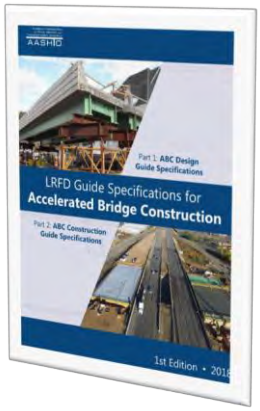
# ABC-UTC 2023 In-Depth Web Training Module 1

## Available Precast Substructure Specifications and Resources





Presented by:
Michael P. Culmo, PE
Chief Bridge Engineer
CHA Consulting, Inc.

September 12, 2023

CHA



# Project Design Development Needs

- In order to execute a project, the designer needs three major items

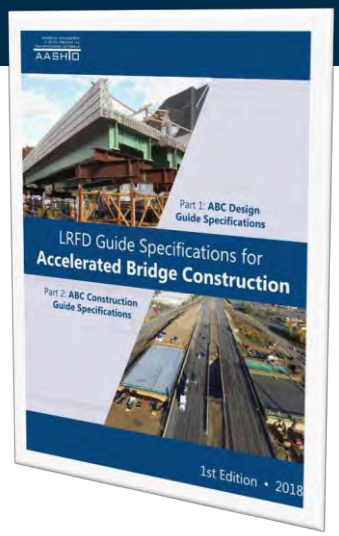

Design Specifications

Construction Specifications

Resources exist to cover all three of these items for substructure design

# 2018

## AASHTO LRFD Guide Specifications for Accelerated Bridge Construction




- Many substructure connection details are included
  - UHPC
  - Pocket & Socket Connections
  - Lapped bar reinforced connections
- Includes Seismic Provisions
- For more information:
  - Refer to previous FIU ABC UTC Webinars
  - Search NCHRP Projects
  - Locate Project 12-102A Website
    - Detailed training modules are available



# Specification Overview

- Guide Specification Contents

1. Design Introduction
2. General Design Provisions
3. Design of Prefabricated Elements
4. Detailing Requirements
5. Durability of ABC Technologies

Design Specifications

6. Construction Introduction
7. Temporary Works
8. Fabrication and Assembly Planning
9. Layout and Tolerances
10. Concrete Structures
11. Steel Structures
12. Geosynthetic Reinforced Soil / Integrated Bridge System

Construction Specifications

# Emulation Design Theory

## Design precast substructures to "Emulate" Cast-in-place concrete

- This is the basis for virtually all of the AASHTO LRFD Guide Specifications for ABC
- The only differences are the connections
  - Construction Joints → Precast Connections
- If an emulation approach is used:
  - The design of the substructure is the same as cast-in-place construction



# 2022 PCI NE Substructure Guide

- Includes detailing for all substructure types
- Based on the AASHTO LRFD Guide Specifications for ABC
- Includes Seismic Details
- Published May 13, 2022
- Available at: WWW.PCINE.ORG
- Let's take a look

Construction Details

# Guidelines for Precast Substructures used in ABC

## Introduction

This guide is a replacement for the previously published *Guidelines for Accelerated Bridge Construction* developed by the PCI Northeast Bridge Technical Committee (2014). Previous editions of that document included general information on Accelerated Bridge Construction (ABC) including the use of full-depth precast concrete deck panels. In recent years, there has been a significant amount of publication of ABC related information including the *2018 AASHTO LRFD Guide Specifications for ABC*. Based on this, a significant reduction in information in this document was in order to avoid conflicting information. This document focuses on recommended guide details for precast substructure elements. These guideline drawings represent typical details for the design and detailing of precast concrete substructures. The details presented provide an example of the drafting layout of typical precast concrete substructures. Several different substructure types are shown. The details cover a majority of the substructures used in the Northeast. Details and reinforcement shown are schematic. The designer should design and detail each substructure according to the specific requirements of each bridge.

Pertinent information from the previous PCI Northeast *Guidelines for Accelerated Bridge Construction (2014)* are included below.

The use of precast elements such as abutments, pier caps, pier columns, and precast footings can effectively minimize construction time, traffic disruption, and the impact of construction activities on the environment. Details have been revised and developed for the various substructure elements that represent the technologies that are covered in *2018 AASHTO LRFD Guide Specifications for ABC*. **This guide is not intended as a stand-alone document and does not supersede the AASHTO specifications.**

## Designer Responsibilities

It is the designer's responsibility to:

- Design and detail all substructure elements, including but not limited to, components such as piers, abutments, footings and foundations.
- Design precast concrete substructure elements in accordance with the latest edition of the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*.
- Design and check the substructure elements for all anticipated loads.
- Detail dimensions of all elements including internal reinforcing.
- Specify and detail tolerances for both fabrication and installation of all elements. See tolerance notes and details.
- Calculate elevations of top of all precast elements. Elevations to be included on all details.
- Determine the geotechnical requirements of the site and place the applicable information on the plans.
- Place applicable general notes on the plan set.
- Show the estimated weight of each element on the plans.

## Special Notes to Designers

This document depicts schematic reinforcement details. These details have been simplified for clarity by representing reinforcing as a single line. When developing specific project design details, it is important for the designer to detail all embedded items and reinforcing using actual bar diameters (including deformations), actual bend diameters, and tails used in development hooks. This will help identify conflicts during the design process. The reinforcement depicted is not guaranteed. The final design of each element may require additional reinforcing bars and different bar layouts.

## Geometric Configurations

It is preferable to have angles between abutment and wingwalls that are in-line or 90 degrees, although odd angles can be accommodated. The designer should detail elements sizes to promote repetition of forming with consideration given to transportation, fabrication, and construction. Footing widths may be detailed such that there are common dimensions on each bridge project. For instance, on a particular bridge, all footings for wingwalls that are of approximately equal height could be kept identical (dimensions and reinforcing). The economies of repetition may outweigh the perceived benefits of individually sized elements.

Battered elements should be avoided. Batters on abutment and wing stems should be eliminated and the overall thickness of the stems should be minimized to reduce the overall weight of the element. Wall type elements typically are cast horizontally as slabs.

## Tolerances

Designers should specify and account for tolerances in layout of elements and in the width of joints. Designers should specify tolerances for precast elements including fabrication tolerances, erection tolerances (both horizontal and vertical), pile driving tolerances (if applicable), and joint width tolerances. The specified width of joints should be based on the specified tolerances. A recommended guideline for specifying tolerances is *Proposed Guidelines for Prefabricated Bridge Elements and Systems Tolerances*, published under NCHRP Project 12-98. This guideline is available at the PCI Northeast website (www.pcine.org). These guide details include examples of tolerance detailing based on this document.

Recommended element fabrication tolerances are shown on Sheets SUB 15 and SUB 16. These are based on industry practice and should only be reduced after consultation with fabricators. If precast elements are to be connected to cast-in-place concrete, coordinate tolerances between shop and field personnel.

Recommended element erection tolerances are shown on various details within these guide details. Horizontal erection tolerances are always based on measurements from a common working point or line. Erection of elements based on center to center spacing should not be used as this could lead to build up of tolerances.

Recommended joint width tolerances are shown on various details within these guide details. The width of joints between elements are a function of element tolerances, erection tolerances, and placement of fill materials. The width of joints shown in these guide details should not be reduced without careful consideration of tolerances. If narrower joints are desired, smaller tolerances would need to be specified for element tolerances and erection tolerances (Refer to *Proposed Guidelines for Prefabricated Bridge Elements and Systems Tolerances* listed in the reference section of this document for guidance on specifying joint width tolerances based on specified tolerances). Note that smaller tolerances will lead to higher costs.

Vertical erection tolerances should be measured during erection at the top of each element as shown on the guide details. Horizontal joints are provided to accommodate element height tolerances during erection.

## Shipping and Handling

The size of precast elements should be determined with consideration of shipping restrictions, equipment availability, and site constraints. In general, the maximum weight of precast substructure elements weighing on the order of 30 tons should be anticipated. In special cases, very large pieces can be detailed; however, the shipping, handling, and installation costs should be considered. It is possible to ship pieces in excess of 30 tons; however, the equipment required, and the limitation of local bridge load postings may restrict this. Off-loading of pieces can also be problematic. Larger pieces may be feasible if the pieces can be fabricated in close proximity to the bridge and shipped a short distance.

The designer should consider each state's requirement for allowable shipping widths and lengths. The following are general recommendations for maximum sizes of elements (including any projecting reinforcing):

- Width: 12 feet
- Height: 10 feet
- Length: 120 feet

The maximum dimensions noted are chosen to avoid cost premiums typically associated with shipping of large elements over the road. Precast elements shall be checked for stresses induced during handling and shipping. The design for handling is the responsibility of the fabricator (or contractor). The *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction* contains recommended provisions for shipping and handling calculations.





7

# Guidelines for Precast Substructures used in ABC

## Special Materials and Devices

The details contained herein show common precast concrete elements. Some of the details show materials and products that may not be typically found in precast bridge elements. The following is a list of special materials and devices that are shown in these guide details:

- Corrugated Metal Pipe (CMP) Voids: Research has shown that standard galvanized CMP drainage pipes can be used to form voids within precast elements. These voids can be used to make connections between elements and to reduce the weight of the elements.
- Grouted Splice Couplers: These devices can be used to connect reinforcing steel bars. They are mechanical devices that meet the requirements of mechanical connectors as defined in the *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*. These devices are proprietary; however, they are available from multiple manufacturers.
- Leveling Devices: These are devices that are fabricated to allow for fast and accurate adjustment of the vertical elevation of elements. They are typically designed by the fabricator as part of the element lifting and placement hardware. The details depict one type of device. Alternate devices should also be allowed in the project specifications.
- Non-Compressible Shims: Several details depict the use of non-compressible shims between precast elements. The Contractor should be given leeway to select an appropriate material; however, steel shims should be avoided as there is potential for the shims to concentrate forces under the shims due to the relative stiffness of the shim versus the adjacent grout. There are specialty multipolymer shim products in the precast industry that are formulated for this purpose and are acceptable and recommended for this application.

## Construction on Bedrock

A more extensive soils boring program should precede construction of precast footings so that the degree of variation of top of rock elevations can be assessed prior to construction. The uneven nature of construction of footings on bedrock may require preparation of the site prior to installation of precast footings. Over-blasting of rock by approximately 12" to provide room to prepare for a level work area is recommended. This will facilitate the installation of flowable fill or lean concrete under the footings. Designers should consider the use of cast-in-place concrete footings for footings founded on bedrock.

## Construction on Soil

Prior to construction on soil, the area must be excavated and prepared as in conventional cast-in-place construction. Once the area is prepared, there are two recommended methods for preparing the area for installation of precast footings. The first is to pour a low-strength concrete sub-footing to a level that is just below the proposed bottom of footing elevation. The second method is to provide small level areas under the proposed leveling devices or shims. Temporary load distribution plates will be required under the leveling devices or shims when a sub-footing is not used in order to spread the loads to the soil. This method is more cost effective; therefore, it should be considered for most situations.

## Construction on Piles

The use of precast footings (or pile caps) can be difficult. Typical pile driving tolerances lead to oversized voids for pile connections. It is recommended that cast-in-place concrete footings and pile caps be used for footings on pile foundations. These guidelines contain several options for footings on pile foundations.

Precast integral abutment stems are recommended. The typical width of integral abutment stems can often include larger voids that can accommodate pile driving tolerances. The size of the void should be based on driving tolerances. These guide details include recommended void sizes for different driving tolerances (See Sheet SUB 16).

## Grade Control for Precast Footings

Leveling devices are critical in maintaining proper vertical grade control on precast concrete substructures. Embedded leveling devices can be used to allow for adjustment of the footing grade and elevation during installation. A minimum of four leveling devices should be specified for each spread footing element. Each device should be designed to support half the self-weight of the footing element. Experience has shown that these leveling devices provide fast and easy grade adjustment; however, it comes at a cost. Leveling shims can be used; however, the elevation of the non-compressible shim packs should be carefully established in order to erect the footings within the specified erection tolerance.

## Concrete and Grout Notes

Precast concrete:

In general, designers should specify concrete with a minimum compressive strength of 5000 psi. The mix design of the precast concrete should normally be developed by the precast fabricator and approved by the owner.

Site cast concrete and grout:

The designer shall specify the minimum concrete properties for the final construction (strength, cure time, etc.). The engineer responsible for the assembly plan shall specify the required concrete strengths for various stages of the assembly based on calculations developed for the assembly plan. For example: the assembly plans could specify a concrete strength in a closure pour of 2 ksi for a certain stage of construction, provided that the concrete gains the full design strength prior to opening the bridge to traffic.

Recommendations for site cast concrete mixes:

Most states have standard concrete mixes for bridge construction using conventional construction. Accelerated bridge construction projects often require concrete that can gain strength and cure in a rapid manner. Material performance specifications are recommended in lieu of rigid prescriptive specifications. The following concrete strength parameters are suggested for use on prefabricated bridge projects.

- Very early strength concrete: Concrete that will attain the design strength in less than 12 hours
- Early strength concrete: Concrete that will gain the design strength in less than 24 hours
- Conventional concrete: Concrete that will gain the design strength in 7* to 28 days (* Agencies have found that their standard conventional bridge deck concretes can reach a typical strength of 4 ksi in as little as 7 days.)

Shrinkage of early strength concrete can lead to cracking. For this reason, shrinkage compensating admixtures should be considered. Liquid admixtures should be used in lieu of expansive metallic powders.

It is recommended that the states work with local ready-mix producers to develop acceptable mix designs that can meet the required parameters. Ideally, these mixes should be developed prior to bidding an accelerated bridge construction project.

Controlled density fill (flowable fill):

Controlled density fill can be used to fill voids that are not subjected to high unit stresses and are not reinforced. The strength of controlled density fill is often less than non-shrink grout: however, the required strength under a footing is typically well within the limits of common controlled density fills, as most spread footings exert pressures that are less than 100 psi. This will normally include areas that are used to seat footings and slabs. Typical areas include voids under footings and approach slabs. Controlled density fills have relatively slow set times. Use grout to fill voids if fast set times are required. Designers should verify the acceptability of the use of flowable fills with the owner.

Grout:

Grout should only be used for small void grouting. The required strength of the grout should be determined and specified by the design engineer. Normally the design strength is the same strength as the surrounding concrete.

Flowable grout should be specified in areas that require significant horizontal flow of the grout in order to fill the void. This would normally include horizontal joints between vertical elements. For complex voids, the





8

## Guidelines for Precast Substructures used in ABC

engineer may specify a test mock-up grout pour prior to the actual construction. The mock-up should be similar to the final configuration. The contractor should be required to demonstrate that the grout can be placed without voids. This can be proven by dismantling of the mock-up after grout curing.

### Joints and Connections between Elements

Joints fall under two categories. The first category is structural connections that transmit moment, axial, or shear forces between elements. The second category is non-structural connections that may be used for thermal movements or to separate discrete portions of the structure (e.g., abutment to wingwall joint). This guide contains multiple details for different joints and connections between various precast elements. In most cases, several options are provided.

Surfaces of joints should be specified to have an exposed aggregate finish. This is achieved through the use of retarders applied to the forms and/or water blasting after stripping. A specific profile amplitude need not be specified. If the designer prefers to specify an amplitude, it should be specified as 1/8".

### Vertical Joints

A flowable, cementitious grout should be used for vertical joints. It should be introduced at the top of the joint, filling it from bottom to top. Designers should specify the use of rigid formwork for the joints and rodding of grout during installation to minimize voids as a significant hydraulic head will be created due to the typical height of the joints being filled. Backer rods placed at the edges of the enclosed vertical joint as a dam against the fluid grout will not be adequate in restraining the grout due to the fluid pressure. It is recommended that such a joint be restrained with formwork in most cases.

If shear transfer is not required, consider filling this joint with expanding foam sealant or other fillers. This treatment may be considered adequate if the joint is deemed non-structural. The expanding foam keeps the joint free of foreign material. Pre-applied rigid joint filler materials are not recommended. Inserting rigid fillers after assembly is also not recommended. Experience has shown that tolerance between the elements will be compromised with the use of rigid fillers. Installation of rigid fillers after assembly is nearly impossible and results in a poor quality joint. Note that non-structural joints are not shown in the enclosed details.

### Design of Connections

The design of connections shall be in accordance with the *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*. The design provisions for the connections shown in these guide details are covered in this AASHTO Specification. Seismic connections are included in these guide details. Refer to the *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction* for special design requirements for seismic applications. Several of these connections require additional reinforcement within the precast element to achieve the proper seismic performance. It is acceptable to use seismic details in non-seismic regions.

### Construction Specifications

The previous versions of these guide details included significant construction specifications and recommendations. The AASHTO LRFD Guide Specifications for Accelerated Bridge Construction now contains similar provisions and more; therefore, they should be used for the development of construction specifications for precast elements.

### Repair of Non-conformances and Damage during Fabrication and Shipping

As with any manufacturing process, non-conformances and damage can occur in precast concrete bridge products. Examples may include voids, cracks, as well as missing, improperly located, or damaged reinforcement and hardware. The repairs of non-conformances and damage should be in accordance with the document entitled *Guidelines for Resolution of Non-Conformances in Precast Concrete Bridge Elements (Report No: PCINE-18-RNPCBE)* and can be found at www.pcine.org.

### References:

The following references should be used for the development of designs, details, and construction specifications for precast bridge elements. Edition numbers are not included in this list. Designers should use the latest edition of these documents unless the owner places specific limitations on usage of editions.


1. *AASHTO LRFD Bridge Design Specifications*, American Association of State Highway and Transportation Officials.
2. *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*, American Association of State Highway and Transportation Officials.
3. PCI Documents (located at www.pci.org)
   a. *PCI Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products*, PCI MNL-116, Precast/Prestressed Concrete Institute, Chicago, IL.
   b. *Bridge Design Manual*, PCI MNL-133. Precast/Prestressed Concrete Institute, Chicago, IL.
   c. *PCI Design Handbook Precast and Prestressed Concrete*, The Precast Prestressed Concrete Institute, Chicago, IL
   d. *Erection Safety for Precast and Prestressed Concrete*, PCI MNL-132, Precast/Prestressed Concrete Institute, Chicago, IL.
   e. *Erectors Manual—Standard and Guidelines for the Erection of Precast Concrete Products*, PCI MNL-127, Precast/Prestressed Concrete Institute, Chicago, IL.
4. PCI Northeast Documents (located at www.pcine.org)
   a. *Guidelines for Resolution of Non-Conformances in Precast Concrete Bridge Elements*, (Report No: PCINE-18-RNPCBE)
5. FHWA Manuals and Guidelines
   a. *Accelerated Bridge Construction - Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems*, (FHWA-HIF-12-013), U.S. Department of Transportation, Federal Highway Administration, November 2011.
   b. *Engineering Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems*, (FHWA-HIF-17-019), U.S. Department of Transportation, Federal Highway Administration, November 2013.
   c. *Contracting and Construction of ABC Projects with Prefabricated Bridge Elements and Systems*, (FHWA-HIF-17-020), U.S. Department of Transportation, Federal Highway Administration, November 2013.
6. NCHRP Project 12-98, *Proposed Guidelines for Prefabricated Bridge Elements and Systems Tolerances*, (available at www.pcine.org), National Cooperative Highway Research Program, Washington, D.C.


### Usage of this Document:

The following page contains a usage table for each detail contained herein. The table includes the following:

- The connection detail title and sheet location where connection details reside
- Sheet reference where the connection details are recommended for use
- Advantages of each connection detail
- Design/Construction Considerations for each connection detail

The table contains hyperlinks that will bring users to the referenced sheet. Each detail sheet also contains a hyperlink that will return the users back to the table.





9

Detail Usage Table

## Guidelines for Precast Substructures used in ABC

There are options for each connection depicted in these guide details. The designer should choose connection details that are appropriate for the bridge being designed and approved by the owner. It is recommended that the number of different connections in a project be minimized in order to simplify the fabrication and construction. The following table outlines the advantages and disadvantages of each connection to aid in the selection of details.

| Detail Title (sheet #) | Detail Usage Reference (sheet #) | Advantages | Design/Construction Considerations |
|---|---|---|---|
| G1 Grouted Coupler Connection Precast Column to Wall Panel or Footing (08) | (01) (02) (03) (04) (05) (06) | • Placement of couplers is outside the potential plastic hinge zone<br>• Coupler can be pre-grouted just prior to placement of the upper element<br>• Upper element bars can be placed closer to the column face | • Potential for debris to get into coupler during construction (will require covers and cleaning prior to placement of upper element)<br>• Upper element will have projecting bars that may get damaged during handling |
| G2 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (05) (06) | • Less chance of debris getting into the coupler during construction<br>• Upper element is easier to handle without projecting bars | • Grout must be pumped into coupler after placement of upper element<br>• Upper element bars need to be placed deeper into the section to provide cover over the couplers |
| G3 Grouted Coupler Connection Column to Bent Cap (09) | (01) (02) (03) (05) | • Same as G2 | • Same as G2 |
| P1 Pocket Connection Column to Bent Cap (10) | (01) (02) (03) (05) | • Simple connection made with conventional concrete<br>• Placement of concrete is easy<br>• Can accommodate significant tolerances<br>• Can be used in seismic regions | • Layout of bars in cap and column need to be carefully coordinated to avoid conflicts during erection<br>• Temporary support of cap may require temporary supports and braces |
| P2 Pocket Connection Wall Panel to Cap (11) | (03) (05) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances | • Ports required to place concrete |
| P3 Pocket Connection Column to Bent Cap Connection Using Post-Tensioning (PT) Duct Pockets (11) | (01) (02) (03) (05) | • Simple connection made with either conventional concrete or grout<br>• Placement of fill concrete is easy<br>• Can accommodate larger tolerances when compared to grouted coupler connections<br>• Can be used in seismic regions | • Requires smaller tolerance when compared to connection P2<br>• PT ducts may interfere with layout of cap reinforcement. Special detailing may be required. |
| P4 Pocket Connection Cast-In-Place Footing to Precast Column or Wall Panel (12) | (01) (02) (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• Can be used in seismic regions<br>• Bottom mats of reinforcement can be placed prior to erection of upper element | • Requires temporary support and bracing<br>• Top mats of footing reinforcement cannot be placed until after the upper element is erected |
| P5 Pocket Connection Footing to Wall Panel (12) | (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Can be less expensive than grouted coupler connections | • Layout of projecting footing bars needs to be coordinated with wall panels<br>• Requires temporary bracing of wall panel<br>• Size of voids may require wider wall panels<br>• Clusters of projecting bars from footing are not as efficient as grouted coupler bars, which may limit height of wall |
| S1 Socket Connection Cast-In-Place Footing to Column (13) | (01) (02) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• All footing reinforcement can be pre-tied and placed before erection of the column | • Requires temporary bracing of column<br>• Requires special surface treatment of embedded portion of column |
| S2 Socket Connection Pile to Wall Panel (13) | (04) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Backwall can be integral or a separate element | • Requires tighter pile installation tolerances in order to keep pipe size and stem width reasonable |
| K1 Key Connection Abutment and Wall Pier Stem Shear Key (14) | (03) (04) (05) | • Simple connection made with conventional concrete | • Forming required to retain concrete |
| K2 Key Connection Footing Key (14) | (03) (05) | • Same as K1 | • Same as K1 |
| K3 Key Connection Wall Key (14) | (04) (05) (06) | • Simple connection made with non-shrink grout | • Forming required to retain grout |
| RC1 Reinforced Closure Joint (07) | (02) (03) (04) (05) | • Can be used to create a flexurally continuous footing or other element | • Footing can be designed as individual footings for dead loads and continuous for live loads |

Note: Blue text represents hyperlinks to detail sheets





10

# Detail Usage Table

## Guidelines for Precast Substructures used in ABC

There are options for each connection depicted in these guide details. The designer should choose connection details that are appropriate for the bridge being designed and approved by the owner. It is recommended that the number of different connections in a project be minimized in order to simplify the fabrication and construction. The following table outlines the advantages and disadvantages of each connection to aid in the selection of details.

| Detail Title (sheet #) | Detail Usage Reference (sheet #) | Advantages | Design/Construction Considerations |
|---|---|---|---|
| G1 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (04) (05) (06) | • Placement of couplers is outside the potential plastic hinge zone<br>• Coupler can be pre-grouted just prior to placement of the upper element<br>• Upper element bars can be placed closer to the column face | • Potential for debris to get into coupler during construction (will require covers and cleaning prior to placement of upper element)<br>• Upper element will have projecting bars that may get damaged during handling |
| G2 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (05) (06) | • Less chance of debris getting into the coupler during construction<br>• Upper element is easier to handle without projecting bars | • Grout must be pumped into coupler after placement of upper element<br>• Upper element bars need to be placed deeper into the section to provide cover over the couplers |
| G3 Grouted Coupler Connection Column to Bent Cap (09) | (01) (02) (03) (04) (05) | • Same as G2 | • Same as G2 |
| P1 Pocket Connection Column to Bent Cap (10) | (01) (02) (03) (05) | • Simple connection made with conventional concrete<br>• Placement of concrete is easy<br>• Can accommodate significant tolerances<br>• Can be used in seismic regions | • Layout of bars in cap and column need to be carefully coordinated to avoid conflicts during erection<br>• Temporary support of cap may require temporary supports and braces |
| P2 Pocket Connection Wall Panel to Cap (11) | (03) (05) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances | • Ports required to place concrete |
| P3 Pocket Connection Column to Bent Cap Connection Using Post-Tensioning (PT) Duct Pockets (11) | (01) (02) (03) (05) | • Simple connection made with either conventional concrete or grout<br>• Placement of fill concrete is easy<br>• Can accommodate larger tolerances when compared to grouted coupler connections<br>• Can be used in seismic regions | • Requires smaller tolerance when compared to connection P2<br>• PT ducts may interfere with layout of cap reinforcement. Special detailing may be required. |
| P4 Pocket Connection Cast-In-Place Footing to Precast Column or Wall Panel (12) | (01) (02) (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• Can be used in seismic regions<br>• Bottom mats of reinforcement can be placed prior to erection of upper element | • Requires temporary support and bracing<br>• Top mats of footing reinforcement cannot be placed until after the upper element is erected |
| P5 Pocket Connection Footing to Wall Panel (12) | (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Can be less expensive than grouted coupler connections | • Layout of projecting footing bars needs to be coordinated with wall panels<br>• Requires temporary bracing of wall panel<br>• Size of voids may require wider wall panels<br>• Clusters of projecting bars from footing are not as efficient as grouted coupler bars, which may limit height of wall |
| S1 Socket Connection Cast-In-Place Footing to Column (13) | (01) (02) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• All footing reinforcement can be pre-tied and placed before erection of the column | • Requires temporary bracing of column<br>• Requires special surface treatment of embedded portion of column |
| S2 Socket Connection Pile to Wall Panel (13) | (04) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Backwall can be integral or a separate element | • Requires tighter pile installation tolerances in order to keep pipe size and stem width reasonable |
| K1 Key Connection Abutment and Wall Pier Stem Shear Key (14) | (03) (04) (05) | • Simple connection made with conventional concrete | • Forming required to retain concrete |
| K2 Key Connection Footing Key (14) | (03) (05) | • Same as K1 | • Same as K1 |
| K3 Key Connection Wall Key (14) | (04) (05) (06) | • Simple connection made with non-shrink grout | • Forming required to retain grout |
| RC1 Reinforced Closure Joint (07) | (02) (03) (04) (05) | • Can be used to create a flexurally continuous footing or other element | • Footing can be designed as individual footings for dead loads and continuous for live loads |

Note: Blue text represents hyperlinks to detail sheets



| Detail Title (sheet #) | Detail Usage Reference (sheet #) |
|---|---|
| G1 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (04) (05) (06) |

Note: Blue text represents hyperlinks to detail sheets

PCI NORTHEAST

CHA



11

# Detail Usage Table

## Guidelines for Precast Substructures used in ABC

There are options for each connection depicted in these guide details. The designer should choose connection details that are appropriate for the bridge being designed and approved by the owner. It is recommended that the number of different connections in a project be minimized in order to simplify the fabrication and construction. The following table outlines the advantages and disadvantages of each connection to aid in the selection of details.

