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Analysis of Bridge-Bearing Capacity Detection and Evaluation Technology

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Abstract: A bridge project is taken as an example to analyze the application of bearing capacity detection and evaluation. This article provides a basic overview of the project, the application of bearing capacity detection technology, and the bearing capacity assessment analysis. It is hoped that this analysis can provide a scientific reference for the load-bearing capacity detection and evaluation work in bridge engineering projects, thereby achieving a scientific assessment of the overall load-bearing capacity of the bridge engineering structure.

Keywords: Bridge engineering structure; Bearing capacity; Calculation model; Detection points; Quantitative standards

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1. Introduction

Load-bearing capacity testing and evaluation are the most critical tasks in bridge engineering projects' quality and safety assessment [1]. Based on this, reasonable technical measures should be taken to evaluate its bearing capacity. In this way, its bearing capacity can be determined, thereby supporting its subsequent operation, maintenance, and application [2].

2. Project overview

The total length of the bridge project studied is 30 m, divided into the left and right parts. The upper part is a hollow beam-slab structure called hollow plate beam concrete. The pile foundation is a bored pile in the form of reinforced concrete. The foundation is a structure with a single row of piles. The load design value of the overall bridge is level 20 for cars and level 100 for trailers. The specifications of the top plate are 11.8 m, the width of the bottom plate is 5.5 m, the distance from the beam legs to the bridge is 7.0 m, and the single section size of the pier top is 8.5*3.5 m. There are 20 pile foundations on the bearing platform; each has a diameter of 2.0 m, and the overall design specification is in the form of end-bearing piles. Since the bridge project is in a mountainous area, groundwater, such as karst water, loose rock pore water, and bedrock fissure water, is corrosive to the reinforced concrete foundation structure. Moreover, the bridge has been in continuous use for nearly 20 years. Therefore, to ensure the use effect and the safety of the bridge project, its bearing capacity should be evaluated properly. This article analyzes the detection and evaluation of the bridge engineering load-bearing capacity.

3. Application of bridge bearing capacity detection technology

3.1. Establishment of bearing capacity calculation model

Establishing a scientific and reasonable calculation model for this bridge engineering structure is crucial when testing its load-bearing capacity. In this project, the beam grid system is used to establish the bearing capacity calculation model [3]. The stiffness parameter reduction was analyzed based on the actual measurement results of the bridge project and the deterioration of the steel-concrete structure. The contribution of the bridge railings, sidewalks, and bridge deck paving to the overall structural load-bearing capacity was considered. The strength of concrete and steel bars and their elastic modulus were measured, and the nonlinear constitutive relationship of concrete was comprehensively considered. The steel bars were treated as plastic materials after yielding [4]. If the strain distribution of concrete and reinforcement, load conditions, and cross-sectional deformation parameters are given, the most unfavorable positions under given load conditions could have been calculated. Then, the actual load effects on each cross-section could be obtained. However, because the external load parameters could not be determined in this project, it might lead to inaccuracies in the calculation model. To solve this problem, the partial coefficient setting method was used to reasonably allocate values to reduce the uncertainty of external load parameters. With the safety of the bridge as the basic assumption, the safety factor in the calculation model was continuously reduced to obtain more accurate calculation results [5]. The sub-item coefficients were calculated based on the following two conditions.

The first condition is that the gravity effect of the bridge engineering structure will negatively affect its bearing capacity. Therefore, the partial coefficient in this state can be calculated according to Equation 1.

$$S_u = 1.2S_G + 1.4S_Q \tag{1}$$

Among them, S_U represents the partial coefficient, S_G represents the gravity effect produced by the bridge structure itself, and S_Q represents the live load effect on the stress section of the bridge structure.

The second condition is that the gravity effect of the bridge engineering structure will positively affect its bearing capacity. The partial coefficient in this state can be calculated according to the following formula:

$$S_u = 1.0S_G + 1.4S_Q \tag{2}$$

If no load test is carried out, the values of the partial coefficients can be set according to the design requirement. Considering the aforementioned conditions, the following calculation model was created.

$$F = \frac{R - r_G \times S_G}{r_Q \times S_Q \times (1+\mu)} \cdot S_u \tag{3}$$

In Equation 3, F represents the actual load-bearing capacity of the bridge; R represents the force section resistance; r_G represents the partial coefficient of the bridge under dead loads; r_Q represents the partial coefficient of the bridge under live load; μ represents the impact coefficient formed under live load [6].

