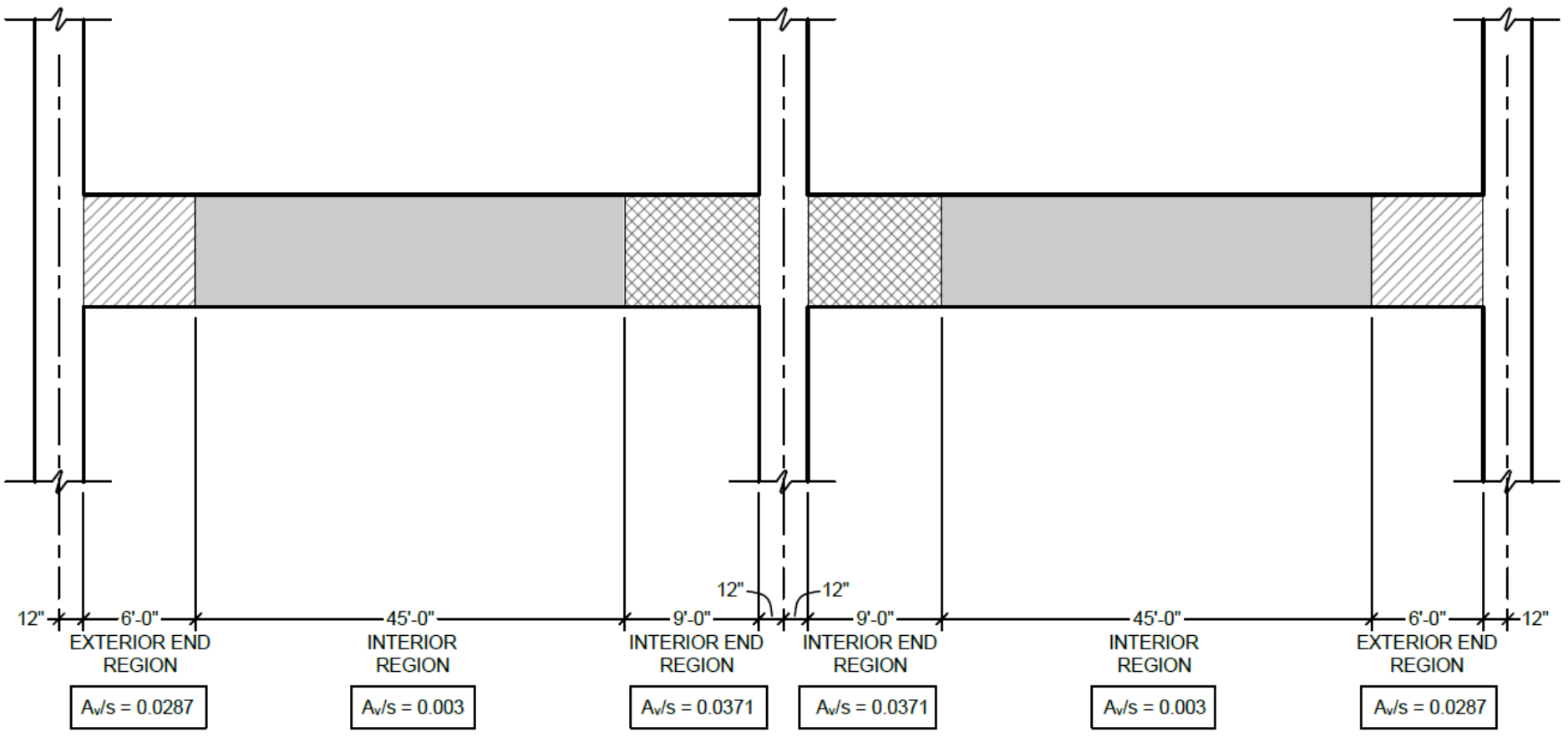
Design Spotlight: WWR Shear Reinforcement in a Parking Garage Post-Tensioned Beam, Part II

This blog is a continuation of the previous entry posted for January 2022.

Step 7 – Design and configure shear reinforcement

The engineer has selected A_v/s (in^2/in) ratios that result in three different regions along the length of the beam. We will illustrate here how this information is used by the engineer (or WWR detailer) to derive WWR shear stirrup cages specific to the project.