| Detail Title (sheet #) | Detail Usage Reference (sheet #) | Advantages | Design/Construction Considerations |
|---|---|---|---|
| G1 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (04) (05) (06) | • Placement of couplers is outside the potential plastic hinge zone<br>• Coupler can be pre-grouted just prior to placement of the upper element<br>• Upper element bars can be placed closer to the column face | • Potential for debris to get into coupler during construction (will require covers and cleaning prior to placement of upper element)<br>• Upper element will have projecting bars that may get damaged during handling |
| G2 Grouted Coupler Connection Precast Column or Wall Panel to Footing (08) | (01) (02) (03) (05) (06) | • Less chance of debris getting into the coupler during construction<br>• Upper element is easier to handle without projecting bars | • Grout must be pumped into coupler after placement of upper element<br>• Upper element bars need to be placed deeper into the section to provide cover over the couplers |
| G3 Grouted Coupler Connection Column to Bent Cap (09) | (01) (02) (03) (04) (05) | • Same as G2 | • Same as G2 |
| P1 Pocket Connection Column to Bent Cap (10) | (01) (02) (03) (05) | • Simple connection made with conventional concrete<br>• Placement of concrete is easy<br>• Can accommodate significant tolerances<br>• Can be used in seismic regions | • Layout of bars in cap and column need to be carefully coordinated to avoid conflicts during erection<br>• Temporary support of cap may require temporary supports and braces |
| P2 Pocket Connection Wall Panel to Cap (11) | (03) (05) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances | • Ports required to place concrete |
| P3 Pocket Connection Column to Bent Cap Connection Using Post-Tensioning (PT) Duct Pockets (11) | (01) (02) (03) (05) | • Simple connection made with either conventional concrete or grout<br>• Placement of fill concrete is easy<br>• Can accommodate larger tolerances when compared to grouted coupler connections<br>• Can be used in seismic regions | • Requires smaller tolerance when compared to connection P2<br>• PT ducts may interfere with layout of cap reinforcement. Special detailing may be required. |
| P4 Pocket Connection Cast-In-Place Footing to Precast Column or Wall Panel (12) | (01) (02) (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• Can be used in seismic regions<br>• Bottom mats of reinforcement can be placed prior to erection of upper element | • Requires temporary support and bracing<br>• Top mats of footing reinforcement cannot be placed until after the upper element is erected |
| P5 Pocket Connection Footing to Wall Panel (12) | (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Can be less expensive than grouted coupler connections | • Layout of projecting footing bars needs to be coordinated with wall panels<br>• Requires temporary bracing of wall panel<br>• Size of voids may require wider wall panels<br>• Clusters of projecting bars from footing are not as efficient as grouted coupler bars, which may limit height of wall |
| S1 Socket Connection Cast-In-Place Footing to Column (13) | (01) (02) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• All footing reinforcement can be pre-tied and placed before erection of the column | • Requires temporary bracing of column<br>• Requires special surface treatment of embedded portion of column |
| S2 Socket Connection Pile to Wall Panel (13) | (04) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Backwall can be integral or a separate element | • Requires tighter pile installation tolerances in order to keep pipe size and stem width reasonable |
| K1 Key Connection Abutment and Wall Pier Stem Shear Key (14) | (03) (04) (05) | • Simple connection made with conventional concrete | • Forming required to retain concrete |
| K2 Key Connection Footing Key (14) | (03) (05) | • Same as K1 | • Same as K1 |
| K3 Key Connection Wall Key (14) | (04) (05) (06) | • Simple connection made with non-shrink grout | • Forming required to retain grout |
| RC1 Reinforced Closure Joint (07) | (02) (03) (04) (05) | • Can be used to create a flexurally continuous footing or other element | • Footing can be designed as individual footings for dead loads and continuous for live loads |

Note: Blue text represents hyperlinks to detail sheets

Page vi

PCI NORTHEAST

CHA

12

12

# Detail Usage Table

## Guidelines for Precast Substructures used in ABC

There are options for each connection depicted in these guide details. The designer should choose connection details that are appropriate for the bridge being designed and approved by the owner. It is recommended that the number of different connections in a project be minimized in order to simplify the fabrication and construction. The following table outlines the advantages and disadvantages of each connection to aid in the selection of details.

| Detail Title (sheet #) | Detail Usage Reference (sheet #) | Advantages | Design/Construction Considerations |
|---|---|---|---|
| G1 Grouted Coupler Connection Precast Column to Wall Panel to Footing (08) | (01) (02) (03) (04) (05) (06) | • Placement of couplers is outside the potential plastic hinge zone<br>• Coupler can be pre-grouted just prior to placement of the upper element<br>• Upper element bars can be placed closer to the column face | • Potential for debris to get into coupler during construction (will require covers and cleaning prior to placement of upper element)<br>• Upper element will have projecting bars that may get damaged during handling |
| P2 Pocket Connection Wall Panel to Cap (11) | (03) (05) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances | • Ports required to place concrete |
| P3 Pocket Connection Column to Bent Cap Connection Using Post-Tensioning (PT) Duct Pockets (11) | (01) (02) (03) (05) | • Simple connection made with either conventional concrete or grout<br>• Placement of fill concrete is easy<br>• Can accommodate larger tolerances when compared to grouted coupler connections<br>• Can be used in seismic regions | • Requires smaller tolerance when compared to connection P2<br>• PT ducts may interfere with layout of cap reinforcement. Special detailing may be required. |
| P4 Pocket Connection Cast-In-Place Footing to Precast Column or Wall Panel (12) | (01) (02) (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• Can be used in seismic regions<br>• Bottom mats of reinforcement can be placed prior to erection of upper element | • Requires temporary support and bracing<br>• Top mats of footing reinforcement cannot be placed until after the upper element is erected |
| P5 Pocket Connection Footing to Wall Panel (12) | (03) (05) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Can be less expensive than grouted coupler connections | • Layout of projecting footing bars needs to be coordinated with wall panels<br>• Requires temporary bracing of wall panel<br>• Size of voids may require wider wall panels<br>• Clusters of projecting bars from footing are not as efficient as grouted coupler bars, which may limit height of wall |
| S1 Socket Connection Cast-In-Place Footing to Column (13) | (01) (02) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Can accommodate significant tolerances<br>• Good for pile-supported footings<br>• All footing reinforcement can be pre-tied and placed before erection of the column | • Requires temporary bracing of column<br>• Requires special surface treatment of embedded portion of column |
| S2 Socket Connection Pile to Wall Panel (13) | (04) (06) | • Simple connection made with conventional concrete<br>• Can be used in seismic regions<br>• Backwall can be integral or a separate element | • Requires tighter pile installation tolerances in order to keep pipe size and stem width reasonable |
| K1 Key Connection Abutment and Wall Pier Stem Shear Key (14) | (03) (04) (05) | • Simple connection made with conventional concrete | • Forming required to retain concrete |
| K2 Key Connection Footing Key (14) | (03) (05) | • Same as K1 | • Same as K1 |
| K3 Key Connection Wall Key (14) | (04) (05) (06) | • Simple connection made with non-shrink grout | • Forming required to retain grout |
| RC1 Reinforced Closure Joint (07) | (02) (03) (04) (05) | • Can be used to create a flexurally continuous footing or other element | • Footing can be designed as individual footings for dead loads and continuous for live loads |

Note: Blue text represents hyperlinks to detail sheets

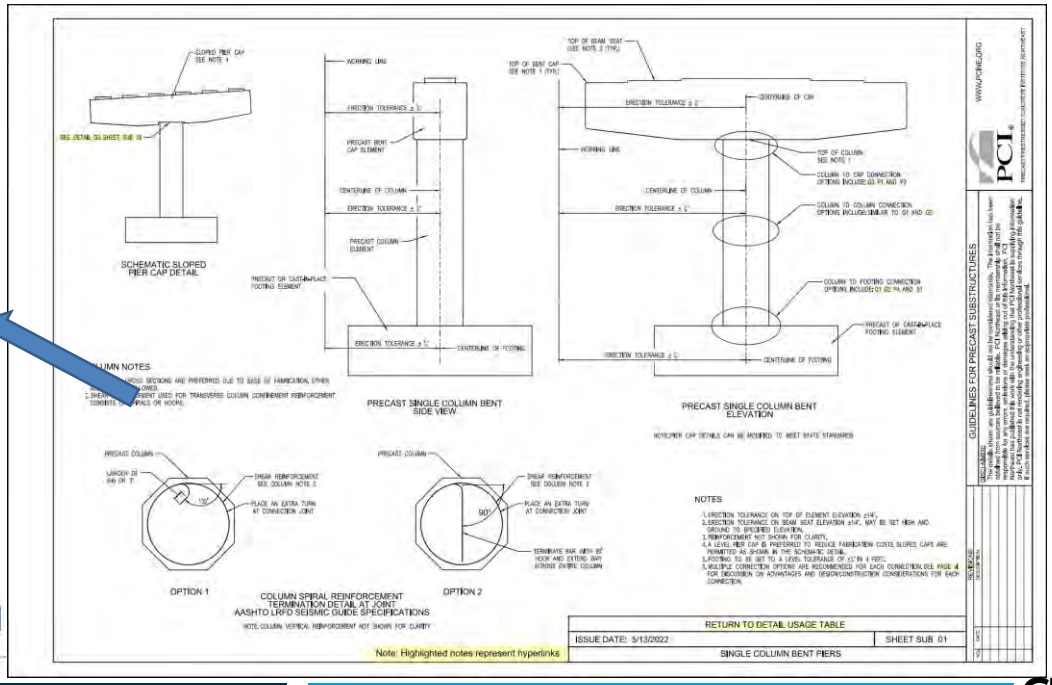
Page vi


| Advantages | Design/Construction Considerations |
|---|---|
| • Placement of couplers is outside the potential plastic hinge zone<br>• Coupler can be pre-grouted just prior to placement of the upper element<br>• Upper element bars can be placed closer to the column face | • Potential for debris to get into coupler during construction (will require covers and cleaning prior to placement of upper element)<br>• Upper element will have projecting bars that may get damaged during handling |




13

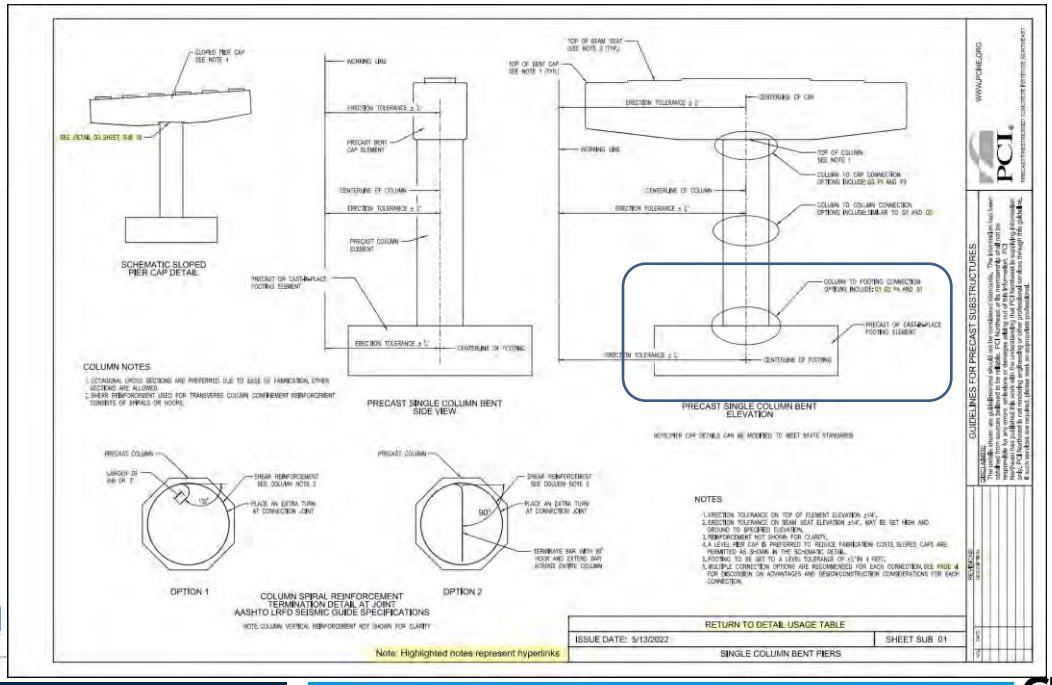
# Single Column Pier






14

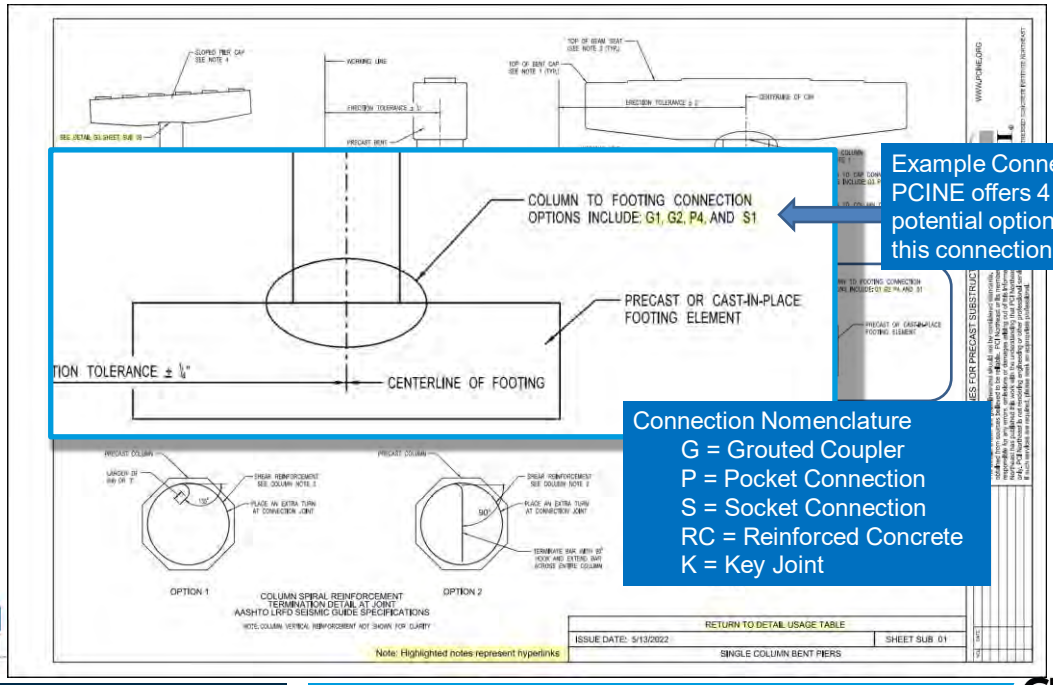
# Single Column Pier






15

# Single Column Pier



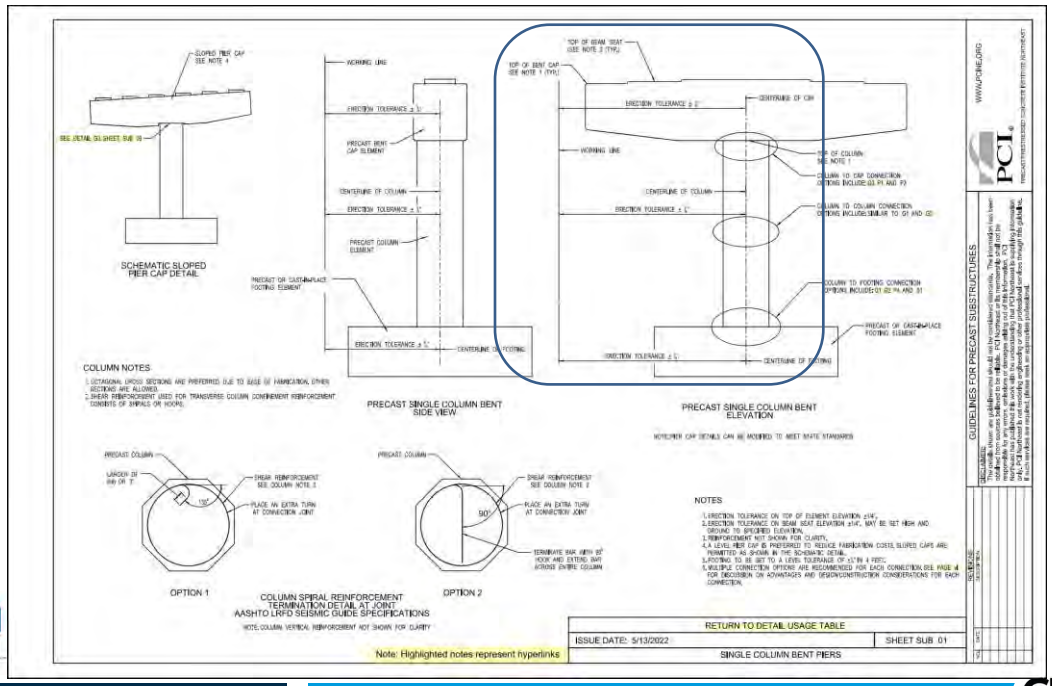

Example Connection: PCINE offers 4 potential options for this connection

Connection Nomenclature
- G = Grouted Coupler
- P = Pocket Connection
- S = Socket Connection
- RC = Reinforced Concrete
- K = Key Joint



