Uncertainty Evaluation of Displacement and Capacity of Shallow Foundations on Rock

Principal Investigator: Samuel G. Paikowsky
Graduate Research Assistant: Robert Muganga (M.Sc)
Research Funded By: National Academies NCHRP 24-31
Date: Spring 2008

ABSTRACT

NCHRP project 24-31 "LRFD Design Specifications for Shallow Foundations" has the objective of developing and calibrating procedures and modifying AASHTO Section 10 (foundations) specifications for the strength Limit State Design (LSD) of bridge shallow foundations. Based on a 2007 questionnaire conducted as part of that project, 40 states reported that 72.6 percent of the shallow foundations built for bridge structures are constructed on/in rock and Intermediate Geomaterials (IGM's). In contrast, few studies have been carried out to examine the accuracy of the available design methods to predict bearing capacity and/or settlement of shallow foundations on rock. A database of 122 load tests on rock-sockets' base and shallow foundation case histories constructed in and on rock or IGM was assembled to investigate the predictability of five (5) bearing capacity and two (2) settlement design methods. The investigated bearing capacity design methods are: (a) semi empirical method by Carter and Kulhawy (1988), (b) analytical method by Goodman (1989), (c) Hoek and Brown (1980) failure criterion, (d) bearing capacity factor (N_c^*) and unconfined compressive strength (q_u) relations based on the methodology presented by Zhang and Einstein (1998) and examined in this study, and (e) relationships between the measured-interpreted bearing capacity (q_{L2}) and unconfined compressive strength (q_u) modified in this study to be a function of rockmass quality, utilizing AASHTO (2007) RMR ranges. The investigated settlement design methods are: (a) Kulhawy (1978) method and; (b) normalized hyperbolic-model. The effect of joints or discontinuities on the bearing capacity of shallow foundations on rock was investigated using PLAXIS Version 8 Finite Element Code and the results were compared to previous analyses and the database case histories behavior.

The distributions of the biases, i.e. the ratios of the measured to calculated bearing capacity and settlement were used to establish the uncertainty of the methods. The obtained uncertainties suggested that Carter and Kulhawy (1988) method has varied bias depending on the rock's quality and strength with large under-prediction of bearing capacity for low quality rock (i.e. $3 \leq RMR < 44$). Goodman (1989) method was systematically accurate and reliable for all rock qualities. The Hoek and Brown (1980) method consistently under-predicts the bearing capacity (on the safe side) for all rock qualities with significant scatter. Using regression analysis, good quality correlations were obtained for the relationship between the bearing capacity factor (N_c^*) and the unconfined compressive strength (q_u), and between the interpreted bearing capacity (q_{L2}) and unconfined compressive strength (q_u) for foundations of fair to excellent quality rock (i.e. $44 \leq RMR < 100$). The subdivision of the correlations between q_u and the bearing capacity based on RMR ranges provided systematically reliable correlations. Kulhawy (1978) method seems to better predict the settlement of footings on rock while the hyperbolic model seems to better predict the settlement of the base of rock sockets.

Based on the above observations, example analyses of shallow foundations on rock were established and the uncertainty associated with the design, demonstrated.

Thesis Committee:

Dr. Samuel Paikowsky, Advisor and Research PI, Committee Chair
Mr. Helmut Ernst, Chief Engineer, Massachusetts Turnpike Authority
Mr. Nabil Hourani, Head Geotechnical Section, Massachusetts Highway Department
Dr. Pradeep Kurup, Prof., UMass Lowell
Dr. Herbert Einstein, Prof., MIT