2008
Research Needs Priority Topics
Committee for Foundations of Bridges and Other Structures
AFS30

1. Consideration of QA and QC Results in LRFD for Deep Foundations of Transportation Bridges

AASHTO's LRFD design specifications for deep foundations list various methods of bearing capacity verification together with statistically or otherwise derived resistance factors. For deep foundations which, once installed, cannot be directly inspected, frequently used testing and monitoring methods exist for QA and QC. However, while bearing capacity tests may be directly translated into a reduction of the overall factor of safety and thus a potentially improved foundation economy, this is currently not the case for the QA/QC methods even though they make an important contribution to the overall safety of the foundation. QA/QC methods have specific benefits and limitations and, for that reason, they should be specified with capacity reduction factors which are related to both foundation type/material and testing method. It is recommended that the impact of QA, QC and load testing methods on foundation economy, construction time and overall safety factor be studied as a basis for an appropriate set of capacity reduction factors. This effort would pave the way for an improved realization of the benefits of both the LRFD approach and the QA/QC methods.

2. Asset Management Practices for Structure Foundations

Sustainable infrastructure systems require consideration of structure renewal and replacement during the project delivery phase and throughout operation. Inspection and maintenance practices, innovative technologies, and advances in accelerated construction technologies are extending the life of structural assets. In nearly every case where bridge structures receive adequate maintenance and preservation or component replacements, all which extend the systems operational life, no consideration is given to the structural condition of the foundation elements. Sustainable infrastructure practices reach beyond end-to-end solutions, allowing proper consideration and planning for renewal and replacement throughout an asset's life-cycle. Continuing to build new bridge structures on new alignments is not a sustainable practice for transportation organizations and stakeholders.

The design life of bridge structures will continue to increase with government and industry programs focused on innovative technologies, accelerated construction, preservation, and replacement techniques that delay total replacement of bridge infrastructure systems. New super- and substructures constructed using existing foundation systems within established rights-of-way will be necessary to produce significant project schedule and cost savings associated with accelerated construction and reductions in material quantities, as well as the numerous other associated tangible benefits.

Research is needed to close the notable gaps that exist in the geo-communities ability to apply asset management practices to structural foundations. Gaps include condition assessments at a point in time, shapes and scales of degradation curves through time, consideration of condition in the LRFD platform, and integration into the National Bridge Inspection Standards (NBIS) and the National Bridge Inventory (NBI) via recording and coding foundation elements.

3. **Calibration of AASHTO *LRFD Specifications* for Loads Transferred to Bridge Foundations**

Previous researchers have addressed the uncertainty associated with modeling errors and corresponding calibration of resistance factors needed for the design of foundations using the AASHTO LRFD Highway Bridge Design Specifications (*LRFD Specifications*). These efforts have assumed that the magnitude of loads, load statistics and the load factors used for the design of bridge superstructures are equally applicable for the design of substructures, but these assumptions have not been validated. For example, limited data suggest that the magnitude of loads, and vehicle live loads in particular, are less than assumed for design. Consequently, the goal of the *LRFD Specifications* to achieve a more consistent level of safety in the design of structure components has not been fully realized for structure foundations because the reliability of loads used for foundation design have not been properly considered. Research is needed to evaluate loads transferred to bridge foundations and to calibrate load factors considering the appropriate foundation loads and load statistics. The proposed research should employ analytical modeling, controlled load testing, or performance monitoring of in-service bridge structures to study the magnitude and variability of foundation loads.

4. **Actual Performance of Common Structure Foundation**

Classical research in the field of structure foundations has often focused on either unusual foundation types and or poor foundation conditions. With the advent of LRFD there is an information gap about the actual performance of typical foundation types in average foundation conditions. Existing databases that have already been mined for foundation performance information to develop the factors for LRFD do not contain much performance information for typical conditions. Actual deflections of spread footings on competent soils, lateral and vertical deflections of driven pile foundations, or lateral deflections of various retaining wall types in service would help shape the factors needed for intelligent LRFD. Very few agencies have compiled load/deflection characteristics for such ordinary construction, because problems were not expected and the information did not have an obvious use. To properly assess the factors needed for LRFD, physical research into the performance of ordinary structures would be most helpful."

5. **Reliability-Based Calibration of LRFD Specifications for Design of Micropile Foundations**

Micropiles have been used with increasing frequency as structural elements for bridge foundation support to resist static and seismic loading conditions, and as in-situ reinforcements for slope and excavation stability. While several states have used micropiles for support of transportation structures, their wide-spread application will continue to be limited because no AASHTO specifications exist for their design and construction. To help overcome this limitation, ADSC: The International Association of Foundation Drilling (ADSC-IAFD) and the Deep Foundations Institute (DFI) sponsored development of design and construction specifications prepared in the format used for the AASHTO LRFD Bridge Design Specifications (*LRFD Design Specifications*) and LRFD Bridge Construction Specifications (*LRFD Construction Specifications*). These specifications were presented to T-15 of the AASHTO Bridge Committee during the 2003 meeting in Albuquerque, NM for their consideration as guideline specifications. To facilitate development of the guideline specifications for the design of micropiles for highway bridge structures, calibration of resistance factors was accomplished by fitting to allowable stress methods used for micropile design. So while the guideline *LRFD Design Specifications* provide designs that compare reasonably well with current design practice, the resistance factors were not developed using the preferred reliability-based calibrations methods used to calibrate the design specifications. Therefore, if micropiles are to become viable foundation support alternative for new highway structures, for underpinning and seismic retrofit of existing structures, and for scour protection, reliability-based calibration of resistance factors used for their design is required.

6. **Resistance Factor Calibration including Site Variability, and Number of Static Load Tests Needed for Deep Foundations**

Site variability and number of static load tests with corresponding resistance factors have been incorporated in the AASHTO 2008 Specifications. However, the COV used in the step by step criteria (in the commentary) to categorize site variability is not proper because it uses the average SPT, q_c and etc. property value for each “significant stratum” (Step 1) and then uses the mean and standard deviation of this stratum at each location to obtain the COV (Step 2). This COV, however, does not account for horizontal space between borings; therefore, it should not be considered the site variability. Furthermore, high variability site defined as COV larger than 40 percent is also not proper since the field test properties themselves contain COV larger than 40 percent. Therefore, research should be carried out to;

1. Calibrate resistance factors to incorporate sample distance (a computer program/simplified method should be written for this task);
2. Determine required number of static load tests for each site based on (1) for various site variability;
3. Establish a method to zone and categorize a project site (e.g. a long highway bridge) with similar variability and assign a proper variability category, thus, the number of static load tests requirement for each zone to obtain a resistance factor for that zone.