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THE ANALYSIS OF SLOPE STABILITY OF THE STREAM VÝŠINA IN ORLOVÁ

ANALÝZA STABILITY SVAHU POTOKA VÝŠINA V ORLOVÉ

Abstract

This paper analyzes the stability of the slope near a stream in Orlova district. The instability of the slope has a negative impact on a hot water pipeline located in the crown of the slope. The assessment is based on a survey of the current state of the slope, and mathematical models in two cross sections. Mathematical models were developed in software Plaxis 2D based on finite element method (FEM). The results of mathematical models allow locating the critical slip surface in the slope, to predict the unstable areas and possible negative effects of a potential landslide in the hot water pipeline.

Keywords

Výšina stream, slope stability, hot water pipeline, numerical model, Plaxis 2D.

Abstrakt

Příspěvek analyzuje stabilitu svahu u potoka Výšina v Orlové, jehož nestabilita ohrožuje horkovod, který se nachází v jeho bezprostřední blízkosti. Posouzení vychází ze současného stavu svahu na dané lokalitě a z matematických modelů ve dvou charakteristických řezech. Matematické modely byly vytvořeny v programovém systému Plaxis 2D založeném na numerické metodě konečných prvků (MKP). Výsledky matematických modelů umožnily lokalizovat kritickou smykovou plochu ve svahovém tělese, stanovit stabilitně problematické oblasti a prognózovat možné negativní vlivy potenciálního sesuvu na horkovod.

Klíčová slova

Potok Výšina, stabilita svahu, horkovod, numerický model, Plaxis 2D.

1 INTRODUCTION

In the land register of Orlová The Výšina brook is hydrologically insignificant stream forming a stream bed on the parcel number 1625/2 and lining instable wooded slopes. These slopes are surrounded by the urban development and there is a strategic hot water pipeline on the edge of the eastern slope, supplying heat to the whole town of Orlová.

Slope instabilities are caused by erosive factors, geological and hydro-geological conditions in this area and also by the slopes geometry.

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Fig. 1: Photo of the Výšina stream slope and its current condition.

2 GEOTECHNICAL CONDITIONS WITHIN THE AREA OF STUDY

Geotechnical specifications were based on a photo documentation, on results of the boring survey gained from Geofond [6], on a standpoint of The Czech Geological Survey [4] and finally on a report from an engineering – geological survey by G-Consult ltd. [3].

From the geological point of view this specific area is distinguished by the sash rotation of quaternary sandy and clay layers. Subsoil of these layers comprises of Neogene clay sediments that do not penetrate the surface. The top layer is formed by an organic soil cover.

Hydrogeological conditions are influenced by seasonal factors and atmospheric changes.

Groundwater level varies depending on the season of the year. The boring survey shows that the groundwater is bound to the more porous sand layers. Presumably, hydrogeological conditions together with the alternation of clay and sandy soils may result in porous pressures which affect adversely the overall slope stability.

The parcel n.1625/2 ground is affected by enormous erosion caused by the stream Výšina. It is uncontrollably filled with surface moisture from the surrounding slopes which get permanently water from the near roads and are saturated with groundwater infiltrating into the sandy layers. Erosion is also negatively influenced by a drain mouth collector that is cleared by the water pressure several times a year.

Moreover the slopes, besides the geological structure itself, are affected negatively by dangerous frost susceptibility of the clay soil.

The photo-documentation shows enormous erosion on the both stream-banks of Výšina and there is an apparent instability of the surrounding slopes. (so called “drunken trees”, local landslides, erosive influences)- see below photo 2 and 3.

