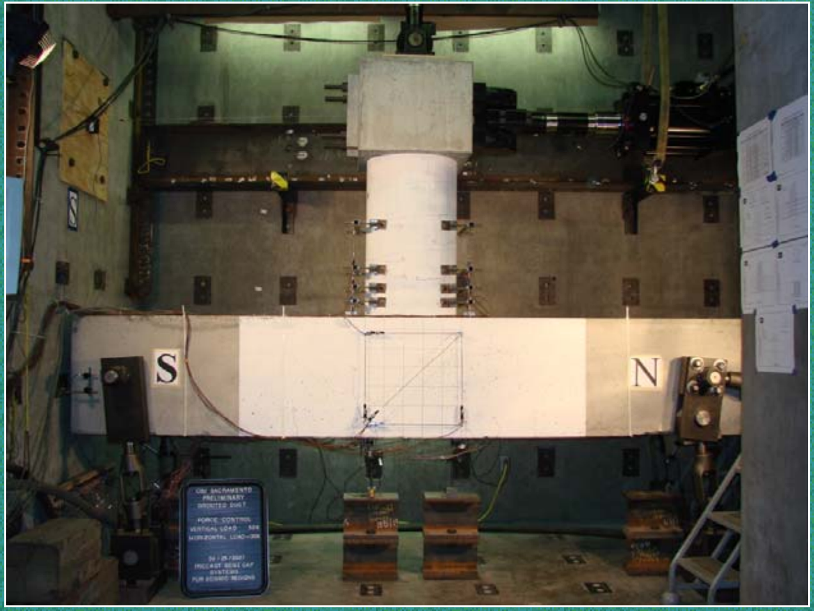
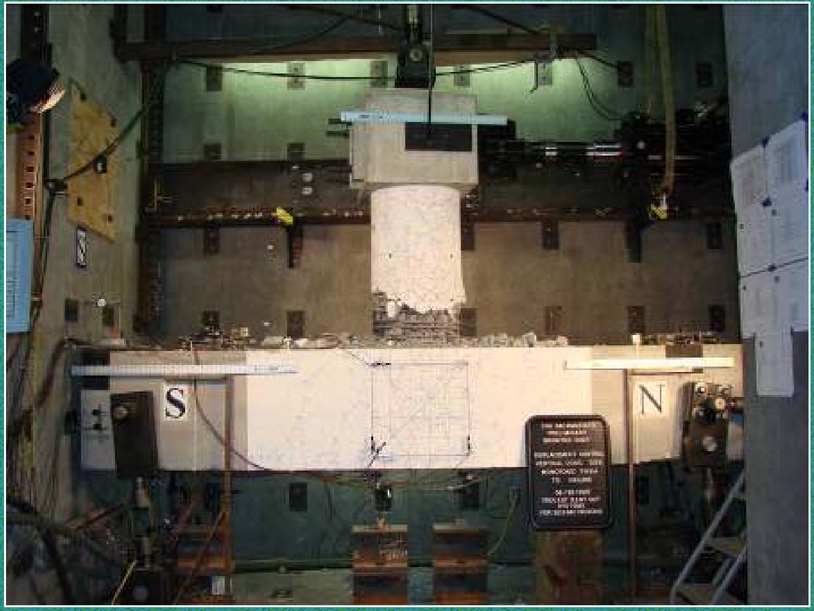
Precast Bent Cap Systems for Seismic Regions (NCHRP 12-74)

Emulative Nonintegral Connections—Design Example and Specifications





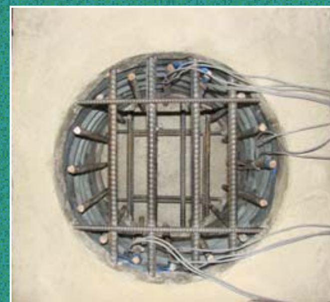
Caltrans-PCMAC Workshop

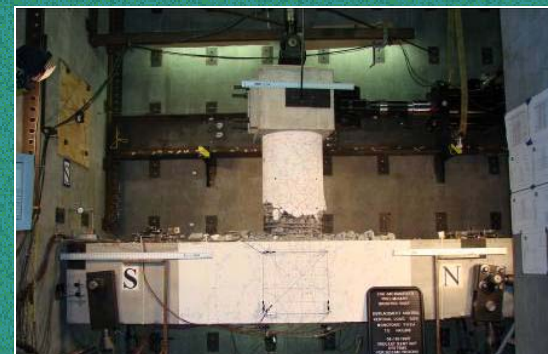
November 3, 2010

Eric Matsumoto, PhD, PE

California State University, Sacramento

Nonintegral Precast Bent Cap Connection—Design & Construction



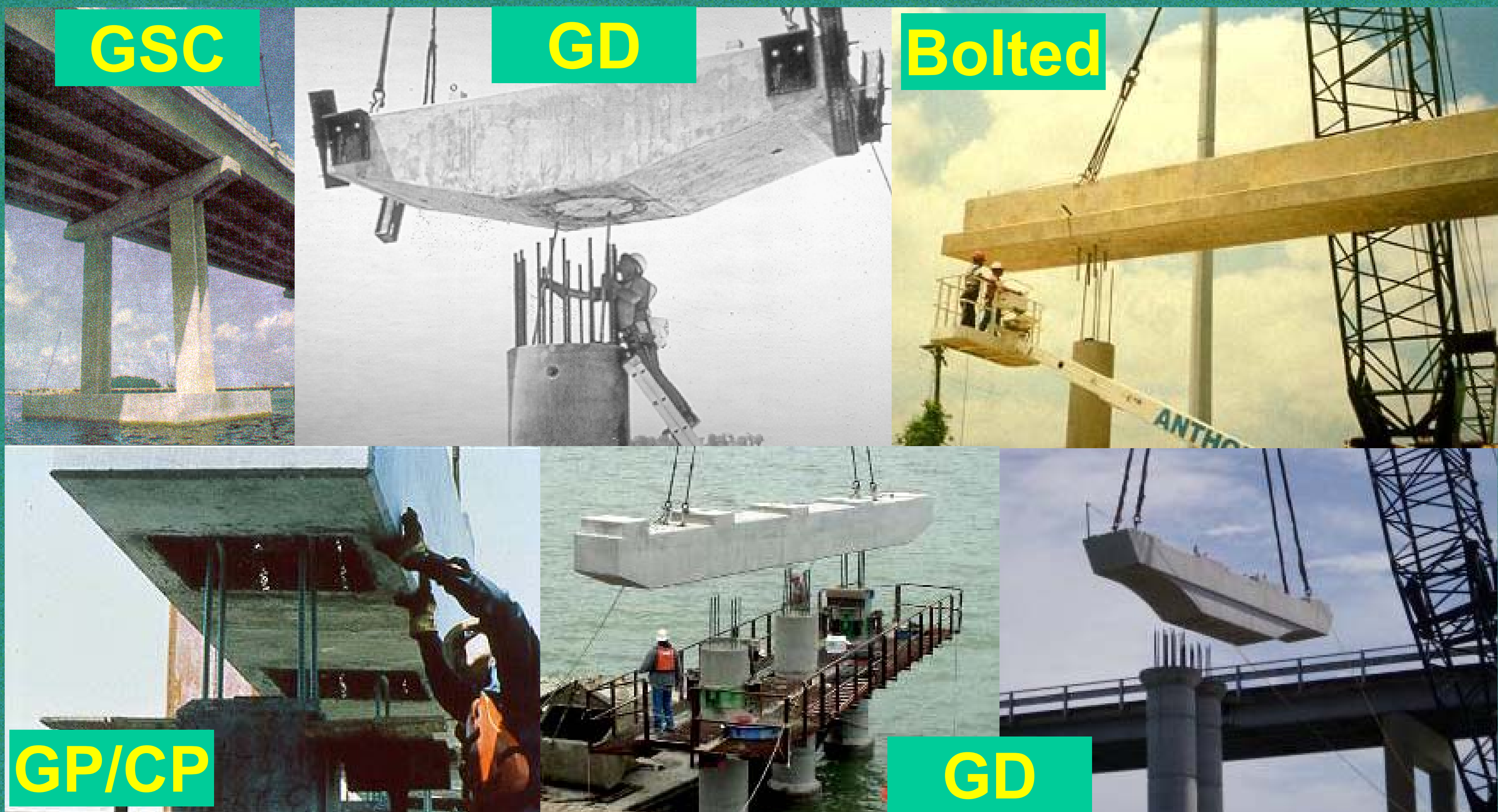


1. Design of emulative nonintegral precast bent cap systems using grouted duct and cap pocket connections in CA follows a process similar to existing Caltrans SDC for CIP.
2. However, successful implementation must acknowledge important differences in design, detailing, & construction.
3. It is recommended that proposed design and construction specifications in AASHTO LRFD Seismic Guide Spec format be considered on project-specific basis until formal review by AASHTO Committees. Flow charts, design examples and connection details are available.

Overview

- Background
  - Specimen Fabrication/Assembly/Testing
  - Emulative Response
- Design Example
  - Design Specifications
  - Flow Chart
  - Example for GD and CPFD
  - Example Connection Details
- Construction Specifications

Precast Bent Cap Systems: Non-Integral



Nonintegral connection also required for integral system

Project Objectives

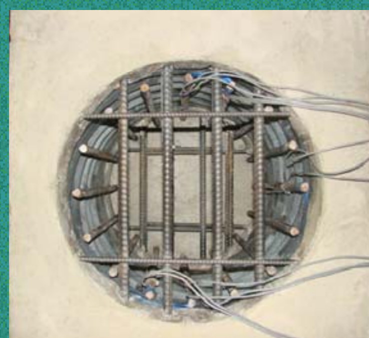
Develop design methodologies, connection details, and design and construction specifications for precast bent cap systems in all seismic regions

- Systems and methodologies for entire U.S.
- Practical, cost-effective connection details
- Design examples
- Design and construction specifications with commentary in *AASHTO LRFD* format
- Implementation Plan

Nonintegral Component Test Matrix

Grouted Duct

Cap Pocket



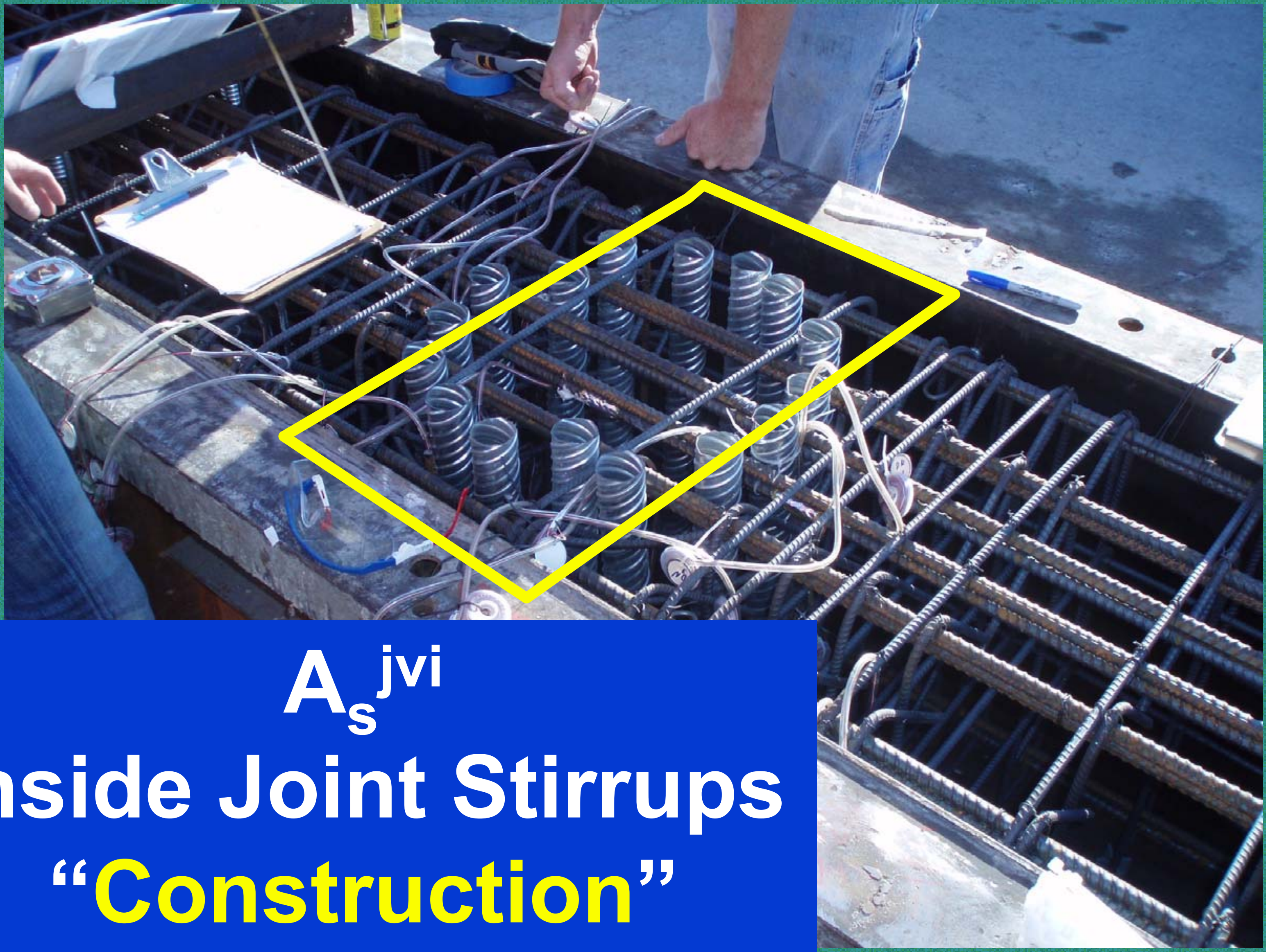
Emulative Test Unit	Location (Date)
Cast-in-place (CIP) Full ductility	CSUS (8/07)
Grouted Duct (GD) Full ductility	CSUS (7/07)
Cap Pocket (CPFD) Full ductility	CSUS (8/07)
Cap Pocket (CPLD) Limited ductility	CSUS (12/08)

