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АКТУАЛНИ ТЕХНОЛОГИЧЕСКИ И НОРМАТИВНИ ПРОБЛЕМИ В ПРАКТИКАТА НА ДЪЛБОКОТО ФУНДИРАНЕ В БЪЛГАРИЯ

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ACTUAL TECHNOLOGICAL AND REGULATORY PROBLEMS IN THE PRACTICE OF DEEP FOUNDATIONS IN BULGARIA

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Abstract:
The results of new experimental and theoretical studies of the pile foundations, carried out according to Eurocode 7, with those according to our current national codes and standards are compared. Results of static load test and calculation according to the Standards for the design of pile foundations are discussed in the report. The difference between calculated and established elastic shortening of the piles is analysed. The results of dimensioning piles using a dynamic penetrometer are compared according to the different standards.

The geotechnical features and prerequisites for foundations of tall buildings in Sofia, Plovdiv, Varna, and Burgas are given. In conclusion, recommendations are given for designing and implementing pile foundations according to modern standards.

Keywords:
piles, Eurocode 7, static load test, geotechnics, elastic shortening, penetrometer.

1. INTRODUCTION

Although the deep foundation has its practical beginnings with the squat dwellings of primitive people, it still represents one of the most large-scale tasks to be solved by engineers. There are not one or two unsolved problems in this field of knowledge, and practice constantly presents us with new cases to solve. The introduction of Eurocode led to the improvement of standards in this field of construction. New technologies and modern mechanization contribute to overcoming a number of previous difficulties, but new questions constantly arise that require research.

2. STATE OF THE ART

The most authoritative and generally applied modern contributions to deep foundation theory in the world are the following:

The pressiometer invented by Menard [1] has long played a pivotal role in determining soil deformation moduli at any depth in a previously prepared borehole. The pressiometer directly determines the modules and bearing capacity of the soil in the horizontal plane, which

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has made it the most reliable source of data for sizing piles subjected to horizontal forces.

Meyerhof [2], Vesic [3] and Fleming [4] are the authors of modern approaches for determining bearing capacity and predicting pile settlement.

England [5] is the author of Bi-directional static load testing, and at the beginning of our century, this method became the most perfect approach to experimentally determine the bearing capacity and settlement of cast-in-place piles. This method was successfully applied in Bulgaria as early as 2008.

Baker [6] as the author of the pilot foundations of a number of skyscrapers around the world, including and in Dubai, reached new dependences for the linear deformations of very long, large-diameter piles, where their elastic compression shortening dominates many times over the other deformations exhibited. In this way, surprising at first glance results from the combing are obtained, but they are categorically confirmed by the monitoring of the building. The other modern scientist with great experience in the deep foundation of skyscrapers around the world is Poulos [7], whose methodology for predicting the settlement of the group of piles in the deep foundations best matches what is proven by the monitoring.

Tomlinson's experiments [8] and the dependences proposed by him for the bearing capacity of pile foundations are also fundamental in the modern building science of the XXI century..

1.1. Unsolved problems

Despite very significant progress, today the main unsolved problems of deep foundations in the world still boil down to the following:

- Reliable and precise prediction of the settlement of the pilot group;
- Criteria for bearing capacity of deep foundations;
- A methodology for precise analytical prediction of the settlement of a single pile.
- Improvement of technologies for foundations in water-saturated soils.

1.2. State of the Art in Bulgaria

During the transitional period of the 90s of the last century, the test static load was practically not practiced in our country. Before that, it also did not have a great tradition in Bulgaria;

The test dynamic loading was also not practiced because there were no projects for the driven piles during the same period. Back then, tabular methods were most often applied, which we know are only suitable for the conceptual design phase. PFNP categorically confirms the world experience and recommends that the dimensioning of the piles be done in the following order: PSN, CPT, SPT, tabular methods.

With the implementation of the new large projects in the construction of buildings, railways and highways after 2001, the practice of trial static and dynamic loading was restored and improved in our country, including and the two-way Osterberg-sell method of England [5]. Dynamic and static penetrometers are used in quite a few cases. Although in the 80s of the last century a pressure meter was imported to our country, this soil testing technology remained unpopular and unapplied in our country.

The accumulated new practice and the progress of scientific research led to several interesting studies in Bulgaria as well.

2. RESULTS OF NEW RESEARCH IN BULGARIA OVER THE LAST 10 YEARS

2.1. Comparison of static load test results with tabular calculations

Maslarski [9] tested a pile with a diameter of 1200 mm and a length of 24 m; made of C35/37 concrete. He calculated the estimated bearing capacity of the pile according to the tables from the Bulgarian standards for the design of pile foundations, published in 1993, to be 1700 kN. The static load test was carried out with a working load of 1700 kN in two cycles - loading up to 100% in the first cycle and up to 150% - in the second cycle, as shown in Fig. 1.

