Analysis of Safety Assessment and Testing of Heavy Traffic Vehicles on Old Bridges Without Data

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Abstract: This article presents a real-life project that aimed to evaluate the safety of traffic vehicles on old bridges without any prior data. The project involved various safety inspections, including conventional, static, and dynamic load inspections and safety assessments. After conducting these tests, it was concluded that the structure of the old bridge is relatively safe, with only a few bumps. The bridge could function normally following appropriate treatment. The analysis provides valuable insights into the assessment of the quality and safety of such bridges to ensure the safe driving of heavy vehicles.

Keywords: Old bridge; Absence of data; Heavy vehicles; Safety inspection; Safety assessment

1. Introduction

The design and construction data for some old bridges may no longer be available. Therefore, to ensure the safety of driving across the bridge, a safety assessment needs to be conducted through a few tests [1]. In this way, the operation, the durability, and the safety of the bridge can be guaranteed

2. Project overview

The project that will be discussed in this paper is an old four-span supported bridge project. The design and completion date of the project could no longer be found. There was only a nameplate on the bridgehead that stated that it was constructed in 1991. Field measurements showed that each span of the old bridge was 16 m, and the width of the bridge deck was 8 m. There was an ongoing building construction near the old bridge, so it had to withstand heavy vehicles like flatbed trucks and dump trucks. The traffic requirements dictated that 100-ton flatbed trucks should be able to pass independently at normal speeds; the 100-ton flatbed truck should be able to pass independently along the center line of the bridge at a normal speed; the 40-ton dump truck should be able to pull over and cross the bridge independently at a normal speed; the 15-ton unloaded dump truck

should be able to return at normal speed and together with the dump truck. However, since the bridge had not been tested for the safe passage of heavy vehicles, the relevant units decided to inspect and evaluate the safety of the bridge based on the requirements mentioned. This article is an analysis of its safety tests and assessment.

3. Heavy vehicle safety assessment, testing, and analysis

3.1. Routine testing

Routine testing is the most basic form of test when it comes to safety testing. It involves an observation of the bridge's appearance, bridge deck system inspection, superstructure inspection, bridge support inspection, substructure inspection, and inspection of other ancillary equipment, etc [2]. It was observed that the main beams of each span in the old bridge project were all made of C40 concrete, and the piers were all made of C35 concrete. Its main load-bearing components were all in good condition. However, there were some noticeable bumps at the 0# abutment and 4# abutment. If a load-carrying vehicle were to pass over these areas, it would subject the main beams of spans 1# and 4# to significant impacts. This could potentially lead to damage or further exacerbate existing damage, thereby compromising the safety and durability of the overall bridge structure. Therefore, the bumps had to be flattened to make the overall bridge deck smoother [3].

3.2. Static load test

Static load test is a crucial part of bridge safety testing [4]. In this test, a 43t truck was stationed on the right and left sides of the bridge. The first test conducted was the deflection test. Two deflection detection points were positioned on the left side of the bridge, namely A1 and A2, along with four deflection detection points on the mid-span section, namely B1, B2, B3, and B4. Additionally, two deflection detection points were set on the right section of the bridge, namely C1 and C2 [5]. The result of the deflection test is shown in **Table 1**.

Table 1. Deflection detection results

Serial number	Project	Deflection test results (unit: mm)							
		A1	A2	B1	B2	B3	B4	C1	C2
1	Level 1 load	0.6	0.3	4.2	4.0	3.1	2.3	0.4	0.0
2	Level 2 load	1.0	0.5	7.5	7.2	5.8	5.2	0.7	0.7
3	Unloading	0.4	0.2	0.1	0.5	0.2	0.7	0.3	0.2
4	Full load elasticity with support	0.7	0.3	7.4	6.8	5.5	4.4	0.5	0.5
5	Full load elasticity without support	-	-	7.0	6.3	5.1	3.9	-	-
6	Full load elasticity theoretical value	-	-	7.6	6.9	5.5	4.9	-	-
7	Test coefficient	-	-	0.92	0.91	0.92	0.80	-	-
8	Residual ratio	-	-	1.3%	6.9%	3.4%	13.5%	-	-

According to this project's specifications, each span beam's deflection coefficient should be between 0.7 and 1.05. The measured deflection coefficient was 0.8–0.95, which was well within the specified range. The residual ratio of each deflection point was also within 20%, which indicated that the bridge was qualified for normal operations.