Grouted Duct Joint

A_s^{jvo}

Outside Joint Stirrups

Grouted Duct Joint

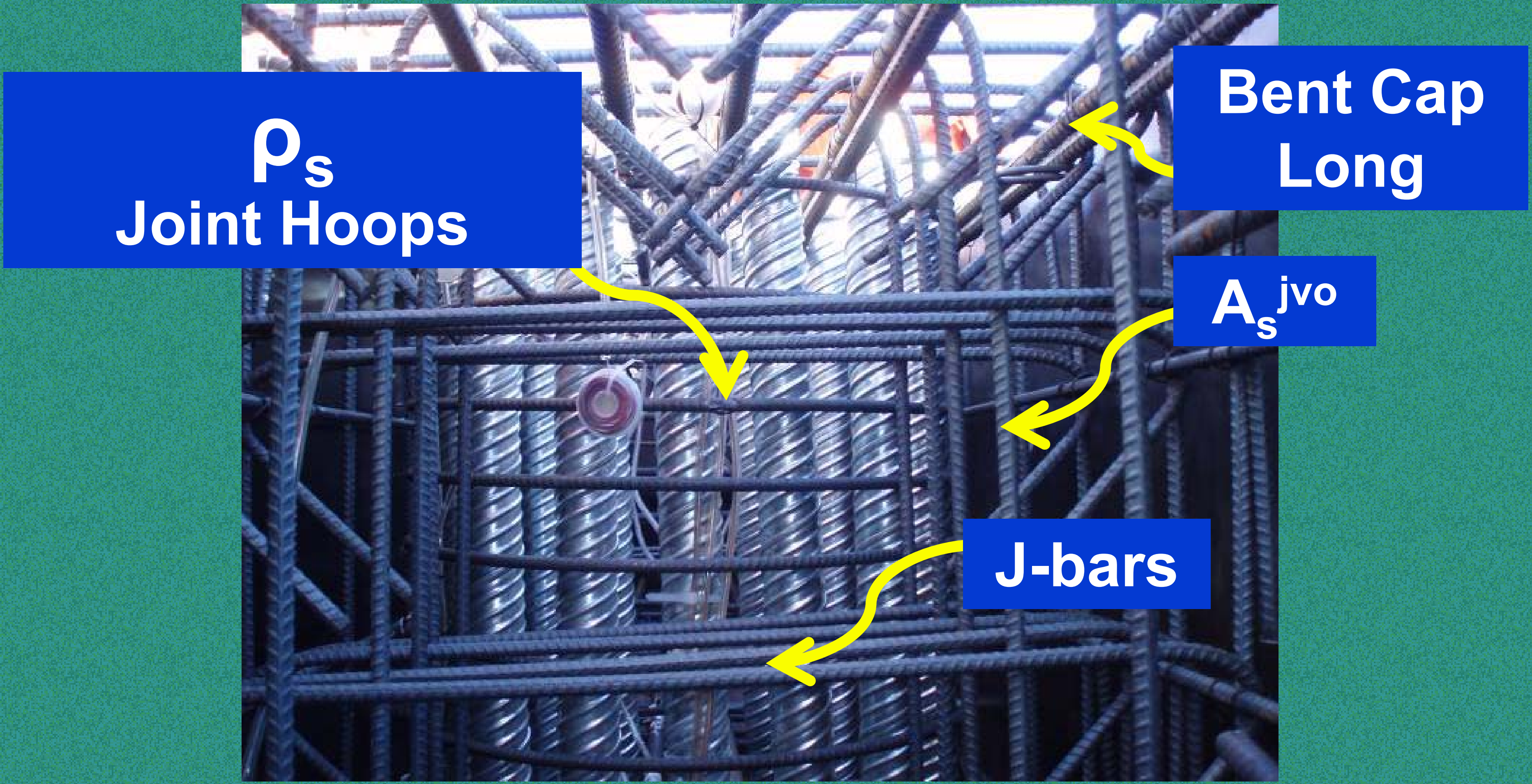


A_s^{jvi}

Inside Joint Stirrups

"Construction"

Joint Shear Reinforcement (Section)

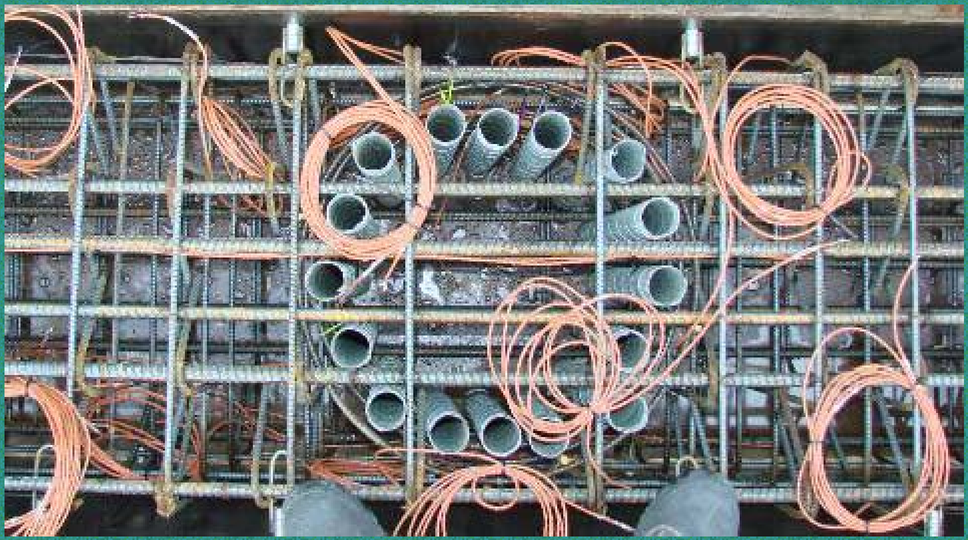


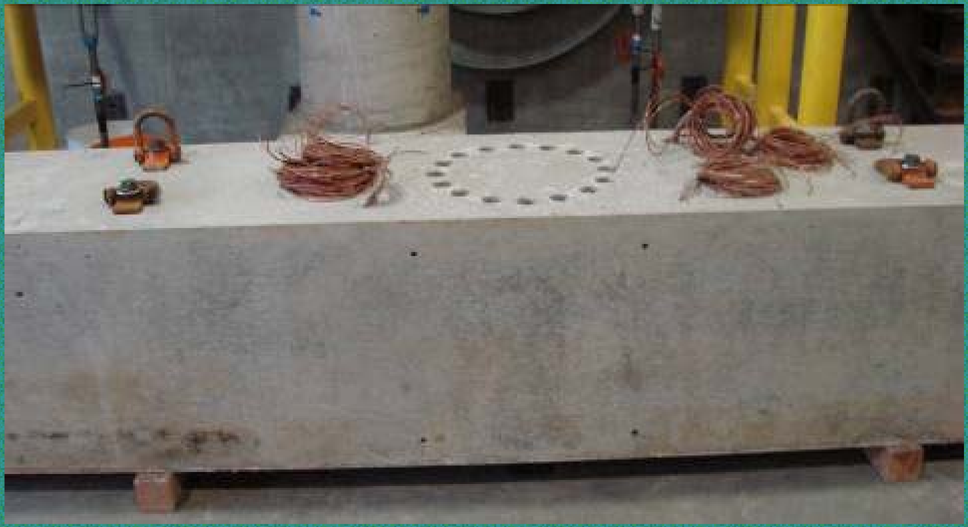
Comparison of Joints

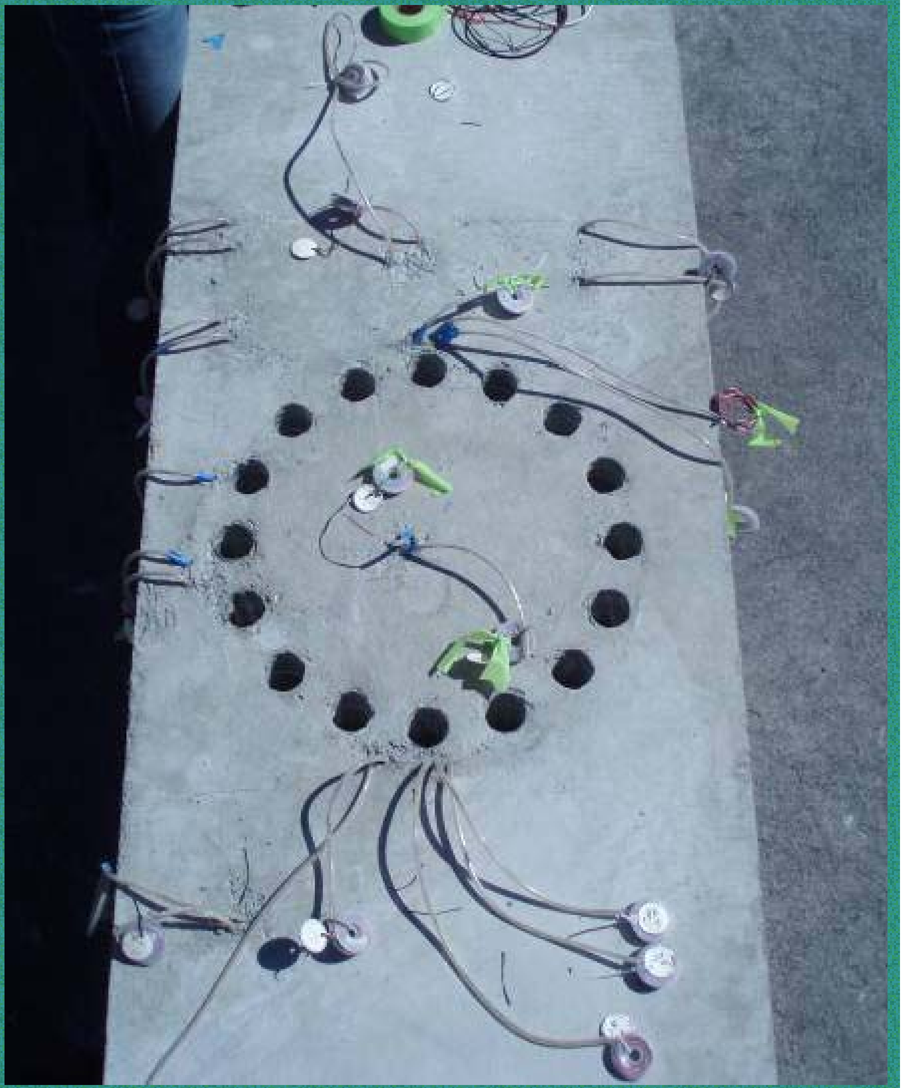
Specimen	Joint Design	Grouted Duct
Grouted Duct (GD)	1.75 in diameter steel corrugated ducts (full height) for column bars; 22 gage (0.03 in); Hoops placed around ducts	 (Hoops not in place)
Cap Pocket Full Ductility (CPFD)	18 in diameter, 16 gage (0.06 in) steel corrugated helical pipe with lock seam; Added hoop at each end resist potential unraveling.	 (Equiv nom. confining force)

Fabricated Column

Fabricated Bent Cap (GD)





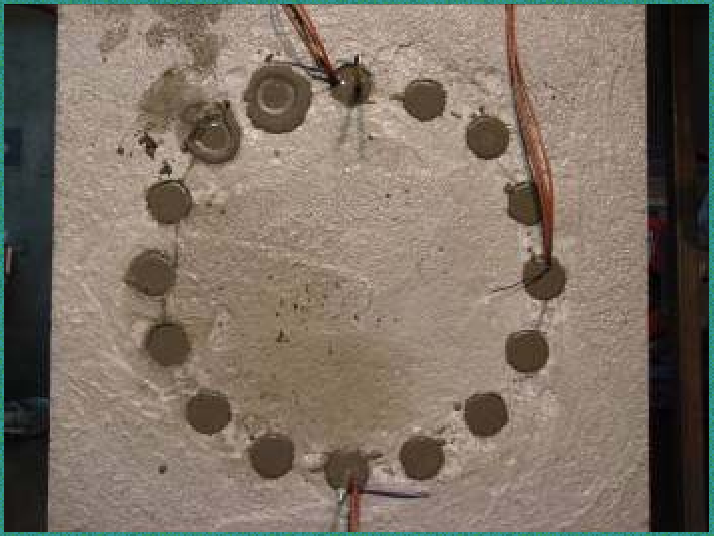


Grouted Duct—Assembly

During Cap Placement

After Cap Placement (PGD)