16

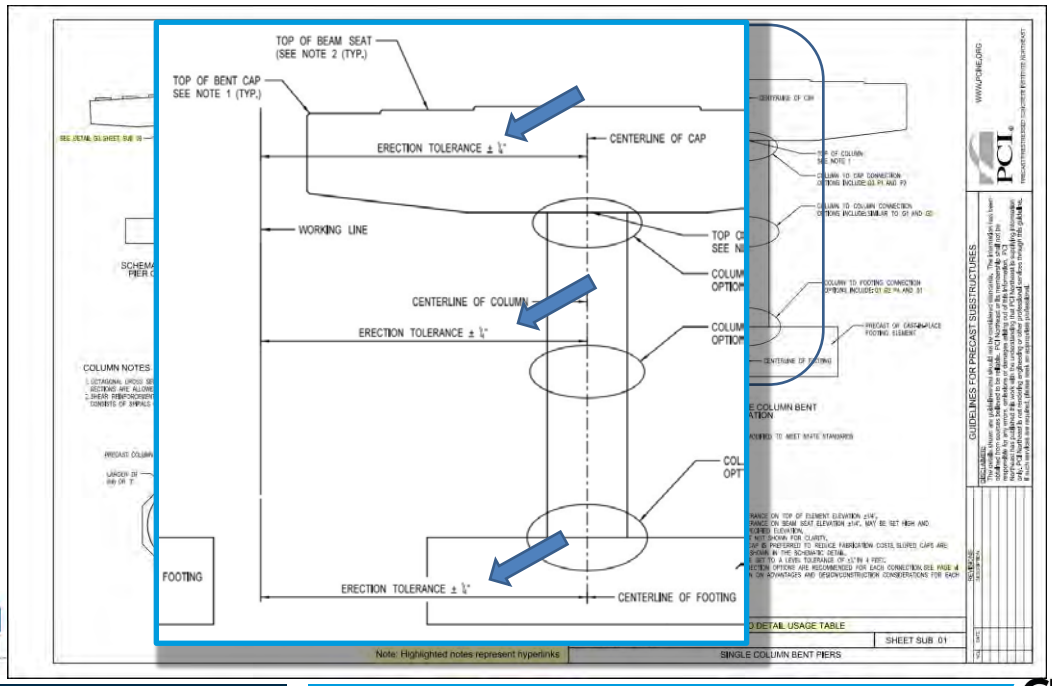
# Single Column Pier



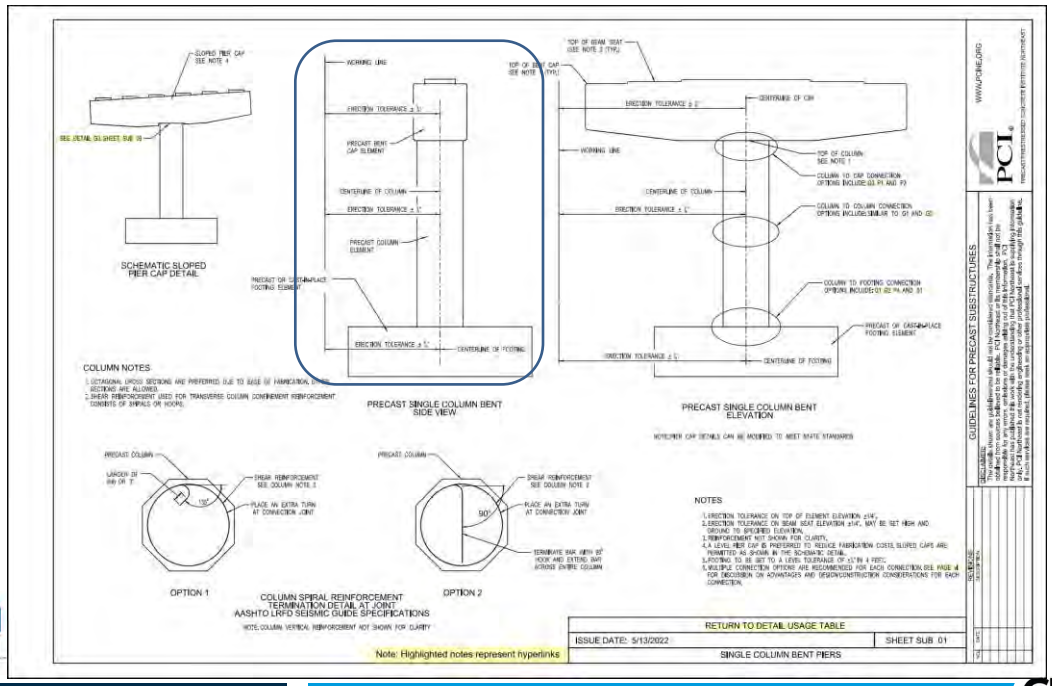





# Single Column Pier



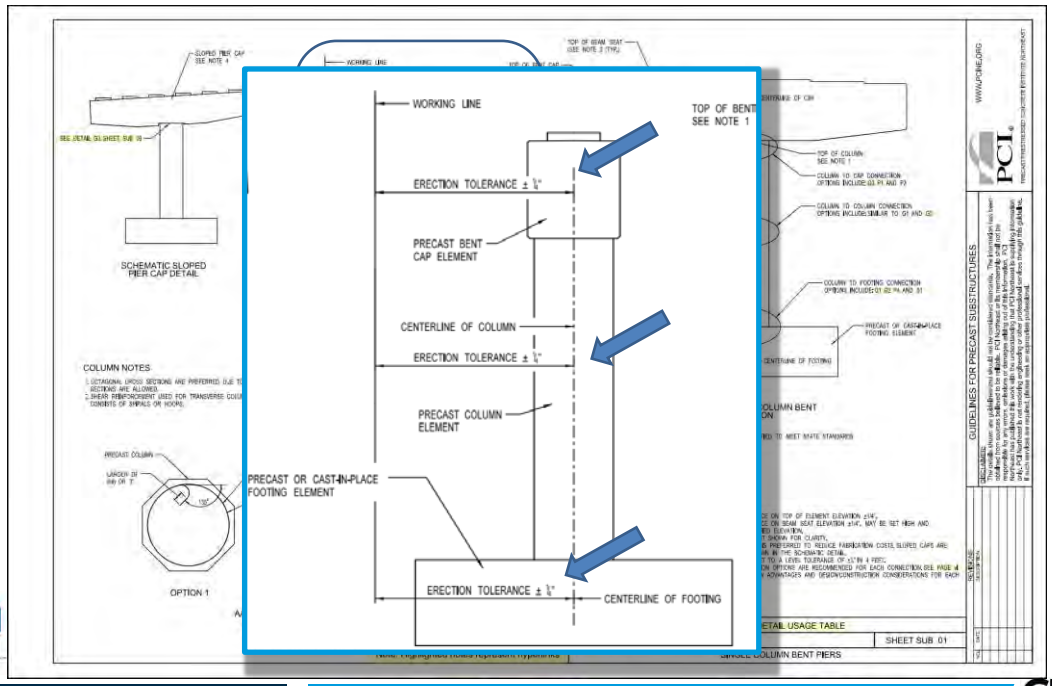
# Single Column Pier



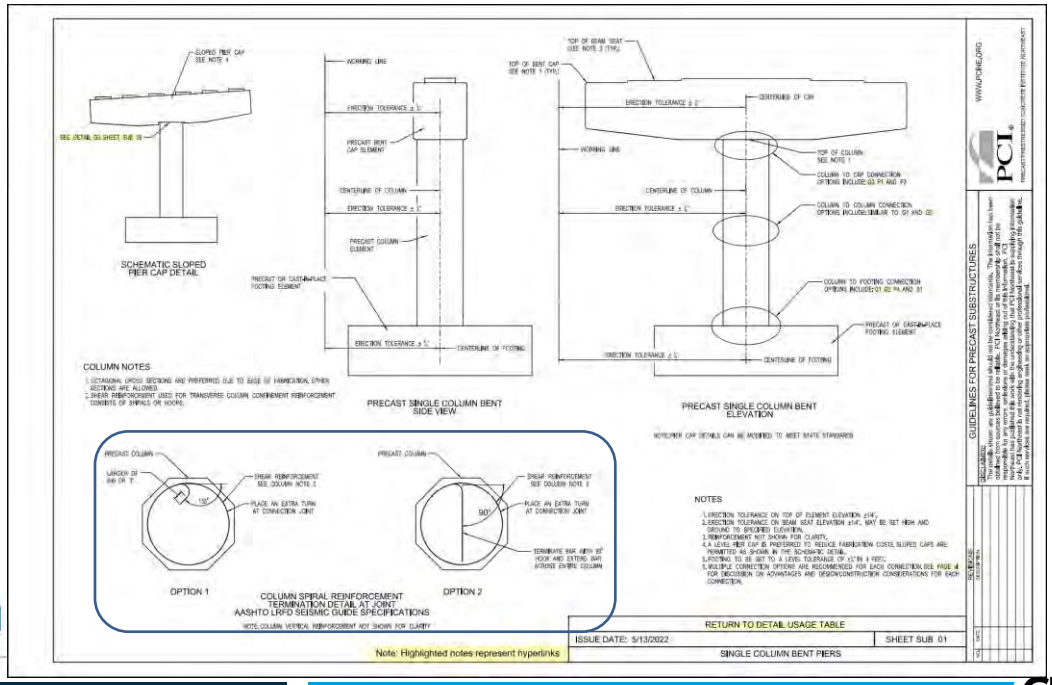





# Single Column Pier



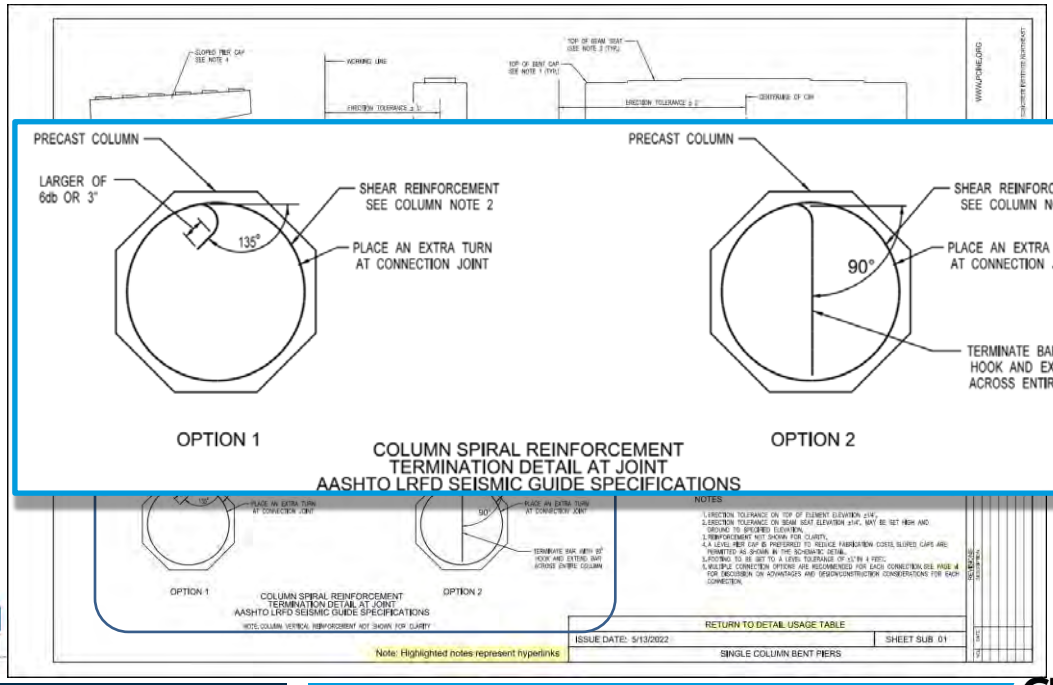
# Single Column Pier






21

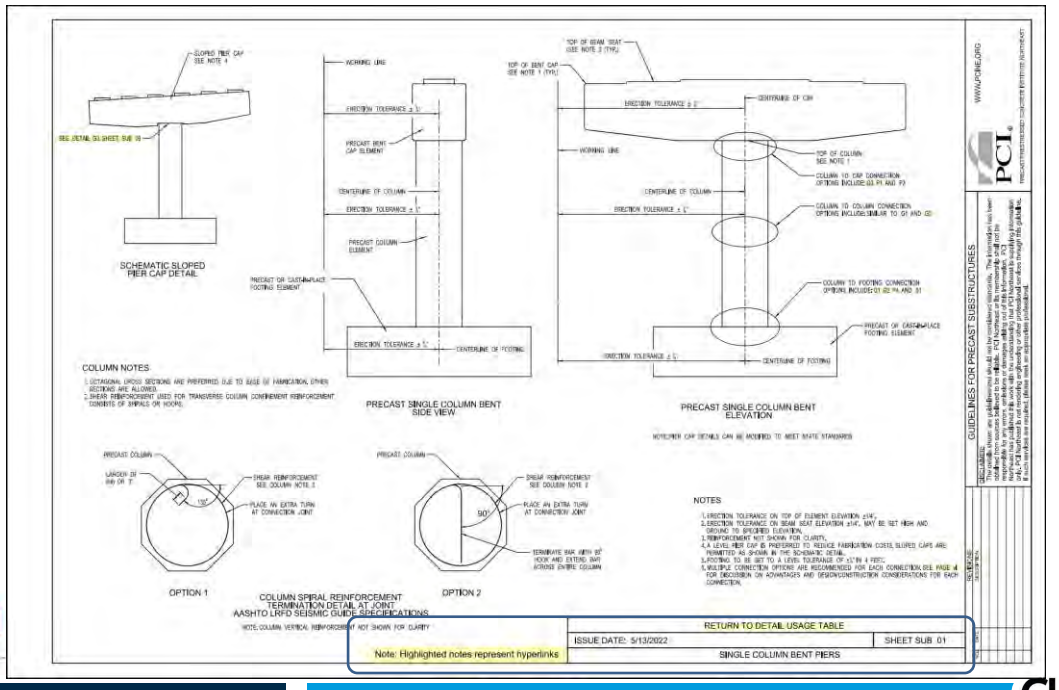
# Single Column Pier






22

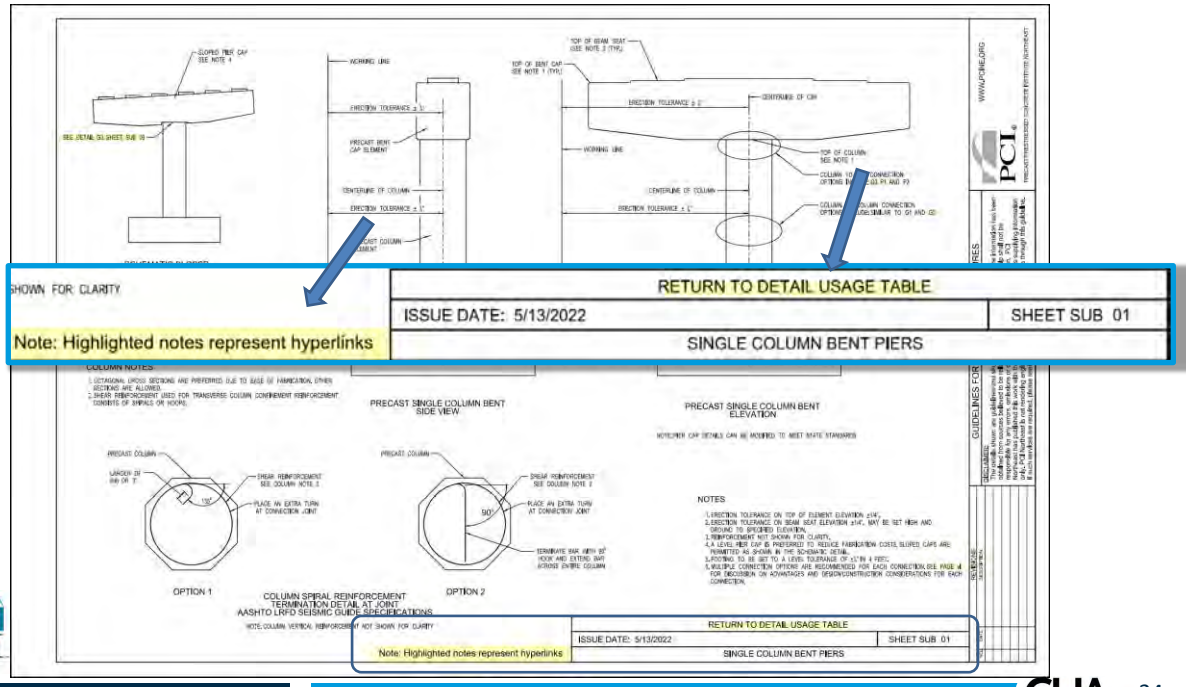
# Single Column Pier



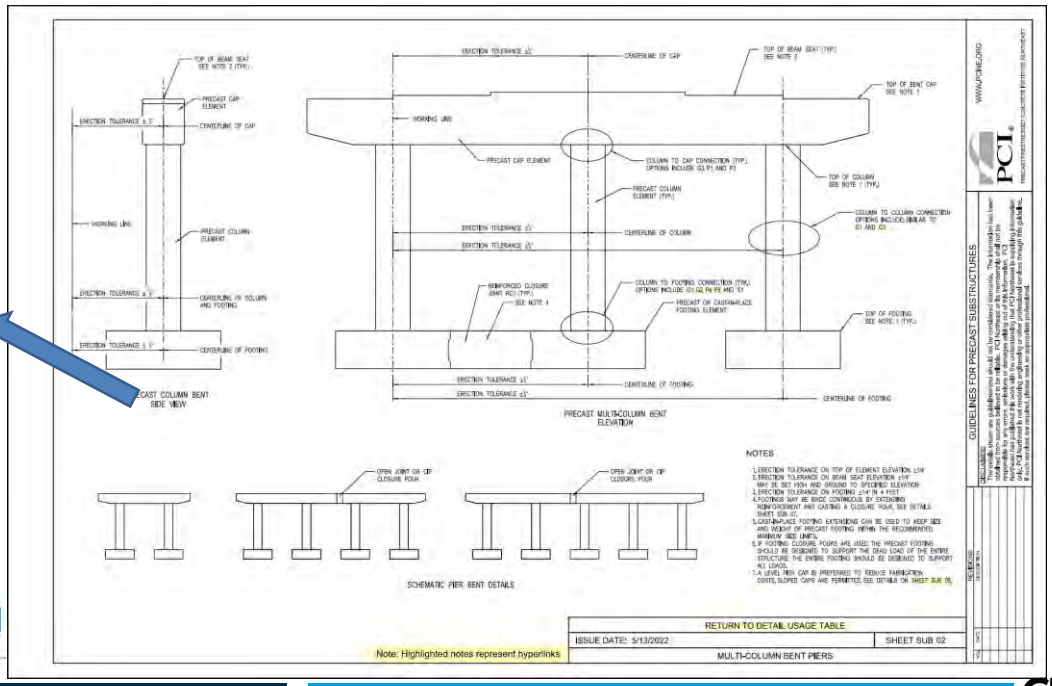





Single Column Pier



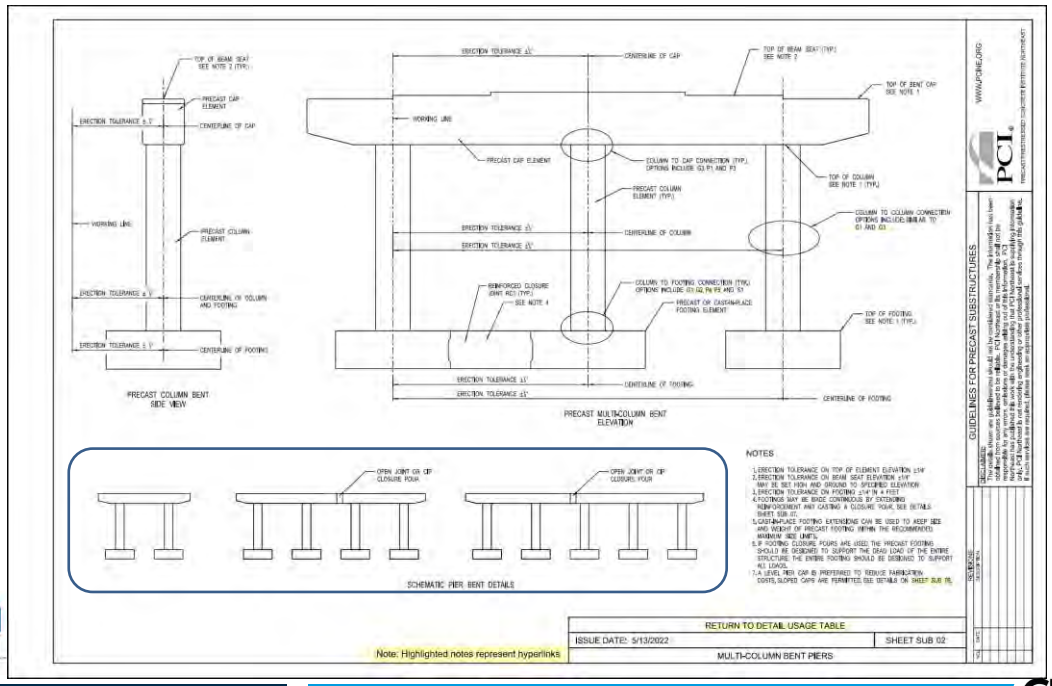
# Pier Bents






25

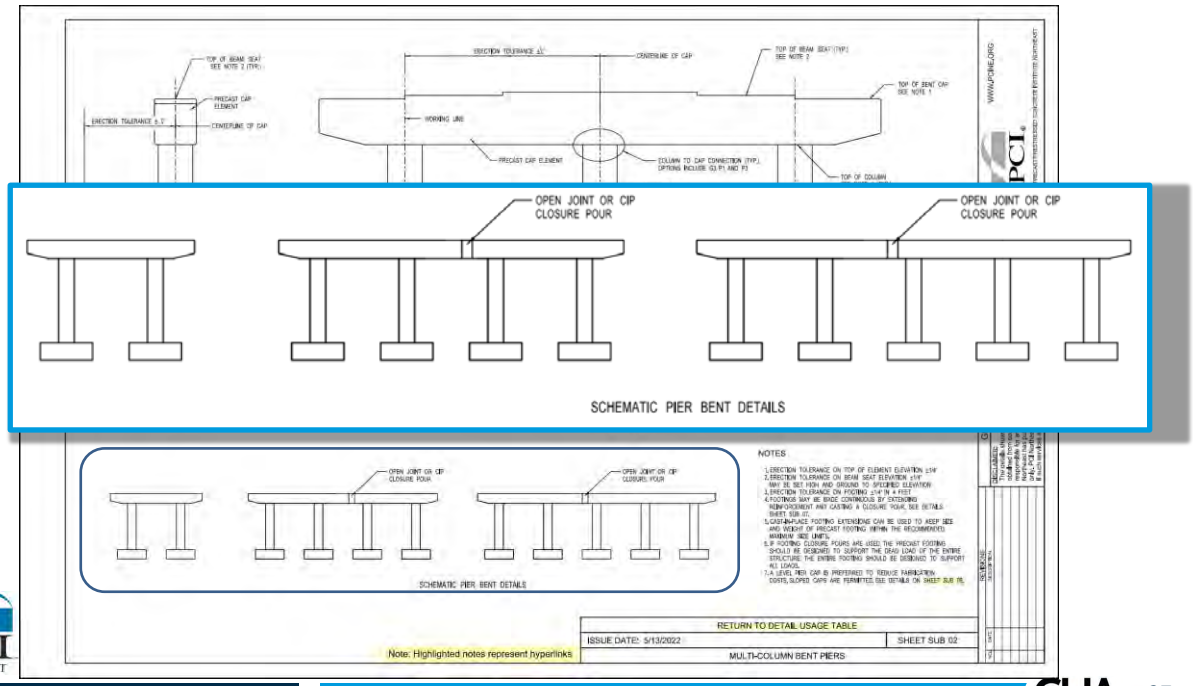
# Pier Bents






26

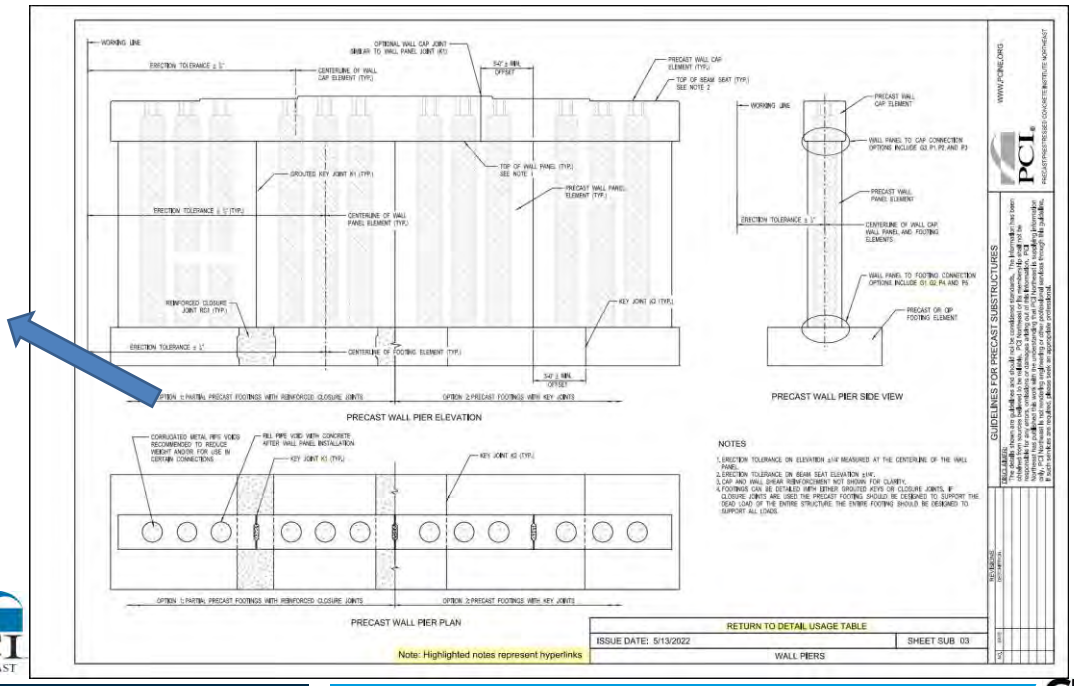
# Pier Bents






27

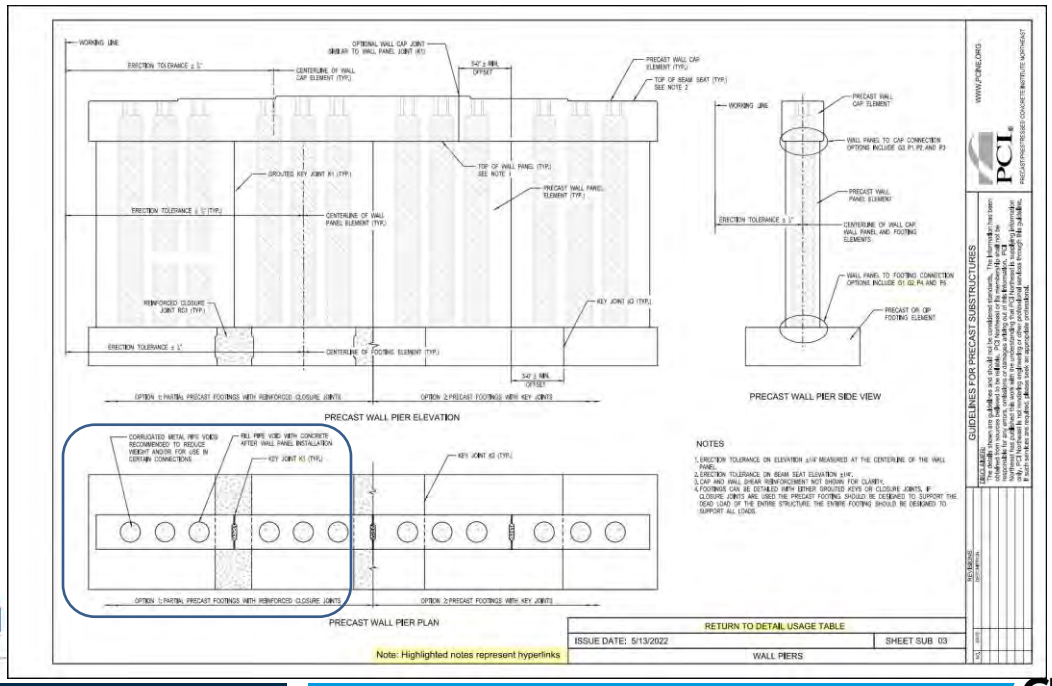
# Wall Piers






28

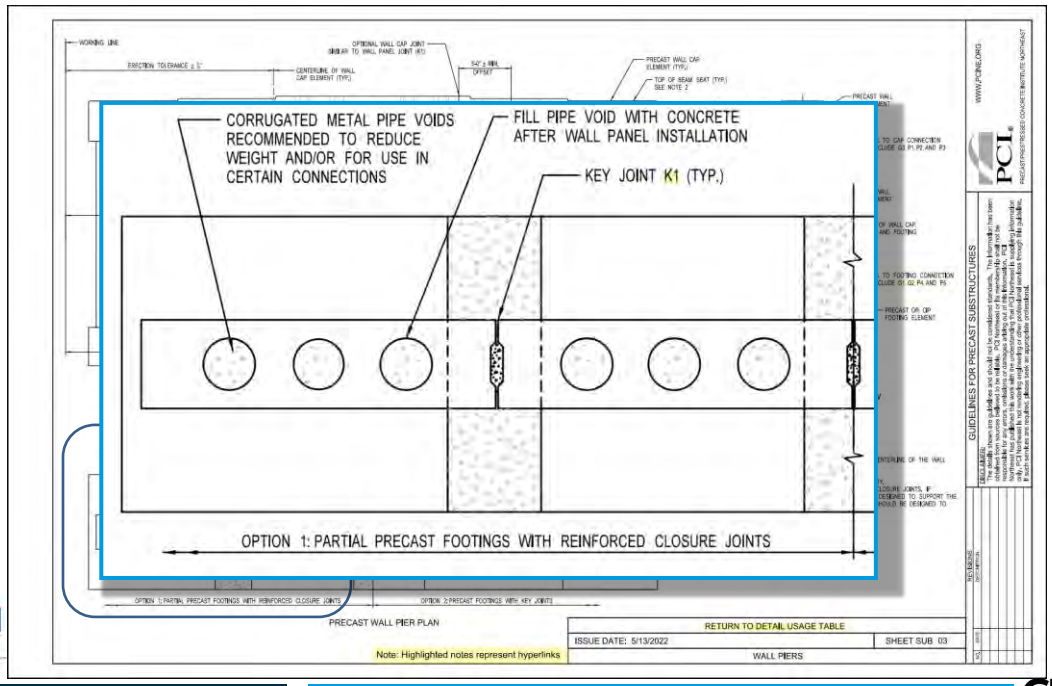
# Wall Piers






29

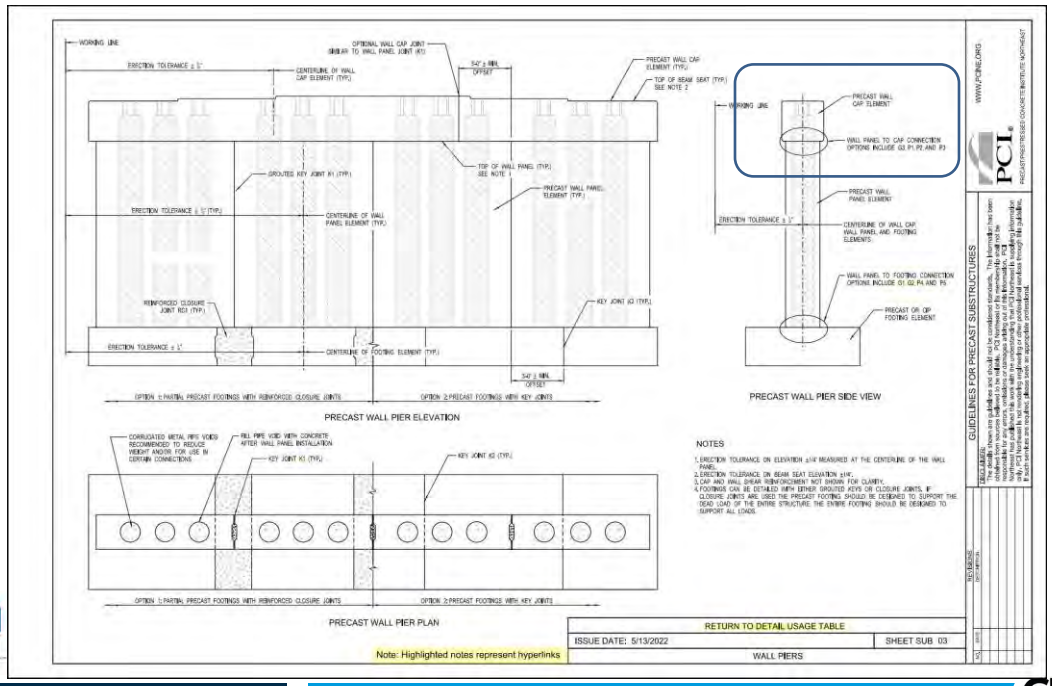
# Wall Piers






30

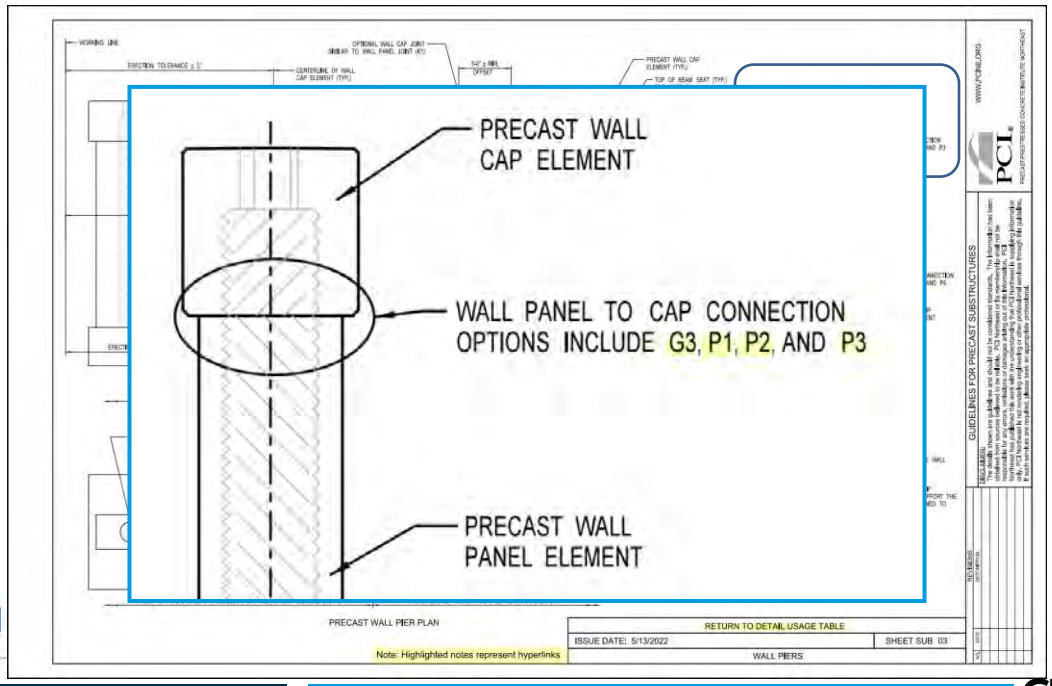
# Wall Piers



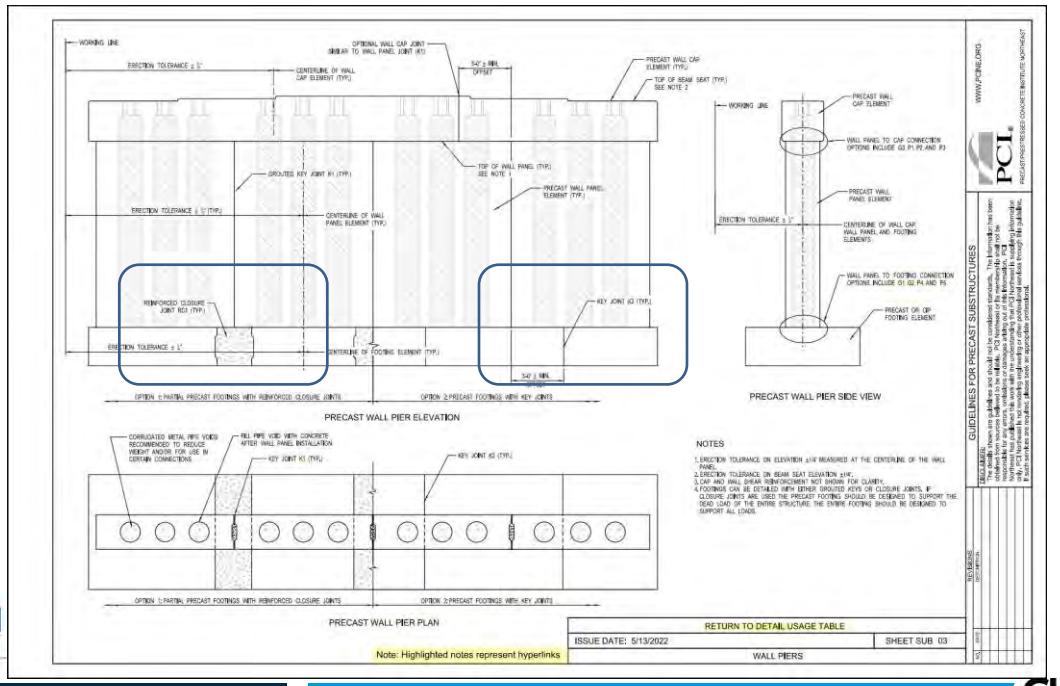





