COMPETITIVENESS OF PIPE-JACKING TUNNEL LININGS

Kolic D.[1], Hörlein N.[2], Schneider K.[3], Steiner H.[3]
NEURON Consult ZT[1], PORR Tunnelbau GmbH[2], ÖBB-Infrastruktur Bau AG[3]
Pasching[1], Vienna[2], Graz[3] (Austria)

SUMMARY

Cable tunnel underneath main railway station in Graz is one recent project showing that construction method is a mayor and decisive factor in the competition. Official tender documents have foreseen conventional (NATM) and/or mechanized excavation method using TBM with segmental lining, but during the bidding procedure an alternative solution has using pipe-jacking approach has won the competition. Pipe-jacking method was used for the excavation of the one kilometre long tunnel having open face shield as excavation head and pipe lining with 3.68 m outer diameter. The lining was pressed from the start shaft along the whole tunnel length. The method has been approved as technically and economically sound solution on the first mechanized excavated tunnel project of HL-AG and as the pipe-jacked tunnel with biggest diameter so far in Austria.

1. PROJECT AWARD

The project itself, a cable tunnel underneath main railway station in Graz, is a part of the new high-speed railway line called Koralmbahn, between cities Graz and Klagenfurt. A lot of new ducts and electric installations for the power supply of the main railway station in Koflach and for new high-speed lines asked for some new connection ways. Less place on the surface opens a subsurface, a tunnel option, as the best way how to overcome all surface obstacles.

Based on project requirements a system of underground tunnels have been developed into a solution consisting of a main tunnel of less than 1 km length, cross-adits and shafts to the surface. The tender documentation has been prepared at the end of 2003, (HL-AG, 2003). The documentation has enabled that bidders may offer different options that have to fulfil basic project requirements. Even though the client has offered two possibilities of construction, conventional (NATM) and mechanized excavation, it was the pipe-jacking solution that won the bid as an alternative to the main bid. The pipe-jacking option is a method that has been used many times in Austria in last decades from construction companies that were also members of this construction joint venture. Therefore their intention was to offer experienced answer to all challenges of tunnel linings on the 1 km tunnel length and at the same time one sound and profound technical solution that is also economically competitive. Special attention has to be paid on the impact of the tunnel excavation and construction method on the surface, especially concerning subsidence analysis.

2. PROJECT DESCRIPTION

The cable tunnel has a length of approximately 877 meters and is passing below the main railway station in Graz and all approaching rail lines. It is stretching in direction north-south, mostly straight except one slight curve with radius R=1000 m in layout.

The tunnel cross section is placed in longitudinal direction with the overburden in the range of minimum 3 meters and maximum 14 meters. In addition to the straight part of the main cable tunnel, cross-adit tunnel is placed perpendicular to the main tunnel, is about 85 m long and is stretching in direction east-west connecting the cable tunnel with the main building of the Graz railway station. In addition, the project has three shafts providing necessary exits for tunnel users and they are located on the northern, central and southern part of the tunnel.

Fig.1 Cross section with minimal overburden (ARGE Kollektor Graz, 2004).

The cross section of the cable tunnel has been defined by space requirements of 12 sets of cable ducts, that will be hanged on tunnel walls and placed in the bottom of the tunnel cross section, and required space for tunnel users that is 1.0 m wide and 2.10 m high, placed in the middle of the cross section. All these space requirements have defined circular cross section with excavation diameter of 3.68 m.

The cable tunnel is constructed continuously using pipe-jacking method. At the same time it is the first mechanized excavation for the ÖBB-Infrastruktur Bau AG (former HL-AG = Austrian high-speed rail). According to the excavation diameter it is the biggest pipe-jacked tunnel diameter in Austria in last 30 years. Due to the length of the pipe-jacked tunnel, the project is classified as long-driven project, anyhow not usual construction considering Austrian circumstances.

3. PRECASTED PIPE LINING

The pipe-jacking drive is performed over precasted pipes that are maximum 3.20 meter long, having outer diameter of 3.68 m, the pipe wall thickness of 25 cm and the weight of 21.6 tons each. All together there are 277 pipe pieces DNi 3180 manufactured with the inner diameter of 3.18 m and in the concrete class C60/75/XC2 (see fig.2). Concrete pipes are reinforced with the average amount of the reinforcement about 64 kg/m^3 of concrete volume and having concrete cover of 3.5 cm. The conductivity of the reinforcement is provided by earthing switches on both pipe ends.

