Study on bridge checking evaluation based on deformation-Stress data

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Abstract. Bridge structure plays a very important role in human traffic. The evaluation of bridge structure after a certain period of operation has always been the focus of the bridge. Based on the data collected from the health inspection system of a continuous rigid frame bridge on a highway in Yunnan, China, it is found that there is a certain linear relationship between the deformation and stress of the bridge structure. In view of a specific section of the structure, the stress value of this section can be derived according to its deformation value. The coefficient K can be calculated by comparing the estimated value to the actual measured value. According to the range of the K value, the structural state of the bridge can be evaluated to a certain extent.

1 Introduction

The research on the monitoring of bridge in the operation period abroad began in 70s. By the mid and late 80s, the monitoring system for the specific installation and operation period of some bridges has been started. Domestic concerns began in 90s, carried out monitoring during operation in jiang yin san jiang bridge, The Second Nanjing Yangtze River Bridge (2001), Runyang Yangtze River Bridge (2000-2004), Su Tong Yangtze River Highway Bridge (2007) [1] and some other large bridge has also established the structural health monitoring system. The main functional goal sof the health monitoring system are to realize data compression, index extraction, online warning, formation of maintenance advice and guidance for operation and maintenance. This paper conducts signal monitoring on a bridge located in Yunnan, China, and analyzes directly. According to the analysis results, it finds a suitable assessment method for such bridges to realize the assessment and determination of the structure.

2 Test section

There is some complicated consistency between the vertical deformation of the continuous steel bridge and the structural stress，because there are many kinds of functions involved in the measured structural response, such as live load, shrinkage and creep, relaxation of prestress, bearing Subsidence, temperature and strain and other variable effects. However, the responses caused by these loads can be separated from the measured data. Finally, the response of the structural response only to the live load can be obtained. The bearing capacity of the bridge is mostly measured by the load carrying capacity of the bridge, so this paper only studies the relationship between the stress and the deformation of the bridge under the action of live load.

The structure influence line is used to characterize the change of the internal force and deformation of a certain section with the change of the load position. At present, the research based on the impact line has been applied to model correction, damage identification and so on. According to this train of thought, combining static load test with point by point loading, the relation between displacement and stress under different section, different live load coefficient and different loading position is analyzed. The bridge structure is regarded as a "steelyard". The loading unit is not “1”, but it is scaled according to the first level standard load specified by the code, and then the comparison result is to find out the rule of live load. The study of this paper adopts the highway - I load, and the test section of the loading test section is shown in Figure1.

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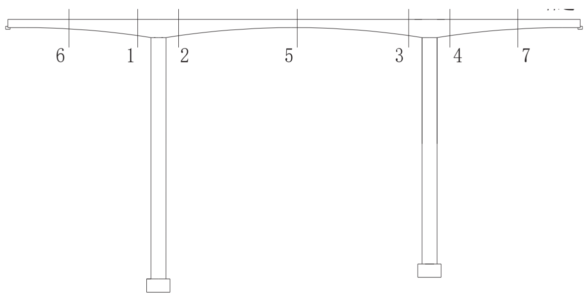

Fig. 1. Test section

3 Relationship analysis

For No. 1 section position, when the live load coefficient is 1, The variation curve of the stress and displacement of the roof as the loading position changes as Figure 2. It can be seen that the variation of structural stress and displacement under the action of live load is in good agreement (The location of the load in the diagram is the edge span of 1/4, the root, and the middle span of 1/2)

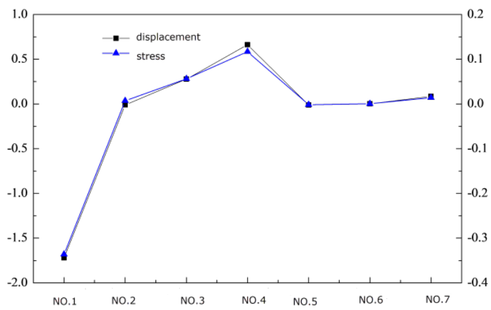

Fig. 2. Structural response under different loading position of No. 1 Section
x-loading position/m; y1-Expression of displacement/mm; y2-Expression of stress/MPa

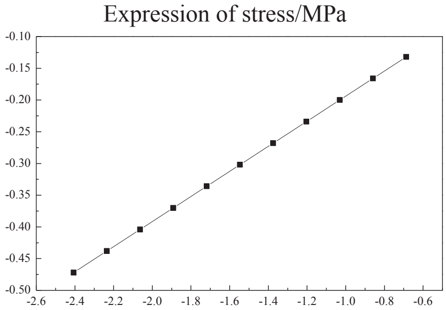

Fig. 3. Response relationship under different live load coefficient(x-displacement/mm;y-stress/MPa)

Also for No. 1 section, consider the different loading coefficients at the same loading section to see the structural response. It is found that from the normal serviceability limit state, the long-term combined live load coefficient 0.4 starts to 1.4 of the limit state of the load capacity, the strain and displacement of structure under load is linearly related to the live load coefficient, and both of them are also linearly consistent, as shown in Figure 3.

