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Construction Technology and Quality Control of Highway Subgrade

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Abstract: With the rapid development of China's economy, highway engineering has also been developed significantly. As an important part of social transportation infrastructure, the construction quality of highway is more and more widely concerned by all walks of life. The stability and durability of the highway is directly related to traffic safety and road service life, while the roadbed as the foundation structure of the highway, its construction technology and quality control is particularly critical. In this paper, the key technologies in the construction of highway research, analysis and summary of the construction process and construction of key technologies, the problems that may exist in the construction of the corresponding measures to minimize the adverse effects of various roadbed construction, to protect the quality of construction and economic benefits. The research result proves that the maximum settlement difference between two sides of the roadbed is only 2mm, and after the monitoring cycle is over, the measurement point of the settlement rate of the roadbed base can reach 98.9%.

1. Introduction

In today's society, as an important link connecting cities and villages and promoting economic development, the construction quality and operation efficiency of highways are directly related to the sustainable development of the national economy and the improvement of people's living standards. With the increasing traffic volume and vehicle loading, higher requirements have been put forward for the bearing capacity, stability and durability of highways. As the foundation support structure of the highway, the quality of its construction directly affects the performance and life of the highway. Highway roadbed construction technology involves a number of aspects, including geological investigation, excavation and filling, roadbed drainage, protection and reinforcement, etc., and each technical link needs to be operated in a fine and strict control. In recent years, with the progress of science and technology and the continuous innovation of construction technology, the roadbed construction technology is also constantly updated and improved to improve the quality of highway construction provides a strong guarantee. By reviewing the existing literature, it is not difficult to find that there are many challenges in the application of highway roadbed construction technology. On the one hand, the selection and application of construction technology need to fully consider geological conditions, climate environment, traffic flow and other factors, and the existing technology is often difficult to fully meet these complex needs. On the other hand, the uneven technical level of construction personnel also restricts the improvement of construction quality. In addition, the quality control system in the construction process is not perfect, and it is difficult to ensure the fine operation and strict control of each technical link.

Therefore, the purpose of this paper is to discuss the highway roadbed construction technology and its quality control methods. By summarizing and analyzing the advantages and disadvantages of the existing construction technology, it puts forward practicable improvement measures and optimization suggestions, with a view to providing scientific guidance and technical support for highway roadbed construction. At the same time, combined with specific engineering examples, the common problems and reasons in the roadbed construction process are analyzed, and corresponding solutions are proposed to promote the overall improvement of highway construction quality. This paper first introduces the research background, the challenges of previous literature, the motivation of the work, the objectives and contributions of the paper, and then reviews the research results on highway roadbed construction technology and its quality control at home and abroad. At the same time, this paper elaborates the construction technology of key links such as geological investigation, excavation and filling, roadbed drainage, protection and reinforcement, and builds a perfect quality control system and puts forward specific quality control measures. Finally, combined with specific engineering examples, this paper analyzes the common problems and reasons in the roadbed construction process, and proposes solutions. Through in-depth discussion and analysis of the above, this paper aims to provide scientific guidance and technical support for highway roadbed construction, and to promote the comprehensive improvement of highway construction quality.

2. Related Works

With the continuous progress of society and the rapid development of technology, the technical points and quality control measures of highway subgrade construction have undergone profound development. Zhang J analyzed the necessity and development prospect of intelligent construction and maintenance of roadbed engineering against the background of intelligent highway, put forward the development direction of intelligent construction and maintenance of roadbed engineering, and summarized the relevant intelligent technology of the whole life cycle of roadbed engineering [1]. Ma Y et al. proposed a new harmonic intelligent compaction quality evaluation index in the context of smart highway: the AICV - Acceleration Intelligent Compaction Value, whose accuracy was higher than the commonly used index CMV - Compaction Measured Value [2]. Wang X et al. proposed an artificial neural network model that correlated compaction measurements with compaction degree by considering the influence of soil properties and control parameters. The predictive model showed good correlation [3]. Meanwhile, Zhang Q et al. combined the RICM technique with the real-time motion BeiDou positioning system to monitor the compaction of two types of silt-filled roadbeds, and proposed a Green's spline interpolation-based method to calculate the compaction quality with color-coded maps at any location. The results proved that its proposed method can realize a fast and continuous assessment covering the whole working area, timely identification of quality defective areas and feedback for improvement [4]. Han C et al. proposed a BIM-based quality control and quality assurance framework for roads that implemented real-time construction data integration in an information model, data analysis and visualization through the combination of models and databases, and quality control and quality assurance using structured construction data [5]. Sivagnanasuntharam S et al. investigated the current state of knowledge of existing asphalt compaction test methods and identified the limitations of their use in the compaction of asphalt pavements. They found that conventional field tests conducted at limited locations for quality control and quality assurance of asphalt compaction often fail to ensure uniformity of compaction [6]. Gou S et al. introduced the key points of roadbed pavement compaction technology in road engineering, which had certain guiding value for road engineering construction [7].

