NCHRP Project 12-102 Seismic

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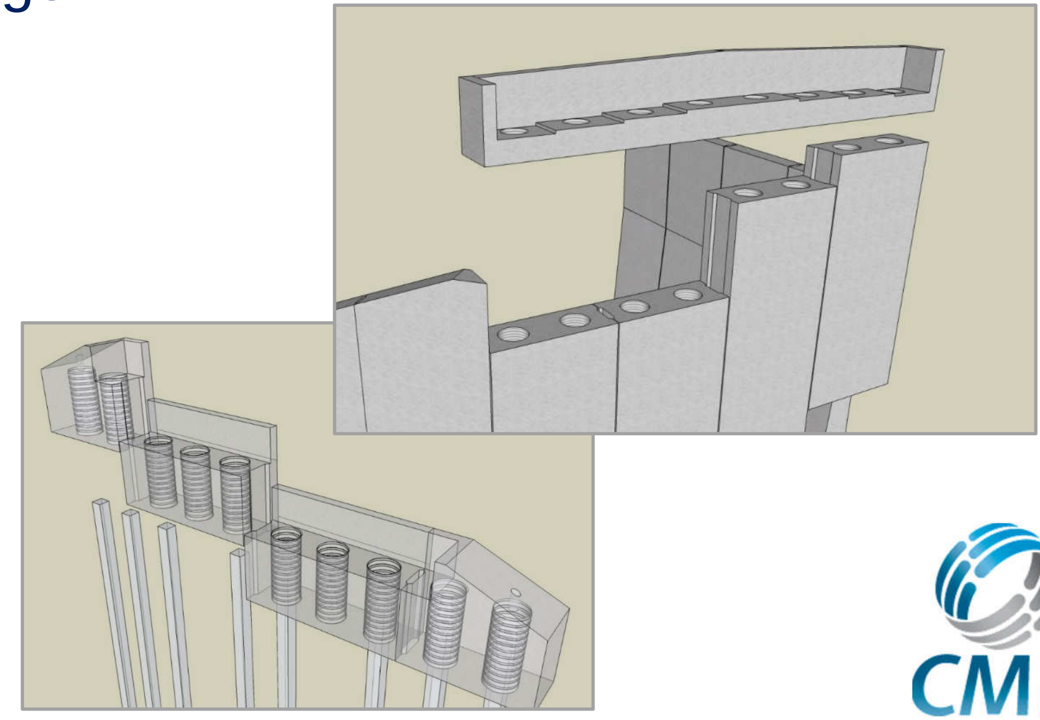

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Review of New Guide Specifications for ABC

Design Guide Specifications for ABC

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

Construction Guide Specifications for ABC

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DESIGN OF PREFABRICATED ELEMENTS

3.4 Seismic Design for Accelerated Bridge Construction

3.5 Prefabricated Element Design

3.6 Connection Design and Detailing

3.7 GRS IBS

3.8 Accelerated backfill

3.4 SEISMIC DESIGN FOR ABC

3.4.1 Seismic Analysis & Design Methods

3.4.2 Load Path

3.4.3 Seismic Systems, Elements, & Sub-Systems

3.4.4 Energy Dissipation

3.4.5 Capacity Protection

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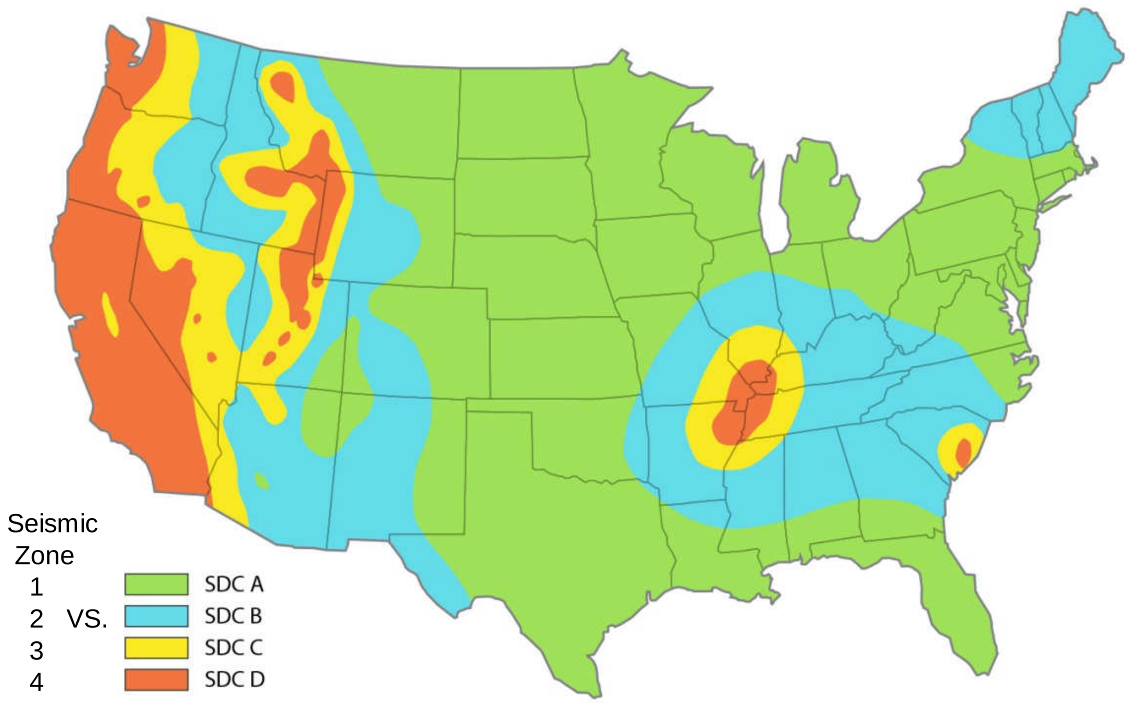
3.4 SEISMIC DESIGN FOR ABC CONT.



Seismic analysis and design of prefabricated elements shall be performed using either :

- Force-Based Design
AASHTO LRFD Bridge (2014)

- Displacement-Based Design
AASHTO Seismic GS (2011)

… set up to accommodate continuing research and advancements.

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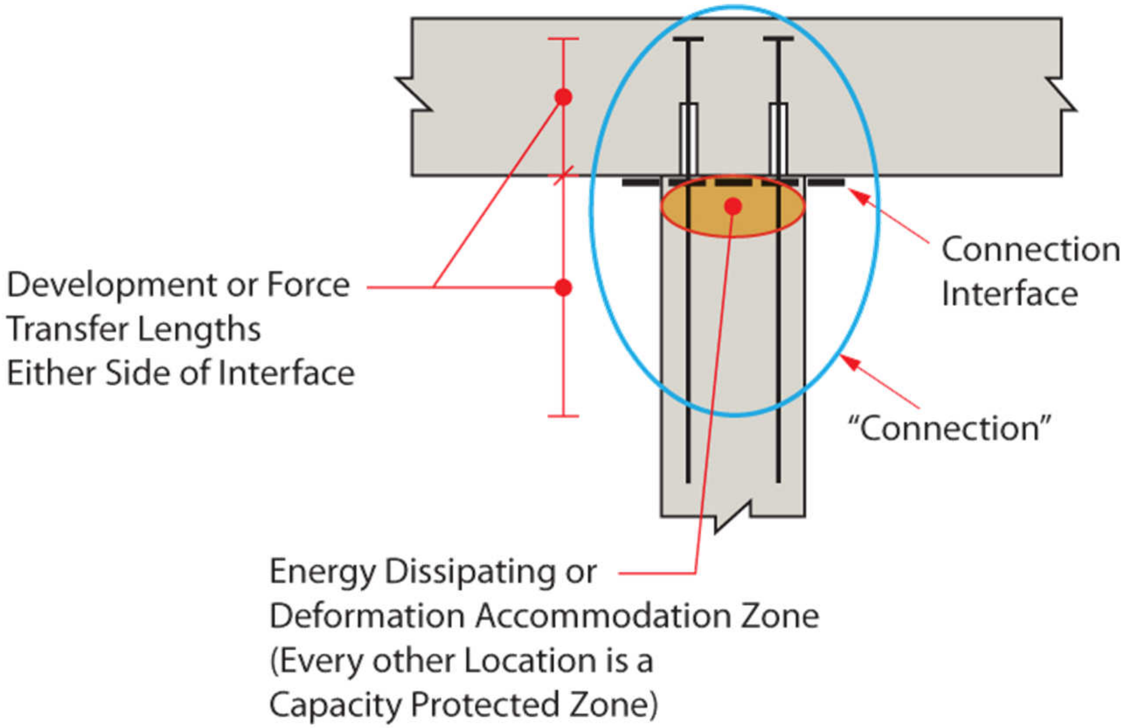
3.4 SEISMIC DESIGN FOR ABC CONT.



