Attachment CS1. Proposed Article 8.13.8—Special Requirements for Precast Bent Cap Connections (AASHTO LRFD Bridge Construction Specifications, 2nd Edition with 2006, 2007, 2008, and 2009 Interims)

8.13.8—Special Requirements for Precast Bent Cap Connections	
8.13.8.1—General	**C8.13.8.1**
This Article describes special requirements for integral and nonintegral, emulative and hybrid precast bent cap connections.	These special requirements are intended to ensure emulative and hybrid 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 Restrepo et. al (2010). 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. Hybrid connections use grouted duct connections to anchor column longitudinal reinforcement. Unbonded post-tensioning is also used in the section to resist lateral demands. The integral connections must provide a stable flexural connection between the superstructure and substructure. These connection can include systems with discontinuous girders at the bent cap, made continuous through longitudinal post-tensioning.
8.13.8.2—Description	**C8.13.8.2**
This item shall govern for connection of precast concrete bent caps to cast-in-place columns, precast concrete columns, or prestressed concrete piles.	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.

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.

Grouted joints shall not exceed 3 inches in thickness for structures located in Seismic Design Categories B, C or D.

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.

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. Clear spacing between the reinforcing and the formed surfaces should be at least three times the top size of the aggregate, to ensure adequate flow of grout to fill all voids.
8.13.8.3.2b Corrugated Metal Duct The use of ducts in a grouted duct connection shall conform to the requirements of Article 10.8.1 except as those requirements are modified or supplemented by the provisions that follow. Ducts used to provide holes in the precast bent cap concrete shall be formed with semi-rigid steel ducts which are cast into the concrete. Ducts shall be galvanized ferrous metal per ASTM A 653 and shall be fabricated with either welded or interlocked seams. Ducts shall be corrugated with a minimum wall thickness of 26 gage for ducts less than or equal to 4-in. diameter and 24 gage for ducts greater than 4-in diameter. Rib height of the corrugation shall be at least 0.12 in. Plastic ducts shall only be used based on applicable research and when approved by the Engineer. Duct diameter shall be based on fabrication and placement tolerances established for the job. Placement and anchorage of ducts shall conform to the requirements of Article 10.4.1.1.	*C8.13.8.3.2b* Corrugated galvanized steel ducts for grouted duct connections have been successfully used in seismic and nonseismic research as well as in practice. Steel ducts provide excellent mechanical interlock with the bent cap concrete and connection grout as well as confinement for the grouted column bar. When steel ducts with the minimum specified duct thickness and corrugation rib height are used together with grouts satisfying Table 8.13.8-1, excellent bond develops and column bars can be safely anchored in a grouted duct within the relatively short anchorage length given in Article 8.15.2.2.2 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design.* Use of plastic ducts can have a significant impact on the behavior, failure mode, and strength of grouted duct connections and should not be used without investigation and approval of the Engineer. Brenes et al. (2006) provides guidelines for use of high-density polyethylene and polypropylene ducts in grouted duct connections, including minimum duct wall thickness, corrugation rib height and maximum spacing between ribs. An increase in development length of approximately 30% was recommended for plastic ducts tested under monotonic tension.
8.13.8.3.3 Cap Pocket Connection *8.13.8.3.3a Portland Cement Concrete for Cap Pocket Fill* Portland cement concrete for the cap pocket fill shall satisfy the provisions of Article 8.2.2 for normal-weight concrete and Article 8.3 for associated materials. The mix design for the concrete fill shall be specified based on achieving a concrete compressive strength at least 500 psi greater than the expected concrete strength of the precast bent cap. Lightweight concrete shall not be used. Concrete shall satisfy Article 8.13.8.5.5a to ensure pocket and bedding layer are completely filled and without voids.	*C8.13.8.3.3a* The specified concrete compressive strength for the cap pocket fill is required to provide a minimum 500-psi margin over the expected bent cap concrete compressive strength to ensure the cap fill concrete is not the weak link in the connection. This margin accounts for the likelihood that the actual bent cap compressive strength will exceed its specified strength as well as the possibility of a low compressive strength of the fill. Use of lightweight concrete is not permitted in the cap pocket because it may unnecessarily pose risk in the seismic performance of the connection. Concrete should be sufficiently flowable to fill the pocket and bedding layer and to flow out of air vents at the top of the bedding layer.

