

A New Construction Method for Deeply Buried Metro Station in Rich Water Strata

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Abstract. In this paper, several difficulty brought by the increase of bury depth of metro station is analyzed. It will be much harder for the construction of metro station with the increase of metro buried depth, especially in rich water strata. A new method, Super Tubular Roof Method (STR), which is suitable for building metro station in deep and rich water strata, is proposed. And, construction sequence, stress system and waterproof system of STR method are described in detail. It provides a referential design and construction ideas for building deeply buried metro station in the future.

Introduction

The level of metro construction has made a lot of progress in China, and operating mileage occupies world front row after decades of vigorous development. The new features of network transfers and constantly denser metro network have appeared in those cities, such as Beijing, Shanghai, Guangzhou, etc., whose subway construction started earlier and metro network is larger. With the continuous denser of metro network, the buried depth of new construction metro lines shows a gradually increasing trend by the affect of existing metro lines. Displayed from Beijing 2020 mass transit railway construction plan, there are about 80km new lines will be built inside of Beijing third-ring road before 2020. In these new lines, the proportion of interchange stations is approximately 65%, and 30 of those are three-line transfer stations. The bury depth of new construction lines usually deeper than existing lines in interchange stations. Considering the fact that the maximum depth of achieved metro station has up to 36 meters, thus, the buried depth of the next round new construction metro stations will exceed 40 meters.

Several New Problems for Deeply Buried Metro

There are some different between the metro construction in deeper strata and that in ordinary shallow buried metro. Construction environment has greatly changed which caused much trouble for the use of traditional shallow-covered excavation methods, with the increase of metro buried depth.^[1]The principle difficulties for the construction of deeply buried metro are as follow:

- (1) The main problem for metro stations in deeply buried condition is caused by groundwater. With the increase of metro buried depth, most part of subway station structure will under water table, which brings great challenge for shallow-covered excavation methods that is usually regard dry operation as prerequisite. And, the situation will be much harder when the metro station affected by confined water layer. Unlike phreatic water, confined water is characterized by abundant water recharge and difficult to drainage. It is more and more difficult to apply common dewatering measures in construction project with the increasing mass awareness for protecting water resources. What is more, in recently, engineering dewatering was severely restricted by local regulation and national policy, and the possibility of charging water resources fee for engineering dewatering is not excluding in the near future. Thus, it will not only result in a serious waste of water resources also increase engineering

costs, if dewatering measures is employed in deeply buried mined underground metro station, especial for the condition of high hydraulic head confined water.

- (2) It is significant changed for the in-situ stress condition of metro station when its buried depth increased. Soil pressure of metro structure is becoming indeterminate.^[2]
- (3) Geological conditions of deeply buried metro will be more complicated.^[3] Take Beijing for instance, metro project may encounter weathered bedrock or thick pebbles, boulders layers in western area, and it might get into softer strata which usually bring more engineering risk in east area.
- (4) Another issue caused by great buried depth of metro is that ventilation and smoke discharge, firefighting and emergency evacuation are more difficult for metro station. Aiming at this problem, a design paradigm was proposed by redesigning the ventilation program and rearranging the distribution of fire compartment for deeply buried metro station.^[4]

Construction Scheme of Tubular Roof Station Main Body

Super Tubular Roof Method

As a new metro construction method, super tubular roof method, abbreviated to STR construction method, utilizes tubular structure to form an impermeable barrier, supporting and stress system. With the protection of tubular roof, metro station could be construction safely. Trenchless technology (usually pipe jacking) is employed to built hermetic impermeable barrier with small- diameter steel pipe (e.g. 1m diameter) and large-diameter steel pipe (e.g. 3m diameter) in the outer contour part of underground space to be built. Then, ring type steel or reinforced concrete internal support whose working principle is similar to vascular stents in medicine is established with certain longitudinal spacing in strata to be excavated by using large-diameter steel pipe. And, large-diameter steel pipe is employed as construction small tunnel to build longitudinal impermeable grouting wall, which is like thrombus in blood vessel, within the tubular roof. Thus, main stress structure of STR is established: tubular as a member in bending resists longitudinal water and soil stress and internal support annular beam bear radial load mainly. Full face excavation method can be adopted for the construction of metro station after figure out “construction safety” problem, and cut-bottom up method can be used for building station permanent structure.

