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# Research on loading experimental method of bridge crane without hoisting weight

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**Abstract.** According to the inspection requirement, static loading test need to carry out on the new installed, moved, major maintenance and renovation crane. Thus an inspection method instead of weight hoisting power was proposed. Based on the finite element method, an analysis model of the bridge crane structure under the stress state is established, and the simulation result is obtained. According to the theoretical analysis, the proposed experiment is carried out in realistic bridge cranes, applying the hanger in crane to stress the wire rope fasten in the bottom of the main beam, stress strain test is also applied to the typical region. The final result indicates that the numerical analysis model is with high reliability, and the experimental method is practical in the bridge crane research.

## 1. Introduction

Bridge crane is widely used for material hoisting and carrying, hold a large mount in the market. It is generally composed of girder, double-trolley, steel wire rope and electric hoist. When in operation, the girder of the bridge crane moves longitudinally along the elevated tracks, lying on the both sides with the trolley transversely, running along the tracks on the bridge. Within a rectangular working area, the bridge crane can make full use of the space to lift materials.

However, the complicated working conditions of the bridge crane make it necessary for supervision and inspection after installation, transformation and major maintenance. According to the requirements of "Inspection and Inspection Rules for Cranes" issued by AQSIQ[1], loading test is an important part for inspection. What is more, most newly installed and partial reinstalled cranes need to be carried load test, the environment in these places limited most the inspection work, besides the load test is a time-consuming job and reduce the production efficiency of companies.

As an important equipment in the field of mechanical engineering, the crane work in the complicated condition[2-4], it is challenge to its structure. At present, many scholars do the research on the load test of crane, Xiong et al applied the finite element analysis and simulation to the box girder structure of the machinery for lifting heavy materials[5]; Yuan et al do model analysis on the lifting heavy machinery structure based on the three-dimensional[6]. Also scholars study the fatigue



life of the cranes[7-8], however focus on the load test simulation, analysis and present the experimental research are few.

In order to meet the requirement of enterprise operation and inspection work, we induced the finite element analysis and experimental research, a lifting load test method for bridge crane is proposed. The lifting allowance of crane itself is applied to replace the weight lifting, so as to achieve efficient and rapid detection. Then, a 0.5 ton bridge crane was taken as the research object, the test results is compared with the analysis data, verify the feasibility of the loading mode, and provide reference for the application of larger tonnage bridge cranes.

## 2. Design and analysis of the bridge crane structure model

### 2.1. Finite element model

Based on the ANSYS14.5 finite element analysis, a bridge crane was selected as the research object to construct the simulation model. The bridge crane was box girder structure, a three-dimensional parametric finite element model is established by the solid185, the angle steel and trolley is also concluded, which the unit number is 158287, and the solid unit has no rotational degree of freedom[9-10]. According to the material characteristic(Q235), the modulus of elasticity(E) is 206GPa, tensile strength is 470MPa, the Poisson ratio is 0.3. The ends frame is taken as the shifting boundary. As showed in figure 1, the whole construct model mainly include the ends frame, girder and the angle steel at the bottom, all the units size are the same as the entity.

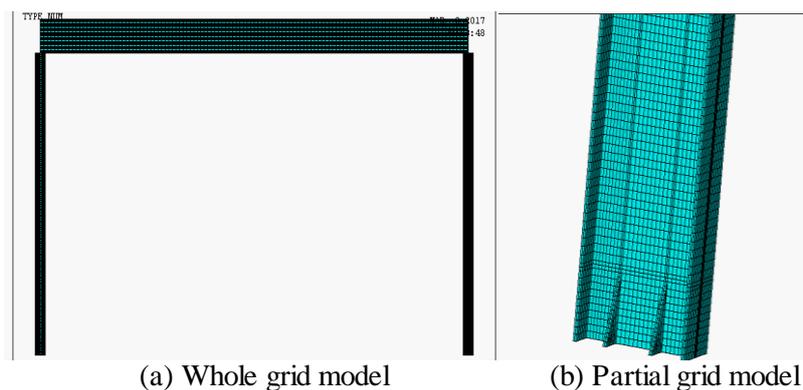


Figure 1. Whole model of the frame.

