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# Research on Construction Technology of Metro Tunnel by Adjacent Excavation in Water-Rich Area and Strongly Weathered Strata

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**ABSTRACT：** The technology proposed in this paper is applicable to the construction of metro tunnel by adjacent excavation in water-rich area and dense building group. It is aimed the excavation scope of tunnel by adjacent excavation in water-rich area, the surrounding rock stability of tunnel vault in strongly weathered strata is poor, and it is necessary under-cross a densely populated residential area with strict requirements on ground subsidence. The conventional construction technology of tunnel by adjacent excavation can not guarantee the safety and stability of tunnel the houses above it. In order to ensure the construction safety and not affect the construction progress of tunnel by adjacent excavation, the construction technology of tunnel by adjacent excavation in waterrich area and strongly weathered strata under dense building group is adopted to improve the construction safety of tunnel by adjacent excavation and speed up the construction progress. This technology is in process, easy to operate, economical and reasonable, easy to promote, simple and effective, and has a certain degree of advancement. It is suitable for the construction of metro tunnel adjacent excavation in water-rich area and dense building group, and has broad prospects for promotion and application.

**Keywords -** water-rich area; stronglyathered strata; metro tunnel; adjacent excavation

## I. INTRODUCTION

Due to the small construction area, flexible and convenient construction, and suitability for different geological, spans, and cross-sections, the shallow excavation method technology has formed a complete set of supporting technology after more than ten years of development and application, and has achieved tremendous and social benefits. At present, in the process of subway tunnel construction, the technical measures and methods of shallow excavation construction are also becoming more and more perfect in the face of construction conditions such as water-rich, various soft geological layers, and dense ground buildings. The subway tunnel in this project is close to the Pearl River, and the hydraulic connection between the Pearl River and the surrounding groundwater is relatively close. There is a fluvial-alluvial sand layer on the overlying strata of the tunnel. groundwater is abundant during construction[1-2]. After the surface water of the Pearl River and the groundwater of the sand layer are connected, a large amount of water infiltration can easily cause collapse of the tunnel structure. The shallow excavation tunnel needs to pass under a densely populated residential area with strict requirements on ground subsidence. However, the tunnel section is large the rock stratum of the tunnel body is hard, and the overlying strata is soft[3-5]. It is impossible to guarantee the stability of the surrounding rock of the tunnel and the of the houses above it with a single blasting excavation. During the dry season in winter, the groundwater level is affected by the tunnel excavation seepage and the decline the Pearl River water level, which can easily cause ground and house subsidence. In order to adapt to the complex construction environment of subway tunnels and the difficulty of ensuring safe excav by conventional technology, especially near the Pearl River, the difficulty and risk of shallow excavation construction under water-rich conditions are high. In order to break through the problems of poor-stop effect and difficulty in ensuring the overall stability of the surrounding rock of soft geological layers in traditional shallow excavation construction technology, the double-pipe non-shrink deep hole grouting technology is used for deep hole grouting water-stop and reinforcement of soft surrounding rock. In order to solve the settlement problem of subway tunnels when they pass underensely built areas with strict requirements on ground subsidence, the tunnel small bench multi-explosion construction technology and the ground layer pre-grouting and groundwater gradient backfilling technology used to reduce the blasting excavation vibration and tunnel seepage water, so as to better adapt to the needs of the future development of subway tunnel construction technology under densely built, and to promote the safe and efficient development of subway tunnel shallow excavation construction technology. Meet the requirements of green construction.

## II. TECHNICAL FEATURES

This technology is based on the traditional shallow-buried underground excavation construction method, on the basis of double-pipe deep hole grouting technology, pre-grouting of the stratum and groundwater recharge technology, and small-step multiple blasting excav technology, it innovates and optimizes the tunnel underground excavation construction technology. The main technical features are as follows: 1. According to the soft underlying layer and the groundwater situation of the tunnel, with the aim of stopping water and reinforcing the stratum, deep hole grouting is carried out within the tunnel excavation line and within meter outside the excavation line, increasing the compressive strength and adhesion within 2 meters outside the tunnel excavation line, and providing temporary support in advance to enhance the bearing of the stratum, to achieve the purpose of stopping water and reinforcing the stratum, and to ensure the stability of the surrounding soil when the tunnel is excavated and under buildings. The cumulative settlement of houses and tunnel vault is within 20mm, and the tilt rate is controlled within 0.002. 2. Since is a group of buildings such as Zifuxin Village above the tunnel of the return line, the buildings within this range should be protected and monitored. Drilling for sleeve valve grouting is carried out along the line 1.0~1.5m outside the house structure, and double-row plum-shaped drilling grouting is carried out, a grouting hole spacing of 1.5m, and the reinforcement range of the sleeve valve pipe is 10~12m below the ground surface.

