

Analysis of tunnel excavation method and construction technology

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Abstract

The method of tunnel excavation is classified and the application conditions, technical points, equipment configuration and progress indicators of different excavation methods of drilling and explosion method are analyzed and summarized, the determination and adjustment basis of excavation method are put forward in this paper.

Keywords

Tunnel excavation, method, technology, main points.

1. Introduction

The tunnel is called underground passage. According to its use function, it can be divided into traffic tunnel, hydraulic tunnel, mine tunnel, pipeline layout tunnel. According to its location, it can be divided into mountain tunnel, cross-sea tunnel and cross-river tunnel. According to the depth of buried depth, it can be divided into deep buried tunnel and shallow tunnel. The determination and geometrical features of the section of the tunnel are determined by its function and special geological environment, the important basis for the selection of excavation tunneling method is also the size and geological condition of the cross section. Tunnel excavation is an important process of construction. The selection of excavation method not only determines the construction progress of the tunnel, but also seriously affects the construction safety, and it is very important to select the tunnel excavation scientifically and rationally.

2. Classification of tunnel excavation methods

There are two main types of tunnel excavation: mechanical tunneling and drilling blasting. Including mechanical, shield TBM tunneling has two ways, drilling and blasting method of excavation method of whole section method, steps, one step method and divided into two steps, three steps and three steps aside core making, other subject method and CD, CRD method, double side gate method, the middle hole method. This paper focuses on the applications and technical points of the common methods of drilling and blasting. The tunnel excavation method is shown in figure 1 below.

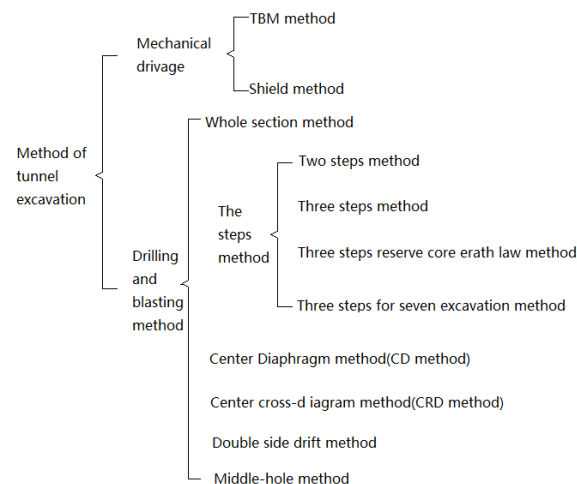


Figure 1. Classification of tunnel excavation methods

3. The applicable conditions and technical points of various drilling and blasting methods

3.1 Whole section method

3.1.1 The applicable conditions of the full section method

The whole section method refers to the design of the contour line of the tunnel to take one of the Blasting, and then the next step of the construction. Its applicable conditions include better surrounding rock level and proper excavation section. The surrounding rock level is low and the self-stability is poor. It is not good for the construction progress and benefit if the whole section excavation must be pre-reinforced. Cross section area is too big, not only have special requirements for drilling and blasting equipment performance, and initiation order complex, and detonator, is more than common paragraph need special manufacturer, higher cost, a blasting quantity is big, bigger to the disturbance of the surrounding rock. For the hydraulic tunnel, the loose ring is too large, which not only affects the durability of the structure, but also increases the cost of consolidation grouting. From the perspective of construction practice, the whole section excavation can be considered as long as the following two conditions are satisfied: (1) the tunnel surrounding rock is I level and II level; (2) the design section shall not be more than 120 square meters. In addition, the whole section method can also be considered for the III level surrounding rock tunnel with a cross-sectional area less than 60 square meters.

3.1.2 Technical points of full section method

(1) Geological review. As long as the tunnel surrounding rock conditions permit, the project adopts the whole section excavation is common, but only on the condition of surrounding rock according to construction drawing provide excavation method there is a big risk, because the whole section excavation disturbance is larger, the rock once change without changing the construction method of surrounding rock is bound to lead to accidents. Therefore it is necessary to carry out in full face excavation excavation constraints of geological sketch and advance geological forecast, actual situation, grasp the tunnel surrounding rock, rock class timely review once appear, level of surrounding rock and design large difference, need to modify the excavation method in time, reduce the tunneling footage.