Although all of the above studies have made effective recommendations at different levels of the highway construction process, their popularity in actual projects is still limited. The degree of standardization of technology application between different projects is not high, and the lack of unified technical specifications and standard operating procedures leads to uneven results in technology application. Therefore, the study explores various aspects of roadbed construction technology, including excavation construction, fill selection and compaction technology, and protection construction technology. In the process of excavation construction, substantial investigation of the construction environment and scientific and reasonable selection of excavation methods are emphasized to ensure the quality of excavation. Meanwhile, for the selection of roadbed filler, the importance of reasonable selection of filler materials according to the criteria of highway type, transportation demand and cycle maintenance is put forward, and the specific technical requirements and operation specifications of filler compaction are introduced. Through the detailed analysis of the technical points of roadbed construction and in-depth discussion of quality control strategies, highway roadbed construction provides a scientific basis and technical support for improving the quality of highway construction is of great significance.

3. Methods

3.1. Common Technology of Highway Roadbed Construction

3.1.1. Roadbed Excavation Construction Technology

When the roadbed construction operation is carried out, it is necessary to make appropriate preparations. For example, a comprehensive survey of the surrounding construction conditions should be carried out, and the construction elements should be reasonably arranged according to the specified requirements. Before the formal excavation, the road riffle section is inspected, and then a relatively gentle location is selected for the excavation operation [8]. As for those gentle many sections, a suitable lateral development method should be selected for treatment. If the slope location is steep, it will be advanced by layered excavation.

3.1.2. Roadbed Filler Construction Technology

As the first condition of roadbed construction, it is crucial to choose suitable roadbed fill material. In the process of selection, the size of the carrying capacity and load rate index around the road section should be fully considered. To some extent, there is a big difference between the particle size and strength of the filler, in order to standardize the corresponding operation and promote the rationalization of the main construction department, it is necessary to carry out the strength test of the roadbed, only in this way can we improve the overall strength value and eliminate the constraints of the instability factors [9]. If the texture of the material is loose, a completely new material is usually selected by replacement. Taking into account the experience and lessons learned from previous work, the study concluded that the combination of coarse granules, lime and fly ash as fill material has a better stabilizing effect and is highly applicable.

3.1.3. Roadbed Protection Construction Technology

In order to improve the quality of highway construction, roadbed protection technology must be carefully selected. Generally speaking, the roadbed protection construction technology covers many aspects, such as support baffle protection technology and scour protection technology. Doing a good job of slope protection is mainly to reduce the impact of surface water erosion and minimize the occurrence of the phenomenon of rock weathering and spalling as much as possible. In the implementation of slope protection technology, generally choosing the new way of furrow seeding and hole seeding, planting turf inside the whole frame surface, and then achieve the purpose of profile protection. With the popularization of the application of scouring measures, the situation of groundwater and surface water can be effectively controlled. At present, the project will basically choose retaining walls and masonry to protect the roadbed [10]. But in science and technology get high speed development today, polyurethane type soil fabric sheathing has been applied in all aspects, and made unprecedented breakthroughs in the process of practice. Choosinge the right tool in the slope reinforcement, should also fully consider the specific location of the anchor installation. At the same time, the concrete structure in the use of the process of its basic function has been improved accordingly, has become a wide chain reaction.

