Technical Condition Evaluation of Urban Class I Special Structure Bridges

Bingjiang Yi

China Merchants Chongqing Testing Center For Highway Engineering Co., Ltd. Chongqing. 400060, China

Email:279847589@qq.com

Abstract. In order to study the reliability of technical condition evaluation method of class I special structural bridges, Taking Chongqing Chaotianmen Yangtze River Bridge as an example, The technical status of *Specifications for Maintenance of Highway Bridges and Culverts (JTG 5120-2021)*, *Standards for Technical Condition Evaluation of Highway Bridges(JTG/T H21-2011)*, *Technical standard of maintenance for city bridge (CJJ 99-2017)* were used to grade respectively, and the degree of compatibility with the actual severity of the damage was compared and analyzed. The results show that the urban standards and highway standards should be used to evaluate the complementarity of the Class I special structure Bridges, rather than the 04 version of highway maintenance specifications.

Keywords: City bridge; Special structure; Technical condition; Standard; Damage; Maintenance; Grade

1 Introduction

Bridge engineering plays a vital role in highway and urban traffic, and its safe operation is an important guarantee for the safety of transportation and has a wide impact on urban infrastructure and public safety, while the maintenance work is the most important part to ensure the safe operation of Bridges. An effective technical status assessment is carried out through the inspection and evaluation of the structural status of the Bridges in operation to provide scientific basis for maintenance work.

According to the positioning of urban Bridges in the road system, Technical standard of maintenance for city bridge(CJJ 99-2017), divide the grade of Bridges into five categories, among which Class I Bridges refer to those with single-hole span greater than 100m and those with special structures. At present, there are three methods for evaluating the technical condition of Class I Bridges, namely, Method 1: Qualified grade and Unqualified grade evaluation method in the Technical Standard of Maintenance for City Bridge (CJJ 99-2017), referred to as Urban Standards[1],which specifies an evaluation method for urban Bridges. Method 2:Component accumulation scoring method in Specifications for Maintenance of Highway Bridges and Culverts(JTG 5120-2021),hereinafter referred to as Highway Maintenance Specifications[2], which

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some local standards have not been updated in time, and the assessment method of urban Bridges still follows the 04 maintenance code, so this paper makes a comparison.Method 3:Hierarchical scoring method in Standards for Technical Condition Evaluation of Highway Bridges(JTG/T H21-2011),referred to as Highway Standards[3][4], it specifies the evaluation method for highway Bridges, and in some local standards, large Bridges and urban Bridges with special structures have begun to use this method. In the selection of assessment methods, the first choice is the assessment method of the local standard of the location of urban Bridges, which varies from region to region. Generally, there are two choices of "Highway Standards" and "Highway Maintenance Specifications". For example, Chongqing local standard adopts the highway maintenance code version 04, and its latest revised version plans to adopt highway marking. The Technical Standard of Maintenance of City Bridge (CJJ 99-2017) is a general assessment basis for urban Bridges and has wide applicability.

This paper firstly analyzes the advantages and problems of the technical condition assessment of urban super large Bridges based on the provisions of the code, and then takes the actual engineering as the background, by comparing and analyzing the compatibility of the technical condition assessed by the various codes and the actual condition of the bridge, selects a relatively reasonable assessment method and puts forward suggestions.

2 Rationality Discussion

The evaluation methods of the three standards have their own advantages and disadvantages[5][6][7],the main process and main meaning are as follows.

The technical condition evaluation of the urban standards is based on the comprehensive evaluation of the good condition and structural condition. The urban Bridges of type I maintenance are evaluated according to the safety status of the structure (component level), and divided into qualified and unqualified levels. For II-V type maintained urban Bridges, the bridge span is divided into assessment units, each unit is evaluated according to the upper structure, the lower structure and the deck system respectively, and finally the whole bridge assessment results are formed. The damage directly corresponds to the bridge parts, such as the percentage, minor, serious and other indicators, which is subjective. When the safety of the bridge structure is affected by the damage of the main components of Class I maintained urban Bridges, it can be judged as unqualified and should be repaired immediately.

The Highway Maintenance Specifications evaluates the technical condition of Bridges as one to five types according to the comprehensive method of the proportion of parts that affect the structural safety. Each part is graded according to the three aspects of "degree of defect", "degree of influence of defect on structural performance" and "development and change of defect". The above three aspects require subjective judgment, and their accuracy is worth discussing[9][10].