	Clear spacing between the reinforcing and the formed surfaces should be at least three times the top size of the aggregate, to ensure adequate flow of concrete to fill all voids, including the bedding layer.
8.13.8.3.3b Steel Pipe The steel pipe used to form the void in the precast bent cap concrete shall be a lock-seam, helical corrugated pipe cast into the concrete. The steel pipe shall satisfy the requirements of ASTM A 760, Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains, and the lock seam shall satisfy the requirements of AASHTO T 249, Standard Method of Test for Helical Lock Seam Corrugated Pipe. The pipe shall satisfy the thickness required by Article 8.15.3.2.2 of *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. Where required, coupon testing to determine material properties shall be conducted in accordance with ASTM A 370. Plastic pipe shall not be used. The pipe diameter shall be based on fabrication and placement tolerances established for the job. Placement and anchorage of steel pipe shall conform to the requirements of Article 10.4.1.1.	*C8.13.8.3.3b* Lock-seam, helical corrugated steel pipe has been successfully used in seismic research as well as in practice for precast cap pocket connections. These pipes provide excellent mechanical interlock with the bent cap concrete and connection concrete fill, and also serve as joint reinforcement. When the steel pipe is designed in accordance with Article 8.15.3.2.2 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* and is used together with concrete satisfying Article 8.13.8.3.3a, excellent bond is expected to develop and column bars are expected to be anchored in the pipe within the relatively short anchorage length given in Article 8.15.2.2.2 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. Plastic pipe should not be used because it cannot serve as seismic reinforcement.
8.13.8.3.4 Connection Hardware All connection hardware such as friction collars, shims, falsework, or other support systems shall be in accordance with the requirements shown in the plans.	*C8.13.8.3.4* Friction collars and shims may be used to support the cap during placement. When shims are used, compressible shims such as those made of plastic are preferred over steel shims to help ensure load eventually transfers to the hardened bedding layer grout. Plastic shims should be made of engineered multipolymer high-strength plastic with a modulus of elasticity slightly less than the hardened grout at the time of load transfer. Steel shims have a stiffness at least five times that of the bedding grout and therefore can act as hard points between the column and bent cap. Calculations should be made to determine the potential effect of shims in the compression zone of the bedding layer. Where steel shims are used, additional cover should be provided for corrosion protection. Specific measures to prevent movement of shims during cap placement should be detailed in the plan sheets. To facilitate complete grouting of the bedding layer, the total shim plan area should be limited and shims should be placed away from the exposed surface of the bedding layer unless shim removal is planned.
8.13.8.3.5 Hybrid Precast Concrete Connection Hybrid precast bent caps using grouted duct connections shall satisfy the requirements of Article	*C8.13.8.354*

8.13.8.3.2 as modified in this Article. *8.13.8.3.5a Hydraulic Cement Grout (Non-Shrink)* Grout used in grouted duct connections in conjunction with hybrid precast connections shall meet the requirements of Article 8.13.8.3.2a. Polypropylene fibers shall be added to the grout matrix during mixing at a 3 pound per cubic yard fraction. Fibers shall meet the requirements of ASTM C1116. *8.13.8.3.6 Integral Precast Concrete Connections with Vertical Joints* *8.13.8.3.6a 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. Polypropylene fibers shall be added to the grout matrix during mixing at a 3 pound per cubic yard fraction. Fibers shall meet the requirements of ASTM C1116. Grouted joints shall not exceed 3 inches for structures located in Seismic Design Categories B, C and D. **8.13.8.4—Contractor Submittal** *8.13.8.4.1 General* In advance of the start of precast bent cap placement operations in the field, to allow the Engineer not less than a 30-calendar day review period, the Contractor shall submit the following documents: 1) Precast Bent Cap	*C8.13.8.3.5a* The use of fiber reinforced grout is required to maintain the integrity of the grout joint during large compressive strains associated with controlled rocking performance. *C8.13.8.4.1* See Matsumoto et al. (2001) for further information on these provisions.