10.2478/v10160-011-0011-1

Fig. 2: So Called "Drunken trees"

Fig. 3: The local partial landslide

3 NUMERICAL MODELS OF THE SLOPE

The slope stability was developed by software Plaxis 2D used for deformation and stability analysis of geotechnical tasks and is based on finite element method [5].The calculation was executed by a Mohr-Coulomb´s constitutive model defined by the primary strength parameters – cohesion and friction angle. Degree of stability *F* is in this mathematical system given by a method called reduction of strength parameters and is defined as a ratio between the input shear soil strength determined by cohesion c and by the friction angle φ and reduced shear soil strength needed for keeping failure- free state (defined by cohesion c_r and friction angle φ_r):

$$F = \frac{c}{c_r} = \frac{\tan\varphi}{\tan\varphi_r}$$

Mathematical models of the eastern slope were formed for two significant profiles. The cuts were selected in those places where the slope instability has a negative impact on the hot water pipeline. Models were adapted to available data about geological and hydro-geological conditions of this area. The primary geometry of the models resulted from a geodetic survey, from a contour map approximation and from a terrain reconnaissance. Neither hydrodynamic effects of water flow from the sewer collector were taken into account, nor the vegetation influence or the additional load of hot water line on the slope.

Geological structure in the profiles was assessed in terms of test bore holes with respect to The Czech Geological Survey standpoint and a report by G-Consult Ltd. Soil material parameters, needed for the calculation itself, were accepted on the basis of geological survey and reported reference by G-Consult Ltd. In case there were residual strength parameters available, they were selected with respect to the current unstable visual signs. Listing of accepted soils with assumed parameters see below the table 1 [1], [2], geological structure model in profiles see the figures 4 and 5, hot water pipeline location is marked by an arrow.

