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THE TECHNICAL METHODS FOR BUILDING OF SOFIA METROPOLITAN

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Abstract – *The construction of tunnels is responsible and challenging engineering task. The specialists have to overcome various obstacles associated with geological characteristics of the terrain,water level, under rivers, available buildings, structures, roads and comunication on the surface, with the available equipment. And all this can be done within the prescribed period, and of course, a guarantee for safe and reliable operation. Article consider methods used for building of metro in Sofia. During the building of metro in Sofia are implemented and applied four methods of construction: classical open pit – method, Milanese method, shield method and new Austrian Tunneling Method. The main features of these difrent methods is shown. The used geothechnical structures are presented. The consruction pecularities of tunneling is given. The technological order of building diferent tunnels is shown. The advantages or disadvantages of used methods depending on existing conditions are highlighted. Analise of diferent methods and teir implementation according to the geotechnical conditions are given.*

Keywords – metropolitan, city railway, tunnel, Milanese, open pit, top down, shield methods.

1. INTRODUCTION

Seventy percent of the European population lives in cities and urban areas. Cities are economic, social and cultural centers of European countries.

Europe has only a small number of very large metropolitan regions, such as London, Paris, Prague, Moscow. Most of the urban areas contain between 500,000 and 4 million people.

The construction of tunnels is responsible and difficult engineering task. The experts have to overcome different obstacles connected with geological conditions of the terrain, water level, buildings and transport infrastructure on the surface. They used modern methods and machines. And metropolitan can be done within the prescribed period, and of course, a guarantee for safe operation.

The first decision for building of some underground transport in Bulgaria was occurred in 1968, when the Sofia had 600,000 habitants. The researches have begun and after that in 1972, has been accepted a technical-economic report on metropolitan construction. The municipality aproves the metro scheme (Fig. 1).

The building of first metro diameter started in 1979, according to government decision and documents.

The first metro stations were built between 1979-1991. They are “Liulin” and “Vardar” stations.

The Republic of Bulgaria became a member of the European Union on 01.01.2007. Since then, the construction of metro has begun to develop with fast steps.

Fig.1. One of the first schemes of the Sofia metro, 1981

As it seen in (Fig.1) and (Fig.2) the current metro lines are nearly the same directions as in the first scheme.

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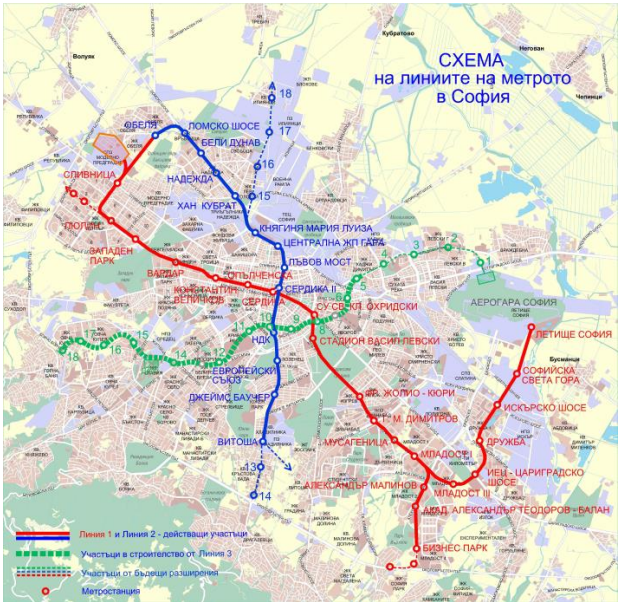

Fig.2. Current scheme of the Sofia metro in 2018 (Metro Line 1 is in red color, Metro Line 2 is in blue color, dashed line in blue shows a section under construction)

In (Fig. 2) are shown metro diameters which are built till now. Metro diameter 1 is in the direction Southeast - Northwest. The construction started in the 1979. It has a total 23 stations and a length of 28 km in 2015.

Metro diameter 2 is in the direction South – Northwest. The construction starts in 1980. The first stations and a part of tunnels were constructed during the building of the National Palace of culture.

Metro Line 3 will be from the Northeast to Southwest - in green color. The construction of the line started in 2015. Until now, metro in Sofia has two lines, length of 39 km and 34 stations [1].

2. MERTHODS FOR BUILDING OF SOFIA METROPOLITAN

The construction of metropolitan is responsible and complex task.

During the building of the metro in Sofia were implemented and applied four methods of construction as follows.

2.1. Classical open pit - method

This method can be performed in two variants - with or without reinforcements of the lateral sides.

a) Opened trenches /pits/ with slopes without reinforcements

When there are no buildings near the metro route, or there are open spaces, it is possible to excavate open trenches with sloping sides.

The stages of excavation is shown in (Fig. 3 a). After digging the trench or pit, the building of structure for the metro tunnels and stations start. The foundations and structures were made general from reinforced concrete. They build most stations from the first metro diameter with sloped trench /pit/. The inclinations of slopes are according the soil type. That slopes are not fortified. After making, the surrounding structure and upper plate, begins the backfilling (Fig. 3 c). This method is very simple.

