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To cite this article: Guang-xing Zhu and Yan Han 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **218** 012006

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Treatment of collapsible loess foundation

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Abstract. Loess is a special scholar soil accumulated and formed in the arid and semiarid conditions of Quaternary. Its hydraulic properties are collapsibility caused by water invasion, easy to disintegrate when it meets water, easy to be carried away by soil particles under the action of flowing water, forming landform phenomena such as collapse and gully. Such diseases as subsidence, collapse and erosion occur frequently for subgrade in collapsible loess area when it is scoured by water immersion. It is a difficult challenge for subgrade engineering to meet the very strict post construction settlement requirements of high speed railways in the process of high-speed rail construction. This paper combines experimental research and engineering examples. For the difficulties encountered in the treatment of collapsible loess foundation, a systematic and comprehensive analysis is made to deal with the measures. The application is introduced from design plan of construction technology, construction quality control and so on. It can provide reference for similar engineering problems in the future high-speed rail construction.

1. Introduction

The high-speed line runs through the collapsible loess area in collapsible loess areas, which is V and VI collapsible loess areas in China. The cumulative length of collapsible loess section is 298 km accounting for 65% of the length of the whole line. The large proportion of subgrade length is an important feature. No slag track is adopted for the line. It requires that the settlement of the roadbed is less than 15mm, and the differential settlement at the junction of road, bridge and tunnel is less than 5mm.

The basic characteristics of collapsible loess are mainly manifested in the following aspects:

The proportion of self-weight collapsible loess is large. The thickness of collapsible loess is large, and the lower limit depth is more than 10~25m, and 30m in some areas. The collapsibility grade of loess foundation is high. The sensitivity of collapsible loess along the line is strong. The bad geological phenomena along the line are mainly loess caves. Cave dwellings and caves along the route are also important man-made geological phenomena.

2. Analysis of difficult problems in collapsible loess roadbed construction

2.1 Post construction settlement control of high-speed railway subgrade in collapsible loess area

For Subgrade in collapsible loess area, the post construction settlement of the roadbed includes the compression deformation of road foundation and the settlement of foundation. In the settlement of foundation, collapsible deformation is a very prominent problem. It is a basic requirement to carry out



foundation treatment and eliminate collapsibility loess foundation. At this point, the post-construction settlement can be decomposed into the compression deformation and the settlement deformation of the foundation below the treatment layer. The sum of deformations cannot exceed 15mm after work for the road foundation and the treatment layer.

2.2 The reasonable depth determining of collapsible loess foundation

The railway roadbed as a kind of structure acts on the foundation and belongs to the strip load with wider width. Therefore, the influence of the overall load of subgrade in the foundation is relatively large, which can reach 20~25m above. The relevant experimental research also shows that the deep foundation compression deformation of the road base is still relatively large, which enough to seriously affect the size of post construction settlement. On the one hand, the treatment of collapsible loess foundation is to eliminate collapsibility. On the other hand, we should also consider the improvement of the compression property of higher compression layer below the treatment layer. So, this involves the problem of treatment depth of collapsible loess foundation. It is difficult to meet the requirements of high-speed railway subgrade post construction settlement. Field test and practice prove that the depth of treatment is small, but the total settlement and post construction settlement of the foundation are relatively large. In a word, determining the economical and reasonable treatment depth of collapsible loess foundation is one of the difficult problems in the construction of high-speed railway subgrade.

2.3 Improvement of loess filler in roadbed

Plain loess belongs to silt and silty clay. The plasticity index is mostly in the range of 8~11, which accounts for about 90%. According to railway subgrade filler it is divided into C category. It is characterized by poor compression property and long deformation duration comparing with A and B category filler. Using loess as filler will hardly meet the requirements of construction settlement below 15mm. On the other hand, it is difficult to carry out physical improvement filling because of the lack of coarse grain raw materials in loess area. So, chemical improvement is a feasible method. At the same time, the roadbed filling is often huge and is often calculated by one hundred thousand square meters. A series of problems need to be tested and solved. Such as what is the way to improve it, how to implement the standards, how to organize large scale construction site and how to operate it.