The second test that was carried out was the strain test. 10 observation points were set on the supported beam's mid-span section, and the strain data of the simply supported beam at its first span under various experimental design conditions were measured. The deflection coefficient obtained at each measuring point was

measured to be 0.75–0.95, which aligned with the specifications of the project. The residual ratio at each strain point position was less than 7%, indicating that the old bridge structure could function normally. **Table 2** shows the test strain detection results in this project:

Table 2. Test span strain detection results in this project (part)

Serial number	Project	Strain detection results (unit: με)				
		Point 1	Point 2	Point 3	Point 4	Point 5
1	Level 1 load	97.6	46.3	50.4	9.4	18.2
2	Level 2 load	204.3	179.8	178.5	176.9	174.3
3	Unloading	10.1	12.5	8.9	10.4	10.8
4	Full load measurement	194.2	167.4	169.6	166.5	163.5
5	Full load theoretical value	238.0	202.1	202.1	181.7	181.7
6	Test coefficient	0.82	0.83	0.84	0.92	0.90
7	Residual ratio	4.9%	7.0%	5.0%	5.9%	6.2%

No significant lateral stress cracks were found on the old bridge structure before and during the tests. Through the static load tests, it is clear that the deflection and strain coefficients of the old bridge structure were consistent with the specifications of this project, and no lateral stress cracks were found during the test [6]. This indicated that each span in the old bridge structure could still work normally and withstand heavy vehicles on full load.

3.3. Dynamic load tests

After the static load tests, dynamic load tests were carried out. These tests ensure that the heavy vehicles can move past the bridge safely. There are two tests involved in dynamic load tests.

The first test was to measure the natural vibration frequency of the bridge without any vehicles on it [7]. The theoretical natural vibration frequency of the bridge without vehicles was calculated to be 8.8 Hz. However, the measured natural vibration frequency of the first span was 9.10Hz, that of the second span was 9.11Hz, and for the third span, it was 9.08Hz. As for the fourth span, its natural vibration frequency was recorded at 9.21Hz. Based on these results, it was clear that the actual natural vibration frequency of each span of the bridge exceeded the theoretical value, indicating that the overall stiffness of the old bridge structure is greater than the expected value, making it suitable for normal operations.

The second test involved driving a test car over the old bridge structure at various speeds to measure the vibrations experienced by the bridge under different driving conditions. This included analyzing the vibration frequency, vibration amplitude, and impact coefficient of the old bridge structure across different driving scenarios of the test car [8]. The vehicle was driven at speeds of 20 km/h and 30 km/h. Several dynamic vibration sensors were placed on the bridge deck and mid-span of each span. The vibrations of each measuring point were measured under dynamic load conditions. According to the requirements of this project, the impact coefficient of the old bridge structure should be 1.218 and below. Under the first test condition with the car driving at 20 km/h, the actual impact coefficients of the four spans of the bridge were measured as follows: for the first span, the coefficient was 1.216, for the second span, it was 1.106, for the third span, it was 1.103, and for the fourth span, it was 1.208.

Under the second test at 30 km/h, the impact coefficients were as follows: 1.231 for the first span, 1.112 for the second span, 1.115 for the third span, and 1.226 for the fourth span. Comparative analysis showed that

the impact coefficients of the second and third spans of the old bridge did not exceed the theoretical values during the two-vehicle driving tests. However, among them, the impact coefficients of the first and fourth span structures exceeded the theoretical values under the second driving condition, indicating insufficient impact resistance. Upon visual inspection of these two parts, it was found that the reason for this situation was that the first and fourth spans were uneven, which made the spans bumpy, leading to a high impact coefficient. If these problems were not addressed, the main beam structures of the first and fourth spans would gradually deteriorate due to the rapid passage of heavy traffic vehicles, compromising the durability of the overall structure and posing significant safety risks. To prevent such problems, before the old bridge structure was put into use, the bridgeheads of the first and fourth spans were leveled. This measure could effectively eliminate bumps and reduce the impact coefficient when heavy traffic vehicles are traveling rapidly [9].