In high seismic areas inelastic ductility is required; thus clearly all members must have sufficient strength and ductility to form the intended structural plastic mechanism.

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… ideal locations for ABC connections

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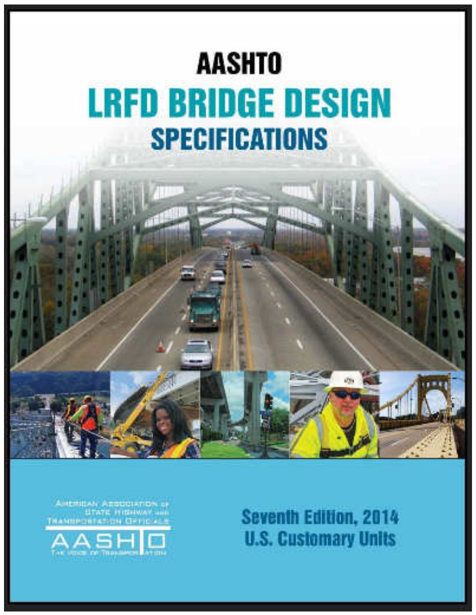
3.4.1.2 AASHTO LRFD (2014)

The force-based seismic design methodology, as defined in AASHTO LRFD Bridge Design Specifications, is permitted when R-factors and prescriptive detailing for energy dissipating PBEs and their connections have been shown through laboratory testing to provide acceptable performance. This document limits the application of force-based design procedures for some prefabricated connections in Zones 2 through 4 when detailed understanding of material behaviors is necessary.

3.4.1.3 AASHTO SEISMIC GS (2011)

Displacement-based design, as defined in AASHTO Guide Specifications for LRFD Seismic Bridge Design, shall be used to ensure proper performance of prefabricated elements and their connections in Seismic Design Categories (SDCs) B through D.

3.4 SEISMIC DESIGN FOR ABC CONT.



…Select a methodology
and use it.
Do not mix and match!

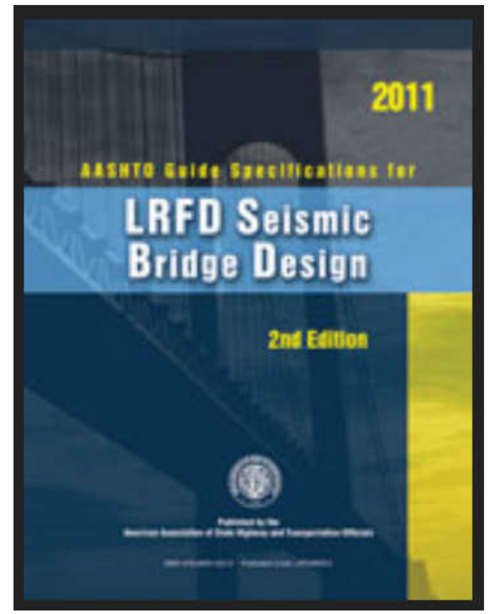
ATTACHMENT A –2017 AGENDA ITEM 3 – T – 4 (REVISION 1)

GUIDE SPECIFICATIONS FOR ACCELERATED BRIDGE CONSTRUCTION

Part 1: ABC Design Guide Specifications
Part 2: ABC Construction Guide Specifications

NCHRP Project 12-102

DRAFT SUBMITTED TO AASHTO SCOBS: January 23, 2017
Revised: June 2, 2017
Revised June 14, 2017



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3.4 SEISMIC DESIGN FOR ABC CONT.

1. Continuity of load path under load reversals
2. Development of cyclic inelastic deformations
3. Maximum forces (moments) occur where we would like to connect prefabricated elements
4. Certain element/material behaviors may cause rapid loss of cyclic resistance
   - Limitations of Rotation Capacity
   - Local Buckling
   - Strain Concentrations

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… Detailing is important!

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3.4.2 LOAD PATH

A continuous load path shall exist between the source of the seismic loads and the foundation. The load path shall enable the transfer of forces between the elements and connections through which it passes.

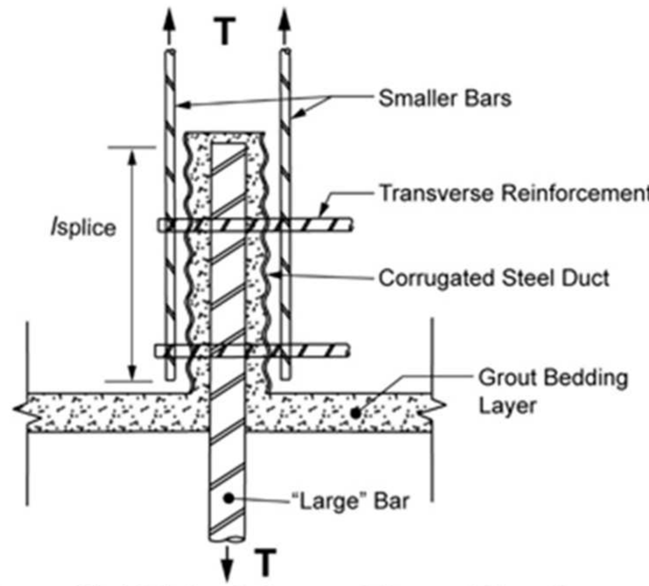

Figure C3.6.5.2-1 – Splicing of Grouted Duct Bars to Other Bars

Example Load Path Detail

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3.4.3 SEISMIC SYSTEMS, ELEMENTS, & SUB-SYSTEMS

