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Study on the Method of Technical Condition Evaluation Index Based on the Measured Results of Natural Frequency of Bridge Superstructure

Hao Zheng[1]

[1] Hunan Expressway Group Co., Ltd, Changsha, Hunan 410015, China

Correspondence: Hao Zheng, Hunan Expressway Group Co., Ltd, Changsha, Hunan 410015, China.

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Abstract

With the growth of bridge service periods and the gradual degradation of the function, and reasonable evaluation of its technical conditions, it is very important for maintenance decision-making. Especially for the bridge after some reinforcement disposal, the original structure does not have conditions in accordance with conventional detection, and it is more difficult to accurately grasp the actual working state of the bridge. The self-vibration frequency is an inherent characteristic of the bridge. When the bridge function declines, its structure rigidity decreases. In fact, the measurement of the self-vibration frequency also decreases accordingly, which directly reflects the working status of the bridge. Therefore, finding the relationship between the actual measurement results of the bridge autobiography and the level of its technical status can not only quickly grasp the working status of the bridge, but also reflect the hidden diseases that cannot be detected with conventional means, and can also be reflected by the self-vibration frequency. The technical condition evaluation method based on the measured results of natural frequency can provide reliable decision-making basis for bridge maintenance management department in bridge maintenance.

Keywords: disease, natural frequency, technical condition index, appraising method

1. Introduction

Bridges deteriorate gradually over their service life, making accurate assessment of their technical condition crucial for future maintenance decisions (Jinxiang Lu, 2013). Numerous methods have been proposed by researchers worldwide (Baixue Hu, Haiqiu Xie & Chunlin Yang, 2004; Jianglie Gong & Yangfan Zhou, 2015; Jinghong Qin, 2015; Yang Guo, Yongfeng Du & Bangying Li, 2008). However, these methods may not be suitable for reinforced bridges or those where conventional detection methods cannot accurately identify deficiencies (Junhai Ma, Airong Chen & Wenxue Zhang, 2006; Wei Liu, 2013). With advancements in sensor technology, measuring the natural frequency of bridges has become convenient. Therefore, identifying the quantitative relationship between a bridge's natural frequency and its technical condition is essential for effective maintenance decisions and management.

2. Current Bridge Assessment Methods

2.1 "Technical Condition Assessment Standards for Highway Bridges" (JTG T H21-2011)

This widely used method for highway bridges has the following features:

(1) Categorization and Rating: Bridges are categorized by type, with detailed component classification.

(2) Quantitative Indicators: Assessment details and quantitative standards are based on component types.

(3) Single-Item Control Indicators: Five categories of single-item control indicators are proposed. Meeting these

indicators results in a direct overall condition rating.

(4) Refined Assessment Model: The model evaluates individual components, bridge parts, deck systems, superstructures, and substructures before providing an overall condition assessment.

However, this method lacks clarity on parameters undetectable by conventional means, such as effective prestress and grout fullness in ducts. Additionally, reinforced bridges pose challenges due to altered structural states after reinforcement.

2.2 "Urban Bridge Maintenance Technical Specification" (CJJ99-2017)

This method categorizes bridges based on their urban significance, using different assessment techniques accordingly. It provides qualitative and quantitative damage descriptions, reducing subjective influence through a scoring model. However, it has logical flaws and shares limitations with the first method, particularly for significantly widened urban bridges beyond current inspection vehicle capabilities.

2.3 International Bridge Condition Assessment Methods

(1) Germany

The Germany's method divides structures into 13 component groups, further subdivided for detailed evaluation. Each damage type has corresponding coefficients for traffic safety, stability, and durability, which determine the condition rating.

(2) Denmark

The Denmark's method evaluates 15 standard components before an overall bridge assessment. The principle ensures the overall condition cannot exceed the highest component rating or fall below any major component's rating.

(3) United States

The "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" assesses condition based on deck systems, superstructures, substructures, and waterway protection. Condition levels range from 0 to 9, with "9" indicating the best condition and "0" indicating an unrepairable state.

3. Proposed Assessment Method

3.1 Natural Frequency-Based Technical Condition Assessment

Given the limitations of current methods, a simple, practical, and objective assessment method is necessary. Many factors, such as initial construction defects, concrete carbonation, steel corrosion, prestress loss, steel plate rusting, and carbon fiber aging, reduce structural stiffness. Understanding the relationship between stiffness decay and technical condition allows for accurate assessment using natural frequency measurements.

