Cornell University School of Civil Engineering
Tests on light beams of cold-formed steel

Cornell University School of Civil Engineering

Follow this and additional works at: http://scholarsmine.mst.edu/ccfss-library
Part of the Structural Engineering Commons

Recommended Citation
Cornell University School of Civil Engineering, "Cornell University School of Civil Engineering Tests on light beams of cold-formed steel" (1940). Center for Cold-Formed Steel Structures Library. Paper 202.
http://scholarsmine.mst.edu/ccfss-library/202
I. IDENTIFICATION OF SPECIMENS.

The method of designation used hitherto is not sufficiently differentiated to identify the present and future specimens since specimens with identical bottom flanges but different top flanges are used. For this reason from now on each specimen is designated by symbols and figures, for example D-18-16-88a in which:

D designates a series of beams,
18 designates the gage of material used for web and bottom flange,
16 designates the gage of material used for the top flange,
8 designates the depth of the section in inches,
8 designates the width of the bottom flange in inches,
"a" designates the particular beam if duplicates are submitted.

In the present and future tests of the specimens given on drawings 63 and 64 of the summary report, the letter D refers to the beams without stiffeners on the bottom flange (left columns of these drawings) and E to those with stiffeners (right columns).

II. OBJECT OF THIS REPORT.

1. Investigation of mechanical properties of the 16 and 18 gage sheets used for the beams of series C.

2. Investigation of the stress distribution in the bottom flange of beam D-18-16-88a under two types of loading and for two lengths of span.

3. Investigation of the stress distribution in the bottom flange of a rolled wide flange I beam WF 6 x 6 - 15-1/2 under two types of loading and for two lengths of span.

4. Comparison of the results of these tests with those of Mr. Winter's analytical investigation of the stress distribution.

(The other two beams of series D and E received have been designed for tests to failure but not for stress distribution. However tests to failure are bound to be carried out systematically, proceeding from the weaker to the stronger beams. Since the specimens necessary for this purpose have not yet been received, no tests to failure have been made on the new series.)

III. GRAPHICAL REPRESENTATION OF THE RESULTS.

The results of the stress investigations referred to in this report are given in the accompanying 5 graphs:

Drawing 65 shows the stress distribution of beam D-18-16-83a at the load point for 6 ft. span and center load.

Drawing 66 shows the stress distribution for the same beam at the load point for 12 ft. span and center load.
Drawing 67 shows the stress distribution for this same beam at one load point for 12 ft. span and quarter point load.

Drawing 68 shows the same at the other load point.

Drawing 69 shows the stress distribution in the bottom flange of a WF 6x6 - 15-1/2 beam at the load points a) for 6 ft. span and center load, b) for 6 ft. span and quarter point load, and c) for 3 ft. span and center load.

In these drawings only the longitudinal stresses are given since the transverse stresses are of no interest.

IV. MECHANICAL PROPERTIES OF THE 16 & 18 GAGE SHEETS.

On these materials the same tests have been performed as those previously reported on for the 14 and 22 gage sheets. (See 5th progress report, section VII.) Two specimens of the same form as before were taken from each sheet in the direction of rolling and perpendicular to it. The results of these tests are given in the following table.

<table>
<thead>
<tr>
<th>Gage</th>
<th>In direction of rolling yield</th>
<th>ultimate</th>
<th>permanent point strength</th>
<th>elongation</th>
<th>Perpendicular to direction of rolling yield</th>
<th>ultimate</th>
<th>permanent point strength</th>
<th>elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>42 700</td>
<td>46 850</td>
<td>17%</td>
<td></td>
<td>47 100</td>
<td>53 650</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>33 400</td>
<td>45 150</td>
<td>34%</td>
<td></td>
<td>34 350</td>
<td>45 900</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>

The permanent elongation is given for 2". Several of the specimens failed near the ends of the test parts of the specimens. For yield point and ultimate strength they did not perform as uniformly as did the 14 and 22 gage sheets.

