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I. E. Madsen

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REPORT OF LATERAL LOAD TESTS ON MILL CRANES

RIVETED CRANE NO. 4088

Submitted to the Crane Specifications Committee

of the A. I. & S. E.

I.E. Nadsen
Assistant Research Engineer
Lehigh University
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I - SYNOPSIS

This report summarizes the results of a lateral load test on the bridge girders of a 10-ton riveted crane of 36 ft. 6 in. span. The girders were of uniform box section throughout, and notched at their ends to fit over the end carriage. The girders were also bolted to the end carriage with adequate end ties. The girders were loaded laterally on the top flange to simulate the manner in which acceleration and deceleration forces load the girder. It was found that the girder as a whole resisted the lateral load instead of the top flange alone as is sometimes assumed. In addition the end ties and gusset plates of the end trucks caused the whole unit to act as a frame so that partial fixity was present. The fixed end moments at the end of the bridge were 60 to 73 per cent of those which would have been present at the ends of the bridge girders provided they had been fully fixed.

II - INTRODUCTION AND DESCRIPTION OF TEST

The action of lateral loads on cranes has long been a disputed topic. Both the amount of load and the stresses due to the lateral load have been doubtful points. This test was made in order to determine what stresses would act in a
riveted bridge girder when a lateral load was applied to the top flange of the girder. Knowing the stresses acting, one could easily compute what proportion of the cross section of the girder resists the lateral load.

The stresses were measured by means of a 10-in. Whittenmore Strain Gage. Gage lines were established at the sections of the girder, where the stresses were desired, by drilling two very small holes in the girder ten inches apart. The distance between the holes was measured by means of the gage before and after application of the load. The difference in length between these two readings gives the strain in the members due to the applied load. The results are generally accurate to $\pm 0.001 \text{ lb per sq in.}$

The lateral deflection was found by measuring the change in distance between the adjacent flanges of the two girders. This was done on both the top and bottom flanges at seven sections along the girder by means of a 0.001-in. Federal Dial. The difference between the readings at the zero load and the final load gave the actual movement of the flanges. The difference between the lateral deflection of the top flange and that of the bottom flange at the same section gave the twist in the girder at that section.
The load was applied by taking up on a turnbuckle which was fastened to the top coverplate of both girders. A calibrated spring was interposed in the system. The closure of the spring was measured with 0.001-in. dials and this was a measure of the lateral load. A sketch showing some of the details of the girder and cross-section is given in Fig. 1.

III - TEST RESULTS

The deflections as measured were the combined deflections of both girders. In Fig. 2, are plotted the average deflection of each girder or the total measured deflection divided by 2. These deflections are plotted along the length of the girder and the center line mark denotes the center line of the bridge girder. It should be noted that the deflection at the end is not zero for the 12,600-lb. load but is about 0.07 in. at the top flange and 0.035 in. for the bottom flange. This is due to the slip in the end connection. The top flange slipped more than the bottom flange due to some torsional slip in the joint.

The twist of the girder is plotted in Fig. 3. Some initial slip is also seen to be present. The torsional constants K, as computed from the curves, are marked on the corresponding curves. It is seen that they are fairly close to the theoretical value of 5500 in⁶, as computed from Erodt's theory.
The lateral deflection corrected for the initial slip noted in Fig. 2, and also for the twist shown in Fig. 3, is plotted in Fig. 4. The curves for the different loads have a somewhat different type of curvature. This is because of the greater fixity at the ends of the girders when the 12,600-lb. load was on the girder.

The stresses were measured on the idler girder. Readings were taken on seven sections along the girder. At each section a number of readings were taken. On the top coverplate, readings were taken at the edges and five inches from the edge. They were also taken at the center line of the web and at distances ten and twenty inches above and below the center line. Readings were also taken on the bottom flange angle one inch in from the edge of the angle.

Fig. 5 shows the stress distribution at the center section and also shows the location of the gage lines. The stress is plotted from the adjacent side of the box section as an origin.

In Fig. 6 is shown the variation of stress along the girder on the inside and outside edges of the top coverplate. The corresponding stresses along the bottom flange are shown in Fig. 7. They are seen to be quite similar. The fact that the top and bottom flanges are stressed practically alike shows that the girder acts very nearly as a unit under the
lateral load. Fig. 3 shows the variation in the average web stress along the girder.

In all the stress curves, the point of zero stress is seen to be at an average distance of sixteen feet from the ends of the girder. This point of contraflexure shows that some fixity is present. In this case, the location of the point of zero stress corresponds to a partial fixity of 75 per cent. The statement 75 per cent partial fixity means that the moment at the end of the girder is 75 per cent of that which would be present if the girder were acting as a fully fixed beam.