Grouting Connection



Grouted Connection

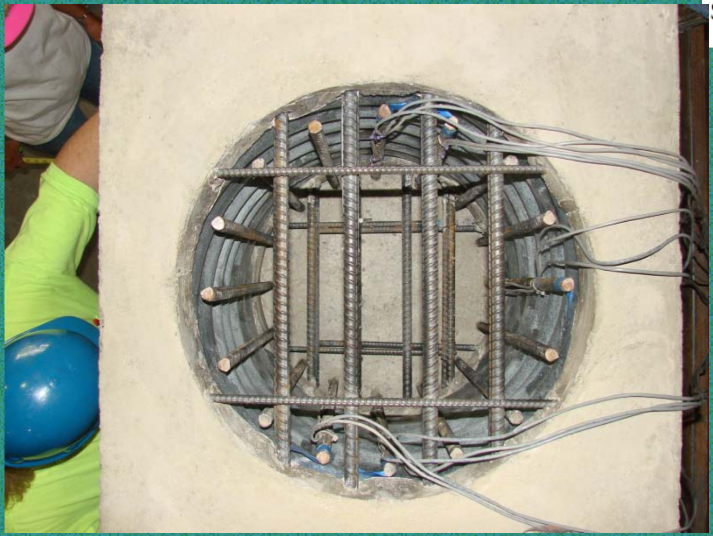
Cap Pocket Joint

Sonotube Dam
at Cap Top

Sand in Sonotube
Dam At Cap Top

Cap Pocket—Assembly

Bent Cap Placement

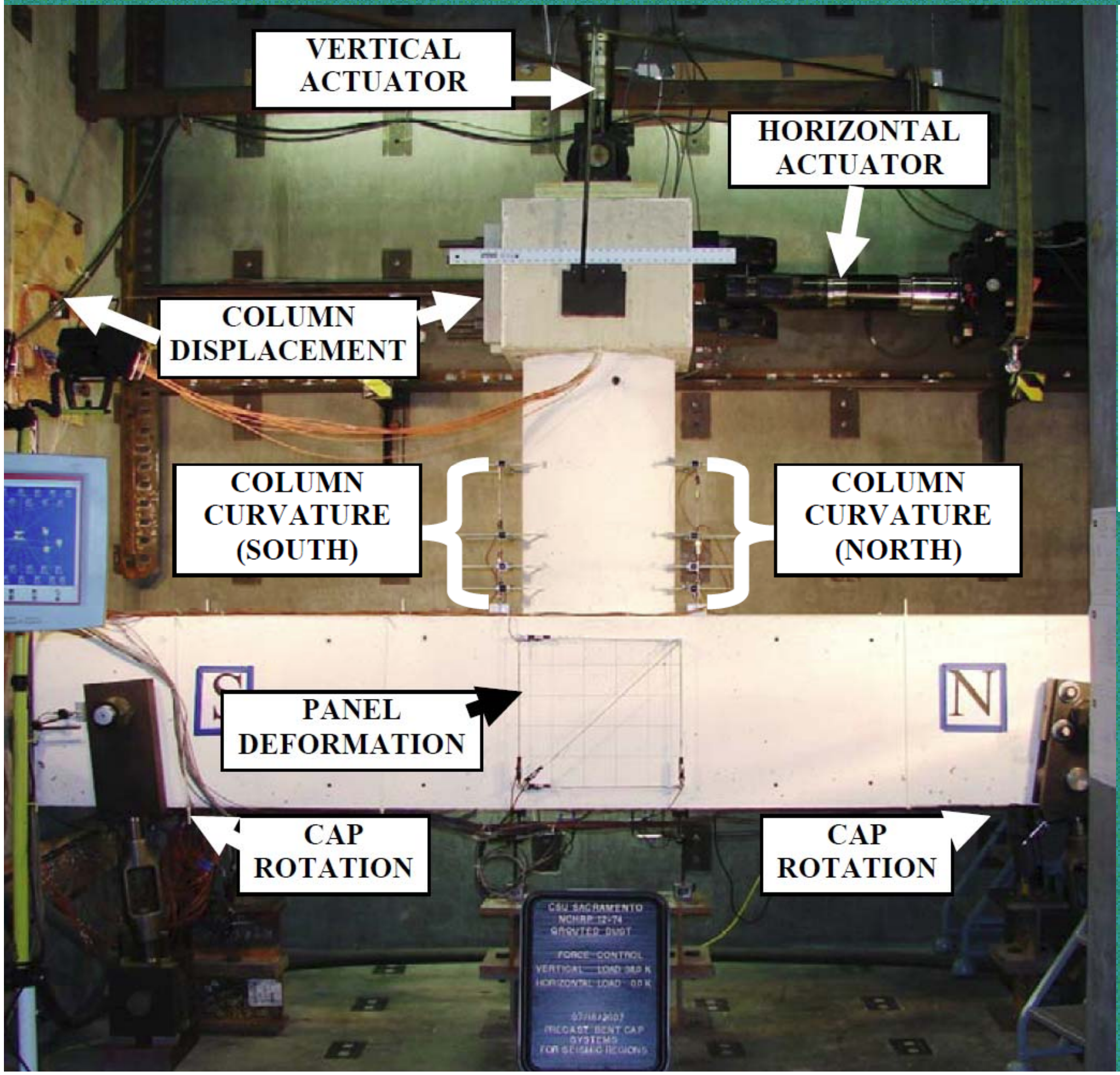


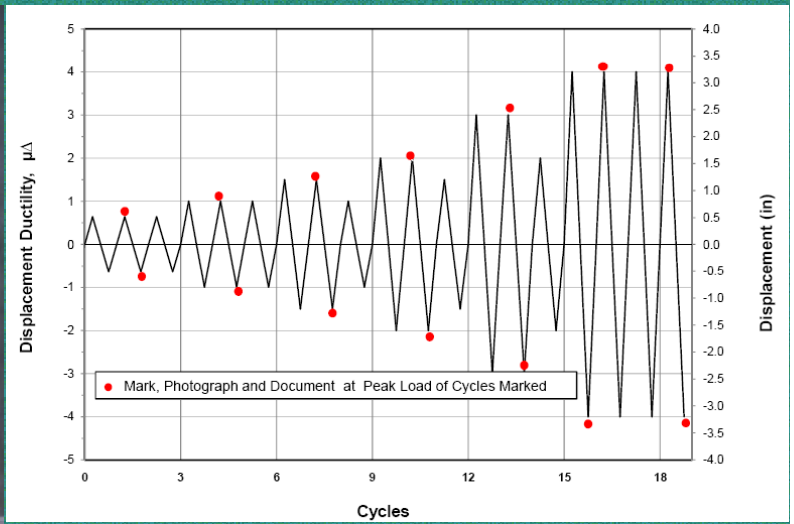
Cap Pocket Assembled

Casting and Vibrating Concrete

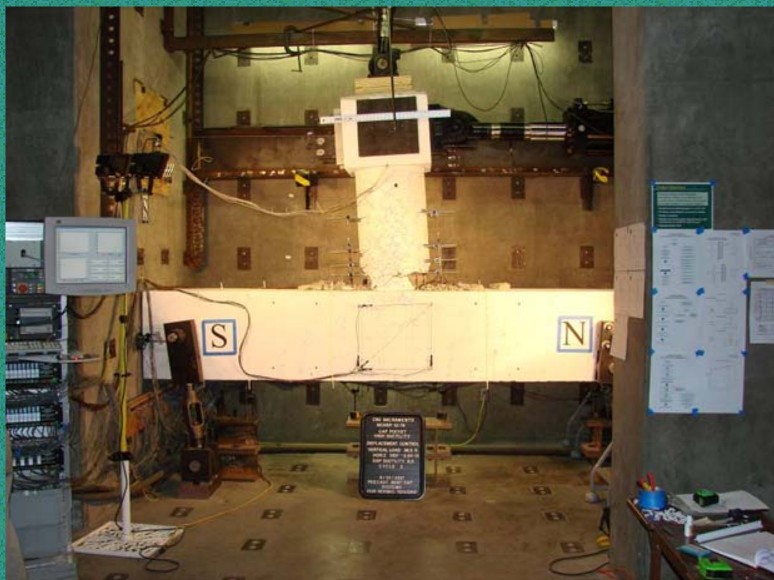
Finishing Concrete

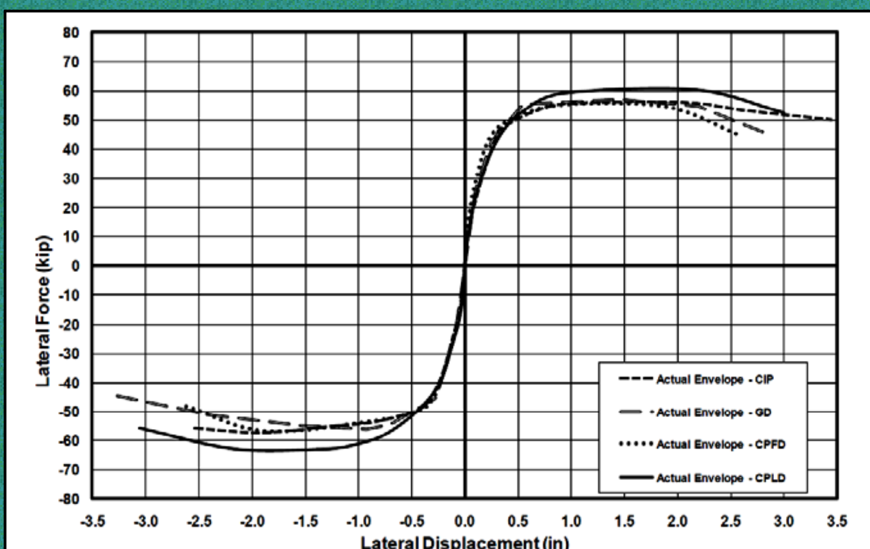
Test Setup and Cyclic Loading

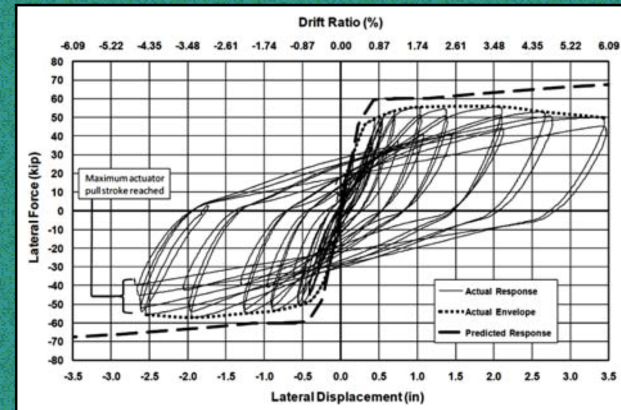


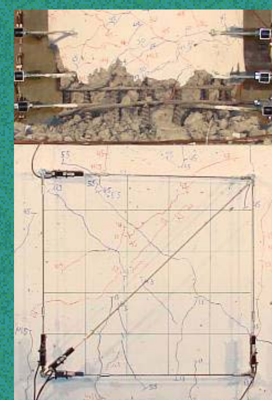


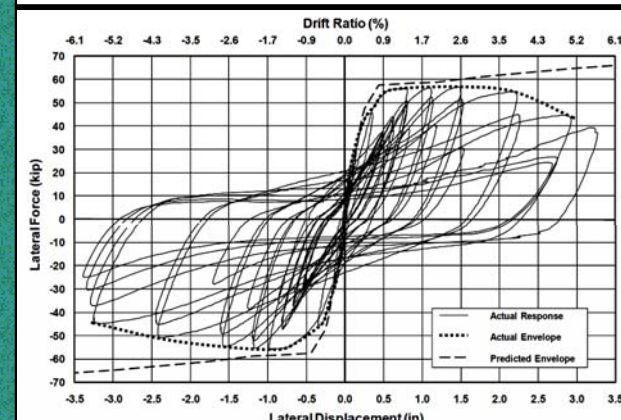
Hysteretic Response—
Full Ductility Specimens

