Prackovice Tunnel – Prague's Portal Modelling and Construction

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SUMMARY: The Prackovice tunnel is located on the section of the D8 highway between towns Lovosice and Řehlovice. The tunnel has two unidirectional tubes of length 270 m and 260 m, each tube has two lanes. The tunnel was excavated in basalts and tuffs, the rock mass was significantly affected by chamber blasting which were realised in the basalt production in the quarry Prackovice in past. In 2005 a pilot adit was excavated as part of realised site investigation. The tunnel excavation was realised without significant complications in 2008 and 2009. The following paper describes some aspects of construction and modelling of Prague's portal of the tunnel, where due to higher deformations additional stabilisation measures had to be adopted.

1. INTRODUCTION

1.1. Basic data

The Prackovice tunnel will be part of the D8 highway section 0805 between towns Lovosice and Řehlovice which is the last uncompleted part of the highway connection Prague – Ústí nad Labem – Germany. The highway D8 is part of the international road E55 Stockholm – Rostock – Prague – Linz – Ravenna which connects Baltic and Adriatic sea.

The Prackovice tunnel is a highway tunnel with two separate tubes of lengths 270 m (Left Tunnel Tube - LTT) and 260 m (Right Tunnel Tube - RTT). Two-lane communication of the category T 9,5 is in each tube.

The company Metrostav was employed as tunnel contractor as part of joint venture of SSŽ, Metrostav, SMP CZ and Berger Bohemia. Czech Highway Agency (ŘSD) is an investor, the detail design was prepared by consultants Tubes and Valbek, company Pragoprojekt coordinates the project, technical supervision is done by Infram, geotechnical monitoring is done by AZ Consult.

1.2. Geological conditions

As far as the geological structure of the area and the terrain configuration are concerned, the Prackovice tunnel tubes pass through a very complicated environment. According to the ČSN 73 1001 standard, the construction belongs to geotechnical category III, i.e. a difficult construction in complicated geotechnical conditions. The tunnels will be constructed in an area where basaltic bodies occur and in sections with thick tuff layers and occurrences of marlstone. During the detailed geotechnical survey, layers of rock prone to intense swelling were identified in the environment of the rock mass consisting of weathered tuff. The swelling was confirmed by laboratory tests. The roughness of the terrain manifests itself by colluvial deposits of varying character.

From the petrological point of view, a relatively wide range of rock types is represented in the area of operations. Regarding vulcanites, the prevailing types will be olivine alcalic basalts and basanites and olivine foidites, which are mostly heavily altered (autometamorphosed). A collective name "basalt" (decomposed, weathered, slightly weathered and fresh) was used for the vulcanites, while a collective name "tuff" (decomposed, weathered and slightly weathered) was used for pyroclastic rocks.

Weathered to heavily weathered (altered) basalts and tuffs unambiguously prevail in the outcrops existing on the quarry face and the surrounding slopes above the future motorway. The major part of the slopes at the portals is covered with debris. The character of the debris is mostly rocky and locally even bouldery; loamy-sandy filling prevails. As the whole, the debris is loose.

It was found out that the rock outcrops are relatively very intensely broken, above all on the slope above the lower platform at the mined Prague's portal. The fissures are open, steeply dipping and mostly crossing the centre line of the motorway on a skew. The rock mass is significantly disturbed by previous chamber blasting.

Cut and Cover part of both tubes is located in a very complicated area from geological and morfological view. The area is part of tertiary complex of vulcanic rock C

1.3. Pilot adit

A pilot adit was driven in advance, through the right side wall area of the final left tunnel tube. The adit was designed with the aim of verifying the real geological and hydrogeological conditions, verifying the suitability and effectiveness of the structural elements to be used for the excavation support and providing access and allowing the start of the work at the northern portal and at the area between the tunnels and bridges over the Uhelná Strouha gully. The gallery was driven in 2004 and 2005. The adit has a horse-shoe shape with primary lining from sprayed concrete with a thickness 200mm.

2. CONSTRUCTION

2.1. Preparatory works

Preparatory works prior tunnel construction started by pilot adit excavation in 2004. The pilot adit excavation explored significant instability of the rock mass disturbed by chamber blasting. Consequently all construction works on the tunnel were halted. In April 2008 an additional site investigation was realised to verify tunnel overburden in the Prague's portal area.

2.2. Start of the tunnel excavation

The tunnel excavation started by excavation of the Prague's portal and by stabilisation of slopes in the portal area in 2008 (Fig.1). The portal is supported by rock dowels together with a sprayed concrete on the surface. Overall stability of the area is ensured by three levels of cable anchors. The whole first level was grouted. Micropile umbrellas with length 20m were realised from portal above profiles of particular tubes. The grout consumption for one drill reached up to 5000 l (multiple of normal values).

Figure 1. Prague's portal area prior start of excavation

Excavation with the New Austrian Tunnelling Method (NATM) from the Prague's portal started in September 2008. NATM class 5a was used for excavation in the portal area, a top heading was splitted into two parts a spiling was used to protect tunnel crown (Fig.2).

