Development of National Specifications for Accelerated Bridge Construction

Photo: Petty Officer 1st Class Steven Smith

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Above: A self-propelled modular transporter (SPMT) moves a tied-arch bridge into place. The accelerated bridge construction (ABC) process allows traffic to be diverted for hours rather than months. With new processes and technology come a need for new design and construction specifications.

Accelerated bridge construction (ABC) technologies have been in development for more than 15 years. These technologies have fundamentally changed the way bridges are built, with construction times reduced from years to weeks—even days. The benefits of ABC are far-reaching and have led to significant increases in road user satisfaction, as demonstrated in user survey polls. This has raised an inevitable question from travelers: "Why can't we build every bridge using ABC?"

The widespread use of ABC technology has been hampered by the lack of an ABC-specific national design and construction specification, one similar to the American Association of State Highway and Transportation Officials' (AASHTO's) *Load and Resistance Factor Design* (LRFD) *Bridge Design Specifications*. Without a national specification, owners must use their own engineering judgment and must refer to various research results to design and build bridges using ABC. This has discouraged many agencies from adopting these practices.

The TRB General Structures Committee coordinated with the AASHTO Bridge Technical Committee on Construction, or the AASHTO T-4 Committee, to formulate a research needs statement (RNS) for the development of a national ABC design and construction specification.[1] The committees also developed RNSs for two particular ABC-related issues that needed further research.

This effort led to two National Cooperative Highway Research Program (NCHRP) research projects: NCHRP Project 12-102, which developed a national ABC design and construction specification, and NCHRP Project 12-98, which studied tolerances in prefabricat-

[1] The TRB Research Needs database can be found at http://rns.trb.org.

ed elements and the dynamic effects of moving entire bridges from prefabrication staging areas to the actual bridge sites (a common ABC technology). Both projects were awarded to CME Associates, Inc., of East Hartford, Connecticut, a firm that has been at the forefront of ABC research and practice since the early 2000s. Having one research team leading both projects was beneficial since the two subjects were so closely integrated.

NCHRP 12-98 Research

NCHRP 12-98 was, essentially, two unrelated research topics combined into one. The first topic addressed a need for a national specification for tolerances of prefabricated elements. Proper management of tolerances plays a major role in the success of a prefabricated bridge project; many of the problems in recent projects can be attributed to a lack of tolerance control. The second topic addressed owner agency concerns with the dynamic effects of moving entire bridges using self-propelled modular transporters (SPMTs) or lateral slide technologies. The goal of NCHRP 12-98 was to develop national guidelines for these two subjects that could be referenced in design and construction specifications.

SYNTHESIS PROCESS

Initially, a literature search and synthesis were conducted. The research for the dynamics of bridge moves was limited to a few investigations by owner agencies and several guidelines published by owner agencies and the Federal Highway Administration. These documents had dynamic recommendations that were based on rules of thumb, not on actual research. The research team also contacted international heavy move companies and found the same results. The only significant literature on tolerances was two guidelines published by the Precast/Prestressed Concrete Institute (PCI) and the American Concrete Institute (ACI).

These publications on precast element tolerances were a helpful start in the development of a national guideline. The project team met with the PCI Tolerance Committee, which oversees the publication of the PCI document, and discussed the basis for the specified tolerances. It was found that the various PCI committees had set recommended tolerances based on a history of plant fabrication and what was reasonable to be achieved on a regular basis—not on hard data analysis.

TOLERANCE RESEARCH FOR PREFABRICATED ELEMENTS

The research team developed a basic statistical data analysis process in which results from actual plant fabrication could be used to develop a reasonable tolerance limit for various dimensional aspects of the elements. The team tried to obtain significant data for analysis; however, little information was available in plant records as these typically only indicate tolerance quality as a pass–fail score. Large volumes of actual dimensional variation data were not available. In the end, however, the tolerances used by PCI were found to represent a reasonable starting point for a national guideline.

In the future, if data become available, the statistical methods developed in the NCHRP project research can be used to verify the suggested tolerances. Recommended tolerances were developed for all commonly used bridge elements (see Figure 1, page 51).

In element tolerances, specifications for joint width tolerances are a major knowledge gap. The width of joints between individual prefabricated elements can be affected by erection tolerance and up to six different element tolerances. A conservative approach that assumes

Photo: Massachusetts DOT

Photo: FHWA

Left: A new bridge superstructure is lifted into place by an SPMT in a Massachusetts DOT ABC project to replace River Street Bridge in Boston. Right: Traditionally, reasonable tolerance limits of bridge elements have been based on a history of plant fabrication. An NCHRP project developed statistical methods to recommend tolerances.

all maximum tolerances occur at any one joint would lead to very wide joints. The research team used Monte Carlo simulations to determine recommended joint widths based on the probability of occurrence of each tolerance. This resulted in reasonably wide joints that would accommodate all tolerances with a 95% probability.

