Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 73/1/73/2 (1995)

Artikel: Testing a thirty-year-old concrete railway bridge in China

Autor: Qian, Yongjiu / Che, Huimin

DOI: https://doi.org/10.5169/seals-55269

Testing a Thirty-Year-Old Concrete Railway Bridge in China

Essais réalisés sur un pont ferroviaire en béton de trente ans en Chine

Versuche an einer dreissigjährigen Betoneisenbahnbrücke in China

Yongjiu QIAN
Dr. Eng.
Southwest Jiaotong University
Chengdu, China

Huimin CHE
Professor
Southwest Jiaotong University
Chengdu, China

SUMMARY

In order to investigate the load capacity of existing concrete bridges, the static, dynamic and destructive tests of a 30-year-old concrete railway bridge which was deteriorated seriously were conducted, from which the stresses, deflections, and crack widths under design loading and ultimate loading were observed, also the load capacity as well as the strength of the concrete and steel. By analysing the test results, the methods to evaluate the strength and the degree of deterioration of existing concrete railway bridges are given in this paper.

RÉSUMÉ

Des essais statiques, dynamiques et conduisant à la ruine ont été conduits sur un pont ferroviaire en béton de trente ans afin d'étudier la résistance de ponts en béton très endommagés. Le programme de mesures comprenait les tensions, déformations et largeurs de fissures sous des charges de projet et des charges de ruine, de même que la capacité de charge, la résistance du béton et de l'acier. L'analyse des résultats d'essais et les méthodes d'évaluation de la résistance et du degré de détérioration des ponts ferroviaires en béton existants sont présentés dans l'article.

ZUSAMMENFASSUNG

Um die Tragfähigkeit bestehender Betonbrücken zu untersuchen, wurden an einer 30 Jahre alten, stark geschädigten Betoneisenbahnbrücke statische und dynamische Belastungsversuche bis zum Bruch vorgenommen. Das Messprogramm umfasste Spannungen, Durchbiegungen und Rissweiten unter Gebrauchs- und Bruchlast, die Traglast sowie die Beton- und Stahlfestigkeit. Der Beitrag beschreibt die aus den Versuchen abgeleiteten Methoden zur Ermittlung der Tragfähigkeit und des Schädungsgrades bestehender Betoneisenbahnbrücken.

1. INTRODUCTION

There ara a large number of old RC railway bridges in China now which were deteriorated to a ceertain extent, some of them had no records about the design and construction or the design grades of them were lower. To make use of them rationally, it will be a key problem to study their load capacity, degree of damage, and remaining life, etc. For solving these subjects, the static, dynamic and destructive tests of a 30-year-old RC railway beam bridge which is located in northeast China was carried out. In the tests, the stresses, deflections and crack widthes in the beam were measured, and the response of the bridge up to failure was also studied. After the tests were finished, the beam was broken to inspect the actual arrangement and corrosion of the steel, and 12 pieces of them were used to measure the mechanical properties of the steel. Based on the studying, we try to propose a method to evaluate the strength and deterioration of old RC railway bridges.

2. METHOD OF TESTS

The bridge in tests was a four-span and simple supported concrete beam, as shown in Figure 1. The bridge was constructed originally in 1933 and repaired later. Now, extensive cracking had developed on the underside of the beams. A part of the concrete in lower flange was peeied off, so the reinforcement were corroded seriously. All of the supports were damaged to some extent because of corrosion of the steel plate and damage of the concrete.

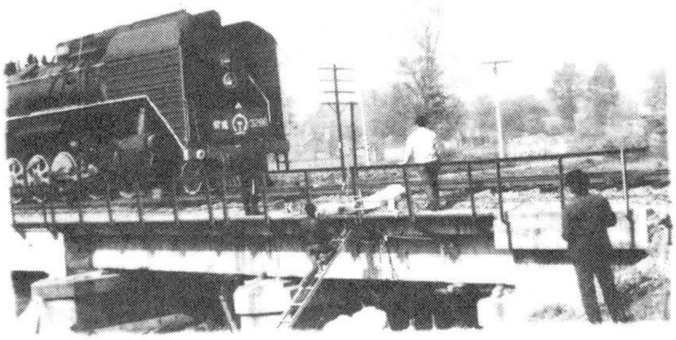

Fig.1 Test bridge

2.1 Static tests

The steam locomotive was used to apply the vertical load on the bridge in the locations where the maximum moment at the middle span and one quarter span were acquired respectively. Each load form was repeated 3～4 times. In the tests, the deflections, strains of concrete and steel and crack widthes were carefully measured.

2.2 Dynamic tests

Vibration of the bridge was excited when the test locomotive was runing through at a speed of 10～80 km/hour. The responses of the test beam were measured with accelerometers and CZ bridge vibrograph. At the same time, the deflection and strain of the beam under dynamic loading were also measured.

