Journal of World Architecture, 2023, Volume 7, Issue 4
http://ojs.bbwpublisher.com/index.php/JWA
ISSN Online: 2208-3499
ISSN Print: 2208-3480

Analysis of Highway Subgrade Slope Protection and Support Technologies

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Abstract: As an important transportation hub in China, the traffic volume and driving speed are important aspects of expressways. Therefore, the protection requirements for roadbed side slopes are higher, and it is necessary to resist rainwater erosion and other damages by protecting the side slopes. Therefore, it is necessary to adopt effective technical means of subgrade protection and support. This paper mainly summarizes the characteristics of highway subgrade slope protection construction and slope protection and support technologies.

Keywords: Expressway; Embankment slope; Protection; Support technology

Online publication: August 29, 2023

1. Introduction

The scale of expressway construction has been expanding continuously. China's expressway mileage has reached 169,100 kilometers by the end of 2021, which made travelling much more convenient. The main construction feature in expressway construction is that there are many sections of deep excavation and high filling. In order to ensure the quality of expressway construction and the stability of the roadbed and subgrade, it is necessary to strengthen the protection and support of the subgrade and slope. Suitable application of protection and support technology methods should be determined during the design stage while considering the condition of construction site to ensure the stability of the slope. Combined with the concept of green architecture, an ecological slope can be created.

2. Characteristic analysis of highway subgrade slope protection

Highway subgrade slope protection is a reinforcement for highway subgrades, and the foundation is stabilized through the construction of the side slope, so the requirements for it are relatively high. Therefore, it is necessary to summarize the construction characteristics in combination with the environment of the construction site and the technologies used, and to control the construction parameters.

(1) High requirements for construction coordination

The scope of expressway embankment slope construction is wide, the project volume is large, and the technical requirements for construction are high, which requires the cooperation and coordination of different construction personnel. Expressway construction projects are generally divided into different sections, which are constructed simultaneously. Moreover, the terrain conditions and geological structures of each section is different. Therefore, it is necessary to work together to ensure that the

process of construction can be carried out smoothly. Special technical personnel should be employed to strengthen overall construction management and ensure the completion of the project by coordinating different parties.

(2) Susceptible to external influences

The construction of expressway embankment slope requires personnel of different professions, so it involves many departments. Besides, the construction of subgrade slopes require are many types and large quantities of equipment and materials, which means that they can be influenced by many external factors. If these factors are properly controlled, it will lead to construction quality problems[1]. The construction of a subgrade slope takes a long time. It usually takes several years to complete a project, and severe weathers during construction will be inevitable. At the same time, the skill level and quality of each construction personnel are different, which will also affect the construction quality of expressway embankment slope. Therefore, it is necessary to comprehensively consider various influencing factors and external conditions to ensure the smooth construction of embankment slope protection.

(3) Instability of expressway subgrade slope

On the one hand, the instability of expressway embankment slope is caused by damages like curved surface and plane damage of the slope surface, which typically occurs 2 meters under the slope surface. Because the sliding force is greater than the anti-sliding force, the slope surface is deformed, causing landslides. Due to its great hazards and serious consequences, landslides should be emphasized in the design and construction of embankment slopes. Slope collapse is also a major problem, which is usually caused by flood damage. In terms of the scope and factors of collapse, subgrade slope collapses can be divided into different states such as chipping, spalling, and collapsing. Rock-soil slopes are more prone to weathering and spalling under rain and shine. If the slope is not protected in time after excavation, the rock-soil composition will become granular and slide along the slope[2]. Collapses are prone to occur at steep slopes, causing rock blocks to topple along joints and layers, and collapse after losing their supporting force. When landslides occur, which lead to a large amount of alluvial deposits, those deposits would gather at the slope toe, which is also leads to a collapse.

3. Highway subgrade slope protection technologies

There are many types of expressway roadbed slope protection technologies. Each technology has its own advantages and disadvantages. Therefore, it is necessary to choose a reasonable construction method depending on the nature of the project, so that the slopes can be firmer and better protection can be provided. Besides, the construction costs should also be controlled. After comprehensive consideration of various factors, the slope protection can then be construction accordingly.

(1) Slope protection of expressways

Plastering is a relatively important means and method of slope protection, and it is mainly used in soft rock formations and rock formation slopes that are easily weathered. Generally, the thickness of the plastering surface is controlled at 3-7 cm, and it can last for 6 to 8 years. Soil compaction is also a relatively common protection method, which is generally used in the restoration of soil slopes. However, the slopes cannot be steeper than 1 ∶ 0.5. Generally, the thickness of the compacted layer is controlled at 10-15 cm, which is thicker than plasters. The protection strength of a hammered surface is higher than that of the plastered surface, which can better resist the erosion of rainwater, and its general service life is 8-10 years. In addition, the spraying method can also be used to protect the slopes. The spraying method involves spraying concrete, mortar, etc., which is more suitable for joint cracks and slopes that are easily weathered. Although this method is convenient and provides good protection, it is costly and does not have a nice appearance.

(2) Vegetation method

Vegetation is a relatively common slope protection method, which is mainly used in low slopes and stable structures, with minor slope erosion. Generally, this method can only be applied for slopes of less than 6 m high, and there should not be heavy water flow at the slope. However, planting grass is not suitable for rock slopes. Instead, biological protection technology should be adopted for rock slopes[3]. Grass planting protection requires less labor and is conducive to highway landscape greening. Tree planting is also a relatively common protection method, mainly used in places with relatively gentle slopes, or on river bank slopes. Planting trees stabilizes the slope and reduces water erosion. Planting trees can prevent soil erosion due to their well-developed root-system, and growth rate can be increased through the combination of grassland and shrubs.

