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SOME INCONSISTENCY IN MICROPILES' DESIGN AND CALCULATION

NEKE NEDOSLEDNOSTI U PROJEKTOVANJU I PRORAČUNU MIKROŠIPOVA

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Abstract

Micropiles (driven piles with no more than 300 mm in diameter/side) are nowadays wide-world used geotechnical structural elements. These elements are equally efficient for strengthening delicate existing foundations as well as for a broad range of soil improvement, as a base ground for new engineering structures. The most significant advantage of micropiles is their ability to be installed in an easy and efficient way and their great load bearing capacity. In the paper, three distinguished, theoretically and regionally different approaches are analysed treating the identical problem of pile capacity evaluation and using the same input data. Applied calculation procedures are carried out and analysed. Significantly different results are obtained and possible causes of their inconsistency are discussed.

Ključne reči
- mikrošipovi
- integritet konstrukcija
- projektovanje u geotehnici

Izvod

Mikrošipovi (ukopani šipovi sa prečnikom/širinom ne većom od 300 mm) se danas širom sveta koriste kao geotehnički konstrukcioni elementi. Ovi elementi su podjednako efikasni za ojačavanje osetljivih postojećih temelja, kao za poboljšanje čvrstoće raznih tipova tla, u funkciji pripreme podloge za nove građevinske konstrukcije. Najznačajnija prednost mikrošipova jeste njihova karakteristika lake i efikasne montaže, kao i njihova značajna nosivost. U radu je data analiza tri poznata, teoretska i regionalna pristupa, kojima se razmatra identičan problem proračuna nosivosti šipova, korišćenjem istih ulaznih podataka. Primenjene procedure za proračun su izvedene i analizirane. Dobijeni su veoma različiti rezultati, i data je diskusija o mogućim uzrocima njihove nedoslednosti.

INTRODUCTION

A pile is geotechnical/structural element, basically invented with the purpose to transfer the structural reactions through the weak and low bearing soil strata to the deeper (and harder) layers of the soil. There are many different types of piles invented with the main purpose to satisfy the structural, soil, and local environmental and economy conditions. All of them can be applied using two main installation techniques: as driven or drilled piles. The paper is concerned about driven, open end, steel pipe piles, up to 300 mm in diameter, often named as 'micropiles'.

PILE LOAD BEARING CAPACITY

The pile is able to carry and transfer any loads from the structure onto the soil. In that way, the pile becomes the specific 'interface' between the structure and the soil through a very complex structure-pile-soil interactive system. The way how the pile bearing capacity is activated varies and it is affected by many factors: type of piles, soil characteristics, manner of drilling or driving, type of loading etc. Generally, the pile load bearing capacity consists of two components: the pile shaft resistance, and the pile toe resistance. The most susceptible to the process of pile bearing capacity calculation is the pile shaft resistance, existing as a result of (1) pile skin friction or (2) cohesion–adhesion between the pile and soil.

The calculation procedure is developed for two of the most characteristic types of soil: cohesionless (sand) and cohesive soils (clay). However, very often the soil is not so clearly distinguishable and mostly spreads not only in many layers but as mutually mixed combinations of cohesive and cohesionless soils. In addition, taking in account the effect of underground water, the problem of choosing the right calculating approach becomes very complex. Therefore, the only way for engineers to get the reliable value of the pile bearing capacity is to carry out on-site load testing of the pile. Testing the pile is an expensive and time consuming performance and in order to escape it, many empirical or semi-empirical methods have been developed so far. Two of them, different but based on various soil shear strength reduction factors are the most prevalent and known as:
(1) total stress, and (2) effective stress method.

In fact, these two methods are very similar by approach, but differ in using undrained (1) and drained (2) shear soil strength.

However, the most uncertain in this matter is the basic approach to the pile resistance calculation essentially defined as: (1) allowable stresses and (2) ultimate limit design approach.

Methods based on allowable stresses are traditional, well established and mostly applied, but conservative using the high global safety factors ranging from 2-4.

The ultimate limit design method is more rational, but still considered risky, not acceptable for many designers and therefore, not included in many codes and standards. Nowadays, the situation clearly shows the global existence of unresolved uncertainties in the pile load bearing capacity calculation.

Here, three distinguished, theoretically and regionally different approaches are implemented to the same problem and use the same input data. Analysing the applied calculation procedures, significantly different results are obtained and the possible causes of their inconsistencies are discussed.

