Dynamic load test and load lateral distribution of box girder bridge in mining area under special load

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Abstract. Dynamic load test of bridge is one of the important indexes to evaluate bridge operation and bearing capacity, however, the test of the lateral distribution of bridge is one of the important means to evaluate the state of bridge. In order to evaluate the stress condition and working performance of a box girder bridge in a mining area under the special load of 100T, dynamic load test and lateral load distribution are studied, dynamic load test is to test the natural vibration frequency damping ratio and impact coefficient of the bridge through pulsating test and traffic running test, the transverse distribution of load is analyzed by deflection method and the experimental value of transverse distribution coefficient is compared with the theoretical value of girder method. The results show that under dynamic load, the first vertical natural vibration frequency of the bridge is 10.986, the damping ratio is 0.015%, and the impact coefficient is 1.07~1.26, the vertical measured fundamental frequency is larger than the calculated fundamental frequency, and the overall stiffness of the bridge meets with the design specification; the transverse connection among the box girders is close and the lateral distribution of load meets with the requirement of the design specification.

1 Foreword

Bridge dynamic characteristics test is one of the important indicators to evaluate the bearing capacity and operation status of bridges, the dynamic vibration test, damping ratio and impact coefficient of the bridge are tested by dynamic load test, study the dynamic load effect of bridge under special load, especially the study of dynamic strain increment and impact coefficient. In order to ensure the normal operation of the box girder bridge in the mining area after the bridge, it is necessary to test the working state of the bridge structure by studying the dynamic load test and the transverse load distribution and to determine the force status of the bridge

At present, more and more scholars study the dynamic load test and lateral load distribution of box girder bridge under special load, some research results have been obtained. For example, Zhang Hongbin designed and tested the bearing capacity of the main beam of the special load bridge[1]; Wang Chaoqing studied the load test of large cargo transportation on the traffic bridge of gupitan ship lift[2]; Jia Yanmin and Yang Yanmin studied the dynamic load test of qiqihar nenjiang highway bridge[3]; Wu Jianqi, Zheng Xiao researched on dynamic load test of highway bridge engineering [4]; Demeke b. Ashebo conducted an experimental analysis of dynamic characteristics of inclined small box girder[5]; Yang Meiliang, Shi Enchong studied the transverse distribution of load based on load test of small box girder bridge[6]. However, there are few literatures about dynamic load test and lateral load distribution of box girder bridge under special load in China. Therefore, the research on this subject is of great value.

This paper is based on the project of K0+527.81 middle bridge in Yunnan national power coal mine, combined with the field environment and finite element software analysis of the bridge, through dynamic load test and lateral load distribution of the bridge, comprehensive evaluation of the stress state and working performance of the bridge K0+527.81 under the special load of 100T

2 Project summary

K0+527.81 middle bridge is located in Shan Xin village, line S304 of provincial highway, across the Dian Xi river, the superstructure consists of 6x20m prestressed concrete box girder, its bridge span connection is simple and continuous; the substructure is composed of ribbed slab abutment, double column abutment and abutment pile foundation. This bridge is 60m in length and 3 spans in total, the total width of the bridge is 0.5m+11m+0.5m, and the beam height is 1.8m, the bridge deck pavement is composed of 15cm thick C50 concrete and inorganic waterproof layer, the transverse slope of the bridge deck is 2% and the design load is 100T.

MIDAS/Civil was used to build the lattice model of the bridge and analyze the structural fundamental frequency, the sports car test is carried out by simulating

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the special load of 100T, under dynamic load, testing dynamic strain of each section of the superstructure, the impact coefficients of the measured points in each section were obtained.

3 Bridge dynamic load test

3.1 Sports car test

The sports car test measures dynamic strain of the mid-span section when passing on the bridge deck at a uniform speed of 10km/h, 20km/h, and 30km/h, collect and analyze dynamic strain analysis with the DH5908 dynamic signal tester, calculating the impact coefficient of bridge span structure under different vehicle speeds, according to the maximum dynamic strain amplitude of bridge vibration.

3.2 Pulsation test

High sensitivity vibration sensors are arranged at 4 equal points of the test bridge span, remove pier section, measuring small and irregular vibrations of bridges caused by various external factors, and then through modal analysis, testing the vibration characteristics of bridges with DH5907N wireless modal tester, the pulsation test point arrangement is shown in figure 1.

