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STABILITY ASSESSMENT OF DEEP SHAFT BUILT IN COMPLICATED GEOLOGICAL ENGINEERING CONDITIONS

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1. Introduction

The present work focuses on the requirements of linking the left and right banks of the Danube river with a pair of steel pipes with a diameter (OD) of 500 mm. As an optimal method of linking a construction an extruded reinforced concrete pipe of OD 2100 mm or a construction of the tunnel adit of OD 4500 mm (Figs. 1 & 2) was designed. A connection via a cable-stayed bridge was rejected as there were reservations concerning the safety of gas pipelines.

This paper deals with the calculation of earth pressures having an impact on the starting and target shaft of the extruded pipe. The calculation method for the earth pressure is made of dependent pressures acting on the side walls of the shaft, so that at the same time the redistribution of the earth's pressure and the technology of their construction were respected.

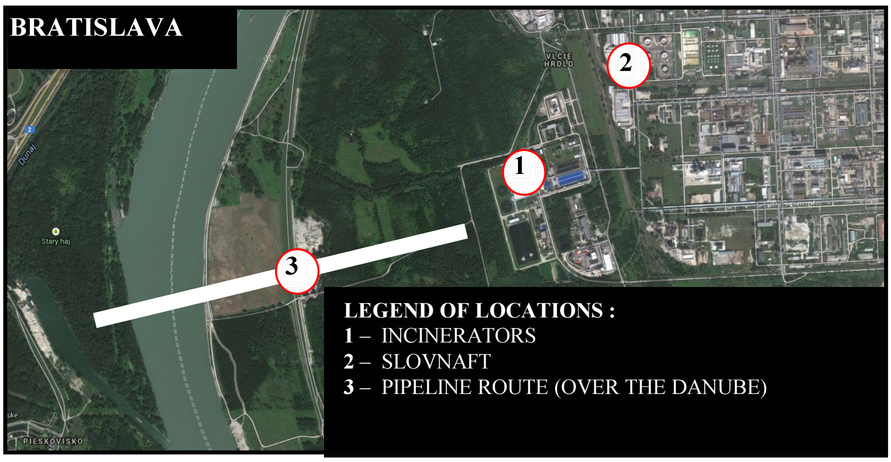

Fig.1. Situation of linking points on the left and right banks of the Danube with a pair of steel pipes of OD 500 mm

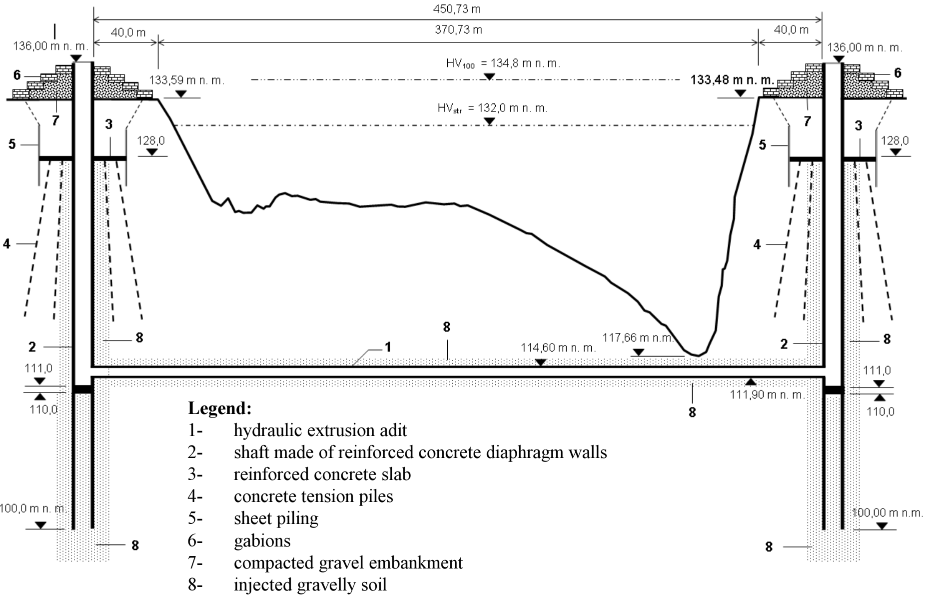

Fig.2. Schematic illustration of the technical solution of a hydraulic extrusion under the Danube

