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Research on Excavation and Support Technology for Large Deformation Sections of Soft Rock in Highway Tunnels

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Abstract: ***The stability of the surrounding rock in the large deformation section of soft rock is poor, which brings difficulties to the construction of highway tunnels. As early as the Ninth Five Year Plan period, research was conducted on the construction technology of large deformation soft rock tunnels, and a large number of research results were obtained and applied to the construction of tunnel engineering. In the deformation process of soft rock Roadworks construction for large tunnels, it is easy to produce large deformation, even collapse, roof collapse and other accidents. It is necessary to carry out detailed Geological survey, reasonable support parameters, and do a good job in quality control during the construction process to effectively improve the deformation of soft rock, control the deformation of surrounding rock, and ensure the safety and stability of the tunnel support structure.***

Keywords: highway tunnel; Large deformation section of soft rock; Excavation support technology.

1. INTRODUCTION

After tunnel excavation, the surrounding rock undergoes significant deformation, especially in sections without advanced support. In the section with water, the rate of water level change is also high. In addition, with the increase of deformation, there is a significant backlog in the tunnel, and support and monitoring should be done to prevent further deformation of the surrounding rock and lining structure. Uneven deformation of tunnel surrounding rock. Due to improper selection of tunnel excavation methods and untimely support, uneven deformation of tunnel surrounding rock is caused, and even local intrusion into the initial support limit is caused. Combined with tunnel engineering monitoring data, uneven deformation on the left and right sides of the tunnel is common. After the initial support is completed, it is found that there is a significant left and right asymmetry in the deformation of the tunnel surrounding rock by measuring the tunnel arch, clearance convergence, etc.

2. ANALYSIS OF THE CAUSES OF LARGE DEFORMATION OF SOFT ROCK IN HIGHWAY TUNNELS

2.1 Geological factors

Soft rock, also known as weak surrounding rock, has loose pores, low cementation degree, and low strength due to cutting and weathering of structural planes. The large deformation of soft rock in highway tunnel engineering is mainly determined by its geological properties, specifically manifested in low self stability after excavation.

From a characteristic perspective, it is prone to collapse. From the perspective of deformation reasons, during the excavation process of the tunnel, the original position of the surrounding rock supporting the tunnel body has changed, forming an empty tunnel wall. Under this condition, the surrounding rock will automatically adjust its own stress and deform towards the tunnel clearance direction. After the excavation of the surrounding rock, the supporting force was lost, and at this time, the rock in other places exerted pressure on the hollow area, causing the soft rock to deform. In addition, soft rock belongs to the property of expansive rock, and once the expansion conditions are met, expansion will occur. When its expansion force is large, it will transfer the expansion pressure to the initial support, thereby causing deformation [1].

2.2 Design Factors

At present, the design of highway tunnel engineering has formed an industrial construction concept, So the specific support design parameters will be relatively accurate. However, due to the variety of surrounding rock types, even if the calculation of theoretical stress state is very accurate, it can only ensure the effectiveness of its contingency design scheme in theory. In actual construction, there are often differences between design values and empirical values, and under the combined action of various external conditions, soft rock is subjected to certain pressure, which strengthens its deformation trend. For example, different levels of groundwater can lead to differences in the coupling effect between water and rock to a certain extent. When the water rock coupling force is greater than the initial support bearing capacity in the design plan, the initial support will deform, and the degree of deformation depends on the magnitude of the water rock coupling force.

2.3 Construction factors

During the construction of highway tunnel engineering, certain vibrations may occur. Mechanical excavation, drilling excavation, or blasting can cause disturbance to the surrounding rock and change its internal stress. In order to maintain self stability, stress arches are generated. Especially when there is a large range of plastic yield failure in soft rock of highway tunnels, the radius of the stress arch in the self stable equilibrium state will increase, further increasing the initial support load.
At the same time, it is difficult to effectively control the deformation of the surrounding rock when the excavation method used in construction is not suitable. Generally, according to the basic principle of "simple first, then complex", the excavation procedure is controlled during the preliminary excavation operation, and the process gradually increases as the excavation operation deepens. If the excavation operation is not closed in a timely manner, it is also easy to affect the soft rock by water, air, etc., expanding its loosening zone and reducing the application effectiveness of circular support [2].

