



Analysis of Subway Tunnel Construction Methods

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How to cite this paper: An, X.Y. (2022) Analysis of Subway Tunnel Construction Methods. *Open Access Library Journal*, 9: e9504.

<https://doi.org/10.4236/oalib.1109504>

Received: October 31, 2022

Accepted: November 15, 2022

Published: November 18, 2022

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Abstract

Urban subway tunnel engineering in reducing travel inconvenience and effective utilization of urban underground space has played an important role. Due to the complexity and diversity of metro tunnel construction, the construction safety accidents occur frequently, so the choice of the reasonable construction method to improve its security and the economy is particularly important. In this paper, the construction steps, construction characteristics and applicable conditions of the common subway tunnel construction methods such as open excavation method, cover excavation method and underground excavation method are analyzed and introduced in detail, which has reference significance for the selection of construction methods in the subway tunnel project in the future.

Subject Areas

Road Engineering

Keywords

Subway Tunnel, Construction Method, Characteristic, Suitable Conditions

1. Introduction

In recent years, due to the scientific and technological progress, economic development, population increase, the increasing traffic pressure, many urban areas rise a flood of building of the subway, the construction of urban subway tunnel greatly alleviates the inconvenience caused by the traffic pressure. Because of the complexity of the underground soil and groundwater, various engineering problems that commonly appear in a subway tunnel excavation process, in order to reduce the engineering problems, it is particularly important to the choice of construction method. At present, many scholars at home and abroad have carried

out a lot of research on the subway tunnel. Jianjun Liu [1] studied the problems and solutions in the waterproof construction of subway tunnels; Xiaobo Du [2] analyzed the connection measurement method based on actual cases; Zhiqiang Tang [3] studied the application of TBM construction method in subway tunnel construction; Taiyue Qi, Bo Gao, and Daiming Tan, [4] [5] studied the influence of subway tunnel construction on the surrounding environment and existing buildings; Chongbang Xu, Youlin Qin [6] the selection of large span tunnel construction method are analyzed; Grim Marcello H [7] under the railway in the selection of the tunnel construction method are analyzed. Serges Mendo Meye, Zhenzhong Shen [8] the distribution law of tunnel seepage field under different types of waterproof drainage is studied. Now the summary of the subway tunnel construction method study is less, based on the existing research, this paper summarizes the subway tunnel construction method and the characteristics of various construction methods, the applicable conditions and so on carries on the analysis comparison, provide a reference basis for practical projects.

2. Ming Excavation Method

In the excavation of underground foundation pit, Ming excavation method is the preferred construction method, which refers to the excavation of soil from top to bottom in the construction process, after excavation to the specified height, and then from the bottom elevation to the top elevation of the main structure construction, after the underground engineering construction bearing capacity meets the design requirements, the earth backfill, until the recovery of the surface. **Figure 1** and **Figure 2** show the construction site of open excavation method. With other construction methods than Ming excavation method possesses the advantages of the operation is simple, rapid and economic, but it is also easy to affect the surrounding environment and underground pipelines, especially the subway tunnel is generally in the crowded area of people and construction (structure), so we should always pay attention to the impact of the surrounding environment. Ming excavation method has the characteristics of a long history and wide application. Ming excavation method is generally applicable to open areas and areas



Figure 1. Construction site drawing of open excavation method.



Figure 2. Construction site drawing of open excavation method.

that have no impact on travel by blocking ground traffic, it is usually widely used in foundation pit engineering with shallow burial depth and large plane size.

3. Cover Excavation Method

Cover excavation method refers to the method of excavating the foundation pit to the design height in the tunnel construction, and then sealing the upper part of the foundation pit and restoring the surface, and digging downward or other procedures in the foundation pit. Cover excavation method can also be distinguished from the construction sequence of cover excavation method, cover excavation reverse method and cover excavation semi-reverse method, cover excavation is the first to complete the construction of the enclosure structure on the surface, and then placed above the maintenance structure of the shape of the pre-formed standard soil structure, in order to maintain the ground passage, Subsequently, continue to excavate under the covered structure to the design elevation, carry out the main structure construction from the bottom up, and backfill the soil until the ground is restored; the reverse method of cover excavation is to complete the construction of the enclosure structure on the surface, and then excavate to the top of the main structure for roof pouring, and then backfill the earth to restore the ground, and finally carry out the soil excavation under the roof and the main structure construction at the same time. cover excavation semi-reverse method with cover excavation reverse method, but cover excavation semi-reverse method is after the completion of the ground recovery, earthwork excavation at the bottom of the roof, to be excavated to the design elevation, the main body of construction from bottom to top. Compared with the ming excavation method, the cover excavation method has small structural deformation and high construction safety factor in the construction process, but the construction progress is slow and the cost is high. Generally, it is applicable when the overground traffic environment does not support long-term interruption and needs to be quickly restored.

