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ORIGINAL ARTICLE

Analysis of The arching phenomenon of bored piles in sand

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Abstract Several bored pile field-testing observations showed the arching phenomena and its effect on side shear resistance. Finite element numerical model is developed in this paper to study the arching phenomena of bored pile and the effect on the overall compression capacity of single board piles. The numerical models developed apply a hardening/softening model (multi-surface) constitutive model to account for sandy soil nonlinear behavior. 2D-axisymmetric Finite Elements single pile model has been developed and validated using several field-testings available in the literature.

The numerical study has been conducted to investigate the effect of arching close to the single pile shaft on pile bearing capacity considering three major influence factors: pile length, pile diameter and sand relative density.

The numerical analyses conducted show the importance of the arching phenomenon on the overall behavior of piles and on the prediction of bored piles bearing capacity.

1. Introduction

Pile foundation has gained popularity lately in Egypt especially in high-rise buildings and heavy structures. Side resistance is an important source of pile resistance, especially for long board piles. Several analytical methods have been developed to predict pile shaft resistant based on soil shear properties. In design practice, the unit shaft resistance (q_{sL}) is often calculated as percentage of vertical effective stress as follows:

$$q_{sL} = K\sigma'_{vo} \tan \delta \tag{1}$$

where σ'_{vo} is initial vertical effective stress, δ is the friction angle mobilized along the vertical shaft wall, and K is the lateral earth pressure coefficient at limit shaft resistance conditions. Due to axial loading of the pile, the soil around piles shears and as a result the normal effective stress acting on the shaft evolves from its initial (geostatic) value to an ultimate value. The new values for the effective normal stress will greatly affect the prediction for the shaft resistance of piles.

Terzaghi [7] proved experimentally using trapped door experiment that stresses in the soil body changes take place during soil shearing and these changes are due to shearing resistance along the boundaries between the moving and stationary mass of sand. Similarly, upon axial loading of pile and shearing of soil around the shaft while the soil lying further away from the pile shaft is stationary causing changing of the stresses along the pile shaft from initial stresses devel-

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oped before shearing. Two distinct zones are developed around the tip of the pile as a result of the downward movement of the pile, these zones are the flow zone and the arching zone as illustrated in Fig. 1 [3].

This paper studies the arching effect in bored piles in sandy soils and possible effect on pile bearing capacity using numerical modeling and advanced constitutive model.

2. Experimental data from single pile loading

The Center for Highway Research (CFHR) has conducted a research program to investigate the behavior of drilled shafts installed in a variety of soils located in Houston. One site named (G1) was chosen in this research to calibrate the numerical model to investigate the suitability of the constitutive model used for soil elements to reproduce pile behavior. Soil profile and soil properties in this site are shown in Fig. 2. The properties of the pile based on Touma and Reese [3] installed in this site are as follows: 18 m length, 0.95 m average diameter, the Young's modulus of the pile shaft is 33 GPa, the Poisson's ratio is 0.2 and the specific weight of the pile shaft is 23 kN/m^3. Touma and Reese [3] showed that the soil profile in the site is a 9.5-m thick clay stratum with an average undrained shear strength of about 86 kPa overlaying sand layer of medium density of an average standard penetration number (N_{blows}/ft) = 22.

3. Numerical analysis

For the work described herein, in order to capture the behavior of single bored piles in sandy soils a finite element model is developed using the commercial software ABAQUS 6.10 [6]. The proposed model is able to realistically capture the most important aspects of pile loading.

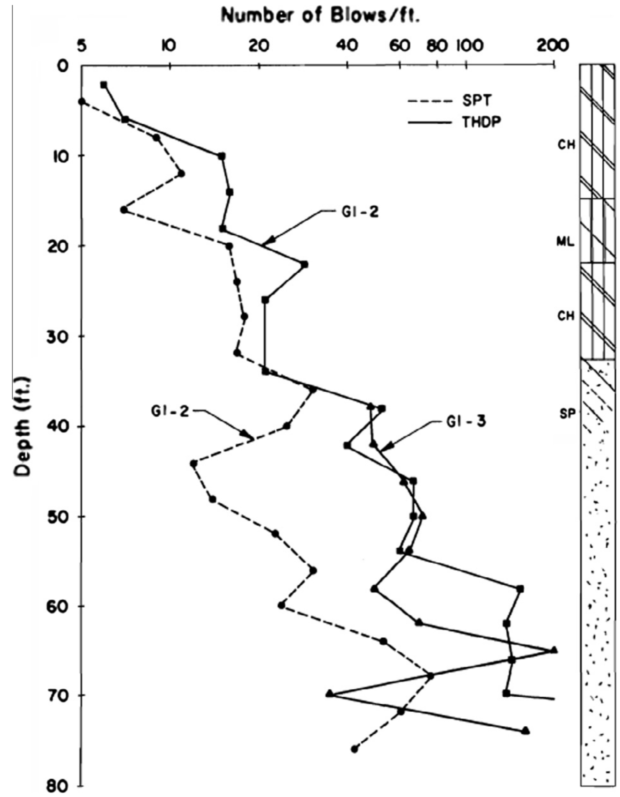

Figure 2 Standard penetration test of selected Site-Gl [3].

3.1. Constitutive model

The constitutive model used in this paper to predict sand nonlinear behavior is Drucker-Prager model (DP) available in ABAQUS 6.10. The DP is noncircular yield surface in the devi-

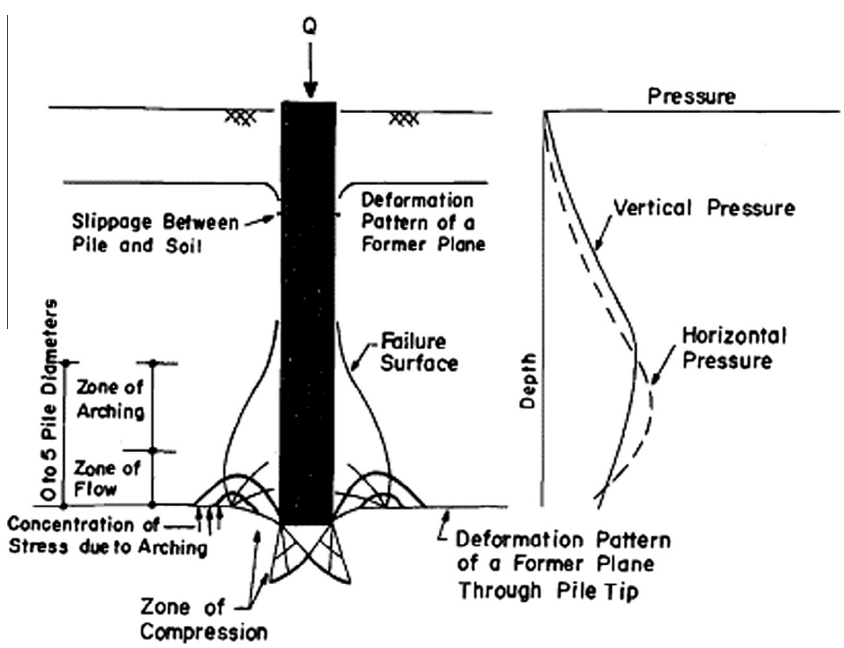

Figure 1 Schematic of the stresses around the pile in the case of a pile loaded axially in compression [3].

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