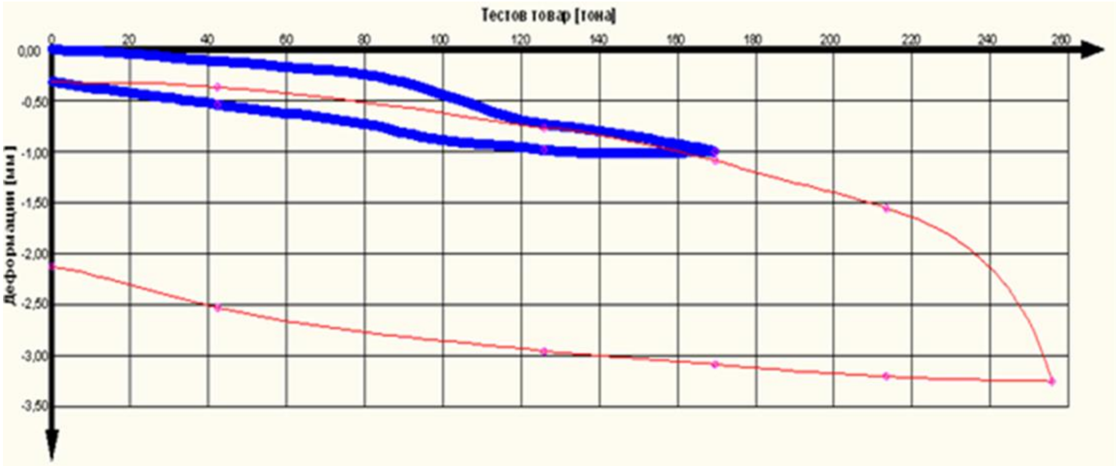

Figure 1. Load - Deformation Diagram [9]

By calculation, the pile should have a load capacity of 1700 kN. Experimentally, the pile was statically loaded with a force of 1700 kN, resulting in a settlement of ~ 1 mm (0.99 mm.) << 12 cm (10% of the pile diameter). The design limit for vertical deformations is 1 cm. The difference between the results of the calculation and those of the experiment is 10 times!

The conclusions drawn from the experiment are three: the assumed design load capacity of the pile, determined by tabular method, can only be used for the conceptual design phase; for the technical design, it is best to make a static test that precisely determines the actual bearing capacity of the pile; the test static load determines the bearing capacity of the piles, even in the absence of reliable geotechnical characteristics for the site.

2.2. A synthetic solution for determining the bearing capacity of bored piles according to the available standards

Maslarski and Kolev [10] highlight a significant difference in the concepts of the Bulgarian and American standards for pilot foundations. The Bulgarian standards for pile foundations perceive the settlement of the piles as one of the necessary calculation checks, and the American standards define it as a basic design quantity in determining the type and dimensions of the piles. Therefore, they are revising the ways of determining the bearing capacity and settlement through static tests according to BDS 2419-74 (now quite outdated). According to the standard, for the obtained values of the design load Pd. the settlement s is checked along the curve line obtained from the experiment. If s > 5 mm, the force at which s = 5 mm is taken as Pd. It turns out that this is a rather absurd statement from the point of view of the superstructure, where the settlement is of the order of 5cm÷10cm (10 to 20 times more), as also adopted in the national annex to Eurocode 7.

According to DIN 1045:2005, the settlement (Ssg) of the piles is a leading quantity and represents the value at which maximum ambient friction is realized. According to DIN 1045:2005, the limit settlement to overcome the peak resistance and activate maximum ambient friction is 3.0 cm. This value is 6 times greater than the Bulgarian standard. It is obvious that this significant difference is unjustified and therefore the adoption of the DIN 1045:2005 standard can satisfy the design requirements for the bearing capacity and settlement of pile foundations.

2.3. Different interpretation of static load test results in building and bridge foundations

In the same study, Maslarski and Kolev [10] emphasized the differences in determining the deformation modules for buildings and for bridges. In bridges, temporary loads exceed permanent loads by several times, they dominate the period of operation and determine the design approach. This also affects their pilot foundations. Alternate loading and unloading for short periods of time. Therefore, the results obtained from the second and third cycles of the static test are authoritative, while for buildings the first cycle is authoritative! The load from the buildings is one-time. Therefore, it is necessary to make a synthesis between the available standards when evaluating the results of the test static load, so that they have compliance with the requirements for deformations of the superstructure. The settlement of piles under buildings is determined by the first load cycle in the static test, and for bridges by the II and III cycles.

2.4. Difference between calculated and established elastic shortening of piles due to interaction with the environment

In another study, Kolev and Maslarski [11] pay attention to the qualitative changes that occur in very long piles loaded with the huge concentrated weight of skyscrapers. The heavy load on long piles acts as a scale factor and a number of their characteristics become more significant! Experiments show that laboratory shortening is ~8% higher than theoretical, but is 13% lower than that measured in situ. Therefore, there is a rationale for a more precise experimental determination of settlement in very long piles.

