Standardization of Segment Shape

Improving the cost-effectiveness of small precast concrete segmental superstructures

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Two relatively small, three-span concrete segmental bridges were recently constructed along the Blue Ridge Parkway in western North Carolina: the Blue Ridge Parkway Bridge over Interstate 26 (I-26) and the Blue Ridge Parkway Laurel Fork Bridge replacement. Each bridge consists of precast concrete box girders fabricated at Coastal Precast System's facility in Wilmington, N.C.

Coastal Precast fabricated 62 segments for the I-26 project and 56 segments for the Laurel Fork Bridge replacement. These quantities are significantly smaller than those required for most precast concrete segmental bridge projects, where the number of segments often ranges into the hundreds. While casting a small number of segments may seem simpler than casting many, small projects like the Blue Ridge Parkway bridges pose their own unique challenges. (See the Summer 2024 issue of *ASPIRE*® for a Project article about the Blue Ridge Parkway Bridge over I-26.)

One of the biggest challenges on small projects stems from the lack of economy of scale. For large projects, each casting cell can be used to cast hundreds of segments. In contrast, the casting cell on the I-26 project was initially used to cast only 62 segments. Purchasing and setting up a casting cell is a significant investment, costing hundreds of thousands of dollars. That cost is the same whether the form is used hundreds of times or 62 times. Using the form fewer times increases the cost per segment.

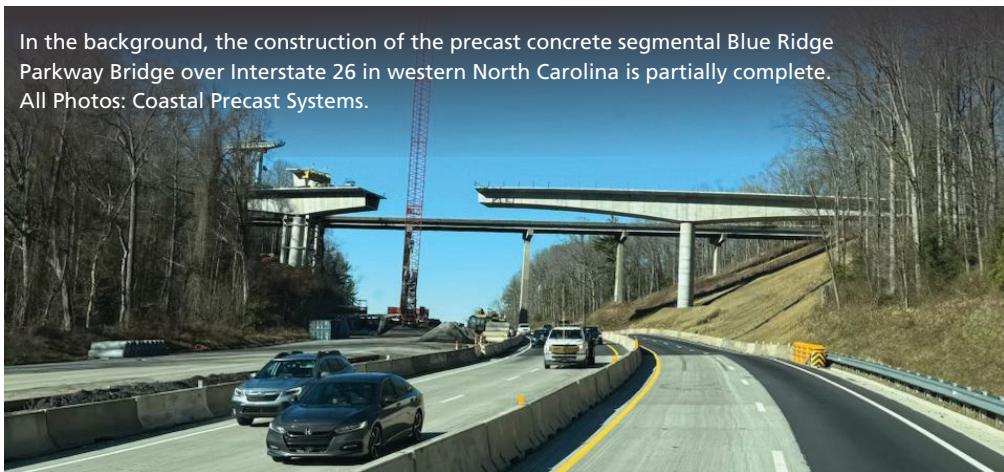
To reduce that cost per segment, a simple (basic) form that has few accessories and functions can be purchased. For example, instead of hydraulic operation of the form, manual turnbuckles can be used, and instead of using multiple individual bulkhead forms that can be swapped out quickly for each variable-depth bulkhead joint, the bulkhead form can be removed, modified with shims and filler sections, and reinstalled.

Another way to reduce the formwork cost per segment is to use the same casting cell for all segment types. On most projects, separate casting cells are used for nontypical segments such as pier and abutment segments. These segments contain diaphragms that require different formwork. These nontypical segments also need two bulkheads when they are cast first because there are no segments to match cast against.

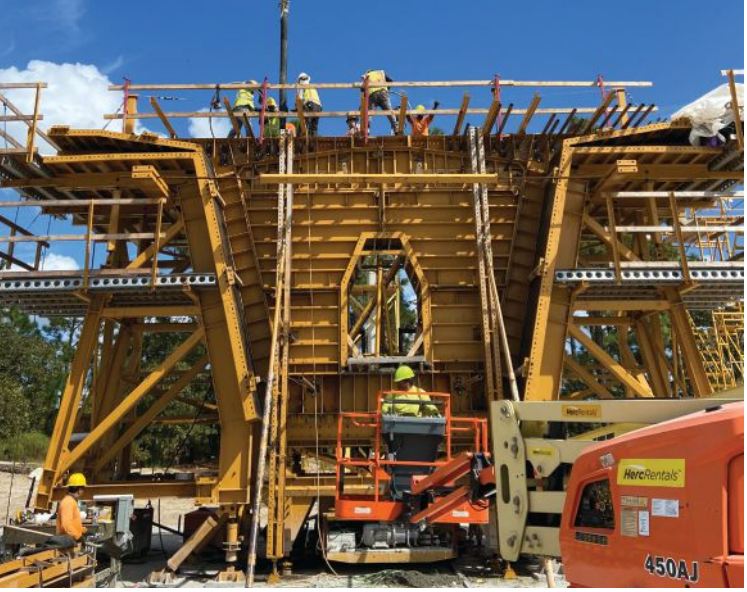
On large projects, additional casting cells may also be used to cast constant-depth segments and variable-depth segments separately. On the small I-26 project, a single casting cell was used to cast all 62 segments—56 variable-depth typical segments (ranging from 8 to 16 ft tall), four pier segments, and two expansion abutment segments.

While using the same casting cell for all segment types reduces the cost of the form, it approximately doubles the casting cycle time. Because one simplified form was used on the I-26 project, two segments could be cast per week on average. However, erection of precast concrete segments at the project site was at a pace of two segnments or more per day. Therefore, a large inventory of segments needed to be amassed to maintain the erection schedule and avoid costly delays. For this project, the longer cycle time was factored into the schedule at the beginning of the project. The additional cost during production (more labor to operate forms and longer casting cycle) was compared against cost of the cheaper form, and because of the small number of segments to be cast, the savings were greater using the simplified form.