In addition considerable work has been done in investigating the modulus of elasticity of all four sheet thicknesses. However serious difficulties have been encountered in these tests resulting from the small thickness of the sheets and this part of the work therefore is not yet finished. It will be reported on when definite results will be obtained.

V. STRESS DISTRIBUTION IN THE BOTTOM FLANGES.

As indicated above in addition to the thin gage beams the stresses have been also investigated on a rolled section WF 6x6 - 15-1/2#. Of the available rolled sections this one has one of the greatest ratios of width to depth and is of comparatively small flange thickness (.27 in.). Previously it has been stated that from theoretical considerations it seemed likely that within certain limits the influence of the flange thickness on the stress distribution was negligible (See 5th progress report, last sentence of section V). The present tests fully confirm this prediction. From the data of drawing 69 it is seen that this rolled beam shows the same type of marked nonuniformity of the stresses as have been observed on
the thin gage beams. The determination of these stresses is not as complete as those on the thin sheet beams since, due to the small dimensions of the beam, it has not been possible to mount the strain gages on the upper face of the bottom flange. For this reason the stresses have been determined only on the bottom surface of the bottom flange.

In order to see whether the behavior of the thin sheet beams is different in different parts of the same specimen, the stresses have been investigated at both quarter points of beam D-13-16-33a (Drawings 67 and 69). As seen from the comparison of these diagrams, especially of those of the averaged mid-plane stresses (bottom graphs) there is considerable difference in the stress values although, judging from symmetry, they should be equal in an ideal specimen. It should be noted however that between the measurements on point "A" and those on point "B" the beam had been taken out of the testing machine. Thus the differences may be partly due to actual differences in the beam and partly to differences in the mounting and loading.

For this reason no quantitative conclusions can be drawn from these discrepancies. It seems however to be established that this beam has a marked nonuniformity in its different parts and it will be necessary to investigate this question further in order that it may be taken into account in future specifications.

In addition another investigation of the type described in the second progress report, section IV, has been made in order to reaffirm the accuracy of the strain measurements and to safeguard against possible inaccuracies resulting from wear of the strain gages. It has been found that repeated measurements of the same strains coincided within the same limits of accuracy as had been obtained in the first tests of this kind mentioned above and that hence the results obtained are still reliable within the same limits, i.e. within 3-7%.

A summary representation of the numerical results of the present stress investigations will be given in connection with analytical considerations in the following section.

VI. COMPARISON OF EXPERIMENTAL AND ANALYTICAL RESULTS.

As mentioned before Mr. Winter has carried out an independent analytical investigation of the stress distribution in the flanges (5th progress report, section IV.) The numerical computations to this work have been performed during the time covered by this report. As a result the "equivalent" or "reduced" width has been determined for I and box beams for different kinds of loading and for a range of dimensions likely to cover all possible practical cases. In order to facilitate an experimental test of this theory Mr. Winter has also computed the ratio of the magnitudes of the stresses at the web and those at the edges for I beams of different dimensions and loadings. In the following table the experimental and the analytical stress ratios are given for all tests covered in this report. The ratios obtained experimentally have been determined by averaging the stresses of the left and the right parts of the flanges and thus should be comparatively free from inaccuracies resulting from instrumentation.
Table 2
Ratio of stresses at joint of web and flange to stresses at outer edge of flange at load point.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Span</th>
<th>Loading</th>
<th>Stress ratio from test</th>
<th>Stress ratio from theory</th>
<th>difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-18-16-33a</td>
<td>6 ft</td>
<td>center</td>
<td>1.22</td>
<td>1.25</td>
<td>+ 5.5%</td>
</tr>
<tr>
<td>same</td>
<td>12 ft</td>
<td>center</td>
<td>1.16</td>
<td>1.10</td>
<td>+ 5 %</td>
</tr>
<tr>
<td>same</td>
<td>12 ft</td>
<td>quarterpoint</td>
<td>1.22</td>
<td>1.10</td>
<td>+11 %</td>
</tr>
<tr>
<td>same</td>
<td>12 ft</td>
<td>quarterpoint</td>
<td>1.14</td>
<td>1.10</td>
<td>+ 3 %</td>
</tr>
<tr>
<td>WF 6x6-15.5</td>
<td>3 ft</td>
<td>center</td>
<td>1.43</td>
<td>1.48</td>
<td>- 3 %</td>
</tr>
<tr>
<td>same</td>
<td>6 ft</td>
<td>center</td>
<td>1.19</td>
<td>1.15</td>
<td>+ 3.5%</td>
</tr>
<tr>
<td>same</td>
<td>6 ft</td>
<td>quarterpoint</td>
<td>1.16</td>
<td>1.15</td>
<td>+ 1 %</td>
</tr>
</tbody>
</table>