3. EXCAVATION METHOD FOR LARGE DEFORMATION SECTION OF SOFT ROCK

The stability of surrounding rock in the large deformation section of soft rock in highway tunnels is poor. During excavation and construction, the excavation section should be minimized as much as possible to reduce disturbance to the surrounding rock. Tunnel excavation for Class V or above surrounding rocks usually adopts methods such as the three step seven step method, side wall heading method, CD method, or CRD method. These methods can be used multiple times, small sections, or adding temporary supports for excavation. By reducing the excavation section, increasing temporary support, controlling the loading amount, and adopting mechanical excavation measures, disturbance can be reduced. Provide advance support before excavation, and promptly carry out initial support after excavation. Support and seal the inverted arch into a loop to reduce or control the deformation of the surrounding rock and ensure the structural stability of the surrounding rock.

This article takes the micro step construction method as an example, which is an improvement on the three step seven step method. The micro step method is to control the length of the upper, middle, and lower steps within 5m during the excavation process, especially for the middle and upper steps, which should be excavated and supported synchronously. After the excavation of the upper step, the tunnel slag is transported out through the middle step. The micro step method can shorten the connection time of the upper and lower steps, timely apply locking anchor bolts, and seal the inverted arch support into a ring, effectively avoiding uneven arch connection and bulging, shortening the inverted arch step distance and sealing time, and controlling the deformation of the surrounding rock. The micro step method can control the step distance of the inverted arch at 15-20m and the closure time of the inverted arch at 15-20d. In addition, during the construction process, the height of the middle and upper steps should also be fully considered to facilitate slag removal and support construction of the upper steps. In order to shorten the height of the upper step and ensure the handover of work between different teams, the micro step method does not set up core soil for excavation. But if there is significant longitudinal displacement on the tunnel face, the core soil should be retained and the length of the core soil should be minimized as much as possible. During construction, the excavation and support speed of the upper steps should be appropriately accelerated, and the deformation of the surrounding rock should be reduced by rapid construction and timely sealing into a ring.

4. ANALYSIS OF KEY SUPPORT POINTS FOR LARGE DEFORMATION SECTIONS OF SOFT ROCK

4.1 Mechanical Excavation

In order to reduce the disturbance of excavation on the surrounding rock of the large deformation section of soft rock in highway tunnels, mechanical excavation should be chosen as much as possible. Construction machinery can choose from excavators, damage hammers, milling excavators, etc., which can effectively reduce disturbance to the surrounding rock and prevent large deformation compared to blasting excavation construction. Due to the small cross-sectional space of tunnel excavation, the work of excavators and crushing hammers is limited, which can also result in significant overbreak and underexcavation. The multi tooth alloy drill bit of the milling and excavation machine can achieve 360 ° rotation, and can chisel out the surrounding rock according to requirements. The excavation section is smooth and round, which can effectively control over and under excavation. Therefore, the milling and excavation machine should be preferred for excavation. In addition, the milling and excavation machine relies on the drill bit to peel off the slag from the surrounding rock, rather than using vibration and impact to damage the rock mass, which has less disturbance to the surrounding rock and is more conducive to controlling the deformation of the surrounding rock.

4.2 Steel arch strength

In the early stage of soft rock deformation in highway tunnels, the combined support method of steel arch frame, anchor rod, steel mesh, and sprayed concrete is usually used for support. The strength of the steel arch frame usually determines the overall strength and stability of the initial support structure. In the large deformation section of soft rock, the deformation of the initial support of the tunnel is often large, reaching several centimeters or even more. If the strength of the steel arch is insufficient, it is easy for the initial support to invade the secondary lining, and even cause instability and damage to the overall structure of the initial support. Therefore, it is necessary to choose steel arches with higher strength and combine them with structures such as sprayed concrete and anchor rods to form a stable initial support structure [1].

In ordinary Grade V surrounding rock sections, I-18 or I-20 I-beams are often used as steel arches, with a spacing of about 750mm. However, for soft rock sections with large spans and large deformations, using I-20b I-beam as the steel arch with a spacing of 500mm will still cause significant deformation in the initial support. After significant deformation occurs, it is even necessary to use arch replacement for treatment. After analysis, using H-shaped steel with thick walls and wide backs instead of I-shaped steel as the steel arch can effectively control the initial support deformation and improve the stability of the initial support structure.

