Detailing Segmental Concrete Box Girders for Constructability – Part 2

by Jeremy Johannesen, McNary Bergeron & Associates

The Great Baltimore Fire of 1904 is a historic example of the need for standardization. At the time, 600 different hose-coupling devices were in use in the United States. Crews responded from as far away as New York, only to find that they were unable to connect their hoses to the hydrants due to the incompatible couplings. Decades later, the United States' engineer-president, Herbert Hoover, pushed for the standardization of screw threads, which was ultimately so successful that we can now assume that threaded fasteners made on opposite sides of the country will fit together.

Although concrete construction is infinitely adaptable, standardization is still key to both the economics and quality of a project. In construction, standardization can be summed up as doing more, thinking less—at least on site or during production. This article summarizes a number of considerations that are specific to segmental bridge construction but also applicable to other types of construction.

Concrete Geometry

The principles for segment geometry are commonly accepted and understood within the industry. Geometry in curved alignments is achieved by chording the individual segments. In plan view, segment joints are perpendicular to the chord of the segment being cast. In profile,

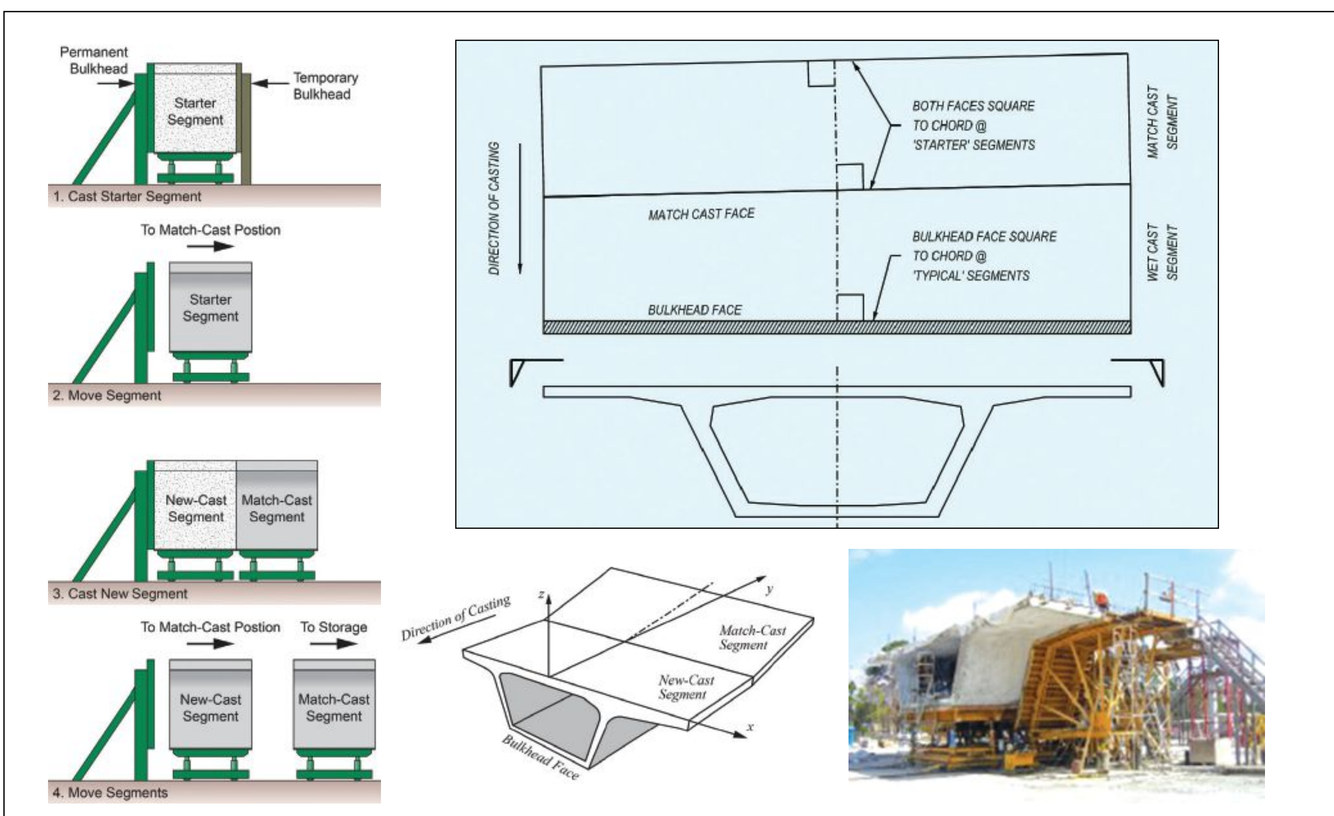

Figure 1. The schematic of the short-line casting sequence (left) shows how the starter segment is moved to the match-cast position and is oriented based on the needed geometry. The new segment is cast the next day. When it reaches its strength, the match-cast segment is moved to storage, the new-cast segment takes its place as the match-cast segment, and so forth. Geometry on a curved alignment is accommodated as shown on the right. The segment made in the new-cast position is flat or straight along the vertical axis with regard to the bulkhead. The relative geometry is achieved through the manipulation of the match-cast side, which was the segment cast the day before. Figure: PCI (left) and McNary Bergeron & Associates (right).