(2) Design and optimization of drilling and blasting schemes. Another technical point of full - section excavation is drilling and explosion design. Drill blasting quality impact on the construction progress is huge, and the design of the scheme is not static, in the implementation of the blasting parameters need to be constantly optimized, so the scheme of the design and optimization are dynamic. But many projects don't say dynamic design even basic blasting solutions, all by excavation construction experience. Experienced, the blasting quality is high, the lack of experience, not only poor penetration and explosion of slag rate of large, continuous cannon, a bit even difficult molding, seriously affect the construction progress, so is the main technical points of the whole section excavation blasting design. The design contents of the drilling and blasting scheme include: cutting type determination, gun hole layout (perforation parameter), quantity, depth, Angle, loading quantity and loading structure, initiation method and starting order. The perforation parameters and the loading quantity and the loading structure need to be modified and optimized during the drilling and blasting construction.

(3) Circular footage and step distance regulation. Circulating footage need according to the level of surrounding rock, section size, determine the equipment condition, adopts the whole section excavation, level I, level II footage of surrounding rock shall not be more than 3.5 m, III grade of surrounding rock shall not be more than 2.5 m, a excavation length of inverted arch excavation, level II rules of surrounding rock is 12 m, III levels of surrounding rock is 6 m; According to the distance of the operating surface of the inverted arch, the surrounding rocks of I, II and III are not greater than 90m. In the absence of adverse geological conditions, the surrounding rocks of II and III should not be larger than 200m.

3.1.3 Equipment configuration and progress indicator of full section excavation

In recent years, due to the ventilation equipment improvement to promote the performance of the ventilation technology advances, grew up in the tunnel construction ventilation mode no longer USES the trackless transport, as long as the surrounding rock conditions permit or through effective supporting can be used after full face excavation adopts full face excavation, create conditions for construction of large equipment into the hole. With the progress of construction machinery technology, all process of tunnel construction can realize mechanization or half mechanization operation, especially the whole section excavation method, all processes have to achieve fully mechanized operation, its main equipment and the efficiency of the introduction is as follows.

Drilling rig: it is mainly used for drilling holes, advance warning holes and bolt holes. At the scene of the most commonly used is given priority to with imported equipment, the main models with atlas, Tom Locke's two big series, tunnel construction with atlas drilling jumbo, its stable performance and high drilling efficiency, maximum speed can reach 20 ~ 30 m/h. But import car is expensive, the high cost of maintenance, especially in the tunnel seepage is larger, the control computer failure frequency is higher, once the failure will affect the progress of a few days, combined with the present domestic cheap labor force, many projects still use portable pneumatic drill drilling YT series is in the majority. And in the tunnel with high security risk, it is generally used in the construction of drilling machine.

Anchor platform car: the anchor platform car has drill hole, installation bolt, grouting function, belongs to the all-in-one machine. Imported equipment is dominated by atlas and Tom rock series, which are usually configured in large tunnels or complex high-risk tunnels.

Concrete shotcrete: a high - risk tunnel with a large tunnel or a complex geology. To ensure the construction progress, concrete shotcrete is required. At present, the domestic commonly used concrete injection hand is the meister series, the production capacity can reach 25 square meters per hour.

Digging, loading, transport equipment: after the bursting of the excavator is mainly used for top, brush to help find and dig keep constraints (remove dangerous stone), the loader USES is the side discharge type, double line tunnel generally within the hole with two jobs at the same time, the slag transport equipment adopts large dump truck, steyr or red rock series, is often used to load more than 25t.

The whole section is excavated, the process is simple, the equipment supporting and blasting technology is feasible, the monthly progress is 180~240m.

3.2 The steps method

3.2.1 The application condition of the step method excavation

(1) Definition of step method. The step method is to divide the design section of the tunnel into two or three excavations. The upper step is a certain distance, and the advance length is greater than 50m or 5 times the diameter of the tunnel. Up and down the steps, the steps are only 3~5m, temporary support or lining quick closure, called micro-steps excavation.

(2) The application conditions of step method. Step excavation is the most widely used method in tunnel construction. II, III level for two steps method of surrounding rock excavation, also can use full face excavation, exactly what the excavation method, not only depends on the grade of surrounding rock, but also consider whether the size of the excavation section and construction equipment matching, the stability of surrounding rock, the construction schedule and construction habits and other factors. Section is too large for construction equipment demand is higher, a detonation dose is bigger also, bigger to the disturbance of the surrounding rock, the surrounding rock stability time is short, this kind of situation usually adopts two steps excavation without using whole section.