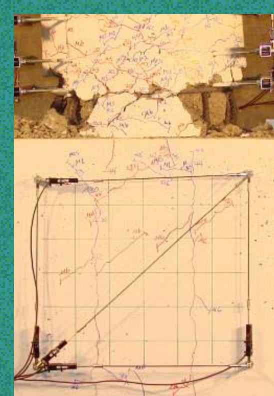


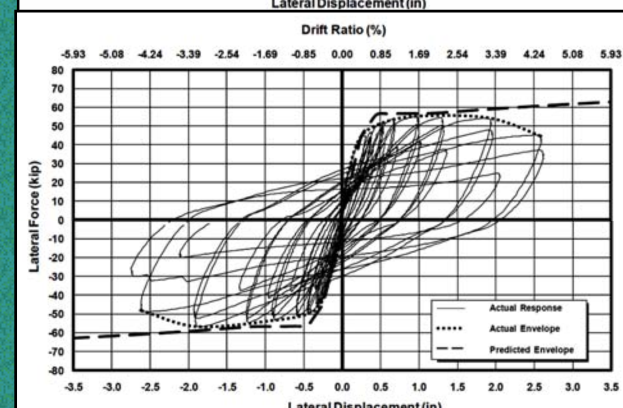












CSUS Deliverables—Design Specs

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Category	Label	Item	Description
Design Specification	DS1	Proposed Article 8.13—Joint Design for SDC A (AASHTO LRFD SGS [17])	New Article for SDC A precast bent cap connection design
Design Specification	DS2	Proposed Article 8.14—Joint Design for SDC B (AASHTO LRFD SGS [17])	New Article for SDC B precast bent cap connection design
Design Specification	DS3	Revised Article 8.15—Joint Design for SDCs C and D (AASHTO LRFD SGS [17])	Revision of current Article 8.13 for SDCs C and D to Article 8.15 for precast bent cap connection design
Design Specification	DS4	Proposed Article 8.8.14—Lateral Reinforcement Requirement for Columns Connecting to a Precast Bent Cap (AASHTO LRFD SGS [17])	New Article to ensure spacing between the hoop at top of column and the bedding layer hoop does not compromise system ductility
Design Specification	DS5	Revised Article 5.10.11.4.3—Column Connections (AASHTO LRFD BDS [25])	Revised Article to ensure AASHTO LRFD SGS is used for emulative precast bent cap-to-column connection design
Design Specification	DS6	Revised Article 5.11.1.2.4—Moment Resisting Joints (AASHTO LRFD BDS [25])	Revised Article to ensure AASHTO LRFD SGS is used for emulative precast bent cap-to-column connection design

Example Design Specification—Joint Design For SDCs C and D

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8.15.5.2.2—Grouted Duct Connection

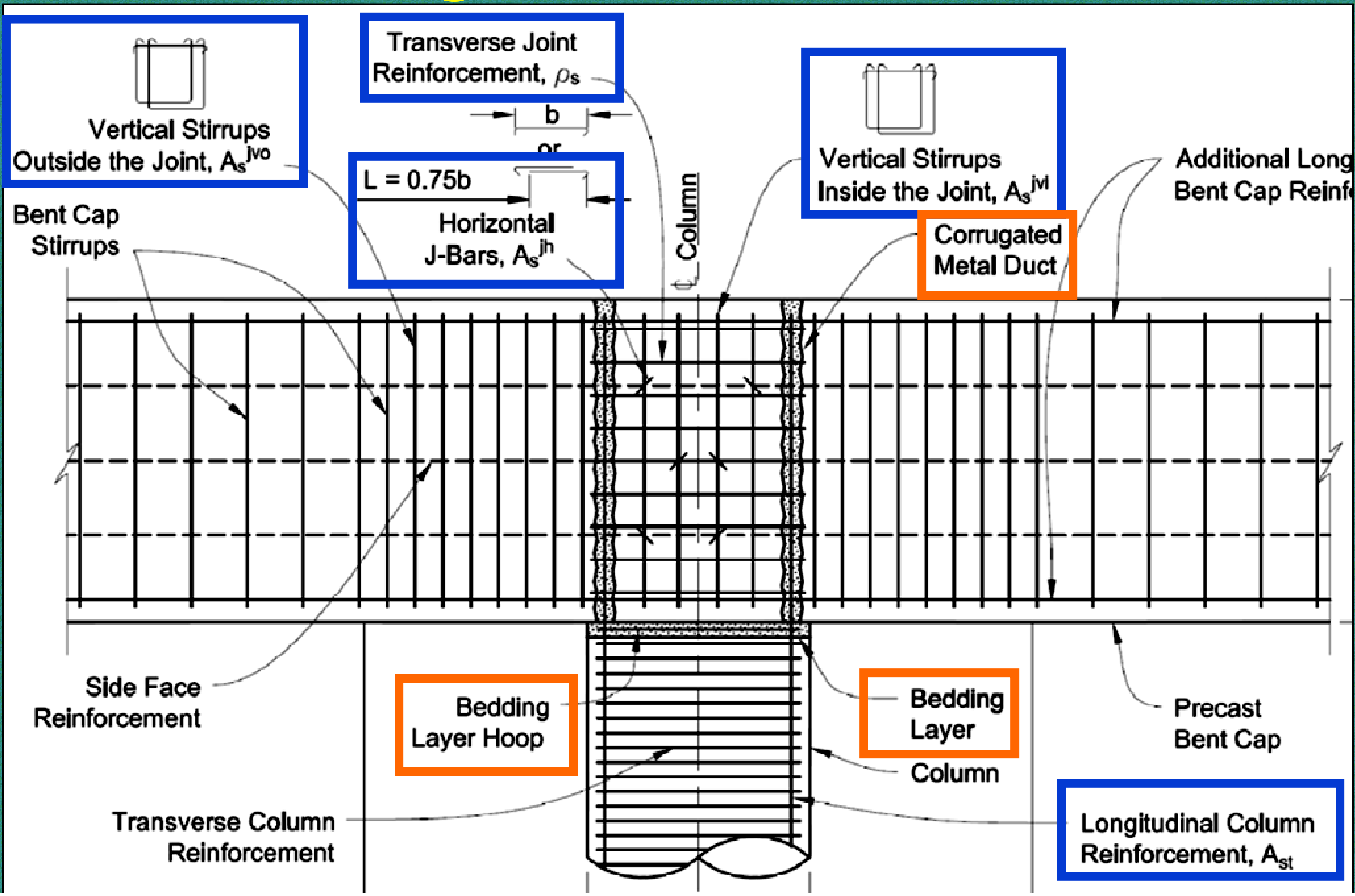
Where the principal tension stress in the joint, p_t, is greater than or equal to $0.11\sqrt{f'_c}$, grouted duct connections shall satisfy the additional joint shear reinforcement required by Article 8.15.5.1. In addition, the vertical stirrups inside the joint shall consist of double leg stirrups or ties of a bar size no smaller than that of the bent cap transverse reinforcement. A minimum of two stirrups or equivalent ties shall be used. Figure 1 through Figure 3 show details of the connection, including ducts, vertical stirrups inside the joint, and bedding layer reinforcement, in addition to the joint transverse reinforcement.

C8.15.5.2.2

The grouted duct connection uses corrugated ducts embedded in the precast bent cap to anchor individual column longitudinal bars. The ducts and bedding layer between the cap and column or pile are grouted with high strength, non-shrink cementitious grout to complete the precast connection. Ducts are sized to provide adequate tolerance for bent cap fabrication and placement and should be accounted for in sizing the bent cap to minimize potential congestion.

Where the principal tension stress in the joint, p_t, is greater than or equal to $0.11\sqrt{f'_c}$, joint shear reinforcement requirements are essentially the same as those for cast-in-place connections. However, where the principal tension stress in the joint, p_t, is less than $0.11\sqrt{f'_c}$, minimum vertical stirrups are required in the joint per Article 8.14.5.2.2a. See Article 8.15.3.2.1.

Example Design Specification—Joint Design For SDCs C and D



CSUS Deliverables—Flow Chart/Design Example

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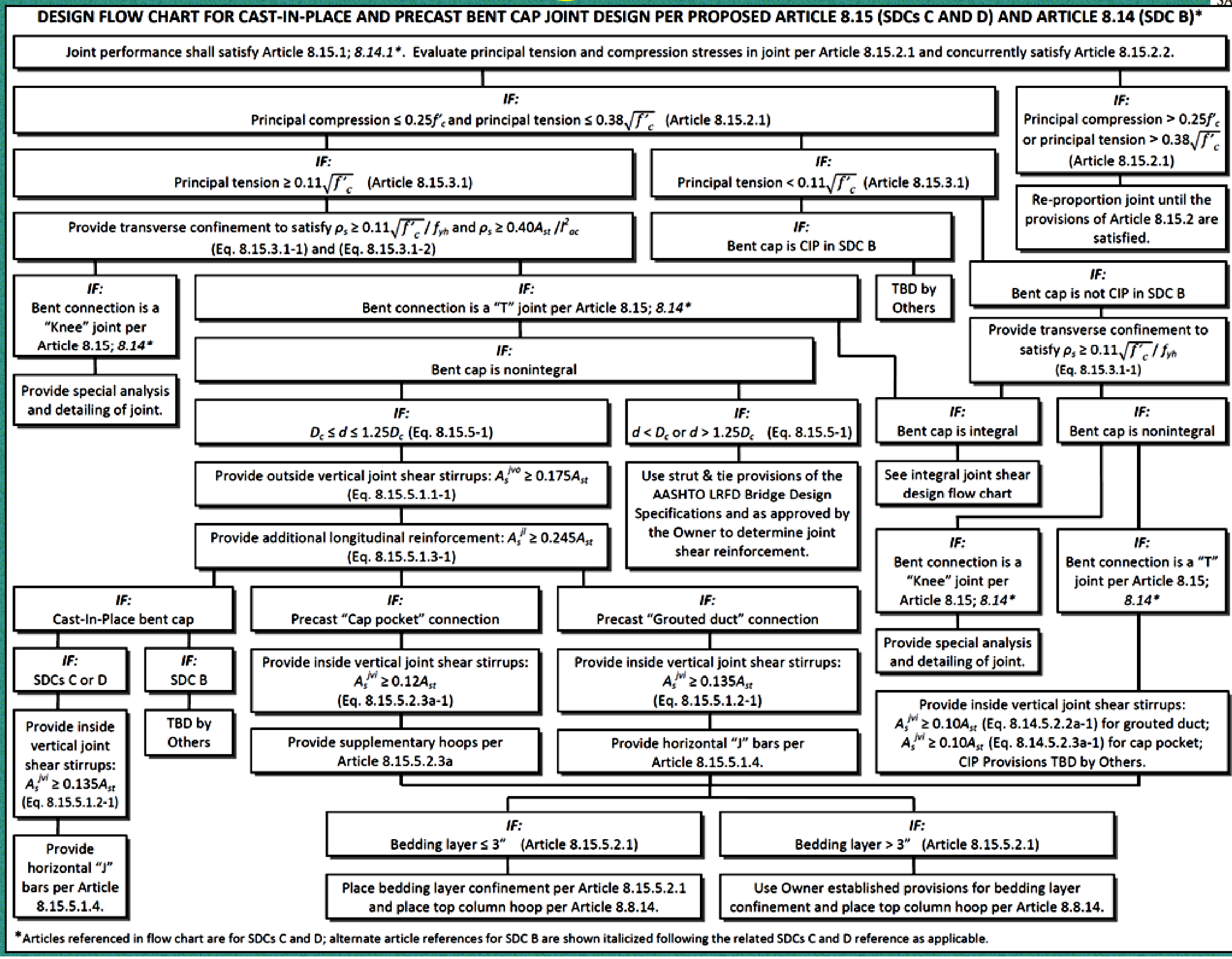
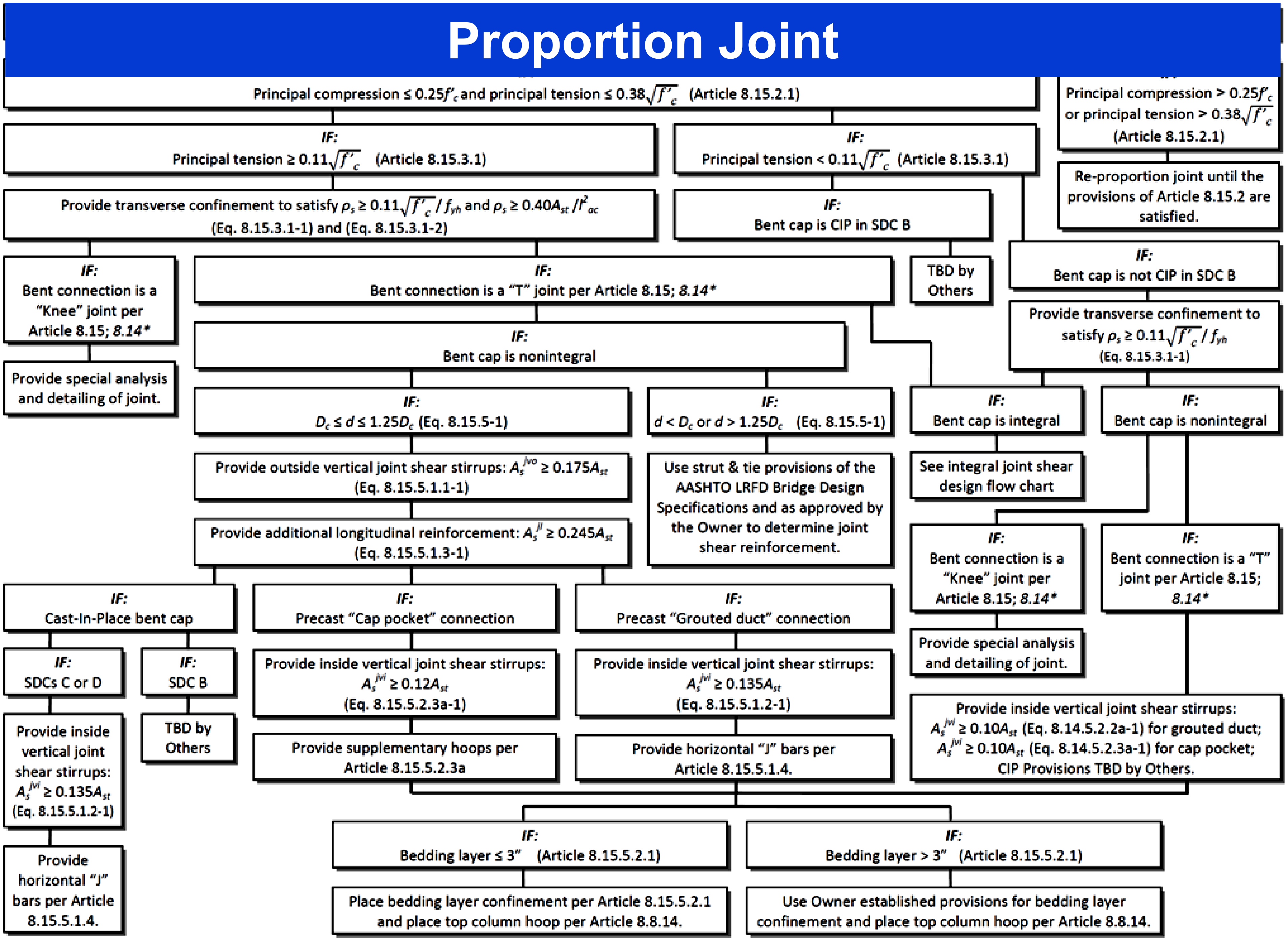
Design Flow Chart	DF1	SDC A Design Flow Chart	Flow chart for design of precast bent cap connections in SDC A
Design Example	DE1	SDC A Design Example—Grouted Duct Connection	Design example for grouted duct connection in SDC A (minimum joint reinforcement)
Design Example	DE2	SDC A Design Example—Cap Pocket Connection	Design example for cap pocket connection in SDC A (minimum joint reinforcement)
Design Flow Chart	DF2	SDCs B, C, and D Design Flow Chart	Flow chart for design of precast bent cap connections in SDCs B, C, and D
Design Example	DE3	SDC B Design Example—Grouted Duct Connection	Design example for grouted duct connection in SDC B (minimum joint reinforcement)
Design Example	DE4	SDC B Design Example—Cap Pocket Connection	Design example for cap pocket connection in SDC B (minimum joint reinforcement)
Design Example	DE5	SDCs C and D Design Example—Grouted Duct Connection	Design example for grouted duct connection in SDCs C and D (additional joint reinforcement)
Design Example	DE6	SDCs C and D Design Example—Cap Pocket Connection	Design example for cap pocket connection in SDCs C and D (additional joint reinforcement)

