DEVELOPMENT OF TRAFFIC AND TRANSPORT TUNNELS IN CZECH REPUBLIC IN PAST DECADES

Jiří Barták[1]

The paper presents a review of the history, current constructions and the most important plans in constructing railway and road tunnels in the Czech Republic. Individual tunnels are briefly, technically described; other significant characteristics of the works are presented, including the tunnelling method which was used during the construction. The only method used in tunnel construction after 1989 is the New Austrian Tunnelling Method. After 1990, 15 large tunnels have been completed using New Austrian Tunnelling Method – 8 railway tunnels and 7 motorway and road ones in Czech republic. Owing to the dominating application of the NATM, a number of technologies associated mainly with excavation support and stabilisation of the overburdeen has developed in our country. The excellent tradition of our underground construction industry and the construction of long tunnels will require full-face tunnel machines in the near future.

Key words: Railway tunnel, road tunnel, tunnelling method, full-face tunnel machines

1 Railway tunnels

A notable day for railways in Czech provinces, having an over 160 years long history, is the 7th July 1839, when the operation of the "First Steam Engine Based Transport Line" between Wien and Brno commenced. Other rail lines were developed very quickly. To cope with the demanding parameters required for the horizontal and vertical alignment of the routes, it was necessary from the very beginning to use tunnels as one of important delineation elements.

The total of 149 rail tunnels at the aggregated length of about 36.5km were built on Czech Railways' tracks during the 19th and 20th centuries. Of this number, 88 tunnels were built on single-track lines and 61 tunnels for traffic on double-track lines. Of these double-track tunnels, a mere 31 tunnels are currently fully used, while only a single track is laid in the remaining 30 tunnels. The total of 103 tunnels are older than 100 years, 16 tunnels are older than 150 years (the Třebovice tunnel, which was abandoned in 2005, was the oldest with its age of 160 years). At the moment, together with tunnels completed in the 21st century, the Czech Railways' network contains 156 tunnels at the total length of 41,649m.

1.1 Tunnels bilt before 1945

Because of the large number of old railway tunnels, it is only possible to mention some of the most remarkable. The oldest work, with a very interesting history, was the construction of the Třebovice double-track tunnel (1842 through 1845) on the Česká Třebová – Olomouc rail line, which was driven

[1] prof. Ing. Jiří Barták, DrSc., Technical University of Prague, Faculty of Civil Engineering, Department of Geotechnics, Thákurova 7, 166 29 Praha 6, Czech Republic, tel.: +420 224354557, E-mail: bartakj@fsv.cvut.cz

along the length of 508m using the German system, encountering serious problems in the environment formed by swelling and heavily squeezing Miocene clays. Despite the big problems during the excavation, the tunnel was completed. In 2005, the old Třebovice tunnel was abandoned forever, within the framework of the railway corridors modernisation project. It was replaced by an open cut with a short cut-and-cover tunnel section 95 m long.

Remarkable structure was the first cut-and-cover tunnel in Czech provinces, which was built in 1845 through 1847 on the rail line Přerov – Hranice na Moravě. The 259m long tunnel was also constructed by the German system, however, the "open" variant was applied, with the side walls carried out in trenches and the masonry vault assembled on a centering braced against the rock core. In 1873, the rail line was relocated 100m south. The tunnel structure was abandoned since it had lost its function. Today it is a listed Czech Technical Monument (fig. 1).

Fig. 1 Abandoned tunnel Slavíč

The first large underground structures built in the centre of Prague were the Vinohrady tunnels. The year 1866 saw the beginning of the single-track rail line between Gmünd and Prague, which was designed to connect Bohemia with the historic provinces of Austria. The construction of the 1139m long single-track Vinohrady Tunnel I, which started in 1869 – 1871, was connected with this project. The construction of the second tunnel (1126m long) and a blind section of the Vinohrady tunnel III (292m long) started in 1940 and was completed in 1944. The Modified Austrian System was applied to this construction.

The longest rail tunnel in the Czech Republic was, till the 1st April 2007, the 1747m long Špičák tunnel on the rail line to Železná Ruda. It was driven by the Modified Austrian System from 1874 to 1877. The tunnel was substantially rehabilitated in 1977 through 1982 using sprayed concrete, welded mesh and rock bolts. Currently the tunnel is operated in a single-track configuration.

