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EVALUATION OF EXPERIENCE IN MODELLING OF DEEP FOUNDATION PITS

ZHODNOCENÍ ZKUŠENOSTÍ S MODELOVÁNÍM HLUBOKÝCH STAVEBNÍCH JAM

Abstract

Foundation of new buildings in the middle of urban areas brings many challenges. For maximum utilization of space, we have to choose a greater depth for foundations, which results in difficulties with stabilization of the foundation pits. For analysis of foundation structure and stability of pit can be used tools of mathematical modelling. For complex structures it pays to take advantage of 3D modelling. The enjoyment of these techniques, however, requires some user experiences.

Keywords

Foundation pit, FEM, Plaxis.

Abstrakt

Zakládání nových staveb uprostřed městské zástavby sebou přináší mnoho komplikací. Pro maximální využití prostoru jsme nuceni zakládat ve větších hloubkách, což přináší obtíže se zajištěním takovýchto stavebních jam. K řešení stability a založení objektu můžeme využít i prostředků matematického modelování. U komplikovaných staveb se vyplatí využít prostorových modelů. Požívání těchto prostředků ovšem vyžaduje určité zkušenosti uživatele.

Klíčová slova

Stavební jáma, MKP, Plaxis.

1 INTRODUCTION

Building new facilities and utilization of open spaces bring the necessity of constructing foundations of the facilities in complicated conditions. An extensive underground portion is often built under the facilities in order to exploit the site. It is then necessary to construct foundations deeper and build foundation pits. We usually reach the depths of 7 to 10 m below surface. Securing stability of such deep building pits is relatively complicated, namely when it is not possible to anchor the casing structures and when it is necessary to ensure water-tightness of the casing structure. We can eliminate quite completely the building pits with slopes for which there is no room in a dense build-up area. The brace casing or underground walls are ideal solutions. At the depth greater than 4 m, it is usually necessary to anchor the wall or strut it via steel strap anchors. In general, it can be implemented 10 m deep, at the most 20 m when divided with reinforcing dams. It is primarily utilized

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for shoring of foundation pit walls above subsurface water level or where the foundation base is slightly submerged below subsurface water level and no risk occurs if water inflow pouring into the building pit is drained, which might affect the stability of adjacent facilities due to removal of fine particles from their subsoil (i.e. by piping or subsurface erosion).

The microbrace fixing represents a lining, strengthening and stabilizing structure that carries out its function just temporarily. It is necessary to strut them almost every time or anchor them with steel walers. This technology is utilized in crowded conditions of urban build-up area and in reconstructions in awkward spaces but for shallow excavations only. The sheet-pile walls which should perform sealing function are utilized as temporary or permanent sheeting structures. They inhibit the flow of water, capture the hydrostatic pressure and thereby provide the excavation pit with watertight sealing. Their installation by ramming or vibro-ramming constitutes a considerable disadvantage in the urban conglomeration because the rising shocks may have a negative influence on the surrounding build-up area. The suitable geological conditions are an important precondition for using the sheet-pile walls Redrilled pile walls are one of the options that can be considered as sealing without any further measures and they are used in unconsolidated strata for securing the building pits, the bottoms of which are found below ground water level. The pile walls are designed as free-standing, i.e. unanchored or anchored in the case of greater depths, rarely also strutted ones.

The walls made of jet grouting represent one of the latest methods for permanent sheeting and sealing of building pits. Being very expensive, they are only utilized locally in places where no other solution is possible and primarily for shoring the existing foundations to the building pit of the adjacent buildings. Based on the geotechnical conditions on site and the required geometric shape of the elements, single-phase, two-phase and three-phase execution systems are utilized. The diaphragm walls (the so-called walls of Milan) are used more and more often for permanent sheeting of extensive building pits as they carry out the sealing function as well. Moreover, they can be utilized as supporting structures for the sub-surface part of the facility and transfer the load pressure from the upper structure. They are most frequently implemented as monolithic structures and in duly justified cases as prefabricated ones, rarely as sealing ones made of a self-hardening suspension. The diaphragm walls can be anchored or strutted at one or more levels [1, 4, and 3].

2 BUILDING PIT MODELLING

Nowadays, mathematical models are used quite often for solving the comprehensive design of a building pit and subsidence of facilities and namely the Finite Element Method in geotechnical practice. It is suitable to utilize namely the spatial models that provide more realistic approach and preparation of a geotechnical model for calculation and assessment of complicated facilities. It is suitable to use special software for building pit modeling. For example one of such program is Plaxis 3D Foundation for spatial modeling.