STR method construction sequence can be summarized as follows:

- a) Along station longitudinal direction construct large-diameter (e.g. 3m diameter) and small-diameter steel pipe (e.g. 1m diameter) by using trenchless technology (pipe jacking or rammer) in the shaft sets at the end of metro station. It is connected by sealing lock among steel pipe which is fulfilled with waterproof grease.
- b) Setting grouting pipe from large-diameter pipe steel toward the soil to be excavated and grouting at a certain distance along the metro station. Reinforcement and impervious grouting walls are formed, and they compose longitudinal sealing system for metro station.
- c) Punching openings on the large-diameter steel pipe at a certain distance, and ring type reinforced concrete internal-support-beam can be built throw those openings by using of hand-dug or curve pipe jacking alone the contour of tubular roof. After that, constructing vertical steel concrete permanent column in the middle of two groups of large diameter steel pipe at the same time.
- d) Shaft in the end of metro station would be adopted to fulfill concrete into small-diameter steel pipe (e.g. 1m diameter).
- e) With the protection of longitudinal concrete filled steel tubes and radial reinforced concrete internal-support-beam, full face excavation method can be used for excavation in metro station. Temporary lateral strut can be set in the location of middle floor slab for two or multiple level station if necessary.
- f) And, station permanent secondary lining concrete can be built from below to above. Binding longitudinal reinforcement in large-diameter steel pipe to form above or below longitudinal beam.

The gap between permanent structure and maintenance structure (tubular) will be backfilled after the metro station accomplished.