Fig.2 Precasted pipes stored in the vicinity of the start shaft (Manufacturer: MABA, Sollenau).

There are several pipe types used in the pipe-jacking methodology : beside regular pipes of 3.20 m length, there are also 2 types of “stretch” pipes before and after the intermediate press station. There are two types of “stretching” pipes in use : the one is with the long steel stretching mantle enabling pressing up to 700 mm and the other one has a short steel mantle enabling pressing up to 300 mm in length. Each pipe has one rubber gasket on its end that protects that the bentonite suspension can not penetrate, from the gap between pipe lining and surrounding soil, through pipe joints into the tunnel. The hard wooden ring with 20 mm thickness is placed in the circumferential joints of pipes to control distribution of pipe-jacking press forces over defined joint circumference area (Schad et alt., 2003).

Due to the very tight construction time schedule the manufacture of pipes has started immediately after the contract was signed with the Client ÖBB-Infrastruktur Bau AG. All pipes are produced in precasting yard in Sollenau, in the vicinity of Vienna, and transported with heavy lorries over 200 km southwards to the tunnel site in Graz. Each pipe has been placed in specially developed and constructed saddle that was fixed on the lorry bottom. The size of pipes has caused serious investigation of all obstacles like bridges and flyovers on the highway to Graz due to the limited traffic profile size.

4. EXCAVATION METHOD

Considering geological conditions the tunnel should pass through gravel layer with some sand along the entire tunnel length. The water level is located underneath the tunnel bottom but instability of gravel layer has asked for some soil improvements. The method of excavation is mechanized excavation with the open head shield and therefore the stability of the face was the mayor fact considering the type and concept of the machine. Open face shield has been designed and constructed before summer 2004 and transported and mounted on the site. The shield machine has the weight of approximately 75 tons and is equipped with the excavating hydraulic arm with rotating “nipple-head” (see fig. 3). In addition the excavation face has been divided into 2 parts with the working platform in the middle of the height and several face-closing plates has been installed as potential support against the face if some instability during the shield drive may occur. In the case of loosing face stability or when rush material inflow may occur closing plates can easily prohibit against further face failure development making the open face surface smaller. In addition further machine capacity has been improved by additional steel plates on the top of the cross section that can further make the face smaller and improve its stability and with installed bore/inject devices that can make test borings advance the machine head or inject immediately instable geological layers.

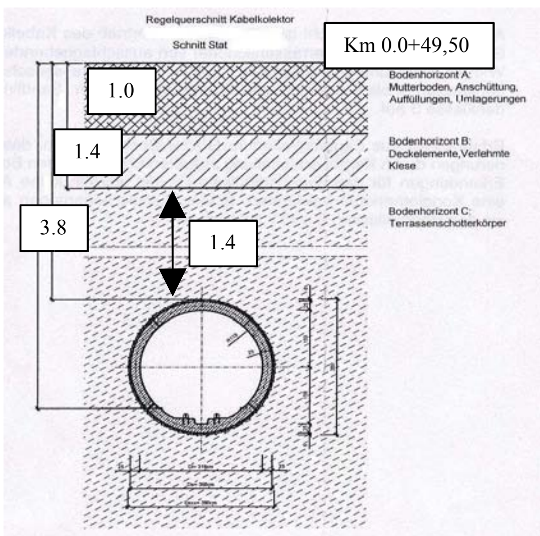

Fig.3 Open face shield (Manufacturer: Herrenknecht, Schwanau).

Excavated material has been transported from the face to the machine rear part by the moving band and then by wagon to the start shaft where was picked up to the surface over one portal-crane. Near to the start shaft was temporary disposal area for excavated material and a storage for pipes that were transported to the bottom of the start shaft with the same portal crane. The pipe-jacking was performed by pressing station that was installed in the start shaft and equipped with 6 hydraulic jacks with 300 tons capacity each that may activate maximum full pressure ring force of 1800 tons (ARGE Kollektor Graz, 2004).