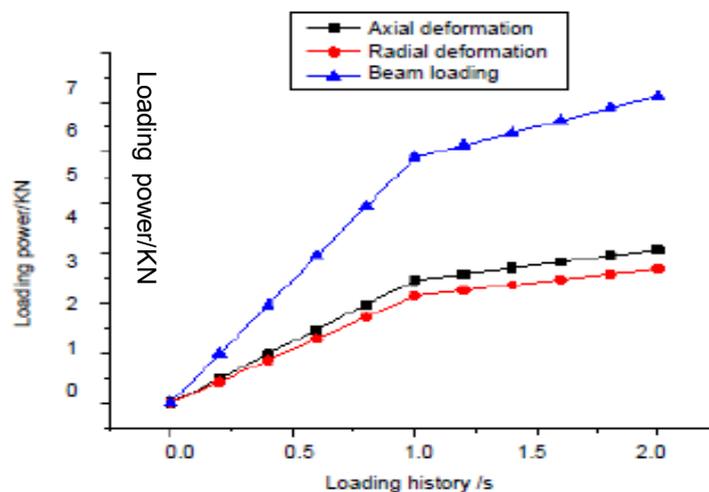


Figure 2. Loading history.

Taking a 0.5 ton bridge crane as a sample, figure 2 shows the loading history. The first stage (0~5kN) load step is divided into 5 steps, the second stage (5~6.13kN) load step is constant, and the increment is reduced to 0.226kN, so as to investigate the mechanical response between the specified load and max test load. As show in the figure, the cross girder is affected by the change of the load obviously[11], the slope in the figure is max, axial and radial of the frame is smaller by the time accumulation, sorting the three change amplitude by the loading is cross girder>axial of frame>radial of frame.

### 2.2. Deformation of whole frame structure

Based on the proposed simulation model and loading history, the whole frame construction is analyzed. Set 0.5 ton, 20 tons, 50 tons for the model cranes, simulating loading condition in different level. In figure 3, a show the whole deformation of the 0.5 ton crane in different time; b is the deformation of 20 tons crane in F=49kN; c, d show the deformation of 50 tons cranes. In figure 3, observing the frames deformation is small, and the whole deformation is gradually decreasing from the middle to the both sides, max deformation located in the middle of the frame, and all the three is agree with the rules.