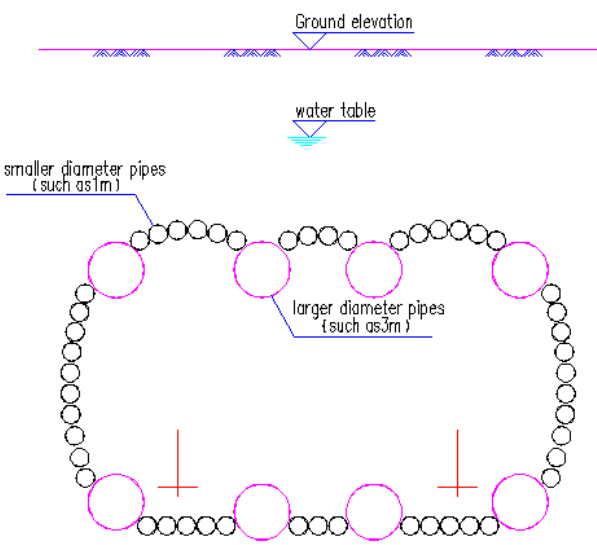


Fig.1 Profile of Tubular Roof

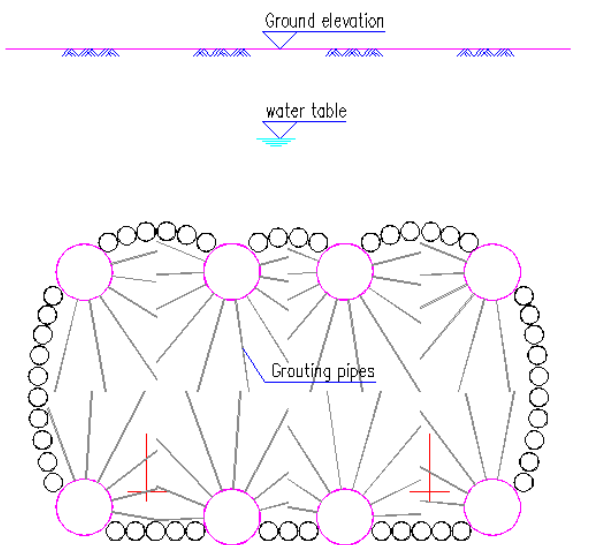


Fig.2 Profile of Check Slurry Wall

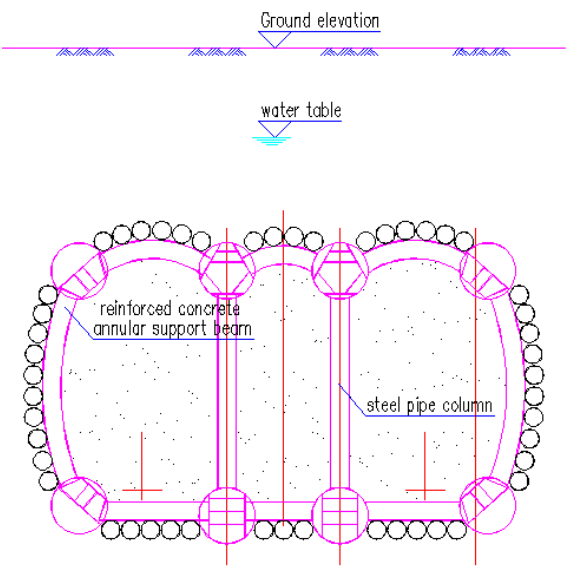


Fig.3 Profile of Annular Support Beam

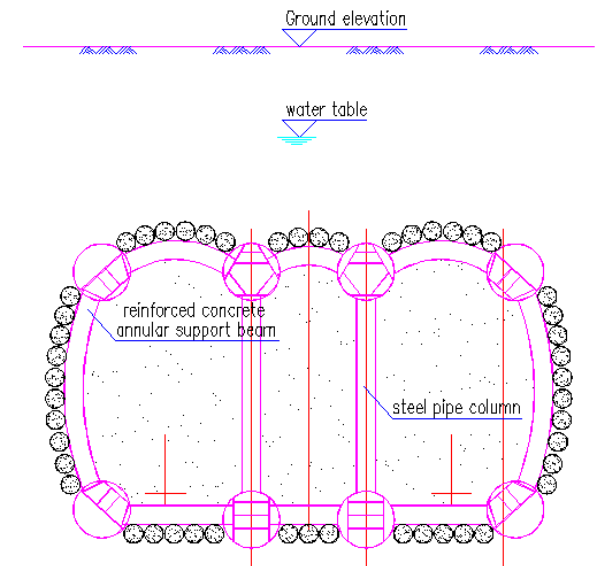


Fig.4 Profile of Backfilled Steel Pipes

g) Until step d completed, cycling step e to f while metro station construction accomplished. It is construction profile of supper tubular roof method shown in graph 7.