(3) Erosion protection technology

Expressway subgrades adjacent to the river are vulnerable to erosion. After erosion, the side slope may be damaged by embankment collapses or landslides, causing serious consequences. Therefore, in order to effectively prevent the erosion of the embankment slope and ensure the stability of the embankment structure proper erosion protection is necessary. Direct protection involves building retaining walls or any form of solid structures, whereas indirect protection involves adjusting the flow rate and flow direction of the waters through the setting of structures in a way that prevents roadbed erosion, such as dams and spur dikes.

4. Highway subgrade slope support technologies

Subgrade slope support technology can be used to improve the safety of expressway construction. The slope support technology used is determined based on the mechanical characteristics and structure of the highway itself. The most common method of roadbed slope support technology is by building retaining walls. There are many types of retaining walls: gravity retaining wall, anchor retaining wall, reinforced retaining wall and cantilever retaining wall, and many more.

(1) Gravity retaining wall

In general, gravity retaining wall is the most commonly used method in expressway subgrade slope support. Gravity retaining walls are heavy, which helps balance the pressure on the ground. Retaining walls are mostly made of mortar masonry or flake concrete depending on the site conditions. The material of the retaining wall must meet the relevant technical requirements, and the construction material can be reasonably selected in combination with the construction site environment[4]. Gravity retaining walls are generally used in road sections with rich stone materials and high foundation bearing capacity.

(2) Anchored retaining wall

Anchored retaining walls uses the original soil at the construction site as the basis, and the stability of the soil is strengthened by setting metal anchors and installing steel mesh and shotcrete on the excavation surface of the soil. The soil and the concrete structure should bind together to prevent the slope from collapsing[5]. Before excavation, the control wires should be checked first to ensure that the excavation is carried out in strict accordance with the drawings to prevent under-excavation or over-excavation. To ensure that the subgrade retaining wall is anchored, the materials used in the production of anchor rods must first undergo field tests and be approved by the supervisor before construction. The ratio of cement and accelerator must be suitable to ensure the stability of the slope structure[6].

(3) Reinforced retaining wall

Reinforced soil retaining wall refers to adding grids into soil, and stability of the retaining wall is maintained through the friction between the grids and the soil. The composition of reinforced retaining wall includes faceplates, tie bars, and fillers, and it is mainly used in filling road sections with relatively flat

terrain. Reinforced retaining wall itself has better tensile effect and strong flexibility[7]. Therefore, it allows slight deformation of the foundation, so it is widely used in areas with low foundation bearing capacity and restricted areas.

(4) Cantilever retaining wall

Cantilever retaining wall is one of the more commonly used methods in the protection and support of expressway subgrade slopes. Cantilever retaining walls are mostly made of reinforced concrete. The composition of the wall includes vertical wall, heel board, toe board, and other structures, and the cross-sectional area of the wall is small[8]. The gravity of the soil at the heel plate can effectively prevent and resist the overturning and sliding of the retaining wall. Cantilever retaining walls are generally used in areas where the height of the slope is less than 5 m and with low bearing capacity, and it occupies less land.

(5) Anti-slide piles

The anti-slide pile method is where anti-slide piles are embedded in the ground for the treatment of landslides or the pre-reinforcement of slopes. The principle of this method is to use the strong resistance of the anti-slide pile to resist the upper sliding force or earth pressure and transmit it to the lower stable stratum[10]. Anti-slide piles are a commonly used slope reinforcement method, which can not only effectively control slope slippage, but also form slope pre-reinforcement when used together with prestressed anchor cables. Anti-slide piles should be placed at appropriate positions of the sliding body to achieve effective reinforcement[10]. If the sliding force is relatively large, one or two rows of anti-slide piles can be considered.

(6) Buttressed retaining wall

A buttressed retaining wall involves placing a force arm along the cantilever retaining wall to serve as an auxiliary support, resulting in a buttress-style retaining wall formed by combining the heel plate and the force arm. The structure of a buttressed retaining wall is relatively simple, and it is thin, which makes it easy to build. The retaining wall is light-weight and has a small cross-sectional area, so it has high requirements for construction materials. Buttressed retaining wall can be used for expressway foundations with relatively low bearing capacity, such as expressways in earthquake-prone areas or areas where stones are scarce. Buttressed retaining walls can maintain the stability of the high-fill expressway section, reduce the amount of earth and stone used, and reduce the construction area.

The small section of the buttress retaining wall helps reduce the gravity of the heel plate, thereby avoiding potential risks like side shifting and overturning. Additionally, it enhances the force-bearing capacity of the retaining wall. Buttressed retaining walls can have pre-supported baffles welded to embedded parts in concrete, and soil poured into the retaining wall. This construction method occupies minimal space, has a short construction period, and meets environmental protection standards.

5. Conclusion

In summary, the application of expressway subgrade slope protection and support construction technology requires implementing targeted treatment measures that align with the characteristics of the expressway subgrade slope. This approach helps avoid potential engineering quality issues. Suitable support methods should be adopted depending on the construction site of the expressway and the structure of the surrounding buildings. By adopting these measures, subgrade slopes can be better protected, allowing for a comprehensive deployment of the construction site while ensuring the stability of the roadbed slope

Disclosure statement

The authors declare no conflicts of interest.

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