BEARING CAPACITY OF PILES ESTIMATE DIFFERENCES

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Summary: *Methods that have been used in determining the bearing capacity of piles are not entirely reliable given the variability of the parameters involved. Most of the methods used are based on theoretical models of the lowest reliability degree. Pile loading tests give a more realistic idea of the pile behaviour under load. In addition, ultimate bearing capacity obtained by pile loading test may be used to calculate the allowable loading intensity at a reasonable factor of safety.*

Keywords: *Piles, bearing capacity of pile, theoretical model, pile loading test.*

1. INTRODUCTION

Determining bearing capacity of a pile is a complex geotechnical task. Which method should be used will depend on many factors, such as reliability of the resulting soil mechanical properties, type of pile, pile performance, and the like. The only methods commonly used in this country are based on theoretical principles, though the current code of practice and standards concerning foundation of engineering structures (Off. Gaz. SFRJ No. 15/1990) [1] allow of pile loading in the axial direction to be determined and proved at least by two of the given five known methods:

1. Formulae for the soil strength mobility degree

The allowable pile loading, by this method, is estimated using relations for the known soil shear strength parameters (φ and c) from lab soil tests.

2. Formulae for the soil strength recorded during the pile penetration test

This method uses dynamic relations, based on the free-falling body collision theory, which requires knowledge of the soil resistance (the number of blows) during pile driving.

3. Formulae using penetration probing data

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Application of this method requires knowledge of the soil resistance to the probe penetration, or a static penetration test.

4. Pile loading test

This method uses formulae for the known pile loading and settlement relation from the pile loading test.

5. Estimate of the capacity of pile empirically learned from piling data in similar soils.

Theoretical models have demonstrated in practice significant unreliability owing to the variability of parameters and the resulting effects, primarily the bearing capacity factor and soil strength parameters; difference between the predicted and the actual bearing capacities of piles exceed 50% [2]. In difference to the mentioned methods, the bearing capacity of piles determined from the pile loading test data gives a much more realistic idea of the loaded pile behaviour. For this reason, most foreign standards (ASTM D 1143-81, DIN 1054-100) and codes of practice, including EN 1997 (EC 7), require pile loading tests for calculation of the bearing capacity of piles [3]. Selection of the right combination of the pile diameter, length and number and the achieved bearing capacity will give optimum engineering and financial foundation of a structure.

All the above stated will be supported by a case example to indicate differences between the theory-based and the static bearing test-based determinations of the bearing capacity of piles.

2. DETERMINING BEARING CAPACITY OF PILES

Differences in the estimates of the bearing capacity of pile between empirical methods and the pile loading test will be enlightened by the example of two test piles in one site of Kostolac [4].

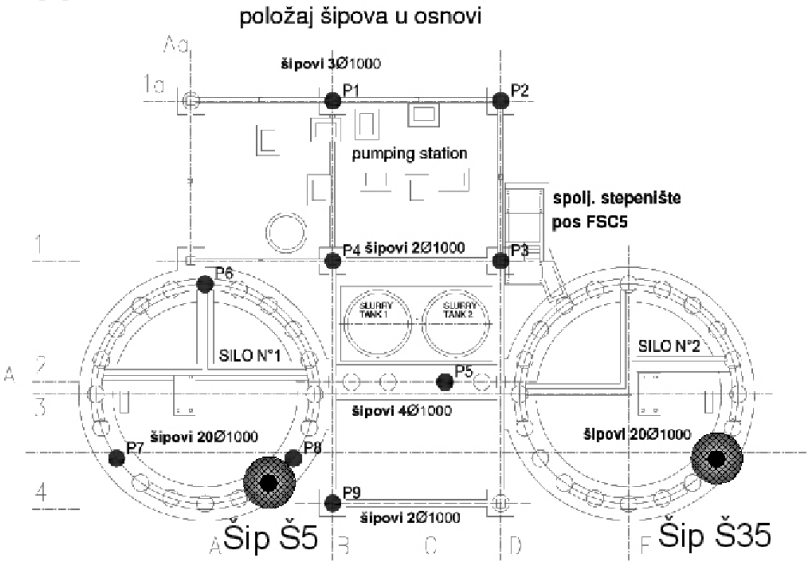

Figure 1. Locations of piles Š-5 and Š-35

According to the common practice of estimating the bearing capacity of piles, first were applied the methods based on theoretical models developed using geotechnical investigation data. The allowable bearing capacity of piles was

$$P_d = 3000 \text{ kN}$$

for which designers selected the number and distribution of piles under the foundation.
In contrast to the common practice in this country, the Employer followed the regulation of checking the bearing capacity of piles by loading tests.