IV, V level surrounding rocks are excavated by three steps or micro steps after effective support of steel arch and anchor and net spraying. The micro-step excavation method is also used to excavate the large cross-section tunnel with small span.

The three steps and the micro-steps excavation method are limited by the working space, the process is interfered with each other, the progress is slow, and the construction of large equipment is not suitable, and few projects are adopted.

The three steps reserved the core soil excavation method and the three-step seven-step excavation method are suitable for the soil layer of the 5th grade surrounding rock, the sand and gravel formation tunnel excavation, mainly by manual excavation.

3.2.2 Key points of the steps

(1) The step length, step length and step distance, length of certain steps need to be consider the geological conditions of surrounding rock and supporting closed time, large equipment needed for construction space, relevant technical documents and technical guide for special requirements.2. The three-stage surrounding rock tunnel will be excavated with long steps, and the steps will be more than 50m, so that there is enough space in the front and back process to avoid interference of the process. Level 4 surrounding rock due to the stable time is short, request support quickly closed, construction often use short steps, step length in 2 ~ 5 times hole diameter, 4, 5 also can adopt micro step excavation of surrounding rock, step length is 3 ~ 5 m.

(2) Supporting requirements: 4, 5 class surrounding rock is generally equipped with steel or steel grille arch, arch of unit processing, bolt connection site installation, up and down the steps of the arch when installation must demand enough clearance, to ensure that the upper and lower arch section of the installation precision. It is strictly forbidden to use reinforcing steel joints for the joints, and it is strictly forbidden to reduce the anchoring rod of the longitudinal reinforcement and arch frame between each truss. Shotcrete must cover the arch.

(3) Blasting technical requirements: blasting operation is required for the hard rock tunnel constructed by step method. In order to minimize the impact of blasting on the completed upper step support system, the lower steps must be controlled blasting.

(4) The three steps are reserved for core soil excavation and the technical points of the three-step seven-step excavation: advance small pipe support, circular excavation, reserved core soil anti-palm surface instability. The length of the reserved core soil is controlled at about 4m, and when the middle or lower steps are excavated, it should be stagger from 2 to 3m, and the inverted arch should be organized immediately after falling, and the temporary support shall be closed in time.

3.2.3 The equipment configuration and progress indicator of the construction of step method

(1) The construction of the step height can meet the operation requirements of large mechanical equipment, the equipment configuration is the same as the whole section, and the construction progress is 100~150m.

(2) In the three steps method or micro level construction, highly restricted because of the first steps, the first step in drilling, muck, shotcrete is large equipment is complete, the need to configure the small equipment of artificial cooperate with work at the same time, so it is difficult to play to the advantages of large equipment. So the excavation method for three steps, you can configure the large equipment, but also need to cooperate with the small equipment, small device is mainly on the steps of drilling and blasting equipment, slag, shotcrete equipment. In addition to drilling and blasting equipment, micro-steps can be configured to excavate the same equipment as the whole section. The construction progress index of three steps or micro-steps is 60~80m.

(3) Three steps aside core step or three step seven excavation method, in addition to the excavation and double slag using small equipment and artificial auxiliary construction, shipping, spray and anchor can be used the same as the whole section of large equipment, progress in about 60 m.

3.3 Center diaphragm method(CD method)

3.3.1 The definition of the center diaphragm method

Center diaphragm method is the division of the stairs, around the tunnel excavation face is divided into two parts, the first at the side of the tunnel excavation of the top-down hierarchical, complete primary support, when sprayed concrete design strength of 70%, according to the excavation on the

other side in the same way. Next door in the method of the core is at the other side of the excavation retaining in the middle of the steel arch and shotcrete support network, which formed in the next door, ipsilateral excavation by steps method according to the condition of supporting internal force and deformation add inverted arch, therefore supporting not closed.

3.3.2 The applicable conditions of the Center diaphragm method

Center diaphragm method is suitable for the part in grade 4 and all 5 levels, of surrounding rock large filling type fault segment, the residual, diluvial layer tunnel entrance section, shallow buried large span tunnel, the surface settlement of building complex, highly demanding tunnel. A massive but hard grade 4 surrounding rock fissure filling less, not suitable for using in the next method, this kind of commonly used weak surrounding rock blasting effect is poor, the conventional blasting destruction of temporary support, in the next door can't lose, but form construction safety hidden trouble.

