Reliability Index Update for Driven Piles Based on Bayesian Theory Using Pile Load Test Results

J.H. Park, D. Kim, and K. Kwak
Geotechnical Engineering Research Division, Korea Institute of Construction Technology, Goyang-si, Gyeonggi-do, Korea

Y. Choo, and C.K. Chung
Department of Civil and Environmental Engineering, Seoul National University, Seoul, Korea

ABSTRACT

Typically, for static pile load test on an axially loaded driven pile, pile is loaded up to twice its design loads. The pile is considered safe if it can resist the maximum test load (twice its design load). However, in the conventional reliability analysis, the non-failed pile load test results had no effect on reliability index calculation. In this paper, an analytical method is used to update reliability index of driven piles based on the Bayesian theory using pile load test results even not conducted to failure. The prior information regarding pile resistance is constructed based on the results of fifty seven static pile load tests performed to failure in South Korea. The prior information includes bias factor, coefficient of variation, and distribution type of the ratio of measured-to-predicted pile resistances. This prior information of measured-to-predicted pile resistances ratio is updated based on the Bayesian theory by adding new pile load test results. For the prediction of pile resistance in our analysis, we used the equation proposed in Korean Design Standards for Foundation Structures. Reliability analyses are performed using updated distribution of the measured-to-predicted pile resistance ratio using First-Order Reliability Method (FORM). It is noted that load tests even not conducted to failure can contribute to reliability analysis and can be used for pile design in a systematic approach.

KEY WORDS: Axially loaded driven pile; static pile load test; Bayesian update; reliability analysis; FORM.

INTRODUCTION

In recent years, geotechnical design practice has been gradually challenged to replace the allowable strength design (ASD) with the limit state design (LSD). In Europe, factored strength design (FSD) method has been established and used for a long time, and in other countries including USA and Canada are gradually implementing load and resistance factor design (LRFD) for various geotechnical structures. Calibration of resistance factor is the essential element of LRFD development, which is purely based on the reliability analysis.

Reliability analysis calculates a reliability index which is closely related to a probability of failure of the system. The reliability index reflects uncertainties (bias factor, coefficient of variation, and distribution type) of load and resistance and nominal values of loads and resistance. In this paper, we focused on how reliability index changes as the uncertainty of measured-to-predicted maximum pile capacity ratio (RM/P) updates based on the Bayesian theory.

Many researchers (Barker et al., 1991; Whitiam et al., 1998; Paikowsky et al., 2004; and Allen, 2005) collected pile load test results conducted to failure. Most of static load tests were not loaded to failure; therefore, pile load test results were not sufficient to build the uncertainty of pile maximum capacity and could not be used for reliability analysis. This was due to the fact that most of pile load tests were intended to check if the piles could resist up to twice its design load. We have collected more than 2,227 static load test data. Out of the 2,227 data, only 57 of them were conducted to failure (Kwak et al. 2008). We constructed the distribution of RM/P based on these 57 pile load test results. Collection of reliable load test data is the most important task for the successful reliability analysis.

The purpose of this paper is (1) to update the prior (or existing) distribution of RM/P (constructed based on the pile load test loaded to failure) based on the Bayesian approach by adding new RM/P data (results of static pile load tests not conducted to failure) from pile load tests and (2) to calculate reliability indices using the updated distribution of RM/P. The reliabilities of piles can be revised with the updated distributions of RM/P following the methods used in this paper. Reliability analyses are performed using the First-Order Reliability Method (FORM) proposed by Rackwitz and Fiessler (1978). This paper considers only ultimate limit state, thus issues of serviceability limit state are excluded.

BAYESIAN THEORY IMPLEMENTATION

RM/P Distribution Update Procedure using Bayesian Theory

The Bayesian approach may play an important role in engineering problems, if limited data are available for reliability analyses.