2. Geological engineering construction of a subsoil and its evaluation

No geological engineering exploration at the construction site of the overhead or underground linking of the left and right banks of the Danube has been performed yet. All the presented data and values have only been obtained from a study of archival materials. The geological engineering conditions in the gas pipeline route are as follows:

The Quaternary is represented by fluvial sediments of the Danube. A inhomogeneous layer is made of gravel and sandy sediments with a thickness of 12.0 to 17.0 m, which alternate irregularly. The gravel and sandy sediments can be characterized as highly anisotropic soils with a predominant horizontal permeability.

Neogene was found at depths from 40.0 to 60.0 m below the terrain by earlier surveys. It is characterized by the occurrence of the two dominant sediments: neogene sands and clays.

3. Geometry plans of the starting and target shafts

The producer of Herrenknecht, A.G. Schwanau, Germany pipe jacking set, prescribes minimal dimensions of the starting and targeting shafts at 7.0 x 5.0 m for a AVN 800 XC – AVN 2000 AC pipe jacking set. However, we had to increase these dimensions with respect to the spreader system, which is made of a reinforced concrete rigid frame (0.5 x 0.3 m) to dimensions of 8.0 x 6.0 m. The depth of the underground sheeting walls is 36.0 m under the terrain. The diaphragm wall will be protected from the outside by the injection of a soil layer. The soil will be injected from a level of - 21.0 m close to the surface level of 36.0 m (Fig. 3). The spreader frame around the perimeter of the excavation will capture the horizontal forces from the active earth pressure and limit the deformation of the sheeting system to the minimum possible rate. After completion of the construction and the mounting of the pipe to the starting and target shafts, the spreader system will become part of the structure's ceilings, which divide the space in the direction of the vertical shaft.

4. Stability examination of the starting and target shafts on the effect of any buoyancy forces

The starting and target shafts are loaded by large buoyancy forces resulting from the water level in the Danube during floods. Therefore, I will consider the stability effect of the buoyancy forces based on the maximum level, which could rise to the top edge of the shaft during floods.

