Analysis of internal force and settlement deformation of a highway tunnel lining

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Abstract: In the highway tunnel construction project, the secondary lining cracking is one of the most common diseases, needs to analyze the reason thoroughly, to clarify its own mechanism, can propose the relatively effective measure from the source. In this paper, the internal force of the lining of a highway tunnel during construction is mainly based on the engineering geological conditions, hydrological conditions, design conditions and so on, this paper analyzes the cracking problem and the cause of settlement deformation, and puts forward some effective treatment measures to prevent the cracking and settlement deformation of the second lining, it can also provide useful experience for other projects.

1. Introduction

In view of the development in recent years, the development of domestic transportation infrastructure is very rapid, and the construction of tunnel projects often meet with special areas, such as: in the loose bottom layer, the emergence of weak loess, etc. , these are all bad geological surrounding rocks, mainly because the mechanical properties of these surrounding rocks are poor, the disturbance range is very extensive, it is easy to appear deformation and so on, and so on. This causes the tunnel engineering after carrying out the construction, the variation of surrounding rock stress is very complex, which not only increases the difficulty of construction itself to a certain extent, but also leads to more frequent safety accidents. For the shallow buried tunnel with small clear spacing and eccentric pressure and weak intercalation in the inverted arch, the deformation will be further aggravated because of the worse mechanical properties of the surrounding rock, more complicated geological conditions and repeated excavation, the overlying rock mass may form potential slip body, which will obviously increase the pressure of the surrounding rock, lead to more obvious deformation problems, and finally lead to the cracking of tunnel structure, even falling blocks, collapse problems, it poses a serious threat to the safety of tunnel construction. Therefore, it is necessary to understand the internal force and settlement deformation of the lining according to the basic characteristics of the stress in the surrounding rock of highway tunnel.

2. The theoretical research of famous scholars

At present, this problem is also attracting much attention in the academic circle, and has achieved rich research results. From this aspect of theoretical research, scholars such as Guo Genfa used the limit equilibrium method to improve the current calculation theory of homogeneous surrounding rock pressure, and thus came to the conclusion that the horizontal soft and hard interbedded surrounding rock pressure theory[1], Starting from the deflection theory of maximum principal stress, Huang Weiming and other scholars put forward the corresponding tunnel bias coefficient and its calculation method, and provided the corresponding theoretical support for the subsequent calculation of tunnel surrounding rock pressure [2] ,For the aspect of experimental research, he shaochi and other scholars have designed similar models and experiments, analyzed the influence of different tunnel construction conditions on surrounding rock, and found that the top-step tunnel should be given priority, this is better for the safety of the tunnel [3] By means of laboratory mechanical tests and numerical simulation, Liu Fu et al analyzed the main reasons for the cracking of the second lining of the arch waist of the tunnel in the surrounding rock with shallow

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buried unsymmetrical pressure, this is usually because stress concentration and horizontal displacement are more pronounced[4] On the basis of field tests and combined with engineering practice, sun shoubang and other scholars have put forward more pertinent treatment measures for the characteristics of stress and strain of tunnel surrounding rock and the basic situation of structural stress change, mainly used in the treatment of landslides. From the perspective of numerical analysis [5] Yang Zhenhua and other scholars used the numerical value to carry on the certain analysis to the Zhegushan tunnel lining cracking principle, and discovered that is mainly because the surrounding rock geology is too bad, and the second lining construction is too early, therefore, need to provide useful suggestions for the timing of the secondary lining construction [6] . Li Cheng and other scholars have analyzed the cracking mechanism of the second lining of Pingtian Tunnel, and combined with the field monitoring data, put forward a more useful treatment plan [7] .

Generally speaking, although these scholars have carried on a series of discussions on tunnel construction from the aspects of theory, experiment and numerical simulation, but for tunnel construction, the stress variation and settlement deformation of surrounding rock are relatively few to be analyzed. Therefore, in this paper, the construction of a highway project tunnel surrounding rock stress and settlement deformation analysis, and treatment measures are discussed accordingly.