3.2. Key Points of Roadbed Sealing Layer Construction Control

3.2.1 Slope Control

In order to ensure that the slope of the closed layer is accurate, smooth drainage, the line between the concrete poured to the height of the mark, first by artificial preliminary leveling, and then use the homemade concrete vibration leveling device (vibration plate comes with a 3% slope) to control the transverse drainage slope. Longitudinal drainage is divided into longitudinal slope section and flat section, longitudinal slope section in accordance with the direction of the longitudinal slope of the line for slope control [11], can be based on the elevation of the top surface of the track plate, supplemented with concrete vibration leveling device with rubber wheels; flat section of the middle position of the two catchment wells for the highest point, to the location of the catchment wells for the lowest point, the base plate side of the line bouncing to control the slope.

3.2.2. Jointing Construction Jointing

Before construction, using a blower to clean the reserved joints to ensure they are dry, free of dust, loose stones, etc. The two sides of the sealed layer joint are glued with adhesive tape, with a width of not less than 6cm. The interface agent is applied to enhance the bonding force, and then silicone is injected [12]. The silicone injection height exceeds the concrete surface by 3-7mm, and a scraper is used to level the sealant. The expansion joints of the sealing layer are filled with silicone and hot asphalt mortar. Firstly, pouring 3cm of hot asphalt mortar, followed by 3cm of silicone. The water cement ratio of asphalt mortar is 0.12, and the anti-seepage pressure (5 days) is $\geq$ 1.7MPa. Figure 1 shows the overall construction drawing.

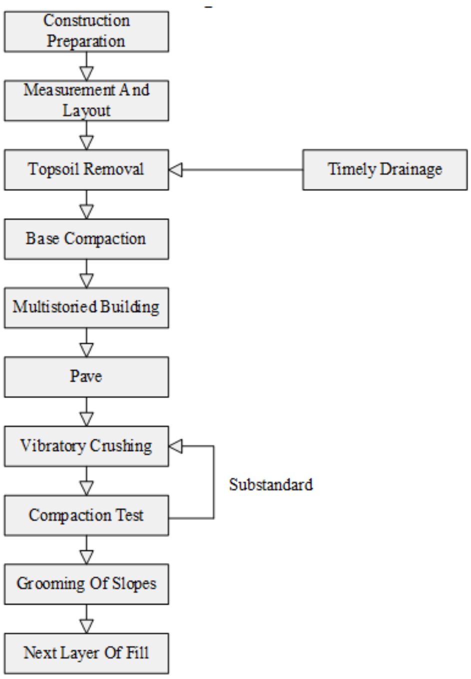

Figure 1: Construction process diagram

3.3. Quality Control Methods during the Construction Process of Highway Subgrade

3.3.1. Scientific Selection of Construction Methods

In order to ensure the efficiency and quality of the project, highway construction enterprises should choose the corresponding construction technology and construction steps according to the different stages of the project. Due to the irrationality of the construction method, it often has an unfavorable impact on the construction of the project, and even brings economic and social adverse effects to the engineering unit [13]. Taking the roadbed drainage design as an example, different regions in China should be constructed according to the local drainage requirements, and it is appropriate to adopt the decentralized drainage method in areas with flat terrain and less precipitation. In addition, the geographic environment around the highway should be fully studied and a more scientific drainage system should be designed to improve the rationality of its design and construction.