DYNAMIC RESEARCH FOR BRIDGE MOVES

The dynamics of bridge moves are important to bridge owners. Concerns include the forces imparted on the bridge during a move, which can lead to damage, as well as the forces acting on the falsework supporting the bridge. The research team hypothesized that a bridge move is akin to a man-made earthquake—the SPMT generates horizontal and vertical accelerations that are similar to ground motions during seismic events, and the falsework and bridge are similar to structures exposed to seismic ground motions. A structure's stiffness would affect the level of forces borne during the move.

The research team studied this theory by measuring base accelerations on a loaded SPMT unit. Several loads were applied to the SPMT to identify any variations in accelerations with different loads. The SPMT then was moved using a preset series of typical maneuvers used during bridge moves and was operated at the highest possible speed to establish an upper bound on the dynamic effects. The photo on page 52 shows a typical test setup.

The results of the testing were used to develop response spectra for both horizontal and vertical motions as well as load combinations and factors. The team also developed an analysis method for bridge dynamics that is similar to seismic design of bridges.

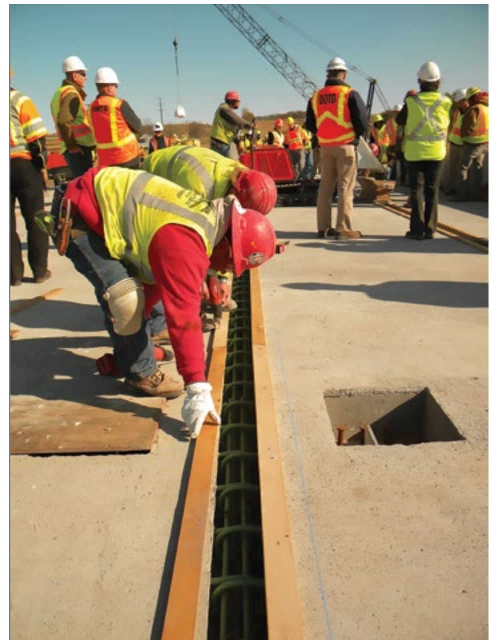


Photo: FHWA

Workers prepare to fill the deck joint between two precast modular deck units. An NCHRP project addresses specifications for joint width tolerances, a need particular to prefabricated elements.