3.4.3.1 Earthquake-Resisting Systems (ERS)

3.4.3.2 Earthquake-Resisting Elements (ERE)

3.4.3.3 Earthquake-Resisting Sub-Systems (ERSS)

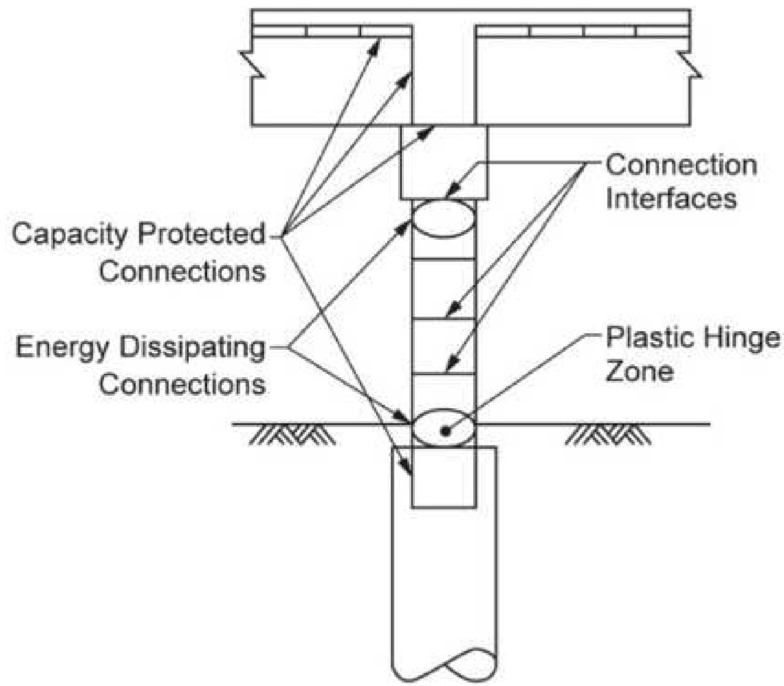
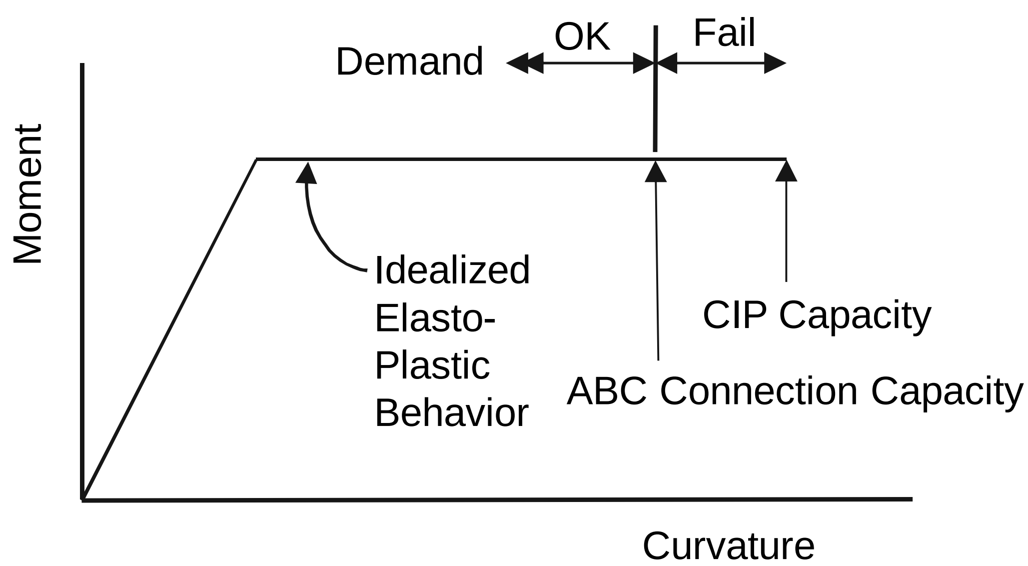


Figure C3.4.3.2-1 Schematic Locations of Connections Relative to Potential Plastic Hinge Zones.

3.4.3.2 DEFINING EREs W/ ABC

Determine what is different from CIP and make a plan for addressing it in the design.



3.6 CONNECTION DESIGN & DETAILING

3.6.1 General

3.6.2 CIP Concrete Closure Joints w/ Lapped Bars

3.6.3 Grout/Concrete Under Footings & Slabs

3.6.4 Mechanical Reinforcing Bar Connectors

3.6.5 Grouted Ducts

3.6.6 Pocket Connections

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3.6 CONNECTION DESIGN & DETAILING

3.6.7 Socket Connections

3.6.8 Full Depth Precast Concrete Deck Panel Connections

3.6.9 Link Slabs

3.6.10 Steel Connections

3.6.11 Integral Substructure to Superstructure Connections

3.6.12 Deck Beam Connections

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3.6.1 GENERAL CONNECTION DESIGN

Provisions in Section 3.6 are not intended to preclude the use of other preferred details as approved by the Owner and so long the designer can demonstrate adequate load transfer as well as consideration for compatibility of deformations and constitutive relations of materials.

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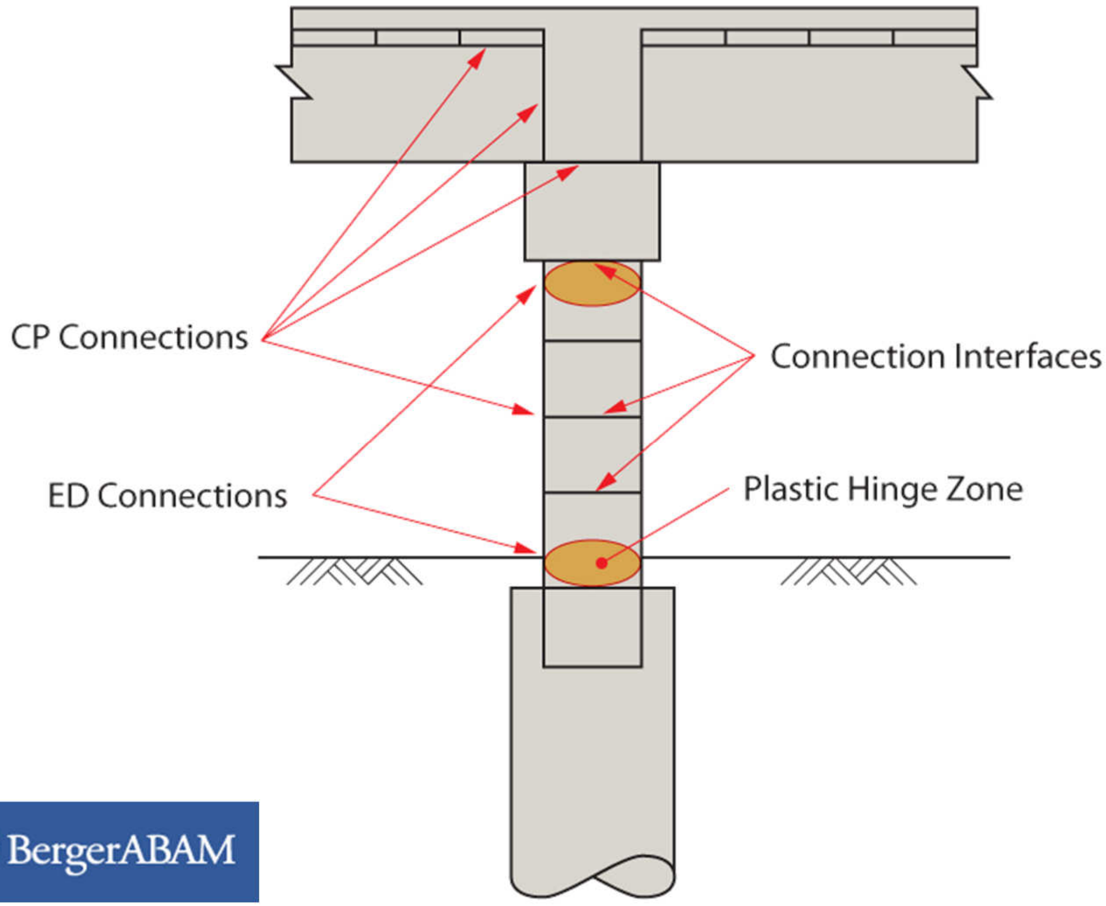
3.6.1 GENERAL CONNECTION DESIGN

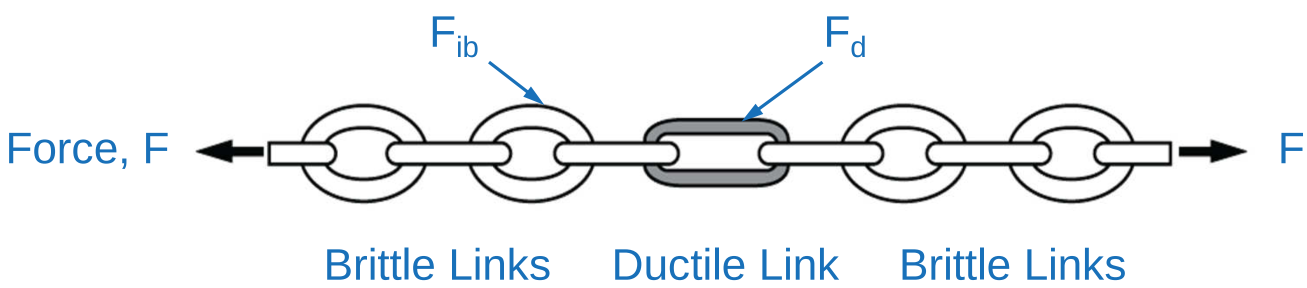


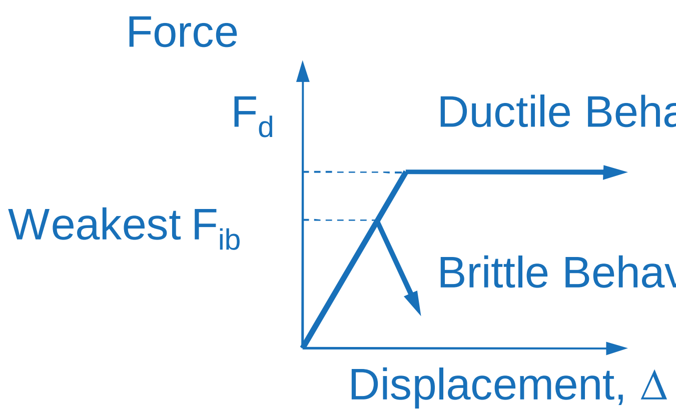
Note ~ In this Example:
Moment Continuity is at
Top and Bottom of Column