joints are vertical at the time of casting (**Fig. 1**).

While it is understood that this process provides a basis for survey control, the process is primarily based on the practical limitations of the formwork system. In very general terms, variability is limited to the match-cast face, or open end of the form.

Design should be based on an understanding of the formwork system, and simplicity should be the goal. To be specific:

- Avoid variations in cross-section thickness, especially within a casting unit.
- Use consistent anchor-block geometry to avoid formwork modifications during the casting cycle.
- Avoid using top-slab anchor blocks, as these significantly complicate the core form design and operation.
- In precast segmental concrete, avoid variations in section depth.
- In cast-in-place segmental concrete, the longer segment length and formwork related to deviator ribs for external tendons pose a construction challenge. Casting the rib as a secondary pour simplifies the formwork and removes nonstandard details from the critical path.

Post-Tensioning Duct Layout

Segmental formwork inherently requires a fairly standard layout. To keep details simple and consistent, consider the following:

- Set the cantilever (top longitudinal) tendon anchorage low enough such that the spiral clears the first transverse tendon (**Fig. 2**).
- In variable-depth structures, index the bottom-slab tendon layout and anchor-block geometry from the inside corner of the box girder. With this approach, the relative geometry between the anchor block and the ducts remains consistent as the depth of the girder varies (**Fig. 3**).
- Use "tight radius" ducts where needed but avoid bends that require custom-bent steel pipes (spelled "pipe$"). Designing with radii that can be achieved using corrugated plastic duct should be the goal for cost-effective design.
- Consider the duct radius in the plane of the bend. It is not possible to bend a duct to different radii in both plan and elevation.

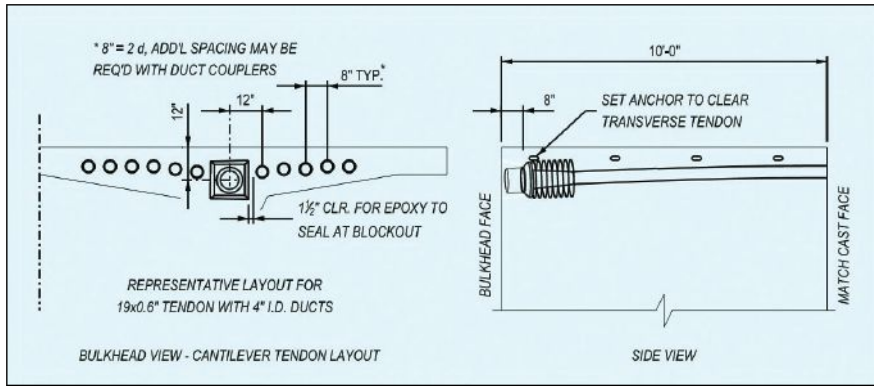

Figure 2. The cantilever (longitudinal) tendon anchorage should be set low enough such that the spiral clears the first transverse tendon. Figure: McNary Bergeron & Associates.