It is seen that the coincidence of the experimental and the analytical data is rather satisfactory. However it should be noted that while the deviations on the rolled section are rather incidental (positive as well as negative), the actual stress concentration on the thin gage beam in all cases is slightly greater than the theoretical one. This fact will be discussed later. The dependency of the stress ratio on the ratio of span to width is more clearly seen if these same data are rearranged according to this criterion.

Table 3
Dependency of stress ratio on ratio l/b
of span over width of bottom flange

<table>
<thead>
<tr>
<th>Beam</th>
<th>l/b</th>
<th>Stress Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>from test</td>
<td>from theory</td>
</tr>
<tr>
<td>a) Center load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WF 6x6-15.5</td>
<td>6</td>
<td>1.43</td>
</tr>
<tr>
<td>D-18-16-33a</td>
<td>9</td>
<td>1.32</td>
</tr>
<tr>
<td>WF 6x6-15.5</td>
<td>12</td>
<td>1.19</td>
</tr>
<tr>
<td>D-18-16-33a</td>
<td>15</td>
<td>1.16</td>
</tr>
</tbody>
</table>

b) Quarterpoint load

<table>
<thead>
<tr>
<th>Beam</th>
<th>l/b</th>
<th>Stress Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>from test</td>
<td>from theory</td>
</tr>
<tr>
<td>WF 6x6-15.5</td>
<td>12</td>
<td>1.16</td>
</tr>
<tr>
<td>D-18-16-33a</td>
<td>19</td>
<td>1.22</td>
</tr>
<tr>
<td>D-18-16-33a</td>
<td>18</td>
<td>1.14</td>
</tr>
</tbody>
</table>

It is thus seen that, regardless of the flange thickness, the stress concentration decreases with increasing ratio of span/width. This is seen especially on the center load tests in which a wider range of l/b has been covered. For reasons of experimental technique it has not been possible to cover the same wide range for quarterpoint loading and thus for this type of loading this dependency does not show so clearly.

VII. CONCLUSIONS.

1) It has been found that considerable concentration of the flange stresses near the web takes place not only in thin sheet beams but also in regular rolled sections.
2) The coincidence of experimental and theoretical values of the ratio stress at web/stress at edge is satisfactory for all seven tests. The difference between the experimental and the theoretical data is about 5% or less except for one test out of seven.

3) For the given beams the stress concentration increases with decreasing ratio of span/width, i.e. with increasing relative width of the bottom flange, regardless of the flange thickness.

4) The coincidence is better for the rolled section than for the thin gage beam. This may be due to the greater uniformity of shape and dimensions of a rolled beam. It is however remarkable that on the thin sheet beam the stress concentration in all cases is slightly greater as it would follow from the theory. It appears likely that this is due to the fact that actually the bottom flange consists of two separate halves, joined only by the spot welds in the web. It can be shown analytically that these two halves have a tendency to separate near the supports and that, if they are able to do so, the stress ratio is increased by this fact. This hypothesis is confirmed by the further fact that the stress ratios on the beams of the "A" series (summary report, V, table 4) are all larger than those observed presently for the same l/b. The distance from the bottom flange to the spot welds in the web is 1 in. in the "A" series, but equal or less than 1/2 in. in the beam D-13-16-88a. Thus the joint of the two flange halves is worse in the beams of the "A" series and actually separation of the flange parts and even breaking of spot welds due to such separation has been observed on beams of series "A" near the supports. In order to investigate this fact it is desirable later on to perform tests on one or two thin gage beams having a single sheet bottom flange. Such beams will be designed in due time.

