



11-1 PRESTRESSED CONCRETE - SHOP DRAWING REVIEW

Introduction

This memo applies to shop drawings for both post-tensioned and pre-tensioned concrete girders and bridges. Shop drawings for prestressed pilings are typically for field personnel use only and are not routinely reviewed by the designers.

See Memo to Designers 1-41 for processing procedures of shop drawings.

The Engineer of Record, referred to as the Design Engineer in this memo, is responsible for approving the shop drawings, which include the anchorage design and details for both the general zone and local zone regions. The shop drawings include the specific tendon layout, anchorage device arrangement, general zone reinforcement, the stressing sequence, and the local zone details for the selected anchorage devices.

Guide for Checking Shop Drawings

Shop drawings are reviewed by the Design Engineer and the Structure Representative. The Design Engineer is the contact person and is responsible for quality control and quality assurance of the shop drawings. The following outline of general responsibilities is to be used as a general guide for reviewing prestressed concrete shop drawings in order to establish uniform practice. Although some items noted for the Design Engineer overlap with the duties of the Structure Representative it will help avoid errors of omission.

Design Engineer

Post-Tensioned Prestressed Concrete Bridges:

- Anchorage system hardware (Caltrans authorized anchorage systems can be found at: www.dot.ca.gov/hq/esc/approved_products_list/)
- Conformance to contract plans (P_{jack} cable path controlling points, anchor set, and initial stress coefficient)
- Girder length
- Prestressing calculations (including elongations)
- Stressing sequence
- Tendon profile and layout
- Bearing Plate Slope (Plate must be perpendicular to the tendon profile at the anchorage)



For Pre-Tensioned Prestressed Concrete Bridges:

- Conformance to contract plans (girder length, concrete strength, and strand harping locations)
- Prestressing strand pattern conforms to $P_{jacking}$ force and “X” to satisfy service limit state and strength limit state at mid-span (software may be used)
- Center of gravity of strands should be checked, but allow for tolerance at girder ends
- Girder end bearing slope
- End block length (if any)
- Numbers and locations of debonding strands (if any)
- The fabricator should be alerted if any special inserts or anchorages are required
- If post-tensioned spliced girders are used, check post-tensioned shop drawings as well

Structure Representative

Post-Tensioned Prestressed Concrete Bridges:

- Blockout dimensions
- Girder flares
- Abutment and hinge diaphragm thickness
- Bearing pad slope

Pre-Tensioned Prestressed Concrete Bridges:

- Girder length and end skew
- Camber and deflection to satisfy final bridge profile
- Girder bracing requirements from Standard Special Provisions
- Abutment and intermediate diaphragm thickness
- Bearing pad slope
- Girder flares (if any)
- Construction sequence (if any)

If the items noted above are incorrect, the plans are to be “Returned for Correction”. If the Design Engineer feels that certain factors need not be considered, or that others should be added, it is their prerogative to do so, provided that the Structure Representative is agreeable. The Design Branch Chief should be informed of, and agree with, the comments on any shop drawings that are “Returned for Correction”. If desired, the designer may elect to involve the post-tensioned or precast concrete committees for their input. However, committee review is not required.

Standard Specifications and Special Provisions

The Design Engineer should establish a close working relationship with the Structure Representative and become familiar with any changes or special conditions that exist in the field. Review the Standard Specifications and the Special Provisions for the particular job.



Contract Plans

Changes from the contract plans or specifications, regardless of magnitude, should not be allowed unless they have been discussed and approved by the Structure Representative. Revisions may be structurally satisfactory but may create contract administration problems. Changes requiring Contract Change Orders as determined by the Structure Representative need special attention. These change orders can be grouped into two categories:

- Changes requested by the Design Engineer or Structure Representative and minor changes requested by the fabricator (where there is no question on approval of the change order by both parties). The shop drawings can be approved but add the note “Contract Change Order to be processed” to each detail sheet involved.
- Controversial changes requested by the fabricator. These drawings must be returned to the fabricator with the added note “Request must be made by the Contractor to the Resident Engineer for Contract Change Order”. The fabricator may ask that the shop drawings be held by the Design Office pending such negotiation. The Design Office should not hold any plans without such a request. See “Cast-In-Place / Precast Construction Shop Drawings” below for a discussion of bar reinforcement changes to accommodate the Contractor’s proposed prestressing method.