Placement Plan per Article 8.13.8.4.2; 2) Design Calculations for Construction Procedures per Article 8.13.8.4.3; and 3) Shop Drawings per Article 8.13.8.4.4. Bent caps shall not be set until the Engineer has approved all required submittals. Any subsequent deviation from the approved materials and/or details shall not be permitted unless details are submitted by the Contractor and approved by the Engineer in advance of use. Two sets of the Precast Bent Cap Placement Plan, calculations, and required drawings shall be submitted and resubmitted as necessary until approved by the Engineer. The specified number of distribution copies shall be furnished after approval. *8.13.8.4.2 Precast Bent Cap Placement Plan* The Precast Bent Cap Placement Plan, at a minimum, shall contain the following items: a) Step-by-step description of bent cap placement for each bent, including placement of the bent cap on the columns or piles and proposed method to form the bedding layer, place grout in ducts or concrete in cap pockets, and ensure grout or concrete is properly consolidated in the connection and bedding layer. b) Method and description of hardware used to hold bent cap in position prior to connection grouting or concreting. Hardware shall be permitted to consist of friction collars, plastic or steel shims, shoring or other support systems. A hardware submittal shall consist of product information, material descriptions, and drawing for friction collars, shims, and shop drawings for shoring if used. c) For grouted duct connections, manufacturer's product information for at least two candidate grouts, including a description of the performance characteristics as specified in Table 8.13.8-1, mixing requirements, working time, curing requirements, and other information related to grouting of precast connections utilizing ducts. For cap pocket connections, concrete fill mix design, description of the method to achieve concrete consistency for filling the pocket and bedding layer, curing requirements, and other information related to concreting precast connections using a steel pipe. d) Hardware and equipment associated with grouting grouted duct connections or concreting cap pocket connections. e) A mitigation plan to repair any voids observed within the bedding layer, coordinated and approved by the Engineer. f) Other required submittals shown on the plans or requested by the Engineer relating to successful installation of precast bent caps and associated hardware. *8.13.8.4.3 Design Calculations for Construction Procedures*	

Design calculations shall be submitted for friction collars, shims, falsework, erection devices, formwork, or other temporary construction which will be subject to calculated stresses. Design of the friction collars, shims, and falsework or erection devices for all bent cap concrete, duct grout, or cap pocket concrete shall be completed under the direction of and sealed by a registered Professional Engineer. Post-tensioned precast bent caps shall also satisfy the provisions of Article 8.16.3.2.	
8.13.8.4.4 Shop Drawings	*C8.13.8.4.4*
The Contractor shall submit detailed shop drawings for approval in accordance with the contract documents. The shop drawings shall satisfy the provisions of Article 8.16.3.3, with the following additions: a) Shop drawings shall completely describe the proposed construction sequence and shall show enough detail to enable construction of the bent cap without the use of the plan sheets. b) Size and type of ducts or pipes for all bent cap connections shall be clearly detailed. Duct or pipe supports, tremie tubes, air vents, and drains shall be shown, including size, type, and locations. c) Bedding layer reinforcement, as well as its location within the bedding layer and its location relative to the first hoop at the top of the column or pile, shall be shown. d) Spacing between the first hoop at the top of the column or pile and the bedding layer hoop shall be shown. This spacing shall not exceed the spacing used for hoops in the plastic hinge region. The concrete cover above the first hoop at the top of the column shall be permitted to be less than that specified in Article 5.12.3 of the *AASHTO LRFD Bridge Design Specifications*. e) A table showing elevations and geometry to be used in positioning the bedding layer collar for bent cap placement shall be provided. f) For the grouted duct connection, details of grouting equipment, grout mix design, and method of mixing, placing, and curing grout shall be provided. g) For the cap pocket connection, details of concrete fill mix design and method of mixing, placing, and curing concrete fill shall be provided. h) Other required submittals shown on the plans or requested by the Engineer relating to successful installation of precast bent caps and associated hardware shall be provided.	Uniform spacing between hoops at the top of the column and the bedding layer is critical to ensure that the system ductility is not compromised. A smaller cover than that used for typical column applications is permitted for the top hoop because the bedding layer provides additional cover after placement of the precast bent cap. Plan sheets should show the intended placement of the first hoop at the top of the column. This requirement for design is addressed in Article 8.8.14 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design.*
8.13.8.5—Construction Methods	
8.13.8.5.1 General	*C8.13.8.5.1*
All tolerances shall be established on a project-	Combined fabrication and placement tolerances