4.3 Locking anchor rod

The bottom of the steel arch frame is prone to stress concentration, and if not treated properly, it is easy to cause sinking and convergence deformation. Setting down anchor rods can effectively improve the stability of the bottom of the arch frame and control the deformation of the initial support structure. The shrinkage anchor rod usually uses mortar anchor rod, and the length of the anchor rod, the fullness of the mortar, and the installation quality are all key factors that determine the stability of the steel arch frame. In engineering practice, grouting steel pipes and profile steel are connected together with locking feet, and a drilling rig is used to drill diagonally downwards along the arch foot, and then the grouting steel flower pipe is buried. At the arch foot, a section steel is used as a longitudinal connection, and a hole is cut in the middle of the section steel for the steel flower tube to pass through. The steel flower tube is connected to the arch frame as a whole to achieve the purpose of shrinking the foot.

4.4 Arch foot support pad and bolt connection

During the construction of highway tunnels, due to the sinking of the arch foot or deformation of the surrounding area, the connection between the arch steel arch and the middle (lower) step is not smooth, resulting in the initial support of the middle (lower) step invading the limit. Therefore, while doing a good job of foot retraction, it is also necessary to ensure the flatness and density of the bottom of the steel arch frame, effectively controlling the deformation of the initial support structure. For example, using prefabricated blocks or connecting steel plates as support for the arch foot to ensure uniform stress on the arch frame, improve the stability of the arch foot, and prevent deformation and displacement caused by the arch suspension. When the steel arch is connected to the position of the steel plate, the surrounding displacement stress concentration area needs to bear a large horizontal shear force, so high-strength bolt connection must be used. Practice has shown that in sections with large deformation in soft rock, when H-shaped steel is used as the steel arch, using M30 high-strength bolts can effectively improve the connection effect and ensure the strength and stability of the initial support structure [2].

4.5 Locking anchor rod

The design length of the anchor rod in the initial support structure depends on the radius of the surrounding rock loosening zone. The larger the radius of the loosening zone, the greater the stress on the upper part of the initial support caused by soft rock deformation. Practice has shown that the deformation amplitude of the cushion plate or bolt with a radius of 9m of the surrounding rock loosening circle is much greater than that of the road section with a radius of 6m of the loosening circle. Therefore, effective measures should be taken to improve the locking effect. Ordinary mortar anchor rods are difficult to reach the design depth, and can use self-propelled anchor rods. This type of anchor rod comes with a drill bit and can be extended for connection, and can be constructed according to the designed anchoring length. In addition, the self-propelled anchor rod is a hollow structure, and the grouting effect is significantly better than that of ordinary mortar anchor rods. Therefore, the reinforcement length and type of anchor rods should be reasonably selected based on the geological conditions of the section with large deformation of soft rock.

4.6 Longitudinal connection

After tunnel excavation, the original natural balance of the surrounding rock is disrupted, and the stress inside the surrounding rock is released, resulting in deformation of the tunnel surrounding rock and support structure. The deformation of the surrounding rock of a soft rock tunnel with large deformation is complex and multi-directional. The vertical deformation leads to the sinking of the arch crown, and the convergence deformation towards the inner side of the tunnel contour line, along the tunnel axis Longitudinal displacement, etc. This requires the integrity of the support structure to control the deformation of the surrounding rock, while the longitudinal connection can connect the arch frame, improve the overall stability of the support structure, and prevent the weak position of the arch frame connection from being damaged under the stress of the surrounding rock. The use of I-shaped steel arch frame anchor spray support structure often results in arch frame overturning and concrete cracking between the arch frames in the later stage of support. The reason is insufficient longitudinal connection strength, and the overall stability of the support structure is poor. Practice has shown that using double connecting bars can effectively improve the longitudinal connection strength, improve the stability of the support structure, control the deformation of the surrounding rock, and prevent the deformation and damage of the lining structure [3].

5. CONCLUSION

The large deformation section of soft rock in highway tunnels has the characteristics of poor stability of surrounding rock, large initial support structure deformation, unreasonable excavation methods and support parameter design, and is prone to large deformation, even collapse and roof falling accidents. In the construction of large deformation sections of soft rock, methods such as mechanical excavation, weak blasting, and small section excavation are used method reduces disturbance to the surrounding rock and effectively controls the deformation of the surrounding rock. In the design of tunnel support structures, the stability of the overall structure of the tunnel can be improved by increasing the strength of the steel arch, reasonably arranging anchor rods, anchor rods, and anchor rods to control the deformation of the surrounding rock and the initial support structure. Therefore, in the design and construction process of highway tunnels with significant soft rock deformation, it is necessary to choose reasonable excavation methods and determine support parameters to effectively control the deformation of surrounding rock and ensure the safety and stability of the entire tunnel structure.

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