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Study on the Construction Technology of Subgrade Pavement in Road and Bridge Settlement Section

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Abstract: With the continuous development of China's economy, the construction of roads and bridges work has put forward higher requirements. Due to various factors, the long-term use of roads and bridges will produce a settlement phenomenon. Therefore, it is crucial to address settlement issues during the construction of roads and bridges to ensure that the quality of subgrade and pavement construction meets national regulations. This paper introduces the harm of subgrade pavement subsidence, analyzes the causes of subgrade pavement deformation, and discusses the technical points of subgrade pavement construction, hoping to provide some reference for relevant practitioners.

Keywords: Road and bridge; Settlement section; Subgrade and pavement; Construction technology

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1. Foreword

In road and bridge engineering, subgrade and pavement in settlement sections are often an important factor affecting structural stability and service life. Since the settlement section is located in the transition area between the bridge and the road, the geological conditions are complex. Due to a variety of factors, it is prone to uneven settlement, leading to road deformation and bridge damage. Scientific and reasonable construction technology can not only improve the quality of the project, but also significantly improve the driving conditions, reduce the maintenance cost, extend the service life of roads and bridges, and ensure traffic and operational efficiency.

2. Hazard of subgrade and pavement settlement of road and bridge

2.1. Affect the driving safety

Subgrade and pavement settlement will lead to uneven connection between the bridge and the subgrade, causing strong turbulence when vehicles pass through. This increases the operational difficulty for drivers, making it easy to lose control and potentially leading to traffic accidents. Especially at night or under bad weather

conditions, the driver's reaction time is limited, and the uneven road surface may lead to vehicle instability. In the process of driving, if the road is suddenly uneven, it will overwork the vehicle suspension system, affecting the stability and handling performance of the vehicle, and further increasing the risk of accidents. Settlement of subgrade and road surface will cause the failure of the drainage system, resulting in water accumulation on the road. The water will reduce the friction coefficient of the road surface, decreasing the adhesion between the vehicle tires and the road, which increases the risk of skidding, especially during breaking and turning. Water will also lead to a water film effect on the road, causing the vehicle to lose contact with the road at high speed, resulting in the vehicle being completely out of control and increasing the risk of serious traffic accidents. The settlement difference between the bridge and the road will cause a jumping phenomenon at the bridgehead, impacting the vehicle chassis and suspension system and increasing road safety risks [1].

2.2. Shortening the service life of the roads

Unsmooth pavement and structural deformation caused by settlement can accelerate the aging and damage of pavement materials. The stress concentration caused by the settlement will cause fatigue cracks under the action of a vehicle load. These cracks gradually expand, leading to serious issues such as road peeling and potholes, reducing the service level of the road surface, requiring frequent repairs and maintenance, and increasing the economic cost of road upkeep. Especially the asphalt pavement, under repeated settlement stress, is prone to asphalt aging and crack expansion, shortening the service life of the pavement. Subgrade settlement will damage the stability of the subgrade and lead to the decline of the overall performance of the pavement structure. The uneven settlement of pavement caused by subgrade settlement will weaken the binding force between pavement structure layers, leading to stripping between pavement layers and loose structures. This phenomenon not only reduces the carrying capacity of the road surface but also makes the road surface more likely to produce permanent deformation under the vehicle load, which further aggravates the settlement and damages of the roadbed and road surface. The decreased stability of the subgrade will also affect the effectiveness of the pavement drainage system, increase the risk of water accumulation, and accelerate the aging and damage of the pavement materials. The settlement difference between the bridge and the road will lead to uneven abutment force, produce additional stress, and increase the risk of damage to the abutment and bridge foundation [2].

3. Analysis of deformation causes of subgrade and pavement in the settlement section of a road bridge

3.1. Deformation of the back foundation

The deformation of the platform back foundation is mainly due to the uneven compaction degree. During the construction process, the compaction degree can be affected by various factors such as construction sequence, material quality, mechanical equipment, operation experience, and so on. If the compaction is insufficient or uneven, the foundation will settle under the load, making the soil structure loose, reducing its bearing capacity, and leading to the deformation and settlement of the foundation. The selection of mechanical equipment and the technical level of the operator directly impact the compaction effect. If the vibration frequency, compaction frequency, and other parameters of the compaction mechanical equipment do not meet the required specifications, it will lead to uneven compaction of the foundation. The platform back foundation is often located in the gully section, and the compressibility and water content of the foundation soil significantly affect the foundation's stability. The gully section soil has high compressibility and large water content. These characteristics will make the foundation prone to compression deformation and settlement under the action

of load. When the water content of the foundation soil is high, the bonding force between the soil particles is reduced, and the bearing capacity decreases, which leads to the large settlement deformation of the foundation under the action of load. When the soil with high compressibility is subjected to an external load, its volume compression is obvious and the foundation settlement is significant. The deformation of the platform back foundation is closely related to the filling height. The higher the height of the bridge embankment filling, the greater the stress of the foundation. Consequently, the greater the filling height, the higher the probability of foundation settlement and deformation. A high filling will put the foundation under greater vertical pressure, increasing the risk of settlement [3].