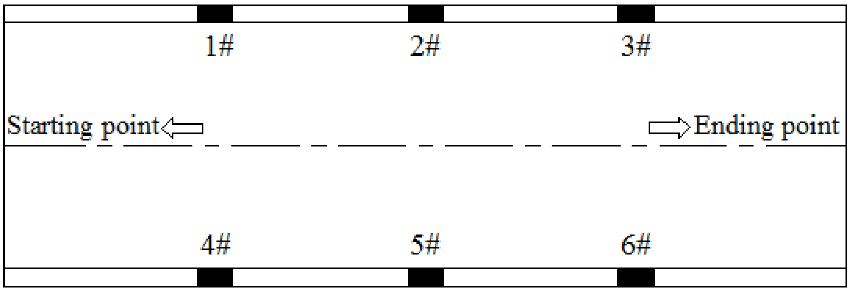

Figure 1. Pulsation test point arrangement

4 Analysis of test results

4.1 Analysis of sports car test results

The sports car test selects 3# beam, 4# beam across J1 section and J2 section, the dynamic strain of bridge superstructure is tested under the action of vehicle load, the strain impact coefficient is calculated and the dynamic strain time history curve is shown in figure 2~4.

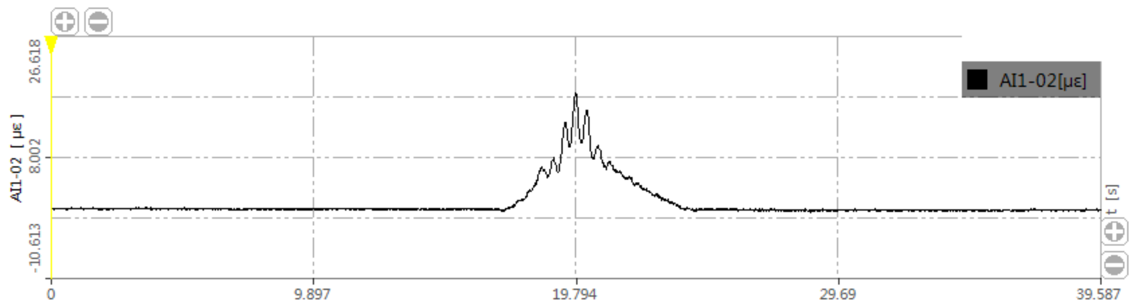

Figure 2. 10km/h time curve

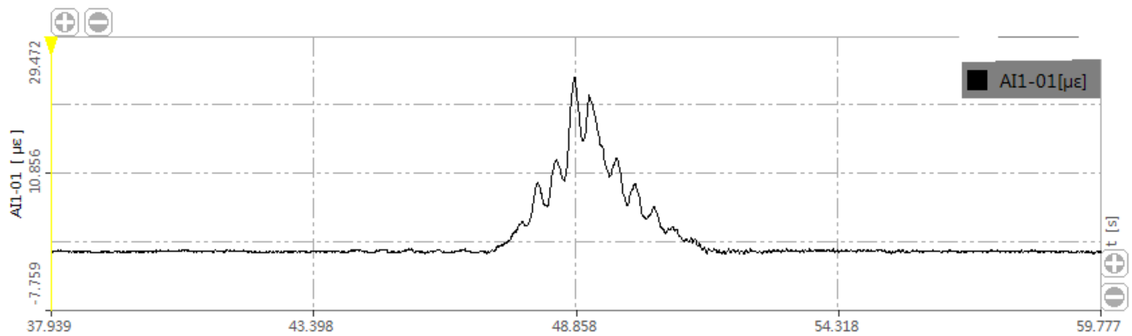

Figure 3. 20km/h time curve

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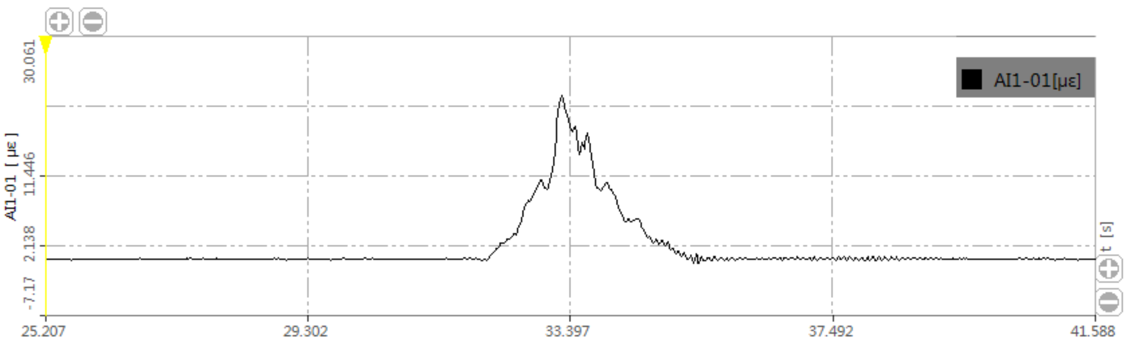