3.3.2. Strengthening the Quality Control of Construction Raw Materials

In the highway roadbed project, the raw materials used are sand and gravel, steel, concrete and so on. When purchasing all kinds of raw materials, the relevant technical personnel should carry out strict inspection and control, and require its raw material production and supply manufacturers to show production license and factory certificate, and cooperate with raw material production enterprises as far as possible. Generally speaking, the soil materials used in highway roadbed construction projects need to be mechanically crushed and naturally sunk to achieve a solid effect, so all the materials entering the construction site need to be monitored for quality, and the test method is used to select the most suitable materials for roadbed construction. On the basis of ensuring material quality, it is also necessary to select the best materials for one's own project based on the surrounding environment of the construction site, so that subsequent construction can proceed smoothly. The signing process for construction materials must focus on strengthening supervision and management to ensure that all material standards meet the requirements of the construction plan before signing and implementing. Unqualified materials must be strictly screened and prohibited from being used in construction. Personnel involved in material signing should continuously improve their professional knowledge and enhance their ability to identify material quality. In the signing process, relevant regulations should be strictly followed, self inspection work should be actively carried out, and any erroneous behavior in the signing process should be corrected in a timely manner, and prevention measures should be strengthened. The quality and performance of the purchased raw materials must be checked again before use. Through sampling surveys, the performance of cement and the quality of steel bars are tested to ensure that they meet the quality standards before they can be officially put into production. When storing various raw materials, it is important to avoid storage environments and conditions that are taboo, avoid contact with active chemicals, and maintain their properties.

3.3.3. Ensuring That Engineering Designers Have Strong Professional Skills and Rich Experience

According to the construction site of highway subgrade engineering, designers play a decisive role. In order to ensure the stability and smoothness of the construction site, the construction unit should hire professional and experienced designers to develop a construction plan that matches the data information and actual construction based on their own engineering characteristics. During this process, designers are required to master the relevant professional knowledge of highway subgrade engineering, strengthen their personal theoretical knowledge reserves, and conduct on-site inspections of the construction site. They should comprehensively consider the construction site, surrounding environment, and construction conditions, and conduct comprehensive evaluations of all the requirements for the entire construction process to ensure the feasibility of the construction plan. There will be no problems in engineering structure, funding, and procedures, and a high-quality and stable highway subgrade will be built to extend the safe service life of the highway.

3.3.4. Choosing Experienced Contractors to Ensure Project Quality

When selecting a contractor, the construction unit should strictly screen for relevant professional qualifications, engineering experience, and undertaking capabilities, and select contractors with strong capabilities to ensure that they have the ability to propose constructive improvement measures for different stages of construction plans in the construction process of highway subgrade engineering, plan the construction period reasonably, ensure the quality of subgrade and pavement, scientifically manage the construction team, and avoid unnecessary losses to the greatest extent possible.

3.4. Quality Inspection Standards

3.4.1. Quality Inspection of Roadbed Grouting Reinforcement

(1) Flatness detection

After grouting reinforcement treatment, the overall flatness of the roadbed needs to be tested, and the test results are shown in Table 1. According to the test results, it can be concluded that after 5 months of grouting reinforcement, the flatness test data tends to stabilize and meets the regulatory requirements.

Table 1: Flatness test results

Pile number		Average flatness detection value (mm)				
Starting station number	End station number	1 month	2 month	3 month	4 month	5 month
M12+150	M15+250	1.2	1.2	1.2	1.3	1.4
M12+250	M15+450	1.1	1.2	1.1	1.3	1.4
M12+450	M15+650	1.1	1.1	1.2	1.3	1.5
M12+650	M15+850	1.0	1.1	1.3	1.4	1.6

(2) Bending detection

The deflection of the surface layer, cushion layer, and base layer in the detection area was tested, and the test results are shown in Table 2. The test results show that the deflection values at the cushion layer, base layer, and surface layer after the treatment construction are all lower than the design requirements, indicating that the use of grouting reinforcement technology can prevent the occurrence of later roadbed settlement and deformation.

Table 2: Results of deflection detection of highway structural layers

Pile number		Representing the average deflection value (l/0.01mm)		
Starting station number	End station number	Surface layer	Cushion layer	Base layer
M12+150	M15+250	16	17	16
M12+250	M15+450	17	18	17
M12+450	M15+650	15	19	16
M12+650	M15+850	16	15	17

(3) Roadbed compaction

In the prevention of natural influencing factors, it is necessary to strictly control the rolling process and rolling steps. From a practical perspective, there may be inconsistencies in the compaction standards for new and old roadbeds, and settlement gradually stabilizes during the operation of the old roadbed. For new roadbeds, if the load force is insufficient, settlement problems will inevitably occur when the pressure is too high. Construction personnel need to develop new compaction standards based on the actual situation on site, and the specific standards for compaction degree are shown in Table 3.

