CONCRETE BRIDGE TECHNOLOGY

Concrete Segmental Bridges—

Preliminary Design Approximations for Cross-Section Dimensions

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This article, which is the second in a series discussing preliminary design approximations, discusses determining preliminary dimensions for cross sections of post-tensioned concrete segmental bridges. These approximations apply to precast concrete and cast-in-place (CIP) cross sections.

As noted in the previous article in this series (see the Winter 2025 issue of *ASPIRE*®), the detailed final design demands will be needed before a structure's design can be approved. However, the preliminary approximations presented herein provide a good starting point for determining cross-section dimensions that typically result in an optimal final design.

The longitudinal design behavior of a concrete segmental bridge typically governs the web thickness. After the basic dimensions of the bridge have been determined, a good preliminary approximation for the web thickness b_w is to provide a ratio of 0.36 to 0.39 in.^{2} of web area (based on theoretical vertical webs) per square foot of deck span area (**Fig. 1**). The preliminary web width of a cross section is approximated as

$$b_w = \frac{\alpha WL}{nh}$$

where

b_w = thickness of one web, in.
α = constant between 0.36 and 0.39
W = deck width, ft
L = span length, ft
n = the number of webs
h = section depth at the pier, in.

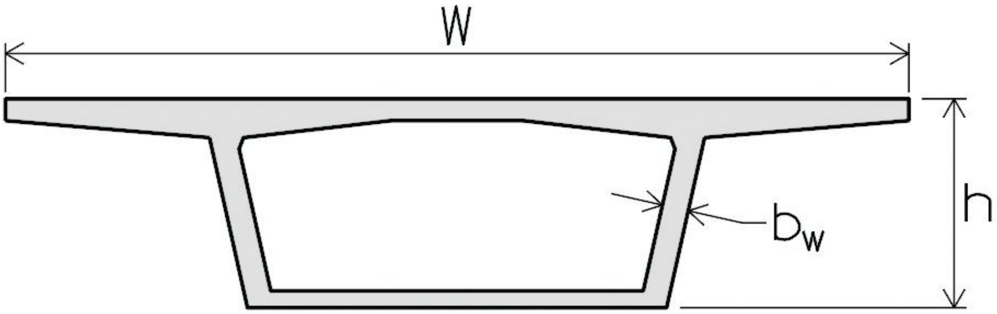
For example, if α = 0.36 is selected for a 316-ft span with a deck width of 53 ft, two webs, and a structure depth of 16.5 ft (198 in.) at the pier:

$$b_w = \frac{\left(0.36\frac{\text{in.}^2}{\text{ft}^2}\right)\left(53\text{ ft}\right)\left(316\text{ ft}\right)}{2\left(198\text{ in.}\right)} = 15.2\text{ in.}$$

Round b_w to 15 in. for advancement to final design. For box girders with two webs, each web will be the same thickness. For box girders with three webs, the thickness $n \times b_w$ is the total width of all three webs. For three-web sections, an indeterminate shear flow analysis is necessary in the final design to determine how much shear each web resists. For preliminary design, it can typically be assumed that the interior web will resist 40% of the shear and each exterior web will resist 30%. The individual web thicknesses can be proportioned accordingly from the total thickness nb_w. The minimum web thickness b_w for each web should not be less than 10 in. for preliminary design.

There is a possibility to further optimize the design for constant-depth structures by linearly tapering the thickness of each web from a maximum at the top to a minimum at the bottom slab. In this case, the web thickness, as determined previously, would be the thickness at the neutral axis. The reason for the tapering is that there can be significant bending near the top of the web due to deck loadings, but there is little bending near the bottom slab. The web thickness at the bottom slab should not be less than the minimum bottom-slab thickness or 8 in. Note that the minimum web width should be used in shear calculations using modified compression field theory in accordance with the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*.[1] For variable-depth bridges, it is recommended to use constant web widths along the height of the webs.

Figure 1. Basic dimensions of a concrete segmental cross section are used for approximating web width. All Figures: R. Kent Montgomery.



