

Construction of the Warsaw metro and auxiliary facilities with the boring method

Fig. 1. Turnout site at the "Ratusz" station

Tunnelling with a boring head is used to avoid a detrimental effect of conducting construction works in areas with multi-storey buildings, trees and dense underground utilities.

Basic advantages of the mining method:

- the environment is protected - preserving greenery and trees along the streets, in the parks, squares, etc.
- the automobile, tramway and pedestrian traffic is not disrupted, with only small periodical limitations, which are not arduous for the population,
- surface of the streets and almost all underground utilities are kept intact,
- the works are performed round-the-clock, without generating much noise at night,
- the works can be performed in any weather,

Table 1. Basic parameters of tunnel lining

| Item | Parameter | Cast-iron tubing | Reinforced concrete tubing |
|------|-----------------------------|------------------|----------------------------|
| 1 | Ring outside diameter, mm | 5500 | 5500 |
| 2 | Ring inside diameter, mm | 5200 | 5100 |
| 3 | Ring width | 1000 | 1000 |
| 4 | Ring thickness | 20 | 200 |
| 5 | No. of segments in the ring | 11 | 10 |
| 6 | Total ring weight, kg | 4800 | 9520 |



Fig. 2. Metro tunnel with cast-iron tubing



Fig. 3. Metro tunnel with reinforced concrete tubing

Mining Works Company

“Metro” Sp. z o.o.



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Selected developments by P.R.G. "Metro" Sp. z o.o.:

- ✓ 10 sections of Warsaw Metro between the Wilanowska and Marymont Stations, totalling 16 km in length,
- ✓ Two-storey metro ventilation duct built under a seven-storey building without any interruptions in its functioning,
- ✓ Underground and two-storey facilities, similar in size and construction technology to the Metro stations and used, amongst others, for reversing trains and as a depot,
- ✓ Parallel microtunnels under the built Metro tunnels to avoid collision with water and sewerage network,
- ✓ Microtunnels, totalling 2,000 m in length.

COMPREHENSIVE CONSTRUCTION
OF UNDERGROUND TUNNELS
from tunnelling with mining method
to installing the infrastructure
necessary for operation



REINFORCED CONCRETE STRUCTURES
underground facilities built with trenchless
method and in an open excavation



WATER SUPPLY AND SEWERAGE
NETWORKS
using a trenchless pipeline installation
technique remotely controlled from the
surface (microtunnelling) and the
open-cut technology



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- the threats related to preserving the walls of deep excavations are minimised,
- the subsurface and hydrological conditions are less affected.

Mining Works Company "Metro" Sp. z o.o., also known under an abbreviated name of P.R.G. "Metro", has been the main contractor for the Warsaw Metro tunnels made with the mining method since the beginning of the 1st line construction. The metro built with this technology comprises a set of two parallel tunnels, most often in dia 5,5/5,2 m cast iron tubing or dia 5,5/5,1 m reinforced concrete tubing. The distance between the tunnel walls is 8 m and between the axes 12-14 m. The average depth of the rail head is 10 – 15 m, the overburden thickness above the tunnels ranges from 6 at the stations to about 9 m in the middle part, the inclination is 3-30 0/00, the minimum vertical curve radius is 2000 m and the horizontal 400 m.

During the metro construction the underground works are permed continuously on a three-shift basis, by four teams in a rotating system. The continuous system uses 155 people on each metro route (140 workmen and 15 supervisors). Average tunnel boring rate was 45-60 metres per month (maximum 75 metres per month) depending on the hydro-geological conditions and the soil drainage.

Despite the fact that P.R.G. "Metro" Sp. z o.o. is suitably qualified to use fully automated tunnel boring machines, the investor chose to build the Warsaw metro tunnels with the SzCzN-15 machine featuring manual mining and the face protection. (fig. 4). The use of this uncomplicated device was favoured by a designed construction method as short tunnel sections (500-1000 m) between the stations were built with open cut technology, which necessitated frequent dismantling, transporting and re-assembly of the head. The Contractor approached the investor with suggestions to use more advanced boring machines, but the slower-than-assumed progress caused by underfunding made us stick to the original solutions.

Basic technical parameters of the SzCzN-15 boring head are as follows:

- outside diameter of the boring head shell, mm 5684,

Table 2. Metro tunnels built by P.R.G. „Metro” Sp. z o.o. by the underground method with the boring head

| Route | Tunnel length, m | | Remarks |
|--|------------------|------|---|
| | East | West | |
| B-8 "Wilanowska" – "Wierzbno" | 558 | 561 | |
| B-9 "Wierzbno" – „Raławicka" | 680 | 681 | |
| B-10 "Raławicka" - „Pole Mokotowskie" | 735 | 738 | |
| B-11 "Pole Mokotowskie" - „Politechnika" | 496 | 502 | |
| B-12/13 "Politechnika" – "Centrum" | 1245 | 1240 | Because construction of the station A-12 "Plac Konstytucji" was abandoned, the B-12 and B-13 tunnels were connected to form the B-12/13 tunnel. |
| B-14 "Centrum" – "Świętokrzyska" | 240 | 240 | Because construction of the station A-16 „Muranów" was abandoned, the B-16 and B-17 tunnels were connected to form the single B-16/17 tunnel. |
| B-15 "Świętokrzyska" – "Ratusz" | 700 | 700 | |
| B-16/17 "Ratusz" – "Dworzec Gdański" | 1023 | 1023 | |
| B-18 "Dworzec Gdański – "Plac Wilsona" | 990 | 990 | |
| B-19 "Plac Wilsona" – "Marymont" | 442 | 443 | |

