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

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SCHOOL OF CIVIL ENGINEERING? CORNELL UNIVERSITY

TESTS ON LIGHT BEAMS OF COLD FORMED STEEL

FOR THE AMERICAN IRON AND STEEL INSTITUTE

Thirty-first Progress Report

February 1943

I. SCOPE OF THIS REPORT

(a) Twenty tension tests were carried out on specimens cut from the steel of which those beams were fabricated for which tension tests are not included in the 27th Report. This completes the tension tests for the present series of beams.

(b) A start was made in the final evaluation of the results of the beam tests. The part of the evaluation completed to date is included in this report.

II. RESULTS OF TENSION TESTS

Tension tests No. 7, 8 and 9 (27th Report) did not furnish any data on the elongation in 2" since all three specimens broke at the fillet. For this reason three more specimens were cut from the same steel with larger radius of fillet (3 in.). The first of these again broke at the fillet. In order, therefore, to force the remaining two specimens to fail within the gage length, a very shallow neck (radius 14") was machined in the center of the gage length. Specimens No. 11 and 12 then failed at this neck and so furnished the required information regarding the elongation.

The test procedure was further refined so that permanent sets of about 3/4% of the total strain could be measured. The proportional limits in table 1 on the next page are therefore based on the occurrence of a permanent set of 1 - 1.5%.

Table 1

Results of Tension Tests

No.	Gage	Proportional	Yield Point upper	Yield Point lower	Ultimate Strength	E	Elong. in 2"
11	--	--	--	--	--	--	20%
12	--	--	--	--	--	--	20%
19	14	32,400	--	36,400	53,400	$29.2x10^6$	40.5%
20	14	31,000	--	36,400 (37,300)	51,500	$30.1x10^6$	40.5%
21	14	32,400	39,600	39,100	53,900	$30.1x10^6$	40%
22	16	26,800	--	35,000	46,600	$30.2x10^6$	40%
23	16	28,300	35,300	34,700	46,700	$29.9x10^6$	40%
24	16	28,300	--	35,700	46,800	$30.8x10^6$	43%
25	16	26,400	--	33,500	45,700	$29.8x10^6$	34.5%
26	16	28,200	33,500	32,400	46,200	$29.7x10^6$	27.5%
27	16	29,300	33,400	32,300	45,500	$30.5x10^6$	26.5%
28	16	20,100	--	30,750	46,000	$29.1x10^6$	40.5%
29	16	26,800	--	34,300 (32,600)	46,300	$29.7x10^6$	44%
30	16	21,800	33,000	32,300	46,900	$28.[illegible]x10^6$	45%
31	13	19,100	--	33,800	49,000	$29.5x10^6$	38%
32	13	20,900	--	34,700	47,000	$29.6x10^6$	39%
33	13	29,800	--	36,100	49,000	$30.0x10^6$	37%
34	20	15,600	--	21,300	41,300	[illegible]	38%
35	20	18,100	--	23,000 (22,700)	40,800	$29.7x10^6$	36.5%
36	20	21,000	--	23,800	41,300	$30.[illegible]x10^6$	33.5%

In order to insure the proper correlation of tension tests and beam tests, table 2 on the next page indicates for each tension specimen the metal from which it was cut and the types of beams which, to our knowledge, were formed from that particular steel.

Table 2

Correlation of Tension and
Beam Specimens

No. Tension Specimen		Cut from	Test Holds for Beams
1-3	29,200	coupon	12-3, 12-5
4-6	28,200	coupon	14-3 1/4
7-9, 11, 12	32,400	coupon	18-3 3/4
19-21		14-2 1/4	14-3/4, 14-1 1/2, 14-2 1/4
22-24		16-2 1/2	16-2 1/2 (originally 18-2 1/2)
25-27	31,200	16-4 1/2	16-4 1/2
28-30	[illegible]	16-3	16-1 1/4, 16-1 3/4, 16-3
31-33	24,900	18-1 1/2	18-1, 18-1 1/2
34-36	22,700	20-3 3/4	20-3 3/4

Discussion

The accuracy of the tests results, judged from the data of three "identical" specimens, is very good indeed, except for a few values of the proportional limit and except for E for specimen 34. In any tension tests the proportional limit is the property most difficult to determine and its value depends to a great extent on the instruments used. The value for E for specimen 34 is evidently due to incorrect measurements.

