LATERAL LOAD TEST ON A TRUSS I-BEAM CRANE

by

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1. SYNOPSIS

This report summarizes the results of a lateral load test made on the bridge of a 175 long-ton trussed I-beam crane of 100 ft. 11 in. span. The stresses and deflections in the crane were measured for the lateral test load of 23,700 lb. The whole truss was found to resist the lateral load. Secondary stresses were present in the truss. The stresses in the crane were computed by three methods, and the computed results are compared with the measured results.

2. INTRODUCTION

Since little is known about the behavior of trussed I-beam cranes, this test was made in order to compare actual behavior with design assumptions.

Crane No. 5879 which is a sixteen-wheel crane, was supported on the equalizer trucks during the test. The crane was tested after it had been completely assembled, but without the trolley.

The stresses were measured with a 10-in. Whittemore Strain Gauge which gives results accurate to about 1300 lb. per sq in. They were measured on the girder, end ties, and...
on a number of the more highly stressed truss members. Since the crane was due for shipment, only a limited time was available for the test and it was impossible to take as many readings as would normally be desirable. Sketches showing some of the details of the girder and the truss members discussed in this report are given in Fig. 1 and 2.

The lateral deflection of the girders was determined by means of a 0.001-in. Federal dial which measured the closure as the loading rig pulled the two girders together. The difference between the lateral deflections of the top and bottom flanges at the same section divided by the distance between the gage points gave the twist of the girder at each section.

The load was applied by tightening a turnbuckle fastened to the top flanges of both girders at the center of the span. The load was measured by a calibrated spring which was placed in the system.

5. TEST RESULTS

The girders were loaded with a lateral load of 25,700 lb. applied on the top flange. This was the maximum capacity of the loading rig. Since the capacity of the crane was 175 long tons or about 392,000 lb., the test load was about equivalent to a lateral load on each truss of six per cent of the live load capacity of the crane.
Fig. 3 shows the lateral deflection of both flanges of the girder under the test load. The center line mark denotes the center of the girder span. The deflections are given in inches and are the measured deflections divided by two since the gage gave the combined deflections of both girders.

The measured twist of the girders is shown in Fig. 4.

The measured stresses due to the lateral load are shown in Fig. 5, 6, and 7. Fig. 5 shows the stress distribution along the top flange of the I-beam girder. The gage lines on which these stresses were measured were located on the top coverplate ten inches from the centerline of the I-beam. This figure shows a large bending stress at the center of the girder. The lateral load was applied at the span center and since this was not a panel point location, the I-beam transferred the load to these points. If the top flange alone is assumed to transfer the load as a continuous beam to the panel points, the computed stress will be $\pm 2700$ lb per sq in. Since there is a resultant tension in the girder of about 600 lb per sq in due to truss action, the combined stress would be $+3300$ lb per sq in. and $-3100$ lb per sq in. The measured values are $+3500$ and $-2700$ lb per sq in which are somewhat higher than the computed.
Fig. 6 shows the stress distribution along the bottom flange of the I-beam. The stresses were measured on the edges of the flanges. The local bending at the load point had little effect on the bottom flange. This shows that the top flange transferred most of the load to the panel point.

In Fig. 7 the average stresses of the top and bottom flanges of the girder are shown. These average stresses are a measure of the load carried by the various members. The stresses in the bottom truss are quite appreciable, and would be completely neglected in normal design procedure.

4. DISCUSSION OF RESULTS

In this country, truss cranes have not been as extensively used as in Europe, even though they may result in lighter cranes on long spans. Some of the reasons for this have been economic, and some have been due to a lack of data as to the stiffness and stress distribution in such cranes. This test was made to determine the latter factors and to compare actual measurements with common design assumptions. Although conclusions drawn from a single test can not be used as a basis for general conclusions, they indicate a trend. Secondly, the measurements do show how this particular crane behaved under the test load. Previous data of this type are very scarce.
Crane No. 5879 is a space frame; it is highly indeterminate, and the stresses can be found only after long, tedious computations. In addition, one side of the crane is a complete I-beam girder and little is known as to how much of the girder takes part in resisting the loads. Finally, the problem is complicated by the effect of the walkway and any end fixity which may be present.

