A MODIFICATION FACTOR FOR THE BEARING RESISTANCE ESTIMATION OF PILE

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INTRODUCTION

A modification factor to take account of in-situ loading test results on the ultimate bearing resistance estimation of a pile is presented based on a reliability method-the First Order and Second Moment method(FOSM). The statistics of soil properties, which are from two typical cases, the current Specification for Highway Bridges (SHB), an in-situ loading test based empirical estimation method, are used for the estimation of ultimate bearing resistance of the pile. It is concluded that the modification factor evaluated by using the empirical estimation method is approximately 1.17. The use of the modification factor will improve the allowable bearing resistance of the pile without losing its reliability in an normal design state, when an loading test has been carried out. To apply the modification factor obtained from in-situ loading test, the similarity in ground composition, strength parameters and dimensions of estimation piles and test pile should be satisfied.

PROBABILITY MODEL

To estimate the axial allowable bearing resistance from the ultimate bearing resistance for a pile, a total safety factor, n, is usually used. On the other hand, if an in-site loading test has been carried out, the uncertainties in the estimation of ultimate bearing resistance will obviously be reduced to some extent, and a modification factor, γ, to take account of in-situ loading test results, is recommended as in Eq.1 [1].

$$Ra = \gamma Ru / n > S \tag{1}$$

Where Ra is the axial allowable bearing resistance of a pile, Ru is the ultimate bearing resistance, γ is the modification factor, n is the total safety factor, and S is the total axial load applied on the pile head.

In a reliability analysis of pile bearing resistance, Ru is regarded as a random variable whose mean value, Ru, and variance, σ_R^2, are derived by the mean and variance of soil properties, such as SPT-N value and coefficient of bearing resistance α_p and α_f, according to an estimation expression for the ultimate bearing resistance, where a statistically independent relationship was provided [2]. The coefficient of variation (COV) of ultimate bearing resistance is $V_R = \sigma_R/\bar{R}u$. According to FOSM method, if the performance function Z=lnRu - lnS is provided, the safety index, β, of ultimate bearing resistance, is given by

$$\beta = \ln(\bar{R}u / \bar{S}) / \sqrt{V_R^2 + V_S^2} \tag{2}$$

Where (–) means mean value, Vs is the COV of the load, S. The meaning of β is shown in Fig.1. The larger the β is, the more the margin of safety in bearing resistance a pile has.

CASE STUDIES

There is a pile of a typical viaduct foundation. Its diameter is 1.0 and length is 15m. To estimate the ultimate bearing resistance, the statistics of soil properties from the current specification and an in-site loading test based empirical estimation method are used. Calculation results of case-(a) and case-(b) are given in Table1. Different values of COV of coefficient bearing resistance are used in these two cases. An average value of the COV of coefficient of bearing resistance all over Japan is used in case-(a), which is derived from the current specifications. While in case-(b) an in-situ loading test based empirical estimation method is used. The empirical relation is $V\alpha=0.35\bar{\alpha}f$, in which αf is the mean value of coefficient of bearing resistance obtained from an in-situ loading test, $V\alpha$ is the COV of αf. It has been known that when an in-situ loading test has been carried out, a more accurate ultimate bearing resistance could be estimated by using this empirical relation than by using the statistics derived from the current SHB [2]. Therefore, it is reasonable that the modification factor γ be assessed by using data of case-(b). In case-(a), the safety index β is 2.80 according to Eq.2, when n=3, $V_R=0.38$, $\bar{S}=Ra$ (herein $Ra=\bar{R}u/n$) and the coefficient of variation of S, Vs=0.1 corresponding to the normal state [2]. In case-(b), let $\bar{S}=\gamma \bar{R}u/n$ and substitute it into Eq.2, then γ is obtained as

$$\gamma = n\exp\left(-\beta\sqrt{V_R^2+V_S^2}\right) \tag{3}$$

Then $\gamma=1.17$ is obtained when $V_R=0.32$, n=3, Vs=0.1, $\beta=2.80$. Thus, with the same reliability index, $\beta=2.80$, the allowable bearing resistance, Ra=1990 kN in case-(a) which is estimated with the total safety factor n=3 can be improved to 2328 kN by multiplying the modification factor $\gamma=1.17$ when an in-situ loading test has been carried out.

TABLE 1. Mean and Variance of Ru
(Depending on Different Estimation Methods)

CASE	BEARING RESISTANCE	MEAN VALUE (kN) $\bar{R}u$	VARIANCE (kN^2) σ_R^2	COEFFICIENT OF VARIANCE V_R
(a)	SHAFT	2561	1615900	0.469
	TIP	3408	3527800	0.551
	TOTAL	5969	5174300	0.380
(b)	SHAFT	2561	114700	0.132
	TIP	3408	3527800	0.551
	TOTAL	5969	3642500	0.320

Fig.1

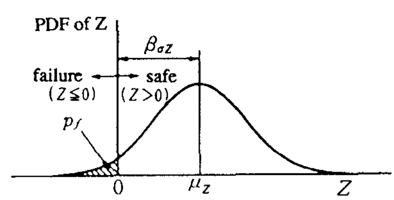

TABLE 2. Modification Factor, γ

CASE	V_S	V_R	β	n	γ
(a)	0.1	0.38	2.80	3	1.0
(b)	0.1	0.32	2.80	3	1.17

CONCLUSION AND DISCUSSION

In the case studies, the modification factor for ultimate bearing resistance estimation is 1.17, which is less than 1.2 suggested by the current specification. Therefore, the effect of in-situ loading test on the estimation of ultimate bearing resistance of pile may be overestimated by using the modification factor suggested by the current SHB, which may lead to an unsafe estimation of bearing resistance of pile in design.

To apply the modification factor obtained from in-situ loading test, the similarity in ground composition, strength parameters and pile dimensions of estimation piles and test pile should be satisfied.

REFERENCES: 1) Japan International Cooperation Agency, Specification for Highway Bridges (Part IV) 2) H. OCHIAI, X. LI, J. OTANI and K. MATSUI, Reliability of Vertical Bearing Resistance of Bored Friction Piles, the Memoirs of the Faculty of Engg. Kyushu University, Vol. 54. No. 1.