# Wall Piers



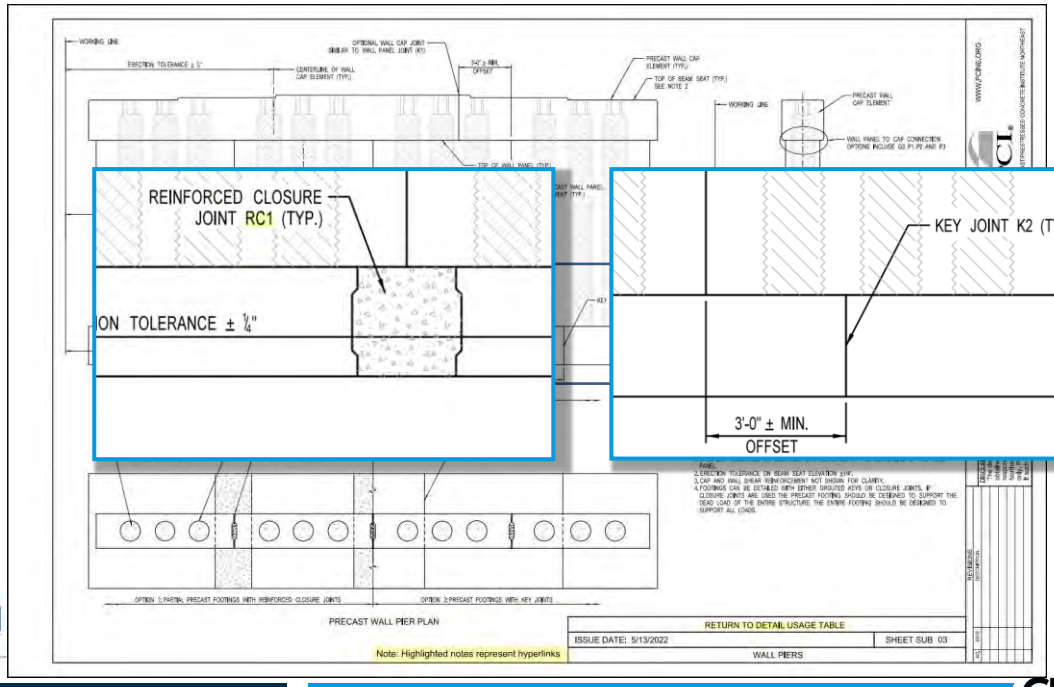
# Wall Piers






33

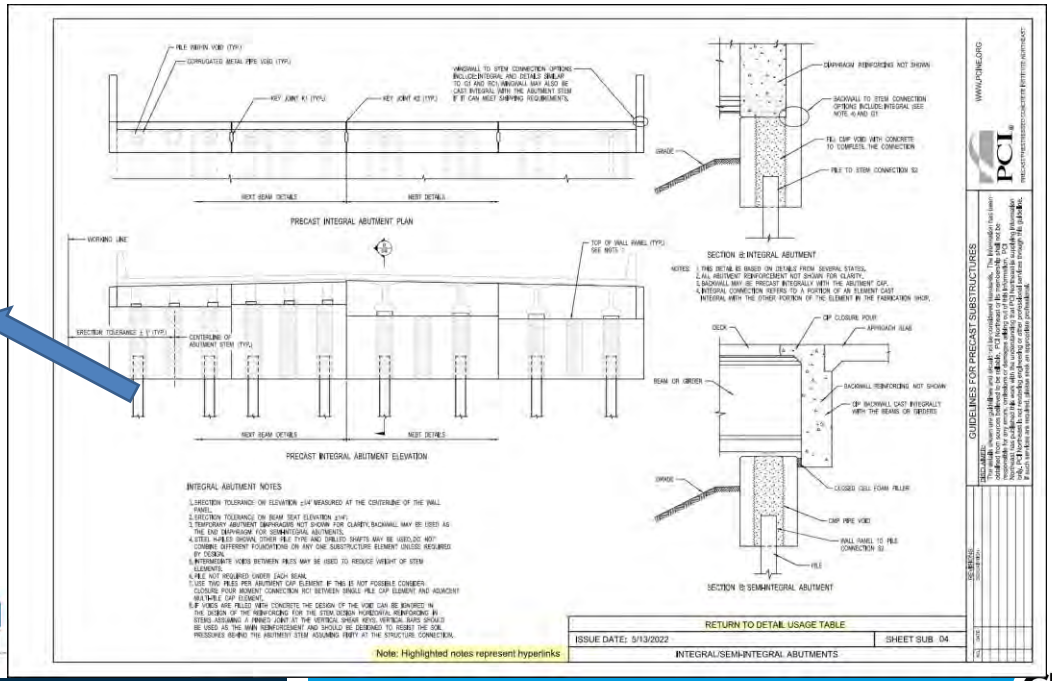
# Wall Piers






34

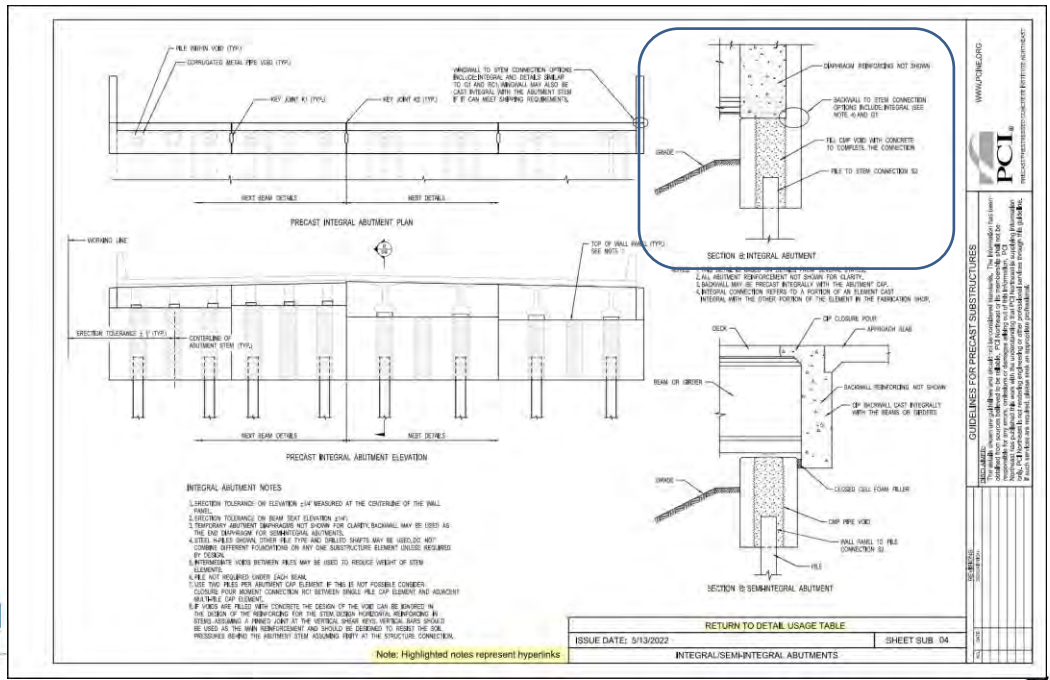
# Integral abutments






35

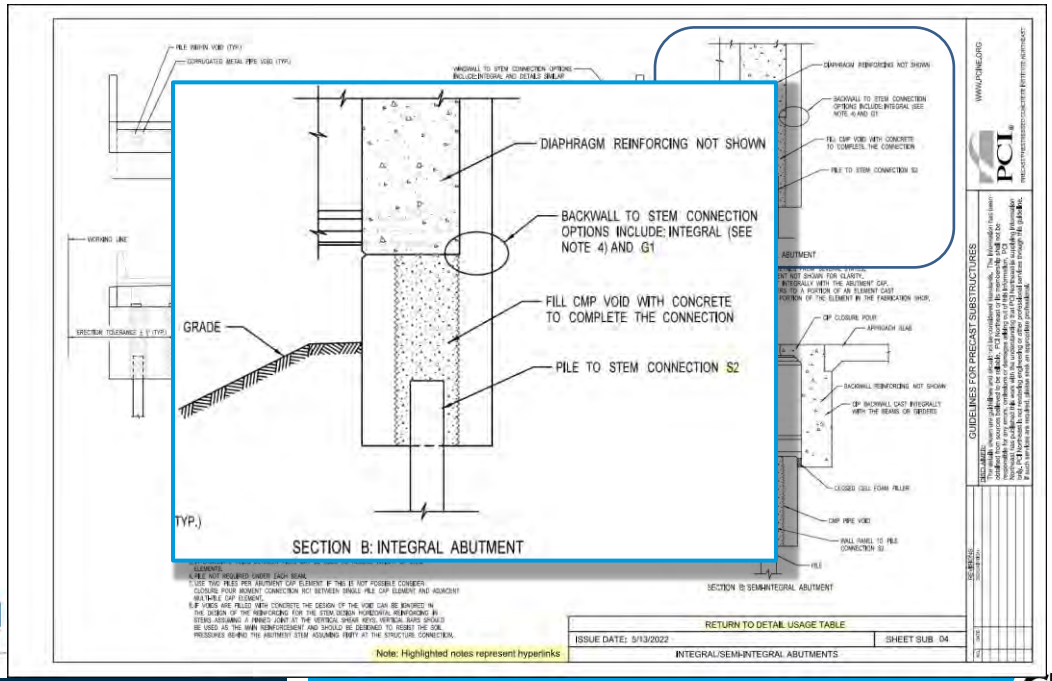
# Integral abutments






36

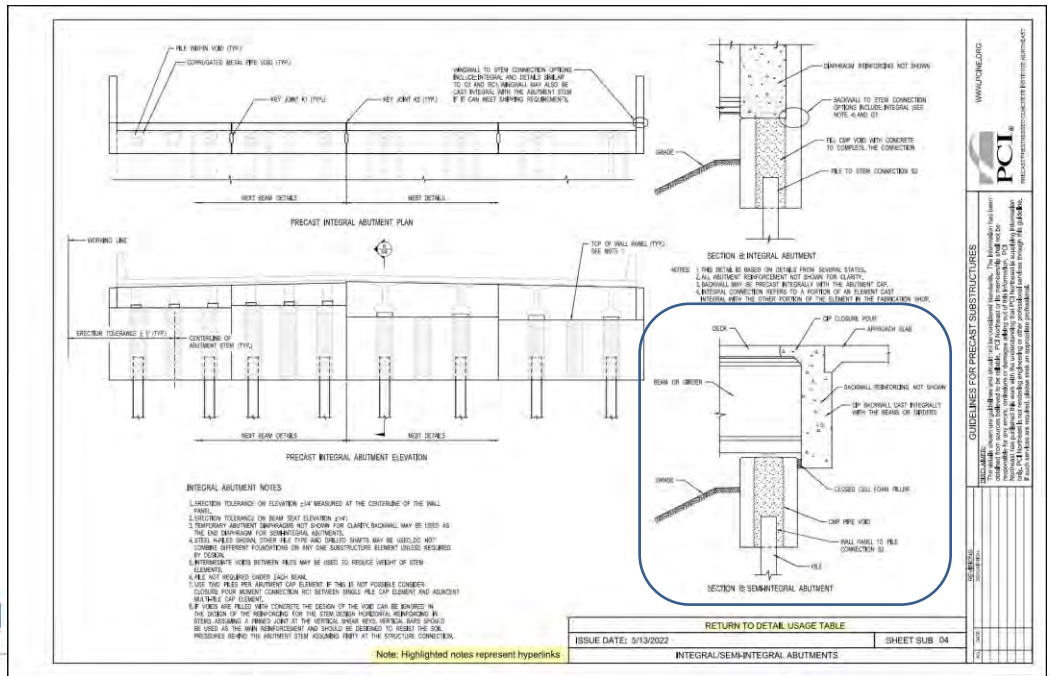
# Integral abutments






37

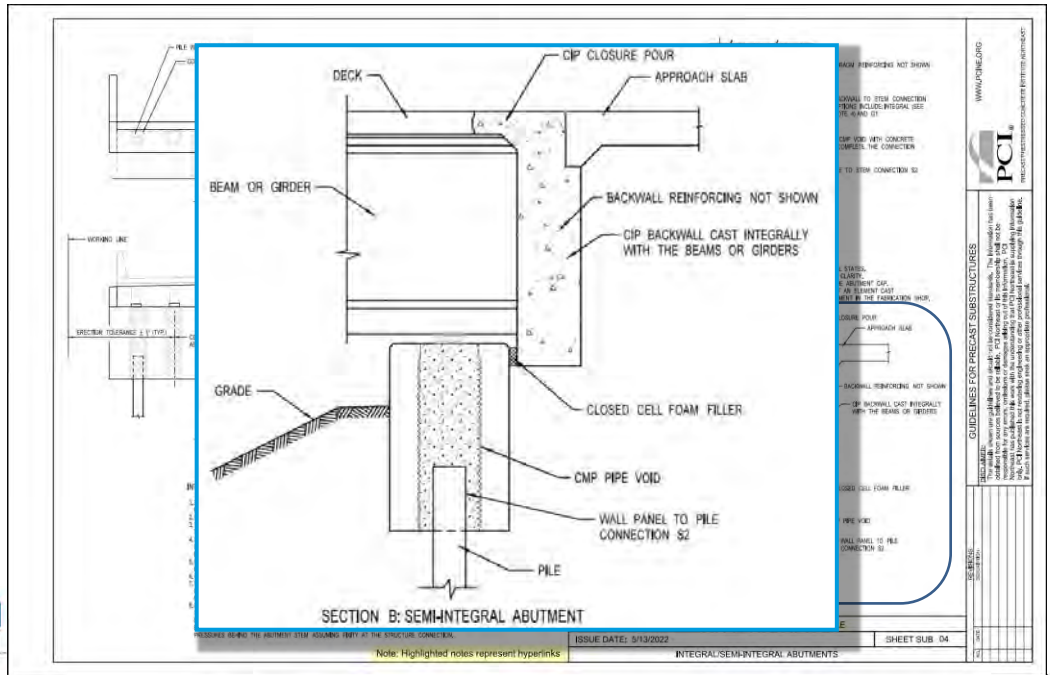
# Integral abutments






38

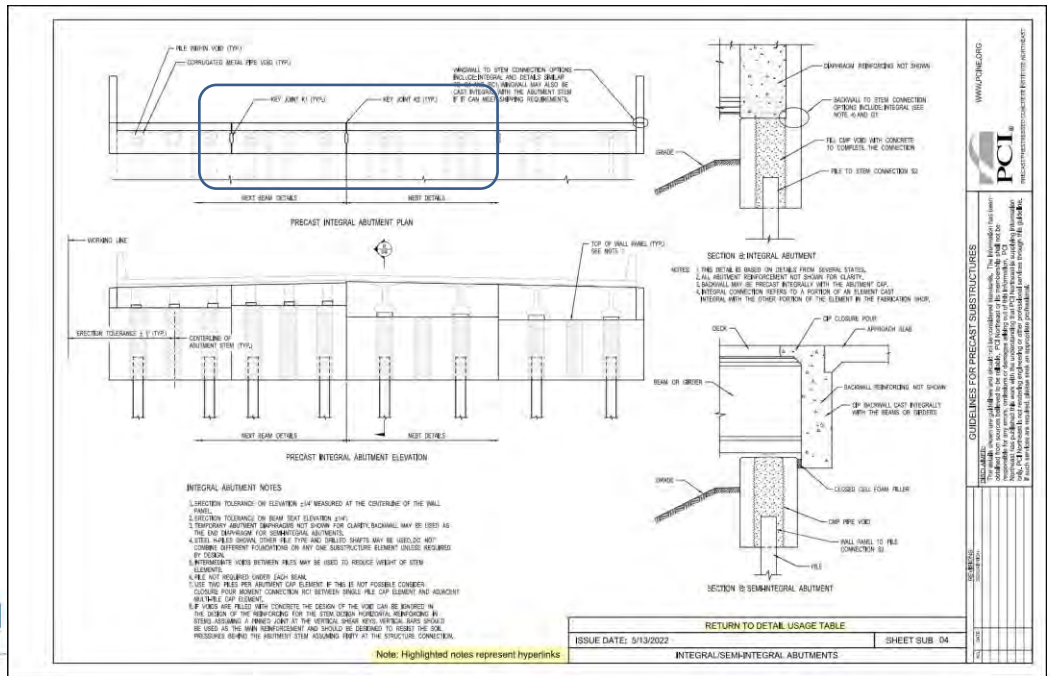
# Integral abutments






39

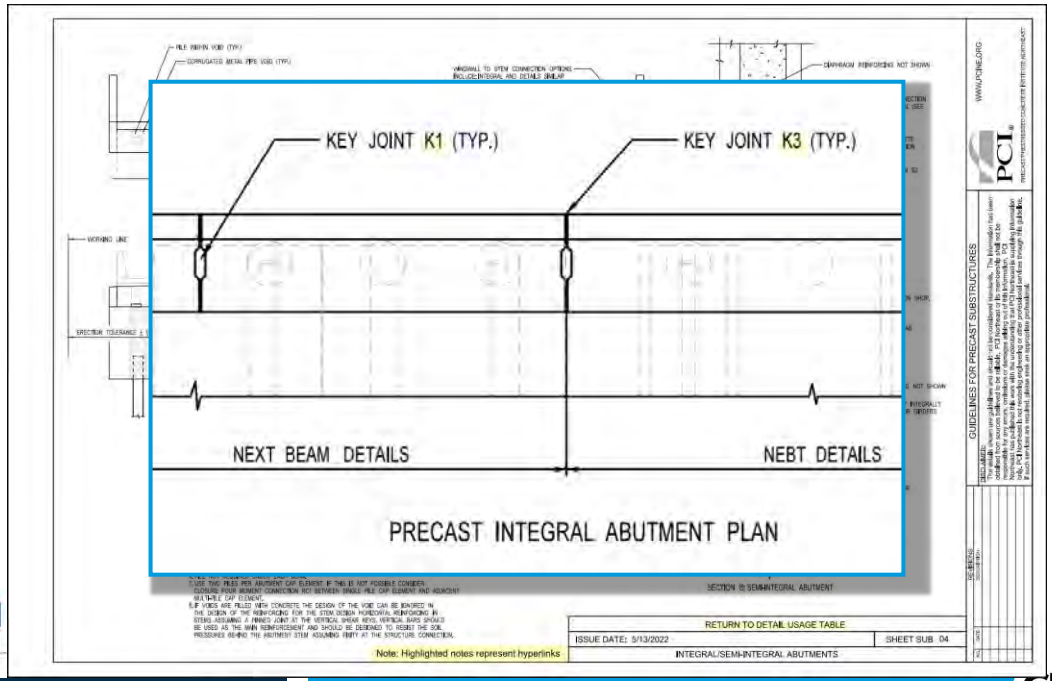
# Integral abutments






40

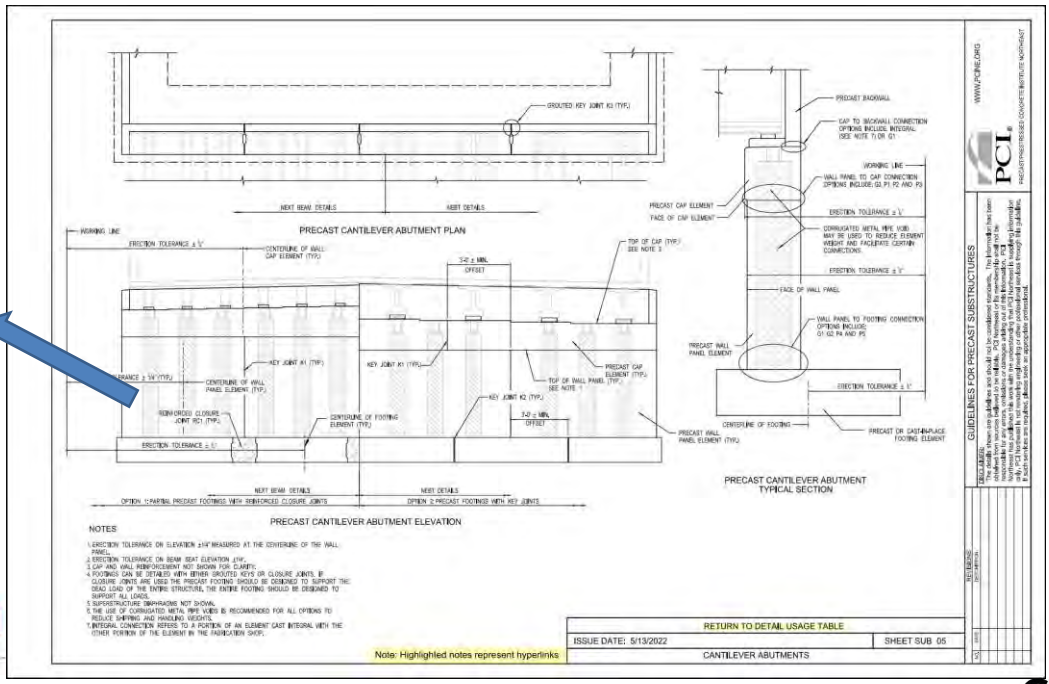
# Integral abutments






41

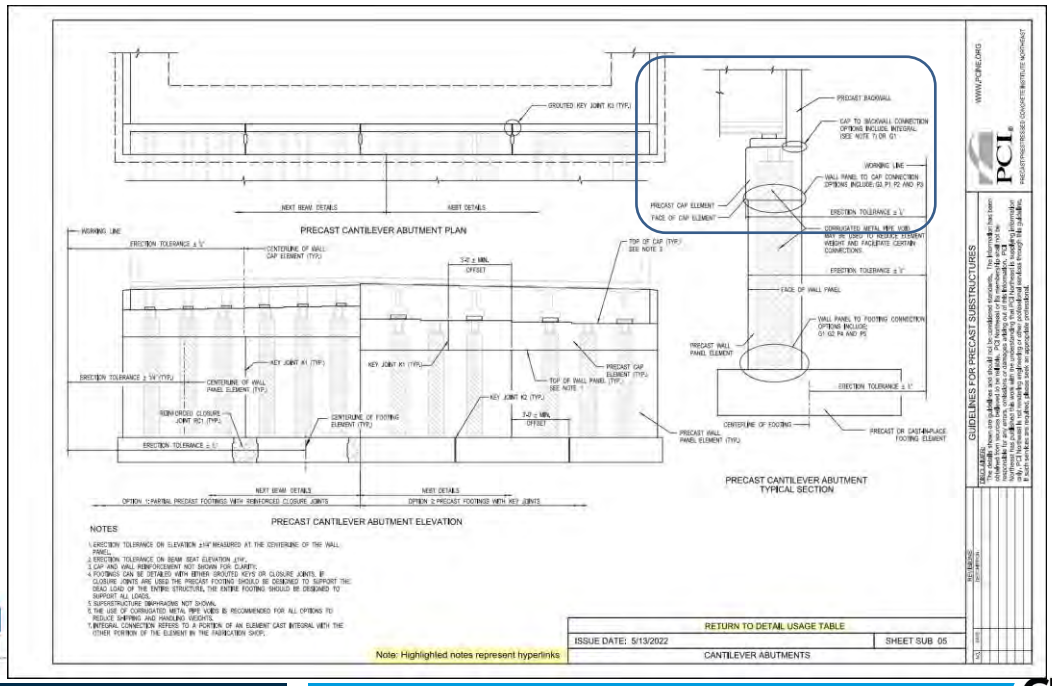
# Cantilever abutments






42

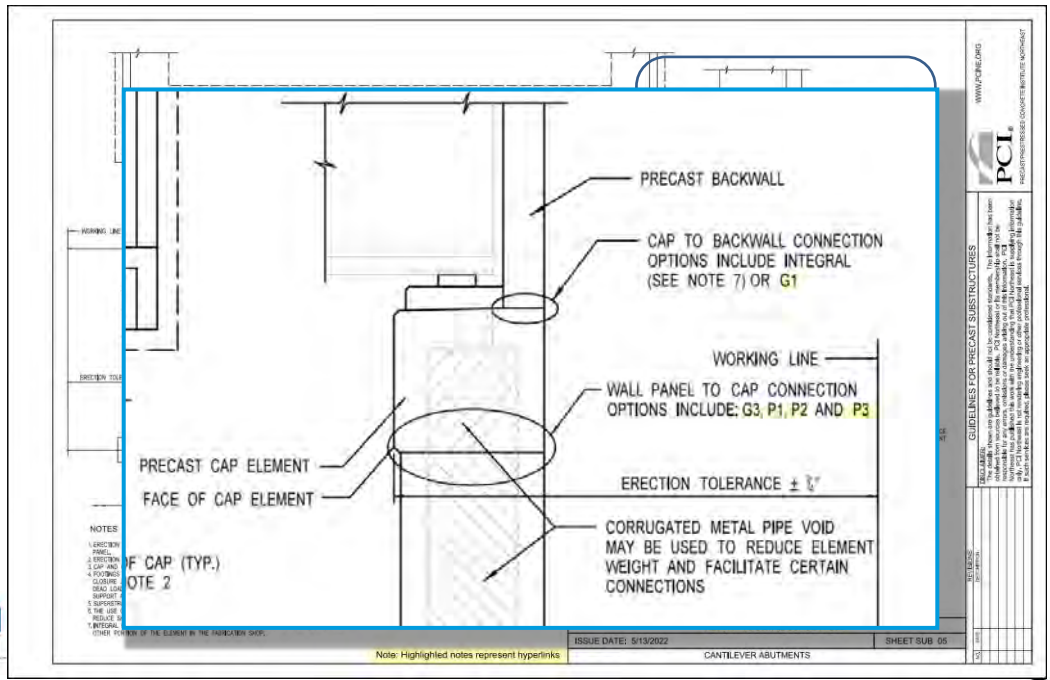
# Cantilever abutments






43

# Cantilever abutments

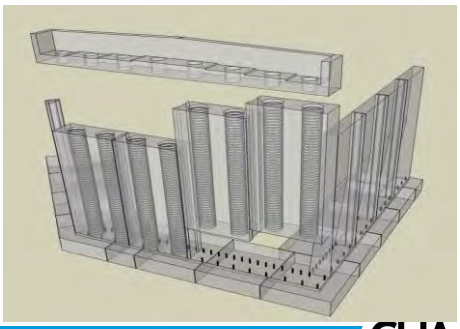





44

# Cantilever Abutments

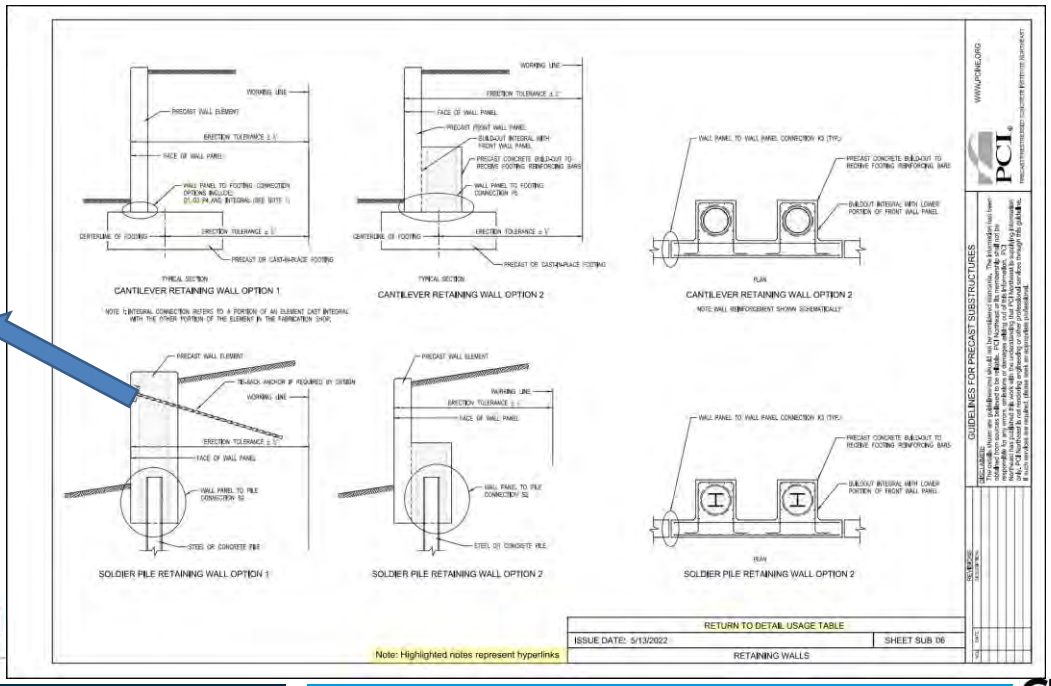
Route 1 Bridge over Route 236
Kittery, Maine
Courtesy of Maine DOT
Precast Wall Cap Concept



