Washington State Department of Transportation
Bridge and Structures Office

Design Memorandum

TO: HQ Bridge Design Office Staff
FROM: Bijan Khaleghi
DATE: December 24, 2021
SUBJECT: Post-tensioned Concrete

Bridge Design Memorandum

This design memorandum updates WSDOT's design policy for post-tensioned concrete bridges to be consistent with the Post-Tensioning Institute's construction specifications in PTI/ASBI M50.3-19 *Specification for Multistrand and Grouted Post-Tensioning*, PTI M55.1-19 *Specification for Grouting of Post-Tensioned Structures*, and PTI M10.2-17 *Specification for Unbonded Single Strand Tendons*. These PTI construction specifications are adopted in Section 6-02.3(26) of the 2022 Standard Specifications.

Permanent post-tensioned concrete bridges shall be designed and constructed as complete post-tensioning system conforming to Protection Level 2 (PL-2), as defined by the PTI requirements. PL-2 provides enhanced corrosion protection and durability to the entirety of the post-tensioning system, which includes tendons and anchorages. The key features that define PL-2 are the use of plastic duct, engineered (Class C) thixotropic grout, and additional protection measures at anchorages.

Since plastic duct is adopted more broadly, this design memorandum also clarifies terminology and code interpretation regarding duct size, diameter, and area. Certain obsolete sections and requirements of the BDM regarding post-tensioning have been deleted.

Bridge Design Manual Revisions

The following sections of the WSDOT Bridge Design Manual are revised as follows:

Replace Section 5.1.5 with the following:

5.1.5 Post-Tensioning Systems

Multistrand grouted tendons with steel strand are the preferred system for post-tensioned concrete bridge superstructures, spliced girders, and bridge components. For post-tensioned concrete bridge decks, unbonded single strand post tensioning systems may be used. The use of other post-tensioning systems and materials shall require the approval of the Bridge Design Engineer.

Multistrand and grouted post-tensioning systems for permanent construction shall be designed and constructed in accordance with Protection Level 2 (PL-2) practices, as defined by the requirements of PTI/ASBI M50.3-19 *Specification for Multistrand and Grouted Post-Tensioning* and PTI M55.1-19 *Specification for Grouting of Post-Tensioned Structures*. Unbonded single strand post-tensioning systems shall be designed and constructed in accordance with PTI M10.2-17 *Specification for*

Unbonded Single Strand Tendons.

Designers should consult post-tensioning system supplier product guides to ensure that multiple suppliers can satisfy the design. Corrugated plastic duct shall be used and shall conform to standard sizes where possible. Common post-tensioning system component sizes and combinations are shown in Table 5.1.5-1. The nominal diameter for plastic duct may be used when interpreting code provisions that reference duct size or diameter without further clarification (i.e. inside diameter, outside diameter, etc.). The interior diameter of plastic duct shall be used when interpreting code provisions that reference duct area without further clarification.

Table 5.1.5-1 Post-tensioning System Sizes

Duct Size (Round)	ID	OD	Corrug. Dia.	Max # Strands (Pull, 0.6"ø)	Max # Strands (Push, 0.6"ø)	Common Anchorage Size (0.6"ø)
3"	2.99"	3.19"	3.63"	12	16	12
3-3/8"	3.35"	3.55"	3.94"	16	20	15, 19
4"	3.93"	4.29"	4.63"	22	27	19, 22
4-1/2"	4.49"	4.80"	5.28"	29	36	27

Dead end anchorages, defined as anchorages that are not accessible during stressing, shall be avoided where possible. Anchorage pourback materials shall be specified in the plans and should be concrete where possible. Epoxy grout may be used in exposed areas or where improved bond is needed. Non-shrink grout may be specified for small protected pourbacks where proper grout confinement is provided.

Delete Section 5.1.6 in its entirety

Replace the 6th bullet point of Section 5.6.8.B with:

6. The clear spacing between the outside diameter of ducts shall be 2″ min. The duct size shall not exceed 4½″.

Replace the 1st and 2nd paragraphs of Section 5.8.1.C with:

The total number of strands selected should be at least the minimum required to meet the strength and service limit state requirements at all points. Check PT supplier literature for duct sizes and strand capacity. The most economical tendon selection will generally be the maximum duct size within the range than can be fit within the web. Commonly-stocked anchorages for ½″ diameter strands include 9, 12, 19, 27, 31, and 37 strands. Commonly-stocked anchorages for 0.6″ diameter strands include 4, 7, 12, 19, 22, and 27 strands. The design should utilize commonly-stocked items. For example, a design requiring 66 strands per web would be most economically satisfied by three 22-strand tendons. A less economical choice would be four 17-strand tendons with 19-strand anchorages. The interior cross-sectional area of duct area shall be at least 2.5 times the net cross-sectional area of the prestressing steel. In the regions away from the end anchorages, the duct placement patterns indicated in Figures 5.8.1-1 through 5.8.1-3 shall be used.