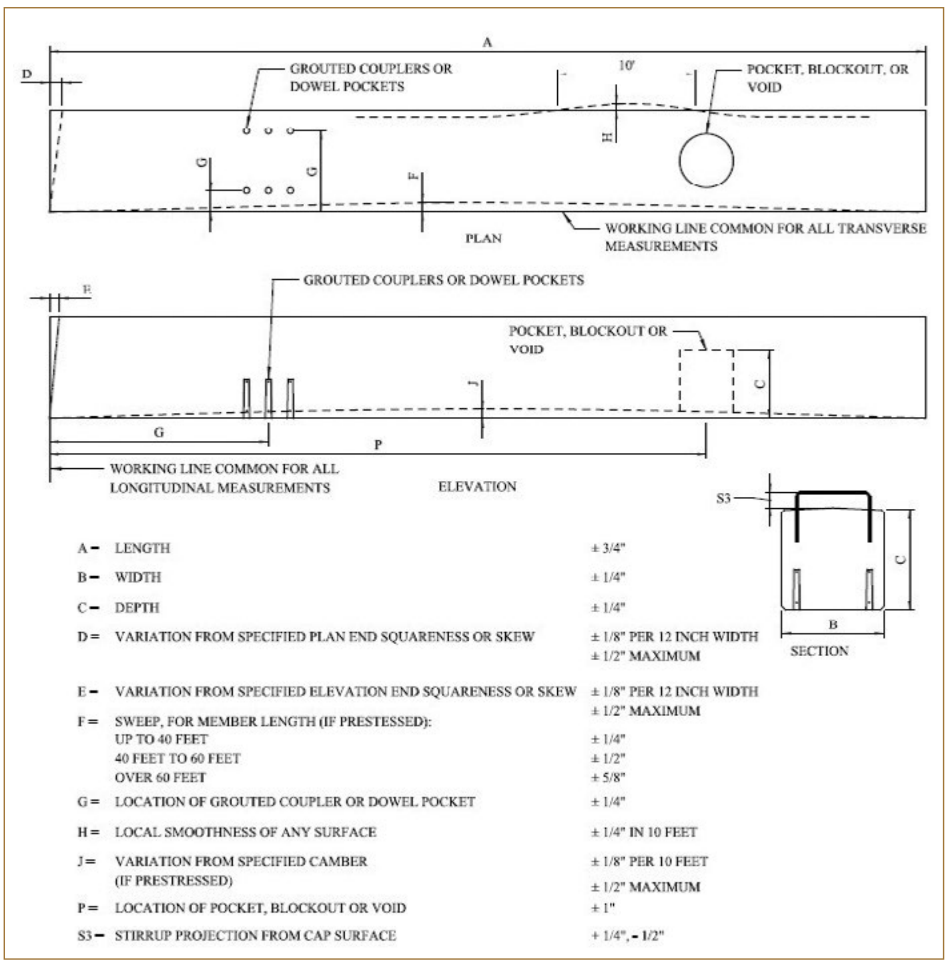


FIGURE 1 Example of a tolerance specification for a precast concrete pier cap.

Additional research was conducted as part of NCHRP 12-98 to study the friction of bridge sliding systems. The results of this research led to recommended design values for lateral slide bridge installations.

GUIDELINES

Using the research data, the team developed two specification-style documents that can be used by designers of ABC projects, published as *NCHRP Web-Only Document 243: Recommended Guidelines for Prefabricated Bridge Elements and Systems Tolerances and Recommended Guidelines for Dynamic Effects for Bridge Systems.*

The guidelines are written in AASHTO specification format with guidelines and commentary. With these documents, designers and contractors now can design and detail prefabricated elements with reasonable tolerances and design bridges and falsework for bridge systems.

Photo courtesy Michael Culmo

Typical SPMT testing setup.

NCHRP 12-102 Research

The goal of NCHRP 12-102 was to develop a national guide specification for all forms of ABC. A significant body of past research was available, but there was no single source of design and construction guidance. No new research or testing would be completed as part of this work, although the team was charged with identifying knowledge gaps in the research that could lead to future studies. The team also queried bridge owners to determine which ABC technologies are in use.

An extensive literature search identified the state of knowledge regarding ABC. As anticipated, ABC is the subject of a substantial body of work. The research team collaborated with the NCHRP project panel to develop a technology readiness evaluation process. Each major ABC technology was evaluated using the following weighted scoring process:

- Level of testing and completeness of research: 25%
- Presence of recommended specifications: 15%
- Level of implementation of the technology on actual projects: 30%
- Long-term durability of the technology: 30%

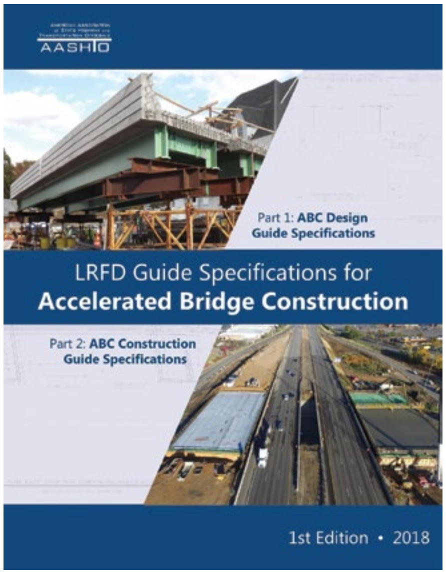
The weights for each criterion were recommended by the research team and coordinated with several state bridge engineers participating on the project panel. The goal of this approach was to gain widespread acceptance of the proposed guide by owner agencies. Each ABC technology was scored, and a threshold value was set for inclusion in the guide. Technologies that met the threshold would be included in the guide, and others would be included in the project report.

The culmination of the project was the development of a complete ABC design and construction guide specification, titled AASHTO *LRFD Guide Specifications for Accelerated Bridge Construction*. All forms of ABC are covered in the specification, as well as both seismic and non-seismic provisions, making it a go-to document for ABC projects.

The NCHRP 12-102 project team carefully developed the guide to be consistent with AASHTO design and construction specifications, including notation, definitions, and references. Each provision has specification language on the left side of the page, and commentary on the right

Photo: Vermont Agency of Transportation

A lateral bridge slide on I-91 in Hartford, Vermont. The study of friction in bridge sliding systems led to recommended design values for lateral slide bridge installations.



For details on the AASHTO *LRFD Guide Specifications for Accelerated Bridge Construction*, visit https://store.transportation.org/Item/PublicationDetail?ID=4134.

side. The document was carefully written to dovetail with the work completed under NCHRP 12-98, and the guidelines developed under that project are referenced where appropriate.