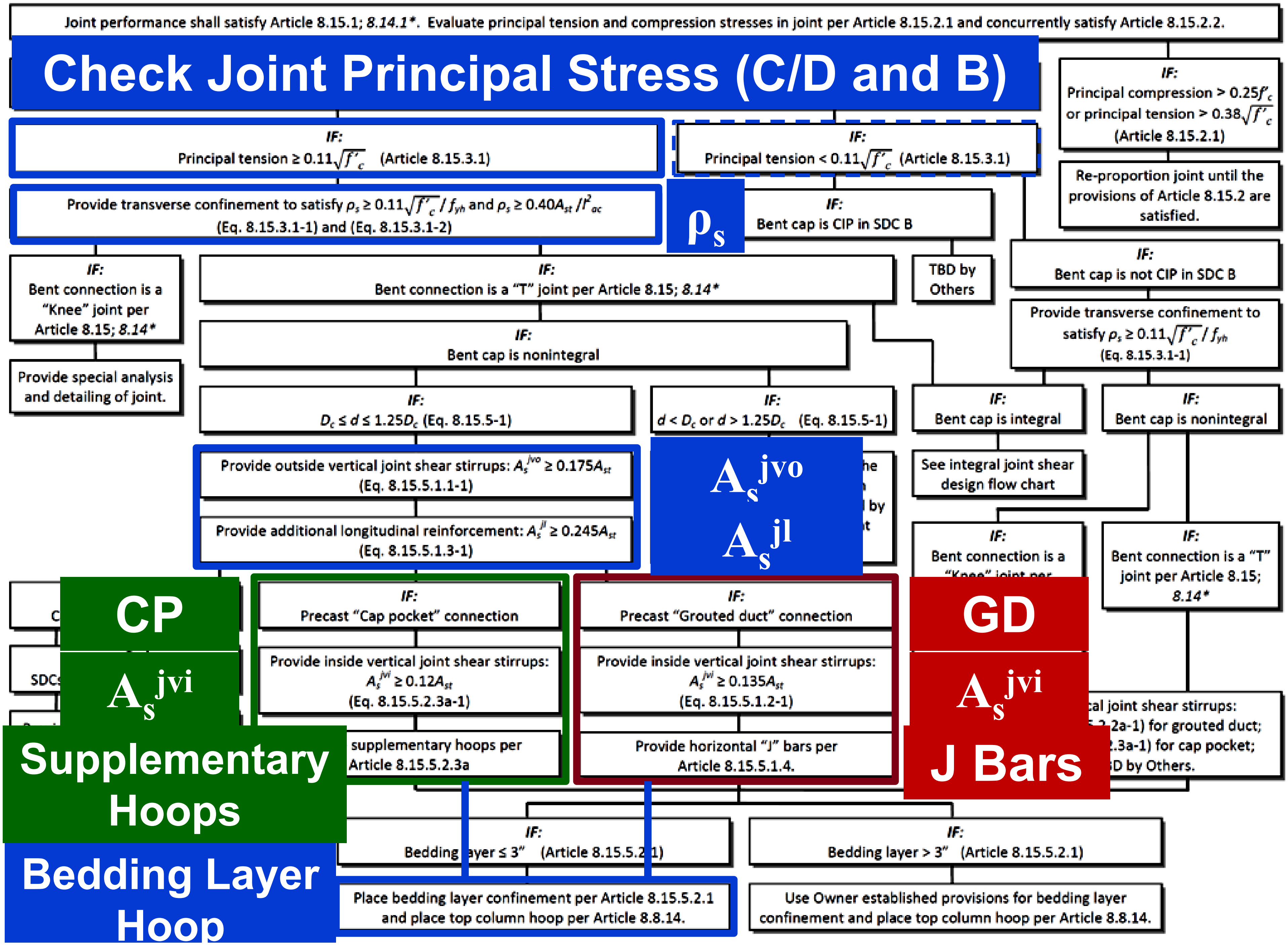
Joint Design Flow Chart



DESIGN FLOW CHART FOR CAST-IN-PLACE AND PRECAST BENT CAP JOINT DESIGN PER PROPOSED ARTICLE 8.15 (SDCs C AND D) AND ARTICLE 8.14 (SDC B)*



DESIGN FLOW CHART FOR CAST-IN-PLACE AND PRECAST BENT CAP JOINT DESIGN PER PROPOSED ARTICLE 8.15 (SDCs C AND D) AND ARTICLE 8.14 (SDC B)*



Joint Summary Reinforcement

$p_t \geq 0.11\sqrt{f'_c}$ (SDCs B, C, D)

Reinforcement Type	Term	2009 SGS	Proposed	
		CIP	GD	CP
Transverse Hoop	ρ_s	Eq. 8.13.3-2	Max (Eq. 1, Eq. 2)	
Inside joint stirrups	A_s^{jvi} / A_{st}	0.135	0.135	0.12
Outside joint stirrups	A_s^{jvi} / A_{st}	0.175	0.175	
Additional Cap Longitudinal	A_s^{jl} / A_{st}	0.245	0.245	
Horizontal J-bar	-	Every other intersection	Same as CIP	NA
Anchorage Length	l_{ac}	$0.79 d_{bl} f_{ye} / \sqrt{f'_c}$	$2 d_{bl} f_{ye} / f'_g$	$2.3 d_{bl} f_{ye} / f'_c$
Bedding Layer	-	NA	Per Spec	
Supplemental Hoops	-	NA	NA	Per Spec

Joint Summary Reinforcement

$p_t < 0.11\sqrt{f'_c}$ (SDCs C, D)

Reinforcement Type	Term	2009 SGS	Proposed	
		CIP	GD	CP
Transverse Hoop	ρ_s	Eq. 8.13.3-1	Eq. 8.13.3-1	
Inside joint stirrups	A_s^{jvi} / A_{st}	NO REQ'T	0.10	0.10
Outside joint stirrups	A_s^{jvi} / A_{st}	-	-	-
Additional Cap Longitudinal	A_s^{jl} / A_{st}	-	-	-
Horizontal J-bar	-	-	-	-
Anchorage Length	l_{ac}	$0.79 d_{bl} f_{ye} / \sqrt{f_c^{'}}$	$2 d_{bl} f_{ye} / f_g^{'}$	$2.3 d_{bl} f_{ye} / f_c^{'}$
Bedding Layer	-	NA	Per Spec	
Supplemental Hoops	-	NA	NA	NA

Joint Design Example—Cap Pocket (SDCs C & D)

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PROJECT	DESIGN EXAMPLES	SHEET NO	1	OF	9
PROJECT NO	NCHRP 12-74	DESIGNED BY	M. STILLER	DATE	11/6/2009
CLIENT	SACRAMENTO STATE UNIV.	CHECKED BY	E. MATSUMOTO	DATE	11/9/2009
SUBJECT	AASHTO SEISMIC GUIDE SPECIFICATIONS NONINTEGRAL CAP POCKET BENT CAP JOINT DESIGN EXAMPLE - SDCs C and D				

AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS)

AASHTO LRFD Bridge Construction Specifications (BCS)

Cap Pocket Joint Design Example For SDCs C and D

Cap pocket connection between a column and a precast bent cap in SDCs C and D reinforces the bent cap joint by means of a helical lock-seam, corrugated steel pipe, eliminating conventional hoops and J-bars. This SDC C/D design example applies to a T-joint of a rectangular, nonintegral precast bent cap supported by circular columns for which the principal tensile stress in the connection exceeds $0.11\sqrt{f'_c}$. In this case, the connection requires additional joint reinforcement. The applicable commentary sections in the AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS) provide additional background.

Notes: 1. The SDC B design example illustrates the procedure to be followed when the $0.11\sqrt{f'c}$ limit is not exceeded. 2. Knee joints such as that represented in C8.15.1 are not addressed in the current SGS, and special design provisions should be identified by the designer.

Geometry and Design Parameters

f'_c = 4.0 ksi (specified compressive strength of bent cap) $f'_{ce} = 1.3f'_c$ = 5.2 ksi (expected f'_c of bent cap)

f'_{c_pocket} (specified compressive strength of pocket fill) Select cap pocket strength to satisfy BCS.

$f'_{c\_pocket} = f'_{ce} + 0.5$ ksi = 5.7 ksi (BCS 8.13.8.3.3a)

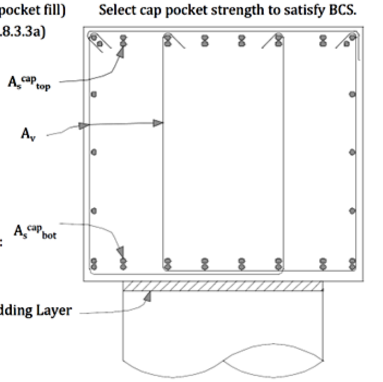
f_{yh} (yield stress of equivalent hoop)

f_{yh} = 60 ksi

f_{ye} (expected yield stress of column bars)

f_{ye} = 68 ksi

f_{yp} (nominal yield stress of steel pipe)



Bent cap width = 7.0 ft (B_{cap})

Bent cap height = 6.25 ft (D_s)

Stirrup bar size: #6

Requirements for Extreme I load case in cap:

Top cap reinf, $A_s^{cap}{}_{top}$ = 16.77 in^2

Bot cap reinf, $A_s^{cap}{}_{bot}$ = 11.40 in^2

Shear reinf, A_v = 4.12 in^2/ft

Column diameter = 5.0 ft (D_c)

A_{st} = 31.2 in^2 (#11 Tot 20)

Hoop bar size: #6

Hoop spacing = 4.0 in

Typical cap section within D_c from face of column.

