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Creep Control and Construction Technology for Laying Ballastless Tracks on a 420m Ultra Long Span High-speed Railway Cable-stayed Bridge

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Abstract: Ballastless track plays a crucial role in railway transportation. Traditional construction techniques are difficult to effectively ensure the stability and safety of ballastless track structures, and cannot achieve effective creep control. In order to improve the effect of creep control and enhance the quality of ballastless track laying in cable-stayed bridges, this paper took the ballastless track laying project of a 420m ultra long span high-speed railway cable-stayed bridge as the object, and conducted in-depth research on its creep control and construction technology. This article first analyzed the factors affecting the creep of ballastless tracks, and then, based on this, ensured the stability and creep control of the cable-stayed bridge structure through tension calculation and cable force adjustment. Finally, based on the calculation results, construction optimization was carried out. This article conducted experimental analysis from two levels: structural safety assessment and creep measurement, to confirm its efficacy. The findings demonstrated that over the observation period, the three randomly chosen control locations' average cumulative changes in the horizontal plane coordinates did not surpass 1 millimeter. The article's conclusion suggested that the creep control and construction technology could raise the caliber and standard of rail transportation while also assisting in enhancing the stability and safety of the ballastless track of the 420-meter ultra long span high-speed railway cable-stayed bridge.

1. Introduction

The ultra long span high-speed railway cable-stayed bridge is one crucial component of modern high-speed railway construction that is critical to preserving the efficacy and safety of train movement. Creep is a common problem encountered while laying ballastless track for cable-stayed bridges, because it directly affects the stability and service performance of the line. Traditional ballastless track laying engineering often deals with track deformation and creep damage, which jeopardizes the safety of the line as well as the efficiency of train operations.

This article takes the ballastless track laying project of a 420 meter ultra long span high-speed railway cable-stayed bridge as an example. Simplifying the construction process and applying creep control technology to solve the problems brought by traditional construction methods have important practical value in improving the safety and reliability of engineering construction and achieving strong growth in the rail transit industry.

This article studied the creep control and construction technology of laying ballastless tracks on a 420m ultra long span high-speed railway cable-stayed bridge in order to improve the safety and stability of ballastless tracks and the quality of transportation. Experimental study was carried out from two levels: creep measurement and structural safety evaluation, in order to confirm the efficacy of creep control and construction technology in this article. In terms of creep measurement, the cumulative mean changes of the three control points during the observation period did not exceed 1 millimeter. In terms of structural safety assessment, the safety factors of the three control points all reached 2.50 or above during the observation period. In practical applications, the creep control and construction technology in this article can effectively improve the safety and stability of ballastless tracks in cable-stayed bridges.

2. Related Works

With the rapid development of bridge and railway engineering, the construction and control of cable-stayed bridges have also achieved certain results. Sheng Xingwang presented the Ganjiang Bridge's structural features and sample features. Multi-scale finite element modeling technology was used to get precise stress analysis of local structures, such as the anchoring zone of the cable and beam in large-span cable-stayed bridges, in order to increase the viability of installing ballastless rails on these types of bridges [1]. Han Zhaoling used the curvature method to study some typical static and dynamic problems of a large-span high-speed railway cable-stayed bridge with a main span of 400m and ballastless track under actual conditions, and showed that using dynamic simulation to evaluate the deformation of large-span bridges is more effective than overly simplified static evaluation [2]. Gou Hongye developed a train track bridge coupling vibration model and a bridge track deformation model, investigated the effects of interlayer connection defects on the safe operation of high-speed trains, and successfully analyzed the safety of train operation via deformed bridges [3]. In order to provide direction for future improvements in the study of train track bridge dynamic interaction, Zhai Wanming provided a brief description of the train bridge dynamic interaction model's evolution, from the simplest moving constant force model to the complex train track bridge dynamic interaction model [4]. Ding Yu established a finite element model, considering the most unfavorable upper and lower deformations of bridges under complex loads, and calculated and analyzed the stress of slabs, self compacting concrete, and bottom plates. The final research results provided reference for railway track design and maintenance personnel [5]. Liu Xiaochun studied the composite performance of the track slab and self compacting concrete filling layer in the plate track structure of the third track system of China Railway. By dividing the full-size plate track structure, the proportion of interlayer connecting steel bars was increased, and the composite effect between the track slab and the filling layer was enhanced [6]. Although existing creep control and construction techniques can improve operational efficiency to a certain extent, most of the construction schemes studied still have limitations in terms of stability and safety.