Moving Research into Practice

The deliverables for the two NCHRP projects included two guidelines and one guide specification. Guidelines are informational documents that provide guidance to designers. Specifications differ from guidelines, however. In AASHTO publications, specifications—for example, the *LRFD Bridge Design Specifications*—are considered to contain mandatory design requirements unless superseded by an owner agency. Though written in a similar format, guide specifications are considered optional. The ultimate goal of NCHRP 12-102 was to develop an AASHTO guide specification.

Special care was taken to develop a document that not only looked like an AASHTO specification but that included the same level of detail and approach. The grammar used for specifications is important—words such as "shall," "should," "may," and "recommended" all have particular, distinct meanings:

- The term "shall" indicates a requirement for compliance with the specifications.
- The term "should" indicates a strong preference for a given criterion.
- The term "may" indicates a criterion that is usable—but other local and suitably documented, verified, and approved criterion may also be used in a manner consistent with the LRFD approach to bridge design.
- The term "recommended" is used to give guidance based on past experiences.

These distinctions are very important, therefore every provision must be weighed for the proper wording to convey the intent of the provisions.

Upon completion of NCHRP 12-102, the research team worked closely with the AASHTO T-4 Committee on the process of securing the guide specification's adoption as an AASHTO publication. This process involved a review of the entire document by all voting members. All 50 states were asked to review the document in detail. The result was hundreds of comments that needed to be resolved. The majority of the comments were editorial; however, some significant comments also needed to be addressed. Through many meetings, the project team worked with the AASHTO T-4 Committee to resolve the comments. The work was complicated and arduous, but well worth the effort; the document improved as a result.

The dynamics of bridge moves are important to bridge owners. Concerns include the forces imparted on the bridge during a move, which can lead to damage.

Photo: Arizona DOT

Using ABC techniques, Arizona DOT partnered with other agencies to build a bridge over Oatman Highway in 96 hours.

In June 2017, a ballot item on the adoption of the guide specification was put forth to the AASHTO Subcommittee on Bridges and Structures. Further comments were offered during the balloting process and changes were made up to the last minute. In the end, the ballot item passed, and the document technically became an AASHTO publication.

After the ballot process, several states still had reservations on some articles in the document. AASHTO and the T-4 Committee took an unusual course of action: the final publication of the document would be postponed for one year while these issues were worked out.

What followed was more meetings and revisions. At the 2018 annual meeting of the newly renamed AASHTO Committee on Bridges and Structures, the guide specification was reballoted and adopted a second time. In November, AASHTO formally published the *2018 AASHTO LRFD Guide Specifications for Accelerated Bridge Construction*. The AASHTO T-4 Committee decided to use the guidelines developed under NCHRP 12-98 as references to the guide specification, as noted in several applicable provisions.

Through the dedicated work of the AASHTO T-4 Committee and the project team, the deliverables have moved to the forefront of the ABC industry.

The following people were involved in the research for these two NCHRP Projects:

NCHRP Project 12-98

Michael P. Culmo, CME Associates, Inc., *principal investigator*
Jennifer Pixley, CME Associates, Inc.
Marvin W. Halling, Utah State University
Marc Maquire, Utah State University
Paul Barr, Utah State University
Kris Johnson, Utah State University
Dennis Mertz

NCHRP Project 12-102

Michael P. Culmo, CME Associates, Inc., and Lee Marsh, Berger ABAM, *principal investigators*
Stuart Bennion, Berger ABAM
Paul Smith, Berger ABAM
John Stanton, University of Washington
Dennis Mertz

The implementation process did not end after the guide specification's adoption. The project team has delivered several presentations on the document at conferences and webinars. Florida International University's ABC University Transportation Center hosted several webinars on both NCHRP 12-98 and 12-102, with an estimated attendance of more than 3,000 people. The research team and NCHRP also seek to develop more in-depth training for the implementation of the guide specification.

Conclusion

NCHRP Projects 12-98 and 12-102 are prime examples of how research can be moved into practice. Too often, research is completed and placed on a shelf or in a library. Through the dedicated work of the AASHTO T-4 Committee and the project team, the deliverables have moved to the forefront of the ABC industry.

"The guide specifications developed under NCHRP 12-102 and 12-98 fill a knowledge gap in the bridge engineering community that will help to facilitate the implementation of ABC across the country," notes Carmen Swanwick, Utah Department of Transportation (DOT), and Chair of the AASHTO Committee on Bridges and Structures.

The *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction* now represent the national standard for ABC and can be used by all owner agencies and designers. The document will bring uniformity of design to all ABC projects—a uniformity that is based on sound research.

Acknowledgments

The project team acknowledges the significant efforts of Carmen Swanwick, Region Two Deputy Director, Utah DOT, and Chair, AASHTO Committee on Bridges and Structures, and Waseem Dekelbab, Senior Program Officer, Transportation Research Board.