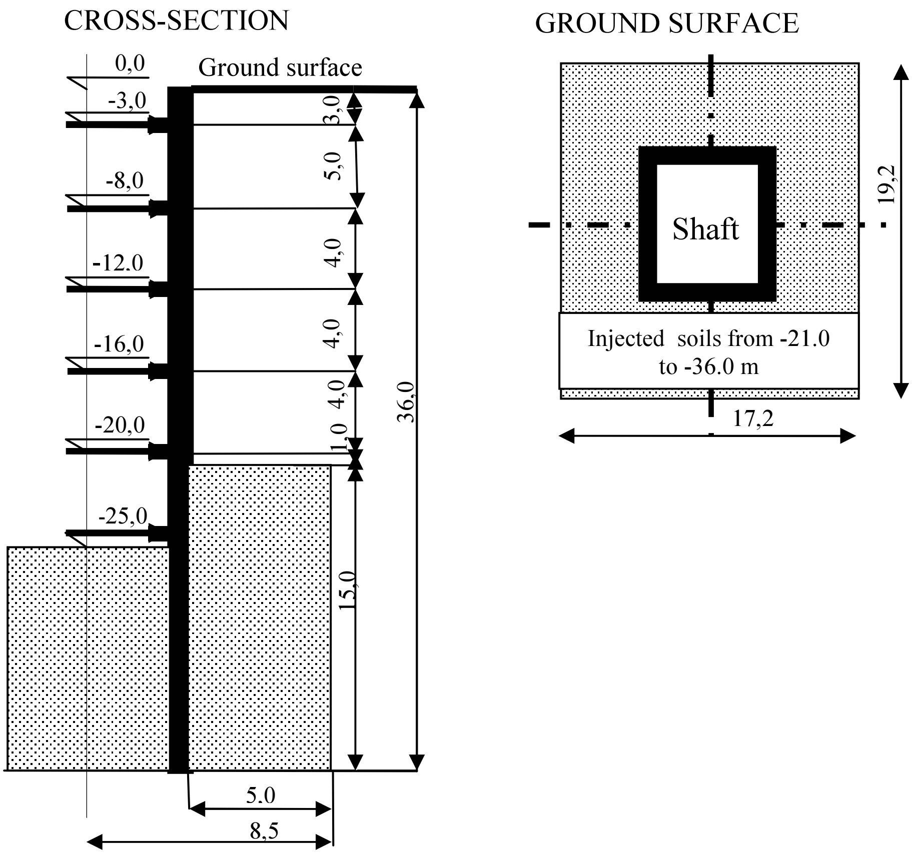

Fig.3. Geometric plan of the starting and target shaft dimensions. The ground plan and section of the shaft

The shaft's stability is solved as a planar task and has to meet the condition that the sum of gravity G and the friction on the lateral surface T is bigger than the size of the vertical buoyancy force U. The basic condition of the shaft stability results from the following inequality of the vertical forces (Fig.4):

$$G + T > U. \tag{1}$$

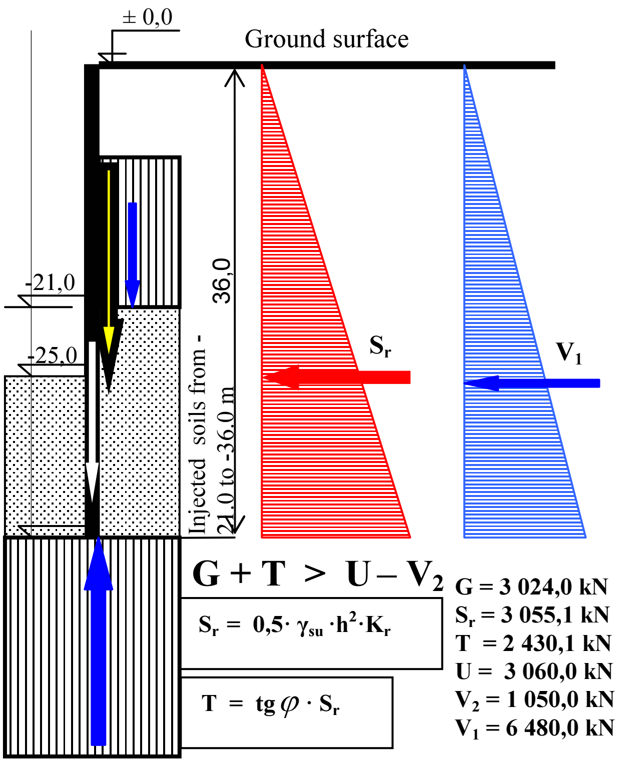

Fig. 4 Scheme of the stability calculations of the diaphragm wall

5. Boundary conditions for calculating the earth pressure acting on the diaphragm walls

In terms of optimizing the construction of the starting and target shafts, six different variants were formulated for the calculations in which the physical and mechanical properties of the subsoil were changed using the GEO 5 computational software of FINE, Ltd. The results of geological engineering exploration works were used, which were made in this field of study in order to determine the computational characteristics. Next the geotechnical properties of sands (S2) and badly granulated gravels (G2) were considered in their natural arrangement in each calculation variant. The author modified their properties (shear strength, compressibility, etc.) by means of injection, so the construction was optimized to the utmost in terms of stressing the sheeting system and ensuring its stability not only during the implementation of the construction, but also after its completion. Finally, the mentioned variants were determined as follows:

- variant 1 -36.0 - 0.0 m sand S2,
- variant 2 -36.0 - 0.0 m badly granulated gravel, G2 medial set,
- variant 3 -36.0 - 0.0 m badly granulated gravel, G2 medial set soil injected with a cement – bentonite mixture,
- variant 4 -21.0 - 0.0 m badly granulated gravel, medial set G2 from -21.0 m part of the soil block injected with a cement – bentonite mixture,
- variant 5 -21.0 - 0.0 m badly granulated gravel, G2 medial set from -21.0 m part of the soil block injected with a cement – bentonite mixture**.** Load of max. horizontal force from the pipe jacking set at a level of – 23.0 m under the terrain F = 5000.0 kN,
- variant 6 -25.0 - 0.0 m badly granulated gravel, G2 medial set from -25.0 m part of the soil block injected with a cement – bentonite mixture. Load of max. horizontal force from the pipe jacking set at a level of – 23.0 m under the terrain F = 5000.0 kN.