3.4. Safety assessment

Based on the actual situation and theoretical analysis of the old bridge project site, traffic conditions for the 100-ton heavy-duty flatbed truck dictated that only one vehicle could pass along the center line, with its driving speed controlled at 30 km/h. For 40-ton heavy-duty dump trucks, normal driving speeds were permitted. Similarly, 15-ton unloaded dump trucks could be driven at normal driving speeds. However, in practical applications, to ensure the safety of heavy vehicle operation and enhance the durability of the bridge, the driving speed of all heavy vehicles was limited to 30 km/h [10].

According to the safety test evaluation results, the overall appearance of the bridge was satisfactory, with no noticeable issues, except for significant bumps detected at abutment 0# and abutment 4#. The static load test shows that the bridge can fully meet the independent driving needs of the 100-ton heavy-duty flatbed truck on the center line and can also meet the load-carrying requirements of the 40t dump truck when it pulls aside on the bridge and when it meets the 15-ton unloaded dump truck on the bridge. Additionally, the dynamic load test demonstrated that the second and third-span bridgeheads met the practical application requirements. However, the first and fourth spans' bridgeheads were uneven, necessitating appropriate leveling measures.

4. Conclusion

Before an old bridge is put into use for heavy vehicles, if its original design and construction information cannot be retrieved, reasonable testing methods must be conducted to evaluate its safety. These tests include routine testing, static and dynamic loads, and more. By assessing the deflection, strain, and impact coefficients of the structure under various test conditions, structural problems can be discovered and addressed in time. This approach ensures the structural integrity of the old bridge and that it meets actual transportation requirements. Additionally, it significantly prolongs the old bridge structure's service life and reduces subsequent operation and maintenance costs.

Disclosure statement

The authors declare no conflict of interest.

References

[1]   Wang H, Lan R, Feng X, et al., 2023, Safety Analysis of Cracking Diseases of the Bottom Plate of an Old Reinforced Concrete Hollow Slab Bridge. Western Transportation Science and Technology, 2023(8): 1–3.

[2] Xin N, 2021, Inspection, Evaluation, and Carrying Capacity Analysis of Old Bridges in A Certain City. Transportation Manager World, 2021(27): 107–109.

[3] Liu L, 2020, Research on Safety Assessment and Shear Reinforcement Methods of Old Prefabricated Hollow Slab Bridges, dissertation, Southeast University.

[4] Jiang Q, Tao F, Zhang Y, et al., 2022, Research on Vehicle Safety Detection Systems Based on Big Data Analysis. Journal of Jiangxi Normal University: Natural Science Edition, 46(6): 649–654.

[5] Fu S, Qie Y, 2017, Application of Comprehensive Assessment Method in Safety Inspection and Assessment of Old Highway Bridges - Taking the Safety Inspection and Assessment of a Bridge in Hebei Province as an Example. Journal of Hebei Transportation Vocational and Technical College, 2017(3): 33–39.

[6] Huang Q, 2023, Discussion on Safety Assessment and Management Technology of Overweight Vehicles on Highway Bridges. Fujian Transportation Science and Technology, 2023(6): 70–75.

[7] Li S, 2023, Research on Water Traffic Safety Risk Assessment in Typical Reservoir Areas in Guizhou Province. Pearl River Water Transport, 2023(9): 26–28.

[8] Zhang Z, 2023, Discussion on the Life Extension Evaluation Method of Shanghai Rail Transit Vehicles. Urban Rail Transit Research, 26(1): 37–41.

[9] Ding Y, 2023, Research on Urban Rail Transit Vehicle Body Crack Control Strategies Based on Safety Risk Assessment. Urban Rail Transit Research, 26(6): 184–187.

[10] Miao F, 2023, Research on Safety Assessment Methods of Bridges Carrying Special Vehicles. Fujian Architecture, 2023(3): 82–85.