3. Creep Control and Construction of Ballastless Track Laying in Cable-stayed Bridges

A cable-stayed bridge consists of three parts: a pylon, a stay cable, and a main beam. It is a type of bridge that uses stay cables to tie the main beam to the pylon and can withstand large spans [7]. In order to construct a bridge structural system where the main beam and the cable tower are crushed together and the stay cable is in tension, the two ends of the stay cable are fastened between them. This kind of bridge construction is crucial to engineering design since it safely supports the weight of the bridge and guarantees its proper functioning.

3.1 Factors Affecting Creep

From a static point of view, when the tension pressures at the ends of the main beam and cable tower are equal, a cable-stayed bridge creates a self-anchored balancing system. In practical applications, the factors affecting creep mainly include three levels:

(1) Material selection impact

One of the key elements influencing creep in cable-stayed bridges is the choice of material for the ballastless track. The stable operating effect of ballastless rails is directly impacted by the thermal expansion and contraction, compressive strength, and deformation performance of materials. Selecting materials with strong stability and adaptability is especially crucial because of the notable disparities in performance between various materials in temperature and humidity settings. High-quality materials can be used to reduce creep and enhance the structure's durability and other mechanical qualities.

(2) Track design and structural characteristics

The creep of ballastless tracks in cable-stayed bridges is also significantly influenced by the structural features and track design. The anti-creep performance of a structure is greatly influenced by the track's elasticity, stability, and flexibility in structural design. The formation and progression of creep are influenced by structural features such as the connection technique and support stability effect. The anchoring relationship between the cable and the tower main beam provides the structural balance of ballastless track in cable-stayed bridges, and the force mechanisms between the constituent parts are quite intricate. If any component undergoes deformation, all other components change accordingly, causing an imbalance in the internal forces of the cable-stayed bridge, making it difficult to maintain the self anchoring balance system and resulting in sustained deformation of the structure [8-9].

(3) Environmental factors

The creep of ballastless tracks in cable-stayed bridges is also affected by environmental factors. Due to long-term exposure to the natural environment, and the influence of external factors such as temperature, sunlight, wind, and loads on materials such as cable-stayed cables, cable towers, and main beams, they are prone to varying degrees of deformation, resulting in stress changes in the structure.

3.2 Creep Control and Construction Optimization

Based on the analysis of creep influencing factors, this article takes the ballastless track laying project of a 420m ultra long span high-speed railway cable-stayed bridge as the object, and its structure is shown in Figure 1. Firstly, through cable force calculation, the stress conditions during the construction process of the cable-stayed bridge are clarified; secondly, appropriate materials and structural forms are selected to meet the requirements of cable-stayed bridge structures; finally, the secondary tensioning method is adopted, and the degree of tensioning is adjusted during the construction process to reduce the impact of creep on the structure, ensuring its stability and adaptability to the entire bridge structure.