3.2. Load conditions and detection point settings

The load-bearing capacity was determined through two load conditions. The first condition was setting a longitudinal load in the middle section of the bridge and a medium load in the transverse direction of the bridge; the second condition was to set a longitudinal load at both ends of the bridge structure and an eccentric load in the transverse direction of the bridge [7]. After the above two load conditions were determined, the detection points on the structure were arranged based on the actual conditions of the bridge project site. To achieve synchronous acquisition of the bearing capacity data of each detection point and prevent the scanning blind spots from overlapping with the detection point data, 30 detection points were set up based on the characteristics of the bridge. The detection data were collected and subbed into the established bearing capacity calculation model. The load capacity of the bridge was then calculated [8].

3.3. Quantitative standard-setting

To ensure standardized subsequent assessment results during the load-bearing capacity testing and evaluation, scientific quantitative standards are needed. Additionally, to facilitate the establishment of bridge engineering archives, the concept of bridge health value should be introduced into the assessment. The actual load-bearing capacity of bridge engineering structures is used as the basis, and their load-bearing capacity is divided into four levels in descending order [9]: (1) Excellent – load-bearing capacity of > 80 t; 2) Good – load-bearing capacity of 60–80 t; 3) Average –load-bearing capacity of 40–60 t; 4) Poor – load-bearing capacity of < 40 t [10]. In this way, the load-bearing capacity of the bridge engineering structure can be reasonably and intuitively quantified, thereby facilitating the operation and maintenance of the bridge and ensuring its safety.

4. Bearing capacity assessment and analysis

4.1. Quantitative assessment of bearing capacity

After determining the load-bearing capacity of the bridge, its health status should be evaluated based on its bearing capacity. To achieve this goal, in this inspection, 10 out of 30 monitoring points arranged on the bridge engineering structure were arbitrarily selected, numbered from 1# to 10#. The data obtained from these points were processed using the load-bearing capacity calculation model, allowing for the scientific acquisition of load-bearing capacity parameters at various monitoring points on the bridge structure. **Table 1** presents the load-bearing capacity values obtained during the load-bearing capacity testing of this bridge engineering project.

Table 1. Bearing capacity values of the bridge

Serial number	Detection point	Bearing capacity	Serial number	Detection point	Bearing capacity
1	Detection point 1#	86.2 t	6	Detection point 6#	84.2 t
2	Detection point 2#	65.2 t	7	Detection point 7#	61.2 t
3	Detection point 3#	69.2 t	8	Detection point 8#	62.3 t
4	Detection point 4#	84.2 t	9	Detection point 9#	84.2 t
5	Detection point 5#	86.2 t	10	Detection point 10#	89.2 t

From the data in **Table 1**, it is clear that, within the studied area, except for detection points 2#, 3#, 7#, and 8#, the load-bearing capacity of the bridge engineering structure at all other monitoring points exceeded 80 t. Additionally, the average load-bearing capacity across all points surpassed 80 t. Comparing these results with the quantitative standards for load-bearing capacity, it is evident that detection points 1#, 4#, 5#, 6#, 9#, and 10# had achieved an excellent status, indicating a very healthy bridge structure. Meanwhile, points 2#, 3#, 7#, and 8# fell into the good category, indicating relatively healthy conditions. Subsequent field inspections at points with good status uncovered issues like localized joint seepage and mortar spalling due to corrosion. Moving forward, relevant personnel need to address these concerns with tailored maintenance and repair measures to elevate their load-bearing capacity to an excellent level. Only then could the overall bridge structure meet the demands of practical use, ensure safe passage for vehicles, and extend its service life effectively.