Spatial models, as it is common in 3D Plaxis program, are made by "extending" the planar model into the third dimension. It is necessary to set up the planar model according to data related to the situation given. By creation of the fundamental ground plan of model geometry, we make use of the ground plan in all the other working planes These working planes are defined by user again as need may be so we can define easily define e.g. the depth of the building pit or the length of a pile, the level of the foundation base, diverse depths of foundations, etc. The working planes are not related to the geological composition. The software is primarily focused on foundations and that is why it contains special geometric elements, facilitating work with creation of models. These elements are primarily for wall structures (wall), floor plates (floor) and bearing piles (pile). Using these plate-wall elements, we can create, for example, a bearing structure of a building which will be founded in the building pit and above it. The structures may be loaded with three types of load. These are planar, line and point loads. An optional use of ground anchors was newly added. In order to create working levels that serve for simulation of working depths, the rock environment must be defined. For this purpose, the borehole function is used where we define the interface among soils according to thickness values of individual layers. There may be more boreholes and the program itself determines the waveforms of individual layers by interpolation and we can also determine the subsurface water level here. We determine the size or depth of a model according to the borehole length selected. The sufficient depth will ensure the correctness of our calculation without being affected by boundary conditions. The boundary conditions of the model are automatically assigned and it is not possible to change them.

The creation of the mesh is ensured by the automatic generator both flatly and then spatially. The geometry is divided by 15-node wedge elements. These consist of 6-point triangles 8-node quadrangles. This division is fixed and cannot be changed. The quality of the reticule can only be influenced by density both in-plane and in the third direction. After creation of the geometry, the calculating program can be launched. In the calculation program, we define the modeling phases, insertion of elements, excavation, etc. The duration of the calculation is significantly affected by the density of mesh of the final elements and by complexity and size of the model. Using the postprocessor, we can display the calculated results of deformations, transformations and stresses. The deformations can be displayed separately in individual directions or as a total value. We can display also the values of deformation differences from previous phases, etc. The stresses are represented as total and effective, or it is possible to display the value of porous pressures as well.

3 ENTRY CONDITIONS OF THE MODEL

The behavior of the ground environment can be simulated by various constitutive models, e.g. linear - Mohr Coulomb, Hardening soil model, Soft soil creep. The Mohr-Coulomb model is the basic and most frequently used one. This elasto-plastic model requires several basic entries, namely deformation modulus E and Poisson's number ν, and furthermore, shear parameters of soil (c and φ). The ideal plasticity is the precondition of this model. When using this model, constant stiffness in each layer is considered. This constant stiffness is utilized for prompt determination of deformations. The deformation module influences namely deformations. The deformation module value is very important and its determination must be taken into account in practice according to the task given and whether it is loading or unloading. For loads, e.g. foundation, earth fill etc., it is necessary to take into account E_{oed} or E_{50} modulus from the three axial test. For unloading, which is for instance tunneling or excavating, it is necessary to take into account E_{ur} (Unloading/Reloading), which is determined from loading and unloading cycles (see Fig. 1). The stiffness according to unloading/loading (U/R) is higher than for loading.

Then the determination of individual modules is as follows:

$$E_{def} = \tan\beta = \Delta\sigma / \Delta\varepsilon$$
$$E_{ur} = \tan\alpha = \Delta\sigma / \Delta\varepsilon^{el} \quad (1)$$

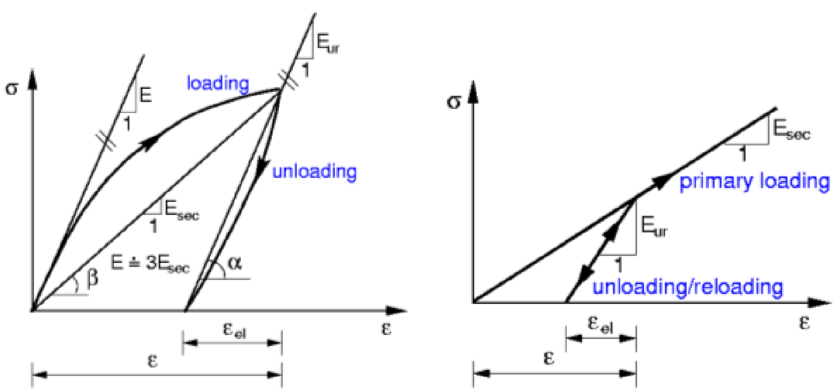

Figure 1: Stress-deformation diagram (taken over from www.fine.cz)

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The value of Poisson's number is given on the basis of triaxial test results. This value is important for determination of the lateral pressure coefficient K_0 at gravitational acceleration. The values usually vary between 0.25 to 0.45. Again, this is a value suitable for models with loading coming from single axis loading. For unloading conditions, it is suitable to use the values ranging from 0.15 to 0.25. The recommendation results from the software manual [2]. That is why the correct determination of input parameters is very important.