2.5. Comparison of the results according to EU7 and according to the Bulgarian standards in the dimensioning of piles by static test load (SLT)

After Eurocode 7 became the official design standard, a number of comparisons were made of the previous Bulgarian norms and standards with the new ones. Thus, from the comparison of the pile sizing methodology with the results of the test static load, Kolev [12] found that the previous standard for this test BDS 2419-74 is much more conservative than EU 7. The reason is in the requirement of BDS 2419-74 for settlement s = 15 mm, which is considered the limit of the load-bearing capacity of the core, (for piles with a section of 35/35 cm). The same criterion according to EU7 has a much higher value s = D/10 = 40 mm (for a pile with diameter F 40 cm). On the other hand, the operational limit settlement of pile foundations according to BDS 2419-74 has a value of slim = 5 mm, and according to Eurocode 7 - BDS EN 1997-1:2005 it is slim = 10 mm. By the way, in the US, slim = 0.5 in = 12.7 mm is recommended, which is even larger.

2.5. Comparison of the results according to EU7 and according to the Bulgarian standards when sizing piles using a dynamic penetrometer (SPT)

The parallel solution of the pile sizing task with dynamic penetrometer results shows that according to Eurocode 7 more economical results are obtained compared to those according to the Bulgarian National Code for pile foundations - the length of the required pile is shorter by 10%. According to Eurocode 7, the share of ambient friction is 82%, of peak resistance - 18%, while according to the National Code, the share of ambient friction is 62%, and of peak resistance - 38%. The advantage of Eurocode 7 in this regard is obvious.

3. GEOTECHNICAL REQUIREMENTS FOR THE FOUNDATION OF VERY TALL BUILDINGS IN PLOVDIV, VARNA AND BURGAS

3.1. Peculiarities of foundation work in Sofia

Under these conditions, the foundation stresses induced by very tall buildings (of 40 and more floors) exceed 800kPa, and the bearing capacity of the soil does not exceed 300 to 350kPa. It is clear that pilot funding is needed! The enormous depth of the dispersion layers (300m to 400m) requires, in turn, the excessively long length of the piles, and this significantly increases the cost of construction. From this point of view, the practical lack of a rock foundation for construction is a limitation to the height of the buildings.

The presence of a fault under the construction site is not a problem if it is proven to be inactive. When the fault is active, it should not be built on! The problem is that the process of proving whether a fault is active is complex and not always straightforward. The danger of an active fault most simply boils down to loss of general stability of the foundation and excessive tilting of the building.

How to overcome the geotechnical problems in Sofia? In addition to the detailed and comprehensive study of the geotechnical characteristics with field and laboratory methods, essential in this case are the geophysical measurements for: (1). seismic wave propagation velocities; (2). determining the period of the earth's own frequency; (3). Electro-tomography - to prove the presence or not of fault sections in the Quaternary strata and below them. In parallel, the dynamic shear modulus should also be established in the laboratory.

3.2. Peculiarities of the foundation in Plovdiv

It is known that the location of Plovdiv on the common flat sand terrace on both banks of Maritsa is a prerequisite for liquefaction of the sand. It is good that the sewer network limits the higher level of groundwater.

The pilot foundation is successfully implemented in Plovdiv. By the time a structure in Plovdiv needs a pile foundation, its underground floors are dropped from the project because they are judged to be ineffective in water-saturated sand. If the project building is located far from the river, it can also be founded on a rock under the sand and then its foundations will be flat and protected by a deep fence wall (12m÷15m).

3.3. Peculiarities of the foundation in Varna

The soil in Varna contains thick layers of clay that filter and reduce the amplification of seismic waves from the nearest earthquake focus in front of Cape Kaliakra.

The main problems until now along the entire Northern Black Sea coast came from the instability of the slopes and the abrasion of the seashore. The bearing capacity of the clay there at high values of the vertical loads combined with the seismic activity can only be provided by deep foundations (mainly piles).

3.4. Peculiarities of the foundation in Burgas

The soil in the low places near the Burgas Bay and around the city is weak: peat, silty clay, fine sand. The shores of the lakes are sediments of peat and silt up to 40 m thick and with very low values of their geotechnical characteristics. There is a danger of sand liquefaction in the coastal areas of Burgas and Varna. The soil in the higher parts of the city, west of the sea, is strong enough for tall buildings.

The seismic hazard in the Burgas region is lower than that in Sofia, Plovdiv and Varna, resp. here is the most suitable place for building tall buildings compared to other cities. A very important feature is the high wind speed near the sea, which represents a significant temporary impact.

4. CONCLUSIONS

Pile foundation in our country has received visible technological development in the last 20 years. There are still unsolved problems of a normative and practical nature in the study and design, but the completed new high-rise buildings, bridges, etc. facilities confirm that the adopted European design standards are a reliable tool for modern design and construction.

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