Table I presents a comparison between the measured stresses and the stresses computed by three different methods. Table II gives a similar comparison for the deflections. The most approximate computation method is to consider the truss as a beam. In Crane No. 5879, the moment of inertia was computed by assuming the chords of the truss to be one flange of the beam and the whole I-beam to be the other flange. The computed I was 116,500 in$^4$. The tables show that this results in a fair approximation for the stresses, and also for the deflections. However, deflections computed by this method will be low since the deflection of the structure due to the strain in the diagonals is neglected. Also this method of computation gives neither the stresses in the diagonals, nor the twist in the crane.

It should be noted in Table I that the stresses were taken on one, two, or three gage lines on each member tested. These gage lines were usually on the edges of the member and on the same section in every case. The tables show, however,
that the stress at a section is not uniform. This variation is probably due to secondary moments in the truss. Trusses are normally considered to be pin-connected at the joints for computation purposes, whereas they are not usually so in practice. In this crane the members were welded to the gusset plates, and the chords were continuous through the truss. These secondary moments will cause bending stresses in the members, but should not appreciably affect the direct stresses. Secondly, the angles can be welded to the gusset plates on only one leg, which results in an eccentric application of the load on the member and consequent bending stresses.

Since there was some bending in the member, the measured stresses may not necessarily give the average stresses and this fact may account partly for some of the discrepancy between the computed and measured results.

In practice, a crane of the type tested is often designed on the assumption that the top truss takes all the lateral load applied to the top flange. Some designers will split the load between the two trusses with the top truss taking the greater proportion. Fig. 7 shows that the bottom truss is highly stressed due to a load on the top flange. Therefore one can not very well assume that the top chord takes all the load, and that the rest of the crane remains unstressed.
In the second method of computation, the load was split between the two trusses and each truss was analyzed as a separate truss. The method of equating deflections was used to determine how much load was taken by each truss. In this method, the trusses are assumed to be pin-ended. It is also assumed that the center cross diagonals transfer the load from the top truss to the bottom. The diagonal is cut to obtain a statically determinate structure and is the member marked "X" in Fig. 2. The deflections of each truss are then computed. The load taken by each truss is that which makes the relative deflection of the cut ends of the diagonal zero. In this crane, the computation showed that the top truss took 15,200 lb. and the bottom truss 3500 lb. of the applied 23,700 lb. lateral load. These results check approximately as the tables show. The method, however, neglects the effect of the side trusses and does not give the stresses in the side truss diagonals.

In the last column of the tables, the computed loads are given for the truss considered as a space frame. This computation method takes into account all the members. Two assumptions were made in the analysis. One was to split the area of the I-beam into two parts and to consider each part as one of the chords of the truss. Secondly it was assumed

* STRUCTURAL THEORY - Sutherland and Bowman
that only the two center cross diagonals "X" transferred load between the trusses. This second approximation is close since these diagonals are at the loaded panel points. When the cross-diagonals are cut, the various trusses are statically determinate for horizontal and vertical loads, and the stresses can be found by the method of deflections.

Since the structure is indeterminate, adding more area to a member does not necessarily reduce the stresses in that member. The result may be that the member will take more load. In this crane, the top chord of the outside truss had twice the area of the bottom chord. A lateral load of 100 lb. on the top chord, results in a maximum force of 223 lb. in the top chord and a maximum force of 122 lb. in the bottom chord. On the other hand, if a lateral load of 100 lb. is applied on the bottom chord, there is a computed maximum force of 141 lb. in the bottom chord and 209 lb. in the top chord. In other words, the lighter the loaded truss, the more load will be transferred to the adjacent trusses. In the case of the crane tested, the computations indicate that if the top and bottom truss were made equally strong, the maximum load in the chords would be less. The trusses would have more of a tendency to take an equal portion of the load, and there would be less twist in the crane.
Fig. 7 shows a slight end moment in the trusses. Stress measurements in the end tie showed that this end moment was about twenty per cent of the fully fixed end moment. Since the truss was very stiff compared with the end tie, the maximum possible end fixity which could be developed if there were no slip in the joint, was forty-seven per cent.