North American approach

To calculate the pile bearing capacity, many computer programs are developed in USA but all of them are based on a more conservative method of allowable stresses for the pile material and for the soil as well. The allowable stresses are strictly prescribed for each type of material and the soil is divided in two clearly distinguished groups: cohesionless and cohesive soils. Depending on the type of soil, one of the two mentioned methods of calculation is applied and the pile ultimate load bearing capacity is determined. The obtained value is then divided by safety factor, ranging from 2-4, depending on particular site conditions, load test results, or degree of soil characteristics investigation. The new LRFD (Load Resistance Factor Design) specification is introduced in North American structural design, but has found a little place in geotechnical practices.

European approach

A more advanced procedure, based on the pile limit state design is proposed by the Eurocode 7. According to ECC 7, three geotechnical categories are introduced and two (favourable and unfavourable) conditions are considered and described in order to choose a particular set of corresponding partial safety factors relating to the materials and the actions as well.

Russian approach

A mixed but tentative, traditional and ultimate limit design is proposed in Russian SNiP 2.02.03-85. All types of piles are considered in relation to the material, but only two kind of piles are treated in proposed calculation procedures:
(1) the pile – column, firmly supported at its end to the hard soil layer, and
(2) hanged on pile, with no any particular end support.

The standard and simple calculation procedure is proposed in both cases with a detailed set of coefficients relating to the soil conditions in general, but to the particular soil characteristics at the pile end and at the pile side surface, as well. The numerical values of these coefficients and the soil bearing capacity (compression and shearing) are given in tables.

EXAMPLE

As an example, the pile axial bearing capacity is calculated for the pile – steel pipe with open end, 219 mm in diameter, driven in sand. All the three mentioned procedures have been applied with the following set of input data:

d = 219 mm (diameter),
t_w = 8.2 mm (width),
$I_x = I_y$ = 3018 cm^4 (axial moments of inertia),
H = 5.0 m (height)
and a corresponding set of outcomes is obtained:

American: N_u = 214 kN
Eurocode: N_u = 154 kN
Russian: N_u = 91 kN

CONCLUSIONS

Careful and comparative analysis of all three procedures of calculation (and many others as well) has identified the possible source of discrepancy.

All three procedures are basically very similar counting the pile axial bearing capacity as a sum of the pile tip and pile shaft resistance. In all three procedures both the pile tip and the pile shaft bearing capacity are assumed to increase linearly (or roughly parabolically in the Russian procedure) to an assumed critical depth (z_c) which appears to be the main source of inconsistency. This value is proposed by many authors and varies significantly from 5d to 20d, where d is the pile external diameter. For example, according to **Vesic's** method, who has accomplished the most extensive research, the value z_c/d is given as approx. bilinear function of the soil internal friction φ ranging between 5 and 18.

Analysing carefully all the proposals for z_c we came to a conclusion that it does not make too much sense treating the value of z_c as the same for the pile tip and pile shaft resistance. We assume that most probably, the pile shaft resistance increases its value not linearly but parabolically, reaching the value of z'_c much deeper, (Fig. 1).

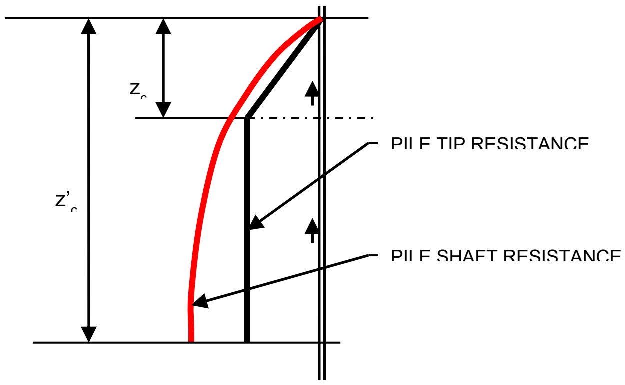

Figure 1. Pile shaft and pile tip resistance

Therefore, it is necessary to make a distinction between these two values calculating them separately. Evidently, the lack of more precise, reliable, decisive and experimentally proven value of the critical depth z_c for the pile tip, as well as for the pile shaft, makes the entire pile axial capacity calculating procedure uncertain and inconsistent through different codes and standards. As a consequence, accordingly, the very high safety factors are required, as well as an expensive and time consuming load testing.

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