2.3 Destructive tests
The 3-point loading method was selected for modeling the actural load distribution for the design load. The tests under working load and design load were repeated for three times first, and then increasing the load step by step for cycling to investigate the effects on larger loads. At last, the destructive test of the beam was conducted.

3. ANALYSIS OF TESTED RESULTS

3.1 Results of static tests
The comparision for the measured and calculated results of the strain in reinforcing steel, deflection in middle span, maximum crack width and depth of neutral axis was as shown in table 1.

Item	Strain of Reba ($\mu\varepsilon$)	Deflection	Crack width (mm)*	Neutral Axis Depth (cm)
Measured Value	80.79	0.76	0.24	25.50
Calculated Value	196.46	1.03	0.04	29.22
η**	0.41	0.73	6.00	0.87

* The measured maximum residual crack width was equal to 0.2mm.
** η = Measured Value/Calculated Value
Table 1 some results from static test

Note that in table 1, the differences between the measured values and calculated values are very large except that of the depth of neutral axis.

3.2 Results of dynamic tests
Fig.2 gives the measured impact factor ($1+\mu$)-V curve. The maximum ($1+\mu$) was as high as 1.43 and some crests existed in the ($1+\mu$)-V curve. The reasons were that the vibration of the bridge was excited by many factors, such as the speed of locomotive, differences in the axleweights, flatness of the rail on the bridge, and the s-shaped movement between the rail and the wheel, etc. As the freqency of the exciting forces was nearing the natural frequency of the bridge, the measured impact factor would be much larger, and a crest appeared in the ($1+\mu$)-V curve. By spectral analysis for the free vibration, the fundamental natural frequency and the damping factor of the test beam were acquired equal to 34.8 Hz and 0.061 respectively.

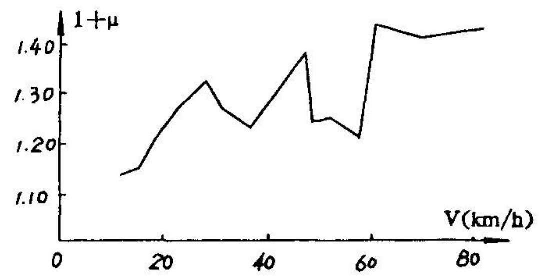

Fig.2 Measure impact factors

3.3 Results of destructive tests
Fig.3 gives the measured load-deflection curve(P-f curve) in destructive test It is shown that the measured deflections both in middle span and quarter

span increase linearly with the load when P_{max} was less then 518.8 kN. If exceeding this value, the measured deflection was increasing visibly and the deformation of the concrete and reinforcement would become nonelasticity, and some of the reinforcing steel in lower flange may be yielded this time. When the load P exceeded 601.8kN, the measured deflection was increasing very rapidly, and the beam had shown very evident yielding phenomenon. When load increasd to 684.7 kN, the beam had totally yielded. When P was equal to 761.7 kN, the beam had come into strengthening stage. The measured destructive load was equal to 1049.8kN. The measured deflections at quarter span and three quarter span were very close to each other, showing that no serious local deteriorations existed which would result in decrease in local stiffness.

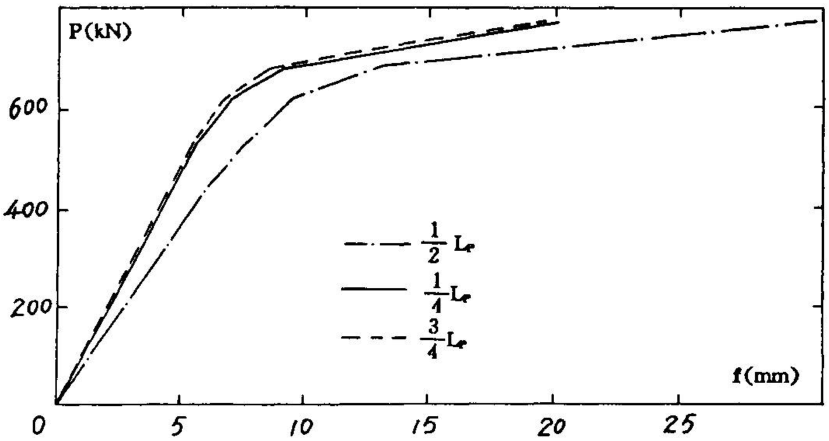

Fig.3 Measured P-f curve

Fig.4 gives the measured crack widthes in destructive test, where the vertical crack W_1 and W_2 as well as the diagonal tension crack W_1' were all that its crack width was maximum. As shown in Fig.4, when no load was act on the beam, the residural crack width was equal to 0.22 mm. When design load acting, it was as big as 0.38 mm. When the maximum load was less then 352.9kN, the beam is still in the range of elasticity although some new cracks had happened. When the load P was exceeded to 601.8 kN, the maximum crack widthes increased very rapidly, indicating that some of the reinforcing steel had yielded.