3. PILE LOADING TEST

The test piles were two (Š-5 and Š-35 in Fig. 1) RC bored piles 1000 mm in diameter, 14 m long.
The test piles were (under the investigation programme) to be loaded to the maximum force (P) 50% higher than the calculated maximum force in the pile. These forces were $P_1 = 1.5x\ 2600 = 3900$ kN for pile Š-5 and $P_2 = 1.5 \times 2900 = 4350$ kN for pile Š-35.
A system of weights (concrete blocks) and a hydraulic press were used to apply the test pressure. The pressure in the system of loading was maintained constant through the pile test.
The quantities measured during the test were: force acting onto the pile, pile head settlement and time of soil consolidation. Pile head settlements were measured in two ways, by comparators and by survey rod.

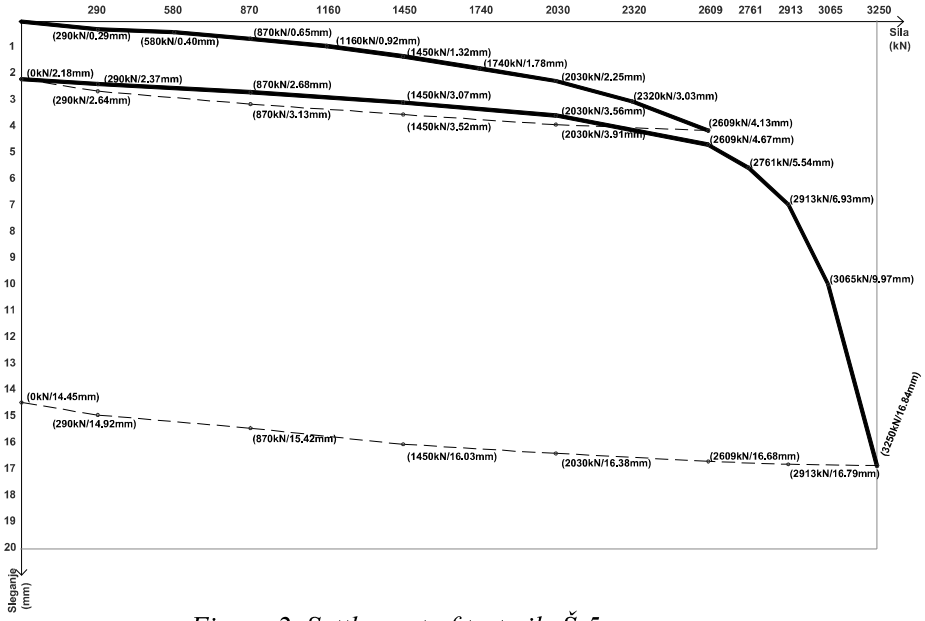

Figure 2. Settlement of test pile Š-5

Behaviour of both piles during the test was usual – the incremental settlement with the increasing pressure was within the expected and allowable range.
This behaviour continued up to P_d = 3000 kN, the allowable bearing capacity of the piles.
A new pressure increment to 3250 kN resulted in greater incremental settlement of both piles, which could not consolidate. It was a sign that test piles entered the state of soil breaking, so the test was discontinued.

4. INTERPRETATION OF TEST RESULTS

Gauged values of the forces applied and the head settlements of piles Š-5 (Fig. 2) and Š-35 (Fig. 3) during the pile loading test indicated likely failure of the piles and the ground around them. For an additional analysis of the occurrence, the ultimate bearing capacity of the piles was estimated via extrapolation of the measured settlement and force by three methods:

(A) Mazurkiewicz (1972) hyperbolic extrapolation,
(B) Van der Veen (1953) expotential extrapolation, and
(C) Hyperbolic approximation.