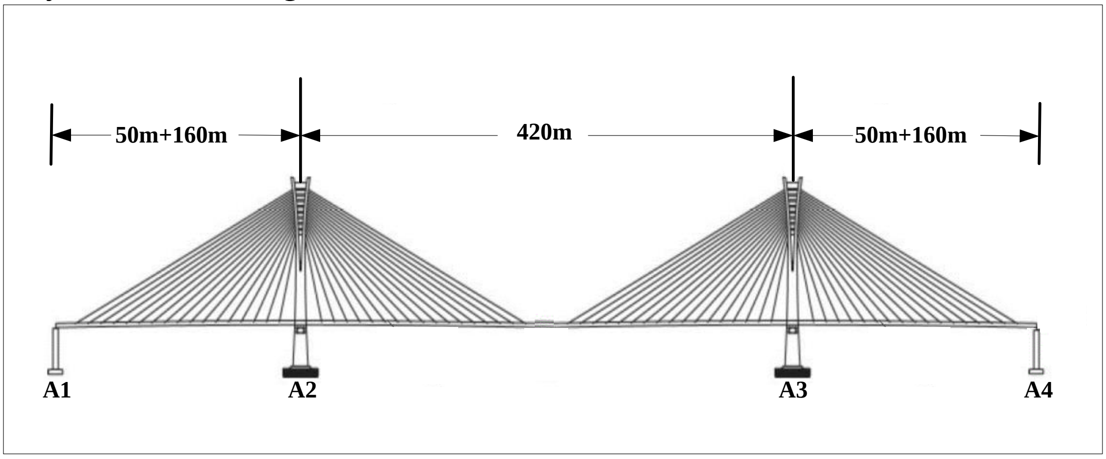

Figure 1: Structure of a cable-stayed bridge spanning high-speed rail

(1) Creep control

During the construction process of laying ballastless tracks in cable-stayed bridges, the main beam is first erected and then tensioned once. After the bridge deck is erected, the cable-stayed cables are tensioned again. In this way, the first tension is replaced by the tension obtained from the second tension. The difference method is used to achieve forward iterative solution of the tension of the cable-stayed system during the construction period. The tension t_1 for the first tensioning is expressed as [10]:

$$t_1 = f_c \tag{1}$$

The difference between the final bridge state cable force f_c and the designed bridge cable force f_d is:

$$\Delta f_c = f_d - f_c \tag{2}$$

The tension for the second tensioning is expressed as:

$$t_2 = t_1 + \Delta f_c \tag{3}$$

Furthermore, the tension input model for the second tensioning is calculated, and the second iteration begins. This cycle continues until the accuracy of the difference between the calculated and designed bridge cable forces meets the requirements. In the actual construction process, calculating tension changes and adjusting cable forces through models can effectively ensure the stability and creep control of cable-stayed bridge structures.

(2) Construction optimization

Based on the tension calculation results, the construction optimization is carried out. This article divides the construction of ballastless track laying into two parts: the laying of concrete base plates and track plates. Before construction, excavation, leveling, and cleaning of the foundation are carried out to ensure that the foundation surface has appropriate flatness and firmness. In response to the characteristics of a 420m cable-stayed bridge, such as a large span and significant differences in cable tension after adjustment, in order to meet the linear error of the bridge as much as possible at a reasonable level while considering construction errors, this article focuses on increasing the thickness of the foundation slab as the main research content and optimizing the construction plan. By setting a thick layer of elastic rubber cushion between the base and self compacting concrete, the thickness of the bottom plate can be increased.

During the specific construction process, concrete is prepared and poured on the track foundation to form a uniform and flat concrete base. The bottom plate is divided into prefabricated sections and cast-in-place sections, with the prefabricated section made of high-performance concrete and the cast-in-place section made of low shrinkage and micro expansion concrete. To reduce the adverse effects of concrete shrinkage and creep on the structure, the storage period of precast concrete panels should be maintained at least 6 months. Prefabricated panels are symmetrically arranged along the centerline of the main beam. The prefabricated panels on one side of the centerline of the main beam are divided into inner and outer dedicated panels, and marked on the prefabricated panels to distinguish between the inner and outer sides.

The laying of track panels is divided into two processes: rough laying and fine adjustment. On this basis, the longitudinal section of the track and the coordinates on the bottom plate are marked. Then, according to the measured position, a dedicated crane is used to place the track plate in place. Fine tuning refers to the precise adjustment of track panels according to design requirements. After all processes are completed, sealing work can be carried out, and the bottom plate and track panels can be poured to achieve the laying of ballastless tracks.

4. Creep Control and Construction Effect Experiment

To verify the effectiveness of creep control and construction technology in this article, the stability and safety of laying ballastless tracks on high-speed railway cable-stayed bridges are analyzed from two aspects: creep measurement and structural safety assessment.

