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MODEL FOR THE INVESTIGATION OF THE BEHAVIOR OF PILES IN CYCLICAL EFFECTS-STAGE 2

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ABSTRACT

The deep foundation is characterized by the transfer of energy from the structure to the ground base, leading to the development of long deformation effects. The concepts used in practice by superpositioning transfer as a function of both the friction on the skin surface and the back resistance demonstrates a deficiency resulting from the development of long-term deformations. Cyclic loading conditions are observed, as a consequence of the development of the peptization of the dispersion system and its auxetic behavior, the formation of strain processes, which leads to the redistribution of forces in the direction-reduction of the component of the skin friction at the expense of the peak-production of the pile bottom.

Over the past few decades, a series of field test procedures in full-scale piles have been assembled in a natural environment of continuous update of the standardization base. Standard procedures are developed in a range of studies depending on the main working pile mechanism and consider four basic approaches for the testing of compressive load – fast, static with one or more loading cycles, bidirectional and dynamic tests. Numerical methods require consideration of model parameters in the context of the soil-pile interaction mechanism, examination of soil parameters and laboratory and in-situ methods of determination in the context of the strain level. Current studies have been proposed for small scale pile models serving as a verification procedure for the implementation of predictive analytical techniques.

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1. Introduction

Analytical predictions in the behavior of deep foundations in the context of different load effects are applied in a practice procedure which, with the introduction of the Eurocode, connects the analytical procedure with the several test standards – EN ISO 22477 series. These tests are considered as the main means of ensuring the operating limit conditions and are the main criteria of the behavior. The never-ending question quickly follows – “Is it enough?”. All tests have “short” periods of loading and cannot observe the effects of creep and the redistribution of forces from friction to bottom resistance at the expense of the realized settlement.

The applied technique also has a monitoring approach, which allows to accumulate experimental experience, which by continuous aggregation allows improvement of the design analytical techniques. The results of this experience complement different aspects of the knowledge about natural matter and its variability. Attention should also be paid to the large-scale effects of large-diameter piles above (600 mm), which in the implementation of the Test procedures are expressed in a series of deformation effects (local crushing in the pile's head, deformation in the beam loading system, sliding along the skin surface of the anchorages, etc.). In the traditional approach for following the Force transfer mechanism soil-pile the differential of both reactions is determined and the settlements are traced as part of the general deformation behavior of the system.

The main shortcomings of the pile systems, as the main sub-section of the Deep Foundation, are their cost and conversion time. The final financial value of the pile foundations was also formed by the large volume of preliminary field and laboratory studies, which increased with the increase of the system scale and the depth of influence on the soil massif, the technical possibilities and constraints, the duration of the construction and installation works, the cost of monitoring [1] and the magnitude of influence on the environment elements.

Among these:

- Are test procedures reliable (EN 1536:2010 English Execution of Special Geotechnical Work-Bored Piles; EN ISO 22477-10 Geotechnical Investigation and Testing – Testing of Geotechnical Structures-Part 10: Testing of Piles: Rapid Load Testing (ISO 22477-10:2016); EN ISO 22477-1 Geotechnical Investigation and Testing – Testing of Geotechnical Structures-Part 1: Testing of Piles: Static Compression Load Testing (ISO 22477-1:2018)) to describe the developing mechanisms in the force transfer in case of constant and variable effects (level of deformation, size and number of load cycles, consolidation provoked by the established pile system (drainage conditions and distribution of deformations ranging with depth))? The recommendation of BDS EN 1997-1 is of high importance here, as it pays attention to many negative influences in tests of piles with large diameters in different conditions.

- What are the levels of deformations [2, 3], in which the strength interactions of the skin friction are reached and what are the increase rates in back resistance as a function of the load cycles number?

- Impact of the magnitude of the initial (static) loads [2] in the subsequent assessment of the effects of the temporary seismic activity.

- Formulation of parameters for verification of analytical procedures and monitoring parameters for general control in the operation process.

The developed model staging tests the effects of creep in terms of the settlement of the piles head and the cyclical effects systems as the main mechanism, led by peptization and as a result – the structural changes made to the skeleton of the soil (auxetic mechanism). The bearing capacity of the ground base for piles and its change in direct connection with the change of the settlement of the pile head is considered.