3. Project profile

3.1 Engineering geological conditions

The project is located in Liushe, Fushou Village, Sanmiao Town, Hechuan District, Chongqing City. The import number of the left line is ZK231 + 355, and the export number is ZK233 + 925, with a total length of 2,570 m. the import number of the right line is YK231 + 343, and the export number is YK233 + 893, with a total length of 2,550 m.1.5% longitudinal slope and 1.5% transverse slope are adopted in the whole tunnel. The excavation of the tunnel body will form a drainage corridor, lower the groundwater level, and have little impact on the daily water consumption of the surrounding residents and the growth of plants. The construction of the tunnel will produce a large amount of waste slag, which should be piled up in a fixed way: the choice of waste slag field is particularly important, and improper choice will lead to new environmental and geological problems, such as: landslide, debris flow, etc. . A few residents live at the entrance and exit of the tunnel. The construction and operation of the tunnel will bring some noise pollution to the residents around.The soft soil in the gully of the entrance section and the shallow buried section of the tunnel is 0-6m thick. Although the soft soil has poor physical and mechanical properties, it has little influence on the stability of the tunnel structure. The tunnel body passes through the mudstone and sandstone of the Upper Shaximiao Formation in the Middle Jurassic, the dip angle of the rock bed is gentle, the occurrence change is small, and no fault structure is found, easy to weathering, collapse, cave roof easy to collapse. The mudstone in the scope of tunnel is easy to be weathered and peeled off, the thin layer of silty sandstone intercalated, the existence of gray-green bands intercalated, and the appearance of a small amount of fissure water make the construction easy to collapse and collapse. The main component of slope avalanche accumulation body is rock soil with a total thickness of 4-12m, which has a great influence on tunnel excavation.Chongqing is rich in groundwater resources, and the formation of groundwater is mainly due to the surface water exposure to sunlight, and direct evaporation of water vapor, when encountered in the atmosphere of cold air, water vapor will condense, drops of water fall to the ground. Under the influence of geological and geomorphological conditions, the groundwater in KRAS is very chaotic. It can be divided into three types: carbonate rock water, clastic rock pore fissure water and bedrock interbed fissure water, its annual reserves are 12.965 billion M3. The exposed area of carbonate rocks is 2903km2, accounting for 35.2% of the whole city. The exposed area of clastic rock is 48953km2, accounting for 59.8% of the total area of the city, and the amount of fissure pore water is 1.962 billion m3, while the amount of water is only 16.8% of the total storage of groundwater in the city. Groundwater flows along sandstone fissures, generally under pressure or artesian flow, but the volume of water is only 490 million m3, about 5% of the total storage of groundwater in Chongqing.

3.2 Working condition of tunnel

From the point of view of this project tunnel, its own geological structure is more complex, many have weathered mudstone sand, or weathered residual water. In the construction area of the tunnel, the geological structure of the inner layer is relatively complex, and the lithology changes greatly, the surrounding rock is mainly soft rock, and it is easy to soften, and the stability is extremely poor, it is easy to appear a series of problems, such as roof fall, collapse.

At present, there is obvious settlement and deformation in the tunnel of this project, which leads to cracks and groundwater infiltration into the tunnel. The groundwater is mainly the pore water of the surface residual layer, and the water of the rock fracture. The main reason is that the rock is broken and the weathering degree is relatively high, which leads to the development of joints and fissures. At the same time, during the excavation of the tunnel, the surrounding rock is easily disturbed, and the surrounding rock itself is easily cracked, or some new cracks are added, or the cracks further expand, the water storage capacity of the surrounding rock is also obviously enhanced, which leads to the relatively rich water in the cracks and pores of the tunnel area. Under the influence of the rainy season, the seepage of the surrounding rock is more serious and the settlement problem is obvious, which further increases the risk of itself. According to the current situation of tunnel construction, many problems such as collapse and uneven settlement have occurred, especially after the construction and operation of secondary lining in the left tunnel, long cracks have appeared, in particular, the side wall and arch waist, there are 1-4 m different length of the cracks.

4. The main cause of tunnel lining settlement

In order to deal with the cracking problem of the tunnel in time and effectively, it is necessary to take into account the topographic conditions, hydrogeological conditions, tunnel design, tunnel construction methods, etc. , this paper analyzes the reasons of the tunnel itself cracking, so as to know the necessary treatment measures of the lining cracking.