Table 1. Stress and displacement of different live load coefficient in No. 1 section No. 1 loading position

Live load coefficient	displacement(mm)	stress(MPa)
0.4	-0.687	-0.132
0.5	-0.859	-0.166
0.6	-1.031	-0.200
0.7	-1.203	-0.234
0.8	-1.375	-0.268
0.9	-1.547	-0.302
1.0	-1.719	-0.336
1.1	-1.891	-0.370
1.2	-2.063	-0.404
1.3	-2.235	-0.438
1.4	-2.407	-0.472

According to figure 3 and table 1, it is found that the response of the vehicle load at the same loading position is positively related to the multiple of the load. There is a linear relationship between the displacement and the strain, that we can ignore the effect of the load on the load. Based on this property, the influence of load multiplier can't be considered. on the other hand, the assumption of "bridge is steelyard" and the loading vehicle is "unit vehicle" is reasonable.

It is found that the displacement and strain of the same measuring point are not completely linear, by using the static load simulation to study the action of different loading positions. This nonlinearity is mainly shown in the root section, and the stress and displacement in the middle span are better. Considering the loading position is from one of the sides to middle of the middle span.

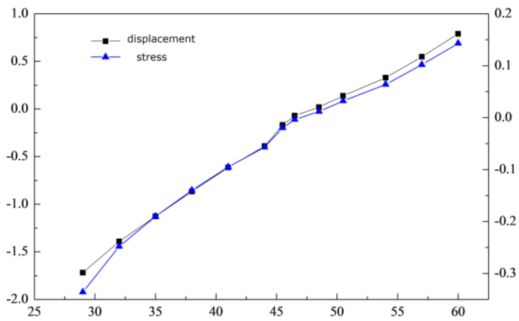

Fig.4. Stress and displacement changes from center of side to center of middle span
(x- loading position;y2-displacement/mm;y1-stress/MPa)

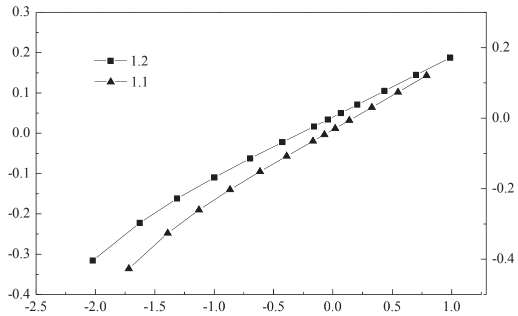

Fig.5. Response diagram under different coefficients (x-displacement/mm; y1-stress1.1/MPa;y2- 1.2/MPa)

Table 2. Stress and displacement relation of different loading positions in center of side span

Loading position /m	Loading coefficient1.0		Loading coefficient1.1		Loading coefficient1.2	
	Displacement/mm	Stress /MPa	Displacement /mm	Stress /MPa	Displacement /mm	Stress /MPa
29	-1.719	-0.336	-1.891	-0.37	-2.063	-0.404
32	-1.391	-0.248	-1.530	-0.273	-1.669	-0.297
35	-1.128	-0.190	-1.240	-0.209	-1.353	-0.228
38	-0.866	-0.140	-0.952	-0.154	-1.039	-0.168
41	-0.614	-0.095	-0.676	-0.104	-0.737	-0.114
44	-0.389	-0.057	-0.428	-0.062	-0.466	-0.068
45.5	-0.168	-0.020	-0.184	-0.022	-0.201	-0.024
46.5	-0.071	-0.004	-0.078	-0.004	-0.085	-0.004
48.5	0.020	0.012	0.022	0.013	0.025	0.014
50.5	0.138	0.032	0.151	0.035	0.165	0.038
54	0.328	0.064	0.361	0.071	0.394	0.077
57	0.549	0.102	0.604	0.112	0.658	0.122
60	0.789	0.143	0.868	0.157	0.947	0.171

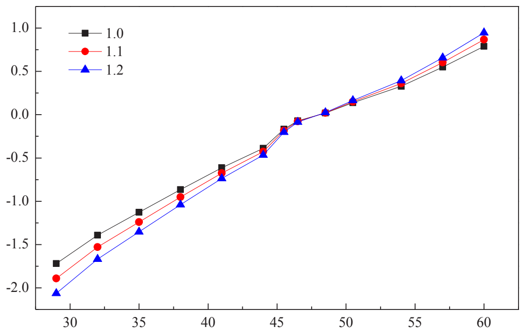

Fig.6. Displacement diagram under different coefficients(x-loading position/m;y-displacement/mm)

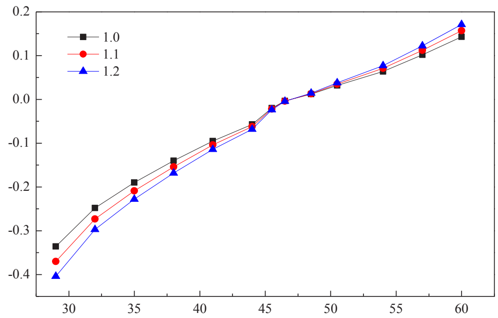

Fig.7. Stress in different coefficients(x-Loading position/m;y-stress/MPa)