In this test, the slip which occurred in the joint reduced the fixity. Also, it is impossible to get 100 per cent fixity since there is elastic deflection in the end carriage due to the stress in the end carriage. The effect of this is to reduce the maximum possible end fixity about five per cent for this crane. It should be remembered that no attempt is usually made to compute or allow for end fixity in design.

The theoretical stress shown in the diagrams were computed using a end fixity of 75 per cent and a value of 4850 in$^4$ for the horizontal moment of inertia. This is the gross moment of the whole girder section. The check is seen to be very close.
As an additional check, the deflection was computed using 4850 in$^4$ for the moment of inertia of the idler girder and 17,544 in$^4$ for the moment of inertia of the motor girder. The difference between the two values is due to the walkway which was on the motor girder when the crane was tested. The computed deflection of the idler girder is 0.072 in. and that of the motor girder is 0.268 in. The average deflection is 0.620 in. The measured average lateral deflection as shown in Fig. 3 is 0.600 in. and provides a good check. The influence of the walkway upon the lateral deflection of the girder should be noted as it reduces the deflection to 0.278 times the value it would have had, were the walkway not there.

No stresses were taken at the 4400-lb. load but deflections were measured. The deflection of 0.262 in. corresponds to a partial fixity of 60 per cent. The fixity at the higher load is greater than that at the lower load. This is probably due to the fact that at the higher load, enough deformation had occurred to increase the number of bolts bearing in the end tie thus increasing the restraint.

It should be remembered that the design lateral load is about 1900 lb. However, this load in the test would have resulted in stresses too low to measure. The fixity will vary somewhat with the load. At very low loads, the friction
of the bolts carries the loads. As the load increases, there is a slip which reduces the fixity but as the bolts start to bear the fixity will increase. This is shown by the increase in the end fixity between the 4,400 lb. and 12,600 lb. loads. The section acting to resist the lateral load does not vary with the load. The twisting of the girder was very close to the theoretical. This shows that the small amount of twist occurring in the test was not enough to cause any rivet slip in the girders and the torsional load was probably carried by the friction grip of the rivets.

The theoretical deflections were computed by the following formula:

\[ d = \frac{6I}{4EI} - \frac{3M}{EI} \]

The \( I \) is the end moment as found from the measured stresses and the other terms are as usually given in the handbooks.

The twist was computed by the formula:

\[ \theta = \frac{Mh^2}{6K} \text{ where } \theta \text{ is the angle of twist} \]

\( G \) is the shear modulus and \( K \) is the torsional constant. \( K \) is computed from Bredt’s formula and is equal to \( K = \frac{4A^2}{\pi} \) and

\[ \frac{1}{\int \frac{dx}{E}} \]

for a box section equals \( \frac{2bd^3}{bt_1^2 + dt} \) where \( b \) and \( d \) are the width and depth respectively, \( t_1 \) equals the web thickness, and \( t \) is the average of the top and bottom flange thicknesses.
IV - CONCLUSIONS

The tests on the riveted crane No. 4683 shows that this crane acted in the following manner:

1. The whole section of the box girder resisted the lateral moment.

2. Partial end fixity was present between the bridge girder and end tie. In the tests made, the value varied from 60 to 75 per cent, as the loads varied.

3. The twist of this riveted girder could be computed very closely by Fillitt's theory. This shows that under the low moment to which the girder is subjected, there was no rivet slip to reduce the torsional rigidity. It should be remembered here that the shearing stress was only about 300 lb per sq in.

4. Slip occurred in the joint between the end tie and bridge girder. There were both rotational and lateral slips, of small magnitude.

5. The walkway along a bridge girder has a very important effect on the lateral deflection. In the case of the crane tested, it reduced the lateral deflection almost 75 per cent.
Sketch of Crane #4683

Fig. 1
Note: These are actual measured values

**Lateral Load Test - Crane #4683**
**Deflection of Girder**

Mar 16, 1940

Fig. 2
LATERAL LOAD TEST - CRANE #4683
TWIST OF GIRDER
Mar. 16, 1940

FIG. 3
LATERAL LOAD TEST - CRANE #4683

LATERAL DEFLECTION OF GIRDER

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Fig. 4
LATERAL LOAD TEST ~ CRANE #4683
STRESS DISTRIBUTION AT CENTER OF GIRDER

March 16, 1940

Fig. 5
LATERAL LOAD TEST
CRANE #4683
TOP COVERPLATE STRESSES

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LATERAL LOAD TEST
CRANE #4683
BOTTOM FLANGE STRESSES

March 16, 1940

Figure 7
LATERAL LOAD TEST
CRANE #4683
WEB STRESSES
Mar. 16, 1940

FIG. 8

Stress in Lbs./sq. in
+6000
+4000
+2000
0
-2000
-4000
-6000
40'
20'
0'
20'
40'

Inside

Outside

Theoretical