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Numerical simulation of displacement model pile test performed in artificial sand deposit

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Abstract

Very often the numerical simulations are based on full scale instrumented and small scale model pile tests. Most of the parameters necessary for modeling of full scale piles is usually derived from in situ tests profiles. This common practice generates a significant amount of uncertainties. Therefore, another pile testing technique - centrifuge test is often used as alternative. Despite its acknowledgment and wide usage, it has some shortcomings, such as scale effects. This paper presents the original experimental and numerical study, performed in comprehensively explored artificial sand deposit, using large scale model pile test and FEM analysis. For the numerical simulation the Hardening soil model was used in order to reproduce highly nonlinear predominant performance of pile base. After the FEM analysis, it was concluded, that shaft capacity mainly depends on the radial stress which were induced in the adjacent soil during installation process. It was also reported, that base capacity strongly depends on pre – consolidation stress, and was highlighted the most important parameter which influences the base load – settlement performance when HS model is used.

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1. Introduction

The development of computational resources during the last few decades enabled investigators to apply numerical modeling for more sophisticated mechanical problems. For this reason, FEM numerical modelling is often adopted to

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get a deeper understanding of the soil movement, the pile behavior and especially the mechanical behavior of the soil – pile system [1]. Usually the numerical simulations are based on full scale instrumented and small scale model pile tests. Most of the parameters necessary for modeling of full scale piles is usually determined not directly, for instance, derived from cone penetration test profile [1-4 etc.]. This common practice brings a sort of amount of uncertainties. More parameters derived using indirect method are used, more uncertainties are generated. This problem is being tried to be solved using a small scale pile tests performed in centrifuges. This type of testing allows to control a physical either mechanical soil`s properties with greater confidence and reconstitute the overburden pressure at the soil mass, but it has also a great flaw named as scale effect [5]. Therefore, the current study has aimed to present the high quality large scale model pile tests performed in artificial sand deposit, which was comprehensively explored using direct laboratory and in situ test methods. The short displacement piles were chosen as the one of the most often used deep foundation type in the Eastern Europe region, which is covered by the glacial origin over consolidated soils laying at shallow depth. The data of model pile load and soil tests are further described and used for the numerical modeling.

2. Experimental setup

The displacement pile tests further described in this paper were carried out in 5.0 m width, 7.0 m length and 4.5 m depth soil box (Fig.1a, 1b). First of all, the box was filled by the compacted sand deposit up to the necessary level. The compaction was carried out using 65 kg weight single direction plate compactor (0.61 x 0.9 m) (Fig.1b). A watering was used in order to improve compaction properties of the soil deposit. According to the primary prove compaction tests, the average 0.15 m thickness of each soil deposit`s sublayer was chosen, consequently 17 soil sublayers were needed to prepare 2.5 m thickness homogenies soil strata. The control of the compaction was carried out using dynamic plate load test (DLPT). The compaction criterion of each soil layer $E_d \geqslant 19$ MPa was adopted. For each layer 12 DLP tests were performed, in all 204 DLP tests for whole artificial soil deposit. Every DLP test was performed at the same place as for each above soil layer.

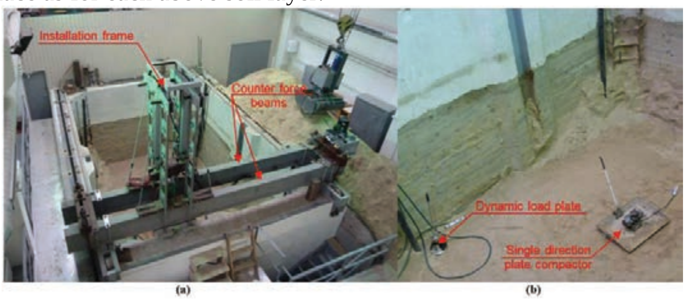

Fig. 1. Equipment of a soil box: (a) itinerant; (b) non itinerant.

From three different levels (see Fig.2a), 9 soil samples (3 samples for each level) were collected for the determination of soil physical properties which are presented in Table 1. It should be noted that specimens were taken after the watering and compaction of particular layer, before filling the next one. For the sampling 87.4 mm width and 42.1 mm height steel rings were used. The sieving test showed that the soil is even graded medium coarse sand, mainly consisted of silica particles. All soil`s physical properties were determined using standardized procedures.

For the determination of soil`s strength parameters 24 direct shear tests under constant normal load (CNL) condition were carried out using circular 71.4 mm width remolded soil specimens. The critical state friction angle $\varphi_{cs}$` defined in Table 1 was derived from the shear failure envelope presented in Fig.2b taking in to account only points where none volumetric strains appeared and setting cohesion equal to zero. The range of dilatancy angle ψ_p` was determined according to relation between the critical state $\varphi_{cs}$` and peak φ_p` friction angles proposed by Bolton [6].