Figure 4. 30km/h time curve

According to the peak and valley of dynamic strain in the test, as shown in table 1,

Table 1 Test value of impact coefficient

Test section	Driving speed / （km.h^{-1}）	Maximum dynamic strain / （με）	Impact coefficient / （1+μ）
J1	10	23	1.07
	20	26	1.15
	30	31	1.21
J2	10	17	1.14
	20	21	1.19
	30	24	1.26

As can be seen from table 1, with the speed of the vehicle increases, the impact coefficient increases significantly and the change is small, the dynamic strain curve with time is good, the maximum dynamic coefficient measured by the test is 1.26, the corresponding dynamic strain increment is 0.26, less than the theoretical calculation value of 0.39, it indicates that the bridge deck is comfortable.

4.2 Pulsation test results and analysis

According to the dynamic response signal of bridge under the environment excitation and the residual vibration signal of the sports car test, the self-vibration characteristics and damping ratio of the bridge can be obtained, the basic frequency test value of the structure and the theoretical value calculated by the finite element software are shown in table2.

Table2 Pulsating test result

Order number	Theoretical fundamental frequency /Hz	Measure basic frequency /Hz	Measured damping ratio /%	Ratio
1order	9.714	10.986	0.015	1.131
2order	13.881	14.893	0.022	1.073

The vertical bending mode and theoretical mode of the first and second order test, the calculation of the vibration mode and the measured mode shape of each step of the vertical bending theory is shown in figure 5-8