The longitudinal design behavior typically governs the bottom-slab thickness t_{bs}. The previous article discussed determining the bottom-slab thickness near the piers for structures constructed using the balanced-cantilever method. If internal continuity tendons are present, the minimum bottom-slab thickness near midspan will likely be determined by the thickness required to accommodate post-tensioning ducts between the mats of reinforcement. If there are no internal tendons in the bottom slab (for example, in span-by-span construction), the bottom-slab thickness should not be less than 7 in. and the ratio of the bottom slab width to the bottom slab thickness b_{bs}/t_{bs} should not exceed 35. These limits also apply to balanced-cantilever construction but will likely not govern over the thickness required to accommodate post-tensioning ducts. In accordance with Article 5.6.4.7.2c of the AASHTO LRFD specifications, the compressive stress limit is reduced by the ϕ_w factor for b_{bs}/t_{bs} greater than 15 (**Fig. 2**). Thickening the bottom slab to decrease the compressive stress to meet the reduced stress limit may be required.

Transverse behavior usually sets the top-slab dimensions. The ratio of the cantilever wing length to interior span length (**Fig. 3**) should typically be set between 0.30 and 0.55, with 0.42 being optimal for transverse design. Cantilever wings that are longer or shorter than the optimal length have been used to achieve other design aims, such as achieving the required gore area geometry.

Top-slab thicknesses can be set as shown in **Fig. 4**. Figure 4 is for single-cell sections, but the principles can be extended to multiple-cell sections. The 9-in. minimum wing tip dimension is to accommodate transverse post-tensioning anchors in accordance with the AASHTO LRFD specifications. Designs for bridges without transverse post-tensioning, such as light-rail transit bridges, can use a minimum 8-in. wing-tip dimension. Haunch lengths for an interior transverse span should be at least 20% of the span, but they may be significantly longer to accommodate cantilever tendon ducts for balanced-cantilever bridges (**Fig. 5**). The haunch length for the cantilever wing is typically set such that the constant-depth portion of the wing does not exceed $LH_c = 10T_c$, unless a longer haunch length is required to fit tendon ducts.

The slope of the web can be used to set the desired bottom-soffit width. For example, highly sloped webs can be used to achieve a narrower bottom soffit and

Figure 2. Compressive stress limits are used to approximate the thickness of the bottom slab.

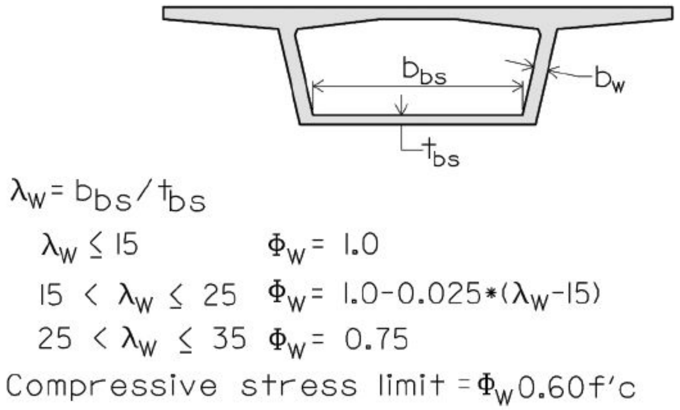


Figure 3. Variables for preliminary approximation of top-slab transverse proportions.

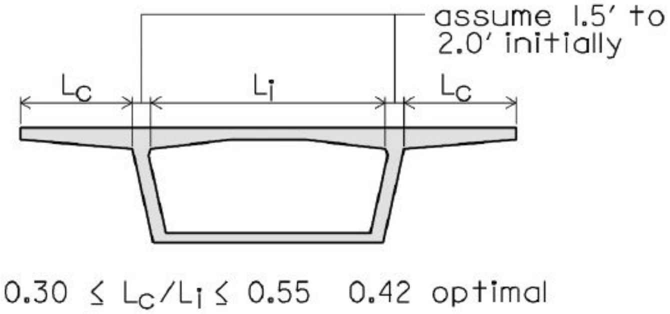


Figure 4. Minimum top-slab thicknesses at various locations in the cross section.

