Index 462-000 Series Post-Tensioning

Design Criteria

AASHTO LRFD Bridge Design Specifications; ***Structures Design Guidelines (SDG)***; ***Specifications*** Sections 452, 453, 462, 938 and 960

Design Assumptions and Limitations

Indexes 462-001, 462-002 and 462-003 depict various details and requirements for post-tensioning systems used on Department projects. Use these Standards with ***Specifications*** Sections 452, 453, 462, 938 and 960 and the Approved Post Tensioning Systems List on the ***Structures Design Office*** website.

Plan Content Requirements

In the Structures Plans:

Design and detail post tensioning tendons and include quantity, geometry, anchorage protection and stressing information on the plans in accordance with these Standards. In cases where the tendon types and anchorage protection details shown in the Standards are not sufficient to meet project specific requirements, obtain Department approval to supplement the drawings with project specific details.

Design and detail using the following standard tendon sizes utilizing 0.6 inch diameter strands: 4, 7, 12, 15, 19, 27 and 31. Design and detail using the following standard bar tendon diameters: 1, 1¼, 1⅜, 1¾, 2½, and 3 inch.

For projects on which permanent post tensioning bar tendons are utilized, complete the "Post-Tensioning Bar Tendon Data Table" shown in Figure 1 and include it in the plans. The following is a column-by-column description of the information to be used when filling out the data table:

Bar Tendon Designation: Indicate the bar tendon designation using a number or letter and number combination.

No. Required: Indicate the total number of required bar tendons of a given designation.

Bar Size: Indicate the bar diameter.

Bar Length: Indicate the bar tendon length measured from anchorage to anchorage (front face of bearing plate).

Stressing Force/Bar: Indicate the stressing force per bar.

Stressing End: Indicate the stressing end as follows:

Ahead Station - Live/stressing end is at the ahead station anchorage for horizontally oriented tendons or at the top anchorage of vertically oriented tendons.

Back Station - Live/stressing end is at the back station anchorage for horizontally oriented tendons or at the bottom anchorage of vertically oriented tendons.

Elongation: Indicate the total theoretical elongation due to stressing.

Tendon Profile: Indicate the tendon profile, e.g. F9, as shown on Index 462-001 or a custom tendon profile. Include the geometric effects of the profile grade and cross slope on tendon geometry when determining the appropriate tendon profile.

Filler Material: Indicate the use of grout or flexible filler.

Anchorage Protection Type: Indicate the anchorage protection type using the requirements stated below.

For projects on which strand post tensioning tendons are utilized, complete the "Post-Tensioning Strand Tendon Data Table" shown in Figure 2 and include it in the structures plans. The following is a column-by-column description of the information to be used when filling out the data table:

Strand Tendon Designation: Indicate the strand tendon designation using a number or letter and number combination.

No. Required: Indicate the total number of required strand tendons of a given designation.

Tendon Size: Indicate the number and size of strands, e.g. 12-0.6.

Tendon Length: Indicate the strand tendon length measured from anchorage to anchorage (front face of anchorage/bearing plate).

Ahead Station Stressing Force per Tendon: Indicate the stressing force per tendon at the ahead station.

Back Station Stressing Force per Tendon: Indicate the stressing force per tendon at the back station.

Stressing End: Indicate the stressing end as follows:

Ahead Station - Live/stressing end is at the ahead station anchorage for horizontally oriented tendons or at the top anchorage of vertically oriented tendons.

Back Station - Live/stressing end is at the back station anchorage for horizontally oriented tendons or at the bottom anchorage of vertically oriented tendons.

Elongation: Indicate the total theoretical elongation due to stressing.

Tendon Profile: Indicate the tendon profile, e.g. F1, as shown on Index 462-001 or a custom tendon profile. Include the geometric effects of the profile grade and cross slope on tendon geometry when determining the appropriate tendon profile.

Filler Material: Indicate the use of grout or flexible filler.

Anchorage Protection Type: Indicate the anchorage protection type using the requirements stated below.

Use the following guide to determine the appropriate tendon profile for typical strand, wire and bar tendons as applicable.

Filler Material	Tendon Profile	Typical Use
Flexible	F1	Internal tendons in beams, girders, flat slabs or straddle pier caps
	F2	External tendons in box girders
	F3	External tendons in U-girders
	F4	Internal tendons in hammerhead or C-pier caps
	F5	Internal tendons in beams, girders, flat slabs, straddle pier caps or footings
	F6	Internal tendons in hammerhead or C-pier caps
	F7	Internal tendons in beams, girders, flat slabs, straddle pier caps or footings
	F8	Tendons in pier columns or walls
	F9	Tendons in pier columns, webs of box girders or walls
	F10	Internal tendons in hammerhead or C-pier caps
	F11	Internal tendons in beams, girders, flat slabs, straddle pier caps, footings or bottom continuity tendons in box girders constructed using the balanced cantilever method
	F12	Top external continuity tendons in end spans of box girders
	F13	Bottom external continuity tendons in end spans of box girders
	F14	Top external continuity tendons and general use
Grout	G1	Internal tendons in flat slabs
	G2	Transverse internal tendons in the top slabs of box girders
	G3	Longitudinal internal tendons in the top slabs of box girders constructed using the balanced cantilever method
	G4	Internal tendons in single span flat slabs
	G5	General use primarily in deck slabs
	G6	Internal tendons in pier columns, webs of box girders or walls

If necessary, custom tendon profiles may be used and/or the note(s) below the Data Tables may be modified on a project by project basis to better define unusual or unique tendon profiles or arrangements. Custom tendon profiles or modifications to the notes must comply with requirements of the ***Structures Manual*** and be consistent with the ***Specifications***. If custom tendon profiles are used:

1. Detail the tendon profiles in a manner consistent with Index 462-001;
2. Label the custom tendon profiles "C1, C2, etc.";
3. Add the following to Footnote 2 beneath the appropriate Data Table if the custom tendon profiles are not shown on the same sheet as the Data Table:

   See Sheet BX-XX for "C" tendon profiles.

Indicate the anchorage protection type using the following descriptions in conjunction with the following figure and the details shown on Index 462-002.

Type 1 - Anchorage protection used for exposed surfaces for tendons on Segmental Box Girder Superstructures, Integral or Straddle Pier Caps, Footings, or ends of spliced Girder Segments.

Type 2 - Anchorage protection used for tendons anchoring in top flange blockouts.

Type 3A - Top inspected anchorage protection used for cantilever tendons on Segmental Box Girder Superstructures constructed using precast balanced cantilever method.

