MODELLING OF UNDERGROUND STRUCTURE

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Introduction

The article informs on physical models of tunnels, which were used for study of selected problems.
Initially, the article brings information on physical models (Fig. 1 and 2) which were used for study of selected problems. It was, on one hand, stating the limit value for the maximum advance needed for maintenance of stability of the tunnels, and also determining the models´ surfaces subsidence caused by the simulation of excavation of these tunnels.
In the next part, experimental models of parallel circular tunnels are presented [1]. Attention is focused on settlement of the models´ surfaces caused by simulation of excavation of these tunnels.

Utilisation of the model for evaluation of the technological procedure of the tunnel excavation

The physical model Geo-Brno 2010 simulated three-dimensional tasks for excavation of an underground structure with variable advance (Fig. 3), with horizontal orientation of planes of discontinuity, for two parallel circular tunnels with an intermediate pillar and low overburden. The physical model was built in spatial steel modelling stand sized 2 000 x 2 000 x 500 mm.
Based on extensive collection of laboratory experiments, the following equivalent material was selected and laboratory tested:

- sand with addition of fat A00 (99.5% +0.5%),
- ballotini with addition of fat A00 (99% +1%),
- ferrosilicon with addition of fat (99.5% +0.5%),
- polystyrene and ecostyrene balls.

The scale of the model is chosen according to the smallest part of the structure (in our case it is the structure thickness). The scale 1 : 20 was chosen for the model. The measurement of the equivalent material stress state was performed by means of pressure cushions, tensometric measurement, mechanical scanners, electromechanical resonance tensometers. Dislocations during the excavation were monitored by means of geodetic point measurement (48 points were installed). Random and systematic errors were excluded, as well as influence of friction between equivalent materials and boundary conditions of the walls (glass, wood) and influence of residual horizontal stress state due to compaction.

Fig. 1 Physical model Geo-Brno 2010 during its building

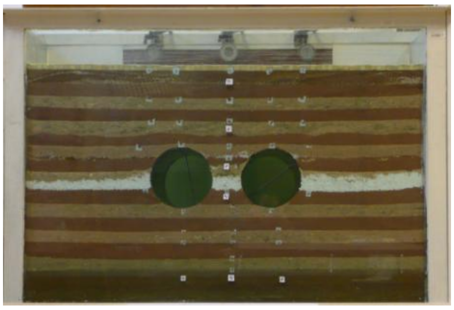

Fig. 2 Physical model Geo-Brno 2010 after finishing the building of the model

The aim of the technological procedure of tunnel driving in the model Geo-Brno 2010 was to determine the limit value of the coefficient K. For the case that the tunnel face is secured and the advance is variable, the coefficient of the limit state of the advance was determined for the left tunnel $K_{zp} = 1$ and for the right tunnel $K_{zp} = 0.5$. The maximum advance needed for the maintenance of stability for the left tunnel was Z_L = 200 mm, for the right tunnel Z_P = 100 mm. The maximum displacement in the middle of the intermediate pillar was 6.3 mm.

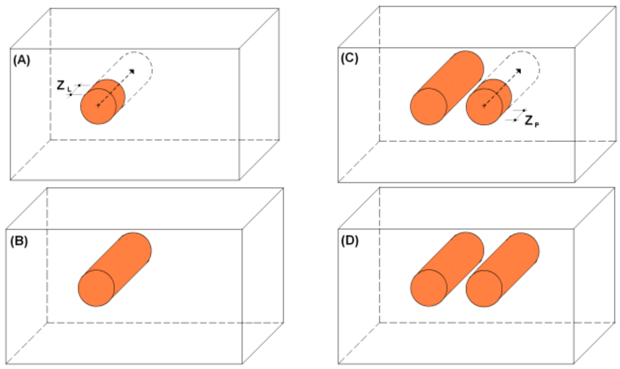

Fig. 3 Technological procedure of tunnel excavation: 1st stage – left tunnel (A, B), 2nd stage – right tunnel (C, D)