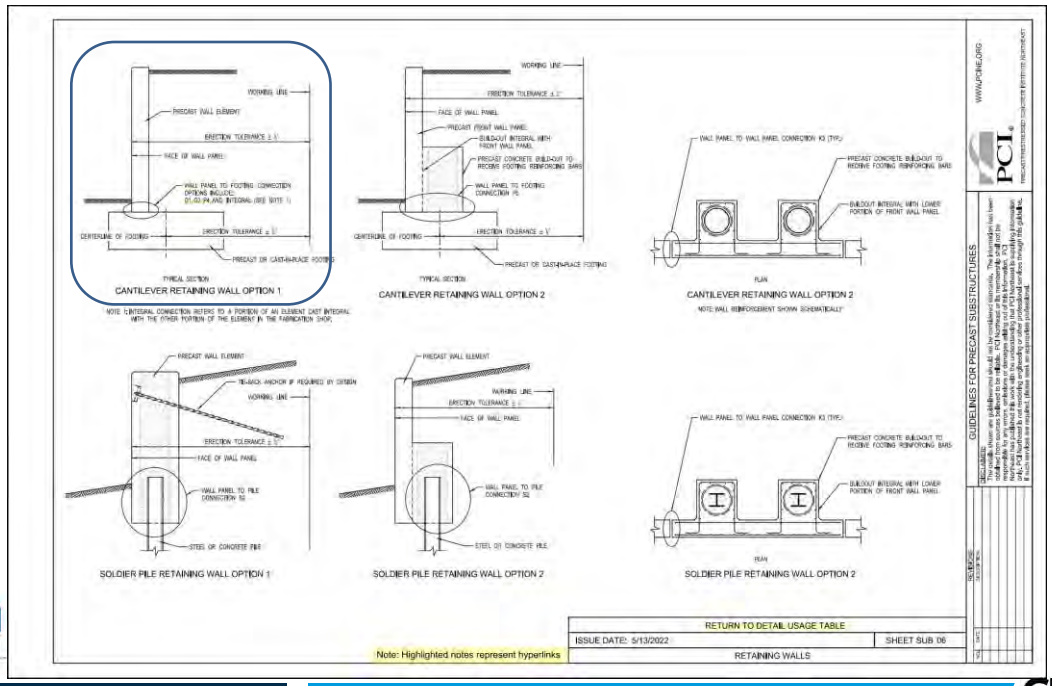




Retaining Walls



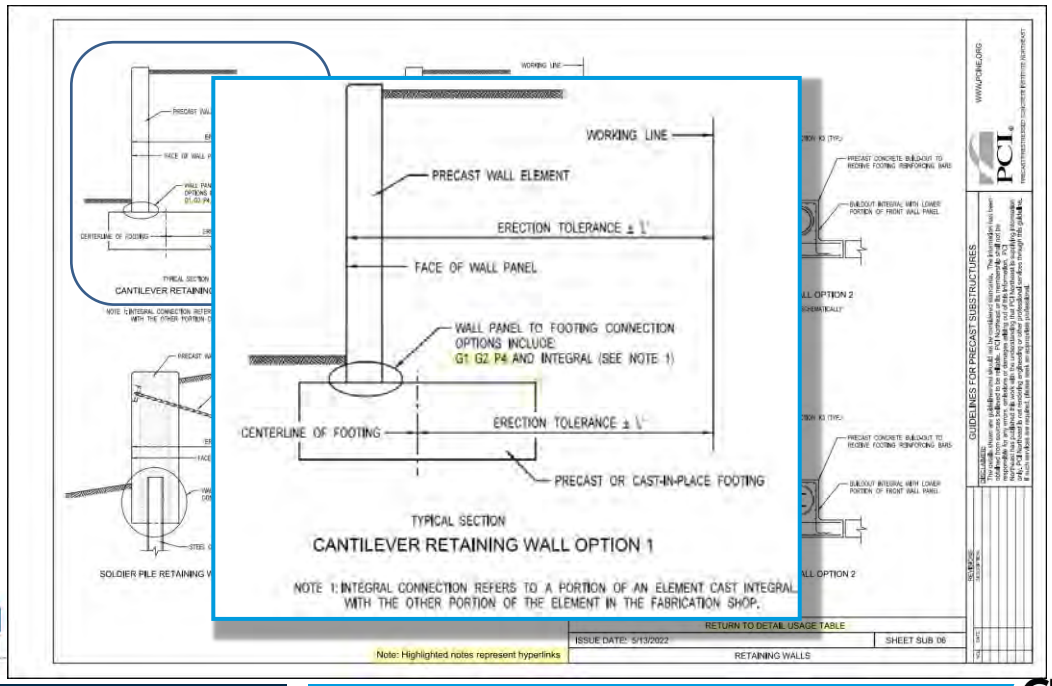
Retaining Walls






47

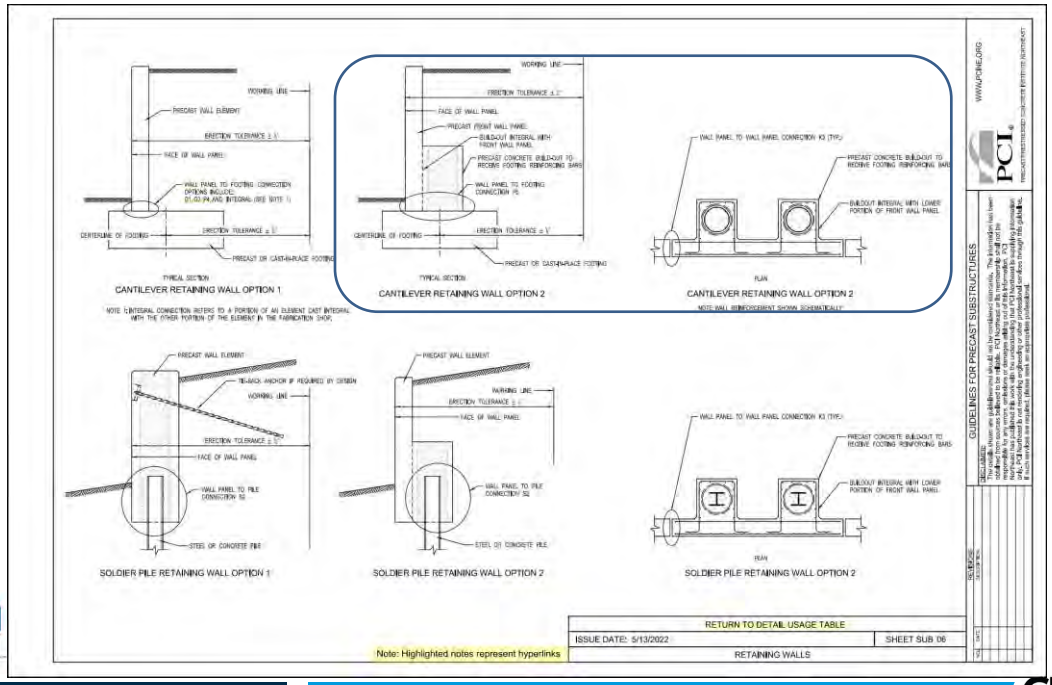
Retaining Walls






48

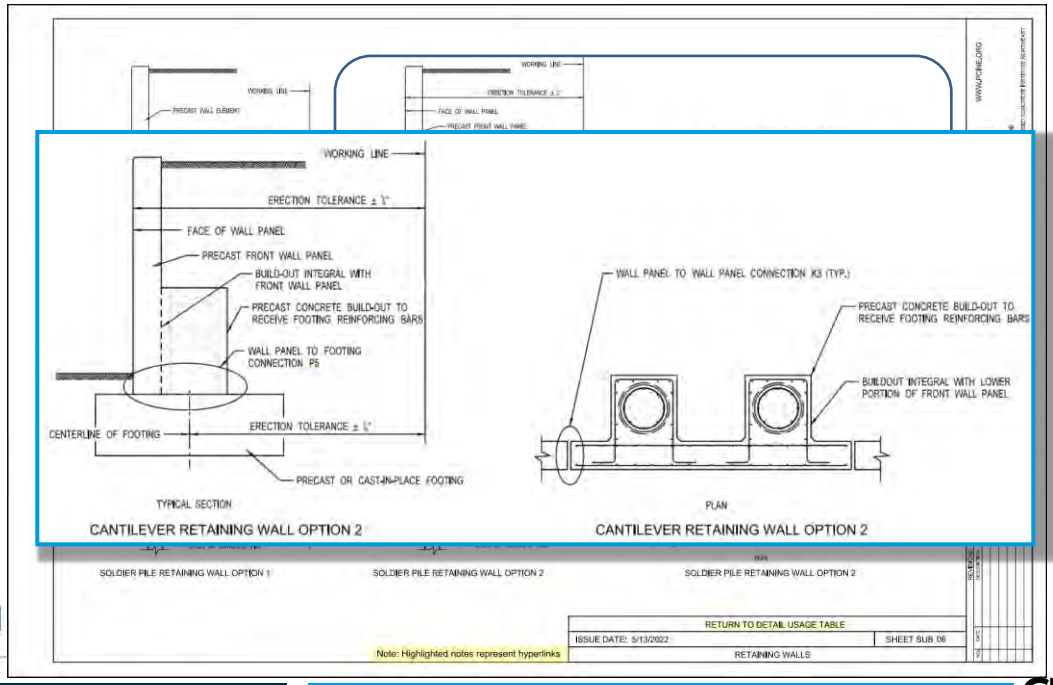
Retaining Walls



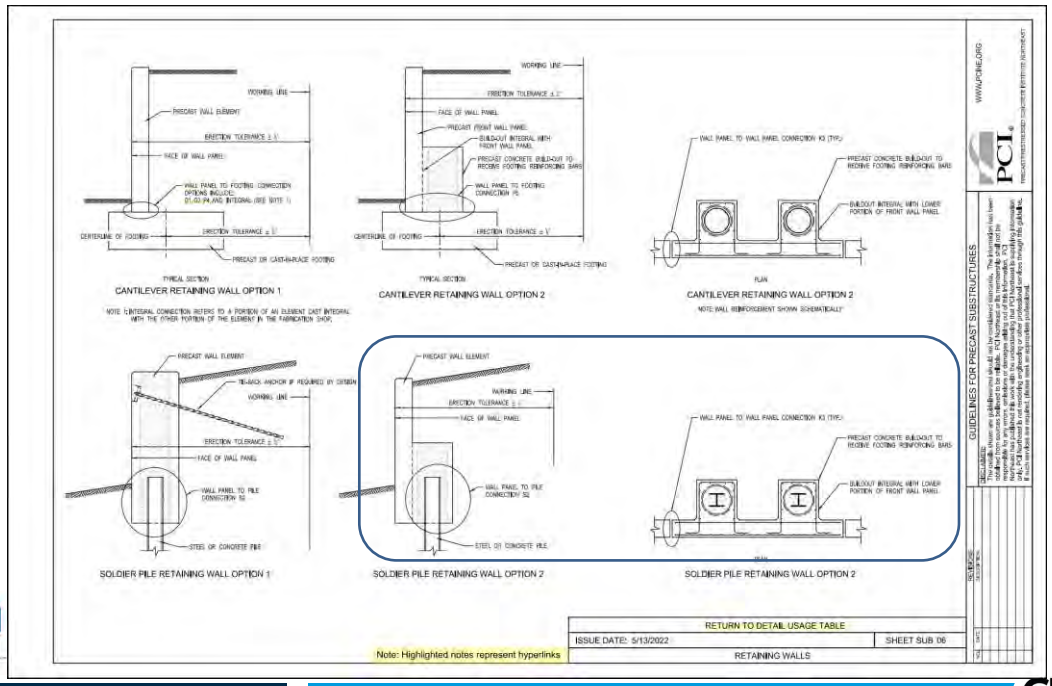





Retaining Walls



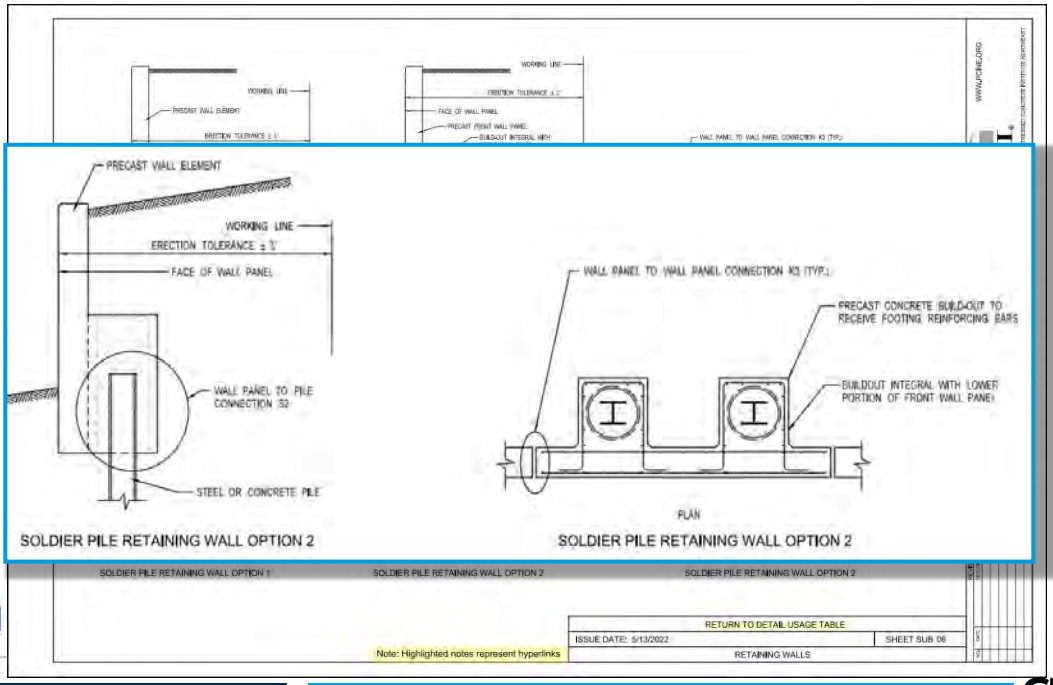
# Retaining Walls






51

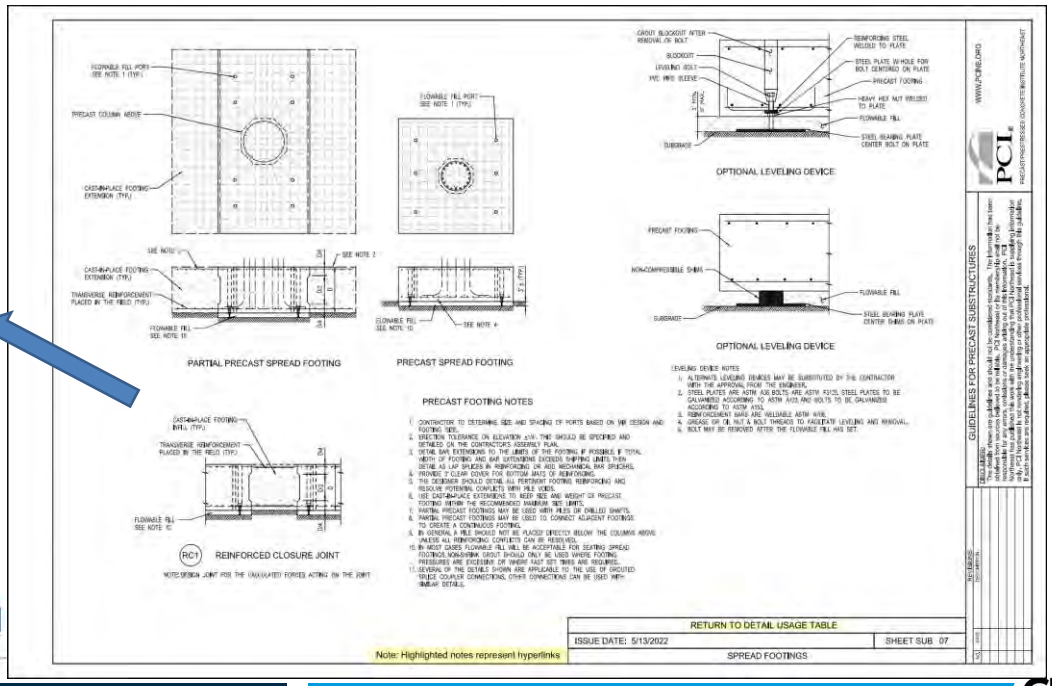
# Retaining Walls






52

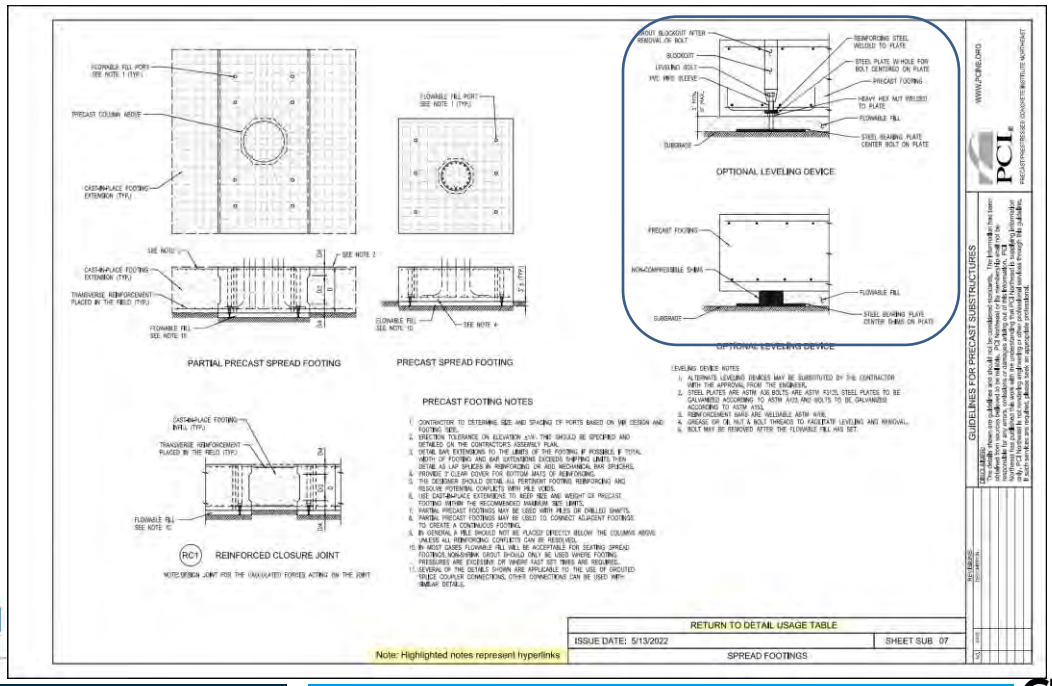
Spread Footings



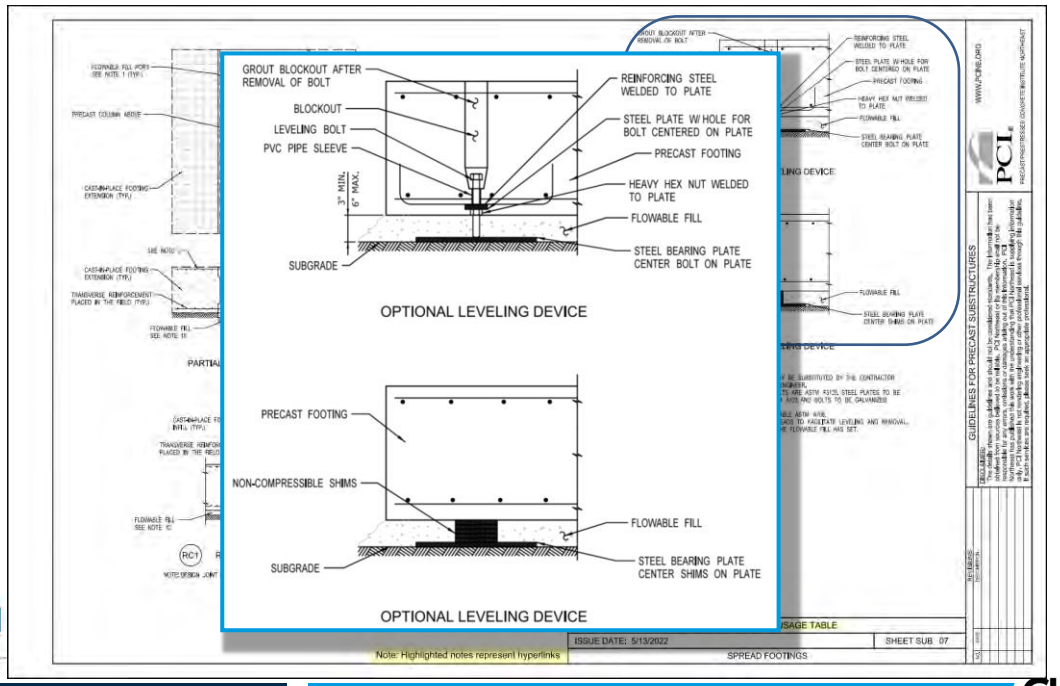





Spread Footings



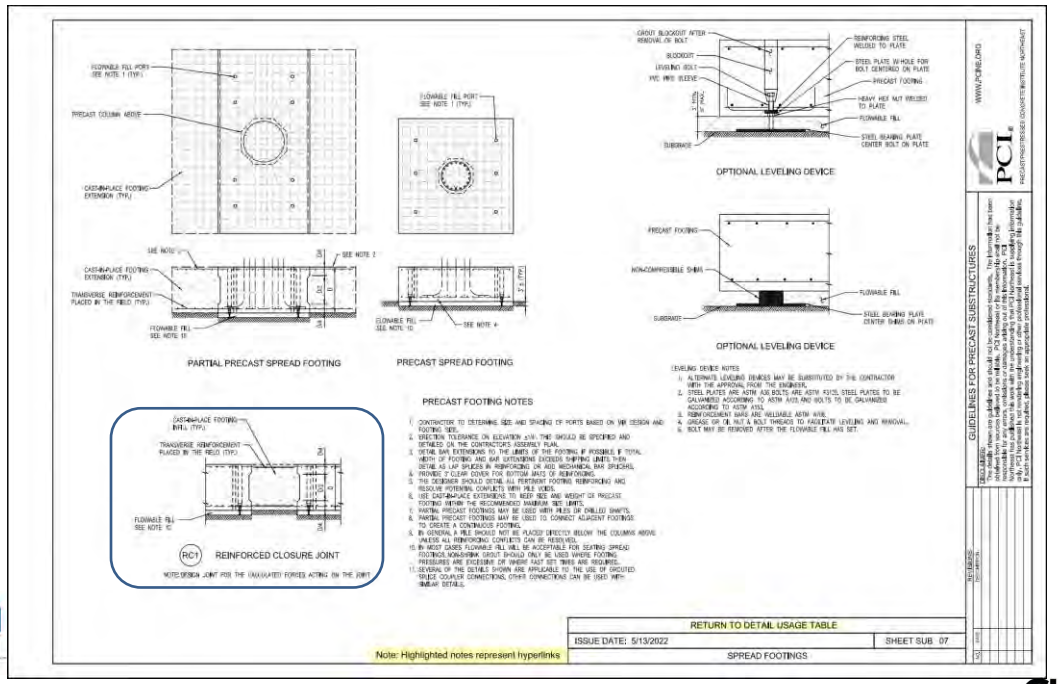
# Spread Footings






55

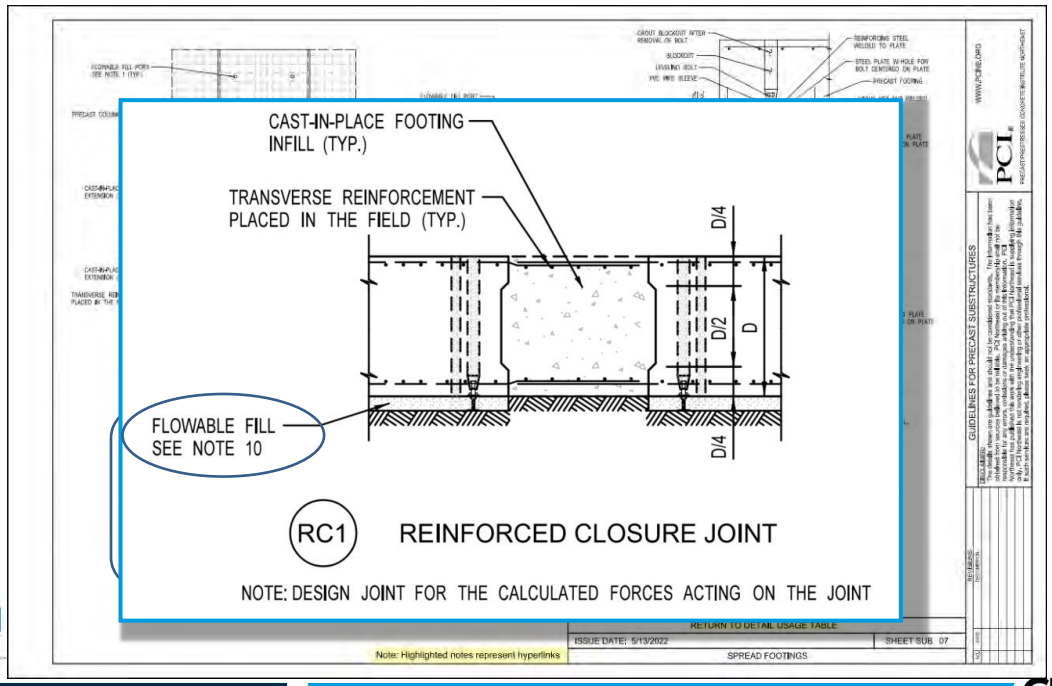
# Spread Footings






56

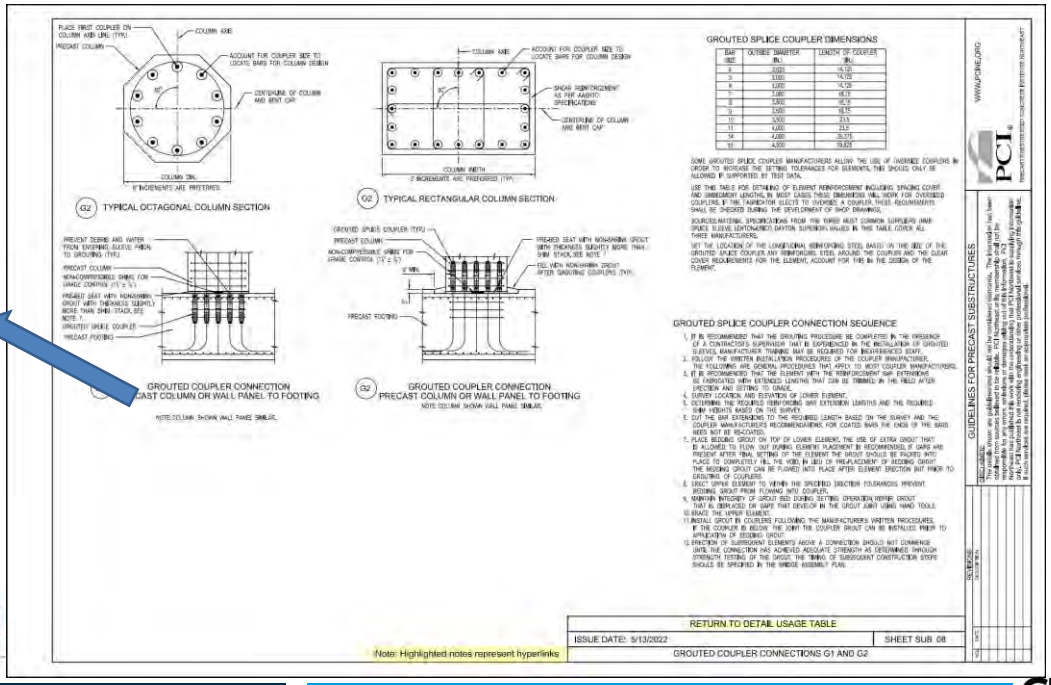
# Spread Footings






57

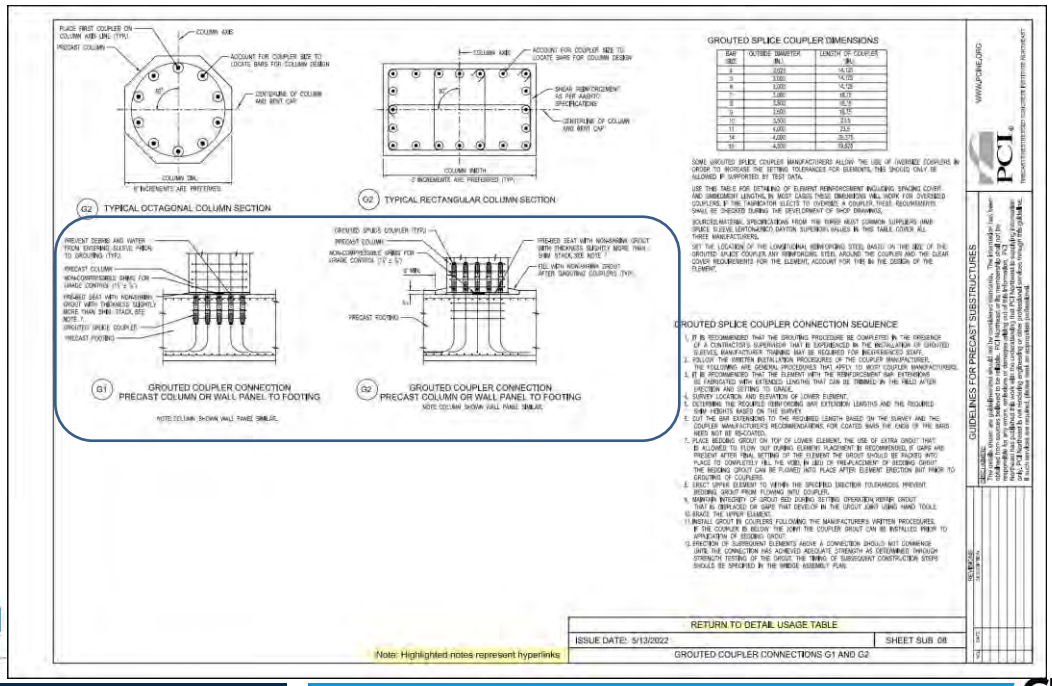
# Grouted Coupler Connections






58

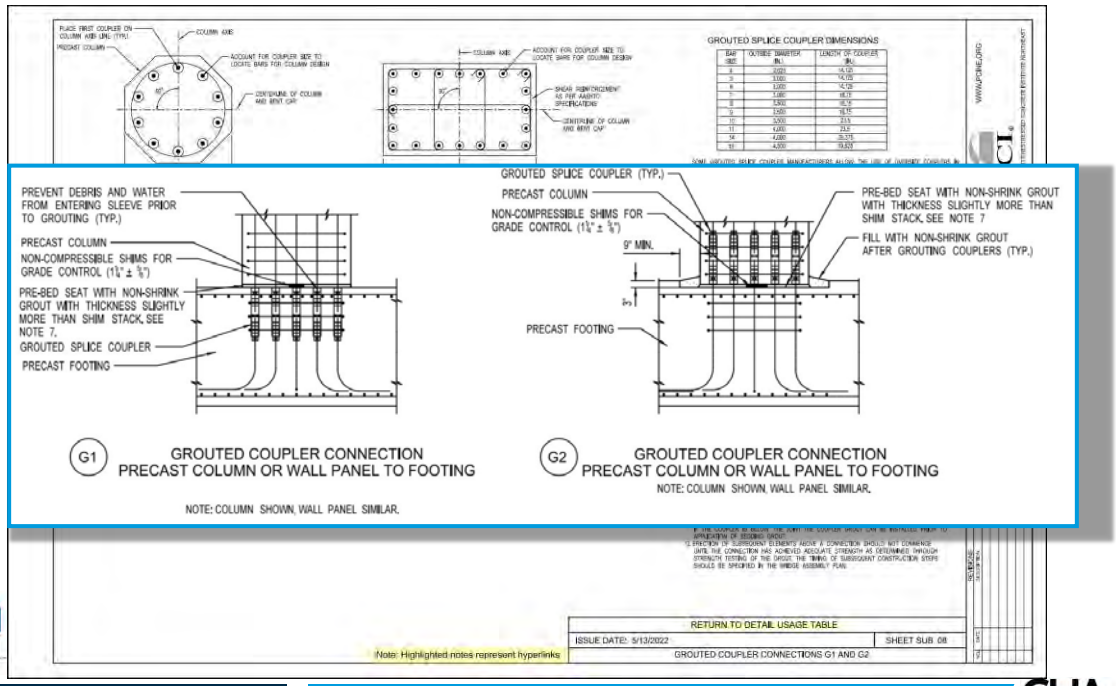
Grouted Coupler Connections






59

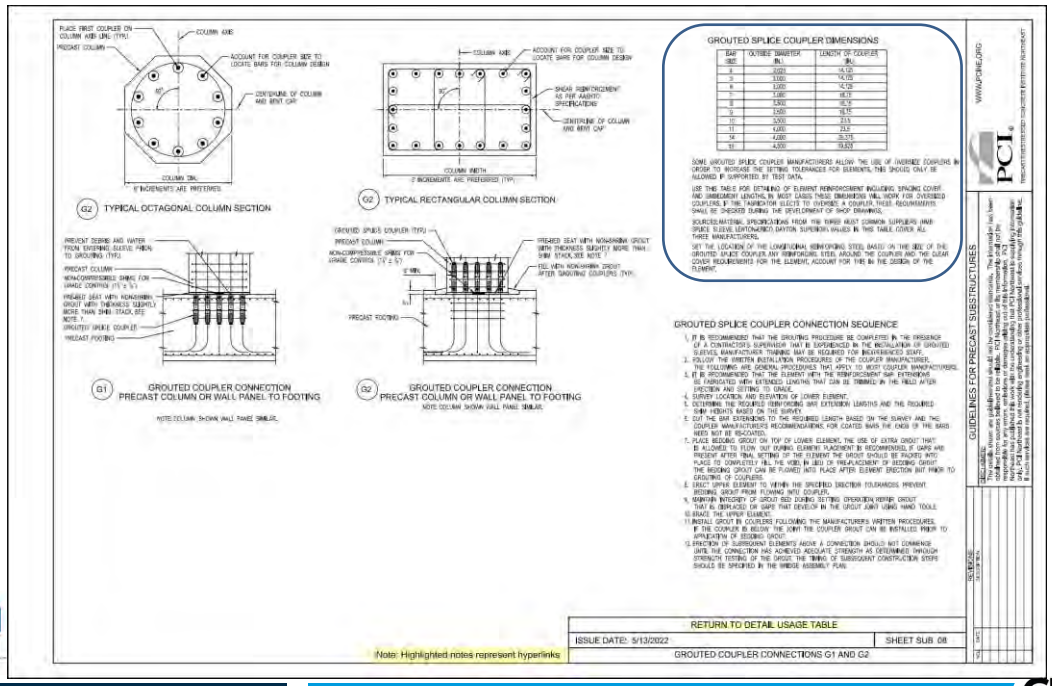
Grouted Coupler Connections






60

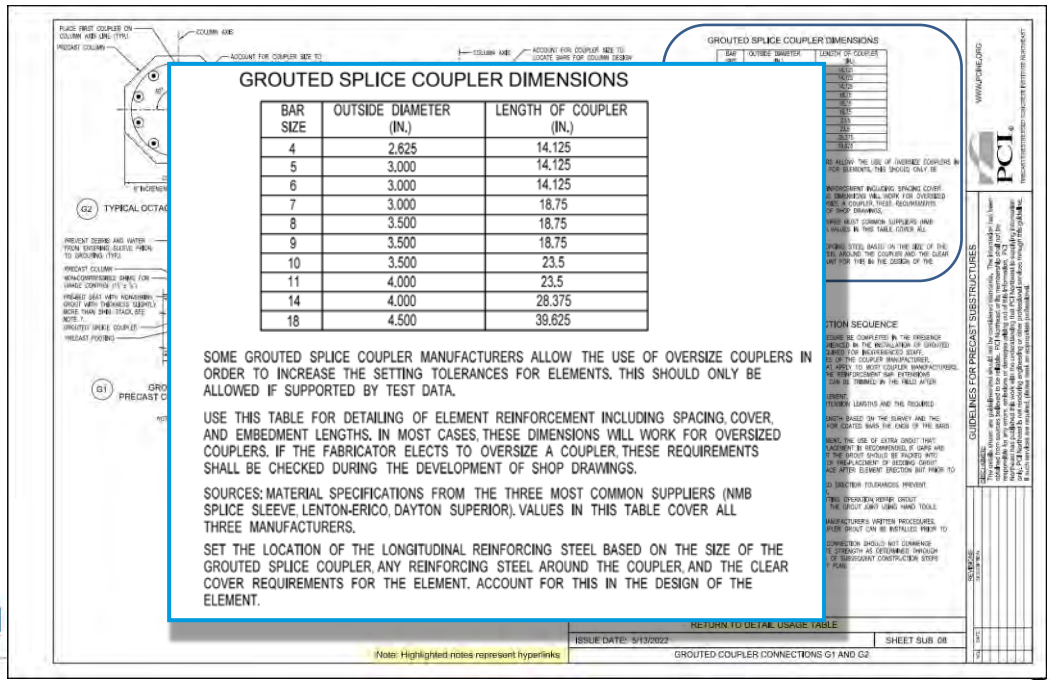
Grouted Coupler Connections






61

Grouted Coupler Connections




## GROUTED SPLICE COUPLER DIMENSIONS

| BAR SIZE | OUTSIDE DIAMETER (IN.) | LENGTH OF COUPLER (IN.) |
|---|---|---|
| 4 | 2.625 | 14.125 |
| 5 | 3.000 | 14.125 |
| 6 | 3.000 | 14.125 |
| 7 | 3.000 | 18.75 |
| 8 | 3.500 | 18.75 |
| 9 | 3.500 | 18.75 |
| 10 | 3.500 | 23.5 |
| 11 | 4.000 | 23.5 |
| 14 | 4.000 | 28.375 |
| 18 | 4.500 | 39.625 |

SOME GROUTED SPLICE COUPLER MANUFACTURERS ALLOW THE USE OF OVERSIZE COUPLERS IN ORDER TO INCREASE THE SETTING TOLERANCES FOR ELEMENTS. THIS SHOULD ONLY BE ALLOWED IF SUPPORTED BY TEST DATA.

USE THIS TABLE FOR DETAILING OF ELEMENT REINFORCEMENT INCLUDING SPACING, COVER, AND EMBEDMENT LENGTHS. IN MOST CASES, THESE DIMENSIONS WILL WORK FOR OVERSIZED COUPLERS. IF THE FABRICATOR ELECTS TO OVERSIZE A COUPLER, THESE REQUIREMENTS SHALL BE CHECKED DURING THE DEVELOPMENT OF SHOP DRAWINGS.

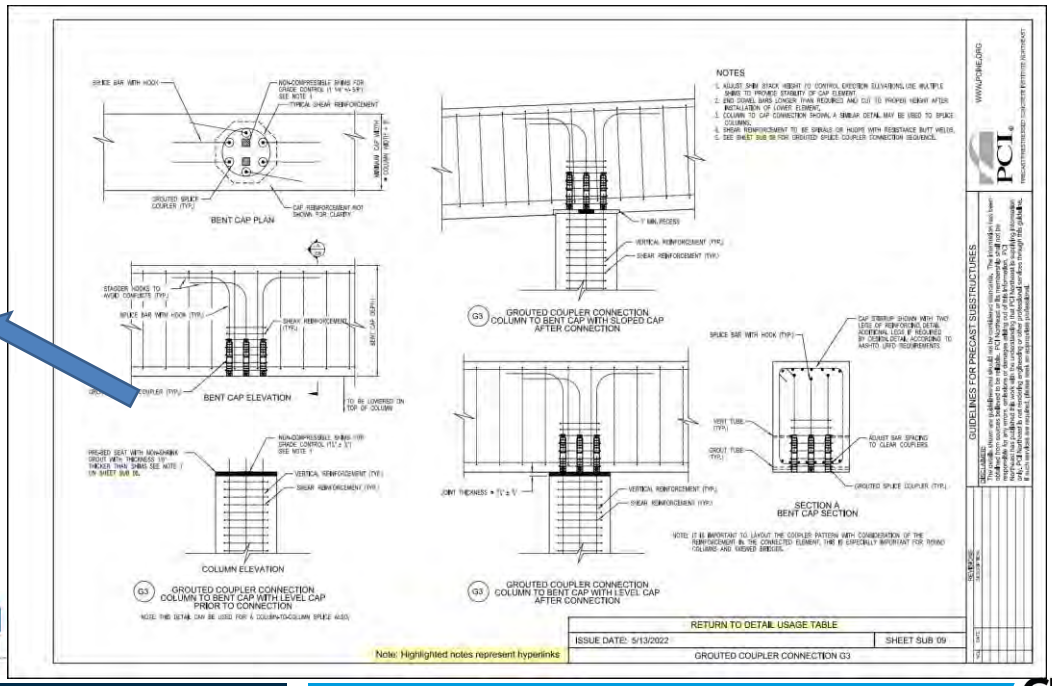
SOURCES: MATERIAL SPECIFICATIONS FROM THE THREE MOST COMMON SUPPLIERS (NMB SPLICE SLEEVE, LENTON-ERICO, DAYTON SUPERIOR). VALUES IN THIS TABLE COVER ALL THREE MANUFACTURERS.

SET THE LOCATION OF THE LONGITUDINAL REINFORCING STEEL BASED ON THE SIZE OF THE GROUTED SPLICE COUPLER, ANY REINFORCING STEEL AROUND THE COUPLER, AND THE CLEAR COVER REQUIREMENTS FOR THE ELEMENT. ACCOUNT FOR THIS IN THE DESIGN OF THE ELEMENT.