The Highway Standards is the main reference standard for the regular inspection of Bridges in the highway industry. It has strong coverage on the types of damage of concrete Bridges, suspension Bridges and cable-stayed Bridges, but incomplete cov-

erage on the classification, components and types of damage of arch Bridges. For example, the components of steel truss tied arch Bridges are not classified separately. Tie bar components are placed in the classification of steel - concrete composite arch Bridges. Therefore, in view of the increasing number of special structural bridge types, when adopting highway grading evaluation, it is necessary to adopt the component classification with better conformity as far as possible to form the quantitative index[11].

To sum up, the Urban standards adopt the one-vote system for evaluation of component diseases, which test the professional ability of inspection personnel. The Highway maintenance standards adopt the method of the whole bridge component level score accumulation for evaluation, which is highly subjective. The Highway standard can be quantified by grading the defects of components layer by layer, but the local diseases are not obvious[8],and the terms for the evaluation of Class I Bridges (especially Bridges with special structures) are not complete[11].

3 Engineering Example

In this example, the steel beam of the main bridge adopts 190.00m+552.00m+190.00m three-span continuous steel truss tie rod-arch bridge. The total length of the steel beam is 934.10m (including the end longitudinal beam), and the full width of the main bridge is 36.50m. The two side spans are variable height trusses, and the middle span is steel truss tie bar arch. The height from the arch top to the middle fulcrum is 142.00m, and the chord of the lower arch rib adopts a quadratic parabola, whose sagittal height is 128.00m and the span ratio is 1/4.3125. The chord of the upper arch rib also adopts a quadratic parabola, and a circular curve R=700.00m is used for transition between the arch rib and the upper chord of the side span. The elevation layout of the bridge is shown in Fig.1.

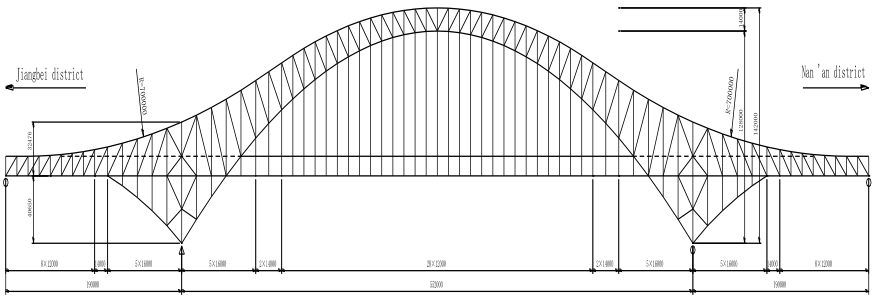

Fig. 1. Schematic diagram of Chaotianmen Yangtze River Bridge Elevation Layout(units:mm)

3.1 Typical damage

The bridge carries out regular inspection once a year. During the process, the main maintenance of the bridge is as follows: In 2020, part of the dust cover of the anchor head was replaced, and nearly 50 high-strength bolts were added in 2021. The disease shows the inspection results of the recent 4 years. The statistics are shown in Table 1.

Table 1. Damage results of main components of Chaotianmen Yangtze River Bridge from 2018 to 2022

Position	Damage type	Quantity (place)			
		2018	2019	2020	2022
Arch rib	Antirust paint off	7	10	12	1
	Corrosion of high strength bolts	362	410	388	0
	High-strength bolt missing	22	23	43	14
	High strength bolts not installed	/	/	/	27
Main truss member	Antirust paint shedding, corrosion	2	2	12	19
	Corrosion of high strength bolts	304	304	319	0
	High-strength bolt missing	11	14	43	23
	High strength bolts not installed	/	/	/	125
Suspender and its anchor head	Corrosion of anchor cup dust cover	217	129	128	63
	Corrosion of anchor head	38	37	9	0
	Anchor cup water accumulation	50	28	19	0
Orthogonal irregular slab	High-strength bolt missing	13	15	26	30
	Antirust paint shedding, corrosion	11	17	35	10
Tie rod and its anchor head	Corrosion of anchor head	/	/	/	8
	Steel strand loosening	/	/	/	22
Horizontal vertical linkage	High-strength bolt missing	/	/	/	24
Overhaul Lane Connection Plate	Common bolt missing	/	/	/	6
Sidewalk slab	Common bolt missing	/	/	/	7