Table 3. Relationship between stress and displacement of different loading position of root section

Loading position /m	Loading coefficient1.0		Loading coefficient1.1		Loading coefficient1.2	
	Displacement /mm	Stress /MPa	Displacement /mm	Stress /MPa	Displacement /mm	Stress /MPa
29	-0.238	0.156	-0.262	0.171	-0.285	0.187
32	-0.227	0.125	-0.250	0.137	-0.272	0.150
35	-0.213	0.980	-0.234	0.107	-0.255	0.117
38	-0.194	0.068	-0.214	0.075	-0.233	0.082
41	-0.172	0.035	-0.189	0.039	-0.206	-0.042

44	-0.147	-0.015	-0.162	-0.017	-0.177	-0.018
45.5	-0.111	0.009	-0.122	-0.010	-0.133	-0.011
46.5	-0.094	-0.004	-0.104	-0.004	-0.113	-0.005
48.5	-0.080	0.009	-0.087	0.010	-0.095	0.011
50.5	-0.059	0.025	-0.065	0.027	-0.071	0.030
54	-0.028	0.050	-0.031	0.055	-0.034	0.060
57	0.008	0.080	0.009	0.088	0.010	0.096
60	0.049	0.111	0.054	0.123	0.058	0.134

It is found that the linear relationship between deformation and stress is consistent with the previous one, although the nonlinearity of the root is very obvious as table 3. But because the consistency of the deformation and strain is mainly studied in the cross section, this linear relationship model can be used.

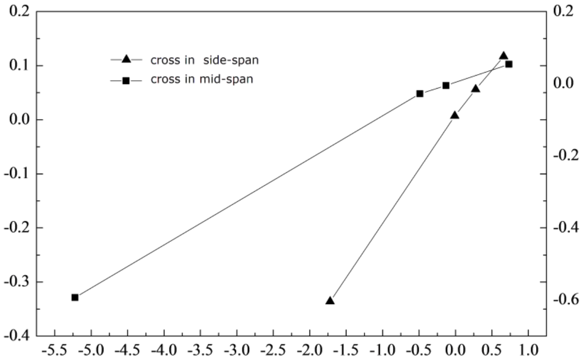

Fig.8. The relationship between stress and displacement under different loading position of No. 1 Section (x-displacement/mm; y1-center of middle span stress/MPa y2-center side span stress/MPa)

4 Evaluation method Conclusion

Based on the analysis of the above data：There is a certain linear relationship between the deformation and stress of bridge structure. Then the stress value of this section is deduced for a specific section of a structure (the predicted value of stress). The coefficient K can be calculated by replacing the predicted value with the actual measured values in the following formula.

$$k = \left| \frac{\sigma_{\text{actual value}} - \sigma_{\text{predicted value}}}{\sigma_{\text{actual value}}} \right|$$

Table 4 Technical grade evaluation of deformation and stress data checking and analysis

Bridge Category	Ratings range	Structure status	Management tools
1	5%>k≧0	Satisfy the design state	Safety or enhanced monitoring
2	10%≧k≧5%	Meet the standard state	Adjustment limit load
3	k≧10%	Internal forces need to be adjusted	Traffic control or bridge closure

According to the above K value in Table 4, the structural state of the bridge can be determined. Managers can take corresponding management measures for this state. To some extent, this evaluation method can reflect the structural state of bridge, but it can't completely reflect the state of structure, so it can only be used as a part of bridge comprehensive evaluation. The study of comprehensive evaluation will be studied in detail in the other papers of the author.

Acknowledgments

Project Source: Yunnan Provincial Department of Education(2017ZZX319);

References

1. FENG Liang-Ping，LI Na. Status Quo and Trend of Research and Development of Long - span Bridge Structural Safety Monitoring System in China[J]. Highway，2009，05:176-181
2. Zong Zhou-hong， Gao min-lin， Xia zhang-hua． Finite element rnodel validation of the continuous rigid frame bridge based on structural health monitoring Part I：FE model updating based on the response surface method[J]，China Civil Engineering Journal，2011. 44(2)：90-98.
3. AASHTO(2003)，Guide Manual for condition Evalua-tion and Load and Resistance Factor Rating (IRFR) of Highway Bridges[s].
4. Ming Liu,Dan M. Frangopol, and Sunyong Kim，Bridge Safety Evaluation Based on MonitoredLiveLoad Effects[J]Journal of Bridge Engineering,2009
5. REN Yuan, HUANG Qiao , LIN Yang-zi.Study and Developmentof Comprehensive Assessment System of Long Span CablestayedBridges [J] .Journal of Nanjing University of Aeronautics&Astronautic , 2007 , 39 (4):535-539.
6. ZHAO Ji-guang , LU Jian , XIANG Qiao-jun, et al.Researchon Highway Maintenance Quality Evaluation System [J] .Journalof Highway and Transportation Research and Development,2006, 13 (4):1-6.