Progress report on rigid steel frame investigation, 1937

W. E. Black
PROGRESS REPORT ON
RIGID STEEL FRAME INVESTIGATION

by Winston E. Black*

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1. SYNOPSIS

The results of the first year's investigation of a two year study of steel rigid frames is presented in this progress report. A complete model frame of the square-Knee type was tested and analyzed, special consideration being given to the determination of the stress distribution of that portion of the frame in and about the knee. This stress distribution is presented in two forms: namely, as principal stresses and maximum shears; and as normal stresses and shears on arbitrarily selected sections. Also, there are given comparisons of critical stresses and reactions for several variations of span length, simulating the effect of sliding foundations.

These results indicate that the entire frame, except the portion within the knee, can be analyzed and designed by the conventional methods and assumptions. The solution of the portion within the knee necessitates an application of the theory of elasticity.

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2. **INTRODUCTION**

During the last decade there has been a growing appreciation of the many structural and aesthetic advantages of the rigid frame type of construction, particularly as applied to short span bridges. However, due to the lack of available information regarding the stress distribution in and about the knee section, the rigid steel frame is still viewed with distrust by many engineers.

To secure this much needed information, the American Institute of Steel Construction recently initiated two investigations on rigid frames. The first is being carried out in conjunction with the National Bureau of Standards and has been established as a Bureau project. A number of reports of the investigation have been prepared, of which two have been published. The second investigation, reported in this paper, was made possible by the establishment of a research fellowship supported by the A.I.S.C. at the Fritz Engineering Laboratory of Lehigh University. The investigation is carried out under the guidance of the Technical Research Committee of the Institute, whose membership is as follows: Mr. Aubrey Weymouth, Chairman; Messrs. H. G. Balcom, F. H. Frankland, O. E. Hovey, H. P. Hussey, Jonathan Jones, and J.R. Lambert. Acknowledgment is due to all the members of this committee for their active interest in the work and their advice and guidance; to Mr. E. L. Durkee and Mr. G. L. Gray of the McClintic-Marshall Corporation for the design of the first model, and to
Mr. Hussey for the design of the second model (not yet tested), and to the members of the laboratory staff for their assistance in the testing of the model.

In the Bureau of Standards investigation, knee specimens are being tested, the sole purpose being to determine the stress distribution therein. At the Fritz Laboratory, complete model frames are being tested to verify the results obtained at the Bureau, and also to permit the observation of other important data regarding the frame as a whole. The model frames have been reduced from imaginary prototypes with a clear span of 72 ft. and considered as the middle one of three such frames spaced 15 ft. apart, with framed floorbeams and stringers supporting a 36-ft. roadway with E2O loading. The linear dimensions of the model are one-fourth and the cross-sectional areas one-sixteenth of those in the prototype. The blueprint at the end of the report shows the details of the model.

3. TEST PROGRAM

In this investigation, two principal problems were to be studied: namely,

A. The stress distribution in and about the knee of the frame and the comparison of the results with those obtained at the Bureau of Standards.

B. The behavior of the frame as a whole and the determination of the efficiency of the knee joint.
The first problem required for its solution, the state of stress at a number of points on the frame so distributed as to give a complete picture of the stress distribution in and about the knee. This was determined by observing three strain measurements at each point. Having determined the state of stress at each gage point, the stress distribution was drawn up in two forms. For comparison with theoretical analyses, it is presented as principal stresses and maximum shears. For the designer, it is presented as normal stresses and shears on critical sections. Since the results obtained at the Bureau of Standards are presented in these forms in their Progress Report No. 2, a direct comparison may be made.

To study the frame as a whole, it was planned to make a series of comparisons between calculated and observed values of the horizontal reaction and of critical stresses in various parts of the frame under various loading conditions. By means of these comparisons, the efficiency of the knee-joint or the degree to which the frame can be expected to act as an elastic structure, could be determined. In the actual testing, the variation in loading conditions was obtained by varying not the applied, but the horizontal reaction. This was done by moving the supports inward and outward by amounts of one-quarter and one-half inch, and resulted in a different reaction line for each position of the supports.
4. **DESIGN AND FABRICATION OF SPECIMEN Ll**

In order to compare the results of the two investigations, the shape of the knee in test specimen Ll was made similar to test specimen No. 1 of the Bureau of Standards project. The size of the model was chosen to fit the testing machine used for loading, and the test loads were chosen to produce unit stresses within the elastic limit of the material. The positions of the load points were so selected that the reaction line of the complete frame approximated the direction of the load line of the knee specimen. The frame as set up in the testing machine is shown in Fig. 1.