3.3.3 The technical essentials of Center diaphragm method

(1) Key points of blasting technology: the four-stage surrounding rock that is constructed by the CD method needs to be excavated and excavated. The principle of "weak blasting and short penetration" must be followed to strictly control the amount of initial explosive charge.

(2) Key points of support technology: 1. The steel support in the front side of the front side should be processed into an outer drum arc, and the size of the radian should be determined with the height of the net air, not too large. The division of unit length should be convenient manual installation, should not be too heavy, usually considering bolted connection form, must in the tire rack processing unit and the assembly test splice fittings, connection plate bolt hole shall not use oxyacetylene gun optional cut, prevent bolt hole, clearance is too large to node stiffness decreases. The installation spacing must meet the design requirements, the arch foot can not be suspended, the longitudinal reinforcement and the anchor bolt are strictly forbidden to cut corners, and the shotcrete must cover the steel arch. 2. The leading small catheter must be arranged according to the design, and the grouting should be strictly prohibited. The grouting construction must have the on-site duty of the engineering technicians, and the grouting record shall be made. In order to find out the abnormal amount of the feed and the abnormal pressure, it is necessary to analyze the reason in time and must install the anti-flow stop stopper. 3. During the excavation of the steps, if the internal force of the support is found to be larger, the deformation rate of the hole is fast, which can increase the temporary steel support.

(3) Monitoring technical points: 1. Special monitoring programs must be prepared. The monitoring contents include the internal force of the support, especially the internal force changes in the middle of the excavation process in the second part, the arch settlement and ground settlement, and the cave chamber convergence. There must be a clear warning value, which can be set according to the construction specifications and technical guidelines without a given warning value. 2. Professional monitoring teams must be set up. 3. It is necessary to carry out work according to the monitoring frequency of the construction specifications and technical guidance, analyze the data in time and feedback the information.

(4) The deformation control technology main points: 1, the ministries is to use two steps or three steps excavation should be according to the geological conditions, the mechanical equipment, determine the size of the cross section, step interval control in 3 ~ 5 m. 2. Whether the blasting auxiliary excavation or manual or mechanical excavation shall be adopted, the circular penetration shall not be greater than 1.5m steel arch spacing. 3. The driving distance of the left and right sides is controlled at 15~20m. After the lagging part of the excavation bottom, the steel frame of the inverted arch must be installed as soon as possible, and temporary support will be closed in the shortest time. 4, next door to dismantle length must be through simulation analysis, under the guidance of monitoring data at the same time to consider who do shop, bar three working procedure can install, lining, parallel operation, if the results of the analysis can not meet the requirement of the three process parallel operation, the process will be only two of the intermittent operation.

3.3.4 The equipment configuration and progress indicator of the construction of Center diaphragm method

Using the method of middle - next door excavation, because of limited working space, large mechanical equipment can not be used, and small equipment and artificial auxiliary construction are often used. It is necessary to use the YT28 air drill to drill holes in the blasting operation, not to use the pneumatic pick for blasting, or to excavate the DS series of small excavators. Use a human trolley or a small dumper. Jet concrete is generally used in the TK series. The construction month progress index is about 60m.

3.4 Center cross-d iagram method(CRD method)

3.4.1 The definition of Center cross-d iagram method

The next door neighbor method is similar to the middle partition method. It is an excavation method that improves development on the basis of the middle partition method. The core technology is to excavate the left and right branches of the tunnel. Upper press about the steps method step by step excavation, down the steps again cross left right after the first excavation, a separate will support both closed loop every excavation, about the exchange, the cyclization step by step excavation technology, it is also a cross in the next door (CRD method) and in the next method (CD method) the essential difference between.

3.4.2 The applicable conditions of the Center cross-d iagram method

Center cross-d iagram method applicable to the shallow buried, large-span, weak rock tunnel, to control the deformation and ground subsidence demanding urban subway has strong advantage in concealed excavation of tunnels, suitable for rock mass for level 4, 5.

2.4.3 The main points of the technique in the Center cross-d iagram method

(1) Division stratification principle: it should be divided according to the surrounding rock conditions, characteristics and section size. It is necessary to consider the deformation and spacetime effect of the surrounding rock, and to consider the uniform force of the supporting force, and to give full play to the human and machine efficiency. The most common one is the two parts, which are divided into three layers.