4. Method of Underground

The excavation method does not excavate the surface during the construction, and the construction is completely underground. It is mainly suitable for the construction area with strict requirements on the ground settlement. Tunneling methods include shield tunneling method, shallow excavation method, immersed tube method, drilling and blasting method, pipe jacking method and so on.

4.1. Shallow Excavation Method

With the shallow depth excavation method for subway tunnel excavation can effectively improve the whole stability of the subway tunnel, is a commonly used method of metro tunnel construction, it shall be carried out in accordance with the “ten figure of eight” policy design and construction, construction technology and procedure is shown in **Figure 3**, Compared with the ming excavation method and the cover excavation method, it has the characteristics of low construction cost, less demolition, and little impact on the ground traffic and the surrounding environment. The shallow buried excavation method is mainly suitable for the soil layer that is shallowly buried (generally buried depth is not more than 20 m), loose and unstable, the surrounding environment is complex, and the groundwater needs to be reduced. At the same time, it is also widely used in other tunnel projects because of its convenient construction and small impact on the environment.

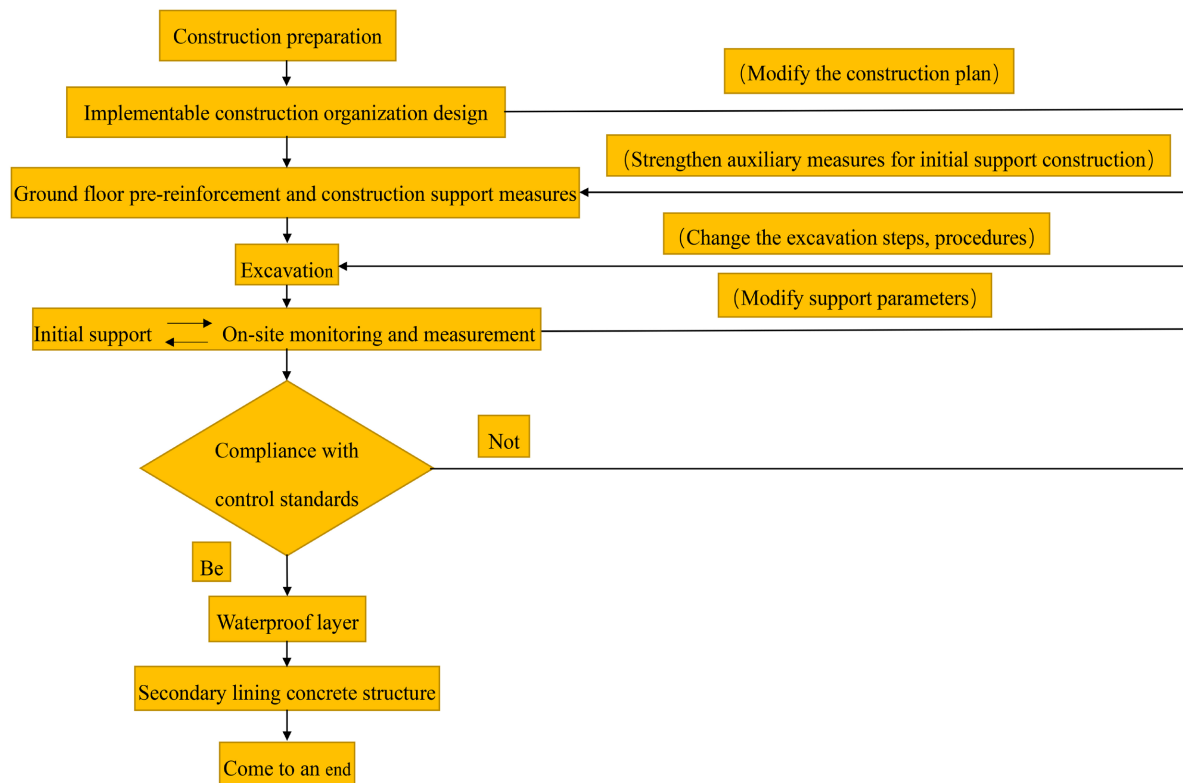


Figure 3. Flow chart of shallow underground excavation construction.