The frame was originally designed with the supports assumed to be hinged, thus permitting the use of the conventional method of analysis and design for a two-hinged arch.

Because of the varying moment of inertia of the frame, it was necessary in this calculation to divide the frame into short convenient sections and employ mechanical integration. The choice of sections is shown in Fig. 2. Having computed the horizontal reaction by this method, the moments, thrusts, and shears were determined. The maximum stresses were computed on three critical sections: that is, vertical and horizontal sections at the inside corner of the knee, and the vertical section at the midpoint of the girder. The second and third of the sections cited were analyzed by the conventional beam formula. On the other section, where the girder comes into
the column, the stresses were computed on the assumption that all of the moment and thrust are transferred into the column through the flanges, and that the web transfers only the shear. The correctness of these assumptions, which are currently used in design by some engineers, is to be determined by the results of the investigation.

Due to the small size of the frame, it was considered advisable to have it fabricated at an ornamental iron works rather than at an ordinary structural shop. Bids were obtained from several such organizations in the vicinity of the laboratory and the contract was awarded to the Bethlehem Fence Works, Bethlehem, Pennsylvania.

The tensile properties of the material from which the frame was fabricated are presented in Table I.

5. TEST METHODS

A. Loading Apparatus - The frame was tested in a 300,000-lb. Olsen machine having a 21-ft. beam which provided an excellent base on which to set the eighteen-foot model. The load was transferred from the moveable head of the machine to the load points of the frame by a system of bars and loading beams as illustrated in Fig. 3.

The horizontal reaction was resisted by a three-quarter inch round bar between the two column bases. To allow adjustment of the reaction and the span length of the frame, the ends
of the tie-bar were threaded and fitted with nuts. Rollers under one of the column bases insured that only a negligible amount of friction might affect the horizontal reaction. These features as well as the hinge detail are shown in Fig. 4 and 5.

In order to prevent lateral buckling or twisting of the thin horizontal girder, trussed frames were built up from the testing machine to the girder at three points; at midspan, and about six inches inside the inner face of each column, as shown in Fig. 3. The frame had a tendency to bear against all of these lateral supports under load, but only at the center was there any appreciable vertical deflection where friction might be developed. Comparative tests, with and without the center support present gave results within the limits of experimental error, so the frictional effect was regarded as negligible.

Several preliminary loadings were applied to the frame before testing to eliminate the effect of rivet slip and other inequalities in the frame and loading rig.

3. Observations and Instruments - All tests were based on a zero load of 1000 lb. and a maximum applied load of 13,000 lb., giving a working range of 12,000 lb. for which the vertical column reaction, designated as P, is 6000 lb. For tests in which a constant span length was maintained, the load was applied in two equal increments, observations being made
at zero load, half load, and full load. When variation of span length was being studied, observations were made only at zero and full loads, the span length being normal at zero load and lengthened or shortened the required amount at full load. The normal span length is the span length under no load.

To determine the state of stress at each gage point on the web, three strain readings, horizontal, vertical, and inclined at 45 degrees, were observed. At each flange gage point only the strain parallel to the flange was observed, for the stresses perpendicular to the length of the flange may be considered negligible. At all gage points, strains were observed on both sides of the frame at the same time to take account of the effect of lateral buckling. The location of the gage points is shown in Fig. 6. These strain observations were made with Huggenberger tensometers with one inch gage lengths. With these instruments the stresses could be observed with an accuracy of about 300 p.s.i. The instruments were held in position as shown in Fig. 7; the tapped holes in the web plate being one-eighth inch in diameter.

The variation in span length was controlled by a 0.001-in. Ames dial bearing against one column base and fastened to a long light angle which was clamped at its opposite end to the other column base. Rollers supported the angle along its length. This detail is shown in Fig. 4 and 5.
The horizontal reaction was determined by observing the strain in the tie bar with a ten-inch Whittemore strain gage and computing the stress therefrom. This instrument is fitted with a 0.0001-in. Ames dial and is accurate to about 300 p.s.i.

