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EVALUATION OF BELLED/TYPE PILES UPLIFT CAPACITY IN SANDY AND SOFT-ROCK GROUND

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論 文 名　：EVALUATION OF BELLED-TYPE PILES UPLIFT CAPACITY IN SANDY AND SOFT-ROCK GROUND
(砂質および軟岩質地盤における拡底杭の引抜き特性とその評価)

区　　分　：甲

論　文　内　容　の　要　旨

Pile foundations have been used to reliably support superstructures. In general, pile foundations are divided into end bearing piles, bearing piles, friction piles, and tension piles. In addition, depending on the type of pile, there are ready-made piles, prestressed concrete piles, and steel piles, where depending on the purpose in-situ, pile system to be used is selected. The structure and geometry of these piles makes them very vulnerable to various forces applied in the horizontal direction. Horizontal loads are applied to structures such as transmission towers, coastal structures, and high chimneys. In addition, Natural disasters such as heavy rainfall events, typhoons, earthquakes, and tsunamis induce horizontal loads on structures. The horizontal load on the structure simultaneously induces both compressive and tensile forces at the foundation of the pile. The previous researchers have proposed various uplift resistance structure systems to effectively cope with the compressive load and uplift load generated at the foundation of the piles, where those systems are currently applied to various structures.

Among the various uplift resistance foundation systems, the belled-type pile is a construction method that has an expanded pile tip similar to the shape of a bell. This pile is effective against horizontal loading due to its shape and is considered as a reliable method not only for the compressive loading but also for the uplift loading due to the bell-shaped tip. In addition, this method generally utilizes cast-in-place concrete. Consequently, the size, length, and shape of the pile are less restrictive in comparison to the ready-made piles. Therefore, various construction cases have adopted this system for large structures. Moreover, due to the development of the construction technology, the applicability becomes higher, where it can be applied to soft-rock ground with an N value of 50. However, a robust model that considers the pile shape, penetration depth, ground conditions, and the complexity of the piles shape to evaluate the uplift resistance of the pile is still lacking. Therefore, in this study, aiming at facilitating the effective construction and design of belled-type piles, the uplift resistance characteristics and the soil behavior of the belled-type piles were investigated using a model test. In addition, based on the results of the model test, an evaluation equation considering the pile tip inclination angle of the belled-type pile was proposed. The evaluation equation proposed in this study can be used as basic data for the design of shallow sand foundation, deep sand foundation, and soft-rock foundation. The dissertation is divided into 7 chapters:

Chapter 1 discusses the research trends on the uplift resistance of belled-type piles, the specific objectives of this study, and the approach of research.

Chapter 2 provides a review of the literature on the proposed evaluation formulas and test methods. This chapter is divided into three sections. The first section examined the uplift resistance mechanisms and basic theory uplift resistance to the previous conventional pile. The remaining two sections introduce in detail the research method and the proposed model of the uplift resistance structure system.

Chapter 3 introduces the test scope and test methods of model tests. Standard of model soil, scale of model ground, method of constructing sand ground according to unit density, method of constructing soft-rock ground using soil-cement, basic characteristics of sand used in model ground, and soil-cement performed on soft-rock ground that introduces in detail the general part of the model test such as the characteristics of the model and the measuring equipment used during the model test.

Chapter 4 explains the results of model tests of conventional piles and belled-type piles performed on sandy ground. Model tests were performed on the sand ground for unit weight, pile penetration depth, and pile tip inclination angle of belled-type piles. In addition, image analysis was conducted using half-circular model tests and the shape of the failure surface of the target ground was clearly observed. Based on the result, the characteristics of the uplift resistance and the soil behavior on the unit weight of sand were confirmed, and the failure surface formation conditions of belled-type piles and the applicability of the ground on the unit weight were verified.

Chapter 5 summarizes the results of the belled-type pile model tests on the strength of the soft-rock ground, the shape of the tip of the pile and the penetration depth of the pile. Based on the results of the model test, the uplift resistance of the soft-rock ground was clearly different from the previously studied sand and clay ground. In particular, the failure mechanism, displacement characteristics and the maximum uplift load trend on soft lock ground are clearly explained.

Chapter 6 proposes an uplift resistance model for sand ground and the soft-rock ground. In the uplift resistance model for sand ground, an uplift resistance model was proposed considering the pile tip inclination angle of the belled-type pile, penetration depth and unit weight of sand. In addition, the sand ground has been proposed in two types, divided into shallow ground and deep ground in consideration of the failure surface pattern. The uplift resistance model on soft ground was proposed using uniaxial compression tests, tensile tests, etc., which were obtained through preliminary tests. The uplift resistance model proposed in this section can predict the uplift resistance of belled-type piles with general soil parameters such as internal friction angle, unit density and shear stress of uniaxial compression test without considering the shape of the failure surface.

Chapter 7 summarizes the main findings of this dissertation and delineates the future work.