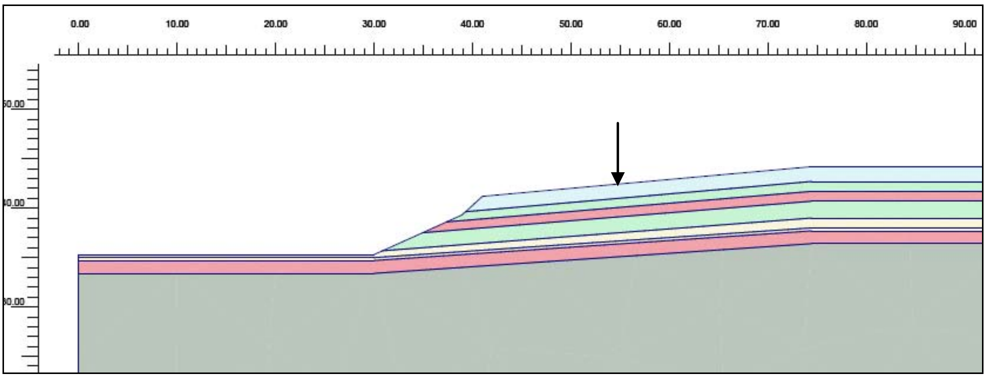

Fig. 4: Modelling geological structure – Model 1

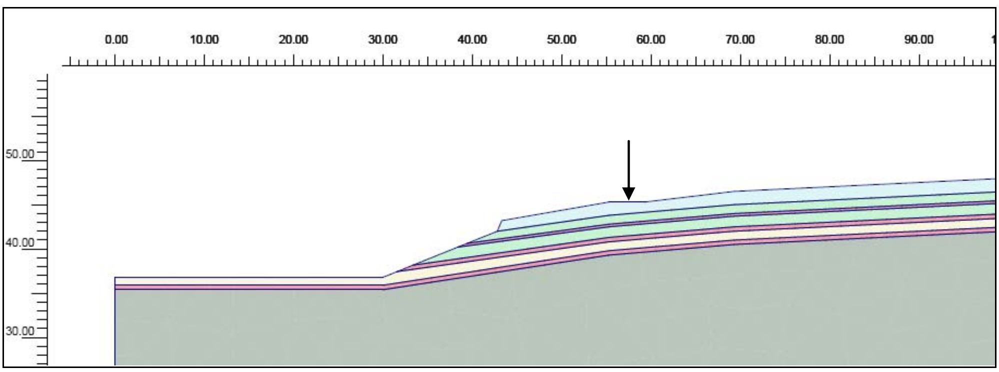

Fig. 5: Modelling geological structure – Model 2

Tab.1 Input soil parameters

	ID	Type	γ_{unsat} [kN/m^3]	γ_{sat} [kN/m^3]	k_x [m/day]	k_y [m/day]	ν [-]	E_{ref} [kN/m^2]	c_{ref} [kN/m^2]	φ [°]
ML(clSi)	1	Undrained	21,0	22,5	0,0864	0,0864	0,40	4000,0	16,0	19,0
CL(clSi)	2	Undrained	21,0	22,5	0,0086	0,0086	0,40	4000,0	8,0	10,0
CL(sasiCl)	3	Undrained	21,0	22,5	0,0086	0,0086	0,40	2000,0	6,0	8,0
SC (clSa)	4	Drained	18,5	20,5	8,6400	8,6400	0,35	8000,0	4,0	26,0
CL (Cl)	5	Undrained	21,0	22,5	8,6400E-5	8,6400E-5	0,40	5000,0	12,0	20,0

All the models respected the presence of groundwater level matching a stable level from the borehole. This conforms to boundary of sandy and clay layers. In the model 1 the assumed water level was 6,2 meters below the surface and in the profile it copies the sandy layer. In model 2 the assumed water level was 2,8 and 4,5 meters below the surface, presumably in the sandy layer again.

4 MODEL ANALYSIS AND STABILITY ASSESMENT

Models were analysed from the maximum total displacements, from the maximum displacements in the water pipeline area, from porous pressures development and from the stability level.

4.1 Model 1

Maximum calculated displacements reached 460 mm. The peak values appeared at the bottom of the slope (see the figure 6). Figure 7 shows total displacements in the water pipeline area. According to the model they are expected to be up to 20 mm. Figure 8 illustrates increasing porous pressures development. The red spectrum marks pressure, the blue one indicates a tension.

The total degree of stability of the model calculation was 1,04. This value is on a boundary line of maximum limit of the shear strength. Therefore, the degree of stability does not reach required rate 1,5 for permanent slopes and indicates the instability of analysed slope structure despite the fact that the model did not take into account any other negative effects. Moreover, groundwater level was quite deep below the surface in the model (resulting from borehole survey and is supposed to vary depending on the climate conditions). For those reasons, we can consider the profiled slope as very unstable and it is likely to have other landslides in this area.