1.2 Tunnels built over 1945 to 1995 period

Ten tunnels were opened to traffic in the first decade after World War II. They were mostly built and also operated as double-track tunnels, with the exception of the Chuchle tunnel (500m long), which links to the so-called Intelligence Bridge in Prague, which is operated as a single-track tunnel. Other tunnel belonging among important tunnels of this period are the Loučky and Havlíčkův Brod tunnels, both over 600m long.

Six other tunnels were built on the Czech Railways' network till 1995. Of them, we must not forget to mention the Nové Sedlo tunnel and two single-track tunnels forming the project for the completion of the Vinohrady tunnel III. The Nové Sedlo tunnel was built on a diversion of the Sokolov – Chodov rail line, which made unblocking of coal resources bound in a protective pillar of the rail track possible. This unique, 210m long structure was designed and constructed in the form of a thin-walled vaulted structure using precast panels assembled on a travelling centering set, the so-called BEBO system (fig. 2). A thin-walled lining must interact with perfectly compacted backfill material.

The project for the completion of the Vinohrady III tunnel (1983 through 1989) comprised the construction of a 35m long bifurcation chamber (the Modified German System) at the end of a germ of the double-track Tunnel III, which had been constructed in the past. The track continued further through separate single-track tunnel tubes (the Ring Method with a segmental lining), which terminated at the common Vršovice portal. The new single-track tunnels do not follow in parallel the routes of the original Vinohrady tunnels I and II. Through 560m and 860m diameter curves, they turn off to a space unaffected by previous tunnelling. The total length of the mined single-track tunnels is 1566m; the left (western) tube is 772m long, the right (eastern) tube is 794m long.

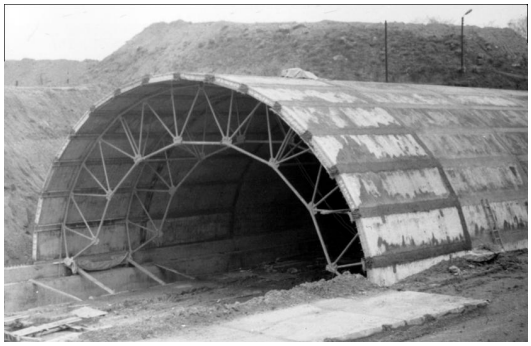

Fig. 2 System BEBO – Nové sedlo tunnel

1.3 Tunnel copleted over 1995 to 2008 period

Four railway transit corridors, priority axes, were defined for the Czech Republic in the framework of international agreements on which the modernisation of track design parameters is the priority task. The importance of the selected railway lines is confirmed by the fact that they were incorporated into the system of Pan-European Transport Corridors. The total length of all corridors in the Czech Republic reaches 1962km. The modernisation of railway lines brought about the necessity of reconstructing existing tracks because their parameters no more complied with the needs for a higher speed, which is assumed to reach 160km per hour. New design parameters, first of all larger-diameter horizontal curves in a rugged topography, bring about the necessity of building new structures, mainly bridges and tunnels.

Till 2008, 7 tunnels were built in the Czech Republic on the transit corridors. The Vepřek tunnel on Corridor I/IV) and the Krasíkov, Tatenice, Třebovice, Hněvkov I and II and Malá Huba on Corridor II/III) and the new Vítkov tunnels, which are part of the so-called New Connection developed in the framework of the Prague Rail Junction, have already been opened to traffic. Great advantage of placing the New Connection line into service is the fact that it interconnected Prague suburbs with each other in a way allowing the routes of all large-capacity commuter trains to be crossed and connected at Prague's main station.

The Vepřek tunnel (390m long) near Kralupy nad Vltavou was the first tunnel on Czech Railways' network to be driven by the New Austrian Tunnelling Method. Other tunnel structures on the corridor lines, with the exception of the Třebovice tunnel, were driven using the same method. The new Třebovice tunnel (95m long) was built in difficult conditions formed by swelling clays, using a cover-and-cut method. It terminated the long and troubled history of the old Třebovice tunnel in 2005, when the tunnel was abandoned and filled with cinder concrete(!?)

Regarding common rail lines, the 1758m long Březno tunnel on the Prague – Chomutov rail line was the only tunnel completed in the above-mentioned period. In 2007, it became the longest railway tunnel on Czech Railways' network. An 1145m long section of the tunnel was constructed using a Perforex pre-cutting method. After the tunnel collapsing and the caving in of the pre-vault tunnelling machine, the remaining section of the excavation was completed by the NATM.