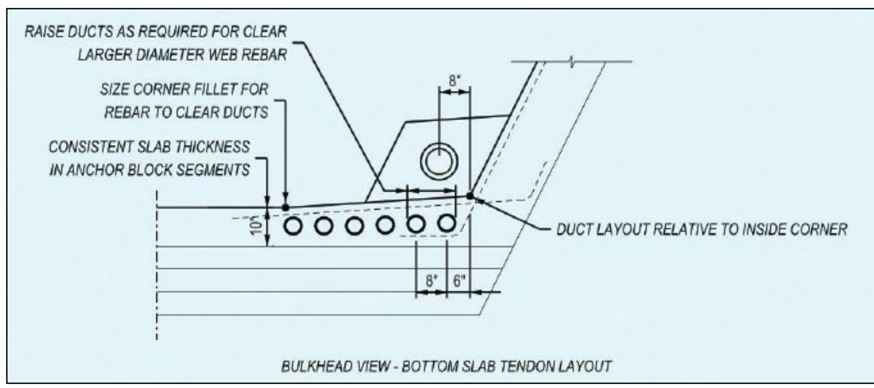

Figure 3. Avoid variations in bottom-slab thickness among segments within a casting unit, and index the bottom-slab tendon layout and anchor-block geometry from the inside corner of the box girder. With this approach, the relative geometry between the anchor block and the ducts remains consistent as the depth of the girder varies. Figure: McNary Bergeron & Associates.

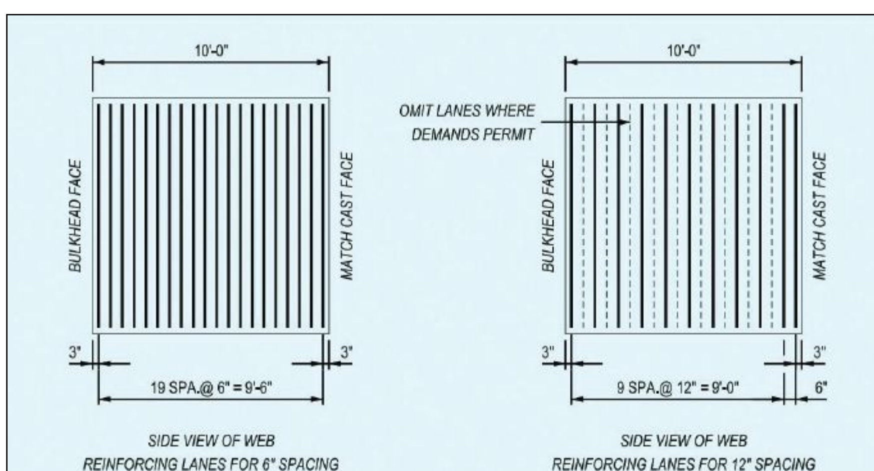

Figure 4. Use reinforcing bar spacings with a common denominator, such as 6 in. and 12 in., to simplify the reinforcement layout and improve efficiency. Figure: McNary Bergeron & Associates.

- Use diabolos for external post-tensioning (PT) to allow standard placement for a range of tendon profiles. Diabolos without stay-in-place plastic formers require additional spacing to ensure clear cover between the reinforcement and the formed hole.

Reinforcement Layout

Many people in the field assume that reinforcing bars should simply be spaced equally over any face of concrete; however, this approach does not lend itself to integration of other items. One simple method to integrate details is to adopt an assumed reinforcement layout early in the design. This creates dedicated reinforcing lanes, and everything else can be integrated outside of the lanes. Drainage, lighting, construction embeds, and even PT can go anywhere as long as they go between the reinforcing bars.

When spacing reinforcement, use common denominators. For example, integrating reinforcing bars with 8 in. spacing with bars spaced at 6 in. will either result in 6 in. spacing with some random gaps, or 8 in. spacing with random bundles. Using spacings with a common denominator, such as 6 in. and 12 in., resolves this problem (**Fig. 4**). Similarly, using obscure spacing invites mistakes. Stick to whole inches or centimeters, which can be easily read on a dirty tape measure.

When segments are rectangular, reinforcing bar layout is simple (offset the first bar half of the nominal spacing from the bulkhead face and then repeat at the nominal spacing). When segments have a skewed face, space the bars parallel to the bulkhead (the square end) from the bulkhead to beyond the anchor block reinforcement or other details requiring integration. Then, vary the spacing in an accordion fashion for a limited length near the skewed face (**Fig. 5**).