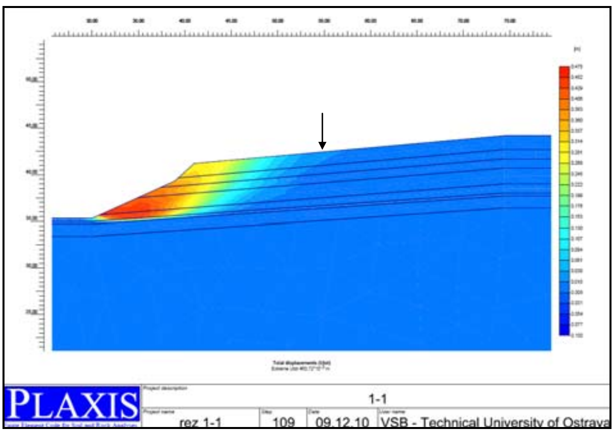

Fig. 6: Maximum total displacements- Model 1

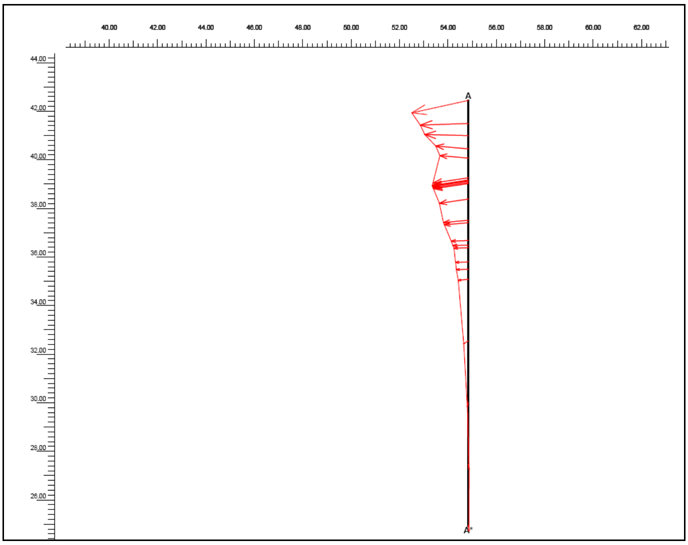

Fig.7: Total displacements at the pipeline area (max. 20 mm) –Model 1

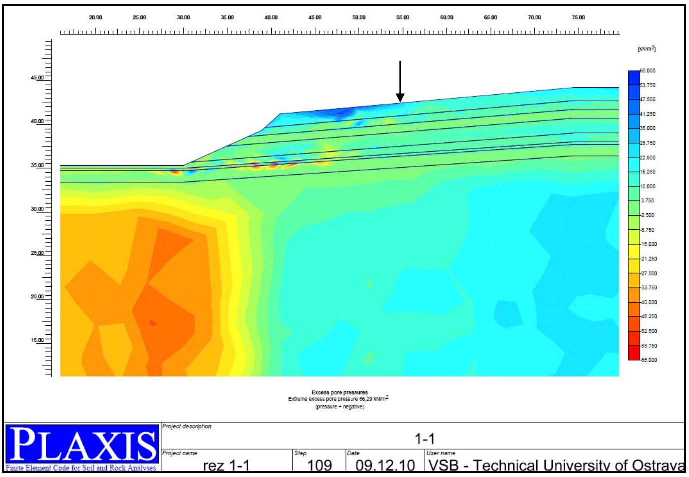

Fig. 8: Porous pressures development

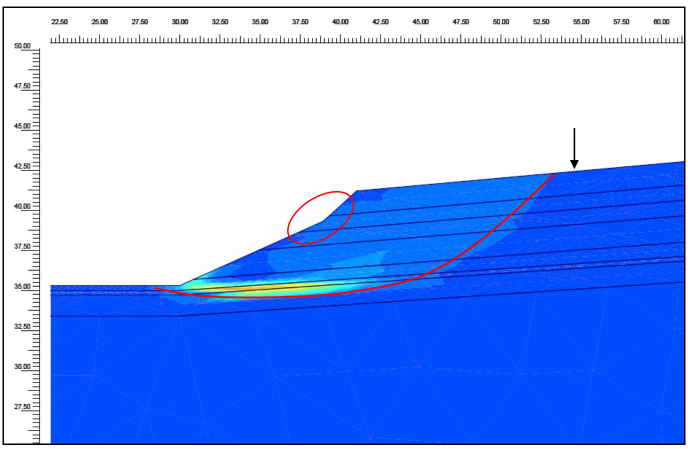

Fig. 9: Localization of slip surface in the slope

The figure 9 depicts the slip surface marking the most critical parts. The fundamental slip surface spreads on the boundary of sandy and clay layer and goes through the bottom of the slope, the partial slip surface is located at the top of it. The figure 9 also shows presumed outreach of the fundamental slip surface in relation to the hot water pipeline. In case another landslide occurred along this critical slip surface, the hot water pipeline would stand on the edge of it and there is no certainty what could have caused some other subsequent deformations.

4.2 Model 2

A mathematical model was made up in two versions. The first version assumed the groundwater level 2,8 meters below the surface. In this case the model stated the degree of stability lower than 1, which indicates significant slope instability.

The second version took into account the reduced groundwater level of 4,5 meters below the surface. In this model version 2, the maximum calculated displacement moves reached 557 mm. The peaks values were reached again at the bottom of the slope (see the figure 10), but the deformation radius is bigger. The figure 11 indicates total displacement moves at the place of hot water pipeline. According to the model we can expect them to be 300 mm. Degree of stability corresponding to the situation in the model 2 equals the value of 1, which means again the instability of the analysed slope profile.