For example, the values for solid clays can be twice as big. According to knowledge acquired when making especially models of deep building pits, the value of the deformation modulus plays an important role. This influence was tested on several different simulated constructions. After drawing the rock (deactivation of the rock in the model), relatively high unloading and growth of deformations occurs. At low values of the deformation modulus, the pit floor heave in the order of hundreds of millimeters occurs. When using an appropriate deformation modulus, this value is significantly reduced and gets closer to reality. The floor heave in the model is seen in Figure 2 (100 times enlarged).

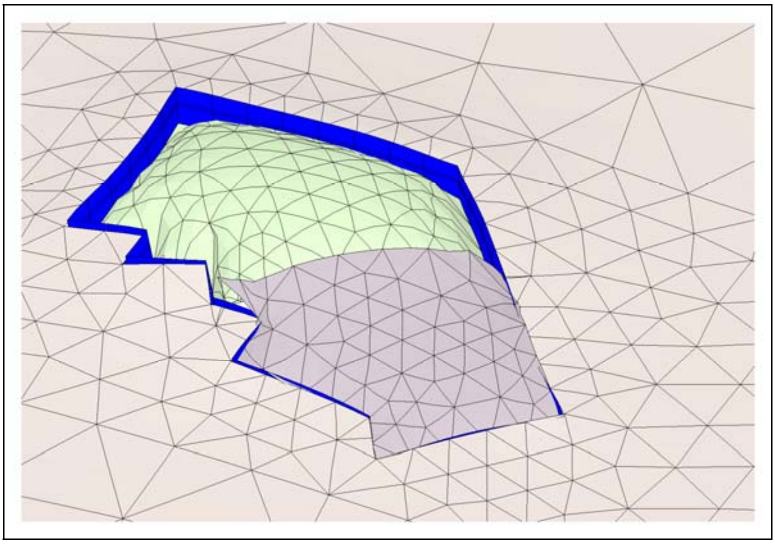

Figure 2: Foundation pit heave

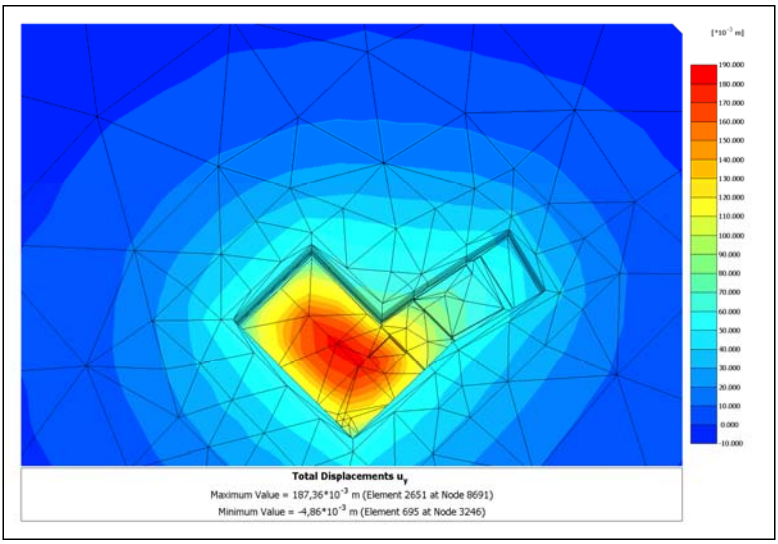

Figure 3: Foundation pit heave

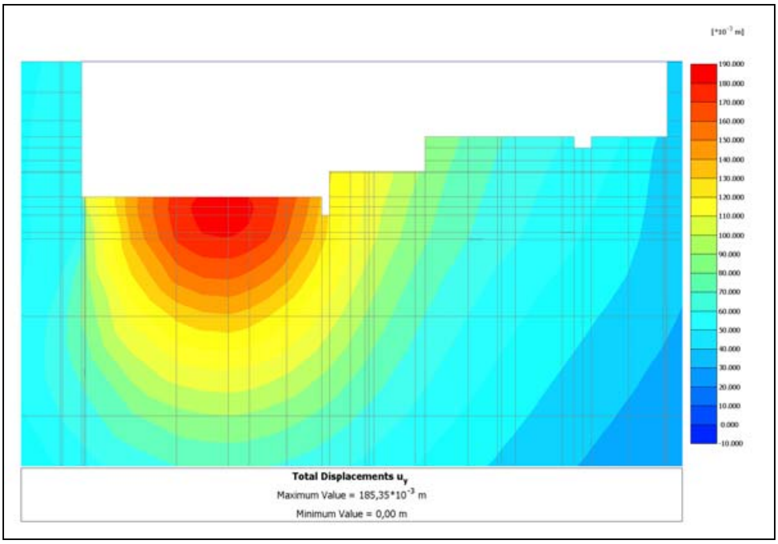

Figure 4: Foundation pit heave in longitudinal section

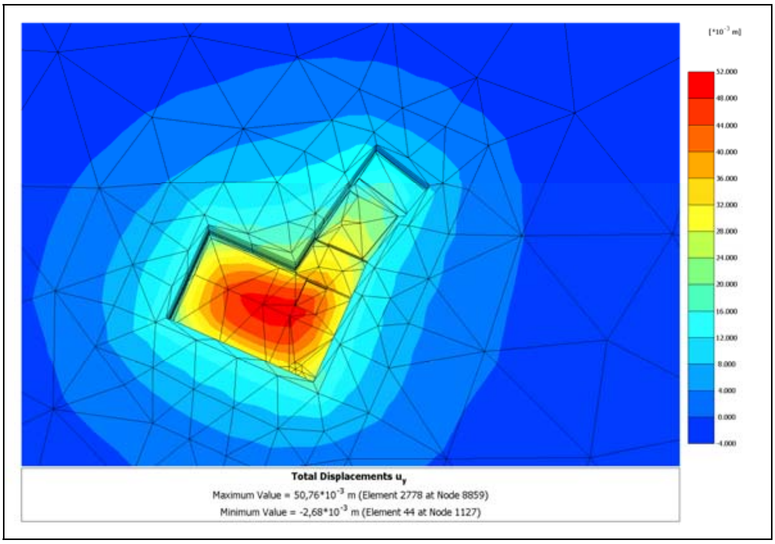

Figure 5: Foundation pit heave, increased deformation modulus

In Figures 3 to 5, you can see the difference of calculated deformations of pit floor (heave) at a different deformation modulus. In the first case, the value of the oedometric modulus in the unloading phase was entered (approx. 15 MPa). The pit floor heave is as many as 185 mm (see Figures 3 and 4). When using the results of laboratory tests where values for loading and unloading of samples were monitored, the difference is apparent. The value of oedometric modulus at the unloading branch is higher (approx. 60 MPa). These values were used during simulation of building pit excavation (see Figures 4 and 5). Subsequently, the modulus from the loading branch was used for loading of the building. The difference in deformations is relatively significant, approx. 135 mm.