Prestressing Calculations

Check the prestressing force with the contract plans or Special Provisions. Require that the Contractor round up when determining the total number of strands.

Check the modulus of elasticity and ultimate strength of the steel samples provided. This information is furnished to the field personnel. The Design Office will have to obtain it from the correspondence file (under “Material”) or the Laboratory. However, results of Laboratory tests are usually not available at the time of review. Normally, a note of “assumed area and modulus of elasticity of prestressing steel used for elongation calculations to be verified with actual prestressing steel used” should be shown on the shop drawings. If this note is not shown, a stamp should be placed on the appropriate sheets as follows:

**“PLANS REVIEWED ON THE BASIS OF
ULTIMATE STRENGTH AND MODULUS OF
ELASTICITY OF STEEL SHOWN ON THESE
SHOP PLANS AND CALCULATIONS. VALUES
TO BE VERIFIED BY TRANSPORTATION
LABORATORY”.**



Typical ranges of values for E_s are as follows:

- Wire = 28,000 ksi to 29,500 ksi
- Bars = 28,000 ksi to 34,000 ksi
- Strand = 28,000 ksi to 29,000 ksi

Check the elongation of the prestressing steel

- One-end stressing formula:
$$\Delta = \frac{T_o (1 + \otimes)(L + 3.5')}{2E_s}$$

Where:

- Δ = total elongation
- T_o = steel stress at the jacking end before seating (generally 202.5 ksi)
- \otimes = initial force coefficient at the point of no movement
- L = Length of tendon
- E_s = modulus of elasticity of prestressing steel (28,500 ksi can be assumed)

- Two-end stressing formula:
$$\Delta_{1st} = \frac{T_o}{2E_s} [(1 + \otimes)L_1 + (3\otimes - 1)L_2]$$

$$\Delta_{2nd} = \frac{T_o (1 - \otimes)L_2}{E_s}$$

Where:

- Δ_{1st} = Elongation after stressing first end
- Δ_{2nd} = Elongation after stressing second end
- L_1 = Length of tendon from first stressing end to the point of no movement
- L_2 = Length of tendon from point of no movement to second stressing end

- To compensate for slack, tendons are usually stressed to 20% of the required load before they are marked for elongation measurements. The Contractor shall submit calculations showing 80% of the total elongation. This is generally referred to as measurable elongation.

Check the force variation between cast-in-place girders

Final Force Variation

- Unless otherwise specified on the contract plans or in the Special Provisions, the maximum allowable force variation between girders must be less than or equal to the ratio of 10 to 9. The force variation between girders are to be calculated using the larger girder force divided by the smaller one.



- Tendons are to be arranged symmetrically in the structure.
- For bridges that carry railroad traffic, interior girders must not have less force applied than the exterior girders.

Temporary Force Variation (during stressing)

- No more than $\frac{1}{2}$ of the prestressing force in any girder may be applied before an equal force is applied in the adjacent girders (this assures a reasonable force distribution between the girders).
- No more than $\frac{1}{6}$ of the total prestressing force may be applied eccentrically about the centerline of the structure during the entire stressing operations.
- The maximum force variation between girders must not exceed the prestressing force of the largest tendon used in all girders.

A single duct layout scheme may be used for all girders in a span even though the contractor varies the number of ducts / force between girders. Check to be certain that the overall center of gravity of the strands provided will meet the center of gravity of the path shown on the Contract Plans.

Check one-end stressing information

- Simple spans are stressed entirely from one-end (by design).
- When one-end stressing is allowed in multiple span structures it will be shown on the contract plans.