2.4 Prevention and drainage problems of loess roadbed

Loess is a special soil accumulated and formed in the dry and semiarid conditions of Quaternary. Especially for the new loess widely distributed on the surface, it has the characteristics of small dry bulk density, loose structure, powder content accounting for the majority and often in a dry state. This forms its unique hydraulic properties, which include that soaking water easy causes collapsibility, meeting water easy to disintegrate, and soil particles are easily taken away under the action of flowing water. In nature, the ground is severely cut and collapsed and form numerous landforms.

It is common to be washed, etched, destroyed by water for railway subgrade, including cutting, embankment and various facilities. So, water is the first "Curse" of railway subgrade in collapsible loess area. For various reasons, the drainage of roadbed has always been taken seriously. However, the water related diseases of the existing lines in the loess region are still common. From the perspective of small regions, we should dredge, arrange, guide and defend for high-speed railway subgrade engineering. Great efforts should be made to improve the overall level and effect of waterproof and drainage. Under the premise of economic rationality, we should minimize floods.

3. Treatment measures

3.1 Roadbed loess filling improvement

3.1.1 Compressive strength. Form the analysis of unconfined compressive strength test results, 7 day unconfined compressive strength are averaged usual larger than 500 kPa for the weight ratio 3%~9% cement modified soil. But the values are probability low 3% and 4% for cement modified soil with R_c 95%. The unconfined compressive strength test is disintegrating when immersed in water 1 day. Therefore, the weight ratio of cement improved soil in laboratory is 5%. Considering the difference between laboratory test conditions and site conditions, the site mix ratio should be 0.5%~1% higher than the test mix ratio. Therefore, the weight ratio determined at 6%.

3.1.2 Compaction technology index. Because of the influence of roadbed fill on water content, particle composition and hydration, etc. when soil samples in laboratory compaction test and actual construction time, it has unreasonableness definite taking the results of the original indoor compaction test as the control index of compaction degree in actual construction. The following aspects should be considered in the construction. 1) Indoor compaction test as construction control should be selected whenever possible when taking representative soil samples. The compaction test must be made in order to better guide the construction for the larger variation of soil in the construction process. 2) The soil samples used for indoor compaction test should consider the situation as far as possible combined with the soil quality of the earth used in actual construction. 3) Hydration will occur when cement meets water. The longer interval between water mixing and rolling, the greater hydration and hardening degree of cement. This will affect the compactness and strength of cement stabilized soil. The maximum dry density of cement improved soil decreases with time. The compactness index is determined by the maximum dry density and the best moisture content after 3~4h mixing combined with initial cement setting time and mixing transportation, paving and rolling ability.

3.1.3 Water content control method. Strict control of compaction water content, determine moisture content of mixed cement soil up at any time, and adjust the upper water network timely according to the test results. The water yield is controlled at the best water content 1.5% level and the amount of water in the soil is uniform as far as possible.

3.2 Pile plate structure technology

3.2.1 Structural type. In the collapsible loess area, the upper part is collapsible loess. The lower part is thick and weak silty clay layer. Under the influence of high filling and large cross section filling, the depth of settlement is greater. The composite foundation treatment method cannot meet the requirements of post construction settlement control. At the same time, lots of culverts are dense, and there are frequent problems of road culverts. It is difficult to control the transition of short-circuit foundation, and the smoothness of short-circuit foundation treated by composite foundation is not easy to be guaranteed. For this reason, a new technology of buried pile type continuous pile slab structure is adopted.

The buried continuous pile slab structure is a new type of foundation structure for high-speed railway no slag roadbed. It is composed of lower reinforced concrete pile foundation, subgrade soil and upper reinforced concrete cap plate. Reinforced concrete slabs are supported by steel piles. Lateral and vertical resistance is provided for subgrade fill and foundation piles. The pile plate and foundation soil form a bearing structure system to bear the upper load.

Sheet pile as load transfer system for pile plate structure subgrade, there are two basic forms. Type I is buried pile type continuous pile slab structure. The roof is set on the bottom surface of the foundation bed, which simplifies the connection mode between the no slag roadbed system and the pile plate structure. The structure form of No slag roadbed is the same as that of the road base section, which is conducive to the construction and maintenance of no slag roadbed laying. Type II is the pile type panel structure in turnout area and the roof is set at the bottom of graded crushed stones. The height requirements of track structure in the main line and turnout area can be adjusted by graded gravel thickness. It can make smooth for top and side of the structure, uniform, and easy to construct.