Delete Sections 5.8.4.D and 5.8.4.E.

Replace the 3rd bullet point of Section 5.8.6.D with:

D. Review of Post-tensioning Installation Drawings

Post-tensioning installation drawings shall be reviewed by the designer (or Bridge Technical Advisor) and consulted with the Concrete Specialist if needed. Review of the drawings shall verify that the plans, specifications, applicable PTI requirements, and design assumptions are satisfied. The PTI requirements include a detailed list of most of the required items. Reviewers should pay special attention to the following:

1. Ensure that the special anchorage device test reports for post-tensioning anchorages are included, and that the tendon drawing details for post-tensioning anchorage local zones are validated by the tested anchorage configuration (i.e. minimum spacing, edge distance, and concrete strength) shown in the test reports.
2. Ensure that the layout of the post-tensioning anchorages is consistent with the design of the general zone reinforcing. If not, either the anchorage layout or general zone may need to be revised.
3. Ensure than tendon vents and drains are properly located and oriented.

Replace Section 5.8.6.E with:

E. During Construction

1. In case of low concrete strength, the design engineer should investigate the adequacy of the design with lower strength if they suspect repairs may be avoidable.
2. If the measured elongation of a strand tendon is within ± 7 percent of the approved calculated elongation, the stressed tendon is acceptable. For tendons shorter than 40 ft, if the measured elongation is within ± 7 percent + ¼ inch, the stressed tendon is acceptable.
3. If the measured elongation is greater than the allowable range, anchorage force verification after seating (lift-off force) should be performed. The lift-off force should not be less than 99 percent of the approved calculated force nor more than 70% f_{pu} A_s.
4. If the measured elongation is less than the allowable range, anchorage force verification of the fixed-end anchorage should be performed. The designer could consider acceptance where the total prestressing force in a web, girder, or even bridge cross-section is greater than 98% of the design prestressing force.
5. One broken strand per tendon may be structurally acceptable. (Post-tensioning design shall preferably allow one broken strand). If more than one strand per tendon is broken, the designed should consider the ability of the other tendons in the structure to provide prestressing and strength.
6. Other problems such as unbalanced and out of sequence post-tensioning, strand surface condition, strand subjected to corrosion and exposure, delayed post-tensioning, jack calibration, etc. should be evaluated on a case-by-case basis in coordination with the contractor, post-tensioning system supplier, HQ Bridge Construction Office, and the Engineer of Record.

Replace Section 5.8.7 with:

5.8.7 Post-tensioning Contract Plans

A. Plan Details

The Plans for post-tensioned concrete shall include a longitudinal section showing the vertical profile of the center-of-gravity of the prestressing force, camber diagram for dead load plus prestress force, and the post-tensioning notes as suggested in Section 5.8.7.B. The following information shall typically be included in a post-tensioning table on a per-web basis: minimum required concrete strengths at the time of stressing, minimum number of strands required, jacking load, anchorage load after seating, and long term prestress losses.

