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Analysis of Roadbed Pavement Designs for Highway Reconstruction and Upgrading

Haonan Ding*, Zhipan Yang, Wei Gan

China Merchants Chongqing Communications Technology Research & Design Institute Co., LTD., Chongqing 400067, China

Corresponding author: Haonan Ding, 18008379971@163.com

Abstract: This paper focuses on the route and roadbed pavement design in highway reconstruction and upgrading projects. It discusses the importance of project design for highway reconstruction and upgrading, highlighting key aspects of route design and roadbed pavement design. The analysis reveals that the main design considerations in these projects include controlling factors of route reconstruction, expansion, and upgrading, as well as route plan design and longitudinal section design combined with roadbed pavement. In roadbed pavement design, it is crucial for designers to thoroughly collect existing data and make reasonable use of the current roadbed and pavement to develop a comprehensive design scheme. This analysis aims to provide a reference for the reasonable design of such projects.

Keywords: Highway engineering; Reconstruction and upgrading design; Route design; Roadbed and pavement design

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1. Introduction

In modern highway engineering reconstruction and upgrading projects, the design of routes and roadbed pavement holds paramount importance. Thus, designers must acknowledge the significance of these aspects and implement practical measures that align with the project's specific requirements and on-site conditions. This approach ensures the quality of the highway project's reconstruction and upgrading design, thereby providing robust support for its subsequent construction and application.

2. Importance of highway reconstruction and upgrading engineering design

With the continuous rise in modern highway engineering reconstruction and upgrading projects, the focus has shifted towards the design aspect, which plays a pivotal role in several key areas. (1) Firstly, through thoughtful reconstruction and upgrading design, there is a notable improvement in traffic load and capacity, meeting the evolving demands of the transportation sector. (2) Secondly, a well-designed plan simplifies subsequent phases, providing crucial support and references, thereby enhancing construction efficiency, quality, and cost-effectiveness. (3) Lastly, a sound design ensures the operational effectiveness of the highway project post-

upgrade, maximizing vehicle efficiency, safety, and longevity while minimizing operational and maintenance costs. Given the significant advantages, this aspect of modern highway engineering has garnered substantial attention, prompting designers and stakeholders to conduct in-depth research to meet the actual needs of reconstruction and upgrades.

3. Key points of route design in the road reconstruction and upgrading project

For highway reconstruction and upgrading, route design is crucial. To ensure effectiveness, designers should integrate actual circumstances and consider the following measures:

3.1. Controlling factors of route reconstruction and upgrading

To ensure the effectiveness of highway reconstruction and upgrading, the designer needs to integrate the reconstruction and upgrading requirements with the site's actual conditions, taking into account various controlling factors: (1) Vehicle characteristics, such as type, size, and weight of vehicles using the reconstructed and upgraded road. (2) Traveling speed, indicating the typical speed of traffic vehicles. (3) Traffic volume and capacity, encompassing the hourly traffic volume and the maximum vehicles passing through per unit of time. (4) Driver behavior, including reaction time in unexpected situations, is typically set at 3 seconds. (5) Infrastructure boundaries, ensuring no obstacles interfere with the specified span and height range. For a tailored design, the designer must account for these factors and develop a suitable plan based on the specific needs of the project and on-site conditions, enhancing and standardizing route design to promote smooth and safe traffic operations.

3.2. Line plane design points

In the reconstruction and upgrading of highways, plane design is fundamental for preserving existing alignments to enhance project efficiency and minimize costs. To ensure effectiveness, designers implement the following measures: (1) Utilizing polygonal complex curves for large arc curves to reduce fitting errors and meet design standards [2]; (2) dividing single circular curves into smaller segments for accurate CAD drawing, ensuring overall route precision; (3) maintaining straight-line routes if existing lengths suffice, avoiding unnecessary modifications; (4) addressing length disparities by lengthening designs or employing curve fitting to meet project requirements; (5) integrating different curve types for adjacent intersections using finite element software modeling, aligning with on-site traffic network conditions; (6) creating reverse curves by enlarging curve radii and connecting them to S-curves, ensuring safety and efficiency. These strategies ensure precise, cost-effective, and safety-compliant plane design in highway reconstruction and upgrade projects.