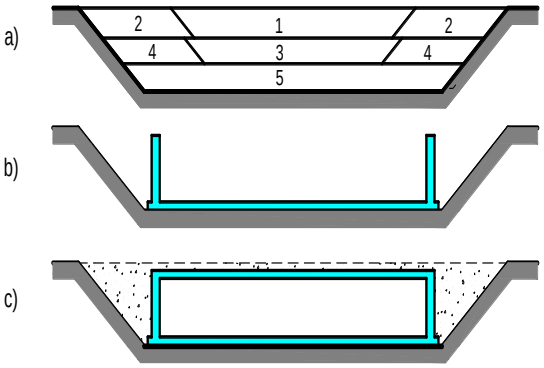

Fig.3. Technological sequence of construction - classical method:

a) stages of excavation, b) building of structure, and c) backfilling

b) Opened trenches /pits/ with reinforcement

Structure of tunnels is built in the fortified trenches. In some cases, the side supporting structure is a part of the strtructure of station.In some cases were built separate internal supporting structure.

Fig.4. "Berlin wall" – Metal column whit wooden wall used to fortify the trenches.

The supporting structure can be metal sheet wall (Fig.5) wooden wall, reinforced concrete diaphragm wall, or pile wall. The distance between piles varies depends on soil characteristic. The wooden walls are strengthened whit metal columns and beams so-called "Berlin wall" (Fig. 4). From the beginning, they imbedded metal columns - 2T. After that, excavate the first level and put the wooden boards to prevent the soil fall. Then going down and digging the second level and put the wooden boards and the next level and so on.

To prevent from higher water level in the excavated pit, were used metal sheet walls or diaphragms. In some cases water level can be decreased by water pumps.

The arm packet has to be in the hole before concreting. In Figure 5 is shown concreting of the tunnel plate. To fortify the sheet metal walls are used metal beams between two sides of metal walls. Instead of metal beams, in bigger distances, between metal sheets, to fortify them are applied anchors behind them. Metal sheet walls support lateral soil.

Fig.5. Tunnel in "Youth" complexe

Using opened trenches with reinforcement were built from the first metro area Sq. St. "Nedelya" to residential complex "Lyulin" and some stations from Sq. St. "Nedelya" to residential complex "Youth". This method is applied in the part of the stations of the second metro diameter – "Central Railway Station ", in front of the National Palace of Culture and others.

Diaphragm walls are mainly applied for strengthening, the stations. Pile walls are used for a few stations.

2.2. Milanese method

This method applies when you need faster recovery the surface over the metro. The technological sequence of construction is as follows: at the direction of the walls of the structure of stations and tunnels build diaphragm walls, without developped a pit.

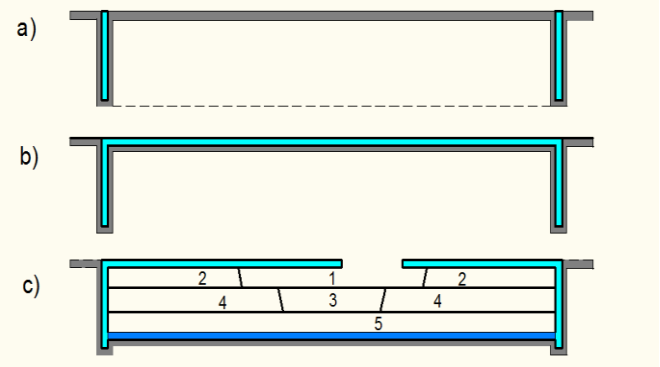

Fig.6.Technological sequence of construction - Milanese method:
a) diaphragm walls; b) building construction; c) stages of excavation.

The diaphragm walls are built in soil before any excavations (Fig 6a). At first made holes in soil by special digging machines for diaphragm walls. Bentonite clayey-soil solution is used to protect the soil sides of diaphragm walls from destroying. The bentonite suspension is calculated in advance and produced on place. In the holes are descended previously prepared arm-packet and start to concrete the wall. These diaphragm walls are used for the external walls of the structure of the station or tunnels. The upper plate of the tunnels or metro stations is built on the diaphragm walls. (Fig. 6b).

After compleating the top plate the zone is filled and the transport trafic is restored. The next step is to carry out excavation work under the protection of top plate and other bearing elements of the structures (Fig 6c). In Figure 7, the anchors reinforcement of 22 m height four row anchored diaphragm wall providing 10 m of free space for work is shown.

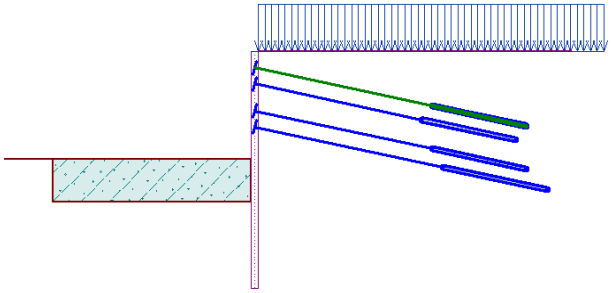

Fig.7. Scheme of diaphragm wall

This method was used in the construction of the "Joliot Curie" and "GM Dimitrov" stations and part of the tunnels nearly of these stations in Sofia. On the second metro diameter in order to minimize the time for stopping or restricting traffic on major streets, this method is applied to the stations: "Maria Louisa", "Central Railway Station" and "James Boucher" under the bulevard Bleack peak".

