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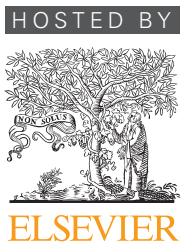

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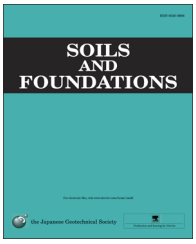

Bearing capacity analysis of open-ended piles considering the degree of soil plugging

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Abstract

This paper presents a new design approach for predicting the degree of soil plugging and the inner skin friction of axial-loaded open-ended piles. The main objective of this study was to propose the SPT-based design method considering the plugging effect, since the SPT test is commonly used to identify the subsoil condition in sandy soils. The plugging effect for open-ended piles was quantified using field plugging measurements and the results of three full-scale field pile load tests. Based on the plugging measurements, the relationship of the plug length ratio (PLR) with the soil properties, pile geometry and pile driving condition was established. Additionally, a linear relationship between the PLR and incremental filling ratio (IFR) was proposed. Full-scale tests were performed on three instrumented piles with different diameters (508.0, 711.2 and 914.4 mm). An instrumented double-walled pile system was used to measure the outer and inner skin friction along the pile shaft. Based on the results of the full-scale field pile load tests, the inner skin friction of the open-ended piles was proposed as a function of the IFR and pile diameter. The predicted values were consistent with the measured values, such as the IFR and inner skin friction. The proposed method can predict the degree of soil plugging and the inner skin friction of open-ended piles and be selected as convenient option in engineering field.

Keywords: Plugging effect; Design method; Pile load test; PLR; IFR; Inner skin friction

1. Introduction

In recent years, open-ended steel pipe piles have been frequently used in the foundations of urban and coastal structures such as harbor terminals, long-span bridges and offshore wind power structures. Because an increasing number of massive structures are being constructed, it is becoming increasingly important to consider the plugging effect the application of open-ended steel pipe piles in foundation design. Some design methods for open-ended piles have been proposed. These methods have resulted in slightly different methodologies that can generally be classified into three groups: (1) cone-penetration test (CPT)-based design methods (Paik and Salgado, 2003; Yu and Yang, 2012; Kolk et al., 2005; Jardine et al., 2005; Lehane et al., 2005; Clausen et al., 2005) (2) standard penetration test (SPT)-based design methods (Lai et al., 2008), and (3) the earth pressure approach (API, 2007). However, the existing design methods have some limitations, such as a heavy dependence on the correlations that are derived from the model tests and CPTs. It is not easy to design the bearing capacity of open-ended piles considering the plugging effect in common practical cases, because the degree of plugging is not well reflected in the design methods. On the other hand, the main idea of this study is focused on