2. Research Scope

After a critical analysis of various research techniques and their capabilities, we offer a combined research staging for a natural determination of the vertical compressive load capacity of piles at cyclic loadings [4]. The scope of the topic foresees the realization of a model study to be developed in two main stages as part of the funding opportunities under the research program and to assist PhD students of UACEG. This is dictated by the large scale (high cost of funds used solely for the purchase of equipment) of the research models and the necessary time for the realization of the procedures. Taking into account these specificities and the volume of allocations, research has evolved in the following two phases:

- The first phase (Stage 1) uses a resource for preliminary preparatory activities, targeting and defining the parameters of the research program. In it the financial resources are mainly intended for the purchase of testing equipment. No expenditure is foreseen for additional aids such as scientific literature, consultancy fees and transport costs for the supply of equipment.

- In the second phase (Stage 2), in the framework of the financial plan for 2019, the elements were developed as a whole and tested.

This procedure is developed with intent to a close simulation of impacts (cyclic, semi-seismic), which causes a change in the stiffness of the dispersion system [2, 3], which leads to a decrease in the shear strength and activation of consolidation processes and rheological phenomena.

The research models are created in a special environment (controlled area), taking into account the duration of the tests carried out. In the work stage all requirements for safe working conditions are met when working with mechanical equipment and electrical voltage. The studies are performed on a series of three piles with rigid profile reinforcement (the longitudinal welded steel pipe Ǿ100×3 mm). The program develops in a two-year period without any claims for its omnipotence. It is important to note that a qualitative trend of piles behavior is outlined and the search directions are determined in the context of the methodology used. The piles are constructed as bored with foam concrete, which possesses strength and deformation indicators close to those of the soil environment. Such specimens fall into the category of small-diameter piles and are often used in the implementation of deep foundation on the discharge technology as small scale test specimens.

In the equipment of the specimens, measuring instruments of the swatch type and Tenzometric circuits in the complete bridge scheme are used, each dose being equipped with three rosettes. Schemes of the HBM company and multichannel transducers system LabJack are used. The reception of the signals is carried out by an analog digital converter with seven channels applicable to each pile specimen.

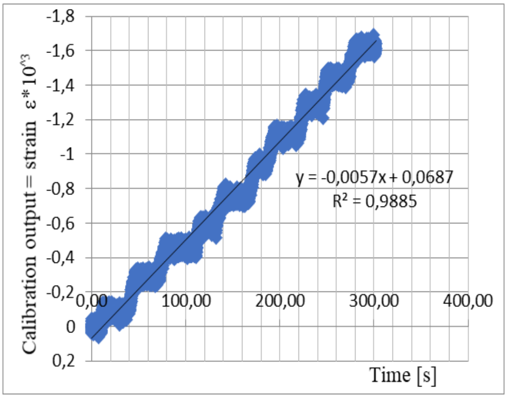
Under the current regulatory basis, the design of the pile systems undergoes analytical and experimental procedures. This is the basic requirement of item 7.4 of [1] for the acceptance of executed piles and pile systems and determination of partial safety factors.

Independent measurement of the skin friction along the length of the pile samples and back resistance, as a result of the impact type:

- Reporting of local deformation effects in vertical dynamic loads;
- Reduction of the friction zone of piles in vertical dynamic loads;

Figure 1. Built-in doses

Figure 2. Pile body



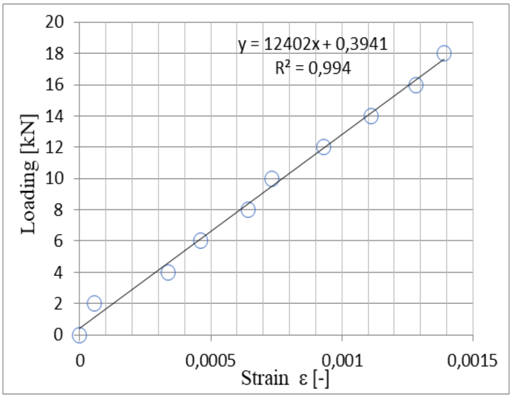


Figure 3. One-dose curves

- Initial static load behavior;
- Friction parameters that can be reliably used as input for seismic numerical analysis;
- A more precise assessment of the behavior in the contact of the upper structure and the ground base (SSI, Soil Structure Interaction);
- The results of the dose tests conducted to determine the initial parameters (working chart) are presented in the following figure.