The deflection of the center of the frame was observed with a 0.001-in. Ames dial.

C. Computations - For the determination of the stress condition at a point from three observed strains, the graphical method presented by Messrs. W. R. Osgood and R. G. Sturm in Research Paper No. 559 of the Bureau of Standards Journal of Research was used. This method is illustrated in Fig. 8.

6. TEST RESULTS

Early tests showed that the two knees of the frame behaved quite similarly, so the majority of the tests were confined to the East end, and only those tests will be given in this report.

The complete stress distribution of the knee was determined for two loading conditions: with the span length normal, and with the supports moved one-quarter inch outward. Fig. 9 shows the magnitude of the maximum principal stresses in the knee, which compare favorably with Fig. 12 of the Bureau of Standards Progress Report No. 2. Similarly, Fig. 10, representing minimum principal stresses, compares well with
Fig. 13 of the Bureau report, and Fig. 11, representing maximum shearing stresses, compares with Fig. 14 of the Bureau report. Similar diagrams for the supports moved one-quarter inch outward are presented in Fig. 12, 13, and 14.

Normal stresses on several sections about the knee are shown in Fig. 15, which is comparable with Fig. 17 of the Bureau report. Attention is called to discrepancies in the normal stress distribution in the two reports on the diagonal section through the knee and on the vertical section through the girder nearest the column. These differences are probably both attributable to the same cause. In the Bureau of Standards test specimen, the bottom flange of the girder did not bear tightly upon the face of the column, throwing much of the compression in the girder into the web and splice angles above the flange. Whereas, in the complete frame almost the entire compression of the girder was transferred through the outstanding legs of the bottom flange. This was due to the presence of shims inserted at this point to insure proper bearing of the flange against the column face. Thus, an extreme concentration of stress was produced. A study of the stress distribution across the flange angles indicated that if proper bearing was obtained, the normal stress curve on the section through the girder at this point would assume the position of the dotted portion illustrated in Fig. 15. Even though this modification is taken into consideration, it is still evident that the web
of the girder is transferring only a small portion of the moment and thrust to the column.

Still referring to Fig. 15, a note of explanation is given here regarding the derivation of the normal stresses on the section through the bottom of the knee, where stiffening angles prevented the observation of stress in the web. The two maximum values are based on actual strain observations on the flanges, while the stresses at the interior points are approximated from values at adjacent gage points. This curve contradicts the assumption that straight line stress distribution exists on the section. However, it must be recognized at the same time that these increased compressions are strictly local, and that in both column and girder the normal stress distribution assumes linear variation within a few inches of the boundary of the knee.

A study of the maximum shears in the knee revealed a comparatively simple solution for the problem of designing the web for shear. The directions of the maximum shears within the knee are almost horizontal and vertical, and computations show that at no point is the horizontal and vertical shear less than 93.8 per cent of the maximum shear at the same point. The average horizontal and vertical shear for the entire knee is 98.4 per cent of the average maximum shear. Thus, a design based on horizontal shear, that gives unit shears comparable to the observed values, can be considered both precise and adequate.
A comparison of the observed horizontal shears and those calculated on the original assumption that all of the moment and thrust in the girder is transferred to the column through the flanges is presented in Table II. The manner in which the forces due to the girder are assumed to act upon the knee is also shown in the Fig. 16.

Comparisons of observed and calculated values of the horizontal reaction and of critical stresses for five variations of span length are presented in Table II. The agreement between observed and theoretical values of the horizontal reaction, as shown graphically in (b) of Fig. 17, is as close as can be expected, considering the accuracy of the observation.

For purposes of comparison, the critical stresses were calculated by several methods as noted in the table. The design assumptions on which the calculations were based are: (1) there is a linear variation of normal stress on the horizontal section through the inside corner of the knee and on the vertical section at midspan, (2) on the vertical section through the inside corner of the knee, all the moment and thrust is transferred through the flanges. The additional set of values for the maximum stresses in the girder at the corner were calculated on the basis of the conventional beam formula.

The maximum compression values for the girder at the corner are all high due to the concentration of stress previously mentioned. However, the average stress across the bottom
flange agreed closely with the values calculated on the first two assumptions. The compression values in the column are also high, which may be partially due to the same concentration. The fact that the tension values in the column are low indicates that curved beam action is also involved.