(2) Key points of support technology: 1. The temporary steel support that has been excavated first must be processed into a steel support unit with a certain radian, and its processing and installation technical points are the same as that of the middle partition; 2. To control the excavation speed of each department according to the deformation and time effect of the surrounding rock, as soon as possible to make the inverted arch and timely seal the ring; 3. Spray concrete to the palm surface in time to prevent the palm surface instability; 4. The key points of other supporting technologies are the same as those in the middle.

(3) Monitoring technical points: the temporary steel support in the next door is under great pressure, especially after the lag part is excavated. The arch shoulder bears a large pull. The monitoring of temporary support internal force is the same as the intersecting technique.

3.5 Double sidewall method

3.5.1 The definition and applicable conditions of double side wall guide

Double wall pilot tunnel method is first excavation tunnel on both sides of the gate, complete supporting in time and then depending on the geotechnical properties of surrounding rock, the section size according to the rest of the two or three steps excavation construction methods, its core technology is still larger across different for small division is the steps of the construction method. Double wall pilot tunnel excavation method is mainly suitable for shallow buried large span of 5, 6 class surrounding rock excavation, gate on both sides of the excavation, if necessary it can also be applied two lining sidewall, so I can save some temporary support measures.

3.5.2 The technical points of double side wall guide

(1) The characteristics and size of the tunnel section: the shape of the guide pit shall be approximately oval, and the width shall be one third of the width of the excavation section, and the height shall be about twice the width.

(2) The excavation and supporting technology main points: two side gate can be synchronous with short steps excavation independently, should be used lag sidewall 10 ~ 15 m is central steps excavation, the ministries in the process of excavation cycle must be applied in a timely manner for support, as soon as possible to support closed loop. Of steel arch support is connected to the wall of steel support construction difficulties, but also stress the key parts, so the side gate on both sides of steel supporting construction must be accurate positioning, to ensure that the whole section steel support can be in the same vertical plane, reduce degree of difficulty of installation of steel arch support, steel support is to avoid distortions. The other technical points of support are the same as those in the cross.

(3) Main points of deformation control technology: the main points of the control technology of the excavation deformation control of the double side wall guide pit are the quality control of the supporting construction and the control of the excavation step. The quality control of supporting construction is the same as that of the adjacent excavation, and the excavation step is also an important factor affecting the deformation. The pit and middle excavation steps are generally controlled at 3~5m, and the surface of the palm is relatively short and stable. In the front of the lateral wall, the distance between the center and the middle excavation is generally controlled from 10~15m, and the steel support is too late to be closed, resulting in the accumulation of deformation and the normal construction of the process. In the middle of the excavation, temporary support should be made in time, the second line should not exceed 30m, and the monitoring data should be adjusted in time.

3.5.3 The technical points of double side wall guide

The construction equipment is basically the same as that in the middle next door, and the monthly progress indicator is 40~60m.

3.6 Middle-hole method

3.6.1 Conditions for the middle hole method

Hole in the method, mainly is suitable for the multi-arch tunnel excavation in shallow buried large section in the hole method may be adopted in weak rock tunnel excavation, but compared with CRD method, the supporting force is not clear, process more complex, and few engineering use except multi-arch tunnel.

3.6.2 The key points of the hole method

(1) The position and drift section size points: the location of the middle drift in multi-arch tunnel wall, cross section form of horseshoe, height should be 1 ~ 1.5 meters high, than in the wall on both sides of Central Line width than the middle wall section 2 meters wide, if consider wall in excavation and concrete construction synchronous parallel operation, moderately can be widened.

(2) The residual part of the two sides of the middle hole is excavated by the step method or the sidewall guide pit method, and the technical control points are the same as those mentioned above.

4. Conclusion

Tunnel construction in recent years, the more the responsibility of the accident, investigate its reason, of course there are a lot of management is not enough, but the accident caused by improper construction method choice also happen from time to tome, the selection of construction methods and technical control points for this it is necessary to review and summarize. Due to the complexity of the tunnel engineering geology, combined with the design stage of geological exploration work is not careful, the designer to draw a template according to the geological data, leading to construction drawing design of a given the geology has large discrepancy with actual situation, and great changes have taken place when the rock mass has construction method without the proper adjustment, will

inevitably lead to accidents. So tunnel construction is not just for construction drawing provided by a hole of surrounding conditions formulates the corresponding construction methods, and should be advance geological forecast, geological review work included in the construction process, ahead of the construction methods of conversion and process.

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