The results of these tests confirm the conclusions drawn from the first set of tension tests (27th Report) viz., (a) That the modulus of elasticity for sheet steel is the same as that of ordinary structural steel, i.e., $30 \times 10^6 \pm 3\%$. (b) Not all but most of the stress strain curves show a gradual transition from the straight line to the yield portion rather than a sharp brake. The stress strain curves are not included in this report but are preserved in our files for future reference.

III. DEFLECTIONS OF BEAM SPECIMENS

As the first step in the evaluation of the beam tests the following work was completed:

(a) The geometric moments of inertia, I_{geom}, were computed for all 15 types of beams tested so far. This I is computed from the measured dimensions of the cross sections, averaged for the three beams of any given type. The width of both flanges are considered with their full, unreduced value. (b) On the basis of this I_{geom} and $E = 30x10^6$ the theoretical deflections are computed for a load interval for which the load-deflection curves reveal purely elastic behavior. (c) The actual, measured deflections were determined for that same load interval, again averaged for the three beams of each type. (d) The actual deflections were compared with the computed ones.

Table 3

Geometric Moments of Inertia, Actual Deflections, and Computed Deflections in the Elastic Range

Beam Type	w/t	I_{geom}	P_{up}	P_{in}	d_{act}	d_{comp}	d_{act}/d_{comp}
14-3/4	10.1	9.77	2000	400	.102	.093	1.09
14-1 1/2	20.3	13.77	2250	500	.129	.115	1.13
18-1	20.8	8.53	2000	400	.126	.114	1.11
16-1 1/4	21.6	10.04	1600	400	.082	.0725	1.13

deflections actual / computed

12-3	28.9	29.03	5000	500	.215*)	.208	1.03	*)
16-1 3/4	29.9	12.34	2000	500	.123	.109	1.12	
18-1 1/2	30.6	10.01	1200	400	.080	.072	1.12	
14-2 1/4	31.2	17.55	2500	250	.123	.115	1.12	
14-3 1/4	43.4	23.85	3000	500	.150*)	.136	1.10	*)
16-2 1/2	46.5	14.69	2250	250	.140	.122	1.15	
12-5	48.1	41.04	4500	500	.153	.126	1.21	
16-3	53.7	17.46	2000	250	.119	.0895	1.33	
18-3 3/4	76.2	17.05	2000	200	.178	.137	1.30	
16-4 1/2	80.3	22.29	3000	500	.200	.146	1.37	
20-3 3/4	103.8	12.92	800	400	.057	.040	1.43	

*) The values of the actual deflections for these two types of beams are not quite reliable. On these beams deflections were measured only on one side of the beam and their value may therefore be affected by twist. See 28th Report, Section III, c

In table 3

w = width of projection of top flange (half-width of flange)

t = thickness of metal

P_{up} = upper load of the load range over which deflections were determined. P_{up} was taken slightly below that load at which the first permanent deflections were observed.

P_{in} = lower load of that same load range, or initial load

d_{act} = average measured deflection over the given load range

d_{comp} = computed deflection over the same range

I_{geom} = geometrical moment of inertia computed from the full cross section as measured, without any reduction of flange areas.

Table 3 is arranged in increasing order of w/t. From the last column of this table it is seen that for values up to about w/t = 30 the actual deflections are in the average about 10% larger than the computed ones. On the basis of the results of the tension tests this discrepancy cannot be attributed to a lower value of E. It seems, then, that this difference is mainly due to the fact that the flanges of none of the beams, as welded, were really plane. Initial waviness, which under load straightens out in the tension flange and increases in intensity, however slightly, on the compression flange is bound to raise the actual deflections above the theoretical value for a perfect specimen.

From about w/t = 40 up the ratio d_{act}/d_{comp} is seen to increase rather rapidly. This indicates a corresponding decrease of the equivalent width of the top flange due to the formation of excessive compression waves. This finding is in qualitative agreement with the observed formation of waves and also with the general considerations on which the design specifications, both for unstiffened and for stiffened flanges were based.

Further results of the evaluation will be reported next month.