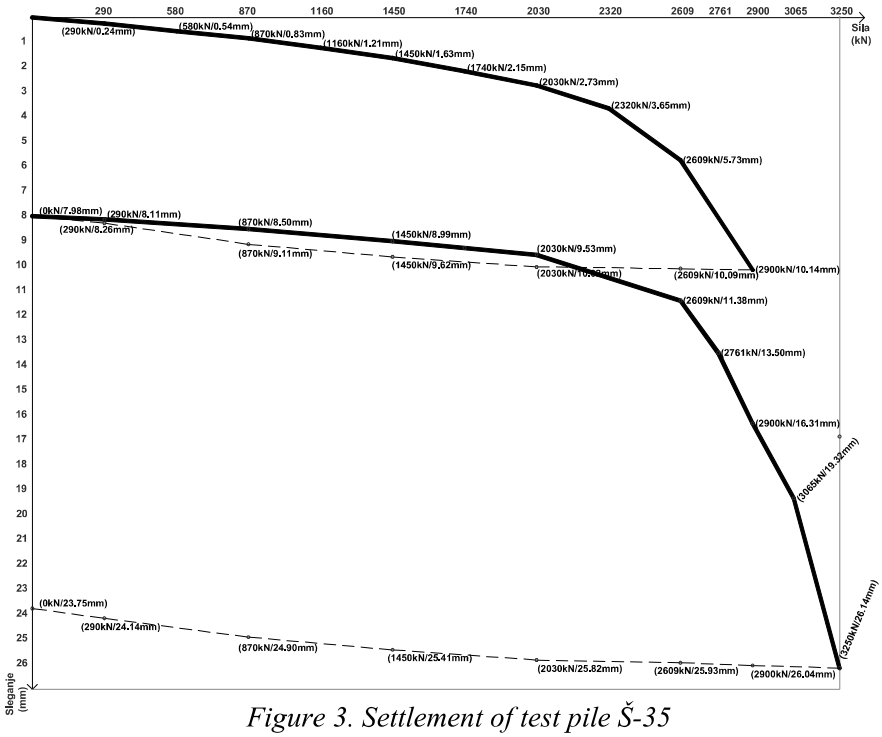

Figure 3. Settlement of test pile Š-35

A. Ultimate bearing capacity of piles by the method of Mazurkiewicz

Analytical values of the ultimate bearing capacity of piles are:
- Pgr = 3290 kN for AB pile 5
- Pgr = 3270 kN for AB pile 35

B. Ultimate bearing capacity of piles by the method of Van der Veen

Analysed values of the ultimate bearing capacity of piles are:
- Pgr = 3254 kN for AB pile 5
- Pgr = 3252 kN for AB pile 35.

C. Ultimate bearing capacity of piles by the hyperbolic extrapolation method:
- Pgr = 3836 kN for AB pile 5
- Pgr = 3831 kN for AB pile 35.

For the ultimate bearing capacity (Pf) of the test piles, the arithmetic mean was taken of the results obtained by the above three methods as given in Table 1.
- Pgr = 3460 kN for AB pile 5 and
- Pgr = 3451 kN for AB pile 35.

Table 1. Bearing capacities by pile test

Test pile	Pile Dia. (mm)	Method of estimate (kN)			Ultimate bearing capacity (kN)	Max. calcul. force P (kN)	Pile settlement (mm)
		Mazurkiewicz-a	Van der Veen-a	Hyperbolic approxim.			
Š-5	1000	3290	3254	3836	3460	2600	4.1
Š-35	1000	3270	3252	3831	3451	2900	10.1

5. CONCLUSION

The described example shows how differences in the bearing capacity of piles between the estimates on theoretical models and on the pile loading test data may easily exceed even 100%. An estimate of the bearing capacity of a pile by load test approximates far closer the pile behaviour under load, whereas the estimates based on theoretical models should be taken only for the values predicted.
On the basis of the above stated we may conclude that the best way of determining the bearing capacity and settlement of a pile is provided by the static loading test. Test-based data allow the use and adjustment of the related theoretical models in estimates of the allowable loading and settlement of piles, and the application of a lower safety factor.
Selection of an optimum combination of diameter, length and number of piles and the achieved bearing capacities of piles will give the best, engineering and financial, model of a structure foundation.

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РАЗЛИКЕ У ОДРЕЂИВАЊУ НОСИВОСТИ ШИПОВА

Резиме: *Сви примењивани поступци одредјивања носивости шипова носе са собом одређени степен непоузданости обзиром на променљивост параметара који утичу на резултате. Већина метода се заснивају на теоријским решењима, која имају највећи степен непоузданости. Испитивања носивости шипова пробним оптерећењем дају далеко најреалнију слику о понашању шипова под дејством оптерећења. Такође, овако добијена гранична носивост омогућава прорачун дозвољеног оптерећења са рационалнијим фактором сигурности.*

Кључне речи: *Шипови, носивост шипова, теоријско решење, пробно оптерећење*