4.1 The bearing capacity of inverted arch base is insufficient

In this project, the invert crack is located in the left tunnel of the tunnel, and the area is more concentrated, usually along the tunnel itself, the longitudinal extension, the crack is relatively long, and the crack width is larger. When one of the invert cracks appears, the corresponding investigation unit will reinvestigate the geological conditions of the invert base of the tunnel itself, and it is found that in the middle of the tunnel, there are basically weak intercalations of 1.8-25.9 m in the invert basement, which include fully weathered argillaceous sandstone and a small amount of strongly weathered argillaceous sandstone, among them, there are great differences in weathering degree at different locations, showing broken layer and more broken layer, which leads to the limited bearing capacity of invert foundation itself and difficult to meet the basic load-bearing requirements of tunnel.

Because the tunnel itself is a shallow-buried tunnel, and the surrounding area is mainly mountainous, for the surrounding rock itself, the excavation of the tunnel has a great impact on it, and the surrounding rock itself is extremely unstable, it is easy to appear deformation and softening of the problem, the basement of the inner and outer weak intercalation of the thickness is obviously not the same, there is a very obvious problem of surrounding rock bias. After the construction of the inverted arch is completed, the vertical load will act on the inverted arch foundation, and the distribution of the load itself is not symmetrical, which will lead to a series of uneven settlement problems of the foundation, as a result, the inverted arch is subjected to a large degree of tensile stress, or a certain degree of shear stress, and in the joint action, a more serious inverted arch cracking problem.

4.2 The geological conditions are complex

There are mainly weathered limestone and strongly and moderately weathered sandy mudstone

in the stratum through which the strongly weathered sandstone and moderately weathered sandstone take a large proportion, and the two often intersect each other, as a result, the geological conditions in which the tunnel is located at that time are more complicated, and after the excavation, the stress distribution of the surrounding rock in the adjacent area is more complicated, tunnel support system is prone to uneven changes in stress, so it is easy to appear stress concentration [8] . At the same time, after the construction of the tunnel, the overlying rock mass will form sliding rock mass in its sliding surface, so it is easy to appear the problem of uneven ground settlement under the gravity of the rock mass itself. Moreover, the load-bearing capacity of the inverted arch base itself is insufficient, thus a series of non-uniform settlement problems will appear, which will lead to the subsidence of the tunnel structure as a whole, and the sliding rock and soil in the tunnel will also sink along with it, when the self-weight stress of sliding rock mass is too large, the rock mass itself is easy to be pulled off, and the surface will appear obvious settlement crack.

4.3 Tunnel design and construction

In the design of this tunnel, the main type is shallow-buried separate small clear distance cross-platform short tunnel, during the construction of this tunnel, the internal topography appears obvious bias pressure problem, which leads to obvious settlement deformation problem, this is mainly because in the construction process, the construction of the left hole, after the construction of the right hole. In general, the design of the tunnel is relatively special, and the distance between the two tunnels is close, so the force of the tunnel itself is more complex than the force of the conventional tunnel. According to the relevant information, when the tunnel itself has the problem of bias, for the construction of such a parallel tunnel, the left tunnel is usually constructed first, followed by the right tunnel, but this construction method is suitable for the cross-platform tunnel, it can not be fully applicable, need to combine the actual situation, the first excavation of the right hole, in order to ensure the safety of the tunnel itself. It can be seen that the choice of the design method and construction method of the tunnel itself is also a subjective factor leading to the tunnel lining cracking settlement [9] .

4.4 Rainfall Surge, surface drainage is not smooth

In the initial stage of construction, the lining cracks will be obviously serious, and the load-bearing capacity of the inverted arch base itself is insufficient, so it is easy to cause the inverted arch itself uneven settlement problem, and also easy to appear the construction crack problem, these are the important reasons that lead to settlement deformation and crack. Through the investigation and monitoring of the cracks in the lining at the later stage, we can know that there is no crack in the inverted arch and no uneven settlement, moreover, surface water and rock mass water are relatively enriched [10] . In the later stage of construction, especially in the second lining crack, the cause of crack settlement is obviously different from that in the early stage. In the later stage of crack development, the main reason is that the tunnel is located in Chongqing area, and it is rainy in summer, in the process of tunnel construction, the effective measures for the treatment of surface water have not been taken because the surface water-proof and drainage work are not taken seriously. Among them, the rock mass above the tunnel itself has a relatively high degree of weathering, fissures develop quickly, and surface water can easily penetrate through the surface fissures and enter the rock mass, further increasing the pressure of the surrounding rock, therefore, the hydrologic change of rock mass is the main reason for the further development of the second lining crack during the later construction of tunnel.