specific basis. Combined tolerances shall include, but are not limited to, fabrication of the bent cap and columns or piles and placement of the bent cap over the columns or piles, including location of column bars within the corrugated metal ducts or steel pipe. All form release agents and curing membranes shall be completely removed from areas of the cap that will be in contact with bearing seat and connection grout.	should be established for each project. Consideration should be made for issues such as the following: differences in tolerances for longitudinal and transverse directions; accuracy of column bars within corrugated ducts or steel pipes; size, type, location and orientation of ducts or pipe to account for cap slope; plumbness of column bars; and provisions for out-of-tolerance substructure elements.
8.13.8.5.2 Handling Handling of precast bent caps shall satisfy the provisions of Article 8.16.7.4.	
8.13.8.5.3 Placement The Contractor is solely responsible for ensuring the stability of the bent cap prior to and during grouting or concreting operations. All grades, dimensions and elevations shall be determined and verified before the bent cap is placed. The contractor shall verify proper alignment between the columns or piles, including column bars, corrugated metal ducts, steel pipes, and other connection hardware cast into the bent cap. All loose material, dirt and foreign matter shall be removed from the tops of columns or piles before the cap is set.	
8.13.8.5.4 Grouting of Grouted Duct Connection The preparation and use of grout for precast bent cap connections shall conform to the requirements of Article 10.9 except as those requirements are modified or supplemented by the provisions that follow. Prepackaged, cementitious, non-shrink grout shall be used in strict accordance with manufacturer's recommendations. Per Article 8.13.8.3.2a, additives or admixtures, including retarders, shall not be added to grout. However, it shall be permitted to adjust the temperature of mixing water or substitute ice for water to extend the working time and pot life. Addition of water to previously mixed grout or remixing of grout shall not be permitted. Water exceeding manufacturer's recommendations shall not be added to the grout to increase flowability.	*C8.13.8.5.4* Grouting is a crucial operation for the grouted duct connection. Because it involves procedures, operations, and equipment that may not be familiar to the Contractor, these Articles provide sufficient detail to ensure connections are properly made in the field.
8.13.8.5.4a Trial Batch At least two weeks prior to grouting of connections, a trial batch of grout shall be prepared to demonstrate grout properties per Article 8.13.8.3.2a and adequacy of equipment, and to familiarize job site personnel with grouting procedures. A batch of grout shall be the amount of grout	*C8.13.8.5.4a* The trial batch is a key step in achieving the required installation and performance of a grouted duct connection. The purposes of a trial batch are to: 1) determine the required amount of water to be added to a particular grout brand to achieve acceptable flowability per Table 8.13.8-1 and pot life under the temperature and

sufficient to complete an entire connection or number of connections and is limited to the amount of grout that can be placed within the pot life determined in the trial batch. For continuous placement using a grout pump, a batch shall be defined as one connection or one bent cap. Partial batches will not be allowed and shall be discarded. The Contractor shall establish grout flowability by measuring efflux (flow) time of the grout with a standard flow cone according to ASTM C 939. The flow time shall be determined twice: 1) immediately after mixing, and 2) at the expected working time corresponding to the pot life of the grout. The ambient temperature and mixing water temperature at the time of trial batch mixing shall be within +/- 5 deg F of that expected at the time of grout placement. The Contractor shall establish that the grout flow time satisfies the limits prescribed in Table 8.13.8-1. Observation of segregation, clumps of grout, or other anomalies in the final trial batch shall be cause for rejection of the proposed brand of grout. Samples used for testing shall be taken from the middle of the batch. One set of six (6) grout cubes shall be prepared as specified in Article 8.13.8.5.4c to verify the compressive strengths shown in Table 8.13.8-1. The Contractor shall validate the proposed grout placement technique by using the trial batch grout and grout equipment in a sample grouting operation similar to the proposed connection grouting. Pumping shall be validated in the trial batch in cases where it is proposed for field placement. Adequacy of the mixer, pump, tremie tubes, vent tubes, and other grouting equipment shall be established. The contractor shall demonstrate that the equipment is adequate for mixing the grout and grouting the connection within the pot life of the batch and does not introduce air into the grout or connection. A wire mesh shall be used to filter out potential clumps when transferring grout between the mixer and containers. *8.13.8.5.4b Grout Placement* All equipment necessary to properly perform grouting operations shall be present before actual grouting operations begin. All grouting operations shall be performed in the presence of the Engineer in accordance with the Precast Bent Cap Placement Plan. Grouting operations shall be performed under the same weather limitations as cast-in-place concrete and as required by the grout manufacturer. Grout pumping shall be required for connections that cannot be completed by other methods within the pot life established for the grout during the trial batch. All additional materials required to ensure proper connection of bent cap to column, such as but not limited to bedding layer hoops, shall be properly placed according to shop drawings. All surfaces to be in contact with the grout shall be cleaned of all loose or foreign material that would in any	humidity conditions expected in the field; 2) determine the grout cube strength corresponding to the flow achieved; 3) examine grout for undesirable properties such as segregation; 4) establish the adequacy of proposed grouting equipment such as the mixer, pump, tremie tubes, and vent tubes; 5) provide jobsite personnel experience in mixing and handling grout prior to actual connection grouting; and 6) help the contractor to make a judicious decision regarding grout brand and its use.