3.2. Embankment deformation

Improper design of the drainage system can cause the embankment deformation. If the permanent and the temporary drainage systems are not effectively combined, the subgrade drainage is not smooth, and water accumulation increases the water content of the foundation soil, reducing its bearing capacity, and easily causing the settlement and deformation of the subgrade. If the subgrade drainage design is insufficient and the rainwater or groundwater cannot be discharged in time, it increases the foundation soil water content which decreases the bearing capacity and aggravates settlement deformation. During construction, if the poor soil on the original ground is not thoroughly removed, it can lead to settlement and deformation of the subgrade under dynamic and static loads. In the construction process of high filling embankment, if it is not operated under standard order, such as the technical specifications are not observed in the process of layered rolling, it will lead to insufficient subgrade compaction, or improper thickness control of layered filling, which causes the settlement and deformation of subgrade. If the construction materials do not meet the quality requirements, such as mixed with mud and marsh soil, large soil block, etc., the deformation problem of the embankment is aggravated. The settlement of the embankment showed significant differences under different geological conditions. On soft land foundations or high-water content, the embankment is prone to cause settlement and deformation. On hard rock foundations, the embankment deformation is small. Inadequate or improper geological investigation before construction will lead to adverse geological conditions in the construction process and increase the risk of embankment deformation. Improper foundation treatment fails to effectively improve the bearing capacity of the foundation, which will make the embankment produce large settlement deformation under the action of load [4].

3.3. Bridgehead deformation

There is a rigid and flexible structure transition between the abutment and the subgrade. The deformation characteristics of the rigid abutment and the flexible subgrade are different, resulting in the deformation differences. The abutment is usually set on the bearing layer with high bearing capacity and small foundation settlement, while the filling height of the flexible subgrade is generally high, which can cause compression deformation under the long-term weight of the bridgehead. Improper handling of the rigid and flexible transition between the abutment and the subgrade will aggravate the deformation of the bridgehead. The quality of the bridgehead back affects the deformation. The selection of fillers with high water content, large pores, and strong compressibility will produce significant compression deformation under the action of load, leading to the settlement of the bridgehead. If the construction unit treats the soft land foundation improperly or selects unqualified fillers to save the cost, it will seriously affect the quality of the later compaction operation, and lead to the settlement deformation of the bridgehead subgrade under the long-term load action. Improper foundation treatment leads to the deformation of the bridgehead, and the platform back area is often located in the river area. The soft land foundation has high water content, large porosity, and low shear strength, making

it susceptible to disturbance during construction. This leads to damage to the natural structure and a decrease in strength. The high subgrade filling increases the base stress, which improves the foundation subsidence rate and causes the deformation of the bridgehead. Improper treatment of the soft land foundation with a lack of effective reinforcement measures will easily lead to the settlement and deformation of the bridgehead foundation [5].

4. Technical key points of subgrade and pavement construction in the road and bridge settlement section

4.1. Set the base plate position reasonably

When determining the position of the slab, the construction personnel shall ensure that the top surface of the slab is consistent with the top surface of the subgrade. Construction personnel should pass detailed measurements and calculations to ensure that there is no height difference between the plate and subgrade, to avoid turbulence when vehicles pass. Before the construction, accurate topographic measurements must be carried out and high-precision instruments of the whole station must be used to determine the elevation of the base plate position where the design should be adjusted according to the measurement results. During the process of connecting the plate and the road, it is necessary to appropriately raise the height of the connection end of the plate and the pavement. According to the longitudinal slope of the road and the bridge deck design requirements, the reverse slope of the base plate connecting end is calculated. Generally, the setting of the reverse slope needs to consider the smoothness of the longitudinal section of the line to avoid the impact when vehicles pass through. During construction, the height adjustment can be achieved by adding a layer of asphalt mixture or cement mixture at the connecting end of the slab to ensure a smooth connection between the slab, the bridge deck, and the road surface. The position of the slab should consider the actual use and traffic flow of the bridge. For a bridge with a large traffic flow, the design of the length and width of the plate should meet the stability and comfort requirements of vehicle use. The length of the base plate is generally determined according to the span and structure form of the bridge, usually between 5 and 10 m. The specific value should be adjusted according to the design standard of the bridge and the actual situation. The width of the slab should be the same as the width of the bridge deck to ensure that vehicles do not deviate [6].