4.1 Creep Measurement

Creep measurement aims to detect and analyze the stress creep data of ballastless track laying on cable-stayed bridges, and check whether the stress changes are within a reasonable range. In the experiment, sensors are used to detect the creep of the control points of the cable-stayed bridge structure. Three control points are randomly selected, and then the tension of the control points is tracked through sensor equipment. The absolute value of the cumulative change in the horizontal axis of the control point plane is statistically analyzed for a period of one period. The final result is shown in Figure 2:

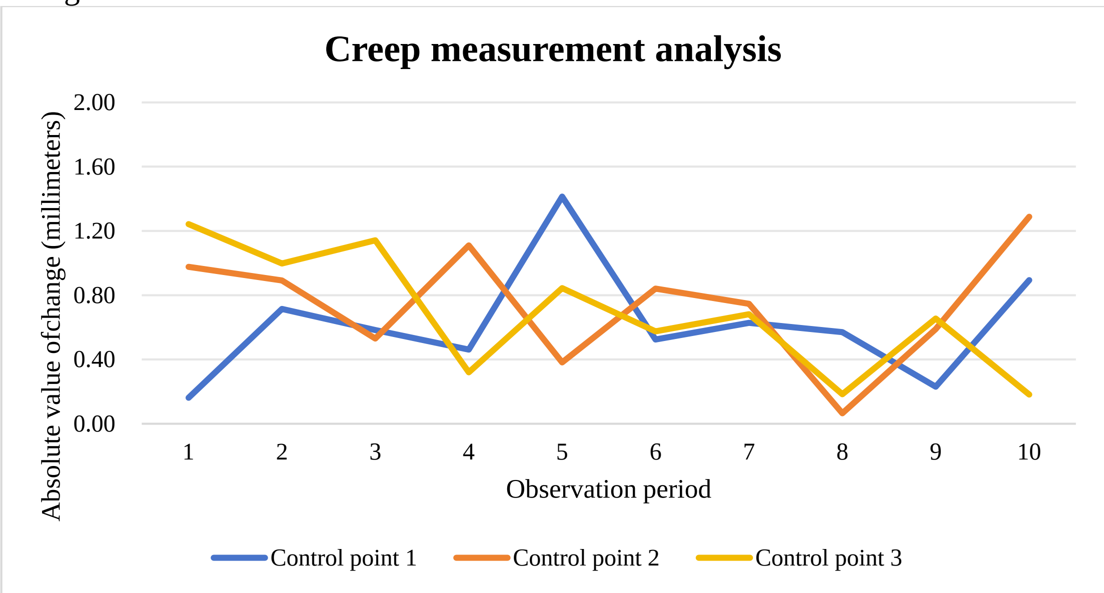

Figure 2: Creep measurement results

From the creep measurement results in Figure 2, it can be seen that the stress creep of the three randomly selected control points remains within a reasonable range during the observation period. Among them, the maximum horizontal coordinate change of control point 1 during the observation period is 1.41 millimeters, and its average cumulative change is about 0.62 millimeters; the maximum variation of control point 2 during the observation period is 1.29 millimeters, with an average cumulative variation of approximately 0.74 millimeters; the maximum variation of control point 3 during the observation period is 1.24 millimeters, and its average cumulative variation during the observation period is about 0.68 millimeters. From the overall creep measurement results, it can be seen that the average cumulative change does not exceed 1 millimeter. This indicates that under the creep control and construction method in this article, the creep effect of laying ballastless tracks on cable-stayed bridges is not significant, and their structures have strong stability.

