Construction Engineering: A Specialty Engineer's Perspective

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On many bridge projects, substantial engineering effort goes into the construction phase. For conventional structures, this role is typically handled in house by contractors since the needs fall under traditional construction engineering: crane pick plans, rigging and handling details, and temporary works. For complex projects, bid documents often require an erection engineer or specialty engineer to perform an analysis of the permanent structure, as the means and methods of the construction phase may control some aspect of the design. The terms "erection engineer" and "specialty engineer" are interchangeable and fall under the umbrella of construction engineering. The involvement of a specialty engineer depends on the complexity of the structure and should be identified in bid documents. Their analysis of the means and methods of the construction phase could be necessary because temporary construction loads control the design, or the means and methods affect the locked-in forces and geometry, or both. This engineering effort is typically performed by a subconsultant to the contractor.

Figure 1. Precast concrete boxes are jacked horizontally into place under State Route 528 for the Brightline high-speed rail underpass in Cocoa, Fla. Photo: Granite Construction.

Specialty/erection engineers need to understand the perspectives of both the designer and the contractor. The specialty engineer answers the question, "How do we build it?" and keeps the following goals in mind while studying the various construction stages of the incomplete structure:

- Control stresses
- Maintain stability
- Control geometry
- Arrive at an acceptable load distribution

Roles and Responsibilities

Deliverables from a specialty engineer include erection procedures, longitudinal construction analysis, geometry control plans, and temporary works designs, all of which are submitted for review by the engineer of record (EOR). The erection procedures and longitudinal construction analysis are commonly submitted together and called the erection manual.

The EOR is typically looking at the bridge throughout its service life, whereas the specialty engineer focuses on the phases between ground breaking and ribbon cutting. If a specialty engineer is not part of the project during the design phase, as is the case in typical design-bid-build and often in design-build projects, then the EOR is responsible for ensuring the structure is constructible. Per Article 2.5.3 of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*,[1] if the bridge is of unusual complexity, "at least one feasible construction method shall be indicated in the contract documents." On some projects, the final erection plan will differ from the scheme shown in the contract plans. The changes are made because the contractor's experience, available equipment, and even subsidiaries owned by the contractor may make another method more efficient and cost

Figure 2. A crawler crane is used to erect Bridge 596 of the Millsboro Bypass project in Sussex County, Del. The engineer of record and the specialty engineer collaborated to ensure that the bridge design accounted for the construction loads. Photo: Richard E. Pierson Construction Co. Inc.

Figure 3. A launching gantry erects an approach span on the Harbor Bridge project in Corpus Christi, Tex. Self-weight of gantries and suspended loads during construction may control the substructure and foundation designs of a bridge. Photo: Flatiron Dragados JV.

effective than the one derived when the EOR performed the design and constructability analysis.

Article 2.5.3 of the AASHTO LRFD specifications also states that critical stages of construction shall be vetted by the EOR to ensure that there are no stress or stability issues. Often, wind loads during critical construction stages are of paramount importance. For a girder bridge, it is necessary to analyze loads for the girders with no deck in place. The construction wind speed, drag coefficients, and shielding effects during construction may control if they are different than those for the final bridge.[2] (See "Wind Loads on Bridges during Construction" in the Spring 2024 issue of *ASPIRE*®.)

Unconventional Construction

When conventional structures are built unconventionally, the contractor often takes design ownership to suit their means and methods. On the Brightline high-speed rail project in Cocoa, Fla., an innovative solution called "box jacking" replaced the traditional staged construction technique (**Fig. 1**). The new method involved building the structure offline, which eliminated lane closures and construction work zones over a one-year period. Within two weeks, the structure was horizontally jacked into place through the existing embankment, while reduced live traffic was maintained above.[3] This scheme was made possible by the construction engineering components that the specialty engineer built into the permanent design of the underpass.

This type of project is becoming more common as right-of-way restrictions, environmental impacts, utility conflicts, construction schedules, and the requirements of additional stakeholders (such as ports and railroads) are becoming more stringent. Innovative construction methods—such as sliding, launching, float in, self-propelled modular transporter moves, or top-down construction—are often required to make the project feasible. Sometimes, the constraints are so great that the construction method needed to satisfy the requirements dictates the structure type chosen for the project. In these situations, it is critical to allow for collaboration among the EOR, contractor, and specialty engineer at the project's inception. This collaboration is easier to develop with alternative delivery methods such as progressive design-build and construction manager/general contractor.