Type 3B - Top inspected anchorage protection used for cantilever tendons on Segmental Box Girder Superstructures constructed using cast-in-place balanced cantilever method.

Type 4 - Anchorage protection used for tendons on the top surfaces of Piers and for exposed blisters in I-Girders.

Type 5 - Anchorage protection used for tendons with interior blisters on Segmental Box Girder Superstructures.

Type 6 - Anchorage protection used for tendons on Flat Slab Superstructures.

Type 7 - Anchorage protection used for transverse tendons (generally 4 strands or less) on Segmental Box Girder Superstructures and other transversely post-tensioned superstructures.

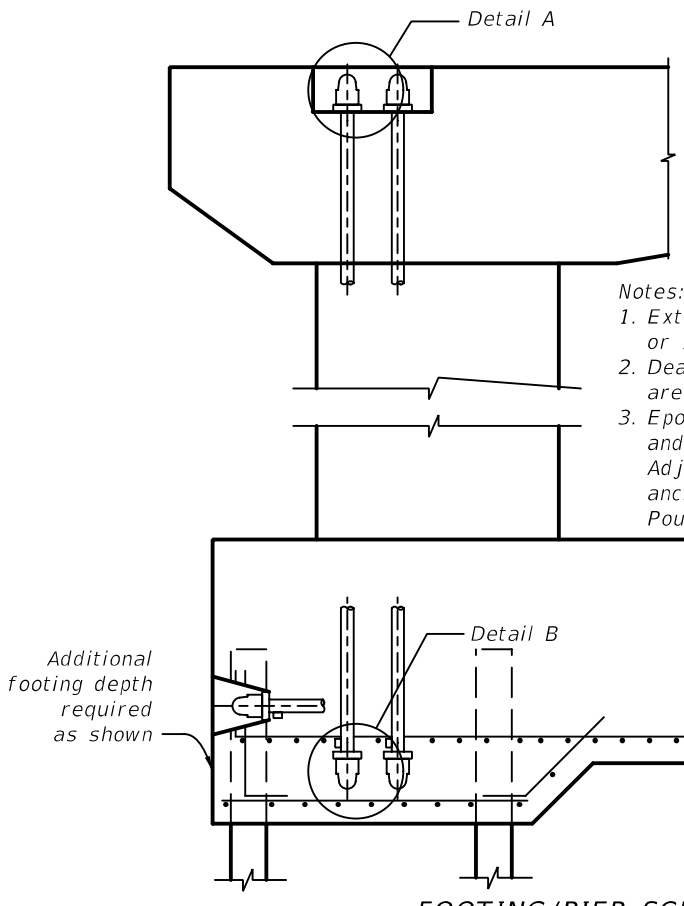
Type 8 - Dead end anchorage protection used for vertical bar tendons.

Type 9 - Anchorage protection used for bar tendons on Segmental Box Girder Pier Diaphragms, Footings, top surfaces of Piers, Integral or Straddle Pier Caps, etc.

Type 10 - Anchorage protection used for bar tendons on the top surfaces of Piers.

Types 11 & 12 - Anchorage protection used for bar tendons primarily on Integral or Straddle Pier Caps.

Anchorage Protection Types for Footing and Pier Post-Tensioning Applications



DETAIL	APPLICABLE ANCHORAGE PROTECTION TYPE
A	1, 4, 9, 10
B	8
C	1, 9

See Design Standard Index 21802.

Notes:
1. Extend elastomeric coating 12" onto concrete edges or 12" beyond edge of anchorage Pour-back.
2. Dead End/Embedded anchorages for strand or wire are not allowed.
3. Epoxy Grout Pour-backs shall not exceed 16 CF and shall fully encompass intended anchorage(s). Adjacent pours may be made for adjacent anchorages after initial cure of previous Pour-back.