The observed maximum tension in the girder at the corner falls between the theoretical values based on the two fundamental assumptions. The assumption that the flanges take all of the moment and thrust leads to the more conservative design.

The agreement between the observed and theoretical values of stress on the section at midspan is within the limits of experimental error.

Fig. 17 and 18 demonstrate that the frame behaves elastically both in respect to the application of load and to the variation of span length.

**AGENDA**

The investigation is to be continued during the academic year of 1937-1938. Further tests on the square-knee model will be run to determine the effect of various support conditions, such as full and partial fixation. The results will be compared with the results already obtained with hinged supports.
A full set of tests will be made on a complete model of the curved-knee type, which is similar to test specimen No. 2 of the Bureau of Standards project. This model has been fabricated and is ready to be tested as soon as the investigation is resumed in the Fall of the current year.
TABLE I

RESULTS OF TENSILE TESTS OF STEEL COUPONS

FOR TEST SPECIMEN NO.L1

<table>
<thead>
<tr>
<th>Coupon No.</th>
<th>Coupon Cut From</th>
<th>Thickness in.</th>
<th>Young's Modulus of Elasticity kips/in²</th>
<th>Yield Point Strength kips per sq in</th>
<th>Tensile Strength in 8 in.</th>
<th>Elongation per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Angle T</td>
<td>0.196</td>
<td>29,000</td>
<td>45.2</td>
<td>64.0</td>
<td>23.7</td>
</tr>
<tr>
<td>2</td>
<td>Angle T</td>
<td>0.193</td>
<td>28,500</td>
<td>43.0</td>
<td>64.6</td>
<td>21.4</td>
</tr>
<tr>
<td>3</td>
<td>Angle B</td>
<td>0.188</td>
<td>28,400</td>
<td>44.4</td>
<td>66.6</td>
<td>23.1</td>
</tr>
<tr>
<td>4</td>
<td>Angle B</td>
<td>0.192</td>
<td>29,400</td>
<td>43.8</td>
<td>65.4</td>
<td>24.4</td>
</tr>
<tr>
<td>5</td>
<td>Angle S</td>
<td>0.189</td>
<td>28,300</td>
<td>39.9</td>
<td>55.6</td>
<td>27.4</td>
</tr>
<tr>
<td>6</td>
<td>Angle S</td>
<td>0.190</td>
<td>26,800</td>
<td>42.5</td>
<td>60.0</td>
<td>24.8</td>
</tr>
<tr>
<td>7</td>
<td>Angle LL</td>
<td>0.159</td>
<td>29,100</td>
<td>47.6</td>
<td>56.7</td>
<td>31.9</td>
</tr>
<tr>
<td>8</td>
<td>Plate RL</td>
<td>0.159</td>
<td>28,200</td>
<td>44.4</td>
<td>51.9</td>
<td>22.2</td>
</tr>
<tr>
<td>9</td>
<td>Plate M</td>
<td>0.162</td>
<td>28,400</td>
<td>45.3</td>
<td>54.5</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28,600</td>
</tr>
</tbody>
</table>