3. Test Results

The samples created are subjected to loading in field conditions using the Enerpak Hydraulic System (Fig. 4). Due to the appropriate conditions, the equipment can be measured independently of both the magnitude of the forces and the deformation of the sample specimen. Vibration impacts are simulated with the work of an eccentric motor with reduced revolution per minute and unbalanced mass. The frequencies obtained with these instruments oscillations in the vertical pile system are 0,8 – 1,0 Hz. Vibration induction device is mounted to the head of each pile.

Figure 4. Testing for field studies

Research into the work of built-in appliances is made within the forecasts and their working diagrams are presented in Fig. 5 and Fig. 6.

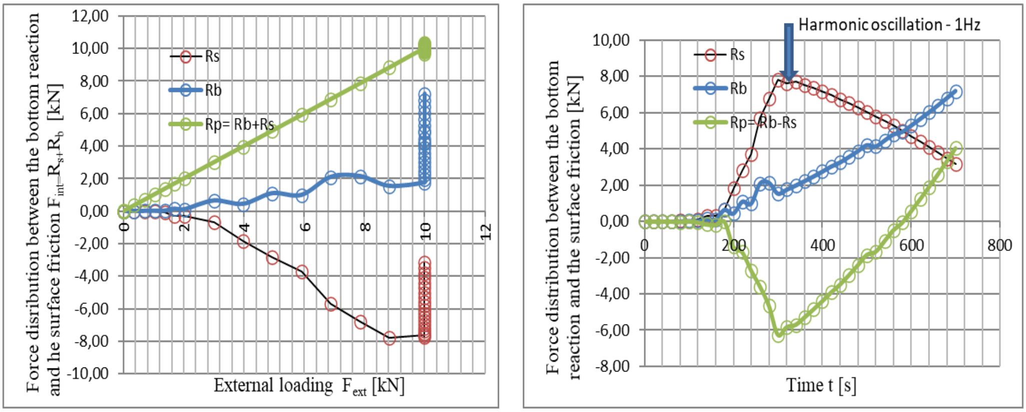


Figure 5. Peak resistance and ambient friction for model № 2

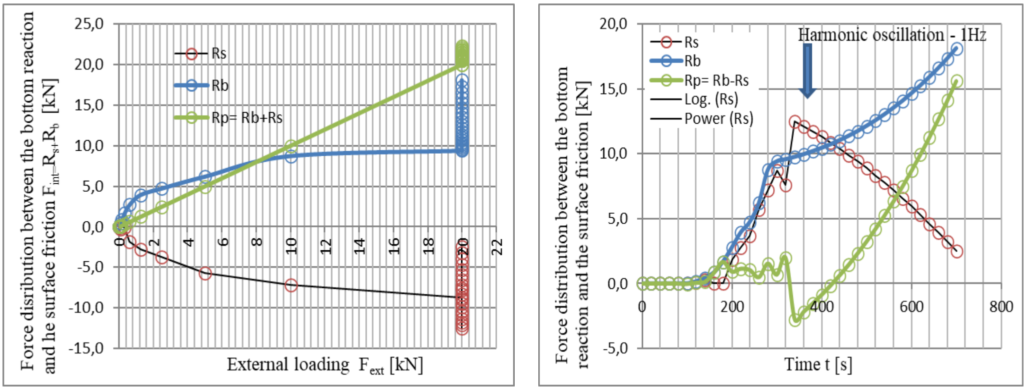


Figure 6. Peak resistance and ambient friction for model № 4

Given the large set of empirical results, only a portion of them are provided here.