Exterior End Region

$$\frac{A_v}{s} = 0.0287\ \frac{in^2}{in}$$

If first stirrup is placed at 2 inches from the column face, the resulting coverage = 5'-10" = 70". Stirrup spacing options achieving equal intervals within this coverage length (without exceeding 24" on center maximum spacing) include the following, with corresponding WWR size shown:

Spacing	Corresponding Av	Two legs of wire size achieving Av
5" oc	0.144 in^2	D7.2
7" oc	0.201 in^2	D10.1
12" oc	0.345 in^2	D17.3
14" oc	0.402 in^2	D20.1
17.5" oc	0.503 in^2	D25.2

Interior End Region

$$\frac{A_v}{s} = 0.0371\ \frac{in^2}{in}$$

If first stirrup is place at 2 inches from the column face, the resulting coverage = 8'-10" = 106". Stirrup spacing options within this coverage length (without exceeding 24" on center maximum spacing) include the following, with corresponding WWR size shown:

Spacing	Corresponding Av	Two legs of wire size achieving Av
4.25" oc + (1) 4" space	0.158 in^2	D7.9
6.25" oc + (1) 6" space	0.232 in^2	D11.6
8.5" oc + (1) 4" space	0.316 in^2	D15.8
12.5" oc + (1) 6" space	0.464 in^2	D23.2
15.5" oc + (1) 13" space	0.576 in^2	D28.8

Interior (Field) Region

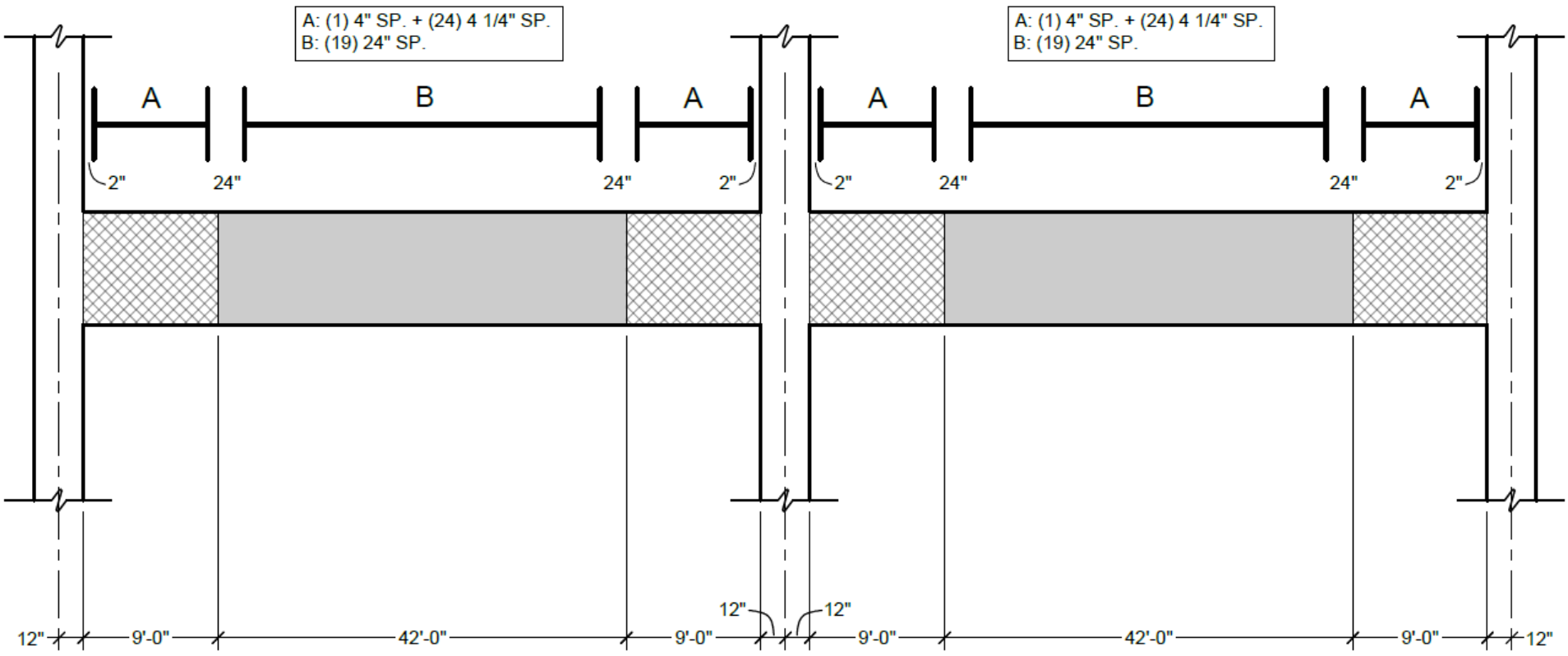
$$\frac{A_v}{s} = 0.003\ \frac{in^2}{in}$$

The field region coverage = 45'-0" = 540". Stirrup spacing options within this coverage length (without exceeding 24" on center maximum spacing) include the following, with corresponding WWR size shown:

Spacing	Corresponding Av	Two legs of wire size achieving Av
(1) 11" + 14" oc + (1) 11"	0.042 in^2	W2.1
(1) 14" + 16" oc + (1) 14"	0.048 in^2	W2.4
18" oc	0.054 in^2	W2.7
(1) 18" + 24" oc + (1) 18"	0.072 in^2	W3.6

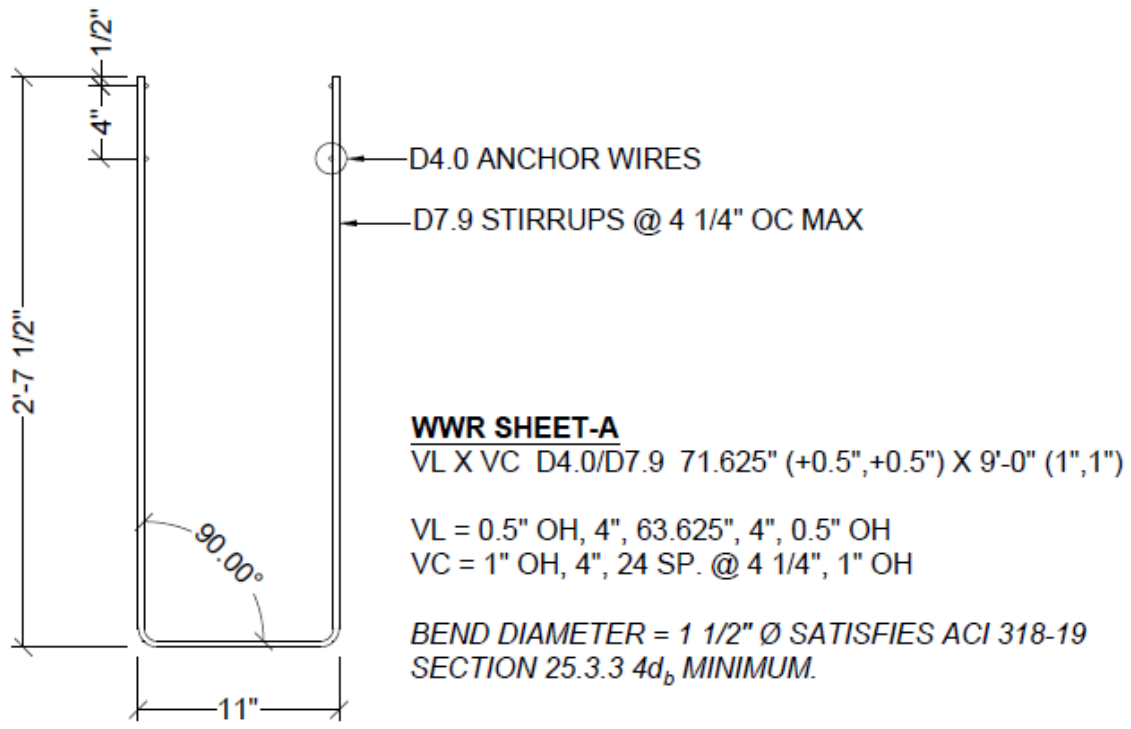
For the sake of simplification of this blog example and for practicality in the field, the following decisions are made:

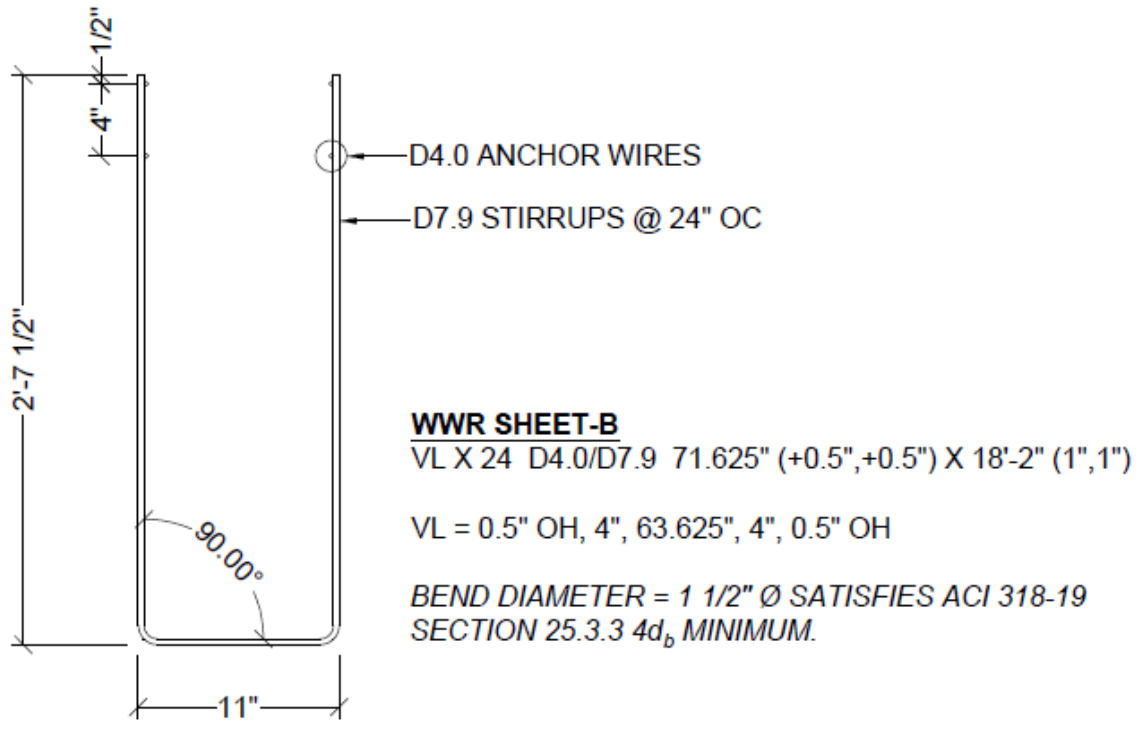
- In lieu of three separate wire sizes (D7.2, D7.9, and W3.6) distributed along the beam length, only D7.9 will be used.
- For both the exterior end region and interior end region, a pattern of D7.9 leg pairs @ 4.25” will be used.
- Resulting coverage areas using D7.9 wires are illustrated below.



Step 8 – WWR mat detailing

The WWR mat bend diagrams, complete with descriptive mat styles, are shown below.





Note that for each 60’-0” beam span, there will be two (2) “A” mats and (2) “B” mats. It may have been possible to produce a single “B” mat that was 38’-0” long (modern WWR welding machines certainly have this capability), but such a long cage could have the potential to be unwieldy for the workers handling and placing it on site, so the region was instead resolved using two shorter mats. Note, too, that a general sweet spot for length of WWR mats to be bent should be on the order of 30’-0”, so the 38’-0” dimension would exceed that threshold.

Step 9 – Summary of Work

In the end, four mats per beam, for a total of eight mats across the two-span continuous beam, are required. Additional notes are presented below.

- “VL” in the item description is an abbreviation for Variable Linewire, an indication of the variable spacing of the D4.0 linewires (linewire = wire that runs in the longitudinal direction on the welding machine). The numbered pattern that follows the abbreviation outlines the spacing arrangement of these linewires, with “OH” representing the overhang at the edge of the mat. For modern welding equipment, one-half inch is a practical minimum overhang length beyond the outermost linewires.
- “VC” in the item description is an abbreviation for Variable Crosswire, an indication of the variable spacing of the D7.9 crosswires (crosswire = wire that runs transverse to the direction of the linewire). The numbered pattern that follows the abbreviation outlines the spacing arrangement of these crosswires, with “OH” representing the overhang at the end of the mat. For modern welding equipment, one inch is a practical minimum overhang length beyond the outermost crosswires.
- For both mat types shown, the shear stirrups are the crosswires, and the anchor wires used in lieu of hooked terminations are the linewires.
- A linewire size of D4.0 has been selected. This wire size satisfies the ASTM A1064 requirement that the minimum anchor wire cross-sectional area be at least 40% that of the structural wires it is tasked with anchoring. For a D7.9 wire, a minimum anchor wire of D3.2 is theoretically required. However, ACI 318 does not recognize welded deformed wire sizes smaller than D4.0, so a D4.0 was selected here. It is conceivable that a plain wire (smooth surface with no deformations) with size equal to W3.2 could be used and still satisfy both ACI 318 and ASTM A1064 requirements, but for the purposes of this blog example, deformed wires were used throughout.
- The width of both mat types, measured between outermost linewires, is shown to be 71.625 inches. With overhang lengths included, the overall crosswire length is 72.625 inches. One might recognize that this value does not equal the sum of the engineer’s U-stirrup geometry, which is 31.5” + 11” + 31.5” = 74 inches. This is simply because the bent length of the wire is naturally shorter than a perfectly square complement of dimensions used to define out-to-out geometry.
- Mat “A” weighs 47.2 pounds. Mat “B” weighs 26.2 pounds. For the two-span continuous beam, a total reinforcement weight of roughly 294 pounds is required. These pre-welded and pre-bent mats are capable of being placed in a matter of minutes by a two-person crew.

For more information on WWR, refer to www.wirereinforcementinstitute.org.