PILOT ADITS FOR NATM TRANSPORT TUNNELS

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SUMMARY
Pilot adits are excavated prior to constructing tunnels with the aim of gathering geotechnical data relevant to the design for the future tunnel construction. Taking into consideration the increased project costs and extended construction time of the tunnelling projects comprising pilot adits, it is necessary to discuss the issue of the benefit and suitability of these galleries for the construction of the tunnels. The following paper brings a summary of pilot adits realised for road and railway tunnels driven by the NATM within the 1990 – 2011 period in the Czech Republic.

1 INTRODUCTION

During the previous 20 years, from 1990, driving of 14 road tunnels and 13 railway tunnels at the aggregate length of about 35 km was commenced and completed in the Czech Republic. Pilot adits were driven for twelve of them, among them all of the longest ones, before the commencement of the tunnel construction itself, running throughout the full tunnel length or along a part of the future tunnel length. The tunnelling projects are presented in this paper by means of basic parameters of the galleries and future tunnels. The tunnels are arranged in a chronological order, according to the construction time. Since several incidents happened during the period of the transport tunnels construction being surveyed, which is a problem closely associated with the problems discussed in this paper, the more serious incidents are also mentioned.

2 CZECH TRANSPORT TUNNELS WITH PILOT ADITS

2.1 The Hřebeč tunnel (1995 – 1996, exploratory gallery 1994)

The Hřebeč tunnel is a bi-directional triple-lane tunnel on the I/35 road near Svitavy, with the length of the mined section of 275 m. The tunnel with the overburden up to 20 m high was driven in complicated geological conditions formed by Cretaceous sediments of cretaceous marl, mudstone and sandstone. The pilot adit was carried out one year before the commencement of the tunnel excavation, within the framework of geological and geotechnical exploration. The profile of the pilot adit was designed to follow the shape of the right-hand side-wall drift within the future tunnel profile. The gallery was driven at the length of 50 m, uphill from the eastern portal. The excavation from the eastern portal started on the left-hand side-wall drift at the length of about 80 m. Then it was interconnected inside the rock mass with the pilot adit, forming the top heading profile. The excavation proceeded back toward the eastern portal. When the portal was being approached, the tunnel collapsed as the result of a failure of the rock mass at the portal. The tunnel construction was delayed for approximately one year. After the collapse the excavation proceeded downhill from the western portal. The part of the tunnel which was not affected by the collapse was made accessible through a shaft sunk from the surface.

2.2 The Mrázovka tunnel (1998 – 2002, pilot adits 1995 – 1997)

The Mrázovka tunnel comprises two unidirectional tunnel tubes, each with a triple-lane profile, two-lane and single-lane sections, bifurcation chambers, 5 cross passages, a cavern for a transformer station and a cavern for ventilation plant, which is connected to a ventilation shaft. The tunnel is roughly 1300 m long; the total length of the mined sections is about 2,200 m. The pilot adit was driven prior to the western tunnel tube excavation, following the tunnel centre line, from the western portal. At the northern portal, the gallery excavation was situated at the centre of the future road tunnel and gradually passed to the vault crown. With respect to the varying relative position of the gallery relative to the tunnel tube alignment, the cross-section geometry was partially modified (the radius of the gallery vault was increased at the future tunnel top). The total length of the pilot adit running on the centre line of the western tunnel tube was 800 m. In the area of Ostrovského Street and before the bifurcation, a pilot adit was driven even on the centre line of the eastern tunnel tube (about 400 m long excavation starting from the western tunnel tube being carried out). Consolidation grouting was carried out from several locations of the pilot adit. During the course of the excavation of both the western and eastern tunnel tubes in the area of the northern portal, deformations significantly exceeded the expected values. The contractor succeeded in stabilising them.

2.3 The Valík tunnel (2004 – 2005, pilot adit 2002)

The Valík tunnel is found on the D5 motorway from Prague to Rozvadov, on a by-pass around the city of Plzeň. This 380 m long motorway tunnel consists of two 11.5 m wide tunnel tubes. The tubes run side by side, without a rock pillar. This design led to reducing the area of the total plan area of the permanent works but, at the same time, to more difficult tunnelling work. The mined tunnel tubes are 330 m each. The excavation passed through weathered to heavily weathered, tectonically fractured Proterozoic shales. The pilot adit (Fig. 1) with the cross-sectional area of 15 m^2 was driven within the profile of the future central tunnel with the cross-sectional area of 71 m^2 (top heading 50 m^2 and invert about 21 m^2), throughout the tunnel length. A concrete pillar fulfilling the role of a support for the primary lining during the excavation of the tunnel tubes themselves, was cast in the central tunnel. The gallery lining was being removed during the course of the advancing central tunnel excavation. The pilot adit position within the central tunnel cross-section favourably affected the excavation of the central tunnel, acting as an anchor increasing the stability of the central tunnel excavation face.