62

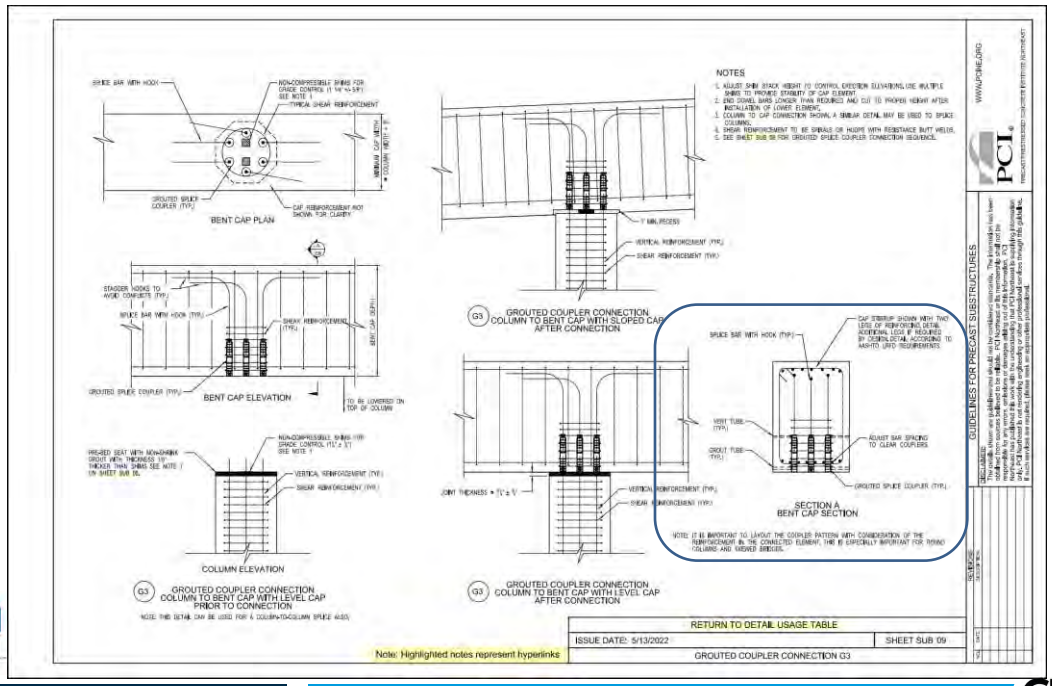
Grouted Coupler Connections






63

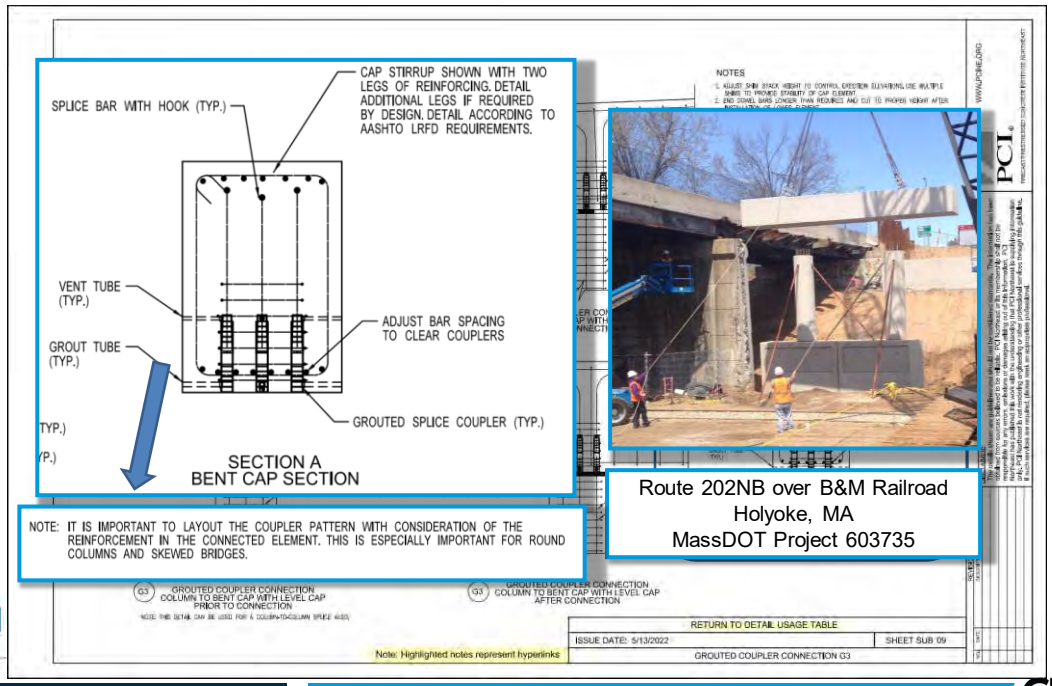
Grouted Coupler Connections






64

## Grouted Coupler Connections




Route 202NB over B&M Railroad
Holyoke, MA
MassDOT Project 603735

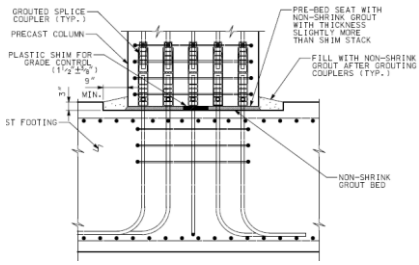




# Design of Grouted Bar Coupler Connections

Couplers have a minor impact on the design

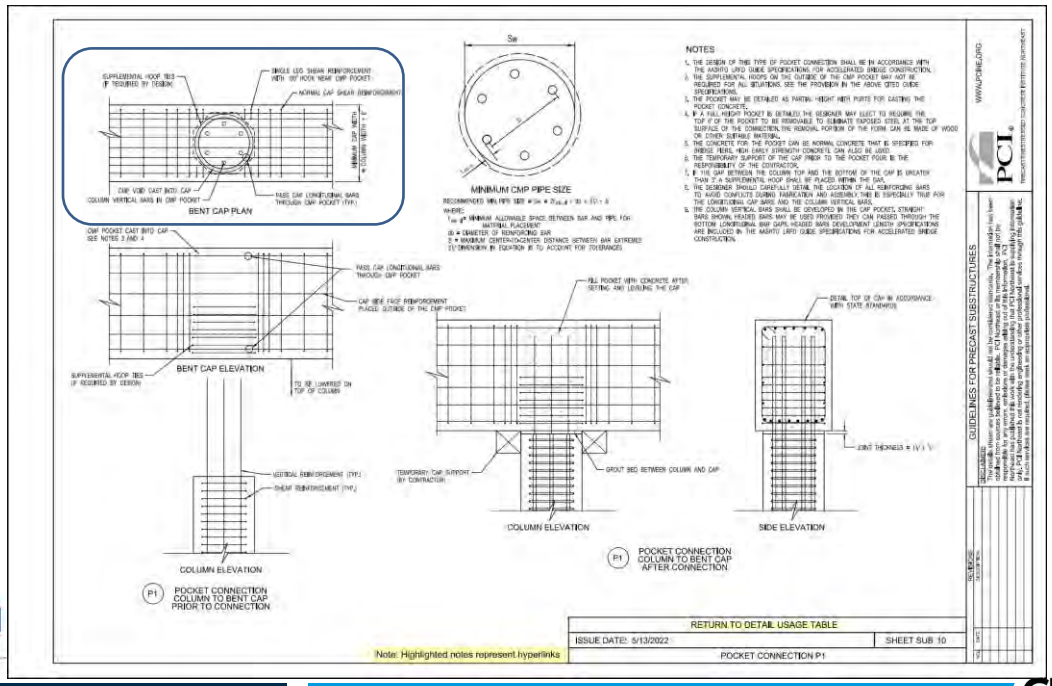
- Coupler Designs
  - The diameter of the coupler is larger than the bar
  - In order to maintain cover over the coupler, the designer needs to move the rebar cage for design
  - This has a minor impact on the section capacity
  - May require larger bars
- This is covered in the ABC Guide Spec
- See NCHRP Project 12-102A Training Module 2 for sample calculations




**3.6.4.4—Type 2 Mechanical Connectors in Plastic Hinge (ED) Regions for SDCs C and D (Seismic Zones 3 and 4)**

Where Type 2 mechanical connectors are used in plastic hinge regions to connect a precast column to a footing or pier cap, the following requirements shall be satisfied.

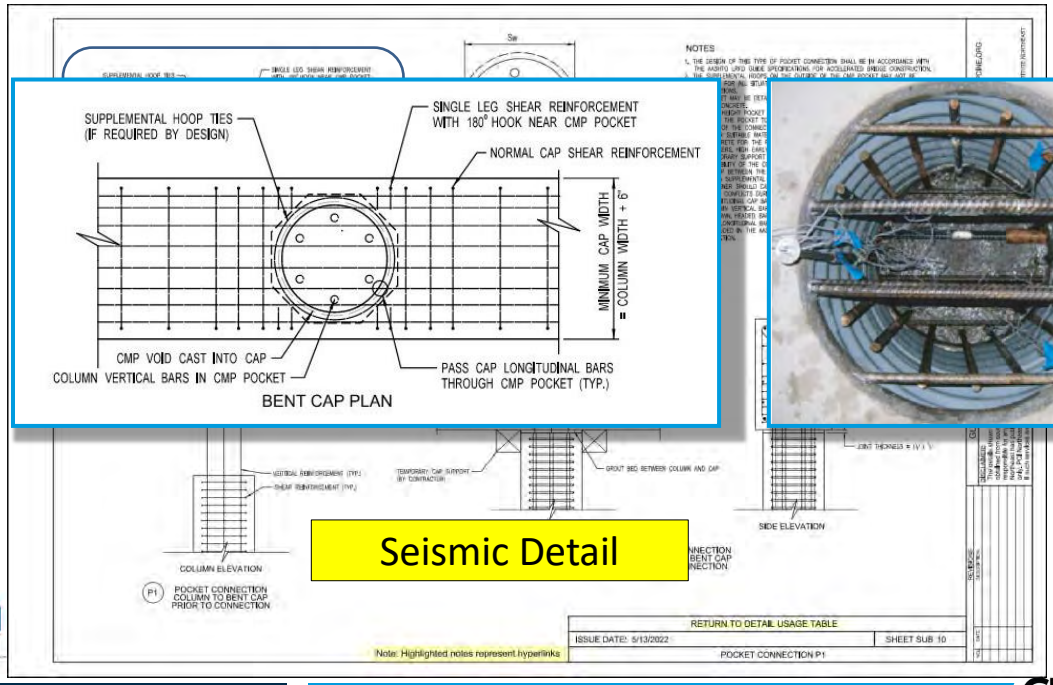
# Pocket Connections



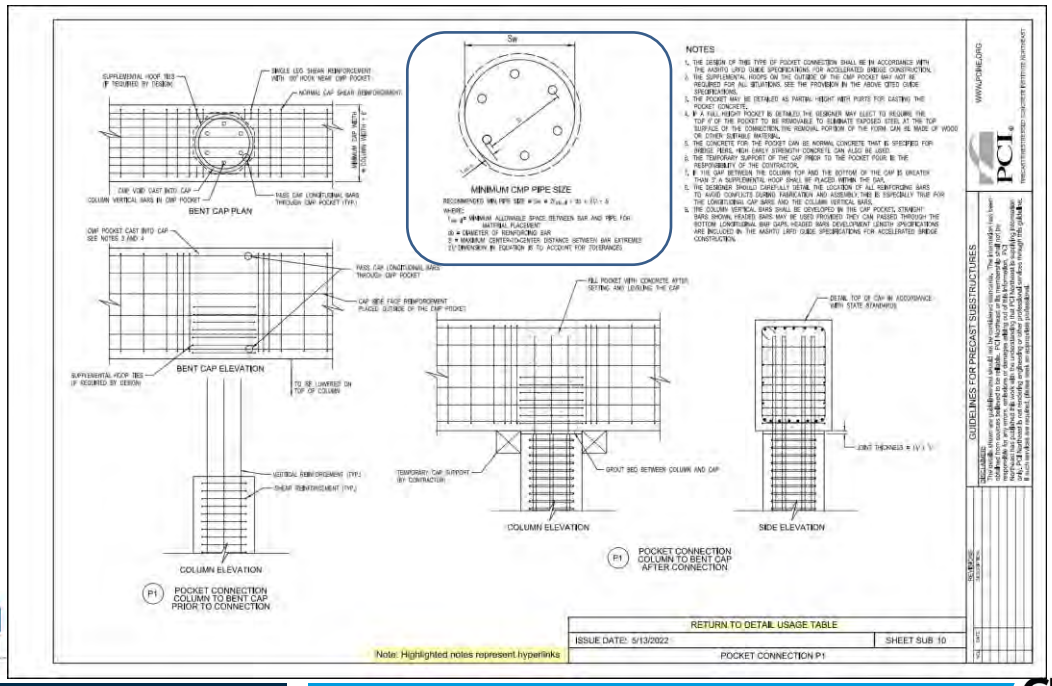





# Pocket Connections



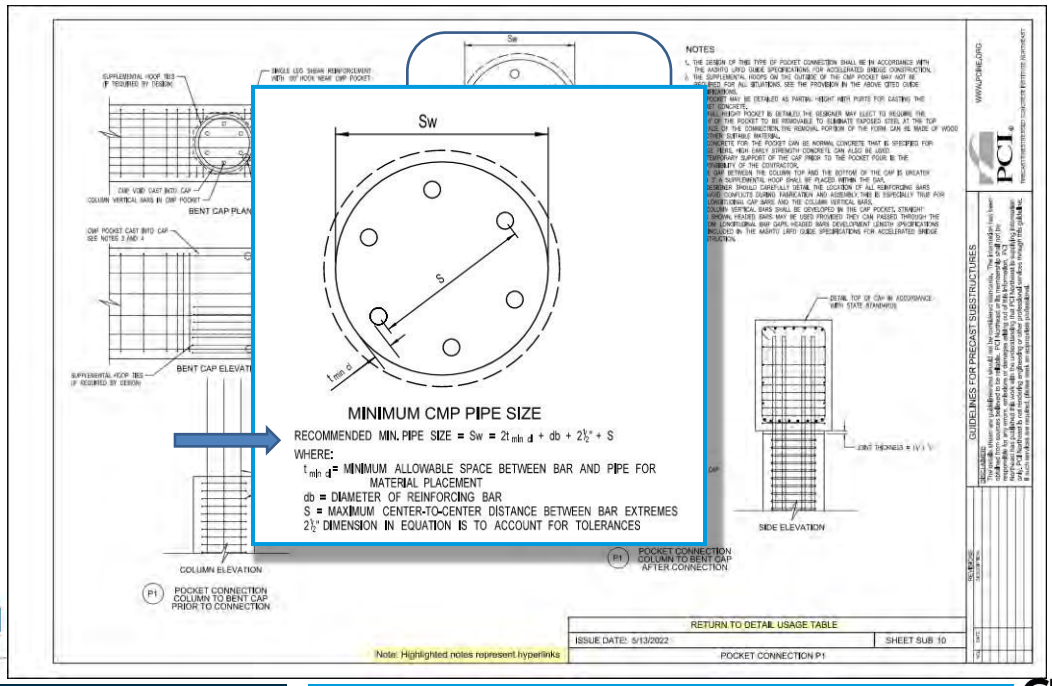
Pocket Connections






69

Pocket Connections






70

# Design of Pocket Connections

- This connection requires a detailed design procedure.
- The 2018 AASHTO LRFD Guide Specifications have detailed provisions.
- See NCHRP Project 12-102A Training Module 2 for sample calculations

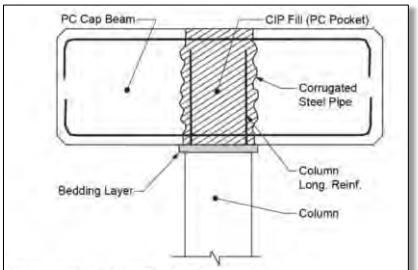



**Figure C3.6.6.1-1—Pocket Connection**

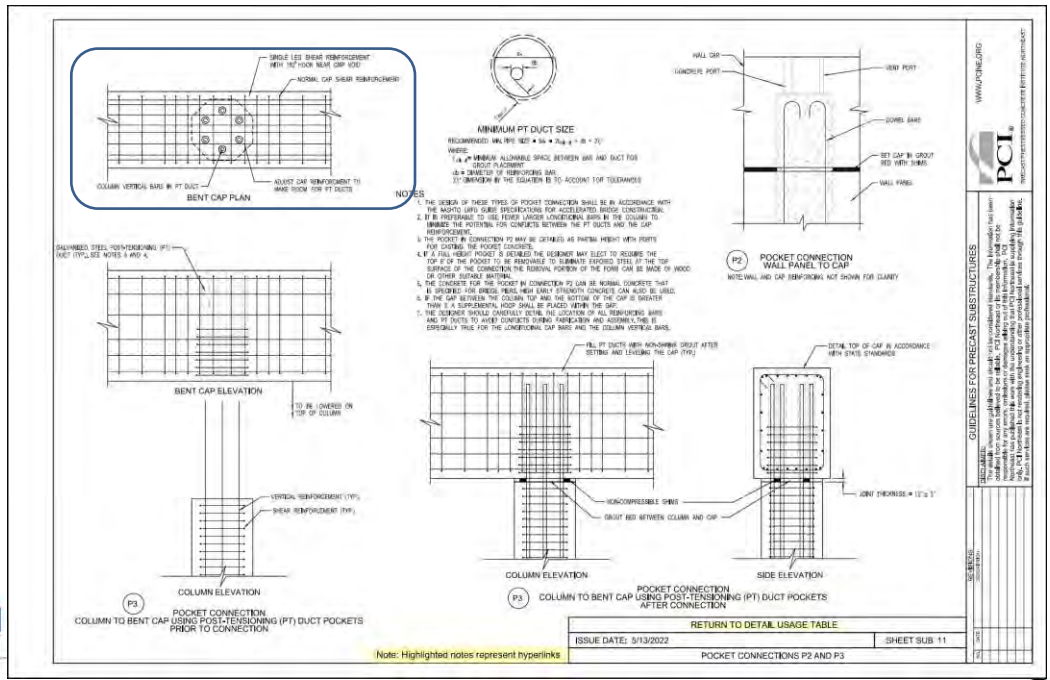
**3.6.6.1—Column-to-Pier Cap or Column-to-Footing Pocket Connections**

Pocket connections involve a column with projecting reinforcement and a receiving precast pier cap or footing containing a pocket. The column is placed such that the projecting reinforcement falls inside of the precast pocket and the connection is completed by filling the void with cast-in-place concrete or grout. A bedding layer between the end of the column and the pier cap soffit or footing top is used to accommodate fabrication and placement tolerances.