B. Post-tensioning Notes

1. THE POST-TENSIONING SYSTEM SHALL CONFORM TO THE REQUIREMENTS FOR PROTECTION LEVEL 2 (PL-2).
2. THE DESIGN IS BASED ON 0.6"ø LOW RELAXATION STRANDS WITH THE ESTIMATED AVERAGE LONG TERM PRESTRESS LOSS DUE TO STEEL RELAXATION, ELASTIC SHORTENING, CREEP AND SHRINKAGE OF CONCRETE SHOWN IN THE POST-TENSIONING TABLE.
3. THE ACTUAL ANCHOR SET, INSTANTANEOUS PRESTRESS LOSS AND JACKING FORCE CALCULATED BY THE CONTRACTOR SHALL BE SPECIFIED IN THE POST-TENSIONING INSTALLATION DRAWINGS. THE DESIGN IS BASED ON INSTANTANEOUS PRESTRESS LOSS ASSUMING THE FOLLOWING:
    a. ANCHOR SET OF 3/8".
    b. FRICTION, m = 0.23.
    c. WOBBLE COEFFICIENT, k = 0.0002/FT
4. THE DUCT SHALL BE ROUND AND THE MAXIMUM SIZE SHALL BE [???]". THE INSIDE CROSS-SECTIONAL AREA OF THE DUCT SHALL BE AT LEAST 2.5 TIMES THE NET AREA OF THE PRESTRESSING STEEL IN THE DUCT.
5. THE COMPRESSIVE STRENGTH OF CONCRETE AT THE TIME OF STRESSING SHALL BE AS SHOWN IN POST-TENSIONING TABLE OR THE POST-TENSIONING INSTALLATION DRAWINGS, WHICHEVER IS HIGHER.
6. ALL TENDONS SHALL BE STRESSED FROM [ONE END, BOTH ENDS, ALTERNATING ENDS, . . .].
7. THE TENDON STRESSING SEQUENCE SHALL MEET THE FOLLOWING CRITERIA:
    a. THE PRESTRESSING FORCE SHALL BE APPLIED SYMMETRICALLY ABOUT THE CENTERLINE OF THE BRIDGE.
    b. THE PRESTRESSING FORCE IN ADJACENT WEBS/GIRDERS SHALL NOT DIFFER BY MORE THAN THE TOTAL PRESTRESSING FORCE OF ONE TENDON.
    c. AT NO TIME DURING THE STRESSING OPERATION SHALL MORE THAN 1/6 OF THE TOTAL PRESTRESSING FORCE BE APPLIED ECCENTRICALLY ABOUT THE CENTERLINE OF THE BRIDGE.

Replace the 3rdh paragraph of Section 5.9.3.B with:

Ducts for longitudinal post-tensioning shall be kept below the bridge deck, and ideally below the top of web when they could be exposed to damage during construction.

Replace the 5th paragraph of Section 5.9.4.C with:

The clear spacing between the outside diameter of ducts at CIP closures of pier diaphragms shall be 2.0″ minimum.

Replace Section 5.9.5 with:

Shop drawings and post-tensioning installation drawings for spliced prestressed concrete girders shall be reviewed by the designer or Engineer-of-Record and consulted with the Concrete Specialist if needed. See Section 5.6.10 for the review of girder shop drawings, and Section 5.8.6.D for the review of post-tensioning installation drawings.

Replace Section 5.9.6 with:

Contract plan preparation for spliced prestressed concrete girders should include the details and notes in Section 5.8.7.

Add Section 15.5.2.D:

D. Post-Tensioning Systems

Multistrand grouted tendons with steel strand systems shall be used for post-tensioned concrete bridge superstructures, spliced girders, and bridge components. For post-tensioned concrete bridge decks, unbonded single strand post tensioning systems may be used.

Multistrand and grouted post-tensioning systems for permanent construction shall be designed and constructed in accordance with Protection Level 2 (PL-2) practices, as defined by the requirements of PTI/ASBI M50.3-19 *Specification for Multistrand and Grouted Post-Tensioning* and PTI M55.1-19 *Specification for Grouting of Post-Tensioned Structures*. Unbonded single strand post-tensioning systems shall be designed and constructed in accordance with PTI M10.2-17 *Specification for Unbonded Single Strand Tendons*.

Replace Section 15.5.3.C with:

C. Post-Tensioning

Dead end anchorages shall be avoided.

A 2″ minimum clearance shall be provided between post-tensioning ducts.

Confinement reinforcement shall be provided to confine curved post-tensioning tendons in accordance with Section 5.8.1.F.

Structure shortening effects due to post-tensioning shall be included in the design.

The camber shall be shown on the plans and shall include the effect of both dead load and final prestressing.

All post-tensioning anchorages in webs of box girder or multi-stem superstructure should be vertically aligned. Tendons adjacent to post-tensioning anchorages shall meet the minimum tangent length and minimum tendon radii requirements of Section 5.8.1.D.

Background

Section 6-02.3(26) of the 2022 Standard Specifications has been updated to invoke PTI construction specifications for post-tensioned concrete structures. The PTI specifications represent industry best practices, and their use will improve the durability and quality of post-tensioned concrete bridges and structures. This memorandum re-iterates existing WSDOT policy for post-tensioned concrete structures as well as adopts Protection Level 2 practices within the PTI specifications. Protection levels identify the appropriate materials and construction quality control practices used for a post-tensioning system to achieve a desired level of durability. This memo also clarifies the appropriate duct dimension to use when applying code provisions that do not specify the exact duct dimension to use. This memo also deletes obsolete provisions such as local zone design for normal anchorage devices. Local zones are designed by the post tensioning system supplier, and most modern post-tensioning systems utilize special anchorage devices which are qualified by physical testing rather than stress based design methods.

Contact Information

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