2.3. Shield method

Mechanized shield method is applied for building of tunnels in dificult geological conditions and in cental part of the city.

Because of archaeological finds in Sofia and considerable length of the tunnels, TBM (Tunnel-Boring Machine) were used. This method is based on a mechanized excavation of soil by a steel cylinder called shield. The tunnel parts are installed under the protection of this cylinder. Tunnels are made from prefabricated arch parts. Al this parts make a cilindrical form of the tunnel (Fig.8). The machine moves by system hydraulic jacks. The jacks are stepped on the ready tunnel archs.

Shape of the cross section of the shield corresponds to the lining of the tunnel and may be circular, rectangular, arched or elliptical. Circular

shield was used in Sofia - metro.

Fig.8. Tunnel made form tunnel boring machine

a)Tunnel-boring machine (TBM)

In Bulgaria, Tunnel-boring machines (TBM) were used for digging the tunnel of the second metro line in Sofia (Fig.9). The tunnel has two lines with internal diameter of 8.43 m. Archaeological layer is located at a depth of 7 m, and this method allows the metro-tunnel lays under it. The project was completed on time, despite aggressive high groundwater and complex geology, all in combination with intensive traffic in central Sofia boulevards.

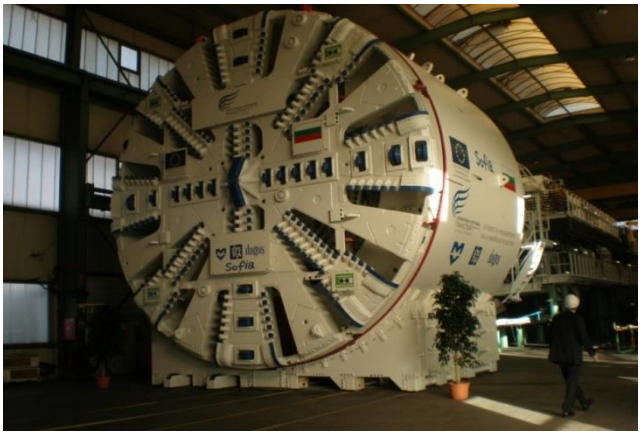

Fig.9. One of Tunnel-boring machine (TBM)

Due to the significant depth of the tunnels, this method was applied to the section between "Sq. St. Nedelya” and the “Vasil Levski“ Stadium as well as the "Road junction Nadezhda - street Han Asparuh" section before Patriarch Evtimii Blvd. Due to the location of tunnels below the groundwater, shields with hydraulic camera are provided. The hidraulic pressure from the shield is bigger than the existing surrounding pressure. This allows to prevent the ground above tunnels and lying over their buildings from collisions. The last TBM for the third line are working by now. The diameter of this machine is 9.40 m for two - way in the tunnel. At the end of July is finished about 77% of tunnels. The middle speed of digging is about 25 m/day.

2.4. New Austrian Tunneling Method

This method is effectively implemented in areas with significant dept and limited water flow. The tunnel is excavated in section (Fig.10). Tunnel can be fully excavated or partially excavated, depends on conditions and then reinforced it. The excavated part of tunnel is stabilised whith preliminary tunnel lining(shell) [2]. Lining can be efectued by reinforced shortcrete, with or whitout anchors. It can be done by special movable formwork. In the next stage the structure of the tunnel are made inside of the preliminary lining.

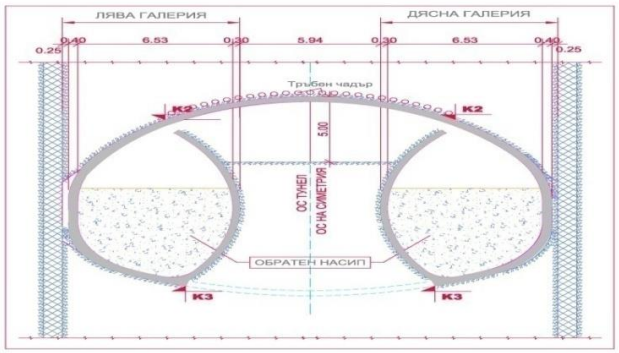

Fig.10. New Austrian Tunneling Method scheme

All railway tracks were designet with two - block reinforced concrete sleepers in rubber boots for reduction of vibrations [3].

The engineering and geological conditions in Sofia were very difficult, because of the higher water level, but the specialists are going thru all difficulties.

CONCLUSION

In the Metropolitan in Sofia, contemporary methods for building and contemporary machines and facilities were used. This article showed the peculiarities of the methods and existing conditions.

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