This approach is similar to timber framing, where rather than spacing the studs uniformly along each wall, the studs are spaced at 16 in. and any remainder is left as a single, short spacing. This is a well-understood technique that does not require integrated shop drawings. Furthermore, it is inherently compatible with different building components. For example, a 4 × 8 ft sheet of plywood is multiples of 16 in.; thus, the sheeting aligns with the framing studs.

While positioning of PT generally has priority over positioning of reinforcing bars, it is worthwhile to detail the transverse tendons between the lanes of reinforcing bars (**Fig. 6**). This is baseball's "hit 'em where they ain't" strategy applied to detailing. Conversely, locating transverse tendons without regard for the reinforcement results in nonuniform reinforcing bar spacings and, sometimes, the need for additional reinforcement to cover the resulting gaps. Addressing these issues requires extra labor.

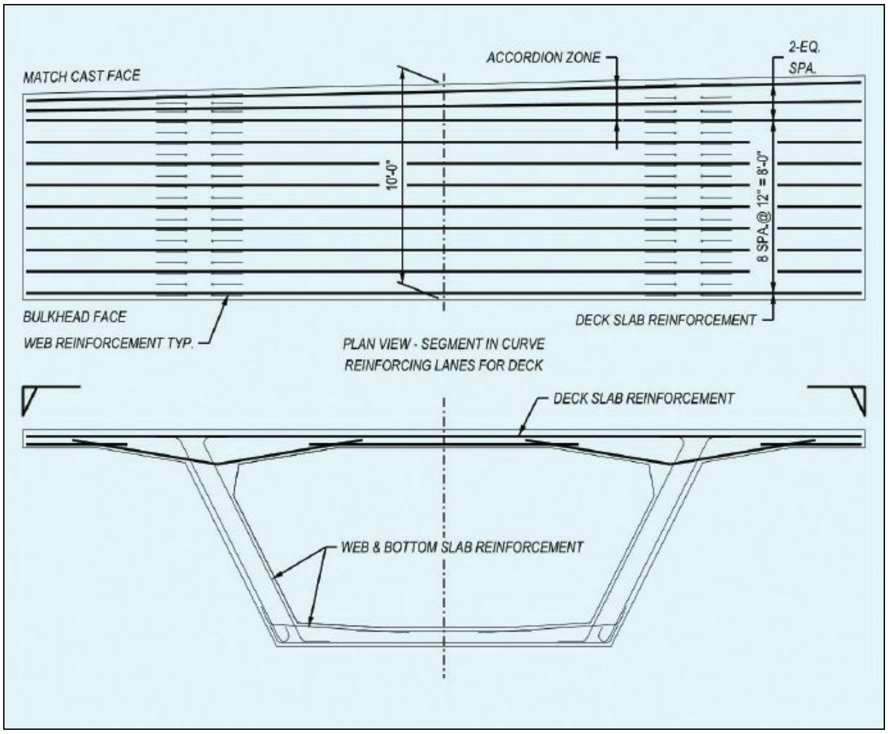

Figure 5. Adopt a reinforcement layout early in the design, and create dedicated lanes of reinforcing bars with spacings of common multiples. When segments have a skewed face, space the bars parallel to the bulkhead (the square end) from the bulkhead to beyond the anchor block reinforcement or other details requiring integration. Then, vary the spacing in an accordion fashion for a limited length near the skewed face. Web and bottom slab reinforcement would be placed using the same approach. Figure: McNary Bergeron & Associates.

