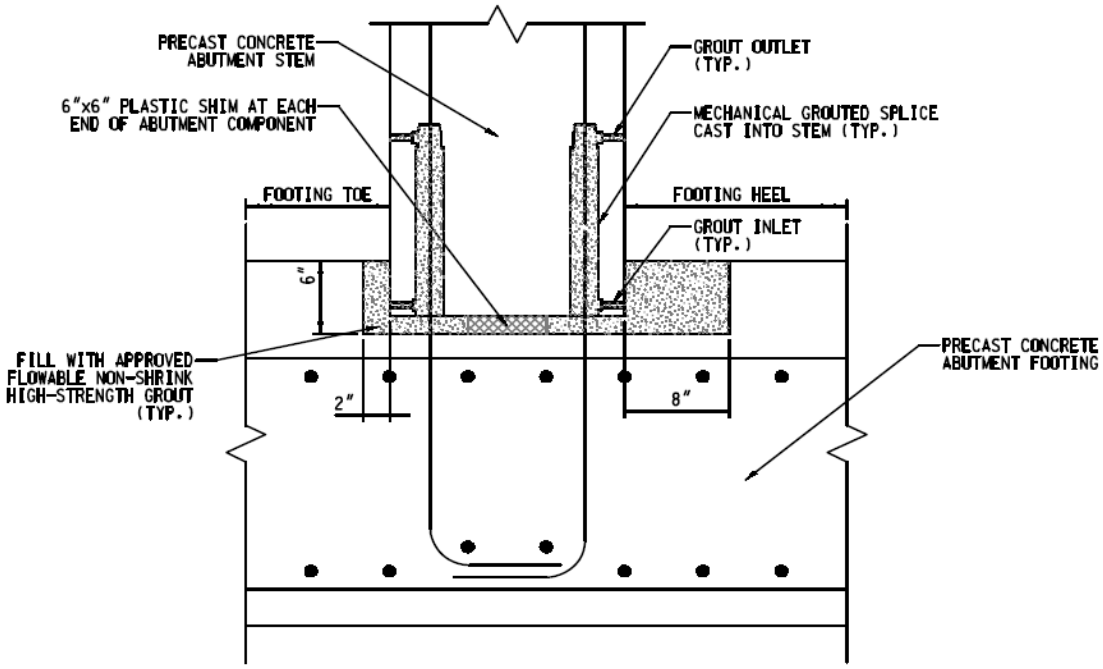


Figure 40 Connection between Footing and Abutment Stem [U5]

4.2.3 Connection between adjacent abutment atems

If the abutment stem can't be prefabricated as one piece, there is need for a connection between the elements. Normally there is no need for a complicated connection. Small closure pours combined with post-tensioning to transfer shear between the elements are sufficient.

Example

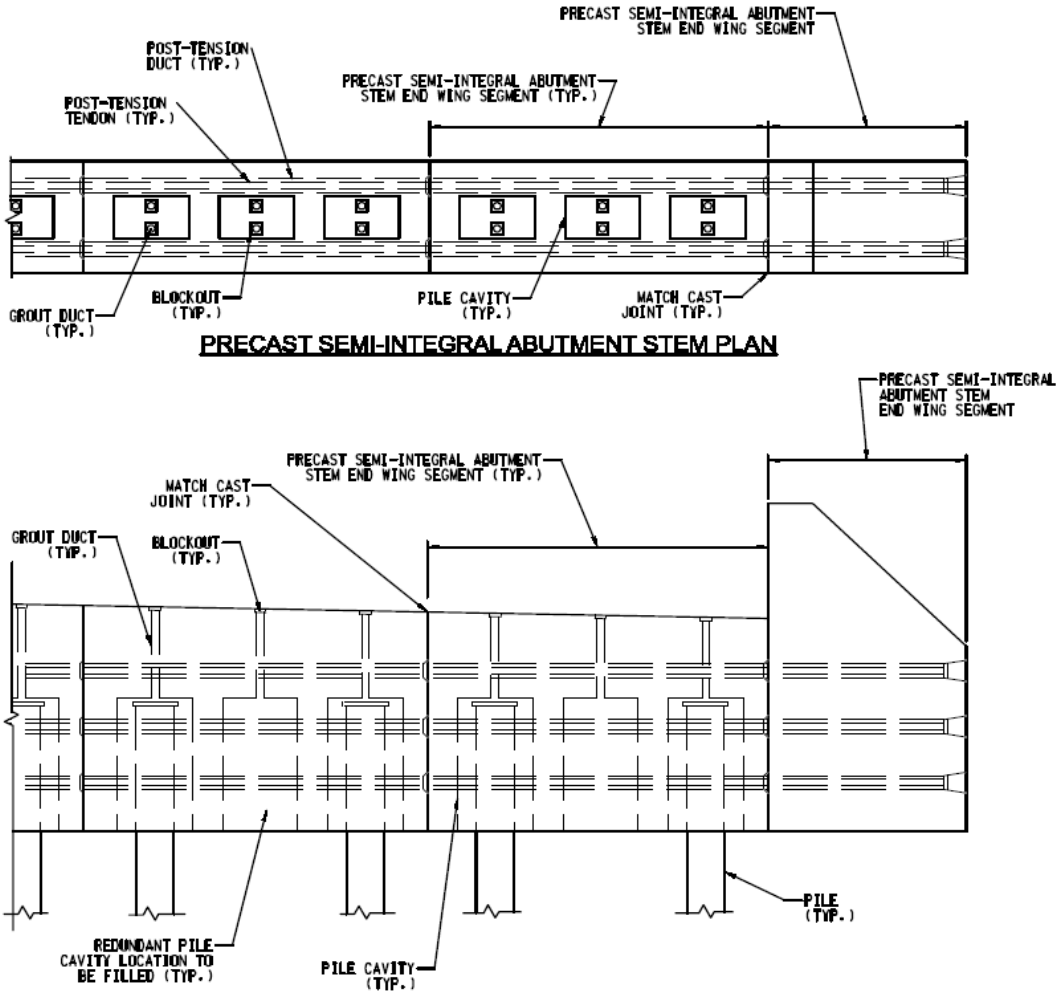


Figure 41 Connection between Adjacent Abutment Stems [U5]

Final leaf

Hannover, 27.09.2019