way prevent bond prior to setting bedding layer forms. Bedding layer forms shall be drawn tight against the existing concrete to avoid leakage or offsets at the joint. All previously hardened concrete surfaces that will be in contact with the grout shall be pre-wetted to a surface-saturated moist condition when the grout is placed. Drain ports or holes shall be provided to allow residual water from pre-wetting to drain prior to grouting. Forms for the closure pour between the cap and column shall be adequately vented to allow air to escape during grouting. Vent tubes shall have a minimum ½-in. inner diameter and shall be flush with the top of the bedding layer. Vents shall not be plugged until a steady stream of grout flows out. Grout shall be deposited such that all voids in the bedding layer and bent cap are completely filled. Grout shall be consolidated at intervals during placement operations as needed. All connections shall be grouted in a manner that deposits the grout from the bedding layer or bottom of connection upward. When pumping is used, grout shall be placed through ports located at the bottom of the bedding layer. To prevent introducing air into the system, when continuous flow grouting is not possible, shutoff valves shall be required. All exposed grout surfaces shall be cured in accordance with manufacturer's recommendations. All grout surfaces shall be inspected post-grouting in coordination with the Engineer. Any voids shall be repaired as specified in the mitigation plan in Article 8.13.8.4.2. Grout shall not be disturbed and connections shall not be loaded until final acceptance of the connection. Final acceptance of the connection shall be after the grout has reached a compressive strength in accordance with the "Final Strength" shown in the plans or as approved by the Engineer.	
8.13.8.5.4c Grout Testing The compressive strength of the grout for "Beam Setting Strength" and "Final Strength" shall be determined using grout cubes prepared and tested in accordance with ASTM C 109 and ASTM C 942. The contractor shall prepare a minimum of six (6) cubes per batch. A Commercial Testing Laboratory approved by the Engineer shall test the specimens for "Beam Setting Strength" and "Final Strength". Grout failing to meet the minimum required compressive strength may be cause for rejection of the connection, grout removal, and re-grouting of the connection by means approved by the Engineer.	*C8.13.8.5.4c* Protection of the grout cube specimens in the field is critical and should be performed as required by ASTM C 942.
8.13.8.5.5 Concreting of Cap Pocket Connection The handling and placing of concrete for the cap pocket fill in precast bent cap connections shall conform	