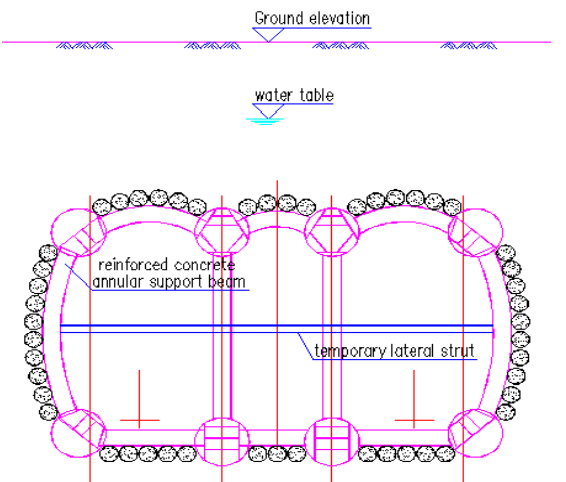


Fig.5 Profile of Temporary Lateral Strut

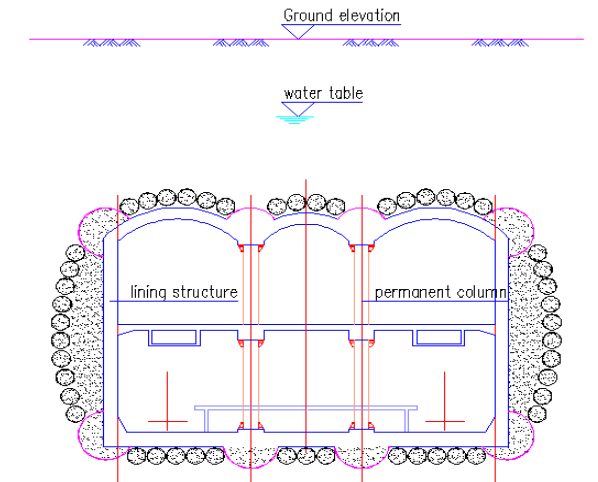


Fig.6 Profile of Permanent Structure

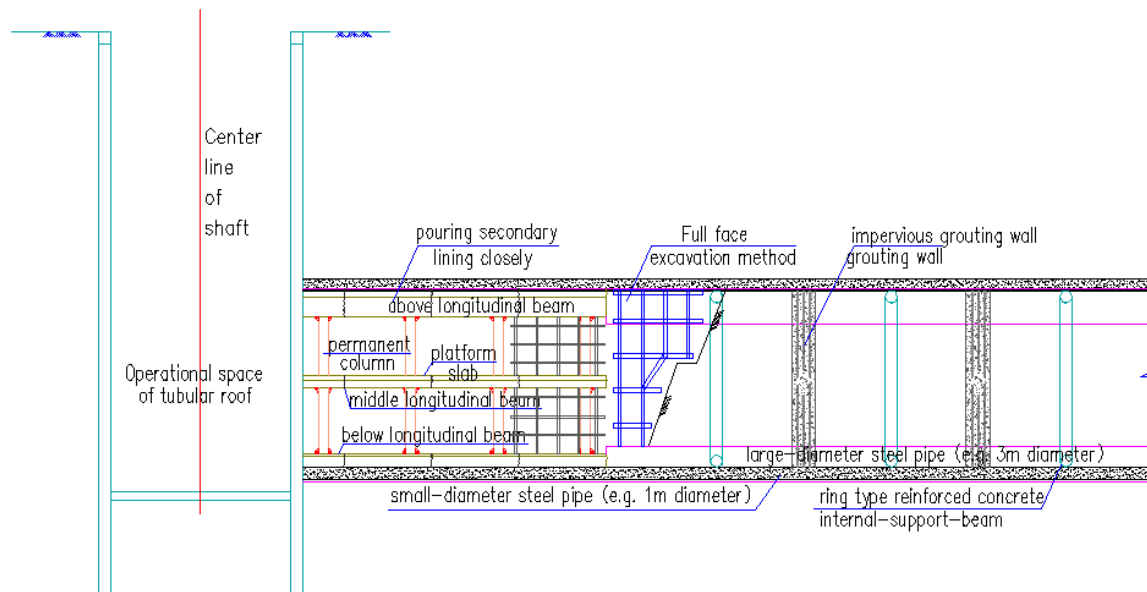


Fig.7 Structure Longitudinal Profile

Waterproof System of Tubular Roof

The waterproof system of STR method is made up of longitudinal and radial sealing system. Large and small diameter steel pipes layout continuously forms the radial waterproof system of deeply buried metro station. Waterproof between steel pipes mainly relies on the special sealing lock shown in figure 8. The sealing lock which is adopted to connect steel pipes is injected with ropy seal oil to block the hydraulic connection of strata in and out of steel pipes. And, sealing lock can withstand higher hydraulic pressure without the risk of leakage. Longitudinal waterproof of metro station is mostly depends on impervious grouting wall which divides the soil inner tubes into several exclusion water soil capsule.

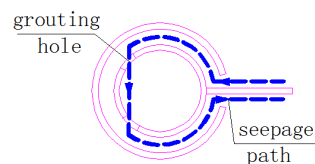


Fig.8 Waterproof Lock

Conclusion

STR method is a effective means to solve the construction difficult in deep and water rich strata condition for building metro station. It needs further study and validate before popularization and application since STR is a new and inexperience method.

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