3.2.2 Main conclusions. The top of the pile plate structure is embedded in the surface of the base bed (graded crushed stone) at the bottom. The seasonal temperature difference load of the pile roof is greatly reduced. The plate length is maximized by reasonable reinforcement. The Pile-sheet structure between the two bridges forms a new continuous structure, which makes the high-speed train run smoothly.

3.2.3 Design points. Pile-sheet structure is suitable for the consolidation of deep and weak foundation, collapsible loess foundation, low embankment, cutting, bridge-tunnel short-circuit subgrade transition section, branch subgrade and existing subgrade with strict deformation control. The design of pile and slab structures should follow the design principles of safety, applicability and economy, and meet the requirements of durability. The design points are as follows.

Considering the optimization of stress state, the bearing platform plate is divided according to the left and right line, and the influence of warpage on the bearing plate and the upper track slab is reduced.

A supporting beam is set up between the cap plate and the pile foundation to reduce the stress concentration at the connection between the pile foundation and the bearing plate. The overall stiffness and resistance to uneven settlement of pile plate structures are enhanced.

The three span is used as a union, and 2cm wide expansion joints are set horizontally between adjacent panels taking account of temperature stress, shrinkage and creep of concrete and other factors for pile slab structure cap slab. The joist and pile foundation are used to avoid the adverse effect of overhanging section on train load impact.

Pile slab structure usually three-span or multi span one by one. Pile cap slab is divided up and down. Bracket beam is rigidly connected with pile, middle span slab is rigidly connected with bracket beam, and side span slab is overlapped with bracket beam. The expansion joint is arranged between adjacent platform plates, and the bearing platform plate is directly connected with the upper track structure.

Pile plate structure design load, dead load, live load additional force and special force.

3.2.4 Design and calculation of pile plate structure. The design of pile slab structure is based on the allowable stress method. Pile slab structure should be calculated according to multi support continuous foundation slab beam. The horizontal constraint of pile body should be considered in the stress analysis of pile foundation. The differential settlement of adjacent piles should not exceed 5 mm. The vertical allowable bearing capacity of a single pile is 0.5 times the ultimate bearing capacity. Check the vertical deflection of the bearing plate, the vertical corner and the width of the crack.

3.2.5 Requirements for pile plate structure construction. The highest 5~10m. thickness is.6-10m, the most.6-10m. row diameter. In the same connection, no larger pile foundation should be adopted at the same time. The spacing between lateral piles should be kept in line with the distance between railway lines. The length of the bearing plate should correspond to the modulus of the block length of the upper track slab. 10 cm thick concrete or lime soil working cushion should be set at the bottom of the slab.

3.3 Roadbed waterproof and drainage

3.3.1 Principles. Subgrade drainage facilities can meet the intensity of rainstorm in 50 years. The flow check includes the possible catchment areas, such as roadbed and roadbed slope. In carrying out drainage design, the following principles and requirements are followed: Intercept all surface water that may flow to the roadbed near the line and drain bridges, and culverts or ditches along the shortest path to ensure the stability of the roadbed. The longitudinal gradient of the bottom of gutter and drain is not less than 2%. The longitudinal slope should be no less than 1% for the flat side ditch gutter and reverse slope drainage ditch side ditch when the longitudinal slope of the bottom of the ditch is

difficult. When the longitudinal gradient at the bottom of the ditch is equal or greater than 300%, a torrent channel is set up. The ditch in the soil area is paved with M7.5 cement mortar. In the collapsible loess area, 0.3 m thick and 28 lime soil impervious cushion are laid at the bottom of the ditch. The distance from the inner edge of the drainage ditch to the toe of the slope is not less than 2 m, and the distance from the inner edge of the gutter to the top of the chasm is not less than 5 m. When various drains lead to bridges or culverts or natural trenches, ensure that the height of the bottom of the outlet is not lower than the elevation of the bridge culvert population or natural trench bottom. The outlets of culverts, side gully and drainage gully should avoid the foot of the embankment slope as far as possible, so as to prevent the water from scouring the foot of the embankment slope.