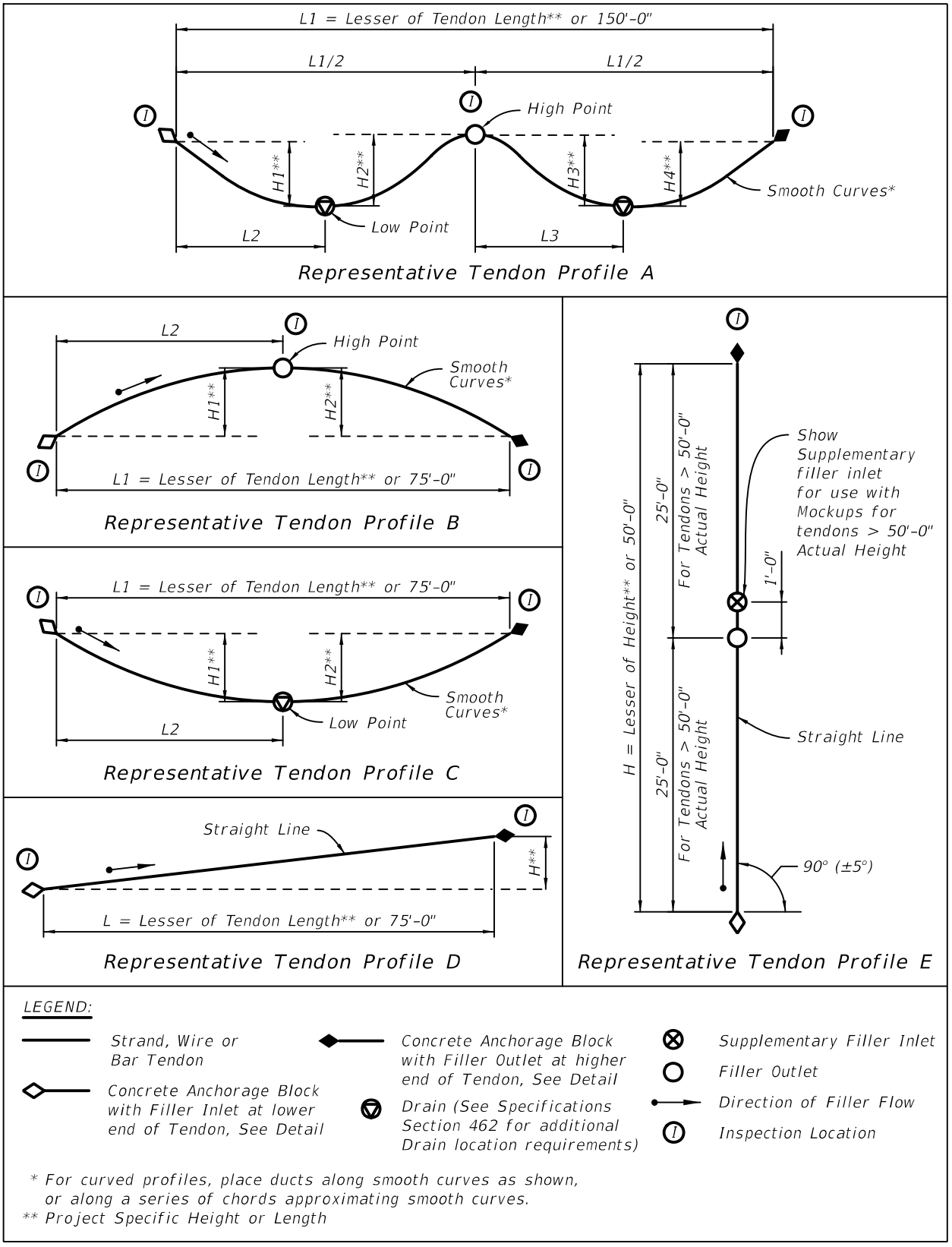
FOOTING/PIER SCHEMATIC

Prepare tendon Mockups and associated details and include them in the plans for use in combination with the filler injection demonstrations required by ***Specifications*** Section 462-7. Mockups are not required for grouted transverse tendons in the top slabs of box girders and for vertical bar tendons in the webs or diaphragms of box girders. Prepare Mockups and details for all other tendons using the following steps.

Step 1: Select a Representative Tendon Profile from the following table and figure for each type or family of tendons on the project. Representative Tendon Profiles are applicable to tendons with either grout or flexible filler.

Actual Tendon Profile (See Index 462-001)	**Representative Tendon Profile**
F1, F2 and F3	A
F4, F6 and F10	B
F5, F7 and F11	C
F8 and F9	E
F12, F13 and F14	D
G1	A
G3	B
G4	C
G5	D
G6	E

Representative Tendon Profiles (with Grout or Flexible Filler)



Step 2: Organize the Representative Tendon Profiles selected in Step 1 into groups in the following order of priority:

a. Filler material

b. Similar/comparable overall tendon geometry. From this point forward, the actual location of a given tendon within the bridge is not a factor in determining the need for a Mockup of the tendon.

c. Lengths "L" and heights "H". Neglect horizontal deviations in tendon geometry when calculating lengths "L".

Step 3: Select at least one Representative Tendon Profile from each group created in Step 2 for further development into Mockups for inclusion in the plans. Keep the number of required Mockups to a minimum by comparing tendons from different groups that have similar/comparable geometries, sizes and filler material and then selecting the governing tendon or particular characteristic from the groups.

Commentary: A Mockup of a long tendon with more complicated geometry may serve as the mockup for a shorter tendon with less complicated geometry and the same filler material, e.g. a single Mockup Profile A with flexible filler may also serve as the mockup for other tendons with Mockup Profiles B, C and/or D, flexible filler and comparable heights "H".

Step 4: Develop a Mockup for each Representative Tendon Profile selected in Step 3 and include it in the plans. Show the following information for each Mockup:

a. Detail Title referencing the project specific tendon numbers for which the mockup is applicable

b. Mockup layout showing dimensions "L", "L1", "L2", "L3", "H", "H1", "H2", "H3" and/or "H4" as applicable. Use the maximum lengths "L" and heights "H" of comparable or similar tendons from a given group. Round off lengths "L" and "L1" of Mockup Profiles A through D and height "H" for Mockup Profile E to the nearest foot. Round off heights "H", "H1", "H2", "H3" and "H4" for Mockup Profiles A through D to the nearest inch.

c. Tendon size, i.e., number of strands or diameter of bar. Specify the largest number of strands or largest bar diameter of all the tendons within a given group.

d. Anchorage size

e. Filler material, i.e., grout or flexible filler

f. Specify the injection of flexible filler with vacuum assistance where required by the Specifications

g. Legend (based on the legend shown on the Representative Tendon Profiles figure above)

h. Specify if the mockup tendon is or is not to be stressed using the criteria in the following table.

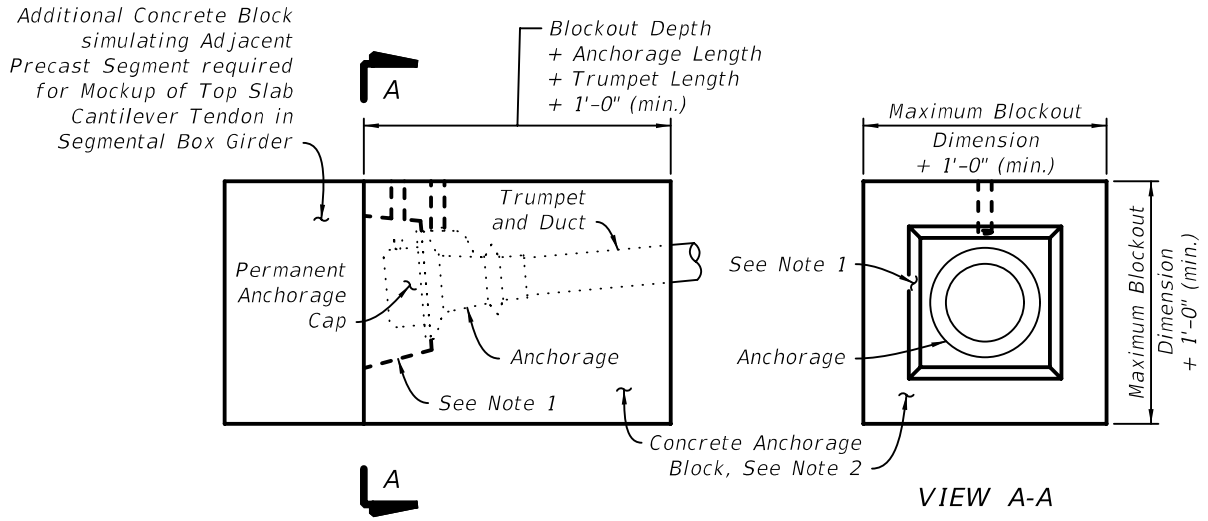
Table of Mockup Tendon Stressing Requirements	
Actual Tendon Profile (See Index 462-001)	**Required Minimum Tendon Stress (% GUTS)**
F1, F2 and F3	1% with tendon stressed from both ends 2% with tendon stressed from one end only
F4, F6, F8, F9, F10 and F12	Mockup tendon not required to be stressed
F5, F7, F11, F13 and F14	1%
G1	1% with tendon stressed from both ends 2% with tendon stressed from one end only
G3	Mockup tendon not required to be stressed
G4 and G5	1%
G6	Mockup tendon not required to be stressed

Step 5: For each Mockup developed in Step 4, show a detail of the anchorage, trumpet and duct adjacent to the trumpet/anchorage embedded in a Concrete Anchorage Block as shown in the following figures. Total encapsulation of a mockup internal tendon in concrete is not required. For mockups of top slab cantilever tendons in segmental box girders, show an additional block of concrete placed immediately adjacent to the face of the concrete anchorage block on the blockout side to simulate the presence of an adjacent cantilever segment. Include the following notes for the Concrete Anchorage Block Details:

a. Use project specific shape and dimensions for the anchorage blockout/recess.

b. Provide nominal reinforcement; spiral or other general zone reinforcement are not required.