Note: Bent cap reinforcement shown reflects that required by Extreme Event I load combination before application of joint shear design requirements.

Joint Performance SGS 8.15.1

Moment resisting connections are designed to transmit the maximum forces produced when the column reaches its overstrength moment capacity, M_{po}.

Note: Capacity of the bent cap section needs to satisfy applicable load combinations, including the Strength load cases and capacity protection during Extreme Event load cases. The bent cap section capacity is not investigated in this design example.

PROJECT	DESIGN EXAMPLES	SHEET NO	2	OF	9
PROJECT NO	NCHRP 12-74	DESIGNED BY	M. STILLER	DATE	11/6/2009
CLIENT	SACRAMENTO STATE UNIV.	CHECKED BY	E. MATSUMOTO	DATE	11/9/2009
SUBJECT	AASHTO SEISMIC GUIDE SPECIFICATIONS NONINTEGRAL CAP POCKET BENT CAP JOINT DESIGN EXAMPLE - SDCs C and D				

Determine the idealized plastic moment capacity of the column, M_p, using section analysis program such as xSECTION, and calculate the overstrength moment capacity, M_{po}, per Article 8.5.

Axial load acting on column per extreme event load case = 820.0 kips (P_c)

f'_{ce} (expected concrete compressive strength) = 1.3 x f'_c 5.2 ksi — SGS 8.4.4

f_{ye} (expected steel yield stress) = 68 ksi

M_p = 5970 kip-ft — SGS 8.5

$M_{po} = \lambda_{mo} M_p$

λ_{mo} = 1.2 (ASTM A706) — Eq. 8.5-1

M_{po} = 7164 kip-ft

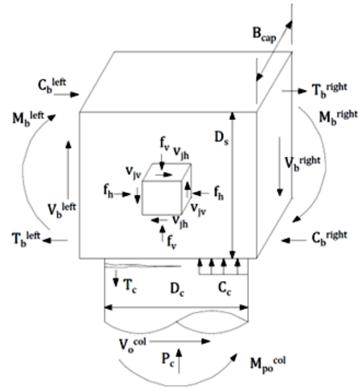
Joint Proportioning — SGS 8.15.2

Principal Stresses

Principal stresses in the joint are limited by the following equations:

Principal compression, p_c : $p_c \le 0.25 f'_c$ = 1.00 ksi maximum

Principal tension, p_t : $p_t \le 0.38\sqrt{f'_c}$ = 0.76 ksi maximum



B_{cap} =	84.0 in	(7.0 ft x 12"/ft)
D_c =	60.0 in	(5.0 ft x 12"/ft)
D_s =	75.0 in	(6.25 ft x 12"/ft)
l_{ac} =	72.0 in	Note 1
P_c =	820 kips	
P_b =	0 kips	Note 2
h =	3.79 ft	Note 3
M_{po} =	7164 kip-ft	Note 3

Notes:

1) Length of column longitudinal rebar extended into cap. See calculations below.
2) No prestressing in section.
3) Determined from sectional analysis. Tension in column longitudinal rebar may also be derived from sectional analysis.

$$p_t = \left|\left(\frac{f_h+f_v}{2}\right) - \sqrt{\left(\frac{f_h-f_v}{2}\right)^2 + v_{jv}^2}\right| = \left|\left(\frac{0.0+0.072}{2}\right) - \sqrt{\left(\frac{0.0-0.072}{2}\right)^2 + 0.313^2}\right| = 0.278 \text{ ksi} \quad \text{Eq. 8.15.2.1-3}$$

$$p_c = \left(\frac{f_h+f_v}{2}\right) + \sqrt{\left(\frac{f_h-f_v}{2}\right)^2 + v_{jv}^2} = \left(\frac{0.0+0.072}{2}\right) + \sqrt{\left(\frac{0.0-0.072}{2}\right)^2 + 0.313^2} = 0.351 \text{ ksi} \quad \text{Eq. 8.15.2.1-4}$$

Cap Pocket Joint Design Example For SDCs C and D

Cap pocket connection between a column and a precast bent cap in SDCs C and D reinforces the bent cap joint by means of a helical lock-seam, corrugated steel pipe, eliminating conventional hoops and J-bars. This SDC C/D design example applies to a T-joint of a rectangular, nonintegral precast bent cap supported by circular columns for which the principal tensile stress in the connection exceeds $0.11\sqrt{f'_c}$. In this case, the connection requires additional joint reinforcement. The applicable commentary sections in the AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS) provide additional background.

Notes: 1. T **Introduction** he procedure to be followed when the $0.11\sqrt{f'c}$ limit is not exceeded. d in C8.15.1 are not addressed in the current SGS, and special design provisions should be identified by the designer.

AASHTO Guide Specifications for LRFD Seismic Bridge Design (SGS)

AASHTO LRFD Bridge Construction Specifications (BCS)

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Geometry and Design Parameters

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f'_{c_pocket} (specified compressive strength of pocket fill) Select cap pocket strength to satisfy BCS.

$f'_{c\_pocket} = f'_{ce}$ + 0.5 ksi = 5.7 ksi (BCS 8.13.8.3.3a)

f_{yh} (yield stress of equivalent hoop)

Step-by-step Calcs

Bent cap width = 7.0 ft (B_{cap})

Bent cap height = 6.25 ft (D_s)

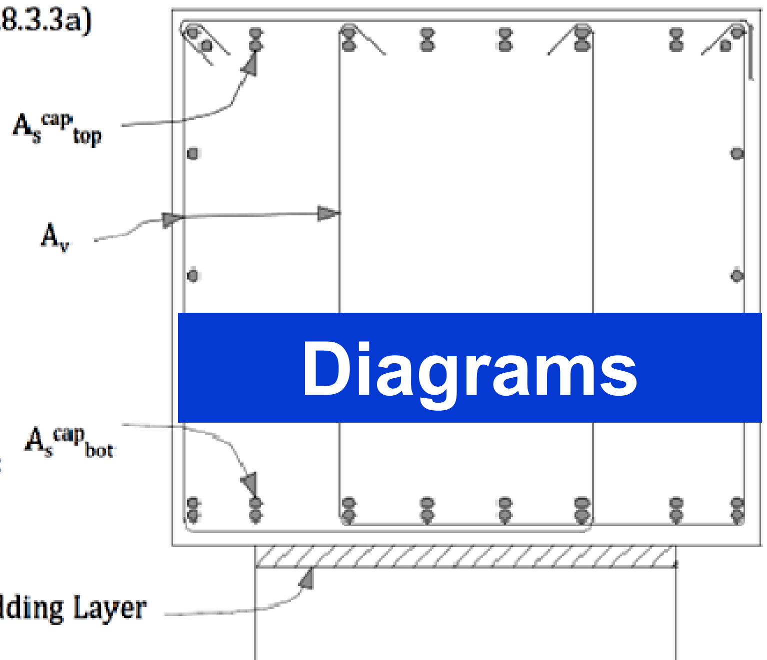
Stirrup bar size: #6

Requirements for Extreme I load case in cap:

Top cap reinf, $A_s^{cap}{}_{top}$ = 16.77 in^2

Bot cap reinf, $A_s^{cap}{}_{bot}$ = 11.40 in^2

Shear reinf, A_v = 4.12 in^2/ft



$F_H =$ 36.1 kips/ft

$H_p =$ 12.0 in/ft (specified unit length)

$f_{yp} =$ 30.0 ksi (manufacturer specified)

$\theta =$ 20.0 deg (manufacturer specified)

$t_{pipe} \geq$ 0.1068 in

Use a 12 gage corrugated steel pipe, 54" nominal inside diameter. $t_{pipe} =$ 0.1046 in (2% under, Say OK)

As a check, compare minimum t_{pipe} from Eq. 8.15.3.2.2-1 to simp

Code References

$$t_{pipe} \geq 0.04 \frac{D'_{cp} \sqrt{f'_c}}{f_{yp} \cos\theta} = 0.1554 \text{ in} \quad \text{and} \geq 0.06 \text{ in}$$

(Note: f'_c refers to bent cap concrete) Eq. C8.15.3.2.2-1

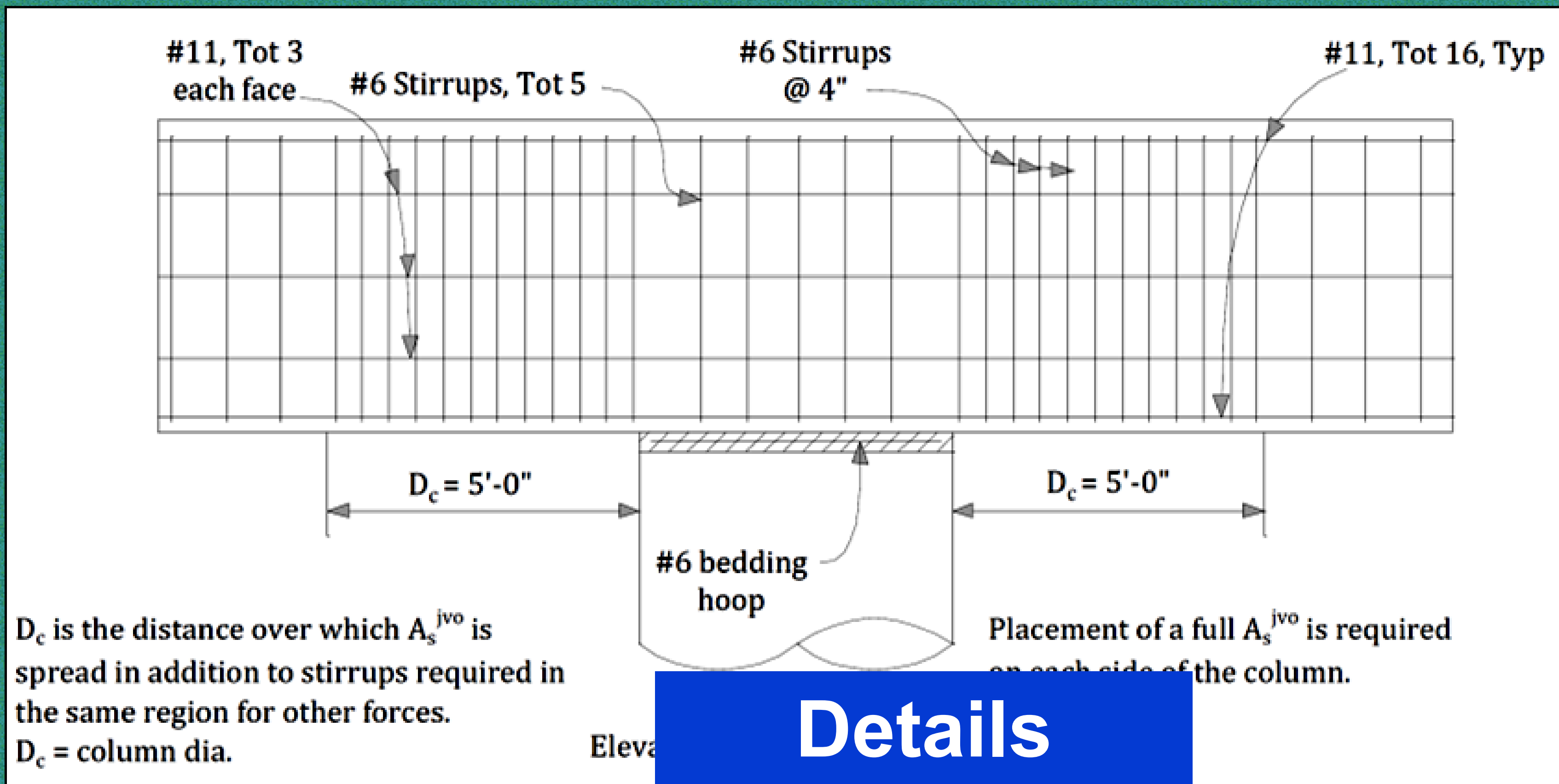
$$t_{pipe} \geq 0.14 \frac{A_{st} D'_{cp} f_{yh}}{l_{ac}^2 f_{yp} \cos\theta} = 0.0982 \text{ in} \quad \text{and} \geq 0.06 \text{ in}$$