ED – Energy Dissipating
(Ductile)

CP – Capacity Protected
(Non-ductile)

3.6.1 GENERAL CONNECTION DESIGN





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3.6.4 MECHANICAL BAR CONNECTORS

- Viable option for connecting concrete elements
- Defined Type 1 and Type 2 Connectors

Defined in ACI-318-14 (Building Code) requirements for structural concrete (Special Moment Frames & Special Structural Walls)

Implied in AASHTO SGS (2011) under “Splicing of Longitudinal Reinforcement in SDCs C & D

Type 1 mechanical connectors shall not be used to splice longitudinal column reinforcement within a distance equal to twice the maximum column dimension from the top of the footing or from the bottom of the pier cap, or at any other location where yielding of the reinforcement is likely to occur as a result of inelastic lateral displacements.

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3.6.4 MECHANICAL BAR CONNECTORS

- Only Type 2 mechanical permitted in plastic hinge regions

Type 2 mechanical connectors shall be permitted in the following locations and conditions:

- Outside of the plastic hinge regions.
- Inside plastic hinge regions for Seismic Zone 1/ SDC A or inside of plastic hinge regions for Seismic Zone 2/ SDC B with the Owner's approval.
- Inside plastic hinge regions for Seismic Zones 3 and 4 or SDCs C and D when the requirements of Article 3.6.4.4 are met.

- Length of mechanical coupler (L_{MC}) is limited to $L_{MC} \leq 15\ d_{barl}$

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3.6.4.4.1 FORCED-BASE DESIGN

- Reduced modification factor R_r

$$R_r = \gamma R$$

- 0.8 for $L_{MC} \leq 4\, d_{barl}$
- 0.5 for $L_{MC} > 4\, d_{barl}$

On-going research, but current research is limited to #8 bars and smaller. Revisions are expected until additional research is complete.

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3.6.4.4.2 DISPLACEMENT-BASED DESIGN

The displacement capacity of each bridge bent shall be calculated using the "Nonlinear Static Procedure (NSP)" outlined in AASHTO Guide Specification for LRFD Seismic Design. Plastic moment capacity shall be based on the moment-curvature analysis of the column section with no mechanical connector and the analytical plastic hinge length shall be taken as the reduced analytical plastic hinge length given by:

$$L_p^{sp} = L_p - \left(1 - \frac{H_{sp}}{L_p}\right)\beta L_{sp} \leq L_p \qquad (3.6.4.4.2\text{-}1)$$

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On-going research, but included as a starting point and expected to be updated as research is developed further.

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3.6.4.4.2 DISPLACEMENT-BASED DESIGN

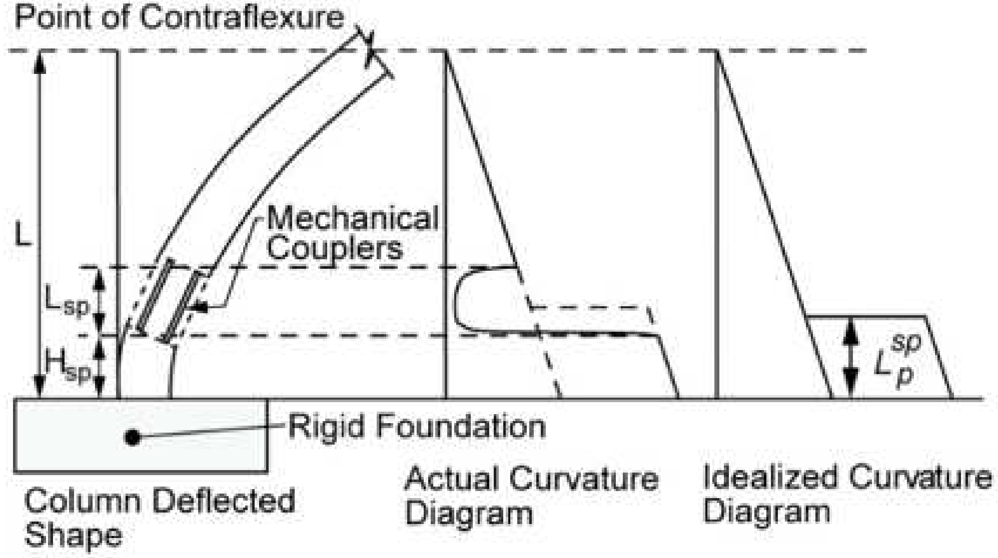

Figure C3.6.4.4.2-1 – Column Deflected Shape and Curvature Diagram

$$L_p^{sp} = L_p - \left(1 - \frac{H_{sp}}{L_p}\right)\beta L_{sp} \leq L_p$$

Table 3.6.4.6-1-- Rigid length factor for permitted mechanical connectors

Mechanical Connector Type	Rigid Length Factor, β
Grouted Sleeve Coupler (GC)	0.65
Headed Reinforcement Coupler (HC)	0.75

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3.6.4.5 DEBONDING OF COLUMN REINF.

Applicable in footing or pier cap when couplers are used. The minimum debonding length, L_{deb}, and anchorage length, L_a, in inches, shall satisfy:

$$L_{deb} \geq \max \begin{cases} 0.4D_c \\ 5000\varepsilon_{ye}d_{bl} \end{cases} \quad (3.6.4.5\text{-}1)$$

where:

D_c = diameter of the column (in.)
ε_{ye} = nominal yield strain of the column longitudinal reinforcement
d_{bl} = diameter of column longitudinal bar (in.)

$$l_a \geq L_{deb} + l_d \quad (3.6.4.5\text{-}2)$$

where l_d is the tension development length

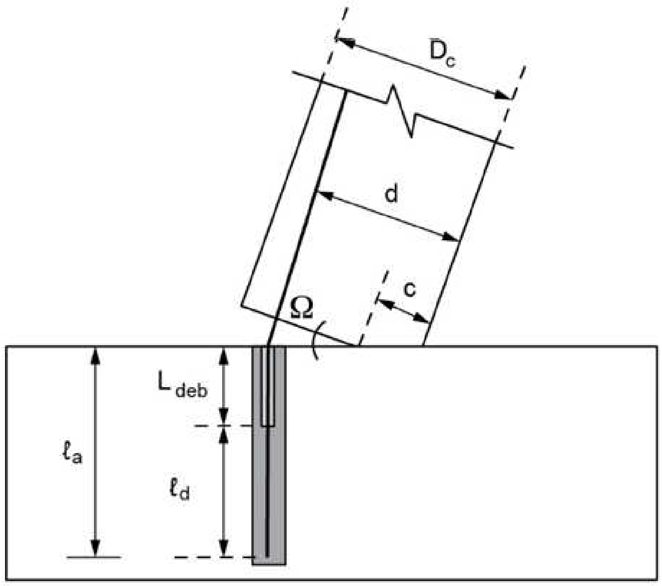

Fig. C3.6.4.5-1 – Approach to Determine the Debonded Length in Column-to-Footing Connection