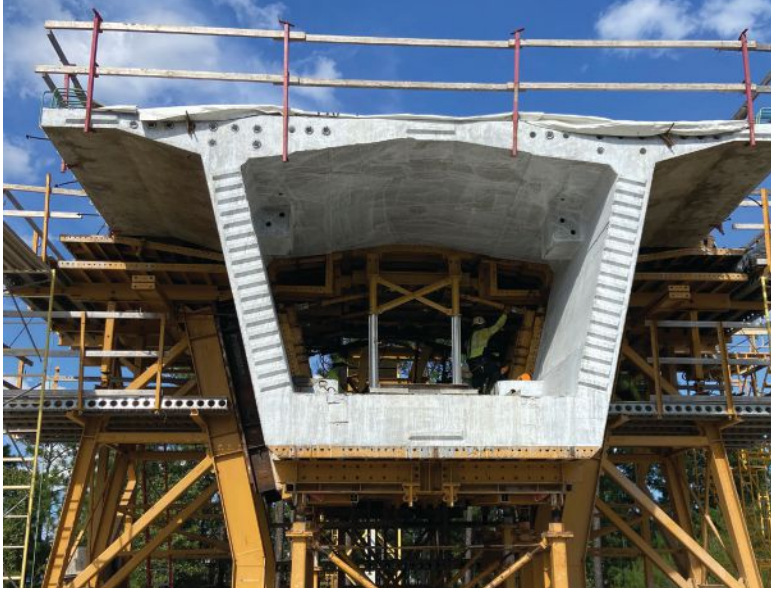
With the help of COWI's Jerry Pfunter, the project's construction engineer (who became the new engineer of record), the precast concrete segment producer modified the shapes of the segments as part of a redesign for the Laurel Fork design-bid-build project to allow reuse of the casting cell from the I-26 project. However, due to the initial differences in the designs of the two bridges, the shapes could not be made identical. To mitigate differences in the shapes, adjustments were made on the Laurel Fork project: the bottom slab haunch



In the background, the construction of the precast concrete segmental Blue Ridge Parkway Bridge over Interstate 26 in western North Carolina is partially complete. All Photos: Coastal Precast Systems.



Casting of a pier segment at the precast concrete manufacturer's facility for the Interstate 26 project.



A variable-depth typical precast concrete segment for the Laurel Fork project is in position for the next segment to be match cast against it in the adjacent casting cell.

was eliminated, the thickness of the top slab was reduced, and the anchor blocks were modified to match specifications used in the I-26 project and the existing formwork. Unfortunately, the joint widths and heights varied between the two projects, so the bulkhead, mandrel, soffit table, and wing form required significant changes. However, the supporting structure of the casting cell was reused without significant modification.

Reusing the segmental casting cell from the I-26 project on the Laurel Fork project saved two months in startup time for the Laurel Fork project. A typical lead time, from ordering forms to casting the first segment, is about five months. After the design of the revised shape was completed, it took three months to modify the forms. This time frame would have been even shorter if the original segment shapes had been more similar.

The cost-effectiveness of using the same shape across multiple projects can be seen with prestressed concrete girders, which are economical in part because the initial form cost can be spread out over numerous projects. Because girder forms are standard shapes used across multiple jurisdictions, they can be used to cast thousands of girders. Therefore, a particular project with only one or two spans does not have to absorb the entire cost of the form.

Typically, segmental casting cells are only used for one project, so the cost cannot be allocated over other projects. If the use of standardized shapes becomes more commonplace, that will open the door for precast concrete segmental superstructures to be an economical option for more projects.

The *AASHTO-PCI-ASBI Segmental Box Girder Standards for Span-by-Span and Balanced Cantilever Construction*[1] are available for download from the American Segmental Bridge Institute (https://asbi-assoc.org/resources). While these standard drawings do not cover spans greater than 200 ft, the basic shape can be used for taller segments. These standard drawings can also be applied to variable-depth segments to extend spans. Using details from those drawings, including web wall slope and thickness, slope and length of cantilever wing base, width of core, and radius at top of web wall, precast concrete manufacturers could invest in typical, multiuse casting cells that could be used on multiple projects. For additional information on the AASHTO-PCI-ASBI segmental box girder standards, please refer to articles by Freyermuth[2] and Figg.[3]

Formwork is modified between the casting of segments for the Blue Ridge Parkway Bridge over Interstate 26 and the Laurel Fork Bridge replacement. In this photo, the width is being reduced for the nearly 3-ft narrower section. The form skin was removed, and I-beams were added to narrow the structure. The form skin was then replaced.

References

1. American Association for State Highway and Transportation Officials (AASHTO), Precast Concrete Institute (PCI), and American Segmental Bridge Institute (ASBI). 2000. *AASHTO-PCI-ASBI Segmental Box Girder Standards for Span-by-Span and Balanced Cantilever Construction*. Austin, TX: ASBI. https://asbi-assoc.org/wp-content/uploads/2023/07/Box-Girder-Segments-PCIASBIEnglish.pdf.
2. Freyermuth, C. L. 1997. "AASHTO-PCI-ASBI Segmental Box Girder Standards: A New Product for Grade Separations and Interchange Bridges." *PCI Journal* 42 (5): 32–42. https://doi.org/10.15554/pcij.09011997.32.42.
3. Figg, E. C. 1997. "Proposed AASHTO Standards for Segmental Bridges Represent a Growing Market for the Precast Concrete Industry." *PCI Journal* 42 (5): 30–31. https://doi.org/10.15554/pcij.09011997.30.31.