4.2. Connecting technology of bridge abutment and base plate

The connection between the abutment and the base plate should adopt the anchor bolt technology to ensure that the two are firmly connected. The anchor should be high-strength steel. Generally, steel number 22 is used as the anchor material. The layout spacing of the anchor bolts is generally controlled at 75~80 cm, and the specific spacing should be designed according to the force situation of the abutment and the base plate. When installing the anchor bolt, drilling should be drilled at the connection position between the abutment and the base plate, and the aperture and depth should be determined according to the specifications and force requirements of the anchor bolt to ensure sufficient anchoring force after insertion. The connection between the abutment and the base plate should be fixed with a horizontal tie rod. The horizontal rod can be made of high-strength thread reinforcement where the diameter and length of the rod should be designed according to the force at the connection. When installing the horizontal rod, the rod hole should be reserved at the connection between the abutment and the base plate to ensure that the rod can pass through the joint and be fastened with nuts at both ends. After installing the rod, the tension test should be conducted to ensure that the rod has sufficient tension to resist the deformation at the connection between the abutment and the base plate. The connection between the abutment and the base slab should be waterproof to prevent rainwater from infiltrating into the connection gap

and causing structural damage. Waterproof treatment can use polyurethane waterproof coating or waterproof coil material, coating or laying of waterproof materials at the connection place, to ensure the seamless connection of the waterproof layer and avoid water seepage problems. During construction, it is necessary to ensure the bonding strength and durability of the waterproof materials to prevent damage due to temperature changes or vehicle loads [7,8].

4.3. Block support technology

The platform support should be fitted with linoleum or rubber pads at the connection between the abutment and the abutment plate to ensure sufficient support and deformation capacity. The size of the oil felt or rubber bearing is generally 2 cm thick, and the specific size should be determined according to the bridge design requirements and the force of the bearing. When laying the support, ensure that the support surface is flat, without wrinkles or bumps, and that the contact surface between the support and the abutment and the plate is uniform. The spacing between the supports should be strictly controlled at about 80 cm. The design of support spacing should comprehensively consider the force situation and deformation requirements of the connection between the abutment and base plate, to ensure that the bearing can evenly distribute the load and avoid local stress concentration. During construction, it is necessary to use accurate measuring tools to measure and adjust the support spacing to ensure it meets the design requirements. Protect the support to prevent damage during construction. Construction personnel should avoid heavy object stacking or mechanical operation on the support to prevent support deformation or damage. After the laying of the support, protection measures should be carried out in time, such as covering the protective film or support frame, to prevent the support from being damaged by external forces [9].

4.4. Chamfer technique

The contact position of the platform end and the bull leg is designed to be chamfered, which can reduce the turbulence and vibration of vehicles. The design of the chamfer should be carried out according to the bridge structure and vehicle driving conditions. Commonly, the angle of the chamfer is between 15° and 30°. During the chamfering construction, the concrete cutting machine or grinding machine can be used to cut and polish the platform end to ensure that the chamfer angle and surface flatness meet the design requirements. Chamfer construction should be closely combined with foundation treatment, drainage design, pavement material selection, and other links. Foundation treatment should ensure that the foundation at the chamfered position has sufficient bearing capacity and stability to prevent foundation settlement from affecting the effectiveness of the chamfering. The drainage design should set up an effective drainage system in the chamfered position to prevent rainwater accumulation at the chamfer, which may lead to road sliding or structural damage. The pavement material selection should consider the durability and skid resistance of the chamfer to ensure the safety and comfort of vehicles when passing. After the completion of the chamfer construction, a quality inspection should be conducted to ensure that the angle and surface flatness of the chamfer meet the design standards. Quality testing can use a laser measuring instrument or level instrument to measure the chamfer angle and surface flatness, ensuring that the construction quality meets the requirements. During the testing process, if the chamfer angle or surface flatness is found to not meet the standard, it should be corrected in time to ensure that the construction quality meets the design requirements [10,11].