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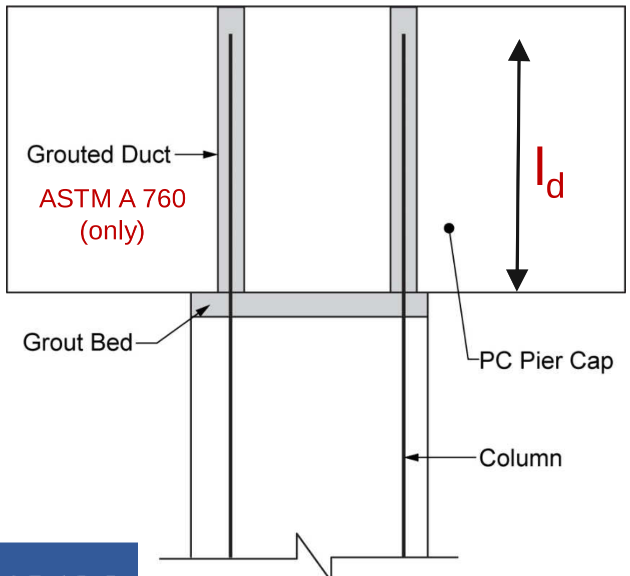
3.6.5 GROUTED DUCTS

- Connect reinforcing bars that projects from one element into a corrugated ducts embedded in receiving member



Source: Brenes (2006)

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3.6.5 GROUTED DUCTS

3.6.5.1 Minimum Development Length

The anchorage length for column grade 60 bars developed into corrugated steel ducts shall satisfy:

$$l_d \geq \frac{0.67 d_{bl} f_{ye}}{\sqrt{f'_g}} \qquad (3.6.5.1\text{-}1)$$

where:

l_d = anchored length of longitudinal reinforcing bars into a pier cap or footing (in.)
d_{bl} = diameter of column longitudinal bar (in.)
f_{ye} = expected yield stress of the longitudinal reinforcement (ksi)
f'_g = nominal compressive strength of grout (ksi)

In lieu of specific data it shall be permitted to use $f_{ye} = 68\ ksi$ for grade 60 reinforcement conforming to ASTM A706 or ASTM A615.

3.6.5 GROUTED DUCTS

3.6.5.2 Splicing w/ Ductility Demands (ED) for SDCs C and D in Grouted Duct Connections

Where tensile force is transferred between reinforcing anchored into steel ducts using high-strength grout and bars adjacent to the duct, the splice length, l_{splice}, shall be the longer of the anchorage length of the bar inside the duct or the splice length of the bars on the outside of the duct.

Transverse steel shall enclose both the duct and the bars outside the duct.

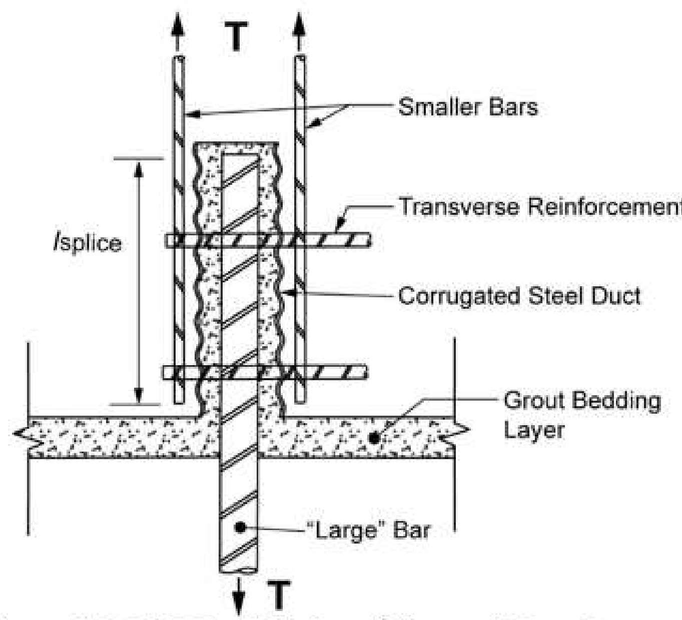

Figure C3.6.5.2-1 – Splicing of Grouted Duct Bars to Other Bars

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3.6.5 GROUTED DUCTS

3.6.5.3 Debonding of Column Longitudinal Reinforcement in Grouted Duct Connections

3.6.5.4 Bedding Layer in Grouted Duct Connections

3.6.5.5 Development of Deformed Steel Bars in Corrugated Steel Ducts using UHPC

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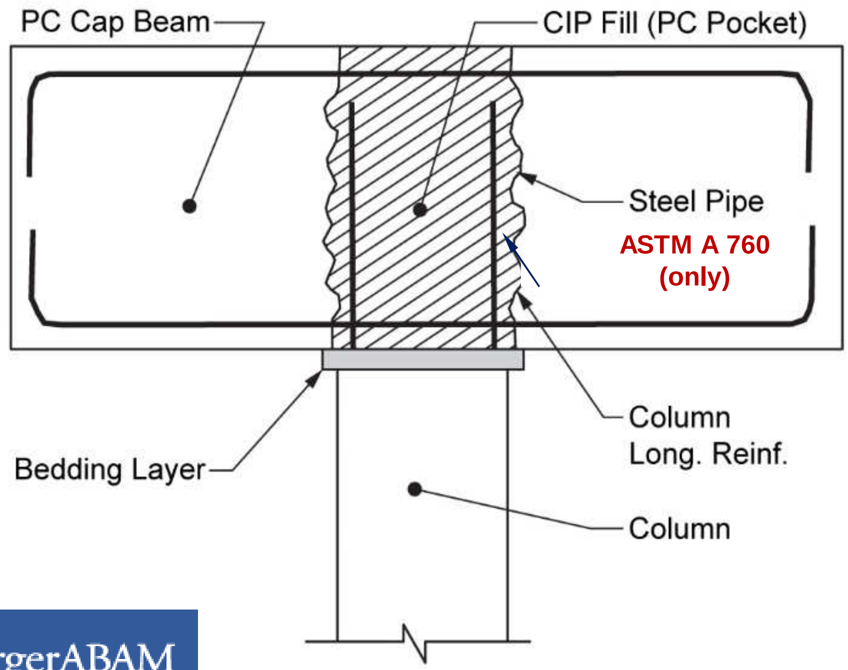
3.6.6 POCKET CONNECTIONS

- Column with projecting reinforcement and a receiving precast footing or pier cap with a corrugated steel-pipe-formed pocket



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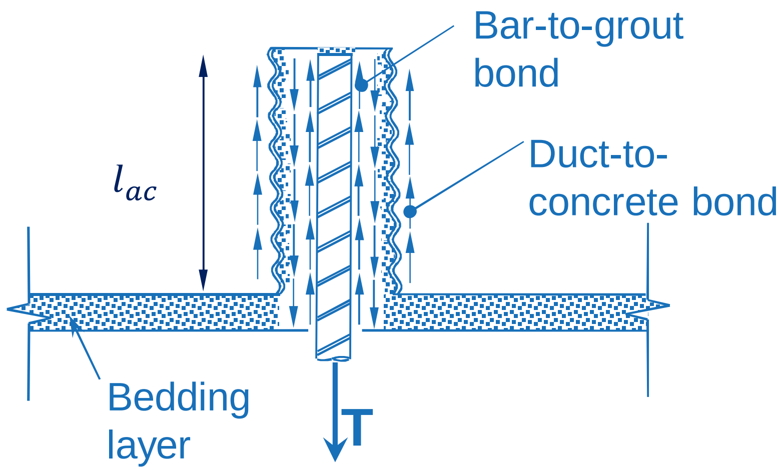
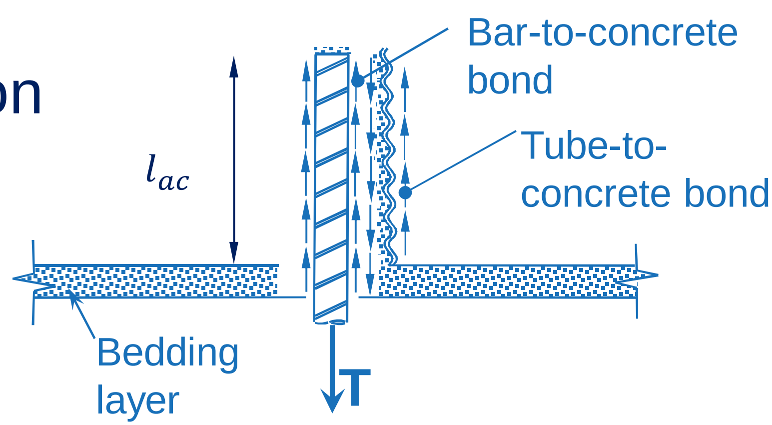
3.6.5 & 6 DEVELOPMENT LENGTH