Check two-end stressing information

Two-end stressing, performed non-simultaneously, is allowed. Check the proposed stressing sequence at the second end as well as the initial end.

Cast-In-Place / Precast Construction Shop Drawings

- Check the placement of the prestressing units, i.e. size, number, type, location and clearance.
- Section 50-1.01c(3) "Shop Drawings," of the Standard Specifications requires complete details to be shown on the shop drawings of the prestress system to be used. Any additions to or rearrangement of the reinforcing steel shown on the Contract Plans, to accommodate the prestress system used, must be included. This ensures that significant changes can be approved, before installation, by both Design and Construction. Specific areas of concern are around anchorages, and where ducts may displace bent cap reinforcement



in continuous structures, or where bent caps are prestressed. Significant changes in reinforcing steel placement must also be shown on the as-built shop drawings submitted after project completion. This does not preclude minor placement variations made and approved in the field, or later significant changes, which were overlooked on the original submittal. These changes need to be detailed and submitted for approval. No contract change order is involved since additional reinforcement, if needed, is included in the price paid for prestressing cast-in-place concrete.

- The Design Engineer should review significant reinforcement modifications for compliance with allowable stresses.
- The Structure Representative should check the reinforcement placement for proper clearances and constructability issues.
- Check the Special Provisions for forming camber, if required. Camber calculations for precast-prestressed girders are to be furnished by the Contractor and shown on the shop drawing submittal.
- Check the camber calculations for completeness and ensure that the calculations include, (a) immediate and time dependent deflections due to prestressing force and girder self weight up until the date of placement of deck concrete, and (b) camber if shown on the contract plans.
- Do not approve or disapprove the Contractor's submitted calculations of camber since responsibility for the accuracy of the calculations rests with the Contractor (see Memo to Designers 11-8).

Check the Anchorage Details

The Structural Materials Branch in DES Materials Engineering & Testing Services (METS) witnesses physical testing of prestress systems and approves them either on a job-by-job basis or a general use basis. In either case, approval may be rescinded by reason of unsatisfactory results. Check Caltrans anchorage system websites mentioned earlier for the list of authorized anchorage systems. Consult with the Post-Tensioned Concrete Committee or Precast Concrete Specialist if needed.

- Blockout requirements are to be shown and dimensioned. Bearing plates should be normal ($\pm 2^\circ$) to the ducts. Factors that enter into the calculation of duct alignment include: bridge profile slope, prestress path, duct splay, and bridge camber. Rough check the Contractor's anchor plate alignment and remind the Structure Representative to verify satisfactory alignment in the field.



- Multi-plane anchorage systems generally require spiral reinforcement in the area immediately ahead of the anchors. Check to see that room is being provided for the spiral reinforcement. Diaphragm widths may need to be adjusted from that shown on the Contract Plans.
- Details may be omitted on shop drawings that are adequately shown on the contract plans.
- Previously approved prestressing systems do not need to be furnished as complete tendon assemblies for testing, provided that there are no changes whatsoever in the materials, design or details previously approved.
- New prestressing systems must be authorized.
- DES METS must authorize any new or modified system before the shop drawings can be approved.
- Before shop drawings can be processed for any new system, the Contractor must submit complete details, test data and test tendons to the Laboratory for testing.

Segmental Construction Shop Drawings

In addition to calculations and shop drawings described earlier in this memo, review of additional items will be required for segmental construction. As stated earlier, it is extremely important that prior to checking any submittal the Design Engineer first reviews the project's contract documents and is very familiar with all requirements that are placed on the Contractor. This will ensure that all submittals are made and each submittal is complete. A general list of submittals likely required for segmental structures is given below.

- Shop drawings and Calculations Based On Revised Construction Methods: If the contract allows revisions to be made to the construction methods and the Contractor chooses to make these types of changes (such as revisions to method of segment placement, segment length, post-tensioning layout, etc.) the Contractor is required to submit revised shop drawings and calculations. The calculations need to include a full structural analysis, including allowable stress and ultimate strength calculations for all construction stages and final conditions.
 - Perform an independent check of the Contractor's calculations.
 - Check the Contractor's proposed changes for conformity with the contract documents.
 - Don't begin review of any additional submittals (see below) until the Contractor's proposed changes and calculations are approved.