3.2 Procedure of the Assessment Method

(1) Collect the initial natural frequency of the bridge structure: After the bridge is completed and passes acceptance inspection, test and record the initial natural frequency of the bridge as baseline stiffness data.

(2) During regular inspections, measure the natural frequency of the bridge using dynamic testing methods. Compare the measured natural frequency with the initial natural frequency to determine the bridge's technical condition assessment coefficient.

(3) Based on the technical condition assessment coefficient, calculate the bridge's technical condition assessment index. Use the index to determine the technical condition rating according to the following table.

Table 1. Bridge Technical Condition Assessment Standards

Assessment Index	**Index Range**	**Assessment Scale**
Technical Condition Assessment Index	[0.92, 1.00]	1
	[0.88, 0.92)	2
	[0.85, 0.88)	3
	[0.78, 0.85)	4
	< 0.78	5

3.3 Advantages and Disadvantages of this Assessment Method

The index method based on natural vibration frequency is simple to operate and has clear mechanical concept, especially when bridge function degradation and damage cannot be detected directly. Compared with traditional methods, this method has the following characteristics: (1) Overcoming the limitation of current bridge detection methods, such as the effective prestress of prestressed steel bar, the fullness of prestressed hole and cast-in-place concrete in steel tube, the internal damage of original structure after sticking steel, the aging degree of carbon fiber cloth, the corrosion degree of stay cable, etc. There is no good detection method to determine the degree, but this method directly skips the detection step and directly establishes the relationship between stiffness and technical condition scale, which greatly simplifies the detection process. (2) The method only needs to obtain the natural frequency of the structure, and other factors are not considered. The operation is fast and convenient, so the evaluation method is simpler.

Of course, there are some problems in this method: (1) The model adopted in this method is a power series relationship between technical condition evaluation index and natural frequency, and the physical concept is clear, but the correlation between them is still lacking enough evidence. (2) For conventional girder bridges and arch bridges, the experience of obtaining the natural frequency of the structure through pulsation test is relatively mature. When encountering more complex bridge structures, such as cable stayed bridges, suspension bridges, etc., to obtain the natural frequency of the structure, different test methods often get different results. Even if it is the same method, different test methods are adopted to get different results. Therefore, a lot of research and analysis work is still needed to accurately test the natural frequency of complex bridge structures.

4. Application of Engineering Examples

Ten bridges of a certain country and province in Hunan Province are evaluated according to the evaluation method of “Technical Condition Evaluation Standard for Highway Bridges” (JTG T H21-2011) and the evaluation method of bridge technical condition index based on bridge natural frequency recommended in this paper. After comparison, it is found that the evaluation results are basically consistent, which proves that the method recommended in this paper is applicable to the evaluation of bridge technical condition. The results obtained are shown in Table 2.

Table 2. Statistics of technical condition evaluation results of bridges

No.	Bridge Name	Bridge Structure	Assessment result of the first method	Bridge Technical Condition Index	Assessment result of the second method
1	Mi Shui Bridge	6×20m Hollow Slab	2	0.91	2
2	Sun Shui River Bridge	3×40m T Beam	2	0.90	2
3	Feng Ping Overpass	4×30m T Beam	3	0.87	3
4	Mo Shi Bridge	5×25m T Beam	2	0.89	2
5	Yun Shan River Bridge	4×20m Hollow Slab	3	0.86	3
6	Ba Xian Bridge	6×30m Small Box Beam	2	0.91	2
7	Huang Tan Bridge	5×30m T Beam	2	0.89	2
8	Jian Xin Bridge	5×40m Box Beam	3	0.85	3
9	Hua Xi Bridge (No. 1)	4×20m Hollow Slab	2	0.89	2
10	Hua Xi Bridge (No. 2)	5×40m T Beam	4	0.82	4

5. Conclusion

(1) There are some limitations in the current evaluation methods of bridge technical condition, especially for the evaluation of reinforced bridges.

(2) The evaluation results obtained by the evaluation method based on the bridge natural frequency evaluation index recommended in this paper are consistent with those obtained by the evaluation method of “Technical Condition Evaluation Standard for Highway Bridges” (JTG T H21-2011), which proves that this method is applicable and reliable to the evaluation of bridge technical condition.

(3) It is a practical and rigorous evaluation method to obtain the natural frequency of bridge, which is simple to operate, small in scale and without interrupting traffic. However, for other bridge types, its correlation needs further study and verification.

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