3.6.5.1 Grouted Duct Development Length



$$l_{ac} \geq \frac{0.67 d_{bl} f_{ye}}{\sqrt{f'_{cg}}}$$

3.6.6.3 Pocket Connection Development Length



$$l_{ac} \geq \frac{d_{bl} f_{ye}}{\sqrt{f'_{cg}}}$$

3.6.6.4 CORRUGATED PIPE THICKNESS

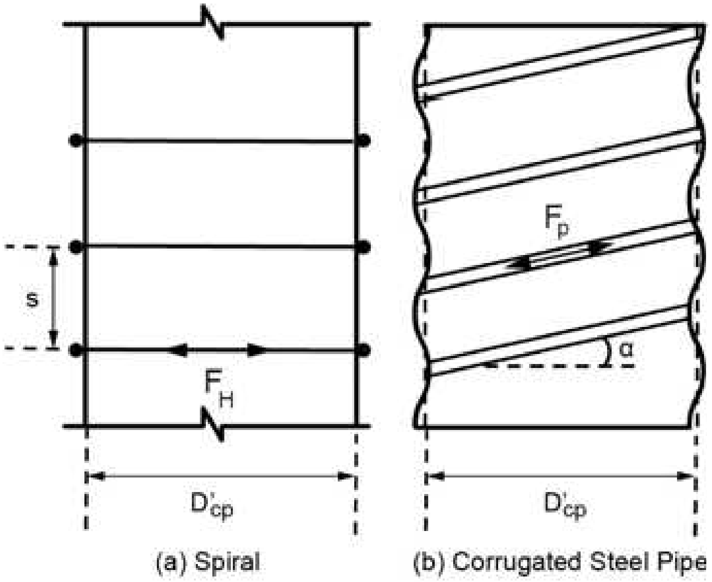


Figure C3.6.6.4-1 – Confinement Provided by Spiral a Corrugated Steel Pipe

A minimum thickness of corrugated steel pipe:

- For SDC B (Seismic Zone 2):

$$t_{pipe} \geq max \begin{cases} \dfrac{0.11\sqrt{f'_{cp}}\, D'_{cp}}{4 f_{ypipe} \cos(\alpha)} \\ 0.060\ in. \end{cases} \qquad (3.6.6.4\text{-}1)$$

- For SDCs C and D (Seismic Zones 3 and 4):

$$t_{pipe} \geq max \begin{cases} \dfrac{\rho_s D'_{cp} f_{yh}}{4 f_{ypipe} \cos(\alpha)} \\ 0.060\ in. \end{cases} \qquad (3.6.6.4\text{-}2)$$

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3.6.6.4 CORRUGATED PIPE THICKNESS

Additional prescriptive transverse reinforcement is also required, as described below.

ρ_s = volumetric ratio of transverse reinforcement

ρ_s shall be calculated as the minimum joint shear reinforcement ratio for SDCs C and D in *AASHTO Guide Specifications for LRFD Seismic Bridge Design.*

When principal tension stress in the joint is not calculated, ρ_s in Equation (3.6.6.4-2) shall be taken as:

$$\rho_s = \max \begin{cases} \dfrac{0.11\sqrt{f'_{cp}}}{f_{yh}} \\ 0.40\dfrac{A_{st}}{\left(l_{ac}l_d\right)^2} \end{cases} \qquad (3.6.6.4\text{-}3)$$

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3.6.6 OTHER SECTIONS

- 3.6.6.5 Bedding Layer
- 3.6.6.6 Abutment to Pile Pocket Connections

Nominal shear transfer resistance, V_n at the pocket to precast abutment interface and area of the pocket A_{cv}, shall be:

$$V_n = 0.13\sqrt{f'_{cp}}\,Acv$$

$$A_{CV} = \pi\, d_v\, h_v$$

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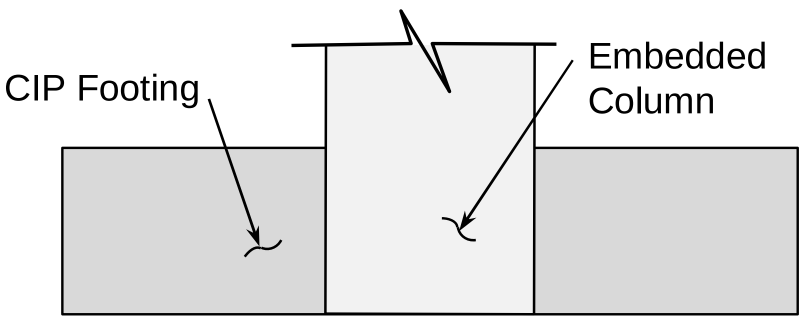
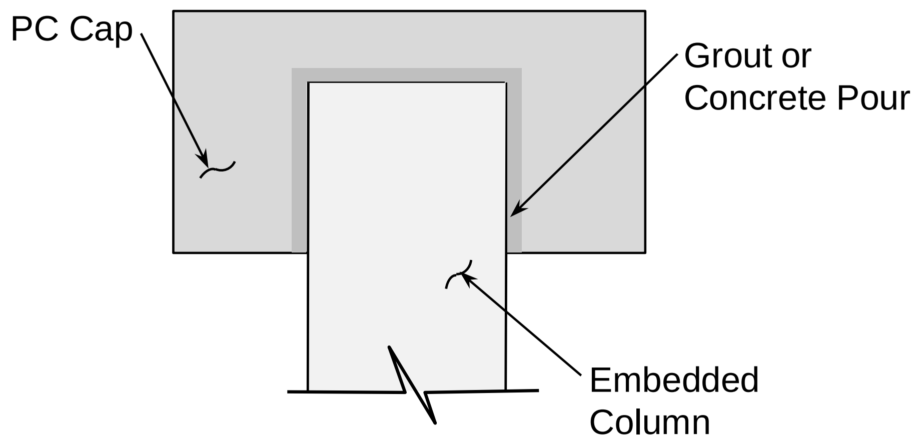
3.6.7 SOCKET CONNECTIONS

- Embedment of precast column or pile into receiving element
- Socket can be:



a) Wet (cast-in-place)



b) Formed (precast)

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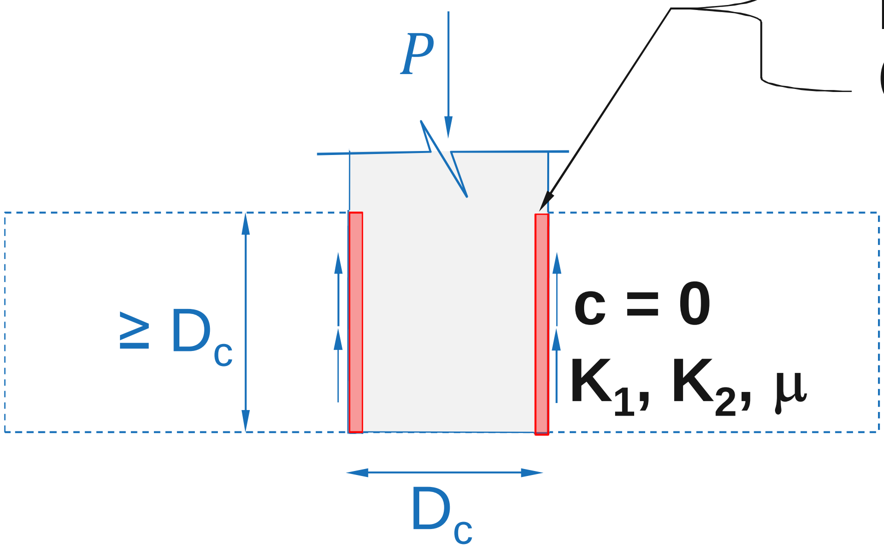
3.6.7.2 SOCKET IN CIP FOOTING



if $L_e \leq 1.5D_c$
Intentionally roughening (0.25") is required

(concrete placed against a clean concrete surface), Except μ is limited to 0.5 when $L_e < 1.1\ D_c$