- Integrated Drawings: These drawings will depict all post-tensioning information as well as reinforcing bars, formwork, temporary supports, etc.
 - Review the submittal and determine which sheets constitute the prestressed concrete shop drawings.
 - Normally, shop drawing review is not required by the Post-Tensioned Concrete Committee. The designer is responsible for any post-tensioning anchorage system review.
 - Discuss all comments with the Structure Representative to insure that there is agreement and that redlines relating to the prestressed concrete items do not cause conflicts elsewhere in the design.

- Prestressing and Grouting Submittal: This item includes descriptions and details pertaining to the post-tensioning and grouting operations. In addition to requirements covered earlier in this memo, the Prestressing and Grouting Submittal for a segmental structure also needs to include elongations, forces and losses in the strand at each construction stage, grouting direction and sequence, procedures for handling blockages and repairing grout voids, etc.
 - If appropriate, check that blind or fixed anchorages are not used.

- Geometry Control Plan: This item will detail how the structure's geometry will be monitored and corrected during construction to achieve the required final alignment. The Geometry Control Plan will include such items as descriptions of the general construction techniques, construction sequence and schedule, methods to monitor geometry, types of erection equipment, location of temporary supports, types of closure devices, etc.
 - Verify that provisions to monitor deflections at each stage also include deflections due to prestress losses, concrete creep and shrinkage, and daily and seasonal temperature changes.
 - Confirm that formwork at closure pours and hinges are supported such that applied loads yield equal deflections on both sides.

- Construction Manual Submittal: This item includes descriptions and details of the forming system, casting procedures, section dimensions, rebar and post-tensioning layout, temporary support details, erection equipment, etc.
 - Verify that the unbalanced pier moments shown on the plans are not exceeded.



- Concrete Mix Design (potentially followed by test result): This item includes all details of the concrete mix and theoretical properties calculated for creep, shrinkage and modulus of elasticity. If the contract documents require testing of the concrete to determine values for creep and shrinkage coefficients and modulus of elasticity, then specimens will be collected, tested, and test results forwarded to the engineer at a later date for approval.
- Thermal Control Plan: This item includes descriptions of the concrete mix, expected heat of hydration temperatures, procedures to control concrete temperature during placement and while curing, and temperature monitoring and recording methods.

Segmental structures should be designed to prevent opening of joints under extreme loading conditions. Any changes proposed by the Contractor regarding closure pours, expansion joints or additional post-tensioning steel intended to act as continuous mild reinforcing, should be reviewed for its effectiveness in preventing joint opening. (Note: research projects are ongoing to gain a better understanding of the impacts to our segmental structures when joint opening occurs. At this time the general consensus within Structure Design is to prevent any joint opening from occurring.)

If the Special Provisions require that the Contractor submit shop drawings directly to the Structure Representative, then Structure Construction will assume the responsibility of tracking the Contractor's submittals and of distributing all submittals to the pertinent review personnel (including multiple review parties in the case of integrated drawings).



The following table shows the general responsibilities of segmental shop drawing review.

Table 11-1

Segmental Shop Drawing Review Responsibility		
Submittal Description	Lead Reviewer Combines all comments on all sets and stamps them "Approved" or "Rejected"	Secondary Reviewer Reviews single set of plans and provides comments/corrections to Lead Reviewer
Integrated Drawings	Construction	Design
Prestressing Submittal	Design	Construction
Grouting Submittal	Construction	N/A
Geometry Control Submittal	Construction	Design
Construction Manual Submittal	Construction	Design
Concrete Mix Design	Construction	Design
Thermal Control Plan	Construction	Design

Note: Because reviewer responsibilities may vary by project, early agreement between construction and design on who performs lead and secondary reviews is necessary.

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