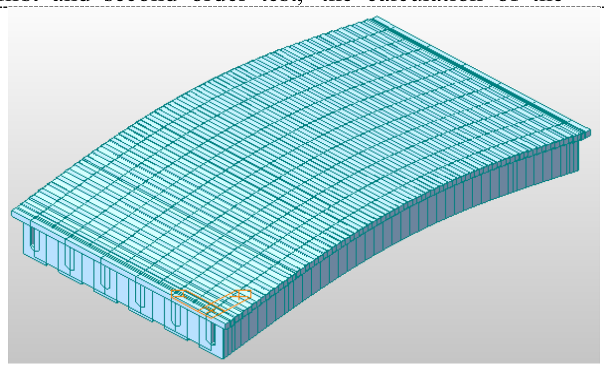

Figure 5. First order theoretical mode

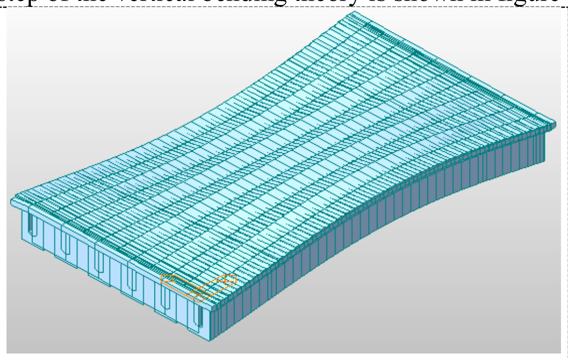

Figure 6. Second order theoretical mode

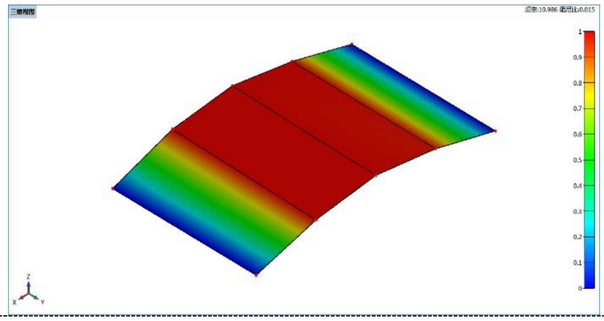

Figure 7. First order measured mode

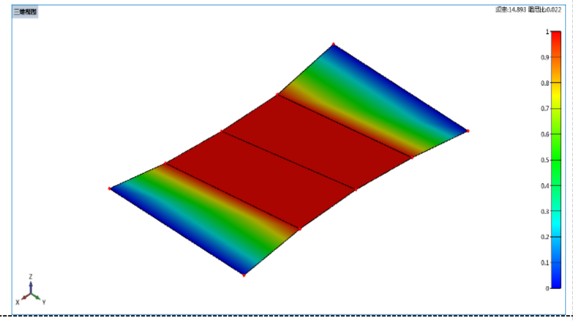

Figure 8. Second order measured mode

It can be seen from table 2 and figure 5-8. the measured fundamental frequency is higher than the theoretical inherent fundamental frequency, it indicates that the measured structural stiffness is higher than the theoretical stiffness, the ratios of measured fundamental frequency and theoretical fundamental frequency in the first and second vertical bending were 1.131 and 1.073 respectively, meet with the requirements of the specification ≧0.9[7], it shows that the overall structure stiffness of the bridge is good; the vertical bending mode of the first and second order tests agrees well with the theoretical mode, the first and second order damping ratios were 0.015% and 0.022%, damping ratio is very small, it indicates that the overall performance of the bridge is good, the structure has strong anti-attenuation force.

5 Analysis of transverse distribution of load

The transverse distribution of box girder load in mining area was studied by finite element analysis and static load test, analysis and static load test, the transverse distribution of the load between the box girders is analyzed under the condition of no diaphragm girders, according to the theorem of displacement reciprocity, the load is proportional to the deflection, the transverse distribution coefficient of beam load can be based on the measured deflection of each section, according to calculate formula (1)

$$m_i = \frac{f_i}{\sum_{i=1}^{i=n} f_i} \tag{1}$$

Among them: *mi* is the lateral distribution of the *i* box girder, f_i is the deflection value of the *i* beam, *n* is the number of beams

The deflection method was used for analysis, comparing with the measured values obtained from the static load test with the theoretical values of the beam finite element model, the theoretical and measured values are shown in figure 9-10.

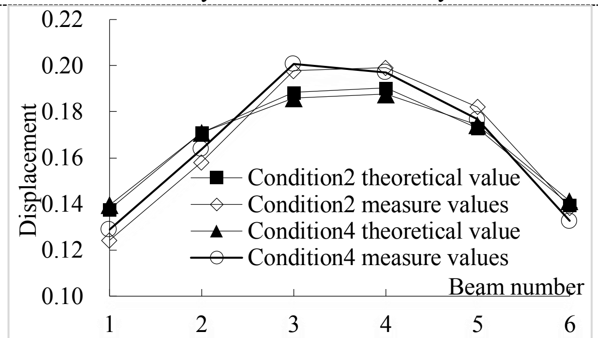

Figure 9. Condition2 and 4 displacement lateral distribution

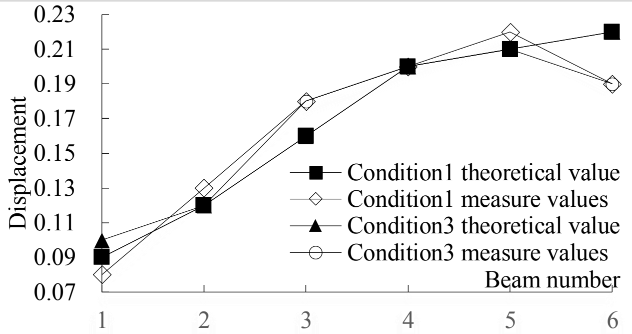

Figure 10. Condition1 and 3 displacement lateral distribution

As can be seen from figure 9-10, under all conditions, the measured displacement distribution of beam 1#~6# is close to the theoretical value, and the change of the two is uniform and the change trend is basically the same, it is shown that the measured value of the load test is in accordance with the theoretical value of the space girder method, the beam and lattice method well reflects the mechanical behavior of the whole bridge structure; according to the analysis of error percentage, the maximum relative error percentage is only 3%, it shows that the test has sufficient precision; the bridge has a relatively close lateral connection between the beams without a cross-beam, the special load along the lateral distribution of the bridge basically reaches the expected effect at the time of design.

6 Conclusion

K0+527.81 middle bridge, through dynamic load test study, dynamic test results show that the ratios of measured frequency and theoretical frequency of vertical first and second order vibration are 1.131 and 1.073 respectively, meet with the requirement of ≥ 0.9 in the specification; in the sports car test, the dynamic strain increment is 0.26, less than the theoretical calculation value of 0.39, it indicates that the bridge deck is comfortable. Through transverse distribution of load study, the measured value of the load distribution coefficient is close to the theoretical value, the two trends are basically the same, it is shown that the measured value of deflection method is in agreement with that of girder method, the transverse connection between the beams of the bridge is relatively close without the transverse girders.

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