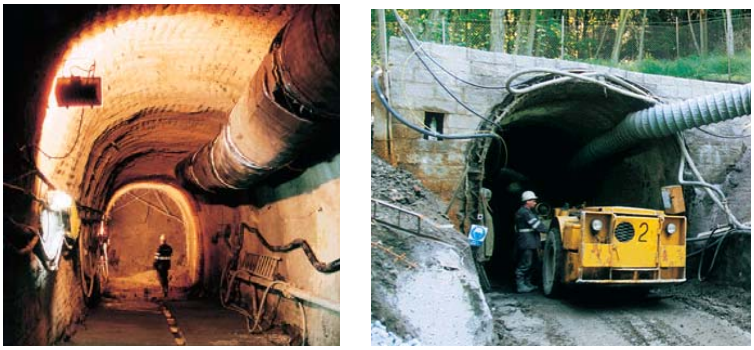

Fig. 1 The Valík tunnel pilot adit

2.4 The Panenská tunnel (2003 – 2005, pilot adit 2001 – 2002)

The Panenská tunnel is part of the D8 motorway leading from Prague around Lovosice and Ústí nad Labem to the border with Germany. The tunnel comprises two double-lane tunnel tubes interconnected by cross passages. The mined section is about 2.0 km long. The tunnel was driven in an environment formed by a faulted gneiss crystalline complex with pervasive granitic porphyry vein bodies. The construction of the Panenská tunnels construction was preceded by a detailed

geological survey, inclusive of the excavation of two pilot adits, carried out from both the northern and southern portals of the future tunnel. The excavation of the pilot adits started in September 2001 and finished in October 2002. The excavated cross-sectional areas of the galleries were 23.5 $m^{2;}$ the aggregate length of the galleries was 300 m (150 m from each side). The excavation of the galleries and the tunnel proceeded without more significant problems.

2.5 The Březno tunnel (2002 – 2007, pilot adit 1996)

The Březno single-track railway tunnel is found on the track section between Březno u Chomutova and Chomutov. The total length of the mined tunnel and the total length of the tunnel are 1478 m and 1758 m, respectively. The tunnel with the overburden height up to 30 m was driven in complicated geological conditions, consisting mainly of highly plastic clays and mudstone. Polished surfaces of numerous discontinuities caused low stability of unsupported excavation. Another important factor was the effect of previous mining activities on the rock mass in the portal areas. The cover (gravel-sand) reached down to the depth of about 6 m. The tunnel construction started in 2002, using the Mechanical Pre-cutting Method (MPM). In 2003, after completing 860 m of the drive using the MPM, the tunnel collapsed. The remaining part of the tunnel was driven by a sequential method (an analogy to the NATM). Two collapses propagating themselves up to the surface happened on this section. An escape shaft was sunk in the location of the buried Perforex machine. The tunnel was commissioned in 2007. During the project planning stage, in 1996, a "pilot adit" was driven off the alignment of the future tunnel, in the eastern part of the overburden slope of the Libouš opencast mine. The objective of this gallery was first of all to verify properties of the rock mass and short-term and long-term deformational properties of the mass, to determine calculation parameters and make the development of a realistic numerical model possible.

2.6 New Connection tunnels – the Vítkov tunnels (2005 -2006, pilot adit 2002)

The rail tunnels provide a new link between Hlavní Nádraží, the main Prague station, and stations in Prague districts of Libeň, Vysočany and Holešovice. The project consists of two double-track tunnels 1250 m and 1150 m long, respectively. The excavation passed through tectonically affected shale and quartzite strata, without more significant problems. A 20 m deep shaft was sunk at the western portal of the tunnels and an opening drift was driven from it. The drift was expected to encounter an anticipated interface between different geological formations of the Prague Fault. The opening drift driven along the top heading of the future southern double-track tunnel was about 100 m long, with the cross-sectional area of 10 m^2. This pilot adit was driven at the request of the Bureau of Mines; the Prague Fault was not encountered by the adit. .