4.2 Structural Safety Assessment

The purpose of structural safety assessment is to verify the safety of the ballastless track structure laid on cable-stayed bridges. As a special structural form, the track part of a cable-stayed bridge plays a crucial role in the entire bridge. This article calculates the strength of ballastless tracks under different load combinations and evaluates the safety factors of three control points during the observation period based on this. The final result is shown in Figure 3:

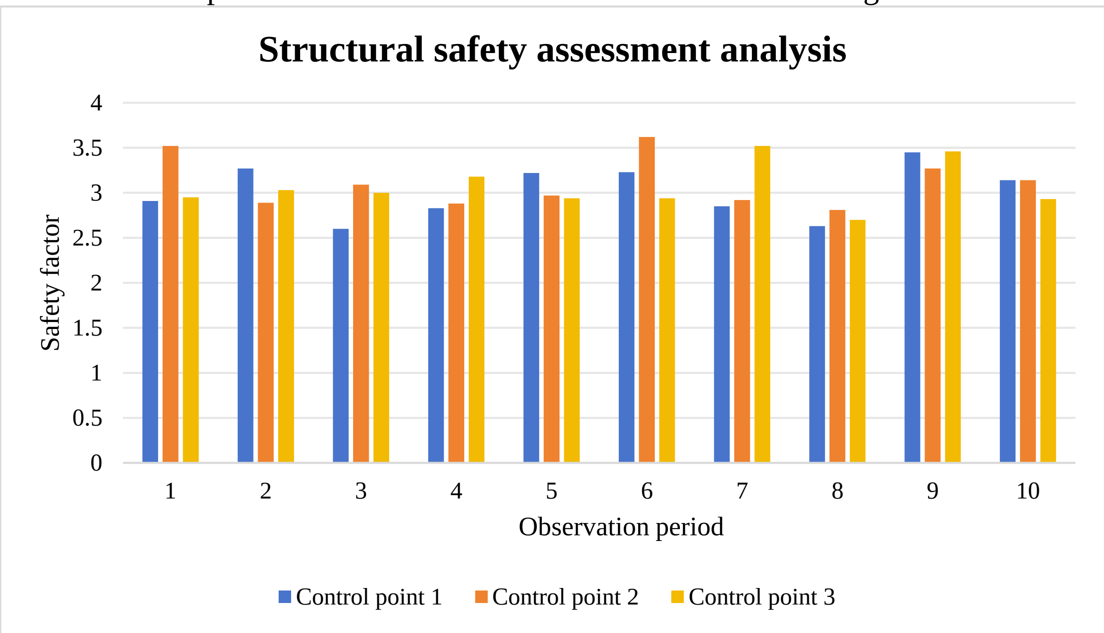

Figure 3: Results of structural safety assessment

From the structural safety assessment results in Figure 3, it can be seen that the safety factors of the three control points have all reached above 2.50 during the observation period. Among them, the highest safety factor of control point 1 reaches 3.45, and its average safety factor during the observation period reaches about 3.01; the highest safety factor of control point 2 reaches 3.62, and its average safety factor during the observation period is about 3.11; the highest safety factor of control point 3 reaches 3.52, and its average safety factor during the observation period is about 3.07. From the overall results, it can be seen that under the creep control and construction technology in this article, the safety factor of laying ballastless track structures on cable-stayed bridges has been maintained within a reasonable range, and its structure has high safety.

5. Conclusions

With the increasing demand for high-speed rail construction, the quality of ballastless track laying for ultra long span cable-stayed bridges has become an important factor affecting transportation safety. In order to optimize the laying of ballastless tracks and achieve good safety and stability, this paper took the laying of ballastless tracks on a 420m ultra long span high-speed railway cable-stayed bridge as the object, and conducted in-depth research on its creep control and construction technology. This has not only improved the creep control of ballastless track laying in cable-stayed bridges to a certain extent, ensuring the stability of the engineering structure, but also enhanced the safety factor of the ballastless track structure, making it more ideal in terms of safety. Although the research on creep control and construction technology for laying ballastless tracks on a 420m ultra long span high-speed railway cable-stayed bridge has certain guiding significance for improving the quality and reliability of ballastless tracks and improving transportation levels, there are still some limitations in this article. In future research, it would be considered to conduct in-depth discussions on creep control of ballastless tracks under different environmental and construction conditions, in order to promote the high-quality development of rail transportation.

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