On the Millsboro Bypass project near Millsboro, Del., Bridge 596 is a conventional precast concrete deck bulb-tee bridge that is being built with top-down construction through an environmentally sensitive area (**Fig. 2**). This project uses a 300-ton crane supported on the previous span as each subsequent new span is built. The crane loads control the design of most of the bridge components—most importantly the girders and piles. To make this scheme possible, the EOR and specialty engineer collaborated to work the construction loads into the permanent design.

Complex Structures

As structural complexity increases, the role of the specialty engineer also increases. Spliced-girder bridges require a longitudinal construction analysis, erection procedures, post-tensioning calculations, a multitude of temporary works, as well as details to reset bearings after the post-tensioning operation. The longitudinal construction analysis is a true staged-construction analysis that considers time-dependent effects of the concrete. The temporary works often include strongbacks for drop-in segments, temporary diaphragms, lift rigging details, and temporary falsework for pier beam segments.

Concrete segmental bridges often require specialized equipment for construction. Specialty engineers may design the equipment directly or independently check the design supplied by a manufacturer. They will also perform detailed analyses of the structure for the construction phases that support the specialized equipment to ensure that the imposed demands are within acceptable limits. For example, analysis may focus on a launching gantry used to erect precast concrete segments for a segmental bridge. Gantries typically suspend an entire span, so the additional dead load during construction from the gantry self-weight, which can be upward of 3 million pounds, may control the substructure and foundation design. The heavy reactions on the pier segments and columns may also be eccentric, requiring additional stability measures. In coastal regions, the increased wind area from the gantries may require upsizing pier columns for hurricane-force winds during construction. For the Harbor Bridge project in Corpus Christi, Tex., the approach-span piers were upsized at selected spans to act as storage areas for the gantry during hurricanes. The expectation was that there would be enough time to back-launch the gantry to one of the upsized spans before the storm's arrival (**Fig. 3**).

Signature Structures

Signature bridge designs (for example, designs for long-span arches or cable-stayed bridges) are often controlled by the loads during the construction phase, and due consideration for the erection method is therefore required. Typically, specialty engineers are engaged to analyze the structure during the construction phase when the EOR is developing the contract plans. The roles of the EOR and the specialty engineer typically dovetail toward the end of the project when as-built geometry and forces are recorded during closure sequences. Similarly, for cable-supported structures, as-built geometries and cable forces are recorded. These values are used as a check against the theoretical values in the erection manual, and the EOR uses them later in the as-built load rating.

Sometimes, a structure is the first of its kind and extensive construction engineering by the specialty engineer is required to help bring the project to fruition. That was the case with the Interstate 395 Signature Bridge project in Miami, Fla. (**Fig. 4**). The structure has six arches, the largest of which is more than 300 ft tall and spans more than 600 ft. The arches are precast concrete segmental structures, with the heaviest segment weighing 200 kips.

Conclusion

The specialty engineer's role is distinct from that of the EOR and bridges the gap between designer and contractor. Early involvement of the specialty engineer is essential when site or project constraints dictate the construction scheme and structure selection, and this collaboration is often a key aspect to innovation.

References

1. American Association of State Highway Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.
2. AASHTO. 2017. *AASHTO Guide Specifications for Wind Loads on Bridges during Construction*. Washington, DC: AASHTO.
3. Cho, A. 2021. "Box-Jacking Method Used under Live Traffic, a First in the US." *Engineering News-Record*. April 7. https://www.enr.com/articles/51547.

EDITOR'S NOTE

As a part of the National Concrete Bridge Council Webinar series, "The Critical Role of Construction Engineers in Building Bridges" will be presented by the author of this article, JJ Reily, on October 16, 2024. After that date, a recording of the webinar will be available for viewing. For more information visit https://nationalconcretebridge.org/2024-ncbc-webinar-series/.

Figure 4. Arch No. 2 approaching keystone closure as part of the Interstate 395 Signature Bridge project in Miami, Fla. Unique structures require extensive construction engineering services. Photo: Archer Western.