2.7 The Komořany tunnel – PCRR 513 (2007 – 2009, pilot adit 2003 – 2004)

The Komořany tunnel consists of two unidirectional tubes; it is part of the south-western segment of the Prague City Ring Road project (PCRR). The descending tunnel tube has two traffic lanes, while the ascending tube contains three lanes. The mined part of the tunnel is 1,680 m long. Ordovician strata were encountered during the excavation, which are typified by the flysch background, i.e. the alternation of quartzite and shale. A decision regarding the particular construction was made that a pilot adit would be driven throughout the whole tunnel length because the most difficult geotechnical conditions were expected to be encountered in the central section, where a ventilation shaft was to be sunk. The geometry of the adit cross-section and its position within the tunnel cross-section were adjusted during the planning phase. The adit which was constructed was 25 m^2 in the barrel-shaped cross-section (Fig. 2); it was driven along the top heading centre line of the future triple-lane tunnel top heading. The top of the adit was higher than the top of the tunnel. The lining of the crown remained as a sacrificial structure when the full tunnel profile was being excavated. The adit was longer than the mined tunnel by 56 m and 175 m in Cholupice and Komořany,

respectively. The adit also included approximately 30 m long sections where the profile was expanded to copy contour of the full tunnel top heading.

Fig. 2 The Komořany tunnel pilot adit

2.8 The Slivenec tunnel – PCRR 514 (2006 – 2008, pilot adit 2004)

The Slivenec tunnel consists of two unidirectional tunnel tubes. The tunnel is part of the PCRR project. The 1290 m long mined section of the left-hand (northern) ascending tunnel tube has two traffic lanes. The 1240 m long right-hand (northern) ascending tunnel tube has three lanes. The tunnel tubes are interconnected by seven cross passages driven at 200 m spacing. The tunnel was driven through Ordovician and Silurian rocks, which are frequently tectonically broken and interspersed by faults and folds. The adit with the barrel-shaped cross-section of 25 m^2 was designed as a crown drift following the future right-hand ascending triple-lane tunnel throughout its length. The adit height corresponded to the height of the future tunnel top heading, exceeding the top heading roof level similarly to the adit for the PCRR 513. Seven 12 to 42 m long geotechnical sections with cross-sections expanded to the full width of the tunnel top heading (excavated cross-sectional areas of about 66 m^2) were carried out in the adit. Among other purposes they were used during the course of the excavation as passing bays. The adit was driven in 2004.

2.9 The Královo Pole tunnel (2006 -2010, pilot adits 2002 – 2003)

The construction comprises two parallel double-lane tunnels with the lengths of mined sections of about 1050 m. The tunnels are parts of the Large City Circle Road (LCCR) in Brno. The excavation was carried out through firm to stiff plastic Neogene clays, using an excavation sequence divided into multiple headings. The excavation of three pilot adits was part of the exploration. The galleries with roughly triangular cross-sections were driven on the sides of the future tunnel top heading. They were used during the subsequent construction of the tunnels. The galleries were driven from the eastern portal. The total length of the pilot adits exceeded 2 km (IIA 831 m, IIB 831 m and IB 365 m). The actual deformational behaviour (long term deformations larger than expected deformations) of the pilot adits during the construction and, first of all, after the construction, was allowed for in the design for the excavation of full profiles.

2.10 The Prackovice tunnel (2008 – 2009, pilot adit 2004 – 2005)

The Prackovice tunnel is part of the D8 motorway in the section passing across the České Středohoří highland between Lovosice and Řehlovice. The tunnel consists of two unidirectional tubes and one cross passage. The length of the mined part is 150 m, the total tunnel length is 270 m. The Prackovice construction itself was preceded by a detailed geological survey, including the excavation of a pilot adit from a shaft sunk in the vicinity of the northern (Prague) portal. The excavation of the pilot adit commenced in December 2004 and was finished in June 2005. The cross-sectional area of the adit was 23.5 m^2. The adit alignment followed the future top heading of the left-hand (western) tunnel tube. The total length of the adit was 170 m. Both the adit and the the

tunnel were driven without problems; larger deformations of the southern (Prague) portal were solved by additional stabilisation measures.