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3.6.7.2 SOCKET IN CIP FOOTING

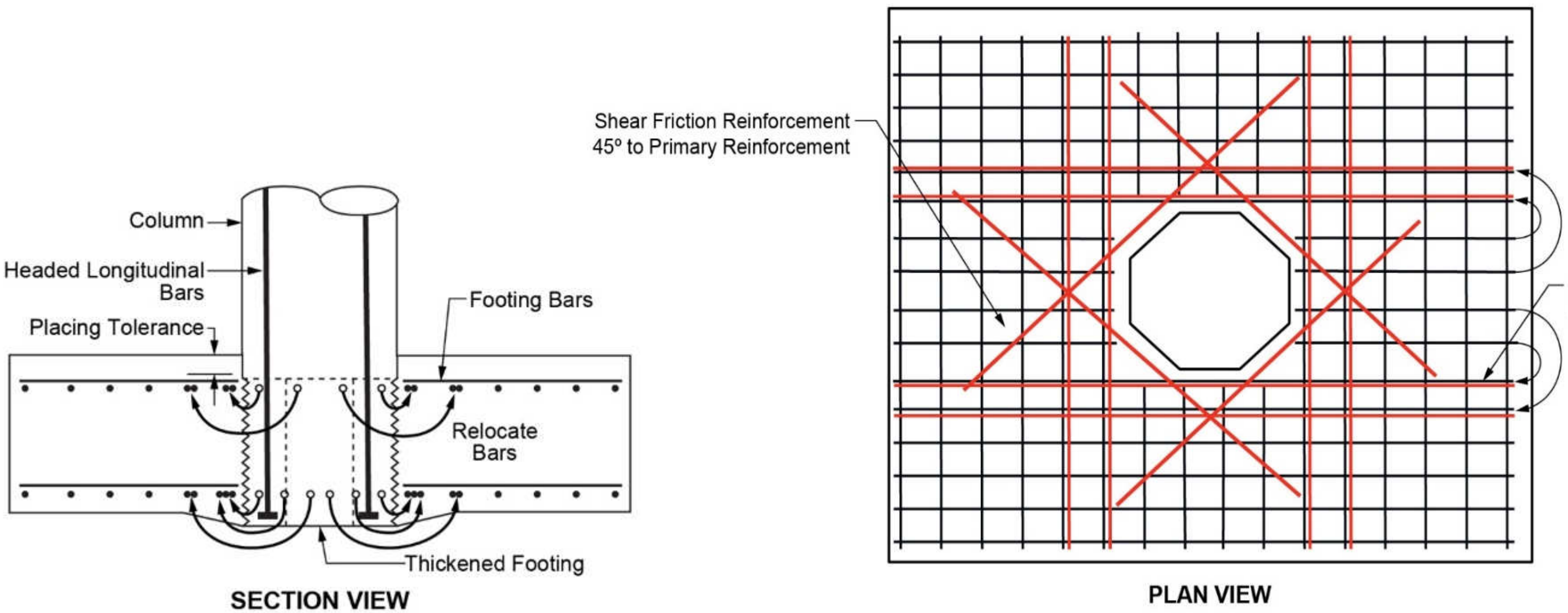

Figure C3.6.7.2-1 Placement of Footing Bars with a Socket Connection

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3.6.7.3 SOCKET IN SHAFT

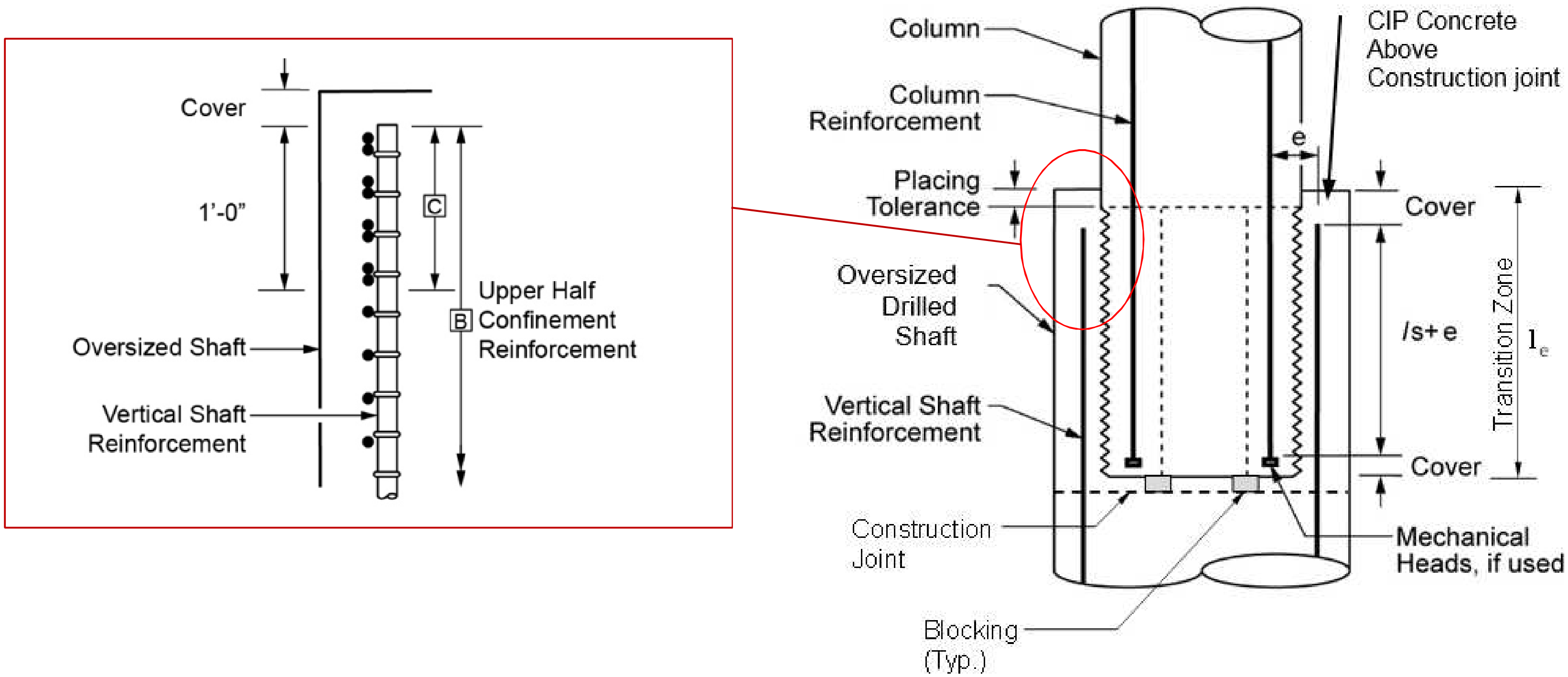

Figure 3.6.7.3.1-1 Column-to-Shaft Longitudinal Bar Arrangement

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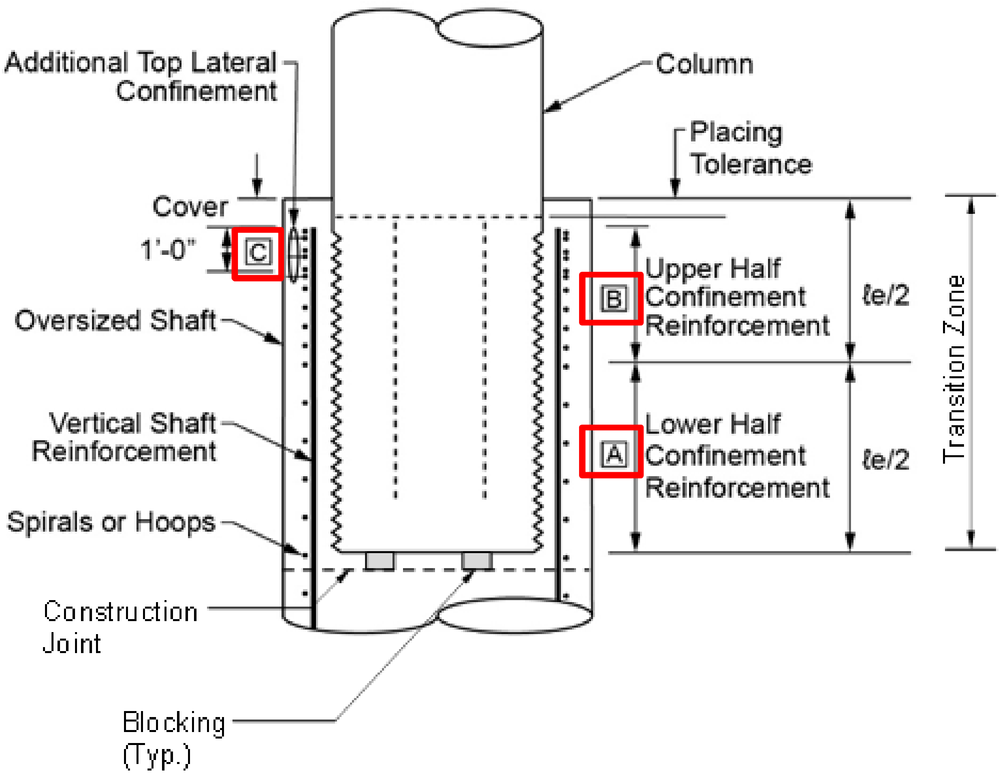
3.6.7.3 SOCKET IN SHAFT



Spiral/Hoops Requirement

$$\frac{A_{sh}}{s_{max}} \geq \frac{k f_{ul} A_l}{2\pi f_{ytr} l_s}$$