Fig. 3 West portal of Březno tunnel

1.4 Tunnels under construction

One tunnel is currently under construction – the Jablunkov tunnel on Transit Corridor III. The 612m long new Jablunkov tunnel will make replacing of two existing single-track tunnels in the framework of the optimisation of the track section between Bystřice nad Olší and the border with Slovak Republic by a single double-track tunnel possible. One of the old tunnels will be converted into a new double-track tunnel using the NATM, while the other old tunnel will be partially used as an escape route. Part of this tunnel will probably be closed. The reconstruction started in 2008 to be finished in 2010.

2 Road tunnels

Compared with railway tunnels, vehicular tunnels were not technically unavoidable on the roads in the morphology of the Czech Republic. For that reason, or for economic reasons, decisions to build road tunnels were exceptional in the past, mostly in cities. Then, in the 1990s, the extensive development of car ownership, which was followed by construction of new capacity roads (motorways, expressways, urban ring roads), led to wider exploitation of road tunnels. Undoubtedly, an important role is played by the increasing respect for nature and the environment in general.

Till now, a total of 20 vehicular tunnels have been in service in the Czech Republic; of this number, 11 tunnels are in urban areas. Fourteen tunnels have been inaugurated since 1990, eight of them since 2000. The total length of all operating vehicular tunnels in the Czech Republic is about 11km, 4.3km of that length are on motorways and expressways, 6.3km on urban roads and 0.4km on the other roads.

2.1 Tunnels built till 1945

Only 4 tunnels were completed in this period. Their lengths vary within first tens of metres. They mostly originated with the objectives to develop required road links and, at the same time, to protect natural monuments or historic structures against threatening them by open cuts. The oldest ones are the 34m long Vyšehrad tunnel from 1904, the 24m long Kokořín tunnel from 1935 and the 40m long Seč tunnel near the dam of the same name in the Železné Mountains. A real curiosity is a tunnel called Pekař's Gate, built in 1914 near the village of Lažany in the Turnov region (fig. 4). It was carved in a sandstone rock block and its length reaches a mere 4 m.

2.2 Tunnels built over the 1945 to 1995 period

This period saw the construction of the 426m long Letná tunnel in Prague, which is a typical urban vehicular tunnel. It was built in 1949 through 1953 by a classical room and pillar system with timbering, using the Modified Austrian Method. During a reconstruction in 2003, the tunnel was equipped with standard safety

equipment and a modern control system. At the same time, the ventilation system delivery was increased, thus it can fulfil the role of fire ventilation today. Other 2 tunnels from this period – the Těšnov tunnel in Prague (1980 – 344m long)
and the Liberec tunnel (1992 – 280m long), are urban cut-and-cover tunnels.

Fig. 4 Tunnel called Pekař's Gate – length 4 m

2.3 Tunnels completed over the 1995 to 2008 period

The remaining 13 operating tunnels were completed in this period. Of the mined tunnels, 7 were constructed by the New Austrian Tunnelling Method (table 1). There is also the longest operating vehicular tunnel Panenská on the D8 motorway in the Krušné Mountains among these mined tunnels. With its length of 2168m, it is, at the same time, the longest tunnel in the Czech Republic.

The 2042m long Strahov tunnel in Prague, the construction of which was drawn out due to historic political changes to long 10 years, was driven using two tunnelling methods, which were distinctive of the Czech Republic in the 1960s through 1990s. From the northern portal, the top heading was excavated using the ring method with an erector, while a non-mechanised semi-shield was applied from the southern portal, with the core excavation carried out from a space which was protected by final side walls (abutments), which had been built in advance.

Apart from three shorter cut-and-cover tunnels (the Husovice - 1998 and Hlinky tunnels - 2007 on the Large City Circle Road in Brno and the Zlíchov tunnel - 2002 on the City Circle Road in Prague), the year 1999 saw the completion of the first earth-covered tunnel, the 93m long Dolní Újezd tunnel on the R35 expressway.
This tunnel was designed as a compoud structure consisting of two identical vaulted cross-section tubes with a common central wall, and without an invert.