Eq. C8.15.3.2.2-2

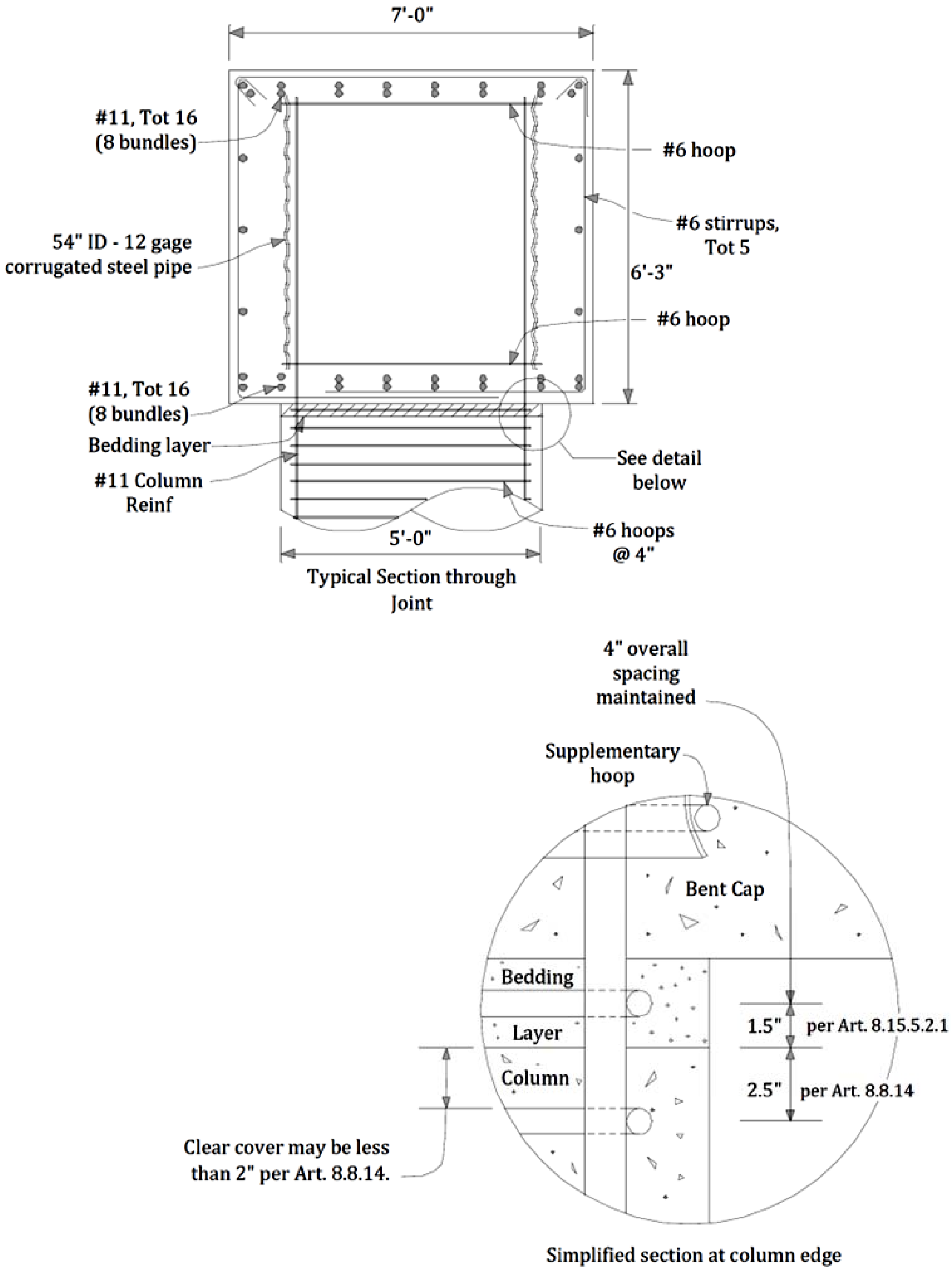
If the refined equation (Eq. 8.15.3.2.2-1) is not used, the maximum of these two simplified equations may be used because they provide a more conservative value. Note that the controlling thickness of 0.1554" from commentary equations is considerably larger than the calculated 0.1068" from the more accurate specification equation. Use of th pipe thickness, especially for larger diameter pipes.

Commentary

Joint Design Example—Cap Pocket (SDCs C & D)

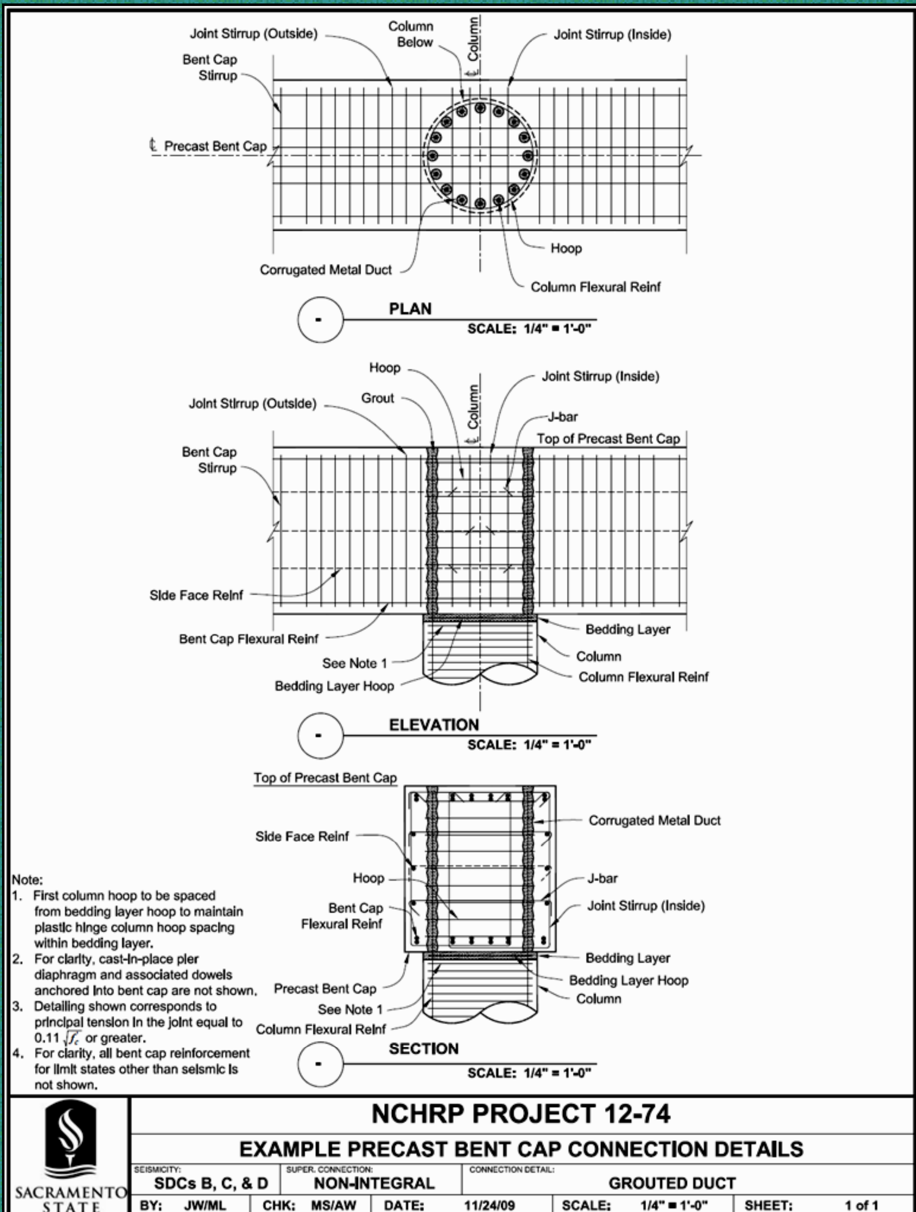


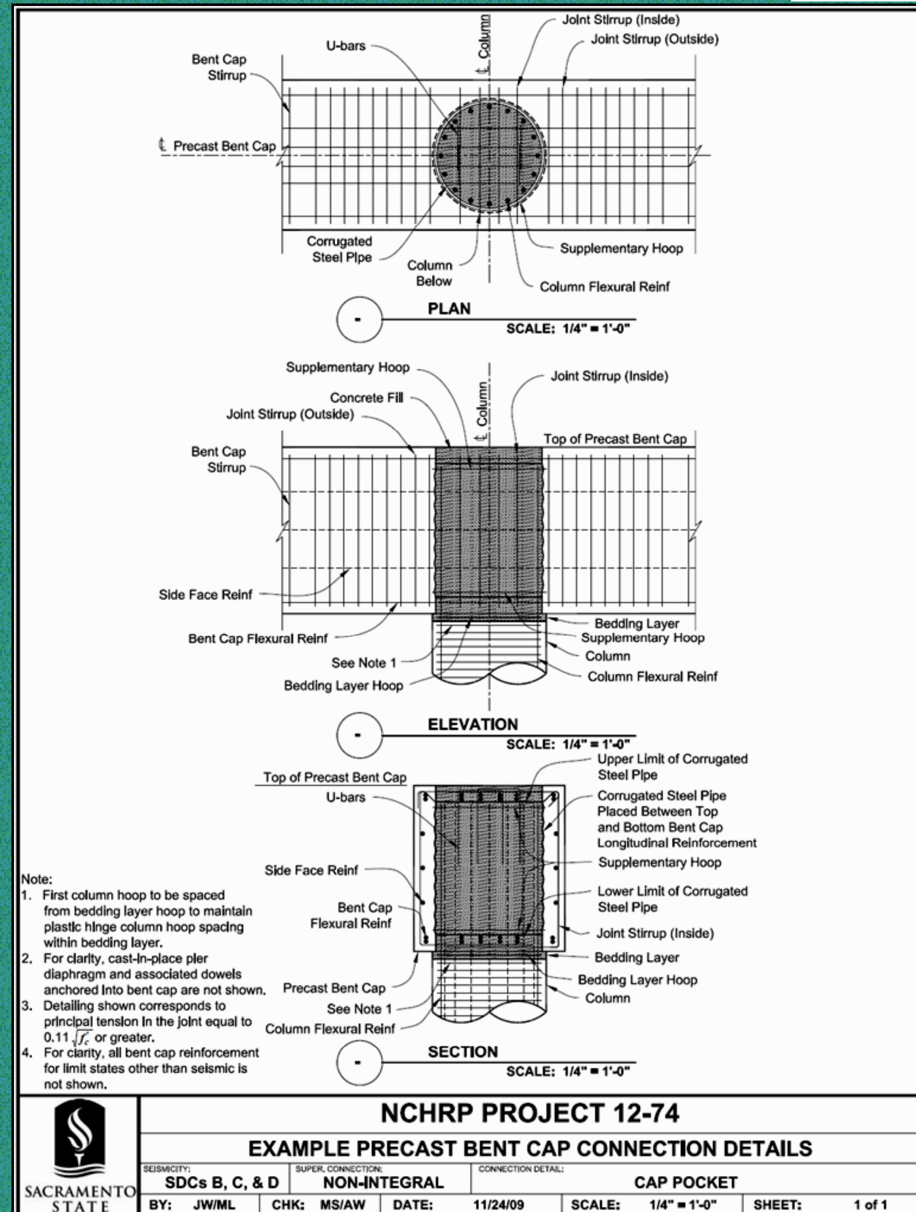
Details



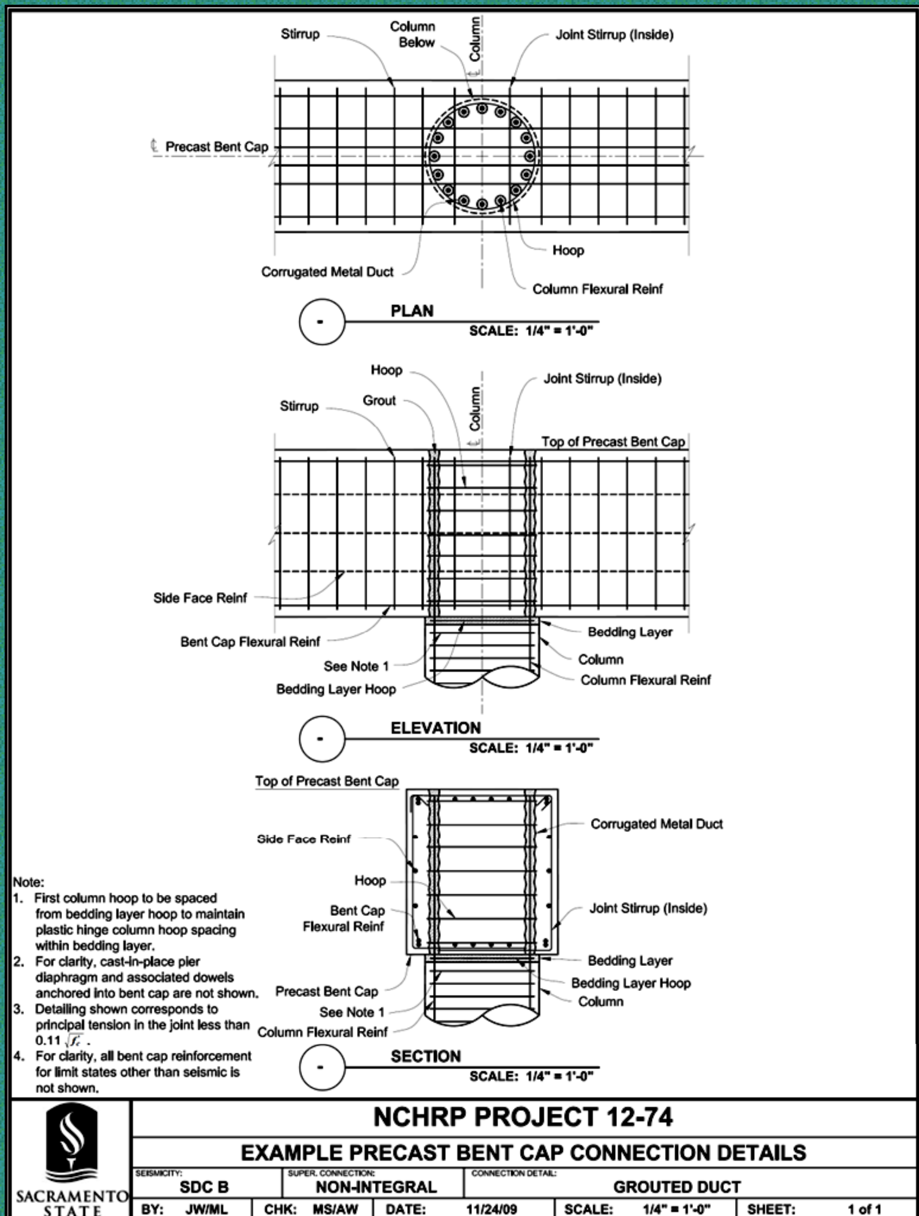
Clear Application of Specs for Hoop at Col Top and Bedding Layer