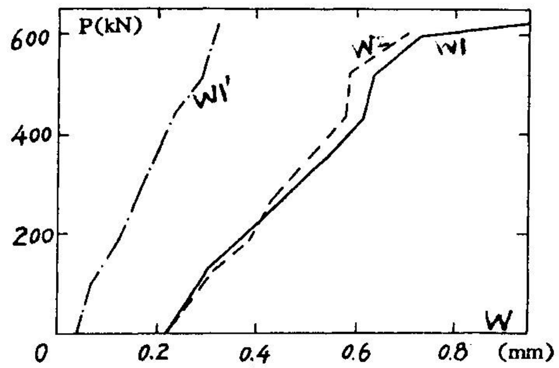

Fig.4 Measured P-W curve

The diagonal tension cracks appeared when the load P was about equal to 352.9 kN, but its maximum cracks widthes were much less than that of vertical cracks, so it had no influences on the load capacity of the bridge.

4. EVALUATION METHOD

4.1 Basical rules for evaluation

Considering the characteristics of the existing structures, the rules bellow must be followed. That is, the geometrical dimensions of the structure must be insitu measured, especially to the weeker sections; the strength of the meterials must be measured in situ; the degree of deterioration in reinforcing steel and concrete in the key sections must be considered.

4.2 Load capacity evaluation

The design and construction records can be used to evaluate the strength for the bridges that no serious deteriorations have happened and the records are applicable. But some times, we had no records about the design and construction or the deteriorations are very serious. For these cases, the methods bellow can be used to evaluate its load capacity.

In practice, many parameters(such as the stresses, deflections, crack widthes, fundamental frequency, etc) can be measured by tests. Suppose that the calculated parameters Y_{jo} is the function of x_i, where x_i are the key factors which affect the strength of RC beams(such as A_s, f_c', etc), that is:

$$y_{jo}=f_j(x_1,x_2...x_i...x_m) \quad (1)$$

Suppose that the number of the measured parameters is N, that is: $0 \leqslant j \geqslant N$, the measured parameters is y_j which is correspond to y_{jo}, we can get:

$$E_{rr}^2=\Sigma(y_j-y_{jo})^2 \quad (2)$$

$$E_{rr}^2=\Sigma\left[y_j-f_j(x_1,x_2...x_i...x_m)\right]^2 \quad (3)$$

The x_i can be calculated by following equation:

$$\frac{\partial E_{rr}^2}{\partial x_i}=0 \quad (4)$$

When the x_i are determined, the strength and serviceability of the bridge can be evaluated by the theory of reinforced concrete, that is:

$$F_d=f_d(x_1,x_2...x_i...x_m) \quad (5)$$

4.3 Evaluation for degree of deterioration

Structural damage evaluation - Here the structural damage represents the damage which results in decreases of the strength. The damage index D_s for this kind of deterioration can be definited as:

$$D_s = M_{us}/M_{uj} \quad (6)$$

where M_{us}=the actual strength. It can be gotten from evaluation;
M_{uj}=Calculated strength.

Then, an other definition is given as bellow:

$D_s>0.95$ no deterioration

$0.8\leqslant D_s<0.95$ permited deterioration

$D_s<0.8$ not permited serious deterioration

The calculated D_s by equation (6) to the test bridge is equal to 0.87. so we consider that the structural damage in the bridge is permited.

Overall deterioration evaluation - Here the overall deterioration represents a kind of the functional decrease, such as, the deformation and stress are *too large or the vibration is too violent due to the cracking or spalling or weathering of concrete, or due to the corrosion of reinforcing steel. The overall damage index can be definited as:

$$D_t=(EI)_m/(EI)_j \qquad (7)$$

where $(EI)_m$=measured stiffness;
$(EI)_j$=calculated stiffness.

Then, we definite:

$D_t \geqslant 0.95$ no deterioration

$0.8 \leqslant D_t < 0.95$ permited deterioration

$D_t < 0.8$ serious deterioration

To the test bridge, the calculated D_t is equal to 0.79. It is concluded that the overall deterioration is serious. By inspection, this deterioration was mainly caused by the weathering and spalling of concrete and the serious corrosion of reinforcing steel.

5. CONCLUSION

1. The deterioration in the test beam was serious;

2. The load capacity of the test bridge is enogh to the design load, showing that the potential strength of RC bridges is large;

3. The measured depth of neutral axis is a stable parameter and it can be used in the strength evaluation;

4. The residual crack widthes and the depth of carbonized concrete were large. The corrosion of reinforcing steel was very serious. The original load capacity and service life of the bridgehad been decreased.

REFERENCES

1. Qihong Wu, The static and dynamic tests on simply supported reinforced concrete beam. Science and Technology of Highway Transportation, No.2, 1990 China.
2. M.P.Young, The inspection, maintenance and repair of highway bridges, The Journal of the Institution of Highway Engineers, Vol.29, No.2, Feb.1982, England.