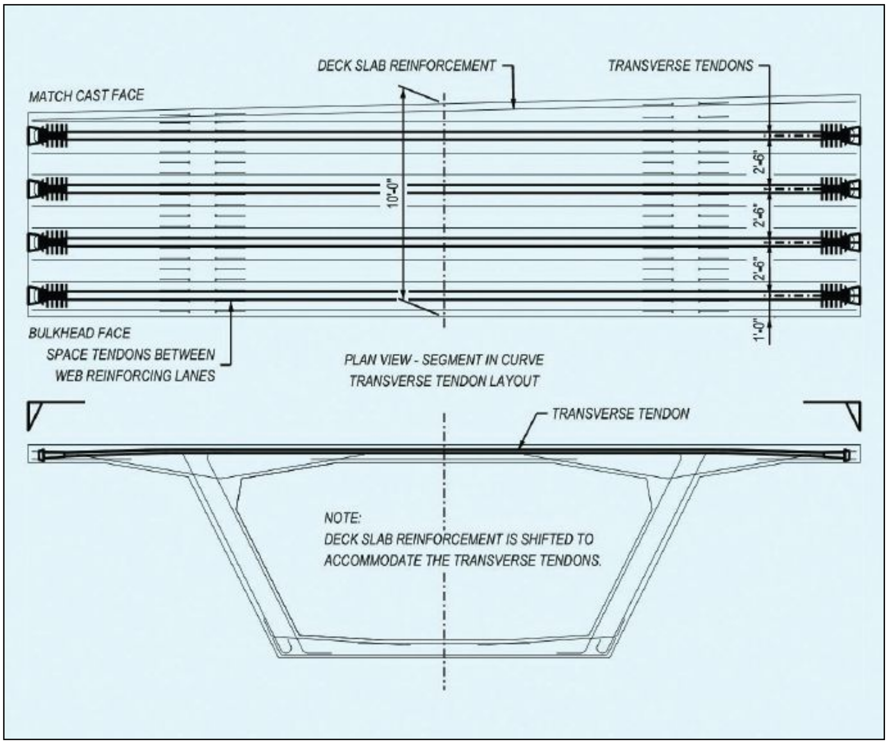

Figure 6. Detail the transverse post-tensioning tendons between the lanes of reinforcing bars. Locating transverse tendons without regard for the reinforcement results in nonuniform reinforcing bar spacings, and additional reinforcement is sometimes needed to cover the resulting gaps; this work requires additional labor. Figure: McNary Bergeron & Associates.

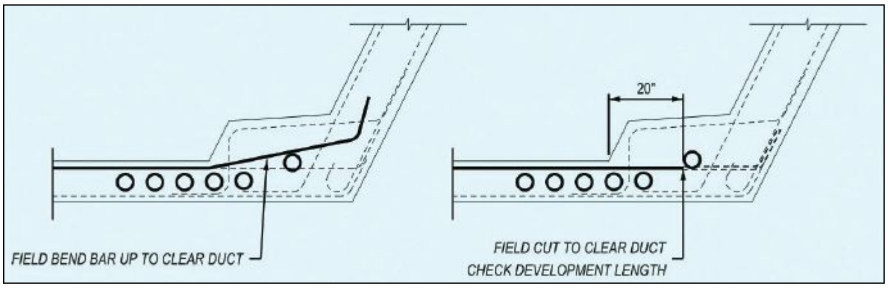

Figure 7. Tendon paths must not be altered to snake through the reinforcement. Where tendons pass through reinforcing mats, a detail should be part of the design. Two options are shown here. Pass-through details like these should be part of the design. Figure: McNary Bergeron & Associates.

Reinforcement at Tendon Anchorages

The anchor blocks' reinforcement must be considered in combination with the actual tendon geometry, so that the reinforcing bars are located in the open lanes between the ducts. Tendon paths must not be altered to snake through the reinforcement.

It is important to slope the inside face of the anchor blocks. By varying the clear cover, the outer block reinforcement may be detailed to follow either straight or deviating tendon paths.

Where tendons pass through reinforcing steel mats, the design should specify how. Shifting reinforcement longitudinally to clear the conflict is not always practical because it displaces too many bars and leaves a large gap. Make the pass-through detail part of the design (**Fig. 7**).

For PT or any large item crossing a plane of reinforcing bars, there is a strong case to be made for field-cutting the "typical" reinforcing cage and adding bars to compensate for the cut bars using a specified detail. This allows crews to focus on production rather than trying to figure out which bars in a group are different from the rest.

Conclusion

This article is a companion to "Detailing Segmental Concrete Box Girders for Constructability," published in the Summer 2021 issue of *ASPIRE*®, and it is intended to provide "lessons learned" from several generations of experience. This includes cases where every segment on the project is cast using a single, already existing, no-frills form. These examples of standardization show that segmental construction can be an economical option. I hope you find these tips useful and I hope they spark some new ideas.

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EDITOR'S NOTE

PCI offers free eLearning modules on many transportation topics—including geometry of straight and curved bridges—that can enhance engineers' detailing and constructability knowledge. See page 27 of the Summer 2021 issue of* ASPIRE® *for additional information and a sampling of course options.