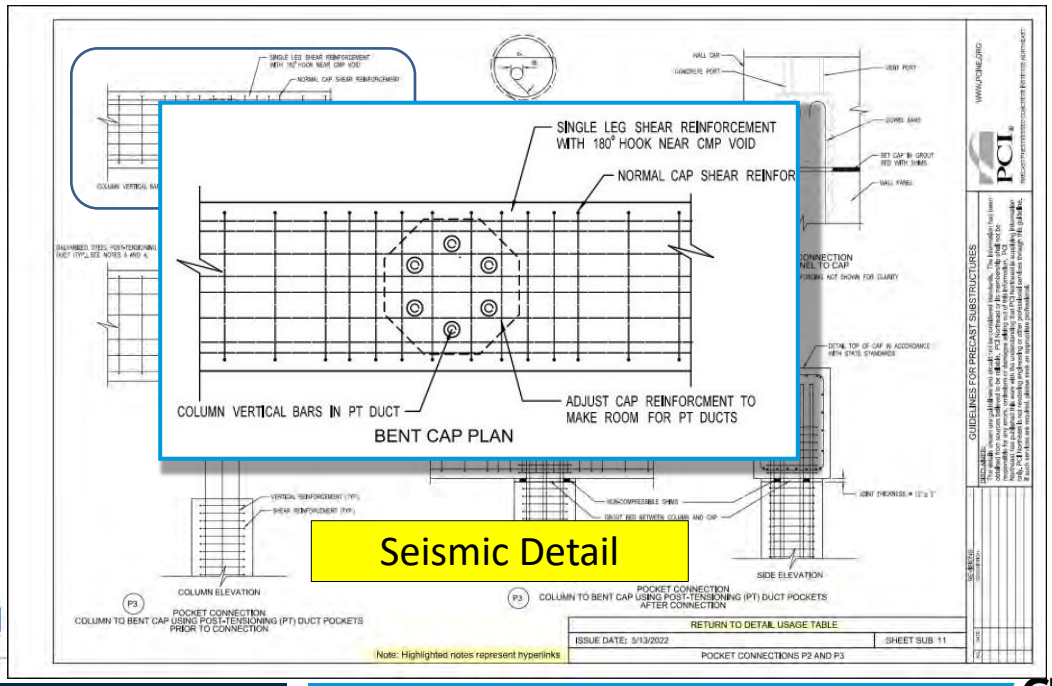




Pocket Connections



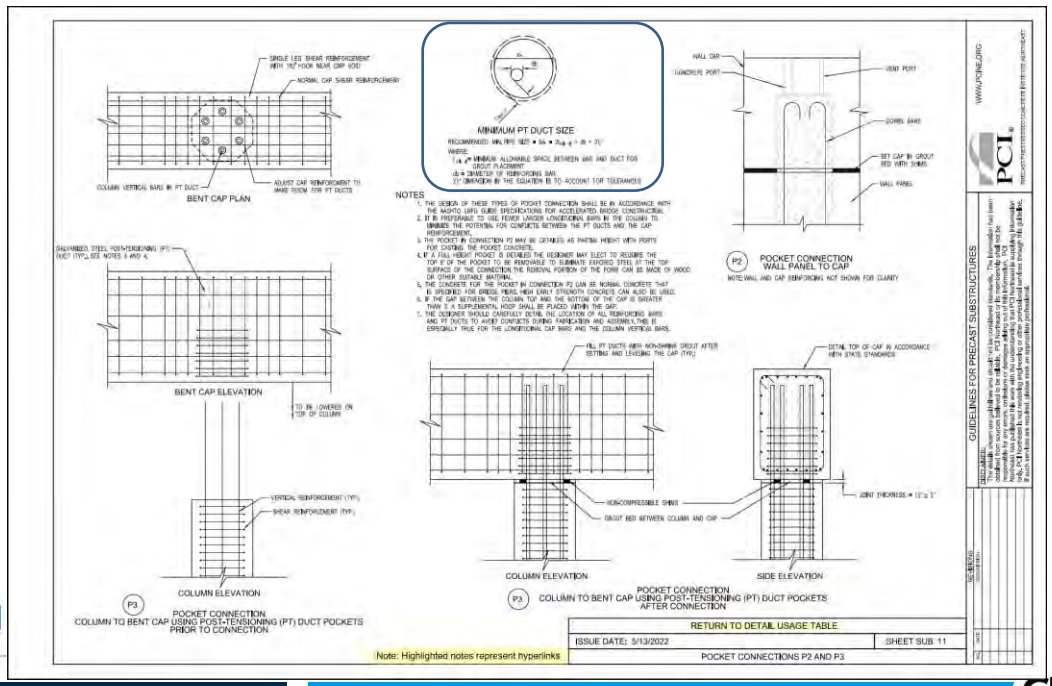
# Pocket Connections






73

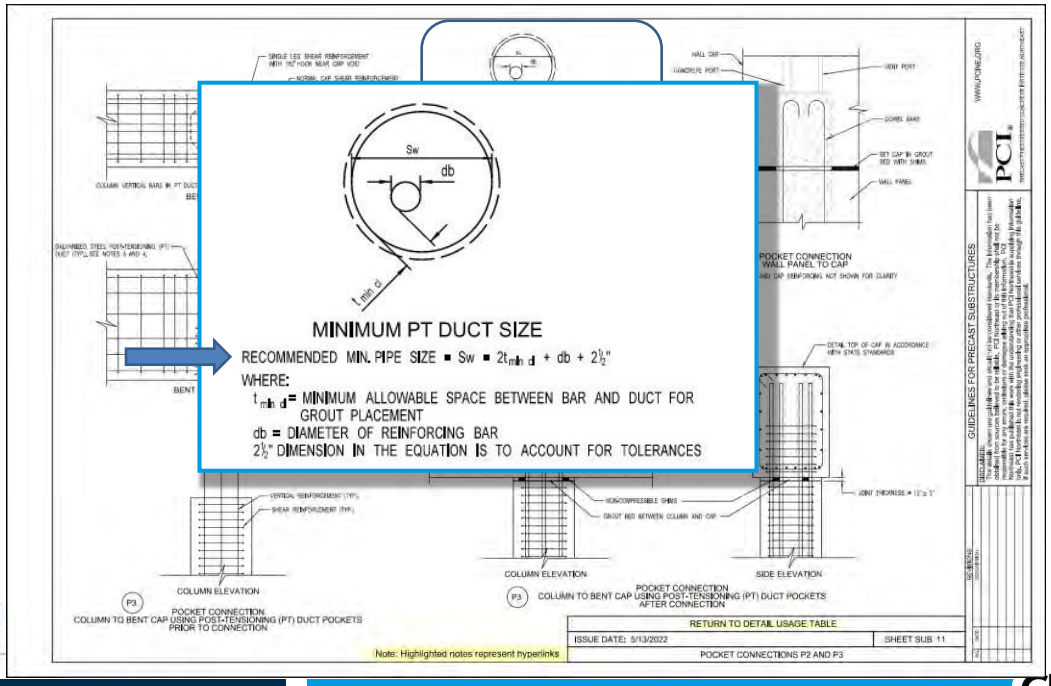
Pocket Connections






74

# Pocket Connections






75

# Design of PT Duct Pocket Connection

- This connection requires a detailed design procedure.
- The 2018 AASHTO LRFD Guide Specifications have provisions.

**3.6.5—GROUTED DUCT CONNECTIONS**

Grouted duct connections are used to connect individual reinforcing bars in tension by grouting the reinforcing bar that projects from one member into a corrugated steel duct embedded in a receiving member. Tensile force transfer occurs from the bar into the grout, from the grout into the duct, and then from the

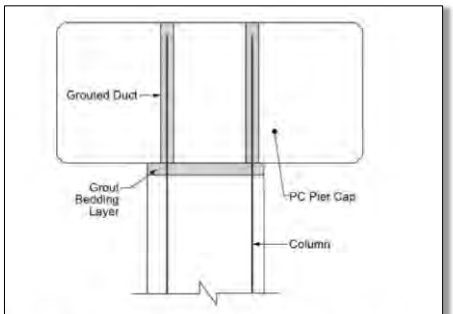
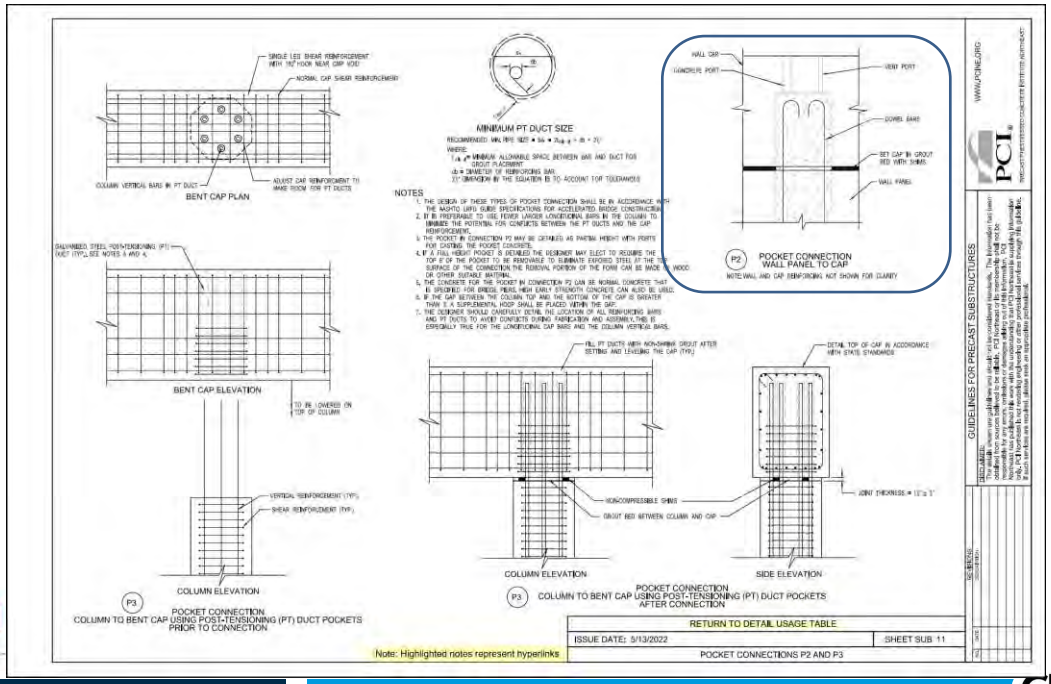