The 304m long Jihlava tunnel on the I/38 by-pass road around Jihlava was completed in 2004. It was constructed by the cover-and-cut method (a modification

Table 1 New road tunnels completed by NATM

Tunnel name	Region	Year of opening	Tubes	Lane in tubes	Length /m/	Order of real.
Hřebeč	Pardubický	1997	1	3	355	1 (9)
Pisárecký	Jihomoravský	1997	2	2	513/500	2 (10)
Mrázovka	Hl. m. Praha	2004	2	2 - 3	1300	3 (15)
Valík	Plzeňský	2006	2	2	390/380	4 (16)
Panenská	Ústecký	2006	2	2	2168/2116	5 (17)
Libouchec	Ústecký	2006	2	2	520/504	6 (18)
Klimkovice	Severomoravský	2008	2	2	1088/1077	7 (20)

Celková délka 6.334 m

of the former Milan method). The tunnel cross-section is a semi-frame with a transverse flat vault, with the legs fixed in sufficiently strong rock. The tunnel excavation was carried out under the protection of permanent structure, i.e. the structural diaphragm walls 800 mm thick and the roof deck

2.4 Tunnels under construction

There are currently 7 tunnels under construction, namely the Prackovice, Radejčín, Komořany, Šabatka, Lochkov, Blanka and Královo Pole tunnels.

The Prackovice and Radejčín are motorway tunnels on the last incomplete part of the D8 motorway between Prague and the border with Germany, in the Lovosice – Řehlovice section. The construction of this section has been complicated owing to its passage across the České Středohoří Protected Landscape Area and obstructions by environmental activists. The construction work has been blocked, despite the resistance shown by population of a number of towns and villages which have been for a long time burdened by intense road traffic, which could otherwise run on the D8 motorway.

The 270m long Prackovice tunnel, which is currently being completed, passes under the crest of Debus Hill, in the area of an abandoned quarry. Just behind a bridge over the Uhelná Strouha groove, connecting to the tunnel, there is the 620m long Radejčín tunnel, running under an opposite slope of a flat crest. Both tunnels run through a relatively complex geological environment comprising heavily weathered and fissured basaltoid bodies and sections with pronounced volcanic tuffitic layers with the character of soils. The New Austrian Tunnelling Method was selected for both tunnels (fig. 5).

Fig. 5 South portal of the Prackovice tunnel

The Komořany, Šabatka and Lochkov are tunnels on the southern sector of the Prague City Ring Road. They will be opened to traffic next year. The major parts of the 1937m long Komořany tunnel and the 1662m long Lochkov tunnel were driven using the NATM. The portal sections were built by the cut-

and-cover technique. The 70m long Šabatka tunnel is a short false tunnel on the right bank of the Vltava River, near the western portal of the Komořany tunnel.

The Blanka complex of tunnels on the north-western section of the City Circle Road, the inner circle, is the largest underground construction project being currently implemented in the Czech Republic. The total length of the tunnel tubes amounts to 12.1km, of that cut-and-cover and cover-and-cut tunnels make up 5.5km and mined tunnel tubes are 6.6km long. There are cut-and-cover and cover-and-cut tunnels under streets in the Letná and Dejvice districts. The majority is cover-and-cut because this technique makes the restoration of at-grade traffic possible within the time which is shorter than in the case of the traditional construction of tunnels in open trenches. Mined tunnels are being driven by the NATM, which was getting to the limits of its applicability in the geologically and hydrologically complicated conditions in the section passing under Královská Obora (the Royal Game Preserve – or Stromovka Park). They led to two total collapses of the cover into the mined northern tunnel tube.

Fig. 5 Královo Pole tunnel in Brno

The 1240m long Královo Pole tunnel on the Large City Circle Road in Brno is, at the same time, part of the Czech Republic's motorway network as the I/42 road. The tunnel is being driven through an environment formed by Tertiary clays by the NATM (fig. 5). Despite initial fears of difficult conditions, it must be stated that the excavation, which has till now (October 2009) managed to complete about two thirds of the length of both tunnel tubes, is proceeding very successfully. Sections of the excavation passing under existing buildings were perfectly coped with by means of compensation grouting. It was the first application of this technology in the Czech Republic of such a great extent.

Reference literature

1. Collective of authors (incl. BARTÁK, Jiří). Underground Construction in the Czech Republic. 1st publication. Praha: Satra, spol. s r.o., 2007. 318 pp. ISBN 978-80-239-8569-6.

This paper originated with the support of the research project VZ 01 CEZ MSM VZ 6840770001 „Reliability, optimisation and longevity of building structures and materials".