Modelling of parallel tunnels

In this parametric study, two parallel circular tunnels were analyzed. The response of the models to the excavation of tunnels was studied for three different distances of tunnels. Also influence of fault zone between tunnels was included (Fig. 4).
Experimental models were realized in a test stand sized 280 x 160 x 200 mm without application of dimensional analysis. Coloured dry sand and polystyrene balls (for fault zone) were used as modelling materials.
After finishing the building of the model, simulation of excavation and collapse of the tunnels followed. The attention is focused here on gradual tunnel driving process only. The simulations of the tunnels´ collapse and its results can be found e.g. in [1], [2], [3]. The excavation of the right tunnel was simulated first, followed by that of the left tunnel. The simulations took place step by step, the face advance length being 20 mm and less. After each step was performed, vertical displacement of the model surface was measured in measurement points (Fig. 4).

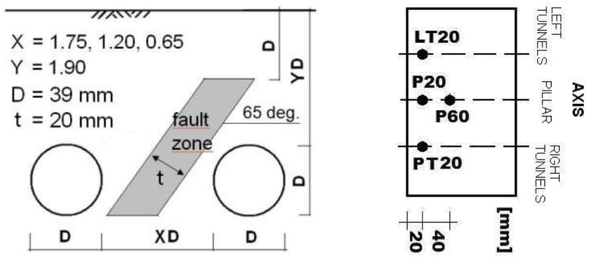

Fig. 4 Experimental models – parametric study (left), measurement points at the model surface (right)

The obtained results were graphically evaluated in the form of variations of respective vertical displacement in the progress of the tunnel excavation. For this purpose, non-dimensional parameters U and L were used, which are stated as

$$U = u/\ u_{\max}\ ,\ L = l/D\ , \qquad (1)$$

where u denotes actual vertical displacement in one of the observed points, u_{max} denotes maximum value of this displacement in the observed points, l is actual progress of the excavation and D is the tunnel diameter.
In Fig. 5 to 8, the obtained dependence of the above mentioned parameters is shown for the shortest (0.65D) and longest (1.75D) distance of the tunnels.

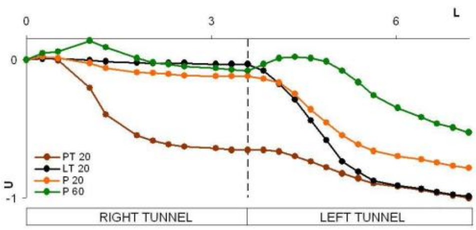

Fig. 5 U-L diagram for excavation of the right and then left tunnel (without fault zone, 0.65D)

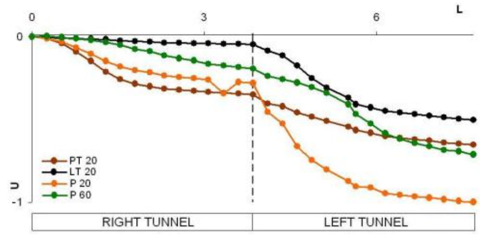

Fig. 6 U-L diagram for excavation of the right and then left tunnel (with fault zone, 0.65D)

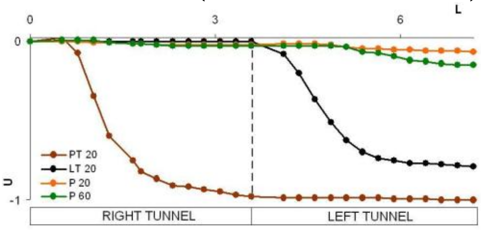

Fig. 7 U-L diagram for excavation of the right and then left tunnel (without fault zone, 1.75D)

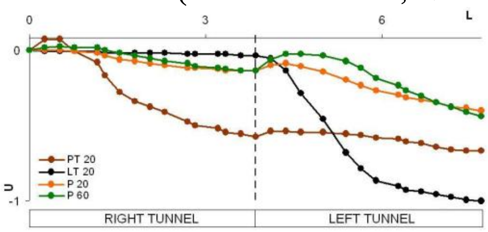

Fig. 8 U-L diagram for excavation of the right and then left tunnel (with fault zone, 1.75D)

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