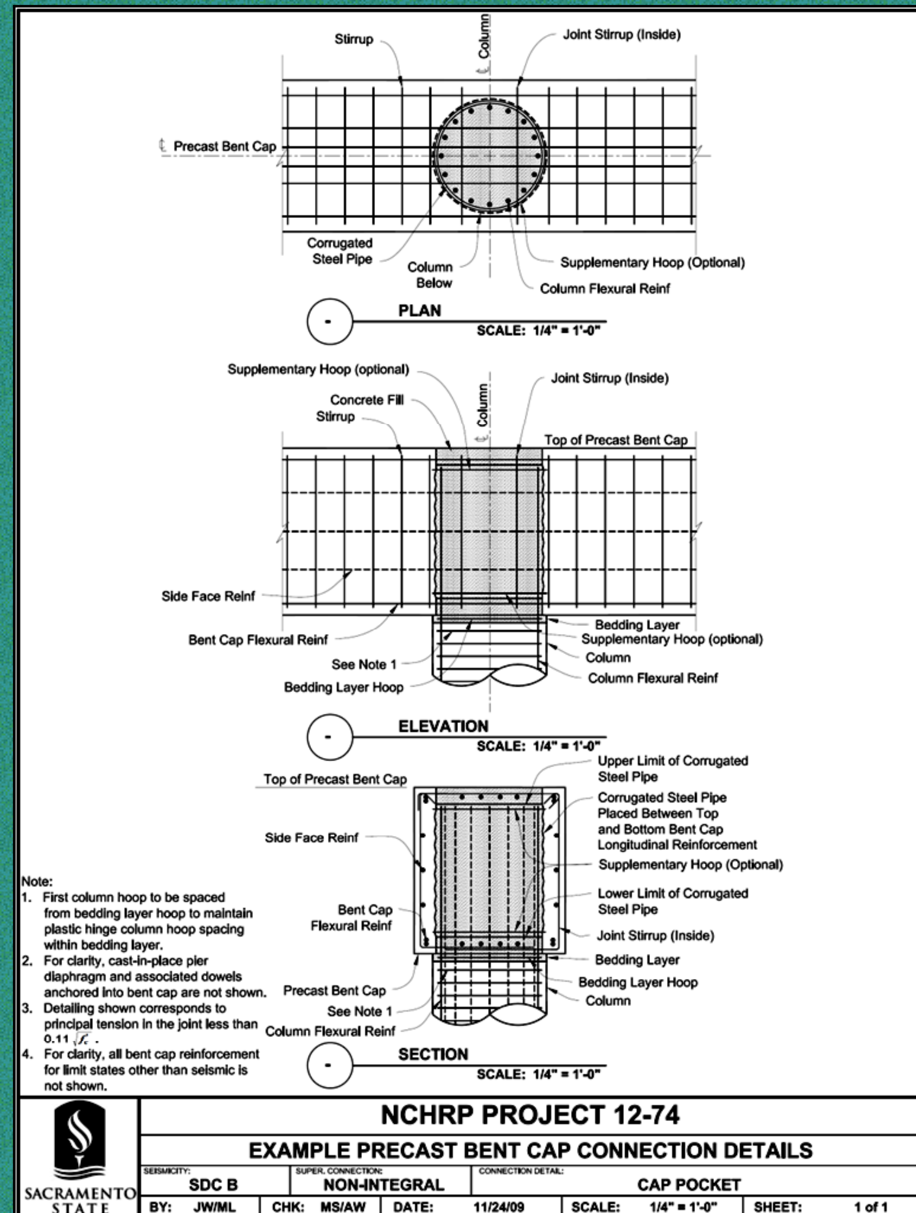
Example Connection Details





Example Connection Details





Construction Specification—Proposed Article 8.13.8

SACRAMENTO STATE

8.13.8—Special Requirements for Nonintegral Precast Bent Caps

8.13.8.1—General

This Article describes special requirements for nonintegral precast bent cap connections using the grouted ducts or cap pockets.

C8.13.8.1

These special requirements are intended to ensure precast bent cap connections using grouted ducts or cap pockets are constructible and also provide the expected seismic performance, durability, and economy. Provisions are based primarily on Matsumoto et al. (2001) and Matsumoto (2009).

The grouted duct connection uses corrugated ducts embedded in the precast bent cap to anchor individual column longitudinal bars. The ducts and bedding layer between the cap and column or pile are grouted with high strength, non-shrink cementitious grout to complete the precast connection. Ducts are sized to provide adequate tolerance for bent cap fabrication and placement and should be accounted for in sizing the bent cap to minimize potential congestion.

The cap pocket connection uses a single, helical, corrugated steel pipe embedded in the precast bent cap to form the cap pocket, which anchors the column longitudinal bars. This pipe, placed between top and bottom bent cap longitudinal reinforcement, serves as both a stay-in-place form and as joint transverse reinforcement. Special forming is required above and below the pipe to form the cap pocket void through the full depth of the bent cap. A flowable cast-in-place concrete is used to fill the void and complete the precast connection. The pipe diameter is sized to provide adequate field tolerance for placement of the precast bent cap over column longitudinal bars, and the pipe thickness is sized to satisfy transverse joint reinforcement requirements.

8.13.8.2—Description

This item shall govern for connection of precast concrete bent caps to cast-in-place columns, precast concrete columns, or prestressed concrete piles.

C8.13.8.2

In subsequent sections of this Article, the term "column bars" refers to column bars, column dowels, and pile dowels.

8.13.8.3—Materials

The materials and manufacturing processes used for precast concrete bent caps shall conform to the requirements of Article 8.13.3 except as those requirements are modified or supplemented by the provisions that follow.

8.13.8.3.1 Portland Cement Concrete for Precast Bent Cap

Portland cement concrete for the precast bent cap shall conform to the provisions of Article 8.2.2 for normal-weight concrete. The concrete mix design for the precast bent cap shall conform to the requirements of Articles 8.13.8.3.2a and 8.13.8.3.3a to achieve the required 500 psi strength margin between the expected bent cap compressive strength and the specified compressive strength of the connection grout or cap pocket concrete fill.

Use of lightweight concrete shall be based on applicable research of connection performance, including seismic effects, and approval by the Engineer.

C8.13.8.3.1

The required strength margin between the bent cap and precast connection grout or concrete fill is intended to help ensure that the connection does not become a weak link in the system. The specified compressive strength of the connection grout or concrete fill is required to exceed the expected bent cap concrete compressive strength by at least 500 psi.

Lightweight concrete can provide significant advantages for a precast bent cap system. However, its use should be based on relevant research including its effect on seismic performance of the connection.

8.13.8.3.2 Grouted Duct Connection

8.13.8.3.2a Hydraulic Cement Grout (Non-Shrink)

Grout used in grouted duct connections shall consist of prepackaged, cementitious, non-shrink grout in accordance with ASTM C 1107 and the additional performance requirements listed in Table 8.13.8-1, including the following properties: mechanical, compatibility, constructability, and durability. Table 8.13.8-1 requirements shall govern over ASTM C 1107 requirements.

Grout shall contain no aluminum powder or gas-generating system that produces hydrogen, carbon dioxide, or oxygen. Grout using metallic formulations shall not be permitted. Grout shall be free of chlorides. No additives or admixtures, including retarders, shall be added to prepackaged grout. Extension of grout shall only be permitted when recommended by the manufacturer and approved by the Engineer.

At a minimum, grout compressive strength and flowability shall be established during trial batches per Article 8.13.8.5.4a. Laboratory testing shall be permitted to establish other properties listed in Table 8.13.8-1.

C8.13.8.3.2a

Table 8.13.8-1 includes provisions intended to ensure the grout used in the connection develops mechanical, compatibility, constructability, and durability properties that help ensure the grout is placed efficiently, achieves performance for rapid construction, and does not become a weak link in the system under the various limit states. For example, Table 8.13.8-1 requires the 28-day grout compressive strength to provide a minimum 500-psi margin over the 28-day expected bent cap concrete compressive strength. This margin accounts for the likelihood that the actual concrete strength will exceed its specified strength as well as the possibility of low grout strength. The 1.25 factor applied to $f'_{ce\ cap}$ in Table 8.13.8-1 accounts for the higher 2-in grout cube compressive strength compared to standard concrete cylinder compressive strength.

Grout should be selected with a compressive strength based on water required for fluid consistency using the ASTM C 939 Flow Cone Test. Grouts mixed to a flowable or plastic consistency in accordance with ASTM C 230 achieve a higher compressive strength but possess inadequate fluidity for filling voids in a precast bent cap system and therefore should be avoided.

Prepackaged grouts are proprietary mixes, and thus no additives should be used in the grout. Additives may adversely affect grout properties and void manufacturer warranties.

Modification of prepackaged grout, including extension with small-size aggregate, is discouraged because of the additional uncertainty introduced in achieving the required properties and the potential risk in resolving liability if the quality of grouted connections is believed to be deficient. For example, ASTM C 33 No. 8 Hard Pea Gravel or Hard Aggregate Chips may contain excessive fines that adversely affect the flow of the prepackaged grout.

Proposed Article 8.13.8 – Continued

1—General

2—Description

3—Materials

3.1 Portland Cement Concrete for Precast Bent Cap

3.2 Grouted Duct Connection

  3.2a Hydraulic Cement Grout (Non-Shrink)

  3.2b Corrugated Metal Duct

3.3 Cap Pocket Connection

  3.3a Portland Cement Conc. for Cap Pocket Fill

  3.3b Steel Pipe

3.4 Connection Hardware

4—Contractor Submittal

4.1 General

4.2 Precast Bent Cap Placement Plan

4.3 Design Calculations for Construction Procedures

4.4 Shop Drawings

Proposed Article 8.13.8 – Continued

5—Construction Methods

5.1 General

5.2 Handling

5.3 Placement

5.4 Grouting of Grouted Duct Connection

- 5.4a Trial Batch
- 5.4b Grout Placement
- 5.4c Grout Testing

5.5 Concreting of Cap Pocket Connection

- 5.5a Trial Batch
- 5.5b Concrete Placement
- 5.5c Testing of Cap Pocket Fill Concrete

5.6 Beam Placement

6—Measurement and Payment

Grout Specification (TxDOT 1748)

SACRAMENTO STATE

Property	Value	
<u>Mechanical</u> Compressive strength (ASTM C 109, 2" cubes)	<u>Age</u> 1 day 3 days 7 days 28 days	<u>Compressive strength (psi)</u> 2,500 4,000 5,000 Maximum [6000, 1.25 (f'_{ce_cap}+ 500)]
<u>Compatibility</u> Expansion requirements (ASTM C 827 & ASTM C 1090)	Grade B or C—expansion per ASTM C 1107	
Modulus of elasticity (ASTM C 469)	2.8-5.0×10^6 psi	
Coefficient of thermal expansion (ASTM C 531)	3.0-10.0×10^{-6}/deg F	
<u>Constructability</u> Flowability (ASTM C 939 Flow Cone)	fluid consistency efflux time: 20-30 sec	
Set Time (ASTM C 191) Initial Final	 2.5-5.0 hrs 4.0-8.0 hrs	
<u>Durability</u> Freeze Thaw (ASTM C 666)	300 cycles, RDF 90%	
Sulfate Resistance (ASTM C 1012)	expansion at 26 weeks < 0.1%	

Final Thoughts

- ✓ Grouted duct and cap pocket connections can be designed using SDC-type process for joint shear. However, differences in design, detailing, and construction must be carefully followed to achieve emulative response.
- ✓ Proposed design and construction specifications are recommended for project-specific use until formal review by AASHTO.
- ✓ Successful implementation is ensured by careful use of specifications with flow charts, design examples, and example details.

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