The main purpose for preparing the parametric study is to optimize the foundation of the starting and target shafts in order to link the left and right banks of the Danube by a gas pipeline. A series of geotechnical calculations of the stability demonstrated that geological engineering conditions at the site of the works have a dominant influence on the stability and feasibility of the planned building structure. Therefore, the following geotechnical calculations were made in six variants that differed in geotechnical conditions for constructing the starting and target shafts . Results of the calculations by dependent earth pressures method are evaluated on figer 5.

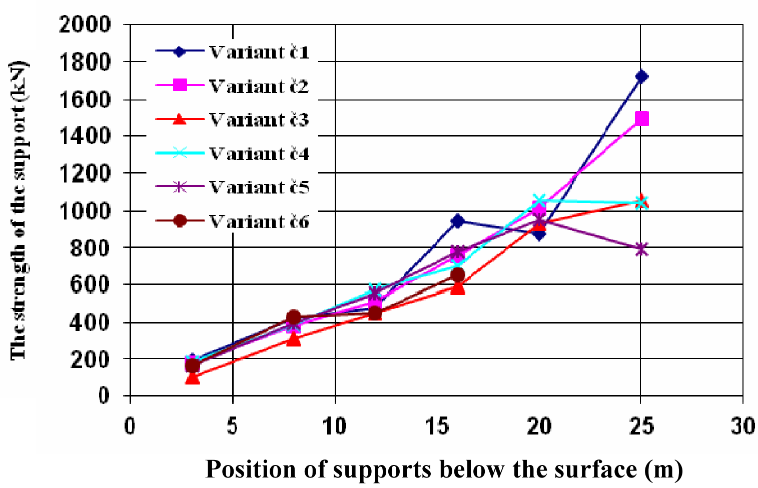

Fig. 5 Results of geotechnical calculations

6. Conclusions

The variant number 4 was considered as the best one for calculating the whole series of stability and geotechnical calculations performed by a method of dependent pressures based on the results of a diaphragm wall's deformation. The use of the GEO 5 computational software in solving various geotechnical problems permitted optimizing the foundation method or enabled the use of geotechnical constructions that led to stable, usable and economic constructions as well. In this specific case it was demonstrated that partial soil injection and improvement of its mechanical properties led to the better stability of the starting and target shafts on the effect of the buoyancy forces.

Denotations of symbols

G - je tiaž šachty, gravity of the shaft, [kN/m],
T - trenie na plášti, friction on the lateral surface, [kN/m],
U - veľkosť vztlakovej sily, size of the buoyancy force, [kN/m],
V_1 - horizontálna zložka hydrostatického tlaku, horizontal component of the hydrostatic pressure, [kN/m],
V_2 - vertikálna zložka hydrostatického tlaku, vertical component of the hydrostatic pressure, [kN/m].

References

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POSÚDENIE STABILITY HLBOKEJ ŠACHTY POSTAVENEJ V ZLOŽITÝCH INŽINIERSKO GEOLOGICKÝCH PODMIENKACH

Summary

Príspevok analyzuje základné predpoklady zabezpečenia stability štartovacej a cieľovej šachty pre výstavbu pretláčaného potrubia pod Dunajom. Inžinierskogeologické podmienky v mieste stavby sú zložité. Podložie je tvorené zle zrnenými štrkmi, hladina vody v Dunaji môže vystúpiť aj niekoľko metrov nad povrch terénu. Šachtu je potrebné zabezpečiť proti veľkým vztlakom pôsobiacim na dno šachty a zemným tlakom pôsobiacim na jej bočné steny. Preto výpočet zemných tlakov pôsobiacich na zvislé steny je vyhotovený metódou závislých tlakov. Na základe toho bol upravený rozperný systém a konštrukcia šachty tak, aby sme dosiahli rovnomerné rozdelenie vnútorných síl a momentov v navrhovanom systéme. Táto metóda výpočtu umožňuje optimalizáciu konštrukčného systému šachty a jej stabilitu pri rôznych zaťažovacích stavoch.