Try to oblique holes to the projection below the house and effectively avoid the friction pile foundation under the house, so as to maximize the reinforcement of the bearing stratum between piles under the house and try to reduce the blind area that cannot be reinforced as a principle. The drilling layout can be adjusted appropriately according to the actual situation on site, and the grouting holes should sealed with cement mortar after grouting. Since the upper stratum of the tunnel is mainly composed of strong permeable layers such as sand layer and strong weathering layer, the ground recharge in the dry season is not sufficient, so on the basis of increasing the "water blocking" measures inside the tunnel, it is necessary to increase the recharge well on the ground and to supplement and recharge the groundwater according to a certain water level gradient according to the monitoring feedback of the groundwater level, so as to ensure that the groundwater remains a relatively stable level, and to minimize the loss of groundwater causing consolidation settlement of the stratum below the foundation of the house. 3. Since the rock layer of tunnel excavation surface is mainly composed of moderately weathered and slightly weathered conglomerate and mudstone sandstone, it is difficult to crush with common mechanical equipment and the efficiency is low, so it is necessary to use blasting method for excavation to speed up the progress.

During the tunnel excavation, the harmful effects of blasting excavation the surrounding environment are monitored at any time. When the harmful effects are large, the small-step multiple blasting method with the same section is used, that is, the large tunnel upper heading face is divided into two small steps, the small step heading area is blasted first, and then the auxiliary area is blasted after the new overhanging face is obtained and finally the surrounding holes are blasted, which reduces the amount of single blasting, and at the same time, the vibration holes are arranged on the excavation contour line to reduce blasting vibration.

## III. KEY TECHNOLOGIES

### 3.1 Double-tube Non-shrinkage Deep-hole Grouting Technology

Deep-holeouting is the uniform injection of cement-water glass slurry into the soil body through grouting holes, filling, permeating, and compressing the water and gas between sand layers clay particles, and filling their positions. Through the hydrolysis, hydration reaction, and agglomeration effect of the minerals contained in the modified slurry and the water soil in the soil body, suspended colloids and agglomerates are formed, which harden to form soil with high strength, low compression, and high impermeability stability. After the soil body hardens, the porosity and water content of the soil body are low, the density increases, and at the same time, due to the compa of the modified slurry, the deformation resistance of the soil body increases, and the deformation modulus is improved, thus preventing or reducing the collapse of the soil body at the front face .

### 3.2 Pre-grouting of the Formation and Gradient Recharge of Groundwater Technology

The grouting reinforcement of the formation is to press the grouting material filling and gelling properties into the formation to be reinforced through the matched grouting machinery, and after the gelling hardening, it fills and blocks the voids in the formation reduces the permeability coefficient of the formation in the grouting area and the leakage amount of water during tunnel excavation, and can also consolidate the soft and loose rock mass to the strength and self-stability of the formation. In the dry season, the groundwater of the house foundation is replenished and returned according to a certain water level gradient, ensure that the groundwater is maintained at a relatively stable level, so as to minimize the loss of groundwater causing consolidation settlement of the soil below the house foundation. 3.3 Surveying and setting out

**3.3 Small Bench Multiple Blasting Excavation Technology**

The small bench multiple blasting method is used, that is, the upper front face of the large section tunnel is divided into small benches, the small bench heading area is blasted and excavated first, and then the auxiliary area is blasted after the new exposed surface is available, and finally the peripheral holes blasted, which reduces the amount of charge for a single blasting, and at the same time, the vibration holes are arranged on the excavation contour line to reduce the blasting.