Table 3: Compaction standards

Type of filling and excavation	Depth from roadbed to bottom (m)	Soil subgrade	Fly ash subgrade
Fill	[0,0.2]	>96%	>93%
	[0.2,1.2]	>96%	>93%
	[1.2,1.7]	>94%	>90%
	[1.7,2]	>95%	>91%
Excavation	>2	>98%	>95%

In order to ensure that the roadbed meets the standard requirements, it is necessary to distinguish the types of rollers, mainly hydraulic rollers, to prevent deformation of the roadbed and improve the overall compaction of the roadbed. Based on the deformation characteristics of the roadbed soil, a scientific observation plan for soil settlement under continuous load is developed to comprehensively analyze the settlement deformation of the roadbed, obtain the settlement law of the roadbed under continuous load, and select construction technology and equipment reasonably according to the settlement observation results. The selection of continuous load compaction equipment should be based on the actual situation of the project, and the dynamic performance of various specifications of compaction equipment should be tested. The specific test data is shown in Figure 2. According to the actual needs of the engineering project and the performance of the construction equipment, the construction process should be reasonably determined, and a test section should be selected for compaction testing.

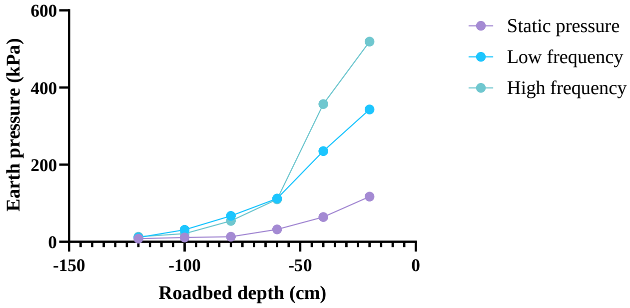

Figure 2: Distribution characteristics of soil pressure during compaction by compaction equipment

4. Results and Discussion

4.1. Analysis of Roadbed Settlement

According to the specifications for the design and construction technology of highway soft soil subgrade embankments, the cumulative settlement of the subgrade should be less than 300mm, the settlement rate of the subgrade during the filling stage should be ≤ 10mm/d, and the settlement rate of the subgrade slope foot should be ≤ 5mm/d. In order to ensure that the roadbed settlement of the project meets the design requirements, a one-year settlement observation will be conducted on key locations of the roadbed, and the test data will be statistically analyzed. Randomly selecting the settlement data of the settlement plates on the left, right, and middle positions of a certain section of the roadbed within one year for analysis and organization, and obtain the settlement variation curve of the key section of the roadbed, as shown in Figure 3.

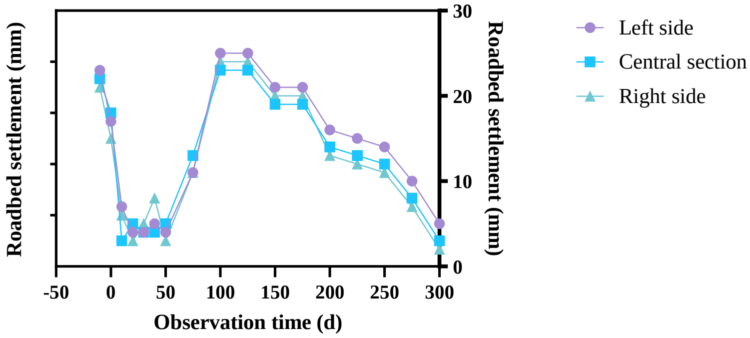

Figure 3: Curve of settlement changes in key sections of the roadbed

According to Figure 3, during the monitoring period, the settlement curves on the left, middle, and right sides of the roadbed top surface are roughly similar, and the overall settlement difference is small, indicating that there was no uneven settlement of the roadbed during the construction process. In the initial stage of roadbed filling, the maximum settlement on the left, middle, and right sides of the roadbed top are 23mm, 22mm, and 21mm, respectively, with a difference of only 2mm in maximum settlement on both sides of the roadbed. The settlement of the roadbed during the mid-term filling period has decreased due to the relatively small amount of roadbed filling and the relatively slow filling process. In the later stage of filling, due to the large amount of roadbed filling and significant increase in load, the settlement of the roadbed began to sharply increase, but the maximum settlement on both sides of the roadbed remained similar.