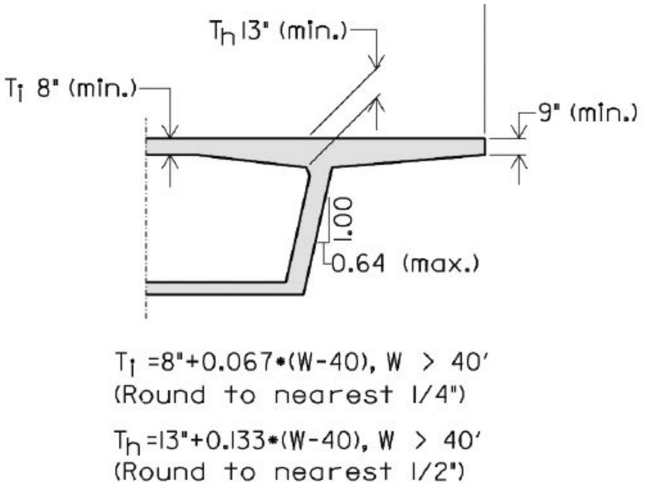
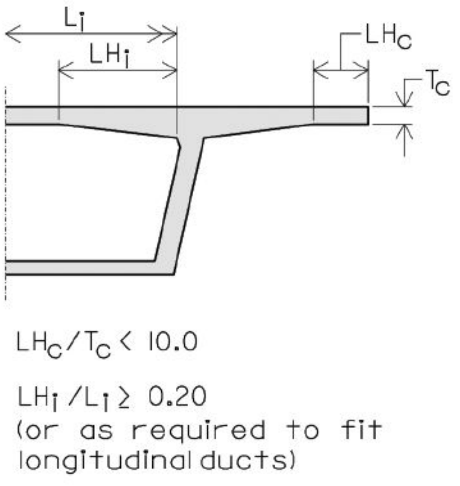


Figure 5. Preliminary haunch dimensions.



smaller pier cap dimension for wider decks. However, the web slope, usually defined on the outside surface of the web, typically should not exceed 0.64:1.00 (Fig. 4). Conversely, larger vertical web slopes (lower horizontal run to vertical rise) can be used to achieve the minimum soffit width to avoid bearing uplift due to overturning moments.

The cross-section dimensions should also consider constructability. The cross section should be dimensioned and detailed for simplicity. Casting cells should be as easy to use as possible such that one typical segment can be cast per day for each casting cell. The casting cell typically comprises five main forming surfaces (**Fig. 6**):

- Core form
- Web/wing form
- Soffit form
- Bulkhead
- Transverse bulkhead

The core dimensions shown in Fig. 6 are essentially the portion of the cross section formed by the core form and the web/wing form close to the cantilever root. Every effort should be made to keep the core dimensions constant for all segments. The core form can be extended down the web for casting variable-depth components. As long as the upper portion of the core form remains unchanged, this adjustment can be accomplished relatively easily and is not considered a change to the core dimensions.

Variable widths can most easily be handled by moving the transverse bulkheads, but this solution has limitations as the length of the cantilever wing is limited by flexural capacity. The width of the core form should be carefully selected to accommodate the required range of widths, and compromises to the optimal ratio of the cantilever wing length to interior span length at the extreme widths (maximum and minimum) may be needed. Using a variable-width core form adds significant complexity to the casting cell and should generally be avoided.

Variable depths are typically accommodated relatively easily using these methods:

- The web portion of the web/wing form is fabricated to accommodate the deepest cross section but remains unchanged from segment to segment.
- Removable panels are used at the bottom of the core form, with enough variation in the panels to accommodate the variable depth requirements.
- The soffit form is fabricated such that its height is adjustable (the core and web/wing forms are stationary). This allows the depth of the segments to vary. Due to the slope of the webs, the bottom-soffit width also varies, and this variation is accommodated by variable extensions from the main soffit form/table.
- The bottom portion of the bulkhead must also be adjusted, typically by variable panels.

These options are feasible if the web slope is kept constant. Detailing variable-slope webs adds significant complications to a design, including having to warp the web forms, and should be avoided when possible. While the modifications described in the previous list are readily achievable when casting one segment per day in each casting cell, they present necessary complications to the casting cell. Therefore, when allowed by short-to-medium span lengths, constant-depth spans are preferred.

Variable crown points can be handled by adjusting the top-slab thickness to achieve the desired cross slopes, while allowing the core form to remain unchanged. This philosophy works when the variation in the top slab results in reasonable thicknesses. If the variation is in the shoulders, it is possible to fabricate a casting cell where the wing form rotates relative to the web form.

The information in this article, together with the insights from the previous article, help the design team set preliminary superstructure cross-section dimensions. The next steps in a good preliminary superstructure design are to determine the amount of post-tensioning, tendon layouts, anchorage locations, and the resulting diaphragm dimensions and deviator locations. These post-tensioning design parameters for the next steps can be determined with simplified preliminary analysis procedures that avoid complex time-dependent models. This approach generates a sound preliminary design as a starting point for a final design, with minimal changes needed during the final design process. The next article in this series will present these simplified methods for preliminary analysis.

Reference

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.

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Figure 6. The five main forming surfaces and the core dimensions in a typical casting cell.