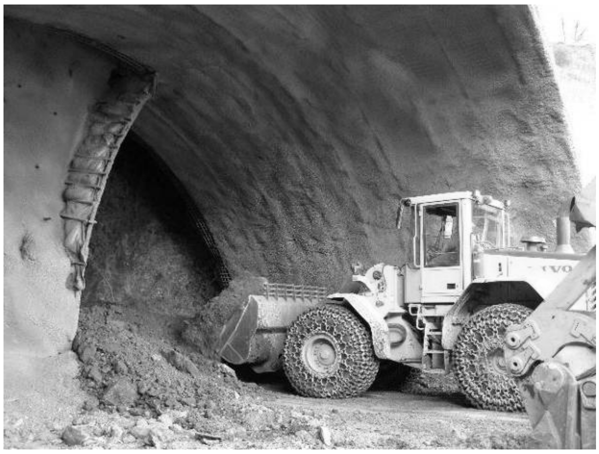

Figure 2. Excavation with splitted top heading

2.3. Stabisation of Prague's portal

In the beginning of 2008 a higher trend in deformations of the right side of the portal was recorded which was caused by interruption of prestressed cable anchors intervening into the tunnel profile of the RTT. Utilisation of the portal wall surcharge together with installation of 5 cable anchor of length 28m were adopted as additional support measures. A block from insitu cast concrete (Fig.3) of the volume 350 m^3 was anchored using 32 inclined micropiles of the length 12m. The last anchor disallowing further excavation was interrupted after stabilization of deformations.

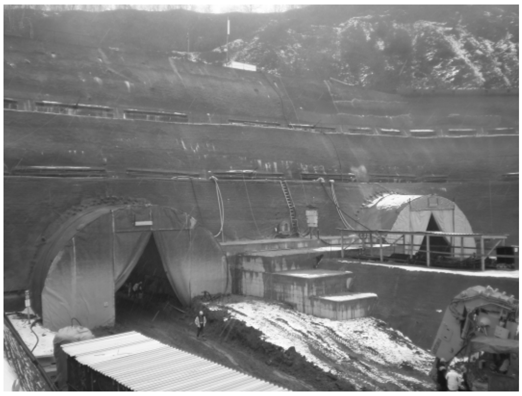

Figure 3. View of surcharging concrete block between tunnels

2.4. Completion of excavation

After overcoming of the complicated tunnel section in Prague's portal area no further significant problems were encountered. The tunnel support class was changed from 5a to 4 which was without vertical splitting of top heading. Basalts of high strength were encountered in the RTT, therefore drill and blasting had to be utilised. The North portal construction was complicated due to a difficult access to the portal (natural reservation Uhelná strouha, forest are with required permit for transport of equipment). Therefore pilot adit was used as access route. The Prackovice tunnel excavation was completed in the middle of 2009.

3. NUMERICAL MODELLING OF PORTAL

3.1. Model description

A numerical model was generated for an evaluation of the portal wall behaviour. The model was generated in code Plaxis using Finite Element Method (FEM). Average geotechnical parameters were used for purpose of modelling (Tab.1). Support measures ensuring slope stability were included into model in line with design and construction (cable anchors, ground nails, sprayed concrete layer). An interruption of lower layer of pre-stressed cable anchors was modelled in compliance with construction. Consequently the portal stabilisation by the cast concrete block was modelled. Also block support by micropiles was considered.

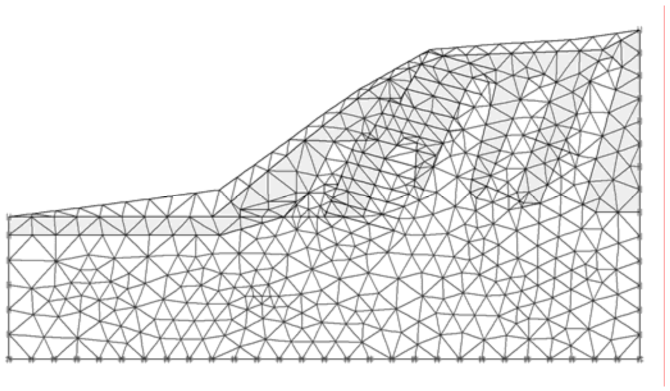

Figure 4. Model geometry

Table 1. Geotechnical parameters used for basic calculation (average values)

Layer	Description	γ	Edef	c	φ	ν
		kN / m3	MPa	kPa	°	
N, Q5	Debris	19.0	7,5	8	29	0.35
N12, N13a	Tuff	19.5	100	35	29	0.30
N13b, N15	Basalt	23.5	650	40	36	0.26

Table 2. Geotechnical parameters used for conservative calculation (pessimistic values)

Layer	Description	γ	Edef	c	φ	ν
		kN / m3	MPa	kPa	°	
N, Q5	Debris	21.0	5	4	29	0.35
N12, N13a	Tuff	19.5	100	30	25	0.30
N13b, N15	Basalt	23.5	500	30	34	0.26

Calculations were realised in the following phases:

1. Primary stress of rock mass
2. The first level excavation
3. The first level support (anchors, nails and shotcrete)
4. The second level excavation
5. The second level support (anchors, nails and shotcrete)
6. The third level excavation
7. The third level support (nails and shotcrete) (Fig.5)
8. Slope stability calculation
9. Deactivation of lower level of anchors
10. Slope stability calculation
11. Slope stabilisation by concrete block
12. Slope stability calculation
13. Micropiles under the concrete block (Fig.6)
14. Slope stability calculation

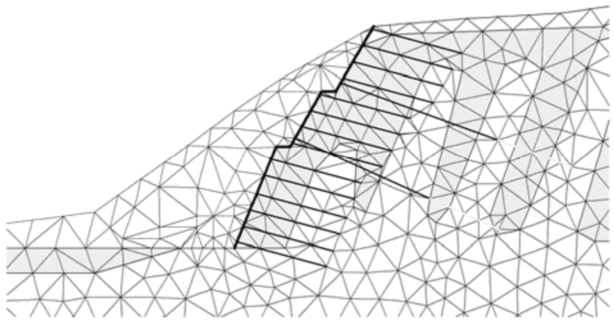

Figure 5. Model geometry after portal completion

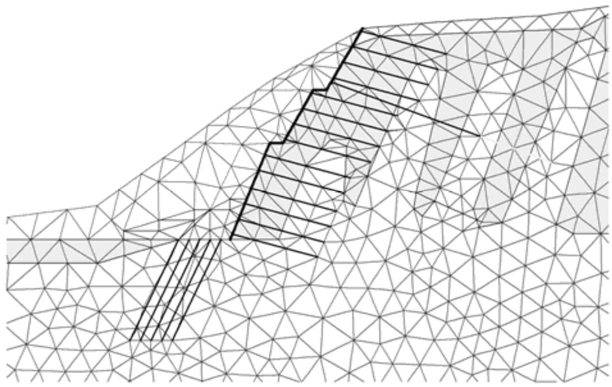

Figure 6. Model geometry with the concrete block

Slope stability was calculated by reduction of shear parameters of the ground (cohesion and friction angle). The final stability was calculated as ratio of original parameters and parameters resulting in unstable slope (ratio of original c and tan ϕ to reduced values)

3.2. Realised calculations

Basic model: The basic model was generated to realistically simulate tunnel portal construction. The average geotechnical parameters were used as input valuies (Tab.1). The model includes all basci phases of construction (ie. also interruption of anchors and stabilisation by concrete block).

Model with pre-stressed anchors: This model was generated to include impact of pre-stressing of anchors. All parameters and phases were the same as in case of basic model, only anchors were prestressed on 200kN (67kN/m‘) which complies with values monitored by dynamometers during construction.

Model without nails: This model was prepared to evaluate portal stability without impact of nails. All parameters and phases were the same as in case of basic model, only nails were not activated during calculation.

Model with unfavourable geotechnical parameters: This model evaluates impact of ground parameters, input geotechnical parameters were taken as lower limit of values from site investigation (Tab.2). All parameters of support measures and phases complied with the basic model.

Model without support: This model was generated to evaluate impact of support measures (cable anchors, nails, sprayed concrete). The model does not include support measure. All parameters and phases were the same as in case of basic model, concrete block was not considered in this case.

3.3. Results of modelling

Results of modelling are presented in tab.3.

Table 3. Calculated values of stability

Calculation phase	Dokončení výstavby portálu	Deaktivace spodní řady kotev	Stabilizace pomocí betonového bloku bez mikropilot	Stabilizace pomocí betonového bloku s mikropilotami
Basic model	1.479	1.431	1.808	1.926
Model with prestressed anchors	1.529	1.487	1.826	1.955
Model without nails	1.264	1.365	1.704	1.776
Model unfavourable geotechnical parameters	1.298	1.245	1.576	1.670
Model without support	1.065			

Realised calculations verified impact of various factors on the resulting portal stability. Calculations proved that in case of unfavourable geotechnical parameters (on the lower boundary of values from site investigation) is resulting portal stability after interruption of anchors and after the concrete block installation sufficient.

Calculated critical failure plane for the basic model is shown on Fig.7. Critical failure of futher generated models is similar.

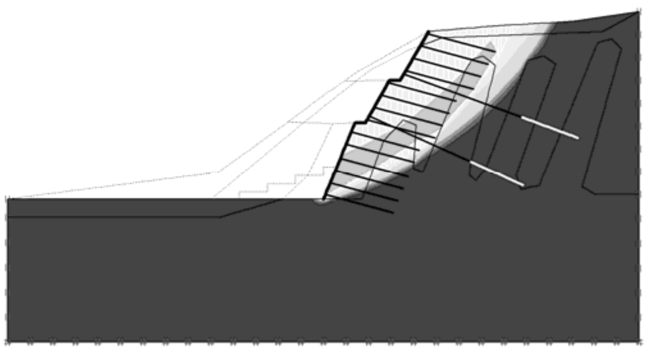

Figure 7. Critical failure plane

Numerical calculations showed a significant impact of the realised concrete block on the portal stability. In case of unfavourable geotechnical parameters the slope stability was 1.25 after interruption of anchors and 1.67 after installation of concrete block.

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