4.2. Analysis of Base Settlement Rate

We had sorted and analyzed the settlement data of various observation points on the roadbed within one year, and calculated the settlement rate of each observation point on the foundation at different periods, obtained the variation curve of the foundation settlement rate, as shown in Figure 4.

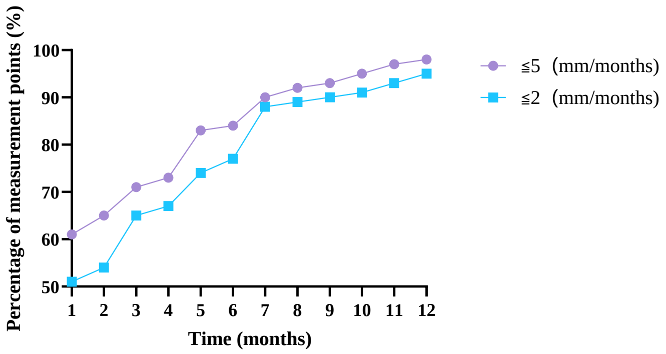

Figure 4: Curve of base settlement rate variation

According to Figure 4, it can be seen that with the growth of monitoring time, the percentages of observation points with settlement rates ≦5 (mm/month) and ≦2 (mm/month) are both increasing, indicating that the overall settlement condition of the roadbed substrate is good. In the early stage of monitoring, the settlement rate of the roadbed foundation reaches 61.9% for measuring points with a settlement rate ≤ 5 (mm/month), and 51.4% for measuring points with a settlement rate ≤ 2 (mm/month); after reaching the middle stage of monitoring, the number of measuring points with a settlement rate of ≤ 5 (mm/month) on the roadbed increases to 84.1%, and the number of measuring points with a settlement rate of ≤ 2 (mm/month) increases to 77.4%, the rate of compliance with the settlement rate of the roadbed measuring points increases significantly; after the monitoring period ends, the settlement rate of the roadbed foundation can reach 98.9% for measuring points with a settlement rate of ≤ 5 (mm/month), and 95.6% for measuring points with a settlement rate of ≤ 2 (mm/month), the compliance rate of the settlement rate of the foundation measuring points is relatively high. Overall, throughout the entire construction period, the settlement rate of the roadbed foundation meets the design requirements and will not affect the roadbed filling and pavement construction.

5. Conclusion

The development of social economy brings brand-new opportunities to China's highway construction. In the link of highway construction, the relevant units must combine the current science and technology to solve the problems faced, eliminate the constraints of unstable factors, and then promote the construction of China's highway towards a healthy direction. Through the in-depth study of highway roadbed construction technology and its quality control, this paper argues that the complexity and importance of highway roadbed construction technology should not be ignored. From geological investigation to excavation and filling, and then to the roadbed drainage and protection and reinforcement, each link needs to be fine operation and strict control. Reasonable selection and flexible use of technology can not only improve the construction efficiency, but also ensure the stability and durability of the roadbed, laying a solid foundation for the long-term use of the entire highway. At the same time, the study proposes to establish a perfect quality control system, implement comprehensive quality monitoring and management, and timely find and correct deviations and problems in the construction process to ensure that the roadbed construction complies with the design requirements and norms and standards.

Although this paper carries out a more comprehensive analysis of roadbed construction technology and proposes corresponding quality control measures, there are still some shortcomings. Because highway construction involves a wide range of geographic areas and diverse geological conditions, the research in this paper is difficult to cover all possible construction scenarios and special circumstances, and therefore may need to be adjusted appropriately according to the specific circumstances in the actual application. Moreover, with the continuous progress of science and technology, new construction techniques and materials continue to emerge, the research in this paper may have certain limitations in terms of timeliness, so the research also needs to continuously adapt to the changes of the times and technological progress. The research in this paper provides certain reference and reference for the development of this field, but it still needs to be further deepened and improved. It is believed that in the future research, academics will be able to achieve more fruitful results and contribute more wisdom and strength to the sustainable and healthy development of China's highway construction.

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