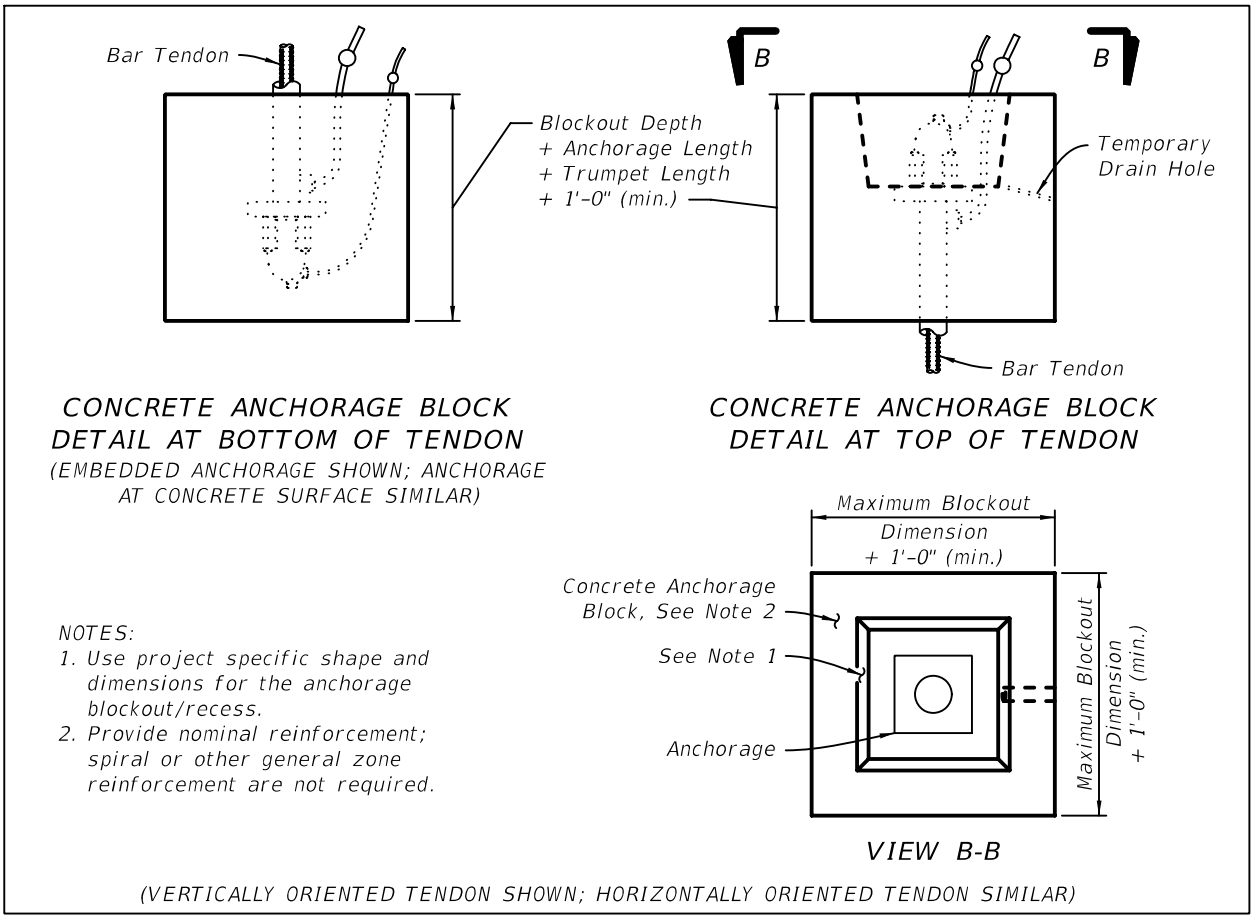
Concrete Anchorage Block Detail for Strand Tendons



CONCRETE ANCHORAGE BLOCK DETAIL

NOTES:
1. Use project specific shape and dimensions for the anchorage blockout/recess.
2. Provide nominal reinforcement; spiral or other general zone reinforcement are not required.

Concrete Anchorage Block Detail for Bar Tendons



Payment

Item number	Item Description	Unit Measure
462-2-AA	Post Tensioning Tendons	LB
462-3	Additional Post Tensioning in Segmental Box Span *Note: Use for rehabilitation projects only*	EA

Figure 1 Post-Tensioning Bar Tendon Data Table

POST-TENSIONING BAR TENDON DATA TABLE									Table Date 07-01-16	
BAR DESIGNATION	NO. REQUIRED	BAR SIZE	BAR LENGTH (Ft-in)	STRESSING FORCE PER BAR (kips)	STRESSING END [1]	ELONGATION (in)	TENDON PROFILE [2]	FILLER MATERIAL	ANCHORAGE PROTECTION TYPE [3]	
									AHEAD STA.	BACK STA.

For non-longitudinal bars, ahead-station denotes left anchorage, back-station denotes right anchorage (looking ahead-station). For mostly vertical bars, ahead-station denotes top anchorage, back-station denotes bottom anchorage.

[1] Stressing End Definitions:
- Ahead Station: Bar Live/Stressing End is ahead-station anchorage.
- Back Station: Bar Live/Stressing End is back-station anchorage.

[2] See Post-Tensioning Tendon Profiles, Standard Plans Index 462-001.

[3] See Post-Tensioning Anchorage Protection, Standard Plans Index 462-002.

Figure 2 Post-Tensioning Strand Tendon Data Table

POST-TENSIONING STRAND TENDON DATA TABLE													Table Date 07-01-16	
TENDON DESIGNATION	NO. REQUIRED	TENDON SIZE	TENDON LENGTH (Ft-in)	AHEAD-STATION STRESSING FORCE PER TENDON (kips)	BACK-STATION STRESSING FORCE PER TENDON (kips)	FORCE @ AHEAD-STATION END AFTER ANCHOR SET (kips)	FORCE @ BACK-STATION END AFTER ANCHOR SET (kips)	STRESSING END [1]	THEORETICAL ELONGATION @ AHEAD-STATION END (in)	THEORETICAL ELONGATION @ BACK-STATION END (in)	TENDON PROFILE [2]	FILLER MATERIAL	ANCHORAGE PROTECTION TYPE [3]	
													AHEAD STA.	BACK STA.