Beside all safety measures that were already installed in the shield machine due to the low overburden additional soil injection improvement was planned along the entire tunnel length. Injections were performed in a regular raster from the surface with the soil improvement mostly in the area of the top of the tunnel cross section. This measure has therefore asked for additional 300 borings up to the depth of 12 meters.

5. ADVANCE PROCEDURE

Every third pipe has three openings for injections of bentonite suspension between outer pipe sleeve and surrounding soil body. This injection enables smooth sliding of pipe lining during pipe-jacking tunnel drive. The system works using intermediate press stations (called "Dehnerstation") that are installed along the whole tunnel length several times and are acting as pushing devices. Each press-station works with several press units (see fig.4) that distribute intermediate press force over ring circumference and provided "worm-type" moving of the whole lining ahead.

Fig.4 View through the tunnel in construction : intermediate press-station (called "Dehnerstation").

After the whole pipe-jacking tunnelling is finished (see fig.5) three shafts (at the beginning, in the middle and at the end of the project) should be excavated and connected to the main cable tunnel. Connection from the tunnel toward shaft will be constructed by conventional tunnelling using principles of NATM : excavation in steps using sprayed concrete of class SpB25/J2/GK11 and bored anchors as primary support. Final lining will be performed in reinforced concrete and will be conventionally performed on cross-adits and shaft structures (Hörlein et alt., 2004).

6. CONCLUSIONS

Pipe Jacking allows pipes or small tunnels to be constructed without digging up the ground. Sections of pipe are dropped into a pit, and pushed horizontally into the ground, to emerge up to a kilometre away. A small-diameter tunnel-boring machine is usually used to excavate spoil at the advancing tunnel heading. The distance which the pipe can be driven depends on the jack strength and the friction between the pipe and the soil. To improve this construction technique, methods of lubrication are applied to reduce the pile-soil friction.A second positive aspect of this methodology is the use of soil conditioning agents to improve the cutting and flowing characteristics of the soil to aid the tunnelling process. Soil improvement may take place from the surface or from the tunnel face.

Third positive aspect is for sure the cost estimate of the pipe-jacking tunnel and therefore direct competitiveness with the segmental lining tunnel solutions. Precasting of all segmental lining systems requires precasting hall with all appropriate equipment for one prefabrication plant. It should be also equipped with several sets of steel moulds for the segment prefabrication. Alltogether just costs for the prefabrication and transport will be far higher than any precasting for the pipe jacking solution. Together with the benefits of construction time schedule one pipe jacking solution will be always favourable to the segmental lining method when the project should be bid for one mostly straight alignment not longer than 1 km for the tunnel part pressed from one pressing station.

Fig.5 View through the finished tunnel, before installation of cables.

The pipe-jacking construction method is available to cope with both cohesive and non-cohesive soils in dry or water bearing conditions. Excavation techniques are also available for jacking through rock, boulders or mixed ground conditions. Therefore direct benefits of pipe jacking methodology are:

- Inherent strength of lining and minimal surface disruption
- Less risk of settlement and minimal reinstatement
- Reduced requirement for utilities diversions in urban areas
- Smooth internal finish giving good flow characteristics and no requirement for secondary lining
- Considerably less joints than a segmental tunnel
- Prevention of ground water ingress by use of pipes with sealed flexible joints
- Significant reduction in social costs when compared to open cut trenching in urban areas and reduced environmental disturbance

7. REFERENCES

HL-AG (2003) : "Koralmbahn Südbahn – Leitungskollektor Graz Hbf", B1356, Diverse Projektsunterlagen.

Schad H., Bräutigam T., Bramm S. (2003), "Rohrvortrieb – Durchpressungen begehbarer Leitungen", *Ernst & Sohn,* Stuttgart 2003

ARGE Kollektor Graz (Porr+Züblin) (2004) : „Statik Pressrohre & Ausführungspläne", Neuron Consult ZT, Pasching, June 2004, pp. 175

Hörlein N., Pöpperl R., Steiner H. (2004), "Der Kabelkollektor Graz Hauptbahnhof", *Zement und Beton 10/2004*, Oktober 2004, pp. 4.