Location

A	(k = 0.5)
B	(k = 1.0)
C	(k = 2.0)

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3.6.7.4 SOCKET IN PC ELEMENT

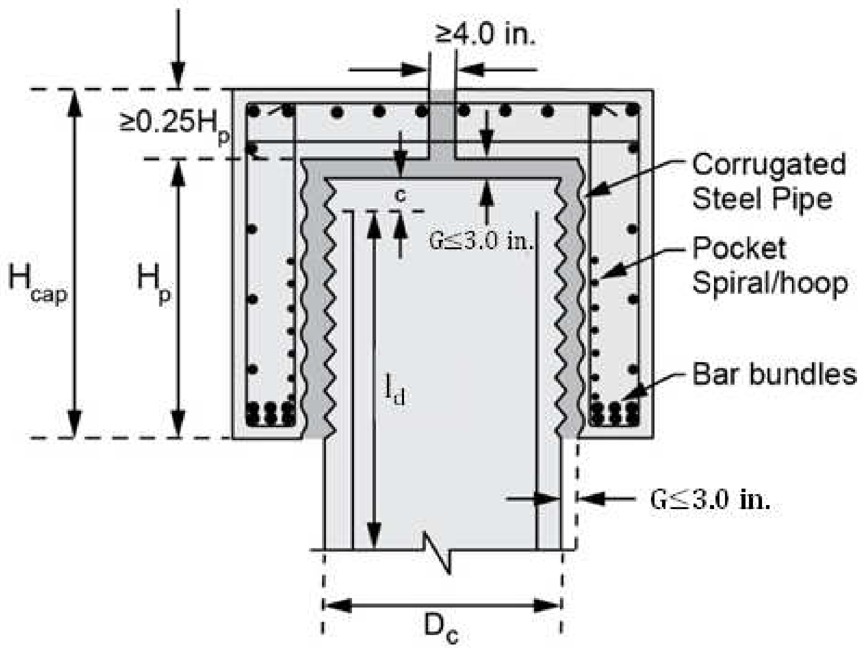

Figure C3.6.7.4.2-1 Details of Pier Cap with Socket

$$H_p \geq max\begin{cases} D_c + G \\ l_d + c + G \end{cases}$$

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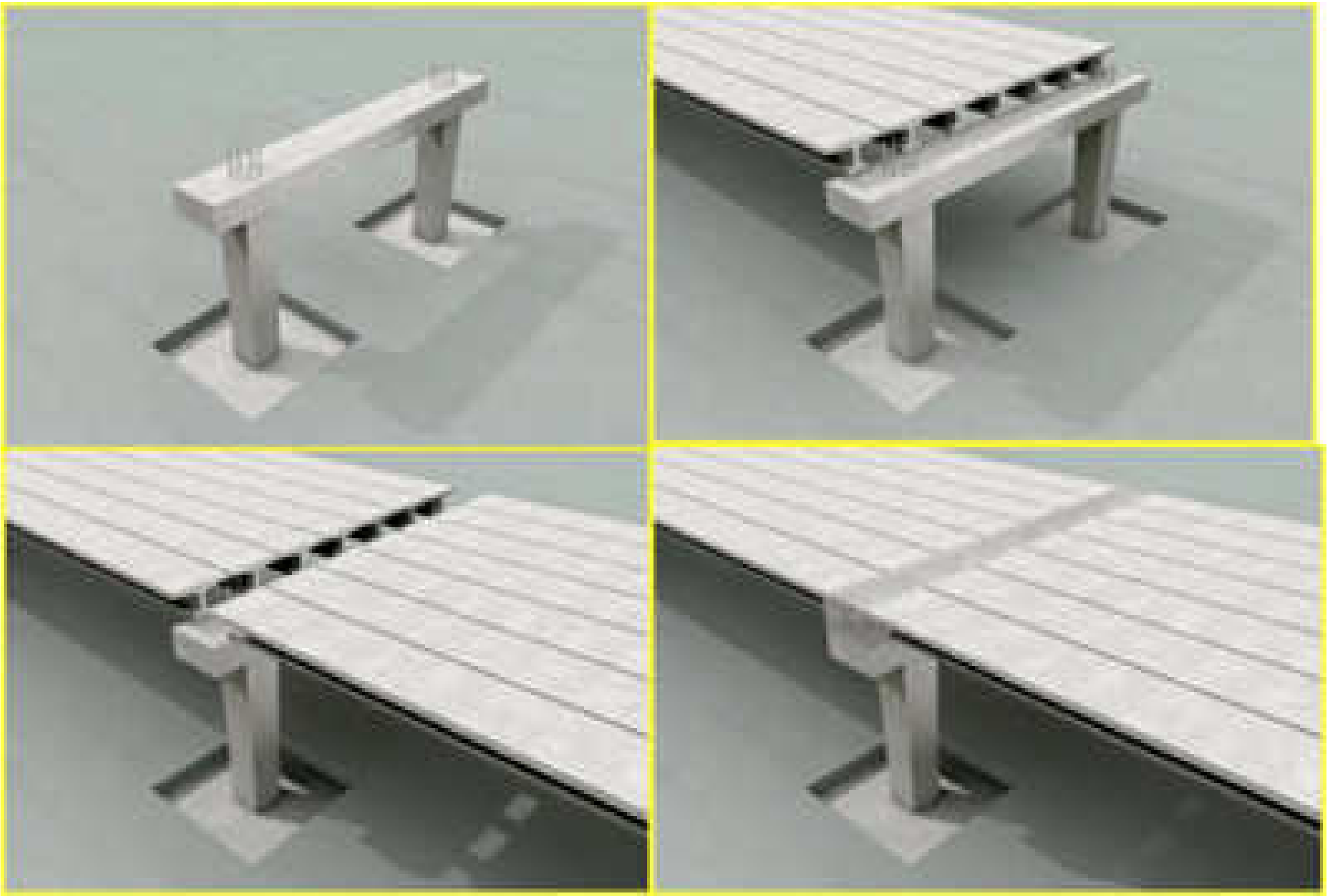
3.6.11 INTEGRAL CONNECTIONS



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Questions?

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