In general, for non-longitudinal tendons, ahead-station denotes left anchorage, back-station denotes right anchorage (looking ahead-station). For mostly vertical tendons, ahead-station denotes top anchorage, back-station denotes bottom anchorage.

[1] Stressing End Definitions:
- Ahead Station: Tendon Live/Stressing End is ahead-station anchorage.
- Back Station: Tendon Live/Stressing End is back-station anchorage.
- Alternate (ahead/back): Tendon Initial Live/Stressing End is ahead-station anchorage with associated elongation. Tendon Subsequent Live/Stressing End is back-station anchorage with associated elongation.
- Alternate (back/ahead): Tendon Initial Live/Stressing End is back-station anchorage with associated elongation. Tendon Subsequent Live/Stressing End is ahead-station anchorage with associated elongation.
- Double: Tendon Live/Stressing End is simultaneously the ahead-station and back-station anchorage with respective elongations.

[2] See Post-Tensioning Tendon Profiles, Standard Plans Index 462-001.

[3] See Post-Tensioning Anchorage Protection, Standard Plans Index 462-002.

Sample Tables

POST-TENSIONING BAR TENDON DATA TABLE — Table Date 07-01-16

BAR DESIGNATION	NO. REQUIRED	BAR SIZE	BAR LENGTH (Ft-in)	STRESSING FORCE PER BAR (kips)	STRESSING END [1]	ELONGATION (in)	TENDON PROFILE [2]	FILLER MATERIAL	ANCHORAGE PROTECTION TYPE [3]	
									AHEAD STA.	BACK STA.
PT-1	6	1¼ Ø	21'-9"	131	AHEAD STA.	0.940"	G5	GROUT	10	10
PT-2	8	1⅜ Ø	16'-6"	165	BACK STA.	0.713"	G5	GROUT	10	10
PT-3	24	1¾ Ø	80'-0"	280	BACK STA.	3.540"	F14	FLEXIBLE	9	8

For non-longitudinal bars, ahead-station denotes left anchorage, back-station denotes right anchorage (looking ahead-station). For mostly vertical bars, ahead-station denotes top anchorage, back-station denotes bottom anchorage.

[1] Stressing End Definitions:
- Ahead Station: Bar Live/Stressing End is ahead-station anchorage.
- Back Station: Bar Live/Stressing End is back-station anchorage.

[2] See Post-Tensioning Tendon Profiles, Standard Plans Index 462-001.

[3] See Post-Tensioning Anchorage Protection, Standard Plans Index 462-002.

POST-TENSIONING STRAND TENDON DATA TABLE — Table Date 07-01-16

TENDON DESIGNATION	NO. REQUIRED	TENDON SIZE	TENDON LENGTH (Ft-in)	AHEAD-STATION STRESSING FORCE PER TENDON (kips)	BACK-STATION STRESSING FORCE PER TENDON (kips)	FORCE @ AHEAD-STATION END AFTER ANCHOR SET (kips)	FORCE @ BACK-STATION END AFTER ANCHOR SET (kips)	STRESSING END [1]	THEORETICAL ELONGATION @ AHEAD-STATION END (in)	THEORETICAL ELONGATION @ BACK-STATION END (in)	TENDON PROFILE [2]	FILLER MATERIAL	ANCHORAGE PROTECTION TYPE [3]	
													AHEAD STA.	BACK STA.
1	6	12-0.6	650'-0⅞"	562.5	562.5	454.9	468.9	Alt. (back/ahead)	10.9	32.2	F1	FLEXIBLE	1	1
2	6	12-0.6	650'-1¾"	562.5	562.5	456.3	456.3	Alt. (back/ahead)	10.8	31.6	F1	FLEXIBLE	1	1
3	6	12-0.6	650'-3⅝"	562.5	562.5	458.4	459.8	Alt. (back/ahead)	10.6	31.0	F1	FLEXIBLE	1	1
4	6	12-0.6	650'-6¼"	562.5	562.5	465.4	465.4	Alt. (back/ahead)	10.6	30.3	F1	FLEXIBLE	1	1

In general, for non-longitudinal tendons, ahead-station denotes left anchorage, back-station denotes right anchorage (looking ahead-station). For mostly vertical tendons, ahead-station denotes top anchorage, back-station denotes bottom anchorage.

[1] Stressing End Definitions:
- Ahead Station: Tendon Live/Stressing End is ahead-station anchorage.
- Back Station: Tendon Live/Stressing End is back-station anchorage.
- Alternate (ahead/back): Tendon Initial Live/Stressing End is ahead-station anchorage with associated elongation. Tendon Subsequent Live/Stressing End is back-station anchorage with associated elongation.
- Alternate (back/ahead): Tendon Initial Live/Stressing End is back-station anchorage with associated elongation. Tendon Subsequent Live/Stressing End is ahead-station anchorage with associated elongation.
- Double: Tendon Live/Stressing End is simultaneously the ahead-station and back-station anchorage with respective elongations.