10 Tie Bar 1 28,600
11 Tie Bar 2 28,500
**TABLE II**

**COMPARISON OF THEORETICAL AND OBSERVED CRITICAL VALUES**

<table>
<thead>
<tr>
<th>Variation of Span-in.</th>
<th>+1/2</th>
<th>+1/4</th>
<th>0</th>
<th>-1/4</th>
<th>-1/2</th>
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<tbody>
<tr>
<td><strong>Horizontal (Observed)</strong></td>
<td>4,590</td>
<td>4,960</td>
<td>5,270</td>
<td>5,600</td>
<td>5,860</td>
</tr>
<tr>
<td><strong>Thrust (Calculated)</strong></td>
<td>4,610</td>
<td>5,080</td>
<td>5,350</td>
<td>5,580</td>
<td>5,890</td>
</tr>
<tr>
<td><strong>Maximum Tension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in Girder</td>
<td>11,700</td>
<td>12,600</td>
<td>13,400</td>
<td>14,150</td>
<td>14,800</td>
</tr>
<tr>
<td>at Corner</td>
<td>12,900</td>
<td>13,900</td>
<td>14,700</td>
<td>15,400</td>
<td>16,150</td>
</tr>
<tr>
<td><strong>Maximum Compression</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in Girder at Corner</td>
<td>19,900</td>
<td>26,800</td>
<td>29,000</td>
<td>26,900</td>
<td>28,200</td>
</tr>
<tr>
<td><strong>Maximum Compression</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in Column</td>
<td>17,300</td>
<td>18,100</td>
<td>20,500</td>
<td>21,600</td>
<td>22,000</td>
</tr>
<tr>
<td><strong>Maximum Tension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in Column</td>
<td>9,950</td>
<td>10,250</td>
<td>10,500</td>
<td>11,100</td>
<td>12,000</td>
</tr>
<tr>
<td><strong>Maximum Tension in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girder at Mid-span</td>
<td>19,900</td>
<td>19,350</td>
<td>13,100</td>
<td>10,100</td>
<td>6,900</td>
</tr>
<tr>
<td><strong>Maximum Compression</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in Girder at Mid-span</td>
<td>22,000</td>
<td>18,600</td>
<td>15,500</td>
<td>12,700</td>
<td>9,600</td>
</tr>
</tbody>
</table>

- Observed values
- Calculated from Theoretical Horizontal Reaction on Bases of Design Assumptions
- Calculated from Observed Horizontal Reaction on Basis of Design Assumptions
- Calculated from Theoretical Horizontal Reaction on Basis of Full Section Acting
- Readings adjusted because of faulty instruments
RIGID FRAME TEST SPECIMEN NO. 1
LOCATION OF SECTIONS FOR
MECHANICAL INTEGRATION.
Fig. 4 - Details of Moveable Base of Frame L1
Fig. 5 - Detail of Fixed Base of Frame Ll
RIGID FRAME TEST SPECIMEN NO. 1
LOCATION OF GAGE POINTS

HORIZONTAL, VERTICAL, AND 45° READINGS TAKEN
ONE READING TAKEN PARALLEL TO FLANGES

Fig. 6
Fig. 7 - Method of Attaching Huggenberger Tensometers
Observed Strains
in millionths inches per inch

Graphical Determination of Principal Strains

\[ \varepsilon_{\text{max.}} = +276 \; \quad \varepsilon_{\text{min.}} = -509 \; \quad \gamma_{\text{max.}} = 2 \times 394 = 788 \]

\[ \sigma_{\text{max.}} = \frac{9}{8} E (\varepsilon_{\text{max.}} + \frac{1}{3} \varepsilon_{\text{min.}}) = \frac{9}{8} \times 28.6 (276 - 509/3) = 3460 \]

\[ \sigma_{\text{min.}} = \frac{9}{8} E (\varepsilon_{\text{min.}} + \frac{1}{3} \varepsilon_{\text{max.}}) = \frac{9}{8} \times 28.6 (-509 + 276/3) = -13400 \]

\[ \tau_{\text{max.}} = G \gamma_{\text{max.}} = 10.7 \times 788 = 8430 \]

Stresses in pounds per sq. in.

Determination of Principal Stresses
from Observed Strains

Fig. 8
RIGID FRAME TEST SPECIMEN NO. L1
MAXIMUM PRINCIPAL STRESS
SPAN LENGTH NORMAL
EAST END LOAD: \( P = 6000 \) #
STRESSES IN KIPS/IN.²
RIGID FRAME TEST SPECIMEN NO. 1
MINIMUM PRINCIPAL STRESS
SPAN LENGTH NORMAL
EAST END LOAD: P = 6000# 
STRESSES IN KIPS/IN.²
RIGID FRAME TEST SPECIMEN NO. L1
PRINCIPAL SHEARING STRESS
SPAN LENGTH NORMAL
EAST END LOAD: \( P = 6000 \) kips
STRESSES IN KIPS/IN.²
RIGID FRAME TEST SPECIMEN NO.11
MINIMUM PRINCIPAL STRESS
SPAN LENGTH = +\(\frac{1}{4}\) IN.
EAST END LOAD = \(P = 6000\)#
STRESSSES IN KIPS/IN.\(^2\)
RIGID FRAME TEST SPECIMEN NO. L1
PRINCIPAL SHEARING STRESS
SPAN LENGTH = + 1/4 IN.
EAST END LOAD = P = 6000#
STRESSES IN KIPS/IN.²
RIGID FRAME TEST SPECIMEN NO.1
NORMAL STRESSES
SPAN LENGTH NORMAL
EAST END LOAD - P = 6000#
<table>
<thead>
<tr>
<th>SECTION</th>
<th>AVERAGE HORIZONTAL SHEARS</th>
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<tbody>
<tr>
<td></td>
<td>CALCULATED ON BASIS OF INDICATED LOADING</td>
</tr>
<tr>
<td>D</td>
<td>6240 LB/IN.²</td>
</tr>
<tr>
<td>E</td>
<td>8040 &quot;</td>
</tr>
<tr>
<td>F</td>
<td>7860 &quot;</td>
</tr>
<tr>
<td>G</td>
<td>7670 &quot;</td>
</tr>
</tbody>
</table>