3.3.2 waterproof and drainage design of loess roadbed. Because of the particularity of Huang's topography, the drainage system of Zhengxi high speed railway is facing many difficulties. There are many steep slopes in loess hilly and higher-order areas, and some steep slopes are over 20 m. The lower part of the steep slope has loose deposits formed by collapse, and the drainage ditch is difficult to pass through. The drainage ditch has long hydraulic gradient and the design of drainage ditch longitudinal slope is difficult for plain and first-order terrain with flat terrain. Loess area is generally short of water, and the natural water system is scarce. The roadbed catchment needs to go far or even nowhere. Due to poor water stability of loess, this series of problems, if handled properly, will cause harm to the bridge project and cause soil erosion, destroying farmland, causing disputes and obstructing construction. The following are drainage designs for different parts.

Drainage in cutting trench. A new type of cutting structure is adopted in the cutting. The surface water seep into the structure to ensure the roadbed in the cutting area has a good working condition. The bottom of the bed and the bottom of the bottom of the bed are filled with lime. The base cushion is made of 37 lime soil. The bottom of all kinds of drainage ditches is provided with lime cushion, which completely prevents surface seepage under packing. In addition, a 2 m wide platform is set up on both sides of the trench to avoid plugging the side ditch during the rainy season, which will affect the drainage of the roadbed.

Surface drainage of embankment. Drainage ditch design should suit local conditions, economic and applicable. As far as possible, choose in the terrain and geology better section in order to save and increase investment in engineering. The outlet of drains can be connected to the natural ditch river as far as possible. The longitudinal gradient of drains is not less than 2%. The flat or reverse slope drainage area can be as small as 1% under special difficulties. The trench usually adopts a trapezoidal section with a depth of 0.6 m and a base width of 0.4 m. Slope reinforced with C15 precast concrete. When the section of drainage ditch cannot meet the discharge requirement, the section size should be determined according to the calculation of 1/50 flood frequency discharge.

Cutting surface drainage. Side ditch, gutter, slope trench and trench are installed in the cutting area. Side grooves are set on both sides of the cutting shoulders, and one or two gutters are arranged outside the top edge of the cutting chasm 2~5m. The cutting with slope platform is equipped with water interception ditch on the slope platform, and lime-soil cushion is arranged at the bottom of all drainage ditches. All side grooves are reinforced by site pouring steel bar, and the drainage longitudinal slope is not less than 2%. Soft rock cutting, strong weathering or structural breakage of hard cutting and moral cutting using a bottom width of 0.6 m, 0.6-0.9 m deep rectangular side ditch. The side ditch is reinforced by concrete 0.2 m thick. Generally, the trapezoid section with deep 0.6m and bottom width 0.4m is adopted in the gutter and reinforced by prefabricated concrete members. Rectangular or semi-trapezoidal sections with a depth of 0.4m and a bottom width of 0.4m are used to reinforce the ditches of slope platforms and cement mortar masonry is used to reinforce the ditches.

Drainage without slag tracks. Every 50m set up a well along the line direction at no slag track curve section line. The surface water of the roadbed is collected in the water collecting well, and the bottom drainage ditch is transversely introduced into the side ditch or the slope drainage ditch to discharge. The water collecting well is reinforced by concrete. The well bore is 0.3m square and the shaft wall is 0.1m thick.

4. Conclusion

The settlement of collapsible dams is effectively controlled by compaction technology and pile plate structure. The post compression deformation of the body is controlled near zero by using improved loess as filling roadbed, and that is advantageous to realize the overall goal of post construction settlement control of roadbed. Combining with the Loess topography and lithology characteristics, systematic effective drainage and drainage measures are adopted to change the serious situation of subgrade water damage in loess area.

Roadbed waterproof and drainage should be further improved systematically and rationality. It need to achieve that no scouring of the roadbed, no water nearby and no adverse effects caused by drainage for facilities outside the line (including farmland). Slope protection should be combined with plants to improve the undesirable appearance of soil. It should do that green and optimizing the environment along the line.

Acknowledgments

This work was financially supported by the general planning subject of Jilin Education Science 13th Five-Year plan: the status quo of innovation and entrepreneurship education system and research on reform path(GH180568).

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