Abstract

Mechanical properties of marine sediment near Koper and numerical modelling of a deep excavation

Engineering geological conditions near the port Koper in southwestern Slovenia forces geotechnical experts and civil engineers to solve problems in foundation various types of objects and purpose of the practice since the fifties of last century, when it began an intensive development of infrastructure of the port. The results of series of geological and geotechnical surveys, monitoring, and long experience with foundation in the local geology shows that it is almost always the 3rd geotechnical category, or foundation of complex structures in difficult geological conditions below the water table. The entire area belongs to Alpine-Dinaric tectonic area. The rock foundation is composed of complexes of flysch sediments Eocene age at which mounted files of recent marine sediments in the area widely submerged river valley fluvial sands and gravels. From the geotechnical point of view it is interesting site, where most buildings were based on a layer of soft marine sediments, where it is through the creation of special methods implemented in the establishment of deep-level endurable layers of gravel and sand of the river Rižana or at the level footingwall flysch. Set of marine sediments near the port Koper, what the founding ground, it seems appropriate for the application of numerical modelling techniques for solving geotechnical problems such as the formation of deep pits, the stability of geotechnical structures, settlement of various types of foundations, etc. Suitability of these methods is based on the minimum tectonic disturbance this layer, geotechnical reviewed overall homogeneity of the massif in the lateral and vertical direction, grain size, poorly grained soil and mineralogy.

Soil in its natural state is not an artificially prepared material in advance with known characteristics. Therefore it is necessary for interaction soil - building structures to investigate various aspects of the behavior of soils in situ by geotechnical testing and laboratory methods of soil mechanics. Ideally, we can build on the results of these numerical methods, 2D and 3D analysis, in the form of a constitutional (material) model in combination with programs using the finite element method (FEM).

In geotechnical practice for solving the above problems are often used numerical models, that doesn't fully capture the important aspects of the behavior of soils, so their results may be misleading. An example might be using a well-known Mohr-Coulomb model, which disregards the dependency behavior of soils in the state variables (stress, porosity,

degree of overconsolidation, etc.). Furthermore, neglecting other important factors such as nonlinearity behavior, this is not in terms of soil mechanics totally correct.

Hypoplastic model enter into this problem, using modern knowledge of geomechanics. The model is based on the mechanics and the critical state theory hypoplasticity, which is being developed since the eighties of last century. An advanced model already takes into account the nonlinearity of the behavior (high stiffness in the field of very small deformations). Since it uses the basic version of the five material parameters, which can be obtained by evaluating the standard laboratory tests, it can be easily used in practice to solve routine geotechnical problems.

For modeling purposes, almost 13 meters deep pit in the highly plastic silt and clay on the intersection Kolodvorska - Ferrarska on the outskirts of Koper has been necessary to use enriched hypoplastic model for so-called concept intergranular strain. The pit was to compare modeling results also modeled by Mohr-Coulomb model. It is the foundation pit of rectangular layout with dimensions of 54.8 x 56.3 and depth of 12,8 m. Sheeting is carried out through the diaphragm walls in combination with spacers from custom slab. Deformation of the pit walls were monitored by inclinometers in the slats L5, L12, L17 and L27.

Laboratory work was conducted on a sample of marine sediments, which was removed from the site at a depth of 3.4 m as intact. Properties of soil laboratory set Arcadis Geotechnika a. s. Consolidated undrained triaxial tests with pore pressure measurements (CIUP) and oedometric tests were performed on undisturbed and reconstituted samples. It were tested totally 6 triaxial samples (3 reconstituted and 3 intact), which was to calibrate the model parameters used 3. Oedometric samples were also tested 6 (3 reconstituted and 3 intact) to calibrate the results of model were used all six tests. Enlargement of the hypoplastic model for the concept of intergranular strain requires five parameters, which can be obtained using less standard laboratory tests. These are the tests to investigate soil stiffness at small and very small strain. In this work was a time measurement of shear waves passing through the sample element by the Bender Elements equipment. On the samples of triaxial tests were installed local deformation sensors (LVDT) for measuring small deformations. Samples were prepared as naturally dried and then crushed to a fine fraction of soil to verify the mineralogical composition of soil. X-ray analysis was made by doc. Přikryl from Institute of Geochemistry, Mineralogy and Mineral Resources, Faculty of Science, UK.

On the results of laboratory tests, using Triax program, were calibrated all the necessary parameters of the both numerical models. Modeling was done in 2D PLAXIS program, which was first defining the role of geometry, the real parameters of the technical

features of the pit (underground walls and struts) and soil parameters of both models. Hypoplastic model parameters were implemented into the program PLAXIS using subroutines, developed by Mašín (2010). Given the two-dimensional analysis of the problem had to be the most appropriate intersection across the construction pit. It was elected a profile passing through the slats of the diaphragm walls L5 and L27, which were situated inclinometer boreholes for comparison of results.

The calculation of both models was divided into eight stages in total, and was conducted through the plastic, respectively elastoplastic analysis, for undrained conditions (water table 1.8 m below the surface). Calculation phases were derived from the real phase of mining pits, but the overall concept of computational phase of the two models had to be adjusted using the modified β method (derived from the β methods already known from the modeling of NATM tunnels) for correction of the surround effect of mining process and propping each level. The combination of different β factors later proved crucial to the results of both models and takes the form of retrospective analysis in order to best represent the simulation realistic conditions. Model building process was conducted in accordance with the principles of numerical modeling, so that type of model was selected as best possible to achieve the desired results, the simplest, yet most concise as possible.

The results of both models were compared with results of monitoring, where a more realistic prediction of hypoplastic model were verified in each stages. It was achieved excellent agreement between the inclinometer measurements and deformation of diaphragm walls, predicted by hypoplastic model both in terms of size distortions, the shape of the curve of horizontal displacements. The Mohr-Coulomb model consensed less at deformations distribution. It was also shown that hypoplastic model predicts a much more realistic deformation of bottom of the pit and close vicinity of the diaphragm walls (thanks to the predictions of higher stiffness at unloading and the very small strain). Conversely Mohr-Coulomb model predicts the deformation of a much larger scale and size, because it is linear and does not respect the above-mentioned aspects of the behavior of soils. Through the hypoplastic model can be in various stages of the calculation show a number of state variables that contribute significantly to the understanding of the processes going on throughout the process of bracing and excavation pit and demonstrates aspects of the behavior of soils.

Modeling the behavior of the deep pit Kolodvorska in Koper was established the legitimacy of using the methods of numerical modeling for solving such geotechnical problems. Based on the research field geotechnical tests and laboratory tests of soil samples, the author of this paper would point out the analogy and portability of the results of numerical

modeling on the local engineering geological conditions in terms of stability of the mechanical properties of soils. In this context, it appears hypoplastic model as a powerful and effective tool to solve many geotechnical problems.