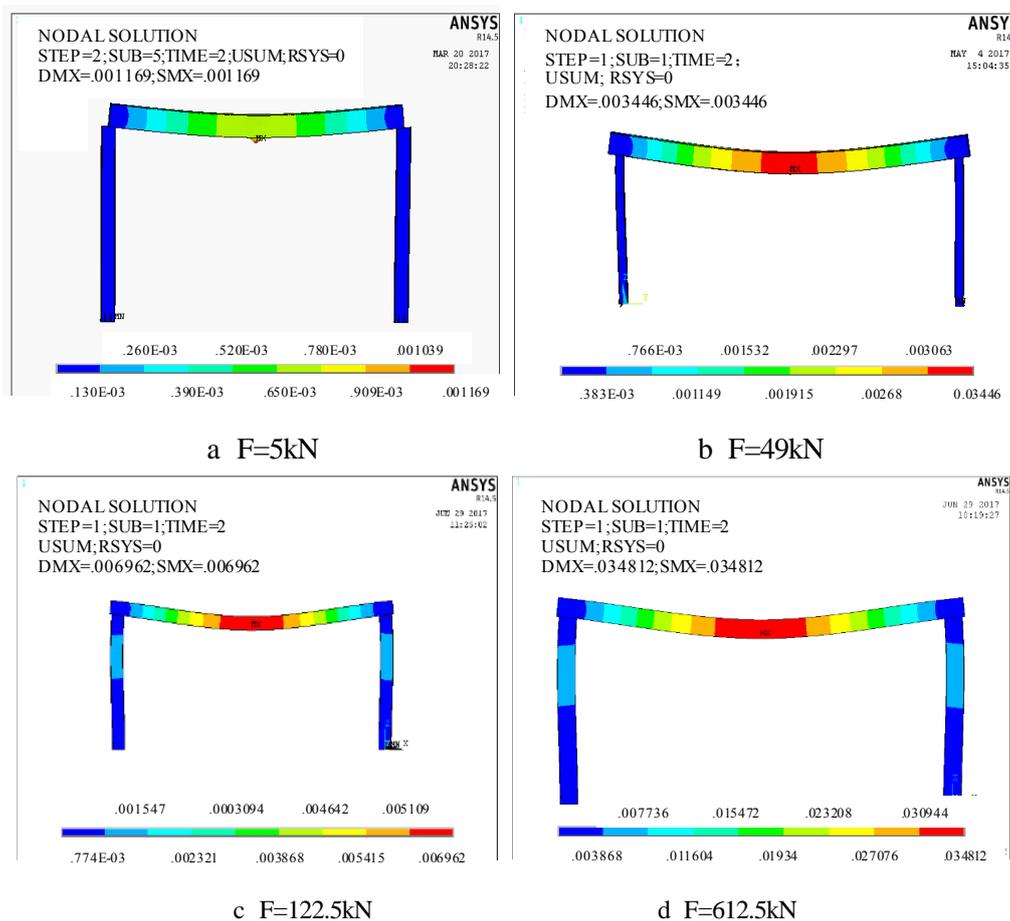


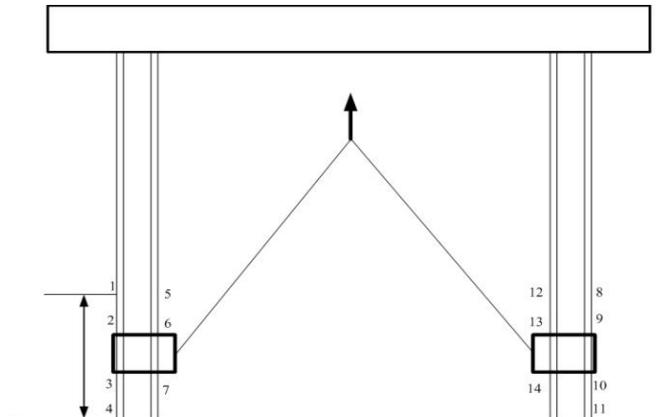
Figure 3. Deformation of the whole frame with different stress.

## 3. Loading experiment

### 3.1. Experimental program

Based on the simulation analysis above, field experiment was carried to validate the accuracy of the finite element model. To ensure the safety of the loading process, a 0.5 ton bridge crane was taken as

the research object. When the trial was carried, hooped both sides of the bottom in the frame and linked the chain, which was stretched in the middle. Moreover, the max loading capacity was 0.69 ton.



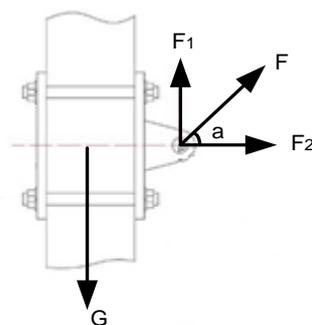
**Figure 4.** Experimental program and testing location.

**Table 1.** testing location.

NO.	Height to ground/cm	NO.	Height to ground/cm
1	68.8	8	71.1
2	61.8	9	64.2
3	14.5	10	24.1
4	11.3	11	15.5
5	68.5	12	72.8
6	62.8	13	63.7
7	25.5	14	24.5

For the trail, the bottom of the frame bear the bending moment and shear force, especially the hooped area, so we attached the strain gauge to gather the experimental data. The detail program and the test location was shown in figure 4 and table 1, 7 test points was set on the frame Respectively, 14 points in all, point 2 and 9 was Three direction strain rosette, the left was double direction.

The hoop device was designed and mandril was also added, to achieve the static loading. Hoop structure is shown in figure 5,  $F$  is the Tension of wire rope,  $F_1$  is the axial force,  $F_2$  is the radial force,  $G$  is the maximum lifting weight,  $\alpha$  is the angle between the wire rope and horizontal. Thus the hoop device is designed taken the pretightening force and the strength of the high strength bolt, and the structure of the mandril is symmetrical, no more detail about the other side here.



**Figure 5.** The hooped device.

### 3.2. Experimental operation

In order to obtain realistic data under proposed operational load spectra, load carrying mechanism of these girders needed identification. Detailed loading step is shown in table 2. What's more, based on the requirement of large crane experiment, Hydraulic rod was installed in tests NO. 4, 5 and 6, in case the stress exceeding capacity lead to girder deformation. The realistic operation without hydraulic rod is given in figure 6 a, and figure 6 b shown the Hydraulic pipe during the stress analyses.

**Table 2.** Loading arrangement

Testing order	loading/kg	loading/kg	loading/kg	Testing order	loading/kg	loading/kg	loading/kg	
No	1	245	585	/	With	4	94	431
hydraulic	2	146	515	/	hydraulic	5	222	304
rod	3	48	334	657	rod	6	35	391
								691



(a) No hydraulic rod loading



(b) With hydraulic rod loading

**Figure 6.** Different loading methods.

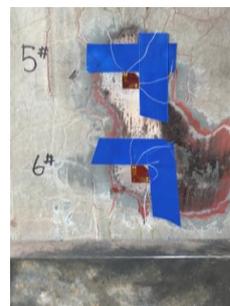
Strain gauge stick on the bottom of frame was utilized to obtain reliable stress data during test, the distribution and location was given below in figure 7, NO. 8-14 and NO. 1-7 are symmetric, no more detailed respectively.