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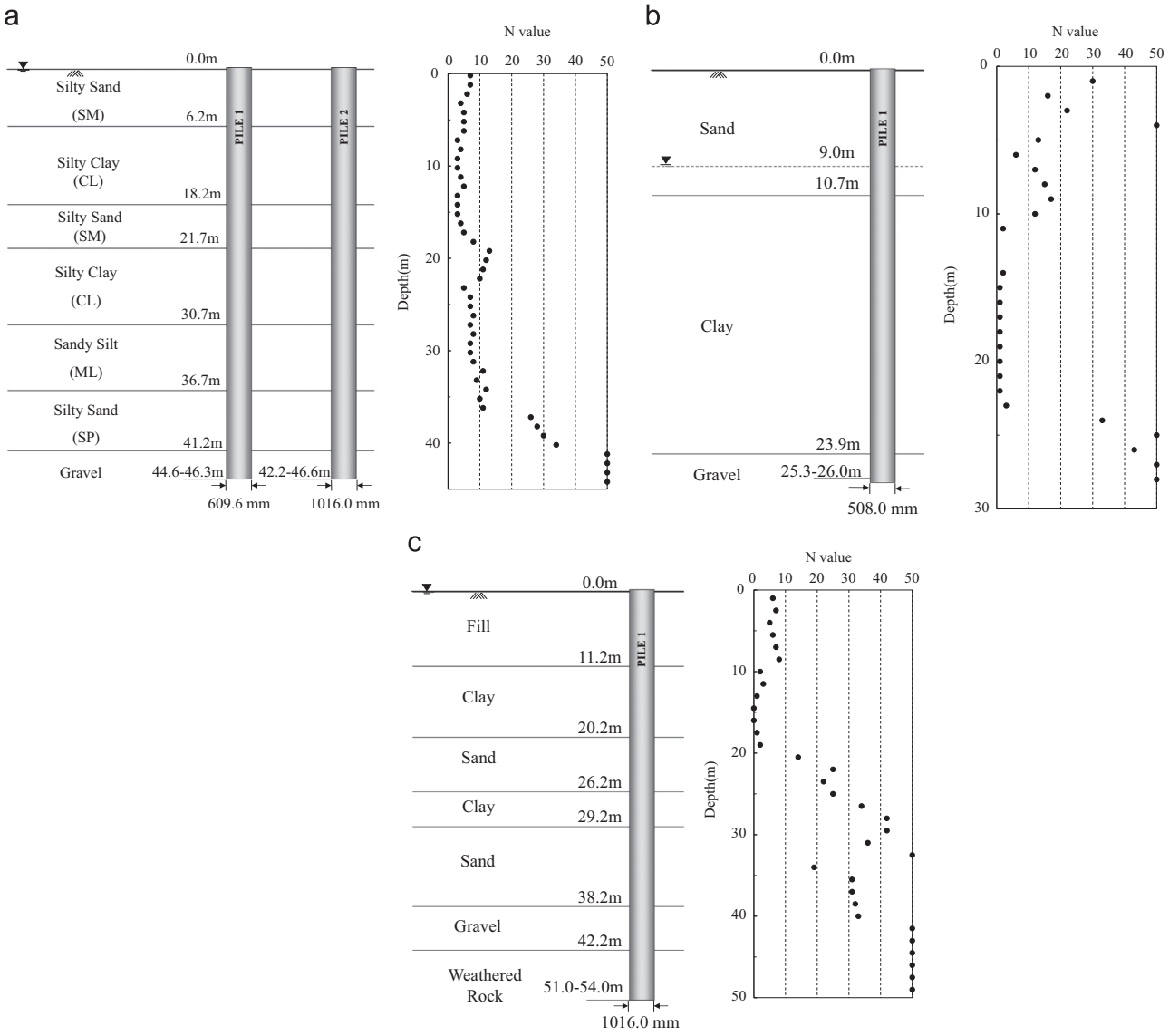

Fig. 1. Soil profile with the borehole and test piles for the PLR measurement. (a) Busan Nakdong river estuary weir site; (b) Busan Mieum district site; and (c) Incheon New Port site.

proposing the design method of driven piles in sands using SPT results. SPT test is common to identify subsoil condition especially in sandy soil. That is why the SPT-based method is selected as alternative one in engineering field.

The bearing capacity of open-ended piles is highly affected by the degree of soil plugging. Numerous studies have been conducted on the plugging effect of open-ended piles. Some researchers reported that the plugging effect of open-ended piles is highly influenced by the pile driving conditions (Brucy et al., 1991), pile geometry conditions (Beringen et al., 1979; Klos and Tejchman, 1981; Szechy, 1959; Kishida, 1967; Matsumoto and Takei, 1991), and soil conditions (Paik and Salgado, 2003). However, it is difficult to establish a distinct correlation between these factors and the plugging effect because of the complexity of the plugging effect.

The overall objective of this study is to propose an open-ended pile design methodology that considers the plugging effect using the results that are derived from full-scale tests and plugging measurements. Various influencing factors of the plugging effect should be quantified and considered when designing open-ended piles. The proposed methods were validated using a field case study. The predicted values, such as the incremental filling ratio (IFR) and inner skin friction are, compared with the measured values from the pile load tests. A new design methodology has been developed to provide a basis for a preliminary design method that would be applicable to open-ended piles taking into account the plugging effect.

2. Quantitative methods for the plugging effect on open-ended piles

The degree of soil plugging can be quantified using the plug length ratio (PLR) and IFR. The PLR is defined as the soil plug length per penetration depth at the end of the pile installation.