4.2. Shield Method

Shield tunneling method is a construction method that uses shield tunneling machinery to excavate tunnels below the surface. Shield tunneling machine is a construction machine that can excavate tunnels underground and provide temporary support for tunnels, which can well bear the earth pressure of the stratum. The overall profile shape of shield tunneling machine has four types, which are as follows: circular, horseshoe, rectangular and arched, due to the well resistance in circular underground earth pressure and water pressure on the mechanical properties, thus has been widely used, as shown in **Figure 4**, need to pay attention to in the construction, shield machine every advance, are casting a lining, and the lining is used in construction, cement mortar filling holes, avoid forming a subway tunnel collapse and ground subsidence. Compared with the ming excavation method, the shield method greatly reduces the influence on the surrounding pipelines, and the noise generated by it is less harmful, Shield tunneling method is the first choice for large diameter and long distance subway tunnel construction.

4.3. Immersed Tube Method

In the immersed tube method, sections of prefabricated tunnel pipe are placed in a dug groove and connected to form a complete pipe. Compared with shield tunneling method, the total length of the line is shorter, the cost is lower, and the construction quality of the tunnel can also be guaranteed, and the operation is simple and safe. The immersed tube method has significant advantages in the construction of underwater tunnels [9] and is the preferred scheme for the construction of underwater tunnels in river segments with stable river bed and low flow. **Figure 5** shows its construction flow chart.

5. New Austrian Method

NATM is the abbreviation of the New Austrian Tunnel Construction method, and the English name is NATM. **Figure 6** shows the model of the New Austrian



Figure 4. Shield tunneling machine.

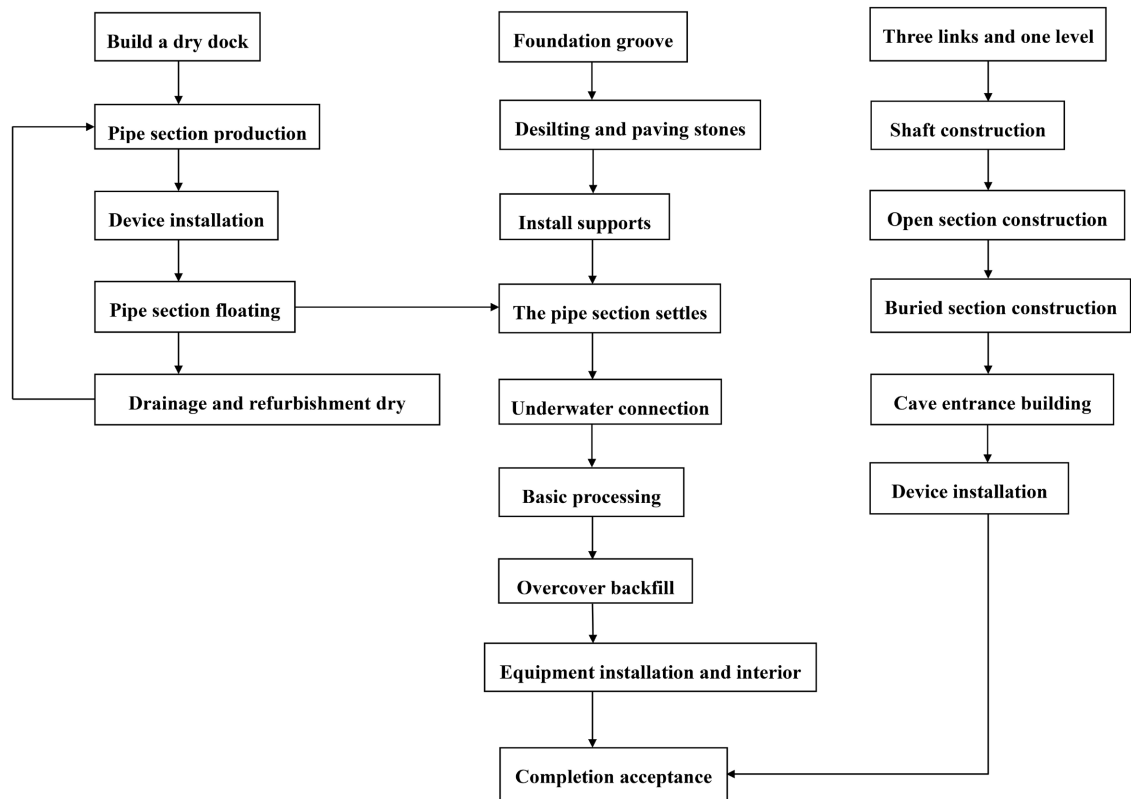


Figure 5. Construction flow chart of immersed pipe method.