According to statistics, the main diseases of the bridge are bolt missing, coating falling off, loosening of tie steel strand and corrosion of steel members. The two diseases, bolt falling and loosening of tie steel strand, have a great impact on the safety of this type of bridge structure, which are mainly reflected in: A total of 104 bolts were missing in the whole bridge, and 152 bolts were not installed in construction. Although there were partial treatment, they were still added rapidly compared to last year, and the whole bridge tie rods were loosened simultaneously, indicating that the structure was in

the process of accelerating damage. It is worth thinking whether the latest technical status assessment can reflect this trend.

3.2 Technical status assessment

In order to verify the conformity of the technical status assessment results with the development of the disease, three standards methods were used to evaluate and analyze the technical status of the bridge in 2022.

Evaluation according to Urban Standards.

The Chaotianmen Yangtze River Bridge is a Class I maintained bridge. The evaluation criteria of Class I maintained bridge in Urban Standards are as follows:

For urban Bridges maintained in Class I, no obvious abnormal degree is seen, which can be divided into the following two grades according to whether there is damage to the bridge structure or whether it affects the bridge safety:1)Qualified level: No obvious abnormality or damage to the structural components of the bridge is seen, but it does not affect the bridge safety, minor maintenance should be carried out; 2) Unqualified grade: damage to bridge structural components, affecting the safety of the structure, should be repaired immediately.

Combined with the judgment basis, the local position of the bridge bolt shedding and part of the tie steel strand loosening do not constitute a "serious impact" on the structural safety, does not affect the structural safety, the technical status can be assessed as "qualified".

Evaluation according to Highway Maintenance Specifications.

The assessment was made in accordance with technical regulations of Highway Maintenance Specifications. The bridge condition index Dr Is used to determine the evaluation index of bridge technical condition, and the bridge deck system, superstructure and substructure are evaluated respectively. According to the observed damage condition and its deducted points, the Dr Of each part and the whole bridge is obtained step by step and stratified. The technical condition assessment results of the main bridge of Chaotianmen Bridge are shown in Table 2.

Table 2. Technical status assessment form of main bridge of Chaotianmen Yangtze River Bridge(*Highway Maintenance Specifications*)

Items	weight	Defect degree and scale	The degree of influence on the use function	Correction of defect development and change	Final rating scale
Wing wall, ear wall	1	0	0	0	0
Conical slope, slope protection	1	0	0	0	0
Abutment & foundation	15	0	0	0	0

Items	weight	Defect degree and scale	The degree of influence on the use function	Correction of defect development and change	Final rating scale
Pier and foundation	15	1	0	-1	0
Scour of foundation	3	0	0	0	0
Bridge supports	5	0	0	0	0
Upper main load-bearing components	25	1	1	0	2
General upper bearing member	15	0	0	0	0
Bridge deck pavement	2	1	0	0	1
Bridgehead and Embankment connection parts	2	0	0	0	0
Expansion joint	5	1	0	0	1
Sidewalk	2	1	0	0	1
Railings, guardrails	2	0	0	0	0
Lighting, signs	2	0	0	0	0
Drainage facility	3	0	0	0	0
Regulating structures	1	0	0	0	0
Others	1	0	0	0	0
Dr=88.2	grade		Class I		

According to the provisions of Highway Maintenance Specifications, the Dr Score of the main bridge of Chaotianmen Bridge is 88.2, which is assessed as a " Class I " bridge and in "good" condition. Daily cleaning and maintenance should be strengthened.

Evaluation according to Highway Standards.

The Highway Standards evaluates each component quantitatively. Due to the particularity of the structure of Chaotianmen Bridge, the method of steel-concrete composite arch bridge is selected for evaluation in combination with the method in the specification. Components of the whole bridge are divided before assessment. The upper structure of the bridge is divided into arch rib, transverse connection system, suspender, tie rod (including anchorage), bridge panel (main beam) and support, while the lower structure is divided into pier, pier foundation and riverbed. The deck system is consistent with the common bridge type. The evaluation results of the number of components and the technical status of the whole bridge are shown in Table 3.

