

# Designing for Construction Loads on Concrete Bridges

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**D**esign engineers use risk management to control or limit design-related uncertainty for the safety of construction personnel and the traveling public. In construction, there is a great deal of uncertainty and risk that must be managed effectively; for example, in addition to safety concerns, there are risks related to cost, quality, schedule, construction means and methods, aesthetics, and environmental impact constraints that may affect design choices. These risks may be considered in one of three ways: ignore the risk, avoid the risk, or design for the risk. Designing for risk requires a thorough understanding of the structure and the variety and uncertainty of the forces that may affect it.

Numerous bridge construction accidents have been attributed to a failure to appropriately consider construction means and methods—the effects of construction loads in particular. Unfortunately, construction loads have long been an underemphasized topic in many specifications and design manuals. For example, the August 1, 2007, collapse of the Interstate 35W bridge in Minneapolis, Minn., was attributed in part to concentrated construction loads on the bridge on the day of the collapse. Following its investigation, one recommendation from the National Transportation Safety Board to the Federal Highway Administration was to “develop specifications and guidelines for use by bridge owners to ensure that construction loads and stockpiled raw materials placed on a structure during construction or maintenance projects do not overload the bridge’s structural members or their connections.”<sup>1</sup>

The American Association of State Highway and Transportation Officials’ *AASHTO LRFD Bridge Design Specifications*<sup>2</sup> is primarily a design-oriented specification, with limited

direction or guidance with respect to construction loads. Article 2.5.3 of the AASHTO LRFD specifications, ninth edition, includes the following:

*Bridges should be designed in a manner such that fabrication and erection can be performed without undue difficulty or distress and that locked-in construction force effects are within tolerable limits.*

*When the designer has assumed a particular sequence of construction in order to induce certain stresses under dead load, that sequence shall be defined in the contract documents.*

*Where the bridge is of unusual complexity, such that it would be unreasonable to expect an experienced contractor to predict and estimate a suitable method of construction while bidding the project, at least one feasible construction method shall be indicated in the contract documents.*

Construction of new bridges, or rehabilitation or widening of existing

bridges, often requires operating heavy equipment on the bridge. As work areas become congested and adjacent construction staging areas are limited, the need to place loads on bridges increases. Construction loads, whether from material stockpiles or equipment, can be of substantial magnitude and produce load effects that differ significantly from those for which a bridge was designed. Construction loads are often of short duration and highly variable. Loads may be concentrated resulting in load effects that may be greater than those of the design vehicles. The effects of construction loads—for example, residual forces and deformations from removal of temporary loads or supports—may remain a consideration after construction is complete. Also, elements and connections of the completed structure that ultimately provide strength, stiffness, stability, or continuity may not be present during certain phases of construction. For these reasons, it is important to assess the effects of construction loads during design.

*An overhead gantry is used for the construction of the U.S. 17 bypass near Washington, N.C. The structure must be analyzed for the loads from specialized equipment. Photo: Flatiron Construction Co.*



It is recommended that design engineers consult with contractors experienced in the erection procedure that is being recommended to obtain the most accurate construction loading information. Construction loads and conditions frequently impact section dimensions and reinforcement, prestressing, or post-tensioning requirements in segmentally constructed bridges. Bridges should be checked for construction loads to ensure that structural damage will not occur during the construction process, and that the construction means and methods have no adverse impact on the service state or service life of the completed structure.

Safe construction of a bridge requires proper coordination, delegation, and exchange of information among the designer, contractor, and owner. Many construction accidents are caused simply due to an improper erection sequence or process.

The design engineer is responsible for designing the bridge per the AASHTO LRFD specifications and the state- or agency-specific policies documented in their design manual, guides, and standard plans. Subsequently,

*Girder erection on Cow Key Channel Bridge in the Florida Keys. When adjacent construction staging areas are limited, erection equipment may need to be placed on an unfinished structure. The structure must be evaluated for these erection loads. Photo: Kiewit Construction Co.*



a contractor with sufficient expertise and experience constructs the bridge per the design documents and project specifications. The contractor selects qualified suppliers to provide materials and structural elements for the bridge to ensure constructability, safety, and durability. Responsibilities for the design of temporary structures and temporary supports, for the evaluation or design of partially completed structures for temporary use or construction loads, and for supervision of site activities to control loads on structures are typically delegated to the contractor or the contractor's construction engineer.

