SUMMARY OF PRODUCT

SHRP2 PRODUCT CLOSE OUT REPORT

Service Limit State Design for Bridges (R19B)

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REGARDING	Close Out of SHRP2 Product: Service Limit State Design for Bridge (R19B)

Background and Purpose

As part of the Second Strategic Highway Research Program (SHRP2) program, the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) initiated the R19B product, *Service Limit State Design for Bridges*, to develop a framework for the statistical calibration of the service limit state in AASHTO LRFD and, where possible, to perform the calibration. FHWA/AASHTO provided product implementation oversight to ensure consistent messaging throughout the implementation.

Tasks completed under the R19B product included:

- Assessing the principles of the statistical calibration of design specifications for structural and geotechnical processes.
- Developing the general calibration process for service limit states.
- Determining specific requirements of service limit states.
- Revising the general calibration process for the unique requirements of each calibrated service limit state.

The results of the research for each limit state were presented and the required revisions to the design specifications were identified.

Executive Summary

The *Service Limit State Design for Bridges* product is one of several SHRP2 products that focus on achieving uniform, longer life span of bridges and provide transportation agencies with guidelines and specifications that allow them to achieve this goal. The R19B product is unique in that once it is completed, the typical user of the design specifications only sees the design provisions that were developed or revised based on research results; however, the processes and calibration methods that form the basis for the specification will be used in the future as researchers make iterative revisions to the specifications as more bridge performance data become available. Understanding the background of the relevant specifications articles allows owner agencies to incorporate site and region-specific requirements, particularly in the area of foundations design.

Deliverables

SHRP2 *Service Limit State Design for Bridges* (R19B) Product Activities and Deliverables include:

- Participated in an FHWA/AASHTO coordination meeting in Washington, D.C.
- Conducted a review and summarized the status of specifications revisions implementation at of the start of the project.
- Developed a white paper, Incorporation of Foundation Movements in AASHTO LRFD Bridge Design Process, on foundations calibration based on the concepts that that were originally developed in the R19B project. The white paper documents the process of calibration and implementation and provides examples to guide agencies as they develop their regional load factors for settlement. The paper is posted at: http://shrp2.transportation.org/Pages/R19B_ServiceLimitStateDesignforBridges.aspx.
- Developed an Implementation Report, Expanded Database for Service Limit State Calibration of Immediate Settlement of Bridge Foundations on Soil, which expanded upon the work of the white paper mentioned above to support balloting of the proposed AASHTO LRFD code changes. The report is posted at the site noted above.
- Provided on-call support to AASHTO technical committees on R19B implementation related to revisions to design specifications.
- Attended one meeting of the AASHTO Technical Committee on Loads (T5) (October 2015) and two meetings meeting of the AASHTO Technical Committee on Substructure and Foundations (T15) (October 2015 and June 2016). Making presentations for the foundations movements related work during all meetings attended.
- Attended two annual meetings of the AASHTO Subcommittee on Bridges and Structures (SCOBS) to monitor the progress of ballot items related to R19B work and make presentations on foundation movements related work.
- Developed materials for the R19B 1.5 day training course addressing structural and geotechnical issues related to service load design (a copy of the typical training agenda is attached).
- Provided 1.5-day training to:
    - 16 attendees from the FHWA Western Federal Lands Highway Division (WFLHD).
    - 23 attendees from the FHWA Eastern Federal Lands Highway Division (EFLHD).
    - 61 attendees from the FHWA Central Federal Lands Highway Division (CFLHD).
- Attended and delivered presentations at:
    - International Bridge Conference (IBC) in June 2016.
    - 42nd Southwest Geotechnical Engineers Conference in May 2017.
    - Preparation of a second White Paper explaining changes.
- Prepared the SHRP2 Project Close Out Report.

Outcomes

Groundbreaking Work involving Calibrating Service Limit States in Bridge Design

The SHRP2 R19B *Service Limit State Design for Bridges* project provided groundbreaking work on the calibration of the service limit states in bridge design. With this work, AASHTO LRFD Bridge design

specification is the first major bridge design specification where the service limit states have been statistically calibrated. The results of the project with regard to the calibration of foundations settlement were included in an agenda item for the June 2018 SCOBS meeting which was successfully passed. The results from the calibration of the following limit states had already been incorporated via revisions to the design specifications or via commentary to relevant design provisions:

- Tension in prestressed concrete components under Service III load combination.
- Fatigue of steel components under Fatigue I and Fatigue II load combinations.
- Yielding of steel components under service II limit State.
- Deflection of superstructures under service I load combination.
- Control of Cracking of reinforced concrete components through the distribution of reinforcement under Service I load combination.

Ability to Quantify Uncertainty in Foundation Movements

The fundamental and most impactful outcome of the R19B product is that bridge designers now have a method by which to quantify uncertainty as it relates to foundation movement. In addition to significant revisions to the load factors for tension in prestressed concrete and for fatigue in structural steel components, R19B resulted in the development of a new process for incorporating foundation settlement into design, based on a statistically-calibrated process that was developed during this project. The project also resulted in comments added to several other areas of the AASHTO LRFD to bring service limit state design issues to the attention of the specifications users. Through this project, a general calibration process for service limit states was developed and the general process to fit the requirements of different service limit state design criteria existing in the specification was revised. The calibration resulted in revisions to the relevant provisions of the design specifications. The ability for an agency to calculate uncertainty represents and paradigms shift in the discipline and key accomplishment.

Provided a Practitioner Understanding of Service Limit State Calibration

Training provided background on the service limit state calibration It also showed participants how to correctly apply the specifications, understand the background of the revised specifications provisions, and identify situations where it is beneficial to develop site-specific load factors (e.g., using route-specific traffic data and settlement estimation based on regional practice and geologic formations which in turn can help promote use of most cost effective shallow foundation instead of costlier deep foundations).

Summary

The R19B product was highly successful in that it resulted in pioneering calibration for foundations followed by training on service load design which provided the attendees with the background and basics of the statistical calibration of bridge design specifications with emphasis on the calibration of the service limit states. It also presented the unique aspects of each limit state calibrated and the modifications to the general calibration process that were required to achieve the calibration of each limit states. In addition, the training presented the attendee with the foundation design knowledge that will allow them to incorporate local and site-specific conditions in the specifications.

Suggested Future Activities or Needs to Support State Efforts

To maximize use of the statistical calibration and amplify the associated benefits, additional support in implementing and training and outreach is necessary. The trainings that were completed as part of this product were highly successful. Given that this represented the initial finalization and launch of the tool, however, the following future activities are recommended:

1. Continue to support AASHTO T15 efforts in incorporating the research results from the calibration of the foundation settlements limit state.
2. Conduct additional regional training sessions and provide assistance in implementation through training and opportunities for mutual group support and collaboration. As states add data, they will produce unique data sets with slightly different values. They may require support in processing the data sets. There is a role for agencies to support states in this manner during implementation.
3. Have implementing agencies share experiences.
4. Ensure that there is varied distribution of agency (federal agencies, locals DOTs, city agencies or DOTs, U.S. Forest Service, etc.) and consultant training participants as well as those from structural and geotechnical disciplines.