Fig. 3 gives the lateral deflection of the crane. If the lateral deflection shown here is compared with that of some box girder cranes previously tested*, and adjusted to take into account the difference in capacity and span, it is seen that the truss crane is fully as stiff. Secondly, Crane No. 5879 has so little initial end fixity, it will remain almost as stiff when the end ties loosen in service. This can be seen by looking at the values for the deflection for partial fixity and no fixity in Table II. The box girders previously tested had a much higher end fixity and loosening of the end tie connection would increase the lateral deflection markedly.

The measured deflections shown in Fig. 3 are less than the computed deflections given in Table 2. This is most likely due to the fact that the computations are made on the basis of pin-end connections and the welded joints would stiffen the truss. Secondly, the walkway may have had some stiffening effect, particularly on the lower chord.

* LATERAL LOAD TESTS ON BOX GIRDER MILL CRANES - I. H. Nadesen
If the twist of the crane shown in Fig. 4 is compared with the twists of the box girders previously tested, it would appear that the box girders have more resistance to twisting.

The above comparisons, however, may not be overly significant since it is very difficult in a comparison of cranes of different capacities and spans to draw any definite conclusions.

5. CONCLUSIONS

The measurements made in this test showed that for the crane tested:

1. The whole truss resisted the lateral load as a space frame.

2. The whole I-beam girder acted as a part of the truss.

3. The stresses computed by the three different methods gave results which were a fair approximation of the measured loads. The solution of the truss as a space frame is the only method which could be used to find the stresses in all the members.

4. When the lateral load is not applied at a panel point, the top chord must be designed to transfer the applied load to the panel points.

5. Secondary stresses were present throughout the truss.
<table>
<thead>
<tr>
<th>Bar</th>
<th>Measured Stress</th>
<th>Measured Stress</th>
<th>Measured Stress</th>
<th>Area</th>
<th>Average Measured Stress</th>
<th>Measured Load (lb)</th>
<th>Computed Stress As Beam</th>
<th>Computed Load As Two Separate Trusses</th>
<th>Computed Load As Space Frame</th>
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<td></td>
<td></td>
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<td>+ 2700</td>
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### TABLE II - COMPARISON OF MEASURED AND COMPUTED DEFLECTIONS

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<tr>
<th>Location</th>
<th>Measured in inches</th>
<th>Computed As Beam Fixity</th>
<th>Computed As Two Trusses Fixity</th>
<th>Computed As Space Framework Fixity</th>
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<tr>
<td>Top Flange Center</td>
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<td>0.374 0.334 0.417 0.330</td>
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<tr>
<td>Bottom Flange Center</td>
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<td>0.276</td>
<td>0.237</td>
<td>0.340 0.300 0.367 0.325</td>
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</table>
Section at £ of Truss
Crane #5879

Fig. 2
LATERAL LOAD TEST
CRANE #5879
LATERAL DEFLECTION OF GIRDER

Nov 8, 1940

Fig. 3
LATERAL LOAD TEST
CRANE #5879
ROTATION OF GIRDER
Nov 8, 1940

Fig. 4
LATERAL LOAD TEST
CRANE #5879
STRESSES IN CRANE
Nov. 8, 1940

Fig. 5
LATERAL LOAD TEST
CRANE #5879
STRESSES IN CRANE

Fig. 6

Nov. 8, 1940
LATERAL LOAD TEST
CRANE #5879
STRESSES IN CRANE
Nov 8, 1940

Fig. 7