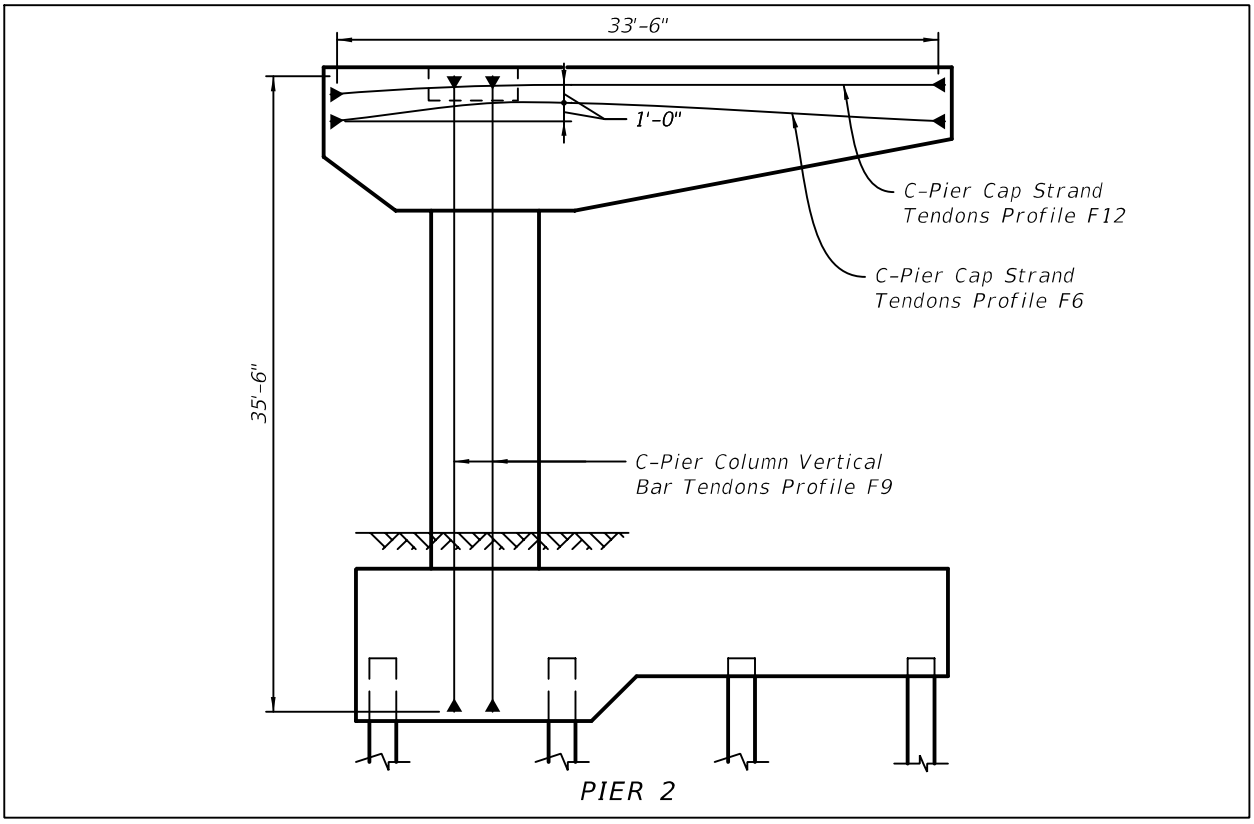
[2] See Post-Tensioning Tendon Profiles, Standard Plans Index 462-001.

[3] See Post-Tensioning Anchorage Protection, Standard Plans Index 462-002.

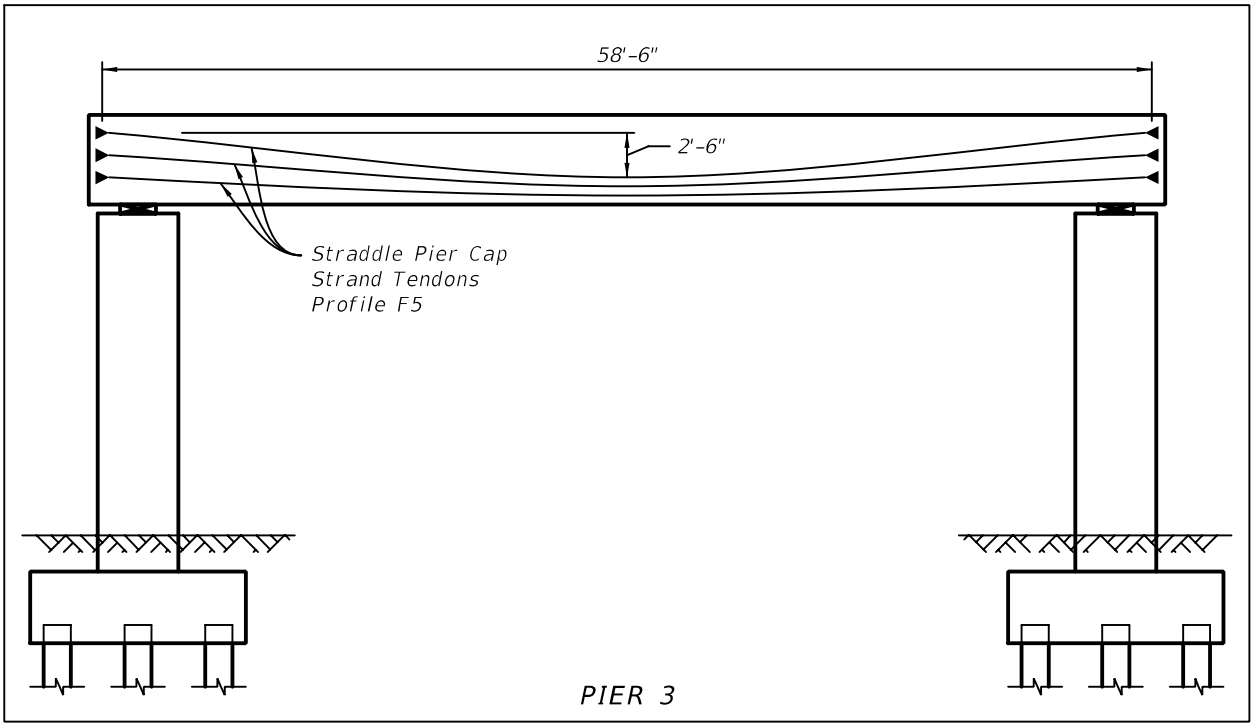
Mockup Example

A four span bridge with Straddle and C-pier substructure and a segmental box girder superstructure as follows:

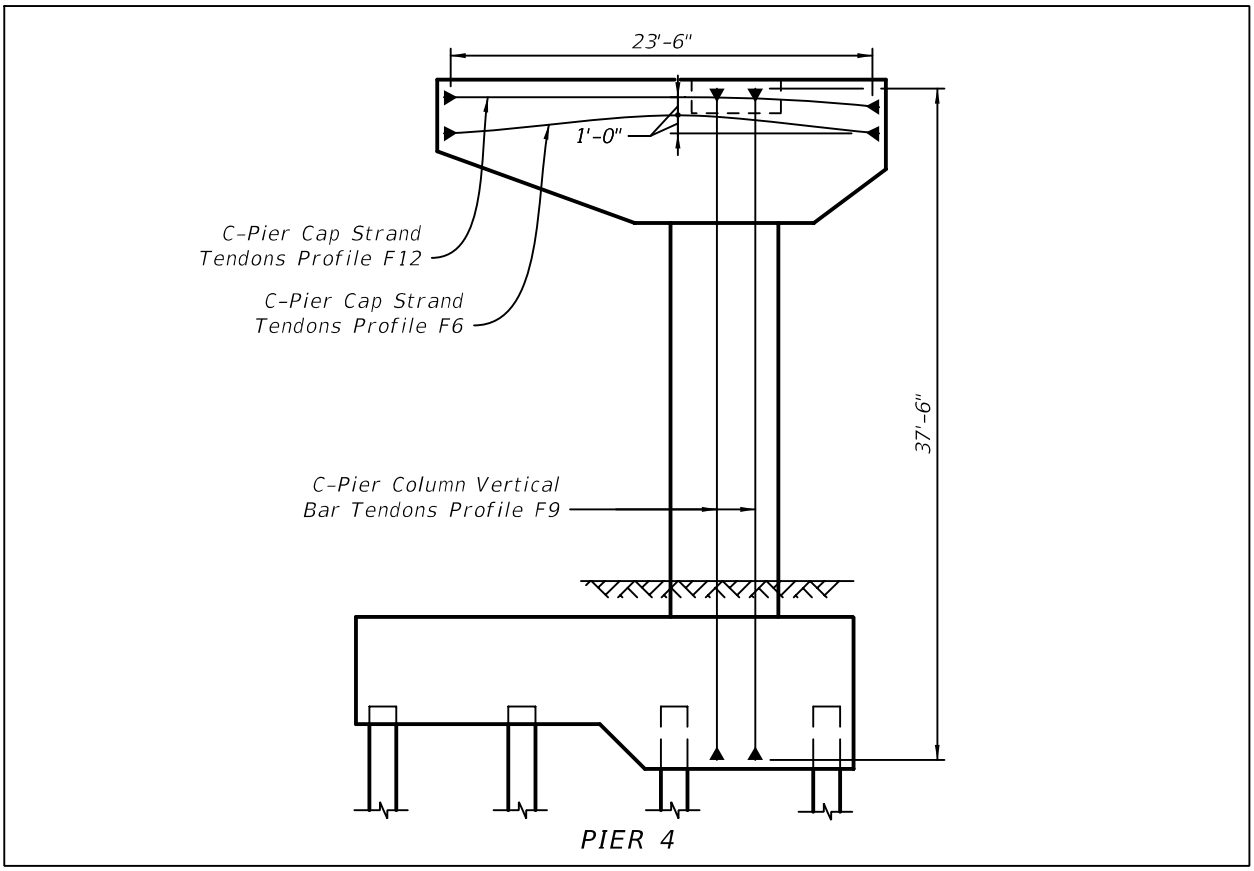
Substructure Pier 2



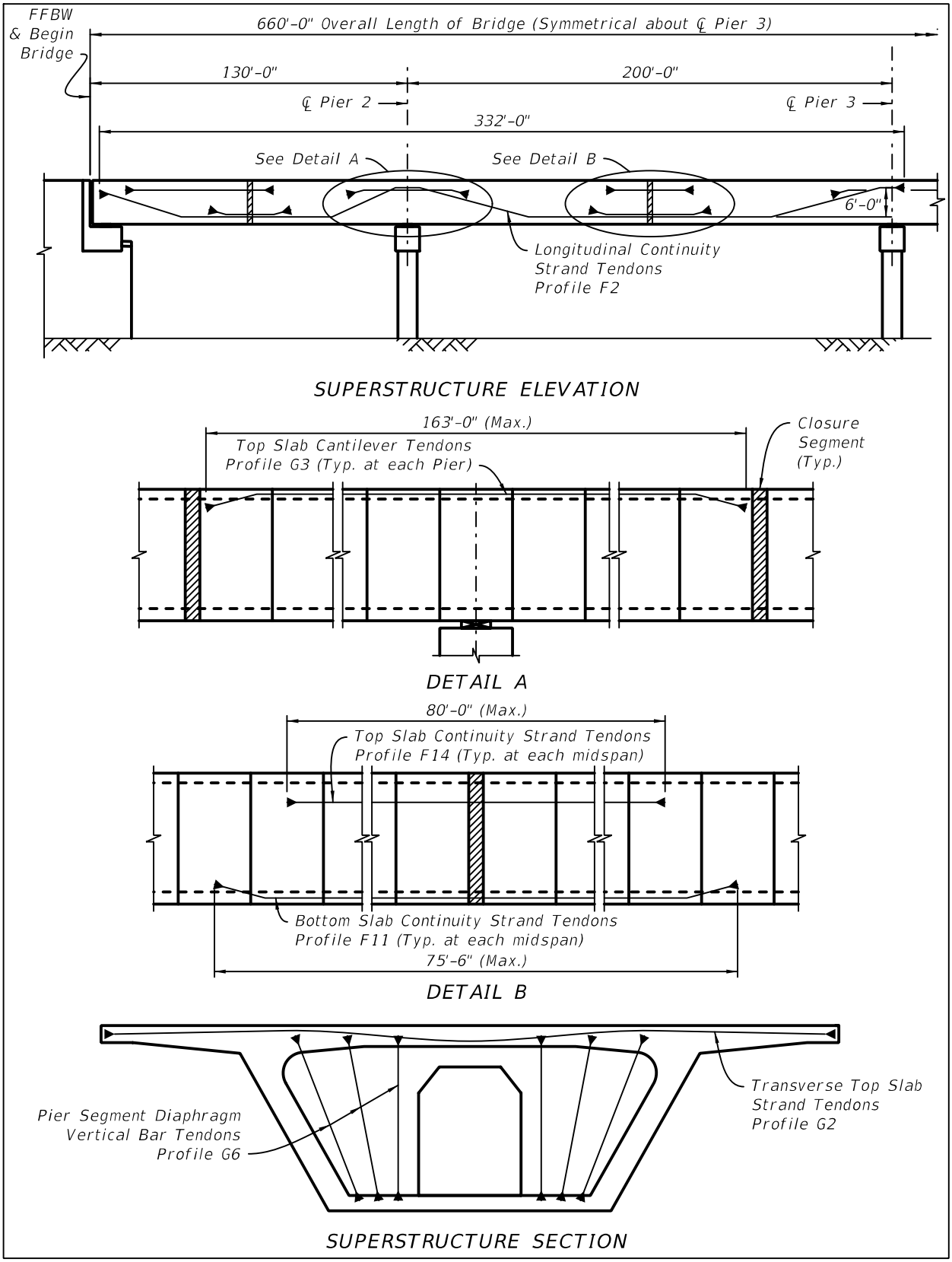
Substructure Pier 3



Substructure Pier 4



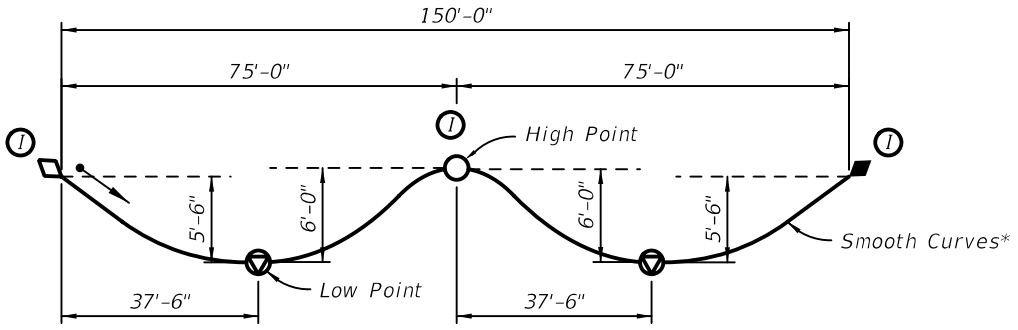
Superstructure



Steps 1, 2 and 3 (presented in tabular form in this IDS for simplicity):