**Figure C3.6.5-1—Column-Pier Cap Grouted Duct Connection**



76

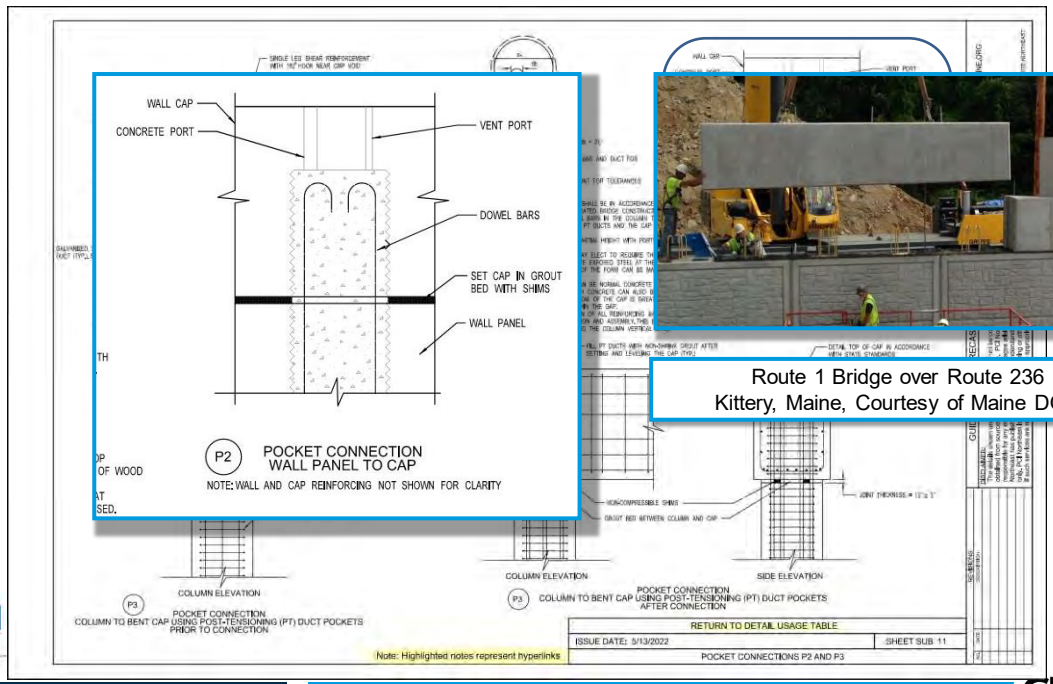
# Pocket Connections






77

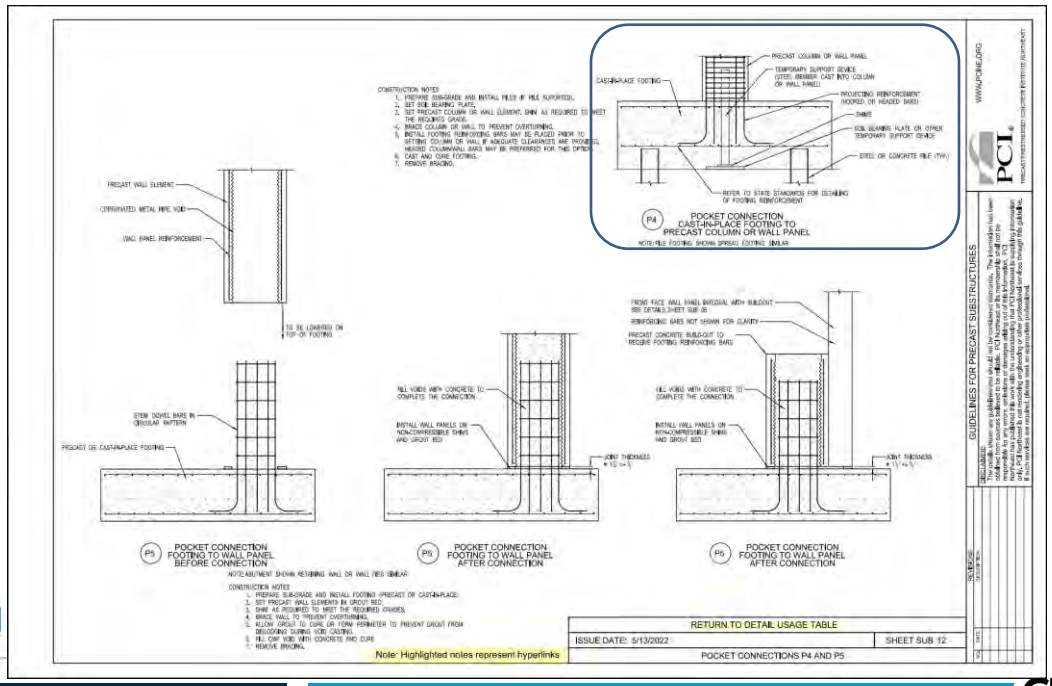
# Pocket Connections






78

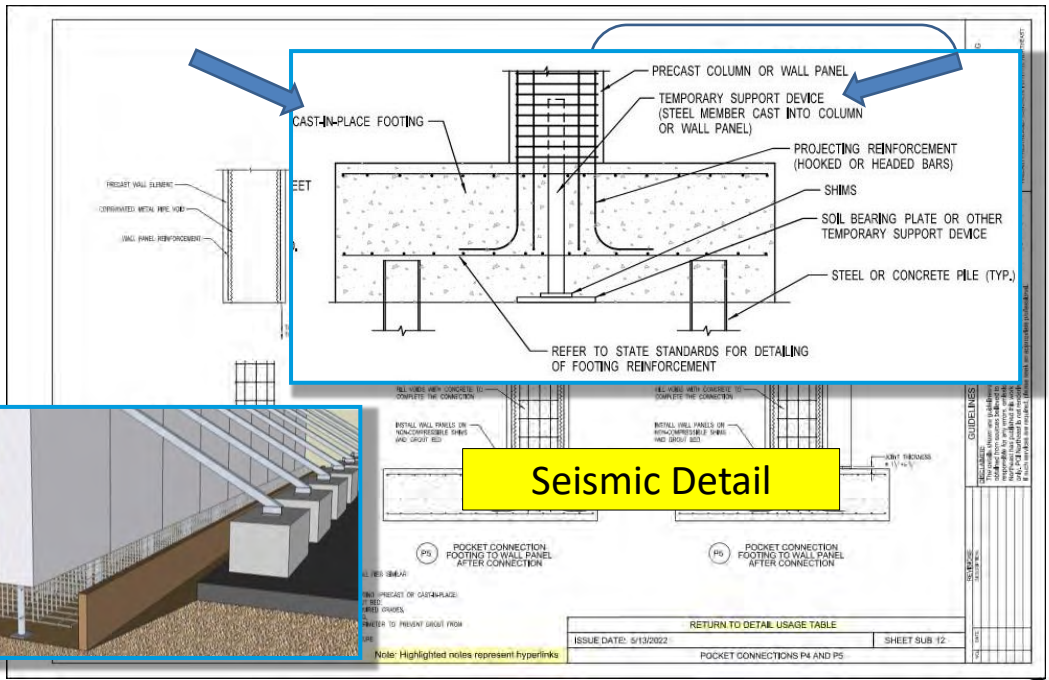
# Pocket Connections






79

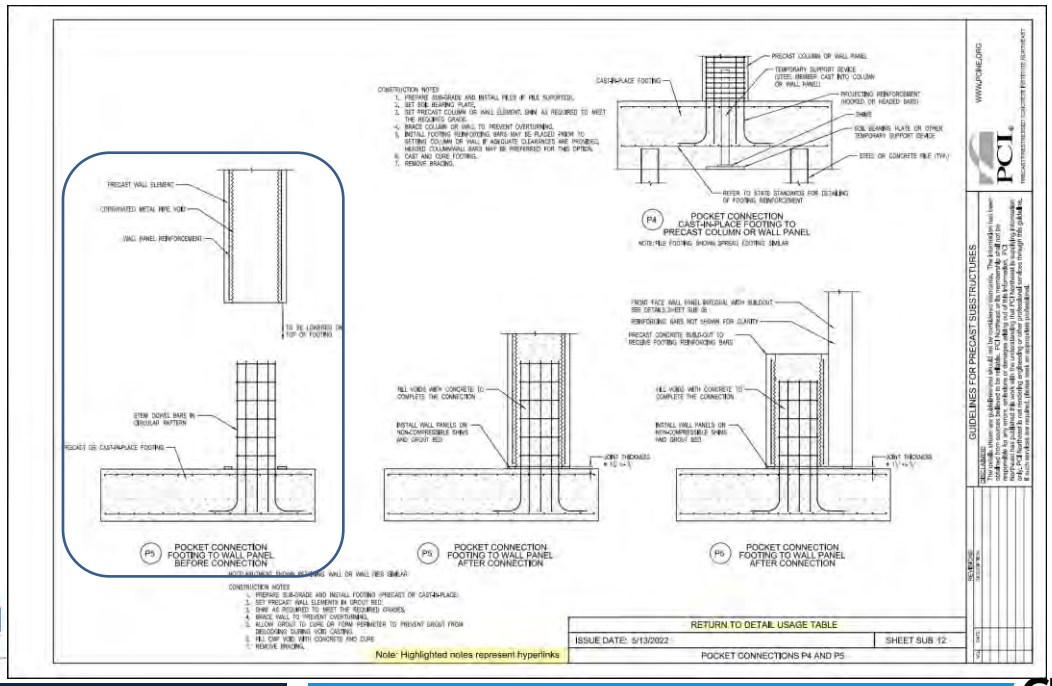
# Pocket Connections






80

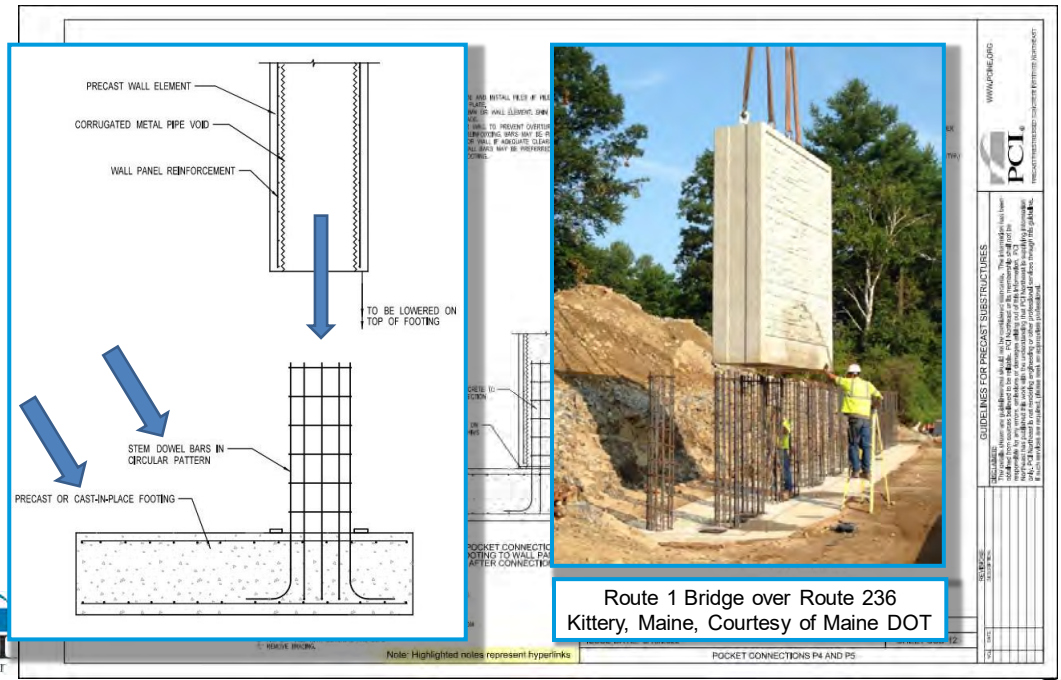
# Pocket Connections






81

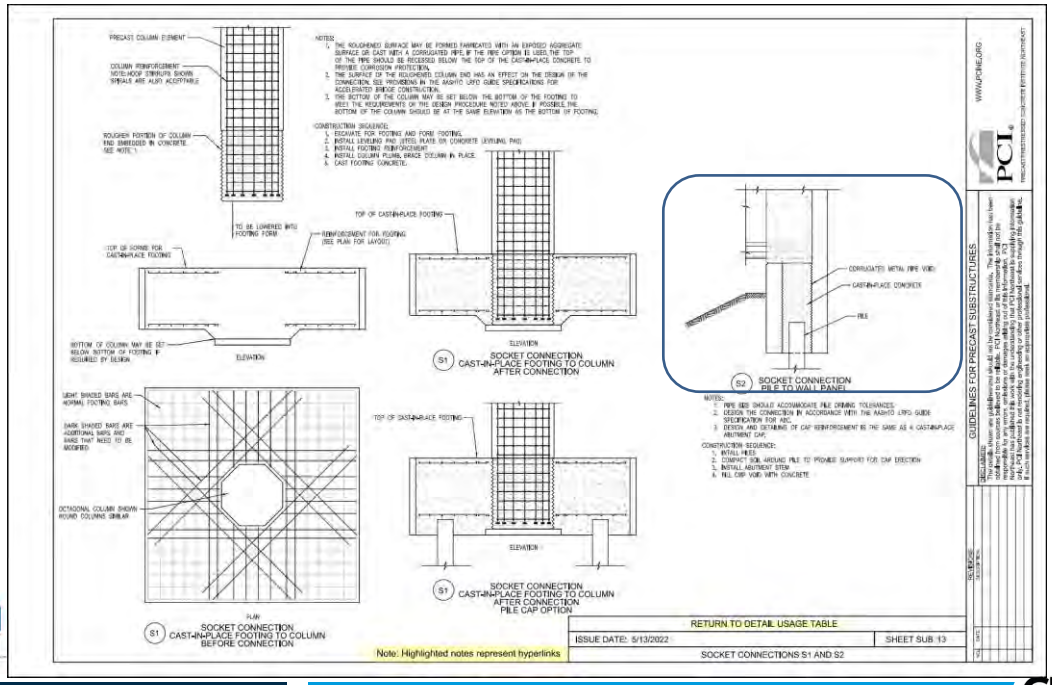
# Pocket Connections






82

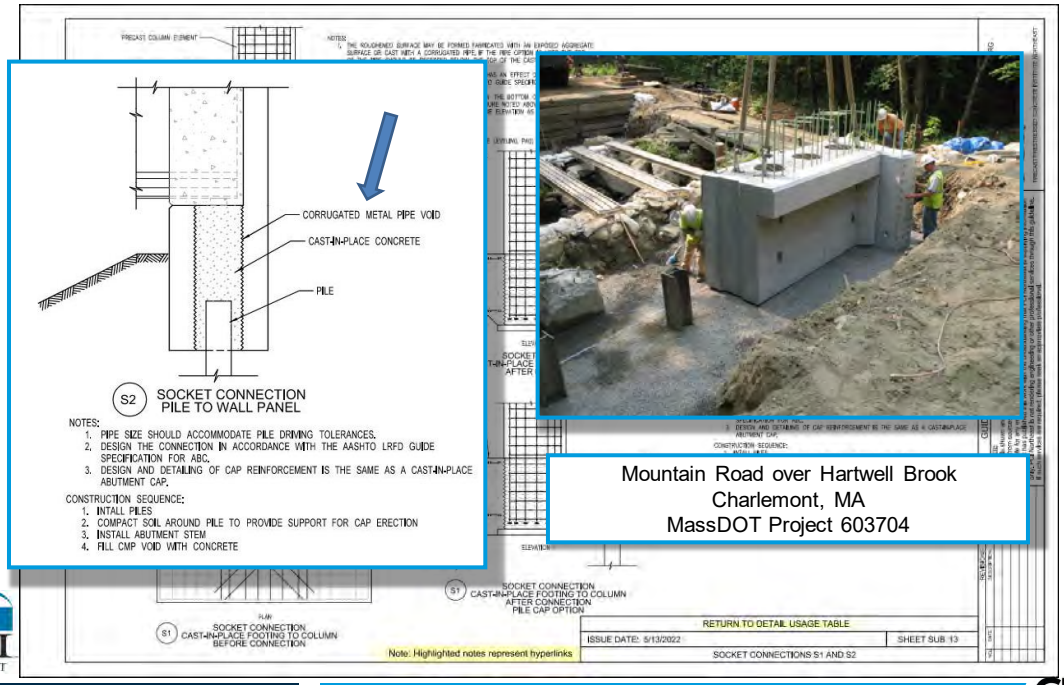
# Socket Connections






83

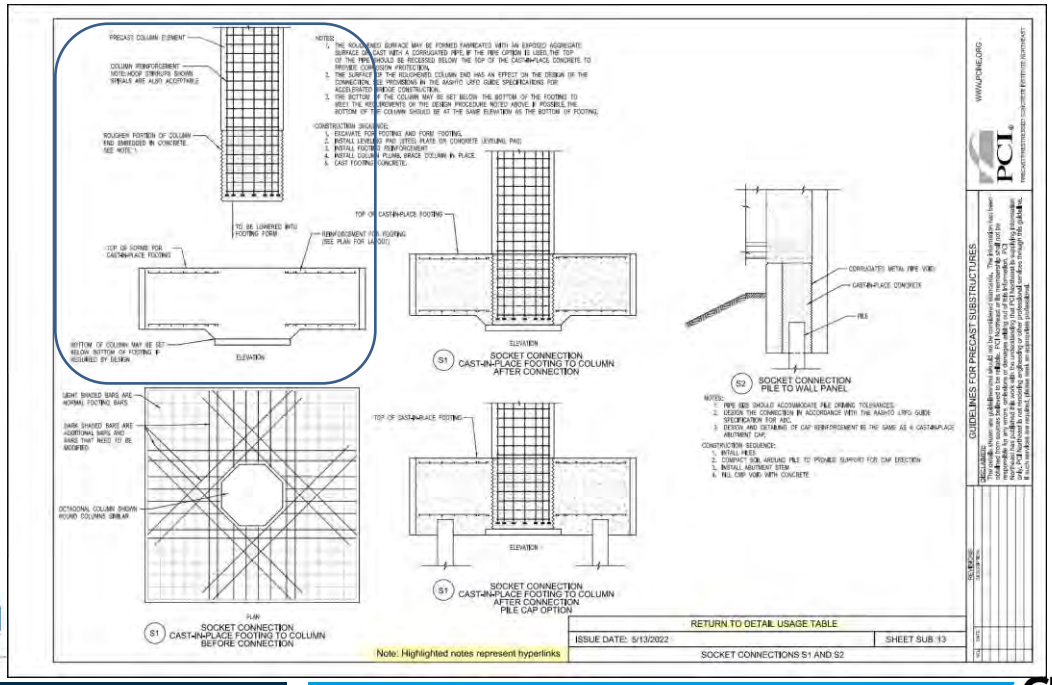
# Pocket Connections






84

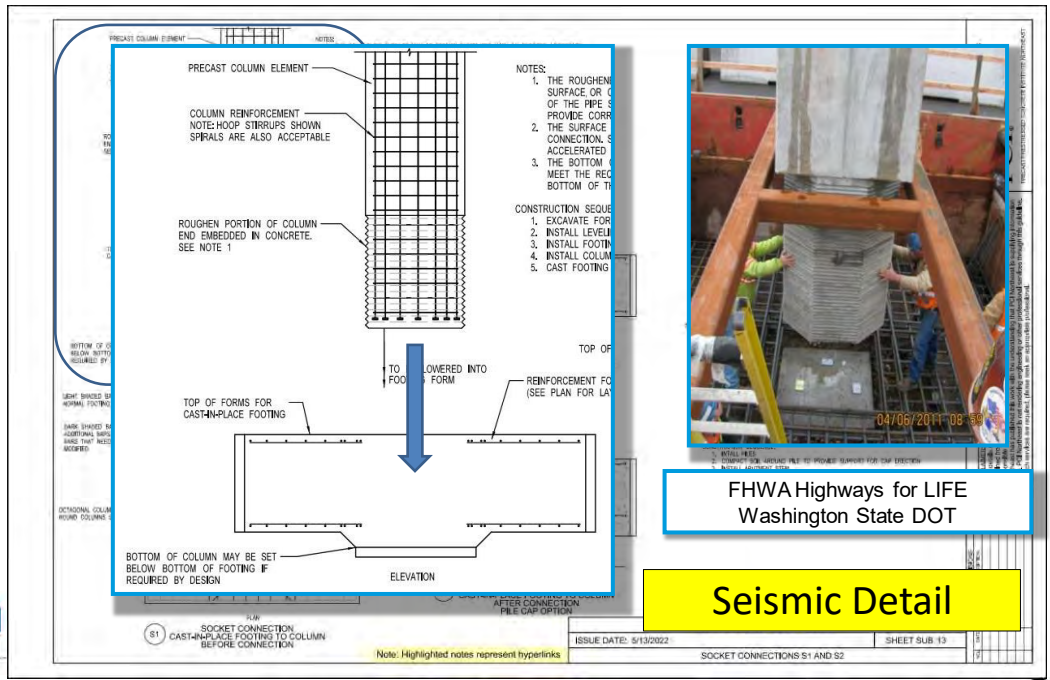
Pocket Connections






85

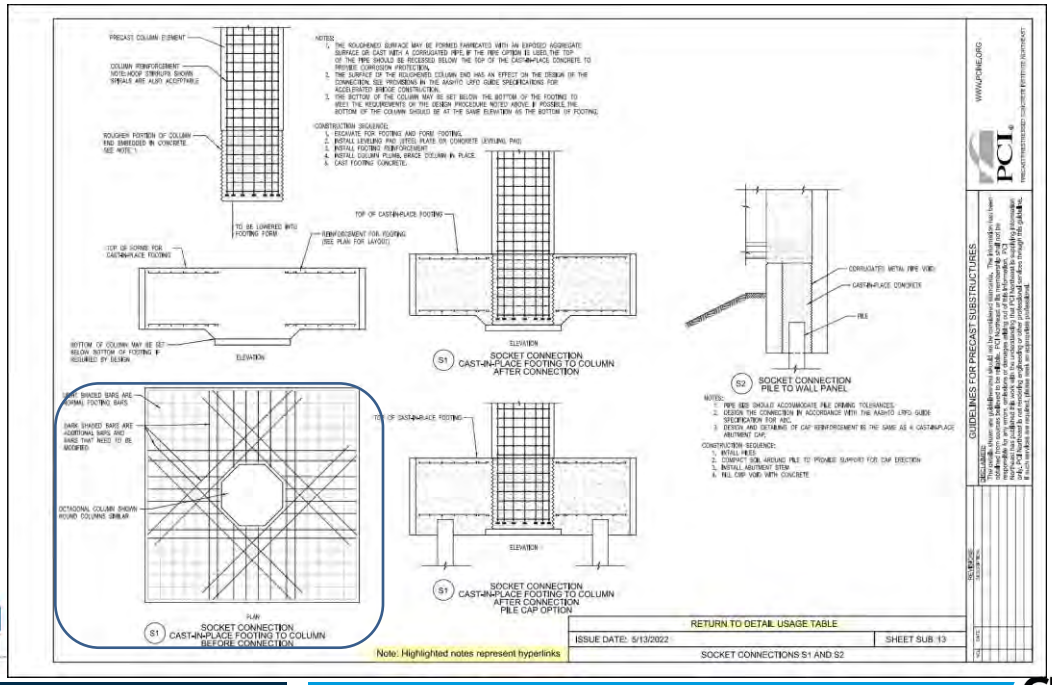
Pocket Connections






86

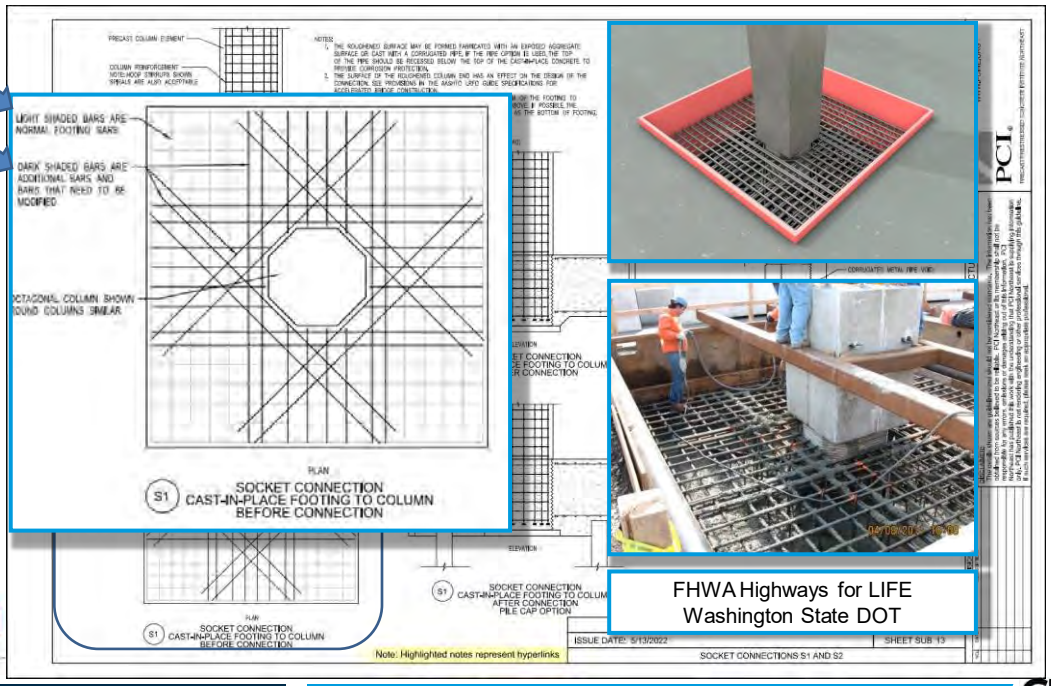
# Pocket Connections






87

# Pocket Connections

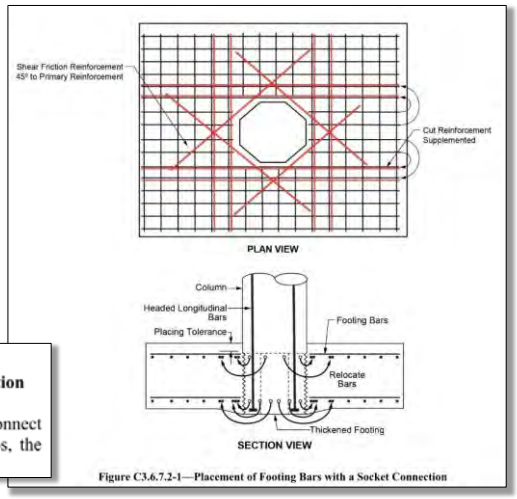





88

# Design of Socket Connections

- This connection requires a detailed design procedure.
- The 2018 AASHTO LRFD Guide Specifications have detailed provisions.
- See NCHRP Project 12-102A Training Module 2 for sample calculations




**3.6.7.2—Precast Concrete Column in Spread Footing or Pile Cap Socket Connection**

Where socket connections are used to connect precast columns to spread footings or pile caps, the following requirements shall apply.

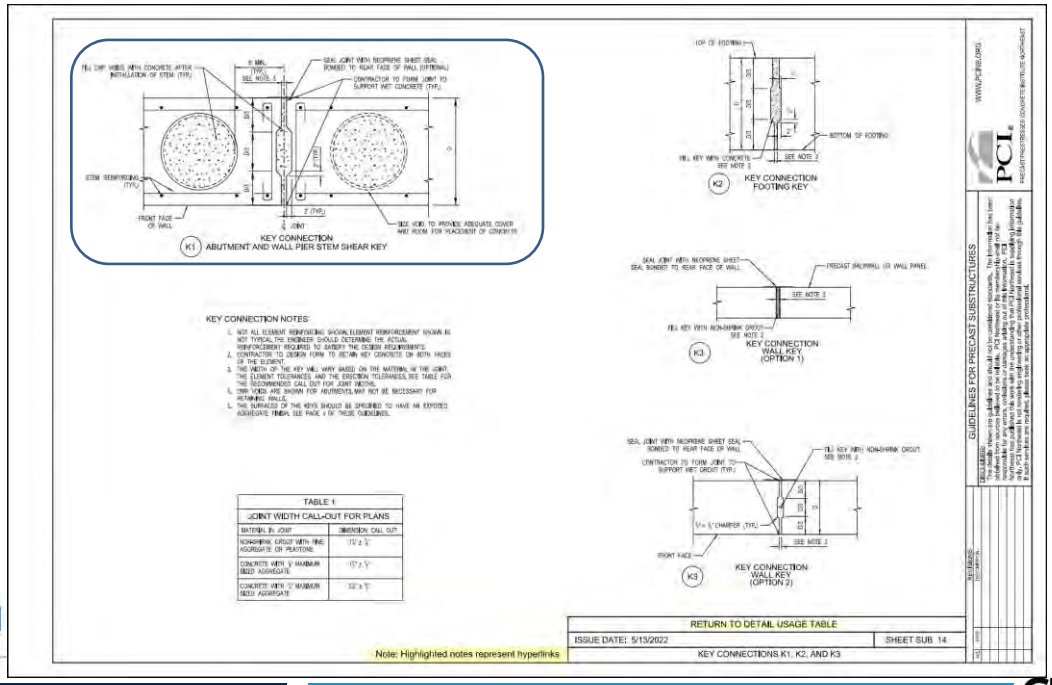
Figure C3.6.7.2-1—Placement of Footing Bars with a Socket Connection

PCI NORTHEAST A Chapter of the Precast/Prestressed Concrete Institute



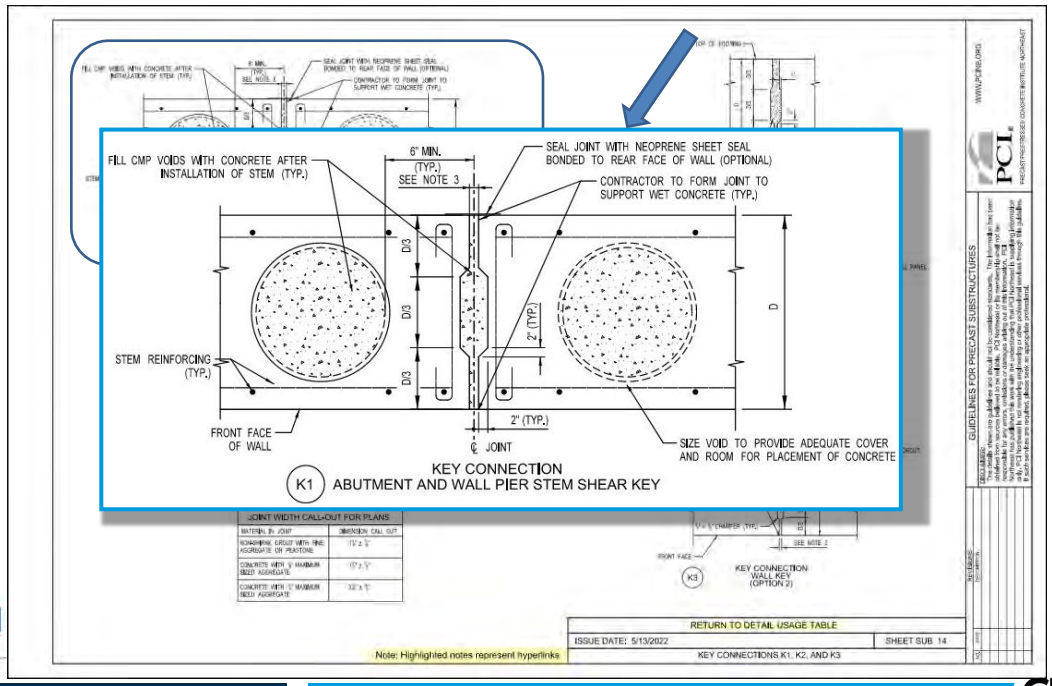


Key Connections




PCI NORTHEAST

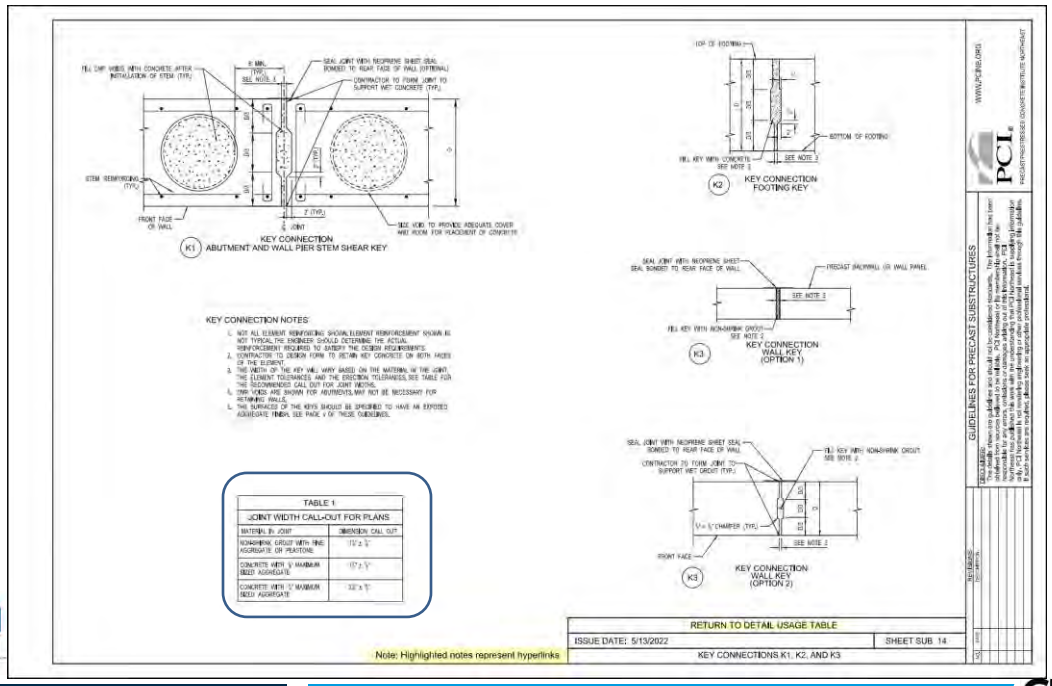
Pocket Connections



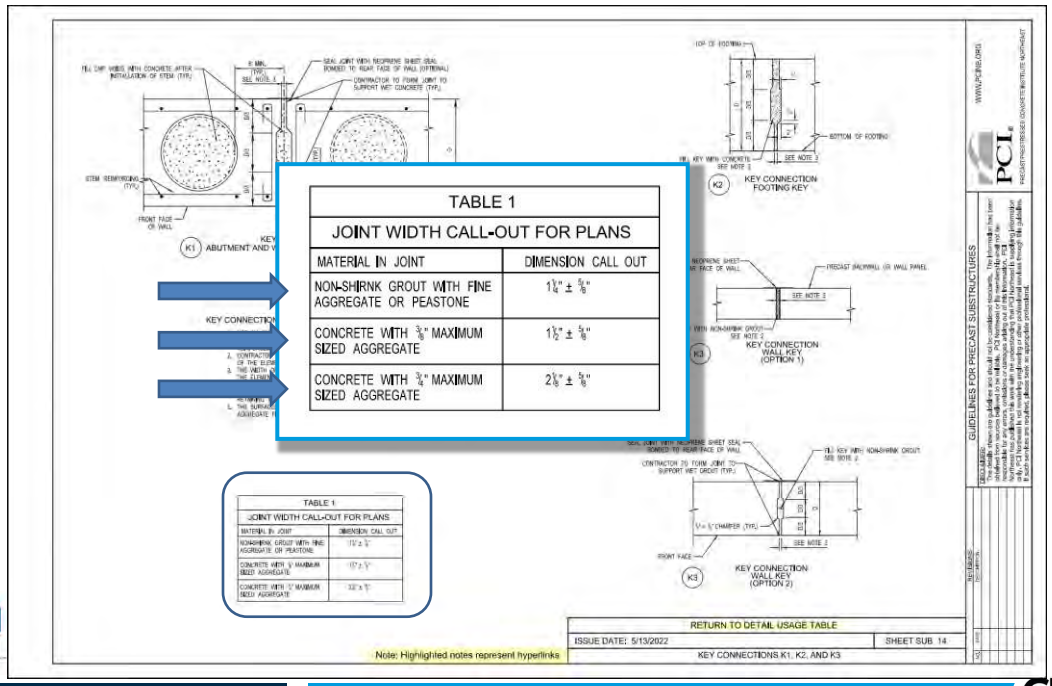





Pocket Connections



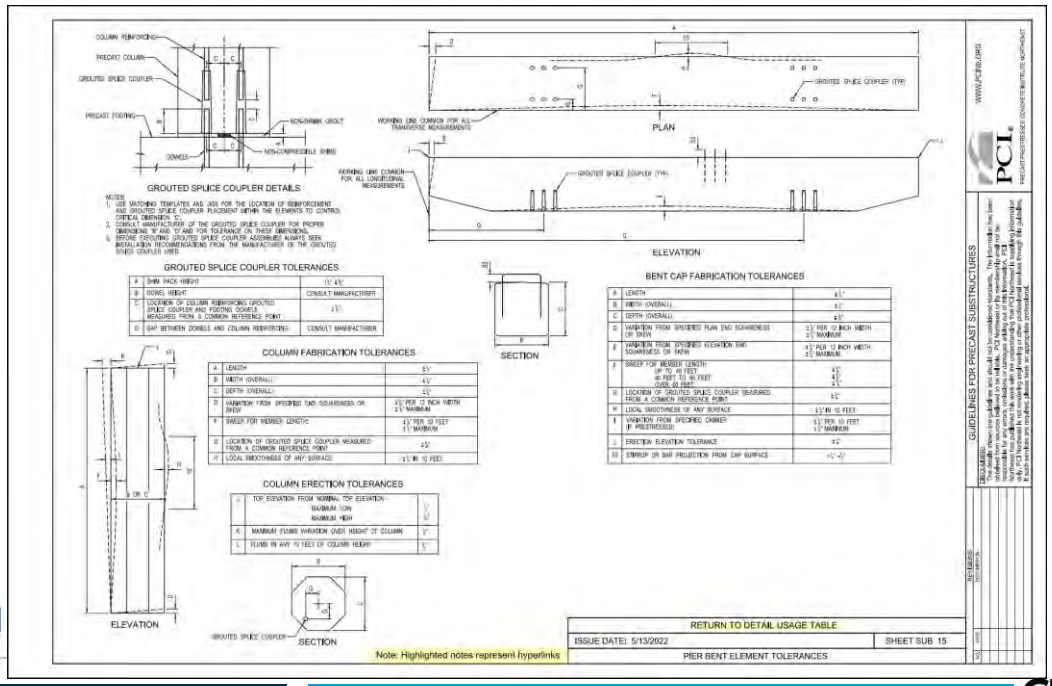
# Pocket Connections






93

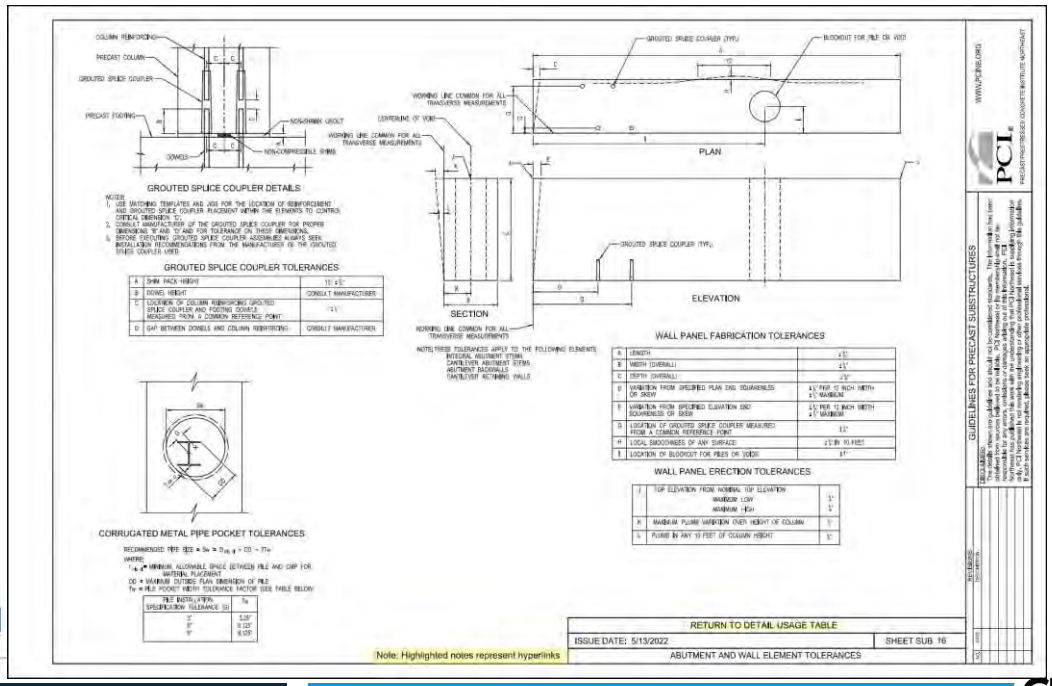
# Pier Element Tolerances






94

Abut. & Wall Element Tolerances





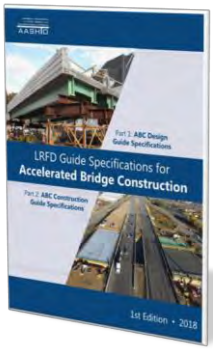

95

# Conclusions

- Designers have all the tools required to execute an ABC Substructure design
  - AASHTO LRFD Guide Specifications for ABC
    - Design Specifications
    - Construction Specifications
  - PCI Northeast Guidelines for Precast Substructures used in ABC
    - Design Details
- With these resources, you can develop a design for all common substructure types


Design Specifications

Construction Specifications







96