RIGID FRAME TEST SPECIMEN NO. 1
STUDY OF SHEARS IN KNEE SPAN LENGTH NORMAL
EAST END LOAD - P = 6000#

FIG. 16
Fig. 17

(a)

HORIZONTAL REACTION - KIPS
SPAN LENGTH NORMAL

(b)

HORIZONTAL REACTION AT FULL LOAD - KIPS

VARIATION OF SPAN LENGTH - INCHES

Computed Values
Observed Values
(a) 

Load - Kips

Deflection - Inches 
Span Length Normal

(b) 

Maximum Deflection - Inches

Variation of Span Length - Inches

Fig. 18
### Section A-A

#### Bill of Material

<table>
<thead>
<tr>
<th>No.</th>
<th>SHAPE</th>
<th>SIZE</th>
<th>LENGTH</th>
<th>W/T</th>
<th>TOTAL W/B</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>63</td>
<td>2 x 2 x 1/2&quot;</td>
<td>20'-0&quot;</td>
<td>2.44</td>
<td>4.44</td>
<td>102.0</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>-</td>
<td>18'-2&quot;</td>
<td>2.44</td>
<td>4.44</td>
<td>68.5</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>10'-2&quot;</td>
<td>2.44</td>
<td>4.44</td>
<td>68.5</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>5'-0&quot;</td>
<td>2.44</td>
<td>4.44</td>
<td>68.5</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>3'-0&quot;</td>
<td>2.44</td>
<td>4.44</td>
<td>68.5</td>
</tr>
<tr>
<td>6</td>
<td>63</td>
<td>2 x 1 1/2&quot;</td>
<td>1'-3&quot;</td>
<td>165</td>
<td>165</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>0'-6&quot;</td>
<td>165</td>
<td>165</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>0'-0&quot;</td>
<td>165</td>
<td>165</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
<td>-</td>
<td>0'-0&quot;</td>
<td>165</td>
<td>165</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>3 x 3 1/2&quot;</td>
<td>17'-11/16&quot;</td>
<td>2.24</td>
<td>4.32</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>3 x 3 1/2&quot;</td>
<td>5'-9&quot;</td>
<td>9.00</td>
<td>18.0</td>
<td></td>
</tr>
</tbody>
</table>

#### Notes:
- All holes to be subpunched and reamed to size with the material assembled, or drilled from the solid with the material assembled. Subpunched holes are to be 3/32 smaller than nominal diameter of the rivet.
- This frame is to be used for test purposes and should be fabricated with corresponding care. It will be inspected accordingly during fabrication. The frame shall be in true alignment and dimension, with freedom as far as possible from locked-up stresses due to cold working or thermal effects.
- The completed frame shall be suitably stiffened with timbers or otherwise, to avoid the possibility of damage in shipment.

### Model of Rigid Frame Bridge Test Specimen No. 1

**Fritz Engineering Laboratory, Lehigh University**

**Date:** Oct 17, 1936  
**Scale:** 1" = 10'  
**Drawn by:** W.E.B.  
**A.I.S.C. Specifications except as noted.**

**Steel:** A.S.T.M. A7-34

**General Notes:**
- Rivets 1/8", Holes 3/16"  
- Web to be 1/6" less than b to b.6  
- Sufficient material for preparation of test coupons, properly identified, to be forwarded with specimen; two coupons desired from each main plate and each main angle, one from each end if obtainable.