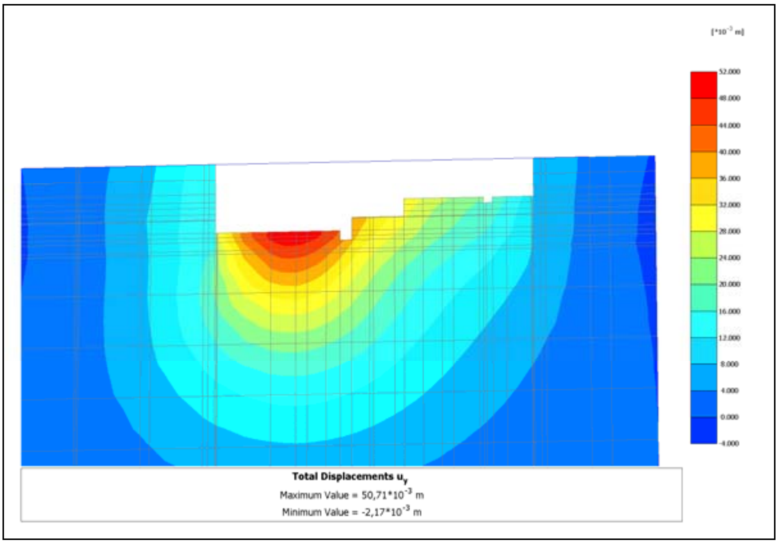

Figure 6: Building pit floor heave in longitudinal section, increased deformation modulus

4 CONCLUSION

The objective of the paper was to present the experience in work with spatial models. The Dutch company Plaxis bv offered two programs for implementation of 3D tasks, namely Plaxis 3D Tunnel and Plaxis 3D Foundation. They are now presented in one of the improved Plaxis 3D 2011 version. These programs create a spatial model with extrusion of the finite element mesh into the third direction. The difference is in the direction of elongation. In the case of Plaxis Tunnel, it is in the direction of z-axis (horizontal axis) and in the case of Plaxis 3D Foundation, it is in the direction of y-axis (vertical axis). We can advantageously use the spatial model for solving complicated geotechnical tasks, which was proved when complicated building objects were modeled.

Selection of suitable input parameters has a principal influence on global deformations. In the case of more complicated constructions, falling into the third geotechnical category, the geotechnical exploration and preparation of the project must not be underestimated. It happens relatively often that the designer has very little information about the given locality on account of financial savings in exploration. He is then forced to proceed to acquiring various input values which may not correspond with given reality. Inaccuracy of input parameters leads to misleading results afterwards. Sensitivity to inputs is makes itself felt primarily in mathematical models which are relatively often utilized at the present time. These problems often occur due to inexperience or unfamiliarity with the given issue.

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