It is, however, the responsibility of the design engineer to include in the contract documents critical design assumptions that can impact the integrity of the structure. The assumed method of construction—including any temporary supports that are required before the structure, or component thereof, can support itself and subsequently applied loads—should also be shown in the contract documents. The maximum construction loads and their locations for which the structure has been evaluated should be quantified. Simple designs can avoid mistakes that arise due to lack of expertise; therefore, wherever possible, simple designs are advisable. Design drawings should be unambiguous, complete, and logical for those involved in the actual construction.

Construction loading analysis should consider, but not necessarily be limited to, the following:

- Erection loads
  - Construction live load: an allowance for miscellaneous items of materials, machinery, and other equipment, apart from specialized erection equipment.
  - Specialized construction equipment load: the maximum loads and load effects from segment or material delivery trucks, or both, and any special equipment, including a crane, form traveler, launching gantry, beam and winch, truss, or similar auxiliary structure during erection.
  - The distribution and application of the individual erection loads appropriate to a construction

phase should be selected to produce the most adverse effects.

- Realistic (not overly conservative) self-weights to ensure the final deck geometry will be correct. For example, an exaggerated concrete density of 165 lb/ft<sup>3</sup> may be specified by the owner for post-tensioned concrete in an attempt to be conservative, but its use may lead to unrealistic geometry and large (unconservative) locked-in permanent load effects and creep redistribution.
- Temporary supports and restraints
  - The stage of construction during which the temporary supports are removed.
  - Residual forces and deformations and/or strain-induced effects from removal of temporary loads and supports.
- Stability of partially erected structures
- Deck placement sequence, if applicable
- Girder stability during lifting and erection and while the element is braced before the deck is placed
- Structural condition of the existing structure to support demolition loading and/or construction loads
  - If the design requires strengthening of an existing structure and/or

*Demolition of the Coastal Highway Bridge over the Lewes-Rehoboth Canal near Dewey Beach, Del. An existing structure must be analyzed for the loads from demolition equipment and for overall stability. Photo: Kiewit Construction Co.*



temporary bracing or support during erection or demolition by the selected method, the need thereof should be indicated in the contract documents.

- Environmental and hydraulic conditions that may affect the construction of the bridge

A time-dependent and multistage analysis must be used for any bridge where the structural static scheme undergoes changes before reaching construction completion (as in segmental construction). Such analysis should also be performed where there are changes in the cross section of superstructure members through composite action and prestressing is applied to the noncomposite and composite cross sections (as in spliced girder construction).

There have been several initiatives that have advanced the state of practice related to the design and construction of temporary works used in bridge construction. For example, the

AASHTO *Guide Design Specifications for Bridge Temporary Works*,<sup>3</sup> the American Society of Civil Engineers/Structural Engineering Institute's *Design Loads on Structures during Construction* (ASCE/SEI 37),<sup>4</sup> and the AASHTO *Construction Handbook for Bridge Temporary Works*<sup>5</sup> can all serve as useful references for construction loads.

Bridges are unique structures, so it is advisable to partner with designers and contractors experienced in bridge erection. Always design to code and leverage the latest proven design and construction techniques. If during construction, there is ever a concern about the application or effect of a construction load, stop work until the concerns are addressed.

### References

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2. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.
3. AASHTO. 2017. *Guide Design Specifications for Bridge Temporary Works*, 2nd ed. Washington, DC: AASHTO.
4. American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI). 2015. *Design Loads on Structures during Construction*. ASCE/SEI 37-14. Reston, VA: ASCE.
5. AASHTO. 2017. *Construction Handbook for Bridge Temporary Works*, 2nd ed. Washington, DC: AASHTO. 

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