4. Conclusions

Based on the studies carried out, the following main conclusions can be drawn:

- The proposed test procedure using a tenzometric system allows to explore the interaction between a pile and a soil strata both in function of time with respect to the number of dynamic load cycles. The dynamic effects in a harmonious form with a frequency of 1 Hz are retained for 6,60 min, which corresponds to 400 cycles with a loading amplitude 24 and 43% of Vesich, 1977 bearing capacity.
- The reduction of the skin friction is 46 in the size of the initial external load in Model 2 of 10 kN, which is approximately relative to the bearing capacity of 24%. The bearing capacity is defined by the formula (1977) for 2% volumetric strains of the soil in the area at the bottom of the pile.

$$R_{p,k} = A_p \times q_{p,k,ult} = A_p \left(c \times N_c + \sigma'_0 \times N_\sigma \right), \quad (1)$$

Where c – cohesion is 1 kPa;

φ – the angle of internal friction is 20 deg;

I_{rr} – rigidity index of the soil is 60;

A_p – cross section area of pile;

$N_c = \left(N_q - 1 \right) \cot \varphi$ – bearing capacity factor for cohesion term (dimensionless);

$N'_q = \left(1 + \tan\varphi \right) \exp^{\tan\varphi} \tan^2 \left(\pi / 4 + \varphi / 2 \right)$ – bearing capacity factor for overburden term (dimensionless);

$\sigma'_0 = 45,31$ kPa – mean effective normal stress of the bottom end of the pile.

- For model 4, the reduction is 51% at the initial external static load of 20 kN, which is approximately relative to 43% bearing capacity.
- An interesting effect is the amplitude of the loading cycle, which in this case is about 2 kN. It is determined by preliminary test of the application without applying loads with the hydraulic system (load jack).
- The measurement of the settlement in the head of the pile is another control parameter followed in this test. Due to the relatively small volume of tests, only three values have been obtained from the experience, which in this case can hardly determine any tendencies with influence on the cyclic load.

With this test procedure, given the limited volume of the field performances, some extremely important conclusions with a direction-qualitative assessment of the behavior of piles in relation $L/Dp < 20$ are marked.

The bearing capacity of the pile requires the examination in direct connection with the vertical movements formed at the head. The magnitude of the settlement of the head in the range of the cyclic load is not directly dependent on the research range of the static load value, but rather depends on the amplitude of the loading cycle and on the number of load cycles applied.

In the production at issue in unrelated materials of low value at the angle of internal friction it appeared that in 400 load cycles the degradation of the skin surface is complete. These characteristics of the behavior of the single pile elements give rise to the conclusion that the assessment of the load-bearing model using Meyerhof's (1976) and Vesic's (1977) plastic models can be applied with success in the assessment of the stiffness coefficient I_r, which is degraded. This degradation can be used as a convenient project criterion under cyclical loading conditions and by controlling the settlement of the ground base at the head of the pile.

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МОДЕЛ ЗА ИЗСЛЕДВАНЕ НА ПОВЕДЕНИЕТО НА ПИЛОТИ ПРИ ЦИКЛИЧНИ ВЪЗДЕЙСТВИЯ – ЕТАП 2

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Ключови думи: *взаимодействие на пилоти-земна основа, динамично поведение*

РЕЗЮМЕ

Дълбокото фундиране се характеризира с трансфер на енергия от конструкцията към земната основа, водеща до развитие на дълготрайни деформационни ефекти. Използваните в практиката концепции за диференциране на трансфера като функция на триенето по околната повърхност и на върхово съпротивление демонстрира един недостатък и той е резултат от развитието на деформациите с дълготраен характер. При циклични въздействия се наблюдава, като следствие от пептизацията на дисперсната система и нейното аустетично поведение, формиране на деформационни процеси, в резултат на което се получава в преразпределение на силите, изразяващо се в намаляване на компонентата на околното триене за сметка на върховата компонента.

През изминалите няколко десетилетия са събрани серия от полеви изпитвания на пълномащабни пилоти в среда на непрекъсната актуализация на стандартизационна база. Стандартните процедури се развиват в спектър от изследвания в зависимост от основния работен механизъм на пилотите и разглеждат четири основни подхода за изследване на натискова носеща способност – бърз, статичен с един или няколко товарни цикъла, двупосочни и динамични изпитания. Числените методи изискват разглеждане на моделните параметри в контекста на работния механизъм, изследване на почвените параметри и методи за определяне в контекста на деформациите. Настоящите изследвания са развити върху маломащабни модели, служещи като верификационна процедура за прилагане на прогнозните аналитични техники.

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