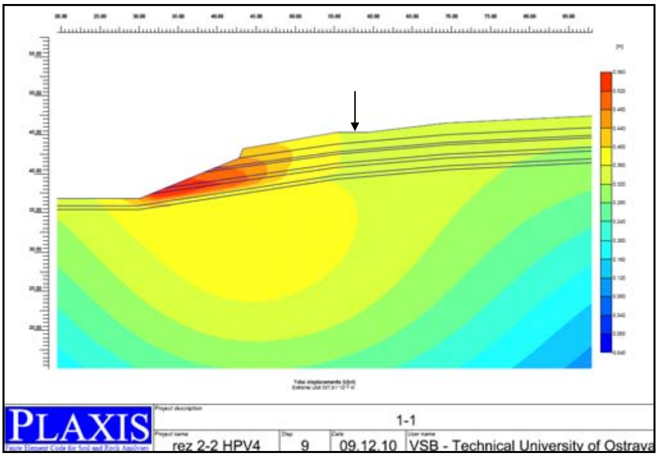

Fig. 10: Maximum total displacements – Model 2

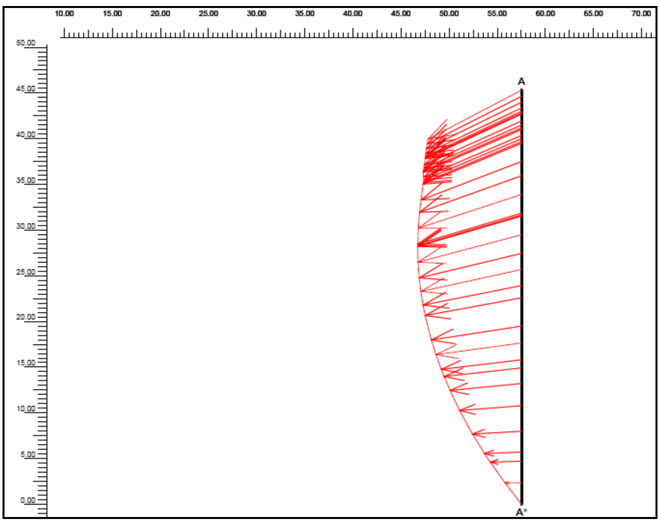

Fig. 11: Total displacements in the hot water pipeline area (max. 300 mm) – Model 2

10.2478/v10160-011-0011-1

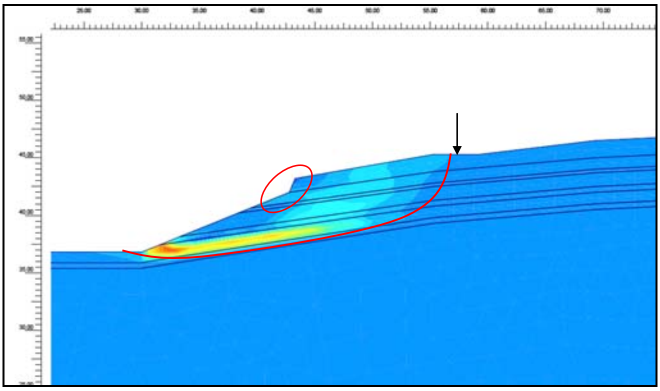

Fig. 12: Localization of slip surface – Model 2

The figure 12 illustrates slip surface of the model No.2 marking the most critical parts. The fundamental slip surface spreads in the clay layer and reaches the line of hot water pipeline. In case there was a landslide along this critical slip surface, the hot water pipeline feet would be in imminent danger.

5 CONCLUSIONS

Based on an available photo-documentation, expert terrain reconnaissance and results of mathematical models, it can be stated that the slope area in question is unstable and the signs of instability endanger the hot water pipeline situated in this place. The situation needs an acceptance and early execution of redevelopment precautions. The scheme of redevelopment precautions and their model analysis were not the subject of an expertise which was realised by Expertise Department at FAST VŠB-TU Ostrava

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