Table 3. Technical status assessment form of main bridge of Chaotianmen Yangtze River Bridge (*Highway Standards*)

Position	Bridge parts	Bridge members	Numbers	Minimum score	Parts' scoring	Position's scoring	Bridge's score
Upper structure	Arch ribs	Upper chords	128	100.00	84.28	80.27	86.00
		Lower chords	104	100.00			
		Web members	296	100.00			
		Joints	218	65.00			
	Lateral connections	Arch upper horizontal and vertical connections	156	100.00	83.50		
		Arch lower horizontal and vertical connections	158	65.00			
		Arch cross-linked members	48	100.00			
		Main girder's horizontal and longitudinal connections	280	100.00			
	Bridge deck (main beam)	Upper chords	140	100.00	82.67		
		Lower chords	140	75.00			
		Upper cross beams	71	100.00			
		Lower cross beams	61	100.00			
		Web members	134	100.00			
		Joint plates	135	65.00			
		Orthogonal irregular slabs	280	65.00			
	Suspenders	/	66	65.00	57.28		
	Tie rod (including anchor head)	Tie rod cables	8	75.00	81.04		
		Anchor heads	16	75.00			
		Tie beams	2	100.00			
	Supports	/	8	100.00	100.00		
Lower structure	Piers	/	5	65.00	84.20	95.26	
Bridge deck system	/	/	11	62.00	57.90	78.92	

According to article 4.1.5 and 3.2.3 of the Highway Standards, the technical condition score of the whole bridge is 86.00, which indicates that the technical condition grade is grade 2, with slight defects and no impact on the bridge function. However, the superstructure score is 80.27, which is grade 2 but close to the grade 3, indicating that the bridge has suffered mild functional damage. And the diseases develop slowly. For this bridge, it is mainly reflected in the relaxation of the tie cable, the large-scale rust of the suspender, the aging of the anticorrosive oil and the development of the disease of the high-strength bolts of the whole bridge year by year.

Analysis and comparison.

According to the Urban Standards, the key damage can be judged whether the structure safety is affected by human judgment, and the technical condition of the bridge is qualified or unqualified subjectively. The key components of this type of bridge, such as the main arch ring, tie rod, suspender and main beam, do not appear serious damage, so it can be concluded that the bridge is qualified, which is more targeted, less influential factors and less workload.

According to the Highway Maintenance Specifications, the technical status of the whole bridge is assessed by the disease and development status of major components, without going into the component level. For example, the upper main bearing components of the bridge, whose components include the main arch ring, suspender, main beam, tie rod, etc., are subject to two types of subjective judgment, and the results of the whole bridge are subject to one type, with weak targeted assessment and strong subjectivity. The result of evaluation differs greatly from the reality.

According to the Highway Standards, the technical status assessment divides the whole bridge into several components. The different diseases of the components are quantified and accumulated layer by layer. With the most targeted and heavy assessment workload, the assessment results are controlled by the rationality of the whole bridge component splitting and the scoring values of the other non-critical components. The full bridge score was 86.00. Therefore, when this standard is used for evaluation, components should be reasonably split, and parts with severe local diseases should be divided into independent evaluation units for technical status assessment. The results should be used as key control indicators for the whole bridge evaluation[8].

Therefore, for urban oversized Bridges, except for local standards or mandatory requirements of relevant units, it is not recommended to choose highway maintenance norms, and the other two methods can be adopted and complement each other in the actual assessment. The Urban standards can directly reflect whether there is damage to key components, which belongs to qualitative evaluation and subjectivity, while the Highway standards can be quantified evaluation index, which is highly targeted and belongs to quantitative evaluation, but the intuitiveness is weak.

4 Conclusion

For the special structural Bridges of Class I maintenance in the city, due to the large component base and complex structure, it is suggested to adopt the two methods of Urban Standards and Highway Standards for the assessment of complementarity. First, the assessment method of Urban Standards with strong pertinence and fewer influencing factors is adopted to make the qualitative assessment of the technical status of the whole bridge. Then, the Highway Standards is used to conduct a separate quantitative evaluation for the parts with serious local diseases, and the final evaluation result is formed for the whole bridge. It is not recommended to adopt the Highway Maintenance Specifications for evaluation.

In the evaluation of the Highway Standards, the component classification and weight of all types of special structural Bridges for Class I maintenance in the city

should be supplemented, and the disease details of components should be targeted to improve the quantification of evaluation results more accurately.

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