to the requirements of Article 8.7 except as those requirements are modified or supplemented by the provisions that follow.	
8.13.8.5.5a Trial Batch At least two weeks prior to concreting of connections, a trial batch of concrete shall be prepared to demonstrate concrete properties per Article 8.13.8.3.3a and adequacy of equipment, and to familiarize job site personnel with concreting procedures. A batch of concrete shall be the amount of concrete sufficient to complete an entire connection or number of connections and is limited to the amount of concrete that can be placed within the pot life as determined in the trial batch. For continuous placement using a concrete pump, a batch shall be defined as one connection or one bent cap. Partial batches will not be allowed and shall be discarded. The Contractor shall establish concrete flowability using AASHTO T 119, Slump of Hydraulic Cement Concrete. The Contractor shall establish that the slump satisfies the requirements of Article 8.13.8.3.3a during all stages of placement of the concrete fill. Observation of segregation or other anomalies in the final trial batch shall be cause for rejection. Samples used for testing shall be taken from the middle of the batch. One set of six (6) cylinders shall be prepared and tested in accordance with Article 8.5.7 to verify the compressive strengths required by Article 8.13.8.3.3a. The Contractor shall validate the proposed concrete placement technique by using the trial batch concrete and concreting equipment in a sample concreting operation similar to the proposed connection concreting. Pumping shall be validated in the trial batch if it is to be used in the field placement. Adequacy of the mixer, pump, tremie tubes, vibrators, vent tubes, and other concreting equipment shall be established. The contractor shall demonstrate that the equipment is adequate for mixing, placing, and consolidating the concrete in the connection within the pot life of the batch and does not introduce air into the connection.	*C8.13.8.5.5a* The trial batch is a key step in achieving the required installation and performance of a cap pocket connection. The purposes of a trial batch are to: 1) determine the required amount of water and admixtures required to achieve acceptable flowability and pot life under the temperature and humidity conditions expected in the field; 2) determine the corresponding cylinder strength; 3) examine the concrete for undesirable properties; 4) establish the adequacy of proposed concreting equipment such as the mixer, pump, tremie tubes, vibrators, and vent tubes; 5) provide jobsite personnel experience in mixing, placing, and consolidating the concrete in the connection prior to actual connection concreting; and 6) help the contractor to make a judicious decision regarding concrete mix and associated operations.
8.13.8.5.5b Concrete Placement All equipment necessary to properly perform concreting operations shall be present before actual concreting operations begin. All concreting operations shall be performed in the presence of the Engineer in accordance with the Precast Bent Cap Placement Plan. Concreting operations shall be performed under the same weather limitations as cast-in-place concrete. Concrete pumping shall be required for connections that cannot be completed by other methods within the pot life	

established for the concrete during the trial batch.

All additional materials required to ensure proper connection of bent cap to column, such as but not limited to bedding layer hoops, shall be properly placed according to shop drawings.

All surfaces to be in contact with the cap pocket concrete shall be cleaned of all loose or foreign material that may in any way prevent bond prior to setting bedding layer forms.

Bedding layer forms shall be drawn tight against the existing concrete to avoid leakage or offsets at the joint. All previously hardened concrete surfaces that will be in contact with the cap pocket concrete shall be pre-wetted to a surface-saturated moist condition when the concrete is placed. Drain ports or holes shall be provided to allow residual water from pre-wetting to drain prior to concreting. Forms for the closure pour between the cap and column shall be adequately vented to allow air to escape during concreting. Vent tubes shall be flush with the top of the bedding layer and have an inner diameter adequate for venting air and allowing concrete to flow out. Vents shall not be plugged until a steady stream of concrete flows out.

Concrete shall be deposited such that all voids in the bedding layer and bent cap are completely filled. Concrete shall be deposited through the top opening of the cap pocket in a manner that deposits the concrete from the bedding layer or bottom of connection upward. Concrete in the pocket shall be vibrated in accordance with Article 8.7.3. All exposed cap pocket concrete surfaces shall be cured in accordance with Article 8.11.

All concrete surfaces shall be inspected post-concreting in coordination with the Engineer. Any voids shall be repaired as specified in the mitigation plan in Article 8.13.8.4.2.

Concrete shall not be disturbed and connections shall not be loaded until final acceptance of the connection. Final acceptance of the connection shall be after the cap pocket fill concrete has reached the "Final Strength" shown in the plans or as approved by the Engineer.

8.13.8.5.5c Testing of Cap Pocket Fill Concrete

The compressive strength of the concrete for "Beam Setting Strength" and "Final Strength" shall be determined using concrete cylinders prepared and tested in accordance with Article 8.5.7. The contractor shall prepare a minimum of six (6) cylinders per batch. A Commercial Testing Laboratory approved by the Engineer shall test the specimens for "Beam Setting Strength" and "Final Strength". Concrete failing to meet the minimum required compressive strength may be cause for rejection of the connection, concrete removal, and re-concreting of the connection by means approved by the Engineer.

8.13.8.5.6 Beam Placement The top surface of any precast bent cap anchorage shall be finished and waterproofed as shown in the plans. Lifting loops shall be burned off 1 in. below the surface of surrounding concrete and patched using material approved by the Engineer. Beams shall not be set until the grout for grouted duct connections or concrete for cap pocket connections has reached a compressive strength equal to the "Beam Setting Strength" shown on the plans. **8.13.8.6—Measurement and Payment** The measurement and payment processes used for precast concrete bent caps shall conform to the requirements of Article 8.17.	

Table 8.13.8-1 Grout Specification for Grouted Duct Connections

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; CRD-C 611 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%	