Fig. 3 The Prackovice tunnel pilot adit

2.11 The Královská Obora – Špelc tunnel (2007 – 2010, pilot adit 2003 – 2005)

The Královská Obora tunnel, which is part of the NW segment of the City Circle Road (the inner ring) in Prage between Stromovka Park and Letná, consists of two unidirectional double- and triple-lane tunnel tubes with the lengths of about 2230 m. The pilot adit with the total length of 1950 m runs along the prevailing proportion of its length within the profile of the future southern tunnel tube (STT); it is positioned eccentrically at the crown of the top heading of the future tunnel. The adit with the cross-sectional area of 10.5 m^2 was constructed using rail-bound transport and passing bays provided at intervals of 150 m. In the section with the shallowest cover at the bottom of the slope from Letná, the pilot adit was even driven within the profile of the future northern tunnel tube (NTT). In the section with the shallow cover under Stromovka Park, extensive stabilisation measures designed to improve conditions for the future tunnelling were implemented from the pilot adit. Two collapses happened in the area of Stromovka during the course of the excavation of the full profiles. They delayed the excavation and influenced the subsequent excavation procedure.

2.12 The Jablůnkov tunnel (2007 – not completed)

The construction of the new Jablůnkov tunnel on the rail track section between Třinec and Čadca (the SR) lies in enlarging the width of the existing single-track tunnel, converting it into a double-track tunnel with the length of the mined (expanded) section of 565 m. The expansion was carried out asymmetrically, leaving the original right-hand sidewall of the tunnel in place. No exploration gallery was driven prior to the tunnel excavation because the existing tunnel allowed the designer to identify geotechnical conditions on the tunnel centre line (more detailed technical background from the construction of the original tunnel was not available). The excavation of the top heading was affected by two incidents. The tunnel collapsed during the bench and invert excavation at the length of about 100 m.

3 TYPES OF PILOT ADIT

Pilot adits are linear underground tunnel workings which are usually driven following the profile of the future tunnel. Pilot adits are parts of geotechnical investigation. Sizes of these linear underground structures are not limited; the term “adit” is used even for profiles larger than the usual formal limit of 16 m^2.

From the aspect of their position, the pilot adits mentioned in this paper were most frequently driven in the following positions within the future tunnel cross-section, with the following geometries (see Fig. 4):

1 – A barrel-shape adit following the top heading centre line (with its roof at the same level as the tunnel roof (1A) or higher than the tunnel roof (1B))

2 – A triangular cross-section adit driven in the area of the sidewall drift (with its roof at the same level as the tunnel roof (2A) or higher than the tunnel roof (2B)
3 – A horseshoe shaped cross-section adit driven within the area of the top heading (with its roof at the same level as the tunnel roof or higher than the tunnel roof
4 – A adit driven outside the tunnel profile (in parallel with the tunnel), which can be used during the tunnel operation for escape, ventilation or drainage purposes.
5 – A adit running outside the tunnel cross-section (non-parallel with the tunnel), which is used during the tunnel excavation as an access adit

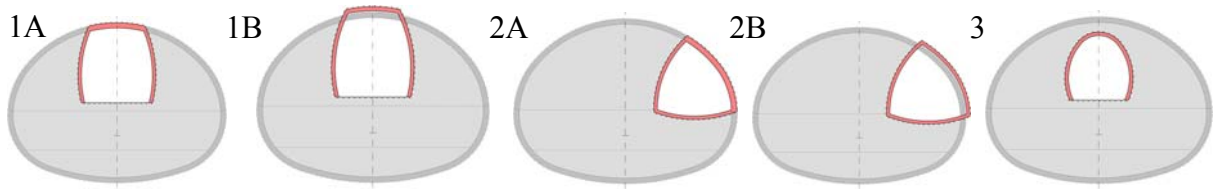

Fig. 4 Positions and geometries of pilot adits and their examples (1 - PCRR 513, PCRR 514; 2 – Královo Pole tunnel, Brno; 3 – Mrázovka, Královská Obora, Prackovice tunnels)

4 BENEFITS OF PILOT ADITS TO REDUCE GEOTECHNICAL RISKS

It follows from the summary (see Tables 1 and 2) that a pilot adit was carried out for all tunnels in the CR where the mined sections were longer than 1 km. Pilot adits are considered to be the most detailed way of geotechnical investigation available before starting the tunnel excavation. It is an interesting fact that a pilot adit was driven before commencing the tunnel excavation nearly in all cases of bigger collapses of transport tunnels in the CR; in the case of the Jablůnkov tunnel there was the existing tunnel available. The only case where no underground exploratory working was carried out was the Brusnice tunnel (Blanka – MyPra). This fact suggests that the excavation of a pilot adit itself, often combined with the stabilisation of the rock mass, does never guarantee complete safety of the excavation.