3.3. Combined with the longitudinal section design of the roadbed and road surface

In road reconstruction and upgrading projects, the longitudinal section design is a crucial aspect of the overall line design. This involves integrating the roadbed and road surface conditions, taking reasonable design measures, ensuring an effective overall design, and significantly reducing project costs. To achieve these goals, designers must control several key aspects. The new roadbed pavement elevation, slope, and differences from the existing road surface should align with the current conditions. For minor differences, the designer can use centerline control for the longitudinal section. However, if expansion is required on one side, elevation calculations, and targeted optimizations based on the specific situation are necessary. A comprehensive analysis of various factors should inform a reasonable design program to address these complexities effectively [3]. In hilly areas, the designer must integrate plane design strategies to ensure a reasonable longitudinal section that meets the overall needs of the highway reconstruction and upgrade. The longitudinal slope design should

consider the length and slope of the existing roadbed to ensure stability and compliance with quality and safety requirements. This comprehensive approach is crucial for maintaining the integrity and effectiveness of the upgraded road [4]. Additionally, the designer must consider the vertical curve radius and sight distance of the existing highway, utilizing finite element analysis software to determine the minimum limit value for combining longitudinal and flat sections. This ensures that the longitudinal section is designed to simplify the reconstruction and upgrading process, reduce project costs, and maximize the project's quality and safety.

4. Key points of roadbed pavement design in highway reconstruction and upgrading projects

The design of roadbed pavement is also crucial in highway reconstruction and upgrading projects. Therefore, the designer should master the design requirements and the on-site conditions.

4.1. Collection of existing data

Before designing the roadbed pavement, the design unit must comprehensively collect existing information to provide a reference basis for subsequent designs. In this process, the staff should comprehensively collect the existing data of the highway project, including the geological site conditions, topography, geomorphology, the quality of the roadbed and pavement, and the traffic volume. The data obtained should be used for the design of the roadbed and pavement. Acquired information should be comprehensively organized and summarized to formulate a reasonable design scheme [5]. After that, the developed design scheme will be shared with all relevant departments for thorough analysis. After comprehensive analysis by multiple departments and staff, the feasibility of the design scheme can be determined, adjustments can be made, and finally, the optimal design scheme can be produced [6].

4.2. Utilization of existing roadbeds and the development of a perfect design scheme

One of the fundamental principles of roadbed design is to effectively utilize the existing roadbed and develop an optimal design scheme. To achieve this, designers must implement specific measures during the design process. Understanding the geological characteristics of the construction site is essential to select appropriate transport vehicles and methods, ensuring prompt removal of excess gravel to prevent accumulation and adverse effects on subsequent construction. Earth excavation height, roadbed slope height, and step height should be carefully designed based on roadbed filling construction standards and site conditions. Typically, roadbed height in reconstruction and upgrading projects should not exceed 11 meters, with step heights controlled between 0.8 to 1.5 meters. Additionally, a water interceptor ditch should be placed approximately 6 meters outside the top of the slope to ensure stability, thus maintaining overall roadbed stability [7]. Regarding roadbed filling materials, designers should determine material types through field tests and align them with actual conditions to establish corresponding material standards. Upon completing the design scheme, an on-site paving test should be conducted on a test section. The design scheme can then be optimized according to the test results and only be applied after it has passed the tests.

4.3. Utilization of existing road surface to develop a perfect design program

In designing the pavement structure, the designer needs to integrate the existing highway pavement with the specific needs of the upgrade to minimize wastage [8]. Drainage considerations, such as existing pavement thickness and drainage conditions, are crucial to ensure effective drainage and prevent issues during construction. Moreover, adhering to route height requirements is vital for designing a suitable foundation structure. For routes

below 2.5 meters, a concrete pavement foundation layer is advised, while routes 2.5 meters and above should use a cement-stabilized gravel structure [9]. In designing the pavement structure, the designer needs to integrate the existing highway pavement with the specific needs of the upgrade to minimize wastage. Drainage considerations, such as existing pavement thickness and drainage conditions, are crucial to ensure effective drainage and prevent issues during construction. Moreover, adhering to route height requirements is vital for designing a suitable foundation structure. For routes below 2.5 meters, a concrete pavement foundation layer is advised, while routes 2.5 meters and above should use a cement-stabilized gravel structure [10]. Typically, the maximum tensile stress for highway bridge pavement should not exceed 10.6 MPa, while the maximum compressive stress should not exceed 16.0 MPa.

5. Conclusion

Highway reconstruction and upgrading projects play a significant role in the development of the modern road transport industry. The route design and roadbed pavement design are crucial elements in these kinds of projects. Only through reasonable design can we effectively meet the reconstruction and upgrading needs of such projects and improve their operational quality and safety. To achieve this, designers and staff must pay attention to the reconstruction and upgrading of routes, roadbeds, and pavements. Furthermore, the specific project conditions and the results of the on-site investigation should be taken as the basis for designing reconstruction and upgrading projects to improve the overall outcome can be improved.

Disclosure statement

The authors declare no conflict of interest.

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