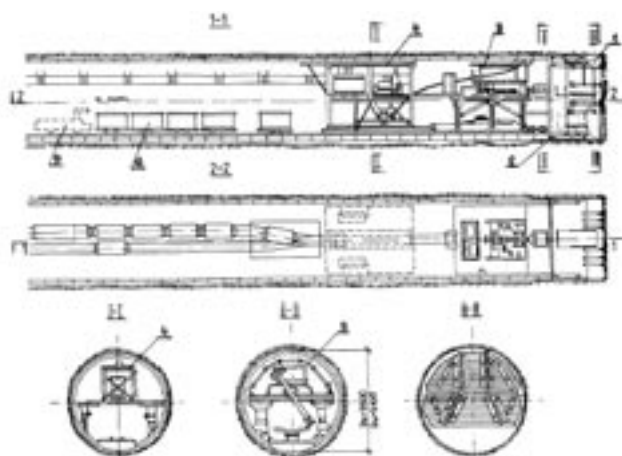


Fig. 4. Non-automated boring head SzCzN-15 with ancillary equipment. 1- Non-automated boring head, 2- sealing and retaining ring, 3- manipulator for installation of the lining, 4 – grouting platform, 5 – batter-operated locomotive, 6 – spoil cars



Fig. 5. Vertical move of winning

- inside diameter of the boring head shell, mm 5560,
- length in the upper part, mm 5135,
- weight 102,5,
- installed motor rating, kW 37.

Underground tunnelling works commence with making the start shafts (rectangular 23 x 13 m, depth 12-15 m, or less frequently round with 10 m diameter). The casing of the start shaft located in a future metro station is the "Berliner wall" or recently the cavity wall. When the boring head is installed in the shaft, the full tunnel boring cycle comprises:

- moving the head into the soil to the depth of 0,25 -1,1 m, gradually, depending on the hydro-geological conditions,
- working the face from top to bottom, with successive placement of temporary wooden casing made of balks or planks and squared timbers, strutted with face cylinders of the boring head,
- loading the spoil on the cars by means of the rocker shovel loader and manually,
- installation of the lining made of reinforced concrete or cast-iron tubing,
- filling grouting.

The movement of the boring head is supervised by the land-surveying staff using a laser in conjunction with theodolite.

The final lining of tunnels is cast-iron tubing (fig. 2) or less frequently the reinforced concrete blocks (fig. 3).

Lining completed, the face works are concluded by grouting with cement-lime mortar. The sealing (secondary) grouting is made about 30 metres away from the face and the connections area sealed with lead wire.

The spoil and materials are transported in the 1,1 m³ cars or at the platforms hauled by batter-operated locomotives. In the start shafts, the spoil is transported by the hoists separately for each tunnel, and the materials are lowered by means of the gantry crane or telfer.

As the main contractor, P.R.G. „Metro” Sp. z o.o. builds also the auxiliary facilities, such as ventilation centres, turnout sites, underpasses or micro-tunnels to avoid collisions with the existing water and sewerage utilities (fig. 8).

The ventilation centres are most often built in the open cut technology. Unless it is necessary regarding the location, they are not designed as underground. Such necessity occurred when the facility had to be located in the court surrounded by buildings. The contractor built a multi-storey ventilation duct under a seven-storey building without any interruptions in its functioning (fig. 9).

The last stage of tunnel construction is making the concrete railway subgrade, followed by laying the tracks. The trains in parallel tunnels travel in opposite directions.

The change of train travel direction and track switching is made on so-called marshalling tracks located in turnout sites. These are two dead-end tracks connected with the main tracks by points. The turnout sites are similar in size to the Warsaw metro stations (fig. 1).

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Fig. 6. Land-surveying personnel



Fig. 7. Tunnel under construction



Fig. 8. Microtunnelling method applied to reconstruction of the duct colliding with the tunnels under construction

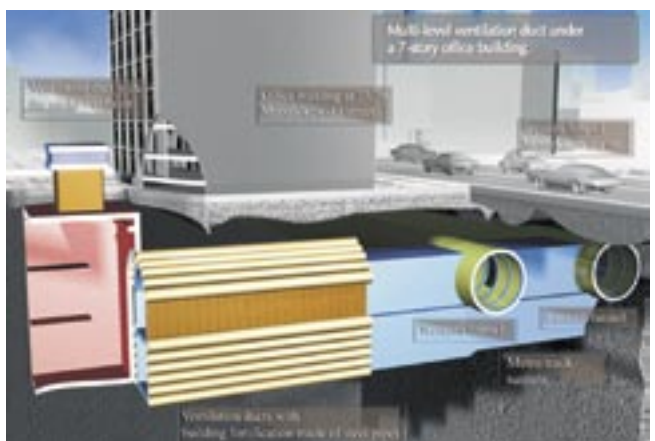


Fig. 9. Two-storey duct under the building for ventilation of the metro tunnels