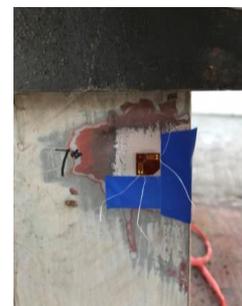
(a) Testing point 1#, 2#



(b) Testing point 3#, 4#



(c) Testing point 5#, 6#



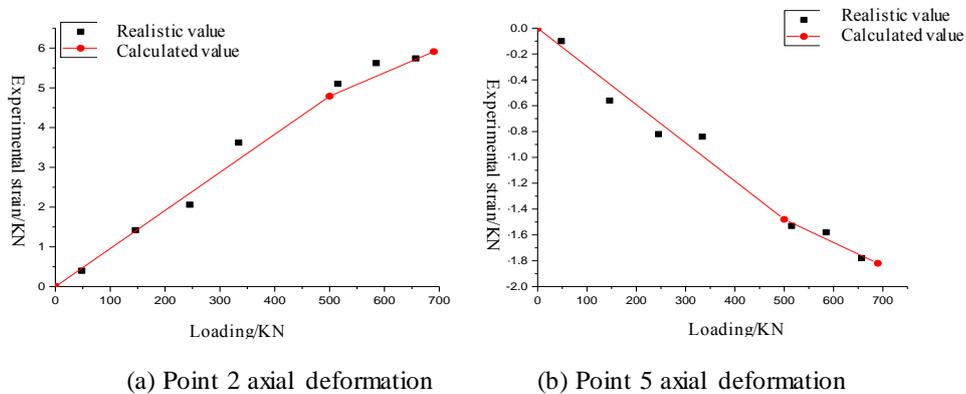
(d) Testing point 7#

**Figure 7.** Location of strain gauge.

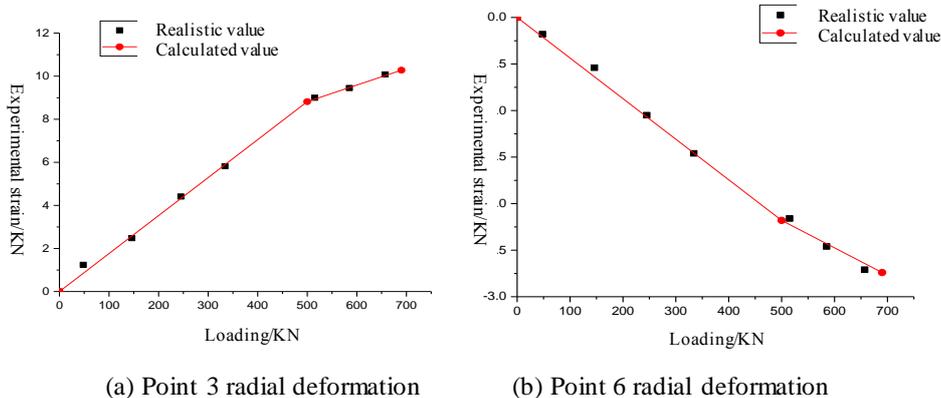
## 4. Result analysis

The simulation analysis, experiment design and material mechanical analysis were all performed above, thus NO. 1-4 realistic data was obtained and analyzed. The axial and radial signal was acquired respectively, simultaneously compared with the Numerical simulation results. Figure 8 shows the axial

deformation of test point NO. 2, 5 and radial deformation of test point NO. 3, 6 were given in figure 9. In the below figure, the horizontal ordinate is load value, and the vertical axis is the strain value. In the plot, dot means simulate results, squareness represent the realistic data.



**Figure 8.** Axial deformation of testing points



**Figure 9.** Radial deformation of testing points.

In figure 8, test point 2 show the positive deformation, point 5 show the negative deformation, in figure 9 test point 3 show positive deformation, point 6 show negative deformation. In realistic operation, test point 1-4 and 5-7 is contrary in the data obtained direction, thus the plot in figure 8 and 9 is opposite partially. But the deformation increased by the loading value, and the realistic data is accordant with the simulation result, the frame deformation is little, less than  $20\mu\epsilon$ . Above result verify the statics loading mode is reliable on 0.5 ton crane, meanwhile deviation between the calculated value and the experimental data was exiting, the crane's specified capacity is small relatively, and the deformation is also smaller, lead to the confusion of the realistic data and strain gauge deviation, and the plot show the result.

## 5. Conclusions

- 1) Finite element analysis and static loading experiment is carried out for bridge crane, the result shows that the experimental data is consistent with realistic data, which verifies the reliability and availability of the loading method. It's with considerable engineering value for application of the static loading method to large amount bridge crane.
- 2) In the test by static loading method, the weight rising is replaced by lifting force, and the deformation of main girder is in permit range. These avoid the potential danger during the weight rising, what's more, promoting the efficiency of bridge crane loading test and shorten the inspection period.

- 3) The hooped device and hydraulic rod need to be optimized in the future, in order to ensure the stability of the main girder during the operation, what's more, providing security and convenience for this loading method applied to the large capacity cranes.

### Acknowledgement

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