I. Problem 1: Reevaluation of Permanent Load Factors for Load and Resistance Factor Design

II. Research Problem Statement

The AASHTO LRFD Highway Bridge Design Specifications (LRFD Specifications) were developed with the intent of implementing a more rational approach for the design of highway structures. As opposed to allowable stress design (ASD), wherein all uncertainty is embedded within a factor of safety, the LRFD approach applies separate factors to account for uncertainty in load and material resistance. The load and resistance factors developed for NCHRP 12-33 were calibrated using a combination of reliability theory, fitting to ASD, and engineering judgment. Calibration using reliability theory is preferred because the approach permits selection of a target reliability or safety index which reflects the probability of failure of a structure component. However, reliability-based calibration requires access to sufficient data to statistically define the variation and distribution of load and resistance using mathematical relationships. Calibration by fitting and judgment is used in conjunction with reliability-based calibration or in lieu of reliability-based calibration when sufficient data are not available, to ensure that designs are comparable with accepted engineering practice.

Loads are either transient or permanent. Transient loads include components from vehicles, wind, impact, pedestrian, water and stream forces, collision forces from vessels and vehicles, earthquakes and ice loads. The load factors in the LRFD Specifications for a majority of transient load types were developed primarily using reliability theory and load test data. The load factors for permanent loads in the LRFD Specifications are presented in Table 1. Except for the dead weight of structure components and attachments and the weight of wearing courses for which load factors could be developed using reliability theory, the load factors for other permanent loads used for substructure design were developed subjectively using engineering judgment, and the judged relative reliability as compared to the range of γ_{Pmax} and γ_{Pmin} established for other permanent loads for which load statistics were better known.

Table 1
Load Factors for Permanent Loads, γ_P (AASHTO, 1998)

Type of Load	Load Factor	
	Maximum	Minimum
DC: Component and Attachments	1.25	0.90
DW: Wearing Surfaces and Utilities	1.50	0.65
DD: Downdrag	1.80	0.45
EH: Horizontal Earth Pressure		
• Active	1.50	0.90
• At-Rest	1.35	0.90

EV: Vertical Earth Pressure • Retaining Structure • Rigid Buried Structure • Rigid Frames • Flexible Buried Structures • Flexible Metal Box Culverts	 1.35 1.30 1.35 1.95 1.50	 1.00 0.90 0.90 0.90 0.90
ES: Earth Surcharge	1.50	0.75

An example of concerns which may be raised regarding the load factors in Table 1 is the relative values of γ_{Pmax} for horizontal earth load. Active earth pressure represents a limit state condition for soil such that the active earth pressure is simply a function of the shear strength of the soil. Conversely, at-rest earth pressure can only be defined if information is available regarding the shear strength and stress history of the soil. As such, the at-rest earth pressure is <u>not</u> a limit state. As values of γ_{Pmax} should reflect the reliability or certainty of correctly estimating a load effect, the value of γ_{Pmax} for active earth pressure should be less than the value for at-rest earth pressure because k_a can be estimated solely based on an estimate of the shear strength of the soil. Interestingly, the relative values of γ_{Pmax} for active and at-rest earth pressures are such that the factored force effects from either load type would usually be about the same.

Another illustrative concern in regard to load factors in Table 1 is their applicability to short-term loading of temporary structures. The load factors in the LRFD Specification were developed for a design life of 75 years. During the construction phase of project however, support of short-term excavations is required. Unfortunately, the LRFD Specification provides no information regarding the load factors to be used for this type of design. As a result, resistance factors calibrated for temporary design result in unusually high values of ϕ because all of the uncertainty regarding the temporary loading must be incorporated in ϕ unless some guidance is available for corresponding values of load factor.

III. Research Objective

The objectives of the research would be to:

- Compile and evaluate data on the variation and distribution of permanent loads for vertical and horizontal earth pressure, earth surcharge and downdrag
- Using reliability-based methods where practical, perform calibration analyses to develop recommended values of γ_{Pmax} and γ_{Pmin} for permanent loads needed for substructure design
- Develop recommended revisions to resistance factors needed for substructure design consistent with the calibration work for related studies

Related Work

Calibration of resistance factors for a recently completed NCHRP project (NCHRP 20-7, Task 88, Developing New AASHTO LRFD Specifications for Retaining Walls), an ongoing project (NCHRP 12-45, Recommended Specifications for Large-Span Culverts) and an upcoming NCHRP project (NCHRP 24-17, LRFD Deep Foundation Design).

IV. Estimate of Problem Funding and Research Period

The estimated cost is less than $250,000

V. Urgency, Payoff Potential and Implementation

Initiation of this work is urgent. The calibration of resistance factors for a recently completed NCHRP project (NCHRP 20-7, Task 88), an ongoing project (NCHRP 12-45) and an upcoming NCHRP project (NCHRP 24-17) have had to or will need to rely on the validity of the AASHTO load factors for permanent loads. Because the permanent load factors used for this calibration work were not developed using reliability theory, a primary feature of the LRFD approach (i.e., similar safety margins in the design of structure components) is not completely possible due to the origins of the permanent load factors in the LRFD Specifications.

User Community
Engineers using the AASHTO LRFD Highway Bridge Design Specifications for substructure design.

Implementation
This project should be implemented through NCHRP.