Figure 6. Model diagram of the New Austrian tunneling system.

Tunneling Method. New Austrian method is based on tunnel engineering practice, combined with the rock mass mechanics principle, combined with anchor and shotcrete, the formation of a new type of construction technology, **Figure 7** is the process of construction. Shotcrete, bolt and measurement are considered to be the three main elements of the new Austrian Method. The principle of the new Austrian method can be used in various types of support. The shallow excavation method follows the construction principle of the new Austrian method, but the most suitable support is the shotcrete anchor support. The new Austrian tunneling method has the advantages of fully protecting the surrounding rock, reducing the disturbance, giving full play to the bearing capacity of surrounding

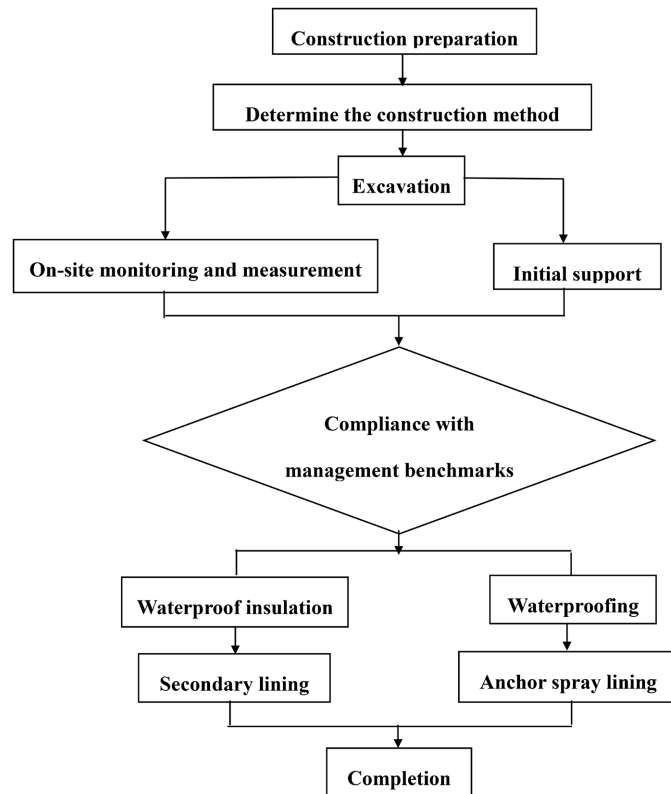


Figure 7. Construction process of NEW Austrian method.



Figure 8. Free-section TBM.

rock, and closing the supporting structure as soon as possible, which is the basic method of subway tunnel construction in the weak and broken surrounding rock area.

6. TBM

TBM is a kind of factory engineering technology, which is mainly used in rock tunnel engineering. TBM mainly includes rock breaking, propulsion, rock ballast handling, guiding adjustment mechanism, dust collection and ventilation equipment. **Figure 8** shows the free-section TBM. The basic process of TBM con-

struction is: construction preparation → full section excavation and slag discharge → outer pipe lining or early support → TBM forward → outer grouting or secondary lining. Compared with the shield tunneling method, it has the characteristics of fast construction speed, high construction efficiency, safety and environmental protection. The shield tunneling method is often suitable for the excavation of subway tunnels in soft soil layer, while TBM is suitable for the excavation of tunnels in rock strata, and TBM has gradually become the main construction method for the construction of large tunnels.

7. Conclusions

The subway tunnel excavation project is complex and changeable, so reasonable construction methods should be selected according to geological conditions, hydrological conditions and construction safety before construction. The following conclusions are obtained by analyzing and summarizing the open excavation method, cover excavation method and underground excavation method:

- 1) As the preferred method of metro tunnel excavation, open excavation is generally applicable to the areas with low traffic requirements and empty areas;
- 2) The cover digging method is generally used in the densely populated urban center, which is widely used in the construction of subway stations;
- 3) In areas with strict requirements for surface subsidence, the digging method is generally adopted.

In a word, subway tunnel construction methods have their own characteristics, but also have certain limitations, in the project construction should be adapted to local conditions, choose appropriate construction technology, to achieve safety and economic double guarantee.

Conflicts of Interest

The author declares no conflicts of interest.

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