CONCRETE BRIDGE TECHNOLOGY

Load Rating Segmental Bridges

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Precast and cast-in-place concrete segmental bridges have become an important part of our country's bridge inventory. The complexities of sophisticated designs, geometries, and construction techniques are more than offset by the adaptability and positive enduring impact of these bridges. Increased sophistication also means greater challenges when load rating segmental bridges. A few of these challenges are discussed in this article.

The complexities of sophisticated designs and construction techniques used in segmental bridges require an accurate estimate of stresses along the entire length of the bridge at the time for which the rating is performed. Retaining the original analysis models that accurately reflect the as-built conditions of the bridge reduces the effort required for load rating. Photo: Johnson Bros.

Level of Effort

Rating a segmental bridge takes more effort than rating a more conventional bridge type. The reason is that segmental bridge load rating needs to be based on an accurate estimate of stresses along the entire length of the bridge at the time for which the rating is performed. Specialized construction analysis software is required to estimate the state of stress according to the contractor's construction methodology and sequence. The time-dependent nature of the concrete and prestressing steel is modeled to predict changes in stress with age, as well as the stress redistribution that results from changing statical schemes during the erection process.

The effort can be reduced if the owner has retained original analysis models that accurately reflect the as-built conditions of the bridge. Projects with less documentation may require substantial work to build models that accurately reflect the as-built bridge and the contractor's construction sequence and erection methodology. In some cases, an in-depth search through construction documents is required to find needed information. Data that are typically collected include:

- Concrete material characteristics (strength, density, modulus of elasticity, creep, shrinkage)
- Prestressing steel and system characteristics (modulus of elasticity, relaxation, friction, wobble)
- Key dates (segment casting, segment erection, span closures)
- Tensioning data (dates, forces, elongations)
- Erection manuals (means and methods)

It is good practice for the owner to collect and catalog this information when building a new bridge to facilitate future load ratings.

Segmental bridge load ratings also take more effort because six different behaviors need to be rated. In the longitudinal direction, a bridge is rated with regard to flexural stresses, flexural strength, web principal tensile service stress, and web shear strength. The transverse cross section of the bridge is rated with regard to flexural stress and flexural strength. Each of these behaviors is rated for design loads, legal loads, and permit loads at both inventory and operating levels at all segment joints. The number of calculations is large, but effective use of spreadsheets or other software helps manage the effort. Recently, we performed load ratings of the new Interstate 20/Interstate 59 Central Business District Bridges in Birmingham, Ala. The load rating of this 172-span, 1-million-ft² bridge required over 160,000 individual rating evaluations. (See the Spring 2020 issue of *ASPIRE*® for details of this project.)

Service Limit State Calibration

Segmental bridge design criteria have matured over time from project-specific design criteria to guide specifications paired with load factor design (LFD) criteria to full inclusion in the current American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications.*[1]

Load-rating methodologies for segmental bridges likewise have developed over time. However, these methodologies have lagged behind design codification because of lack of calibration at service limit states.

The reliability-based AASHTO LRFD specifications were calibrated at ultimate strength with the load factor design requirements of the AASHTO *Standard Specifications for Highway Bridges*.[2] No calibration was performed for service limit states or for fatigue and fracture limit states. These limit states were accommodated by factoring capacities such that member proportions produced under the new LRFD code would be comparable to those designed using the AASHTO standard specifications. Segmental bridge superstructures, though verified at all appropriate strength limit states, are fundamentally structures that are designed for service conditions. The lack of calibration at service limit states becomes problematic for load rating segmental bridges when the change between inventory (service or design load level) ratings and operating ratings (maximum permissible live load level) is expressed by a probabilistic measure (reliability index β changes from 3.5 to 2.5).

Calibration for the service limit state was investigated by the Florida Department of Transportation (FDOT) in 2002, with work performed by Dr. Dennis Mertz and Corven Engineering.[3] This work led to the use of design lanes for inventory ratings and striped lanes for operating ratings. This philosophy is now incorporated into the AASHTO *Manual for Bridge Evaluation*.[4] Unfortunately, the calibrating work performed by FDOT focused on what was a common segmental cross section in its inventory: three design lanes with two striped lanes. Care needs to be taken for other superstructure cross sections. For example, narrower cross sections with two design lanes and one striped lane tend to overstate the operating rating factors, while wider cross sections, designed for four lanes and striped for three, tend to underestimate the operating rating factors.

The good news on this front is that National Cooperative Highway Research Program Project 12-123, "Proposed AASHTO Guidelines for Load Rating of Segmental Bridges," will soon be underway. Unfortunately, the results of the project will not be available for several years. In the meantime, some have used a sliding scale normalized around the FDOT calibrations to try to maintain target reliabilities over a range of bridge widths at operating conditions.

Rating Older Bridges

Segmental bridges that were designed under older specifications often will not rate at inventory level using load and resistance factor rating (LRFR) methodology. The reason for this typically lies in three areas: (1) the change from HS20 loadings of the AASHTO standard specifications to the notional loads of the AASHTO LRFD specifications without service limit state calibration (as discussed in the previous section), (2) changes in shear strength design provisions, and (3) previously unspecified limits on principal tensile stresses in webs. It is important to communicate possible methods of mitigating low ratings to owners who do not want to revert to the load factor rating or allowable stress rating methods permitted in the *Manual for Bridge Evaluation*.

Transit and Heavy Rail Bridges

Segmental construction has proven to be excellent for transit and heavy rail bridges. Particular care should be taken when asked to perform an LRFR of a transit bridge designed under an owner's design criteria that may be LFD based. The reason is again one of calibration. Using owner-defined loads that have remained unchanged with load and resistance factors calibrated to highway vehicles, as in the LRFR, may lead to inappropriately high load ratings at some limit states.

Final Thoughts

Precast and cast-in-place concrete segmental bridges have robust load-carrying capacities. With a proper understanding of loads, design methods, and load and resistance factors, the accuracy of load ratings can be improved, which will allow owners to maximize the use of their segmental bridges as traffic needs change.

Load rating of the new 172-span, 1 million ft_2 structure for the Interstate 20/Interstate 59 Central Business District Bridges in Birmingham, Ala., required over 160,000 individual rating evaluations. Photo: Volkert Inc.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.
2. AASHTO. 2002. *Standard Specifications for Highway Bridges*. 17th ed. Washington, DC: AASHTO.
3. Corven Engineering. 2004. *New Directions for Florida Post-Tensioned Bridges, Volume 10A: Load Rating Post-Tensioned Concrete Segmental Bridges*. Tallahassee, FL: Florida Department of Transportation.
4. AASHTO. 2020. *Manual for Bridge Evaluation*, 3rd ed., 2020 interim revisions. Washington, DC: AASHTO.

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