4.5. Joint treatment technology

A gap of a certain width will be formed at the connection of the base plate and the bridge abutment. To avoid

leakage problems in the gap, reasonable technology is needed to carry out joint treatment. Usually, asphalt catkins, glass fiber, and other materials can be used to fill the gap. During construction, the filling materials should be evenly distributed into the gap to ensure that the filling is dense and free of voids. Filling materials should have good durability and waterproof performance, and can be kept stable for long-term use. The joint treatment requires heating asphalt filling to improve the sealing effect of the gap. Heating asphalt pouring requires special heating equipment to heat the asphalt to the appropriate temperature, and then evenly pour into the filling material. During the perfusion process, the asphalt should be ensured that the gap is filled and closely combined with the filling material to avoid leakage or uneven filling. After perfusion, cooling and curing should be performed to ensure that the asphalt forms a stable sealing layer with the filling material. Seal and durability testing should be performed after joint treatment. The water tightness test can be used to assess the water tightness of the seal. Durability testing can test the joints by simulating vehicle loads and environmental changes to ensure that they remain stable for long-term use. During the testing process, if the sealing or durability is found to not meet the standard, the repair and reinforcement should be made promptly to ensure that the joint treatment quality meets the design requirements [12–15].

5. Epilogue

The continuous optimization and improvement of subgrade and pavement construction technology of road and bridge settlement sections helps improve the engineering quality and prolong the service life. Through scientific foundation treatment, reasonable structural design, and the application of high-quality materials, the settlement and deformation can be effectively avoided, and a smooth transition between bridge and road can be guaranteed. In future engineering practice, it is necessary to continuously pay attention to the application of new technologies and new materials, constantly improve the construction methods and quality control measures, provide more reliable and durable technical support for road and bridge engineering, and promote sustainable development of transportation infrastructure.

Disclosure statement

The author declares no conflict of interest.

References

[1] Lou P, Li Y, Xiao H, et al., 2022, Influence of Small Radius Curve Shield Tunneling on Settlement of Ground Surface and Mechanical Properties of Surrounding Rock and Segment. Applied Sciences, 12(18): 9119.

[2] He J, Liao S, Tan Y, et al., 2022, Analytical Study on the Ground Settlement Induced by Pipe-Roof Tunnelling Considering the Interaction between Socketed Pipes. KSCE Journal of Civil Engineering, 27(1): 417–430.

[3] Tavallaienejad A, Salari H, Behnia C, et al., 2022, Comparative Study on the Design Process of a Shallow Subway Station Isfahan Metro, Iran, Based on Risk Assessment. Indian Geotechnical Journal, 53(3): 562–582.

[4] Zhang J, Cheng Z, 2022, Prediction of Surface Subsidence of Deep Foundation Pit Based on Wavelet Analysis. Processes, 11(1): 107.

[5] Abbasi SJ, Weng X, Iqbal MJ, 2024, Numerical Analysis of Differential Settlement in Road Due to Widening Considering Different Reinforcement Techniques. Applied Sciences, 14(5): 1740.

[6] Chen S, Cui J, Liang F, 2022, Centrifuge Model Investigation of Interaction between Successively Constructed Foundation Pits. Applied Sciences, 12(16): 7975.

[7] Jang J, Lee JY, Redwan M, et al., 2023, Hydrogeological characteristics and water chemistry in a coastal aquifer of Korea: implications for land subsidence. Environmental Monitoring and Assessment, 195(11): 1289.

[8] Chen R, Zhou X, Yu M, et al., 2023, Bayesian updating for ground surface settlements of shield tunneling. Frontiers in Earth Science, 11: 1–12.

[9] Ma B, Wu S, Chen Q, et al., 2024, The influence of existing piles on station settlement during the construction of a tunnel undercrossing under existing stations. Scientific Reports, 14(1): 14024.

[10] Hu T, Xu J, 2024, Prediction of Buildings' Settlements Induced by Deep Foundation Pit Construction Based on LSTM-RA-ANN. Applied Sciences, 14(12): 5021.

[11] Cai G, Zou X, Zhang Q, et al., 2023, Performance of the suspension method in large cross-section shallow-buried tunnels. High-Speed Railway, 1(4): 224–232.

[12] Park S, Kim DS, Kim U, et al., 2022, Low Compressibility at the Transition Zone of Railway Tracks Reinforced with Cement-Treated Gravel and a Geogrid under Construction. Applied Sciences, 12(17): 8861.

[13] Mei Y, Zhou D, Shi W, et al., 2022, Laws and Numerical Analysis of Surface Deformation Caused by Excavation of Large Diameter Slurry Shield in Upper-Soft and Lower-Hard Composite Stratum. Buildings, 12(9): 1470.

[14] Gao X, Tian W, Pang Q, et al., 2023, Analysis of the response subsidence and grouting treatment in the goaf of multi-layer inclined coal seam. Scientific Reports, 13(1): 20711.

[15] Hu D, Zhou R, Xiao L, et al., 2023, A Supershallow Buried Large-Span Rectangular Pipe Jacking Tunnel Undercrossing an Expressway: Construction Method, Monitoring Results, and Numerical Simulation. International Journal of Civil Engineering, 22(5): 757–771.