4.2. Bearing capacity limit assessment

After quantitatively analyzing and evaluating the load-bearing capacity of the bridge, its load-bearing capacity limit was analyzed. For this particular bridge, the actual design load standards of the bridge project were used as a basis for the limit state calculation. Vehicle loading levels such as Class 20 for cars and Class 100 for trailers were used. The mid-span deflection and bending moment were measured at the most unfavorable position (Condition 1). The section bending moment was measured at the most unfavorable position (Condition 2) the shear force at the support section's most unfavorable location was designated as Condition 3. Using these load level conditions as a basis, personnel calculated the load internal forces at various limit positions. **Table 2** presents the results of the limit state testing in the load-bearing capacity testing of this bridge engineering project.

Table 2. Limit state detection results

Serial number	Load level	Limit conditions	Maximum internal force	Bearing capacity limit	Compliance with the specification?
1	Car Level 20	Condition 1	425.13 kN	1826.25 kN	Yes
2	Car Level 20	Condition 2	402.36 kN	2536.25 kN	Yes
3	Car Level 20	Condition 3	411.23 kN	1956.54 kN	Yes
4	Trailer level 100	Condition 1	412.25kN	2012.36 kN	Yes
5	Trailer level 100	Condition 2	405.26kN	2136.25 kN	Yes
6	Trailer level 100	Condition 3	423.81kN	2215.23 kN	Yes

From the data shown in **Table 2**, it is clear that the overall load-bearing capacity limits of the bridge engineering structure meet the design specifications for Class 20 cars and Class 100 trailers. This indicates that the bridge engineering structure is still in normal operational condition. In the subsequent operation and management work, to further ensure the overall load-bearing capacity of the bridge engineering structure, relevant units and personnel need to consider the specific testing conditions and appropriately address areas with lower load-bearing capacity. Only through such measures can the overall quality and safety of the bridge engineering structure be effectively ensured, enhancing the performance of various types of traffic vehicles on it and further extending its service life.

5. Conclusion

In summary, one of the key aspects in assessing the quality and safety of existing bridge structures is thoroughly testing and evaluating their load-bearing capacity at different points. This process is crucial for determining the structures' actual operational status and guiding subsequent maintenance and repair efforts. To accomplish this, it's essential for relevant units and personnel to use the structure's design standards as a reference and employ suitable technical measures for comprehensive testing, calculation, and evaluation of its load-bearing capacity. This approach ensures accurate assessment and supports the development of effective maintenance plans, ultimately enhancing overall engineering quality and meeting practical application needs.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wang Z, 2023, Comprehensive Assessment of Bridge Bearing Capacity based on Special Inspection and Load Test. Anhui Architecture, 2023(12): 177–179.

[2] Sun Y, Mo S, Zhou X, et al., 2023, Research on the Carrying Capacity of a Bridge Renovation Project Under Dynamic and Static Loads. Architecture and Decoration, 2023(21): 172–174.

[3] He Z, 2023, Research on Load-Carrying Capacity Assessment of Existing Masonry Arch Bridges with Missing drawings. Guangdong Civil Engineering and Architecture, 2023(10): 103–105.

[4] Xu J, 2023, Analysis and Analysis of the Load-Bearing Capacity of In-Service Rigid-Frame Arch Bridges Based on Load Tests. Engineering Technology Research, 2023(18): 33–35.

[5] Yao W, 2023, Research on Key Points of Bridge Load Testing Based on Bridge Load-Bearing Capacity and Engineering Quality. China New Technologies and New Products, 2023(13): 105–107.

[6] Wu Z, 2022, Application of Highway Bridge Bearing Capacity Assessment. Construction Technology Development, 2022(10): 49.

[7] Huang H, Liao H, Zhu L, 2022, Carrying Capacity Assessment and Disease Analysis of Long-Span Continuous Bridges. Northern Communications, 2022(1): 9–12.

[8] Wu Y, Yang B, Zhu S, 2022, Research on Load-Carrying Capacity Assessment of Existing Hollow Slab Bridges. China Highways, 2022(6): 110–111.

[9] Gu S, Lu Y, Gu Y, et al., 2024, Experimental Study on Steel Hoops' Stress Characteristics and Load-Bearing Capacity. Highway Transportation Science and Technology, 40(12): 74–81.

[10] Nan H, Wei Q, 2022, Bridge Detection Based on Load Test. Heilongjiang Transportation Science and Technology, 2022(2): 45.