4.5 The construction was not well timed

Because in this construction, due to some objective factors, the construction period was delayed, but at that time, the right tunnel of the tunnel has been fully completed the corresponding construction, but the excavation of the right tunnel has been through, there are 109m left in the reverse arch and 168m left in the secondary lining. According to the corresponding construction technical specifications, the excavation and construction of the shallow buried section, it is necessary to strictly follow the principles of “ Advance pipe, strict grouting, short excavation,

strong support, early closure, frequent measurement, quick feedback and control of subsidence", however, during the actual excavation of this tunnel, the initial support construction work will closely follow the face of the face, but because of some uncontrollable factors outside, it leads to obvious lag in the construction of inverted arch and secondary lining.

And in the initial stage of construction, although some support measures have been taken, the initial support itself belongs to thin flexible support, which requires timely and effective construction and operation after the deformation and stability of the surrounding rock, this can make the support system of the tunnel form a closed loop, and in a better state of stress, so as to prevent further deformation of the tunnel wall rock, avoid the impact on the stability of the tunnel itself. Therefore, in the actual construction process, it is necessary to control the construction time, in order to prevent the settlement of the lining deformation.

5. Countermeasures for settlement deformation of tunnel lining

Through the analysis of the reasons for the secondary lining cracking of the tunnel, we can know that during the construction of the tunnel, the base line side of the tunnel by measuring the tunnel structure itself relatively complex stress, it is easy to crack the problem. Therefore, in view of the field lining cracking and settlement deformation, geological and hydrological conditions, and so on, put forward a useful control measures.

5.1 Temporary emergency measures should be taken

During the construction of this project, temporary emergency measures should be set up for the secondary lining construction in the sections with serious cracks in the inverted arch and the secondary lining, the spacing is 0.8 m to prevent sudden deformation. Moreover, the temporary back arch connection is more firm, and the arch ring and the secondary lining itself fit more closely. The steel arch frame is formed by cold bending, and the steel plate connected with the steel arch frame is mechanically drilled by the steel plate drilling machine, need to use positioning card slot, its accurate positioning.

5.2 Strengthen the treatment of surface cracks

When the surface fissures occur, the rainy season has not yet arrived, so it is necessary to take effective countermeasures to prevent the damage of the overburden layer caused by the rain water along with the fissures. Generally speaking, for the surface cracks, mainly used"Crack grouting + surface plastic film" method to deal with them effectively, first of all, the grouting pipes should be buried in the surface cracks at a certain distance, and the cracks should be buried until the surface, when the cracks are grouted and this part of the operation is completed, clay is also used to fill the cracks directly and to tamp them down. At last, colored cloth can be used to cover them usefully, prevent the problem of rainwater flooding.

5.3 Strengthening the treatment of inverted arch crack

In this case, the inverted arch crack usually occurs because the bearing capacity of the basement is obviously insufficient, and in this case, there is a bias field, which leads to the inverted arch itself is not uniform, and the settlement change is relatively large, therefore, the substrate itself needs to be strengthened. In this construction, four steel pipes were installed at the arch feet of both sides of the tunnel, and used as root piles. The inverted arch foundation was then strengthened by grouting, for the cracks due to settlement deformation, it is necessary to use the same mark of concrete to fill the cracks.

5.4 Strengthen the treatment of the second lining crack

In this construction can be found, the number of second lining cracks relatively more, and the actual situation is more complex, the largest crack width of 2 mm, crack depth of 4 cm, but in which, no obvious water seepage problem is found, but these fractures are mainly due to settlement leading to deformation problem. Therefore, in view of these cracks, it is necessary to strengthen and paste

the carbon fiber cloth.

6. Conclusion

During the construction of the tunnel, it is mainly aimed at the settlement and deformation of the lining, and the analysis of the length of the cracks in the lining shows that the main reason for the settlement is the relatively obvious difference in height between the east and the east, and the net distance is relatively small, there are weak intercalation in the basement itself, which leads to insufficient internal forces of the surrounding rock, resulting in settlement deformation, resulting in cracks. Therefore, in the actual construction process, we should do a good job of temporary emergency treatment, pay attention to the surface cracks, inverted arch cracks, second lining cracks treatment, so as to maximize the quality of construction, prevent the problem of settlement deformation.

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