5) The fact that in the present tests no influence of the flange thickness has shown up does not mean that this fact may be entirely disregarded. Mr. Winter has shown in his analytical work that his solution, which disregards the influence of the flange thickness, is applicable only within a certain range of dimensions. So for the present 18 gage bottom flanges the small thickness of the flange leads to an increase of the stress concentration beginning from a flange width of about 14.5 in. Consequently for the ordered specimens with 16 in. flange width the stress ratio determined experimentally is expected to be slightly higher than the analytical one. It should be noted however that this influence, as seen from the present example, should be felt only in beams of very considerable width which will hardly be used in practice. Thus it seems likely that for all practical purposes this analytical solution will be applicable.

6) It has been found that beam D-13-16-88a has different stress distributions at either quarterpoint under the same load. This is doubtless the result of irregularities in the beam. If this will turn out to be a general and unavoidable property of thin sheet beams, one may take account of this fact in future building code specifications by taking a slightly larger safety coefficient for such beams than for rolled sections.

VIII. CORRECTIONS TO PREVIOUS REPORTS.

1) The widest beam tested to failure of series "A" was not A-14-512a
but its twin specimen A-14-612b. (5th progress report, section V and Summary Report, section V). On A-14-612a only the stress investigation has been carried out. Since in the course of this stress investigation several spot welds broke near the supports and as a result the two halves of the beam began to separate, the test to failure was carried out on the undamaged twin specimen A-14-612b.

2) The heading of table 2 of the 5th progress report and of table 3 of the Summary Report should be "Ratio of stress at joint of web and flange to stress at outer edge of flange at load point" instead of "Ratio of stress at outer edge of flange at load point to the stress at joint of flange and web at load point".
STRESS DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT
D-18-16-885a

Top Surface

Bottom Surface

Mid-Plane

Actual Stress
Stress by Flexure Formula

K_{T_a}

K_{T_b}

K_{T_c}

K_{T_d}

K_{T_e}

K_{T_f}

K_{T_g}

K_{T_h}

K_{T_i}

K_{T_j}

K_{T_k}

K_{T_l}

K_{T_m}

Loading Diagram
STRESS DISTRIBUTION IN BOTTOM FLANGE
AT LOAD POINT
D-18-16-88 a.

Top Surface

Bottom Surface

Mid-Plane

WEB

LOADING DIAGRAM
### Stress Distribution in Bottom Flange

**At Load Point “A”**

D-18-16-88

<table>
<thead>
<tr>
<th>Top Surface</th>
<th>Bottom Surface</th>
<th>Mid-Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>70</td>
<td>83</td>
</tr>
<tr>
<td>7,000</td>
<td>95</td>
<td>93</td>
</tr>
<tr>
<td>5,000</td>
<td>105</td>
<td>93</td>
</tr>
<tr>
<td>3,000</td>
<td>120</td>
<td>93</td>
</tr>
<tr>
<td>1,000</td>
<td>126</td>
<td>93</td>
</tr>
</tbody>
</table>

**Loading Diagram**

- Web: i, j, k, l, m
- 3'-0" to 6'-0"
- 12'-0"
STRESS DISTRIBUTION IN BOTTOM FLANGE
AT LOAD POINT "B"

D-18-16-88 a
STRESS DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT

WF: 6x6 - 15 1/2"

BOTTOM SURFACE

[Diagram with data points and stress values on a graph]