## IV. TECHNICAL IMPLEMENTATION

**4.1 Double-tube Non-shrink Deep Hole Grouting Technology**

Since the overlying str of the parallel metro tunnel are sandy layers and strongly weathered weak layers with strong permeability and poor surrounding rock stability, there is a significant safety risk in underground excavation construction the tunnel in the case of abundant groundwater. However, the traditional double-tube deep hole grouting water stop effect is not ideal. This technology uses deep hole grouting within tunnel excavation line and within 1 meter outside the excavation line to increase the compressive strength and adhesion of the rock layer outside the 2-meter excavation line the tunnel. Cement slurry is used to pre-fill the rock layer voids and provide temporary support to improve the compactness and bearing capacity of the surrounding rock, and achieve the purpose of good water plugging and surrounding rock reinforcement. During the drilling process, it is first up and then down, first outside and then inside, that is, outside the tunnel excavation line 1 meter before drilling inside the excavation line for grouting. The grouting adopts a retreat-style sectional grouting method, with a spacing of 1500mm. Drilling construction is carried out according to the full-section method, with a cycle advance of 20m, and a reserved2m grouting section is used as a grouting disk for the subsequent grouting section.

**4.2 Groundwater Gradient Recharge**

Since the strata above the is mainly sandy layers and strong weathering layers, which are strong permeable layers, the groundwater recharge in the dry season is not sufficient. Therefore, on the basis of increasing "water plugging" measures inside the tunnel, it is necessary to add recharge wells on the ground. According to the monitoring and feedback of the groundwater level hole, the recharge stop water valve is opened separately for gradient water recharge, to ensure that the groundwater in the underground excavation affected area is maintained at a relatively stable level, so as to minimize loss of groundwater causing consolidation settlement of the foundation soil under the house. The recharge well hole is 12m deep and 300mm in diameter, with 200mm PVC casing dropped, and the recharge well water pressure is about 0.3MPa. Stop valves and water meters are set on the branch pipes control the water flow rate, and at the same time, the water level monitoring around the foundation pit is strengthened. Fig. 9 is a statistical table and curve chart of thewater level monitoring from November 2017 to January 2018. According to the change of the groundwater level of the surrounding buildings, the gradient recharge ofwater is carried out to ensure the stability of the groundwater level.

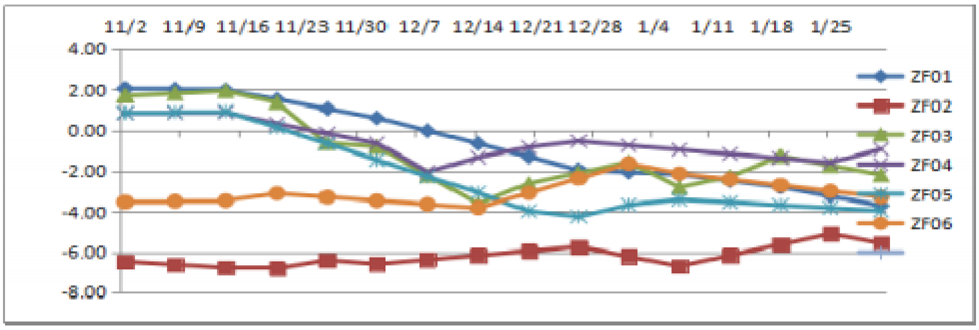


**Figure 1 The groundwater level monitoring curve of surrounding buildings**

**4.3 Small-step multiple blasting excavation technology**

The rock stratum of the tunnel excavation face is slightly weathered and slightly weathered conglomerate and mudstone sandstone, which is difficult to crush with common mechanical equipment and has low construction efficiency, so it is necessary use blasting method to excavate to speed up the construction progress. The tunnel excavation adopts end-to-end excavation, excavating from the north end of the station the vertical shaft end. During the tunnel excavation, the harmful effects of blasting excavation on the surrounding environment are monitored at any time, and when the harmful effects are large the small-step method with the same cross section is used for multiple blasting, that is, the large cross section tunnel upper heading face is divided into two small steps, the step is blasted and excavated first, and then the auxiliary area is blasted after the new overhanging face is available, and finally the surrounding holes are blasted, which reduces the of charge per blasting, and at the same time, the vibration holes are arranged on the excavation contour line to reduce the blasting vibration. The notch holes are generally in the central and lower parts of the excavation face of the upper step, and are about 200mm deeper than other holes; the surrounding holes are arranged on the line of the excavation section, and the bottom of the hole should exceed the design contour line by about 100mm, and the bottom plate holes are also properly dens to prevent under-excavation;