For the implementation of a pilot adit to be beneficial in terms of geotechnical safety and, at the same time, the construction cost, it must meet the following requirements:

- The level of geotechnical information necessary for a quality design and execution of the works must be improved (geotechnical parameters, deformational behaviour and rock mass stability, water inflows etc.)
- The above information must be made provisions for in the geotechnical design so that the work effectiveness is increased and all risks are diminished.
- A structure reinforcing the rock mass and increasing the stability of the excavation face, possibly even supporting a part of the top heading, must be created.
- Excavation conditions in the adit surroundings must not be worsened as the result of loosening, deformations or suffusion.

Correct construction of conventionally driven tunnels using the NATM makes flexible adjustment of the excavation process, excavation support and execution of stabilisation measures in advance of the excavation possible. A prerequisite for the success is that organisational, demarcation of authority related and contractual conditions exist which permit it.

The question remains whether driving of pilot adits for tunnels excavated by the NATM in the CR is necessary from the general geotechnical viewpoint and whether it is beneficial.

Table 1 Overview of road tunnels constructed from 1990 to 2010 in the Czech Republic

Road tunnels	Excavation commencement	Excavation completion	Excavation length (m)	Pilot adit	Excavation accidents
Hřebeč	1995	1996	275	yes	yes
Pisárky	1995	1997	600	no	no
Mrázovka	1999	2002	2200	yes	no
Valík	2004	2005	660	yes	no
Panenská	2003	2005	4000	yes	no
Libouchec	2005	2006	900	no	no
Klimkovice	2004	2006	1740	no	no
PCCR 514	2006	2008	2550	yes	no
PCCR 513	2006	2008	3350	yes	no
Prackovice	2008	2009	300	yes	no
Královo Pole	2006	2010	2100	yes	no
Radejčín	2009	2010	1150	no	no
Královská Obora (Blanka, Špelc)	2007	2010	4400	yes	yes
Brusnice (Blanka, Mypra)	2009	2011	1100	no	yes

Table 2 Overview of rail tunnels constructed from 1990 to 2010 in the Czech Republic

Railway tunnels	Excavation commencement	Excavation completion	Excavation length (m)	Pilot adit	Excavation accidents
Březno	2002	2006	1500	outside tunnel	yes
Vepřek	2003	2003	275	no	no
Krasíkov	2003	2003	1035	no	no
Tatenice	2003	2003	85	no	no
Malá Huba	2003	2004	300	no	no
Hněvkov I	2004	2005	130	no	no
Hněvkov II	2004	2005	430	no	no
New Connection	2005	2006	2400	yes	no
Zahradnice	2009	2010	1030	no	no
Olbramovice	2009	2010	480	no	no
Jablůnkov (expansion)	2009		610	existing tunnel	yes
Tomice I.	2009	2 010	325	no	no
Tomice II.	2010	2011	255	no	no

5 PLANNING AND CONSTRUCTION OF FUTURE TUNNELS

Planning and execution of pilot adits may even have other reasons than geotechnical ones, which may bring about many benefits, such as:

- a possibility of starting the work on the project in advance by driving the pilot adit on the basis o mining regulations instead of building regulations
- fixing of the route, public relations, social acceptability
- easier negotiations and course of the administrative processes necessary
- creating conditions for the future construction in advance (site facilities, communications, transport, energies, media)
- technological benefits during the tunnel excavation (transport in the tunnel, ventilation, access)
- excavation safety (increased stability of excavation face and top heading, drainage, possibility of reinforcing the ground mass)

The following aspect can be presented as the main disadvantages:

- demands for time
- increased construction cost (unless the adit construction is compensated for by its benefits)

For the above-mentioned reasons, the (non-geotechnical) benefit of a completed exploration adit for a tunnelling project and its preparation can be very significant.

6 CONCLUSION

Driving pilot adits for larger tunnel construction projects in the Czech Republic has become a rule. To the full use of the advantages the pilot adits can provide it is necessary to incorporate them properly into the planning process, first of all in terms of time, so that the geotechnical information gained by the galleries can be processed and applied to the design and tender documents. The increased investment demands during the course of a pilot adit can be compensated for by advantages, even though these advantages are hard to economically quantify. A decision on the construction of a pilot adit for future tunnel construction projects should be based on a thorough individual assessment of the particular project.

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