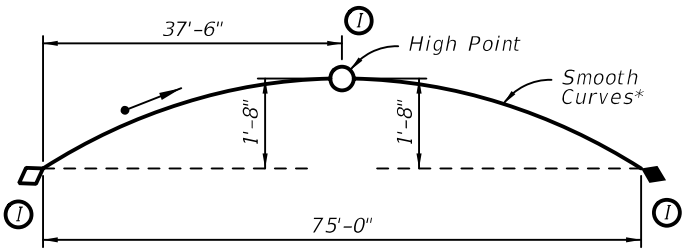
Location	Tendon Type	Actual Tendon Profile (See Index 462-001)	Step 1: Select Representative Tendon Profile	Step 2: Organize Representative Tendon Profiles into Groups	Step 3: Develop a Mockup for inclusion in the Plans? (Yes/No)
Substructure	Vertical bar tendons in columns of Piers 2 and 4	F9	E	Group 1	Yes
	Strand tendons in caps of Piers 2 and 4	F6	B	Group 2	No - use Group 2, Profile A
	Strand tendons in caps of Piers 2 and 4	F12	D	Group 2	No - use Group 2, Profile A
	Strand tendons in cap of Pier 3	F5	C	Group 2	No - use Group 2, Profile A
Superstructure	Top slab cantilever strand tendons	G3	B	Group 3	Yes
	Transverse top slab strand tendons	G2	No mockup required	N/A	N/A
	Longitudinal continuity strand tendons	F2	A	Group 2	Yes
	Top slab continuity strand tendons	F14	D	Group 2	No - use Group 2, Profile A
	Bottom slab continuity strand tendons	F11	C	Group 2	No - use Group 2, Profile A
	Vertical bar tendons in the pier segment diaphragms	G6	No mockup required	N/A	N/A

Step 4: Develop Mockup details for each Representative Tendon Profile selected in Step 3



MOCKUP FOR LONGITUDINAL AND TOP SLAB CONTINUITY STRAND TENDONS AND PIERS 2, 3 AND 4 CAP STRAND TENDONS

TENDON SIZE: 19 – 0.6" Ø STRANDS
ANCHORAGE SIZE: 19 – 0.6" Ø STRAND ANCHORAGE
STRESSING: STRESS TENDON TO 11.1k (DOUBLE END STRESSING) OR 22.2k (SINGLE END STRESSING)
FILLER MATERIAL: FLEXIBLE FILLER
VACUUM ASSISTED FILLER INJECTION IS REQUIRED



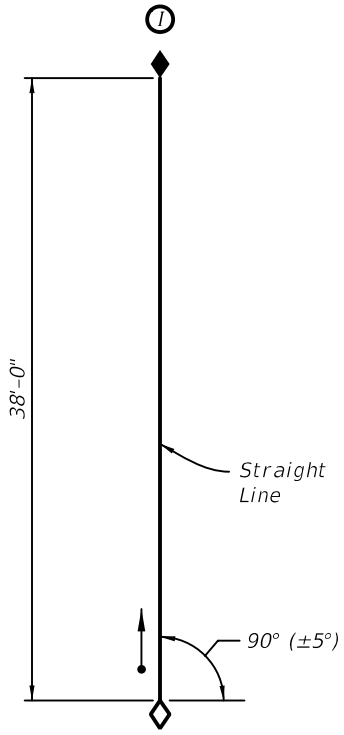
MOCKUP FOR TOP SLAB CANTILEVER STRAND TENDONS

TENDON SIZE: 12 – 0.6" Ø STRANDS
ANCHORAGE SIZE: 12 – 0.6" Ø STRAND ANCHORAGE
STRESSING: NOT REQUIRED
FILLER MATERIAL: GROUT

LEGEND:

- *Strand or Bar Tendon*
- *Concrete Anchorage Block with Filler Inlet at lower end of Tendon, See Detail*
- *Concrete Anchorage Block with Filler Outlet at higher end of Tendon, See Detail*
- *Drain (See Specifications Section 462 for additional Drain location requirements)*
- *Filler Outlet*
- *Direction of Filler Flow*
- *Inspection Location*

** For curved profiles, place ducts along smooth curves as shown, or along a series of chords approximating smooth curves.*



MOCKUP FOR PIERS 2 AND 4 COLUMN VERTICAL BAR TENDONS

TENDON SIZE: 1¾" Ø BAR
ANCHORAGE SIZE: 1¾" Ø BAR ANCHORAGE
STRESSING: NOT REQUIRED
FILLER MATERIAL: FLEXIBLE FILLER

Step 5: Include Concrete Anchorage Block Details for Strand and Bar Tendons as shown in Plan Content Requirements above.

Commentary: Tendon mockups are to be used by the contractor in conjunction with the Grouting Operations Plan or Wax Injection Operations Plan and associated equipment, materials and personnel to demonstrate that the requirements of Specification 462 can be met using the proposed means and methods.

All components of a PT system that will be used for a given tendon in the actual bridge are to be used in the mockup with the exception of segmental duct couplers, corrugated PP duct and steel pipe. Segmental duct couplers only function when clamped together (by PT forces in the actual bridge) and their presence in tendon mockups is not necessary for tendon filling operations to be tested. Smooth PE duct is to be used for mockups of all tendons, including internal tendons which will have corrugated PP duct and all tendons which will have steel pipe in the actual bridge. Corrugated PP duct and its associated couplers are only intended to be used with, and tested to withstand, grouting pressures when located inside hardened concrete. The use of steel pipe is not necessary for tendon filling operations to be tested, smooth PE duct is sufficient.

The tendon geometries, lengths and heights shown in the mockup profiles have been determined to be sufficient for the contractor to demonstrate that filling operations can be conducted successfully for the applicable tendons. The use of longer or taller mockup tendons is not required.