From the point of view of uniform energy distribution and the actual requirements of this project, the following methods are used for tunnel blasting: the holes are arranged in a wedge-shaped, diamond-shaped, square-shaped, etc., and the auxiliary holes are arranged in a uniform manner with a plum blossom shape The spacing of surrounding holes is taken as 400mm ~ 600mm, and the minimum resistance line is taken as 400mm ~ 60mm; the spacing of auxiliary holes is taken as 500mm ~ 800mm;the spacing of notch holes is taken as 500mm ~600mm. In order to reduce the harmful effects of blasting and improve the quality of blasting crushing and the efficiency of excavation, the small-step method the same cross section is used for multiple blasting in tunnel excavation, and the step height is about 3.0m ~ 3.5m. In the timespaced blasting, the notch holes and auxiliary holes are loaded with 1~9 sections of millisecond detonators, and the rest of the holes are loaded with equal intervalators with an interval of 200ms. The blasting sequence of the small step with the same cross section is: notch holes → auxiliary holes → surrounding holes. As in the following figure, the notch area is blasted first (type 1 and type 3 detonators), and then the auxiliary area is blasted (type 5 and type7 detonators) after the new overhanging face is available, and finally the surrounding holes are blasted (type 9 and type 11 detonators), which reduces amount of charge per blasting and is conducive to reducing the vibration effect generated by blasting.

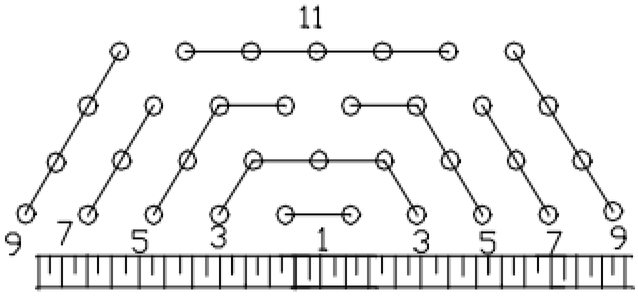


**Figure 2 Schematic diagram of small step initiation**

During blasting construction, the excavation depth and the particle velocity caused by blasting are strictly controlled the safe allowable range (2.0 cm/s). The excavation depth of the left line is not more than 1 meter per cycle on the upper step, the lower step is controlled within 2.5 meters. The upper step of the right line with a large section is 1 meter per cycle, and the lower step is controlled 2 meters. The blasting shock velocity monitoring data is shown in the following table.

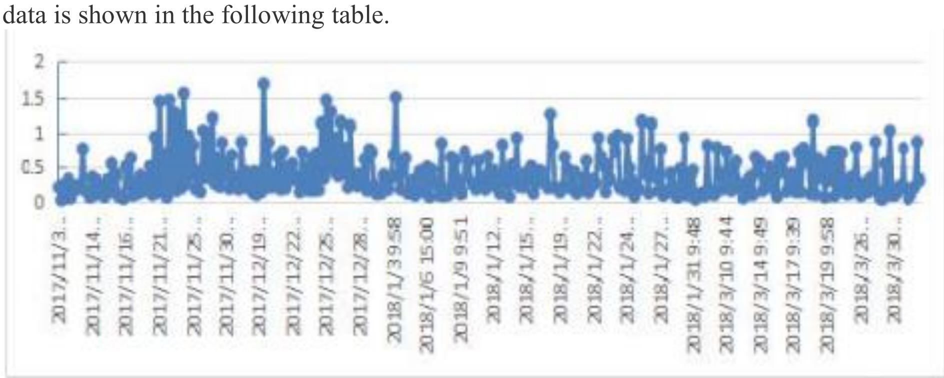


**Figure 3 Tunnel blasting seismic velocity monitoring data**

## V. CONCLUSIONS

This project adopted double-pipe non-shrinkage deep hole grouting technology, stratum pre-grouting and groundwater backfilling technology, and small bench multiple blasting construction technology, which solved the problem of large seepage in strong weathered rock layers under water-rich conditions, and the instability easy collapse of the surrounding rock after immersion. The construction technology problems that the conventional underground excavation construction technology can not guarantee the safety and stability of the tunnel and the houses above it passing under a densely populated residential area with strict requirements for ground subsidence; it also accelerated the construction speed of the underground excavation tunnel and shortened the construction period, which beneficial to the control of the overall construction period.

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