Experiments on girders with welded web stiffeners

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Objekttyp: **Article**

Zeitschrift: **IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht**

Band (Jahr): **2 (1936)**

PDF erstellt am: **11.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-3347

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Experiments on Girders with Welded Web Stiffeners.

Versuche mit Trägern, deren Stege durch angeschweißte Versteifungen verstärkt sind.

Essais sur poutrelles renforcées par des raidisseurs soudées à leur âme.

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A series of tests was carried out to study the effect of stiffeners welded to the webs of joists, in the first place on sixteen joists PN 16, 20, 24 and 30 and secondly on six joists, PN 32 and 34, all the joists having a span of $L = 2$ m and being bent by the application of a concentrated load at the middle of the span.

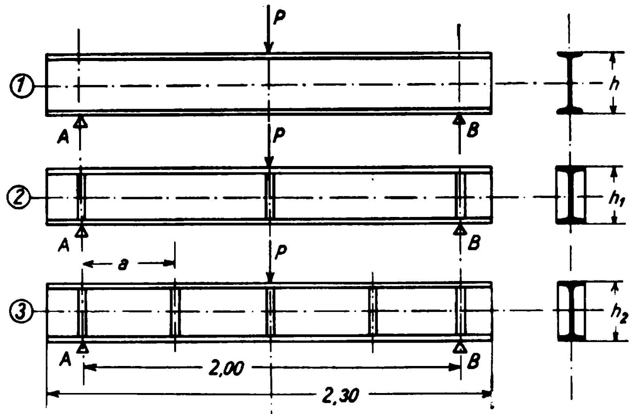

Fig. 1—3.

The joists tested were of three types.

1) Joists without stiffeners on the webs (Fig. 1).
2) Joists having three pairs of stiffeners arranged respectively over the supports and below the concentrated load (Fig. 2).
3) Joists fitted with five pairs of stiffeners at 0.50 m centres (Fig. 3).

Table I shows maximum values of the forces which caused failure of the joists, the suffixes denoting the numbers of pairs of stiffeners.

Table I.

NP	breaking load		
	R_0	R_3	R_5
16	8.6 t	7.425 t	7.6 t
20	15.4	13.75	15.8 .
24	22.9	23.85	26.3
30	39.9	48.45	48.3
32	46.0	58.5	59.5
34	51.0	69.5	72.5

A study of the differences $R_3—R_0$ as given in Table II shows that in the case of relatively deep joists the addition of three pairs of stiffeners increases the breaking load R in proportion to the depth of the joist. In the case of joists PN 16 and 20 no additional strength was obtained by the addition of stiffeners. The last column of the table gives the increase in strength brought about by the addition of five pairs of stiffeners: but in the case of joists PN 16 the strength was thereby reduced, while in the case of the other joists the increase in strength is proportionate to the height of the joist in question.

Table II.

NP	$R_3—R_0$		$R_5—R_3$		$R_5—R_0$	
	tonnes	%	tonnes	%	tonnes	%
16	— 1.175	— 13.7	0.175	2.36	— 1.0	— 11.6
20	— 1.75	— 11.3	2.05	14.9	0.4	2.6
24	0.95	4.15	2.45	10.27	3.4	14.8
30	8.55	21.4	0.15	— 0.31	8.4	21.0
32	12.5	27.2	1.0	1.71	13.5	29.4
34	18.5	36.3	3.0	4.6	21.5	42.2

Here the safe load (with $\sigma = 1200$ kg/cm² and $M = \frac{PL}{4}$, L being 200 cm) is

$$P_b = \frac{4 \cdot 1200}{L} W = 24 W. \tag{1}$$

The factor of safety $n = \frac{R}{P_b}$, or ratio between the breaking load and the safe load, is given in Table III for each of the cases examined.

Table III.

I NP	W cm³	P_b tonnes	n_0	n_3	n_5
16	117	2.81	3.06	2.98	3.05
20	214	5.14	3	2.68	3.08
24	354	8.50	2.7	2.80	3.10
30	653	15.67	2.55	3.09	3.08
32	782	18.75	2.45	3.12	3.16
34	923	22.32	2.28	3.12	3.25

If joists PN 16 and 20 are left out of account it will be seen that n_o becomes less and n_3 becomes greater in proportion as the depth of the joist increases, while n_5 scarcely varies at all, but is always greater than n_o.

Table IV gives the values of σ obtained by substituting for P the values of Q and R given in Table I and taking for W the values listed in Table III. In this way the results obtained from joists of varying depth are brought to a common measure.

Table IV.

I NP	Number of pairs of stiffeners	Stresses σ obtained by substituting the values of Q and R from Table I for those of P in equation (3) Q	R
16	0	29.5	36.8
	3	29	31.7
	5	29	32.4
20	0	29.2	36
	3	27.9	32.2
	5	31	36.9
24	0	26.2	32.4
	3	27.4	33.8
	5	29.7	37.2
30	0	23	30.6
	3	29.3	37
	5	30.2	37
32	0	—	29.4
	3	—	37.4
	5	—	38.0
34	0	—	27.7
	3	—	37.7
	5	—	39.3

The diagrams in Figs. 4 and 6 are a graphical representation of the results stated in Table IV, the abscissae denoting the heights of the joists in centimetres and the ordinates denoting the stresses σ in kg/mm². Had the material of the joist been perfectly homogeneous and the tests been carried out under ideal conditions without any possibility of lateral buckling, and had the formula $\sigma = \frac{M}{W}$ been valid up to the point of failure, the curves would have been horizontal lines.

It will be noted that curve 4 drops while curves 5 and 6 are rising. The first mentioned result was to be expected, and the latter indicates that this loss of strength can be avoided by welding stiffeners on to the webs and flanges of the joists, the phenomenon being due to the collapse of the upper flange.

Figs. 7 and 8 show the manner and magnitude of the effect. Those joists which are provided with stiffeners assume after failure a double undulation with the points of inflection at the centre of the joists (Fig. 7), whereas the joists unprovided with stiffeners (Fig. 8) assume after failure a shape containing only a single undulation; the effect of the stiffeners is, therefore, to promote the double undulation with the consequence that the critical buckling load is increased.

The phenomenon was the same in all the joists. In those with stiffeners both flanges became bent, the upper flange as much as the lower, but the joists without stiffeners remained straight with only a limited amount of deflection. In the joists without stiffeners a crushing of the upper flange underneath the concentrated load was observed and this effect increased with the depth of

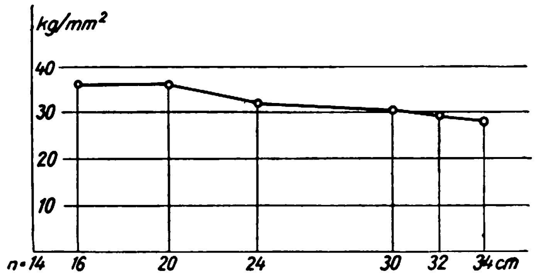

Fig. 4.

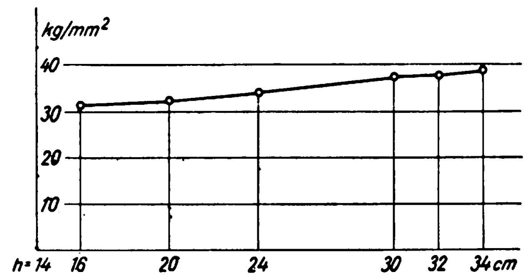

Fig. 5.

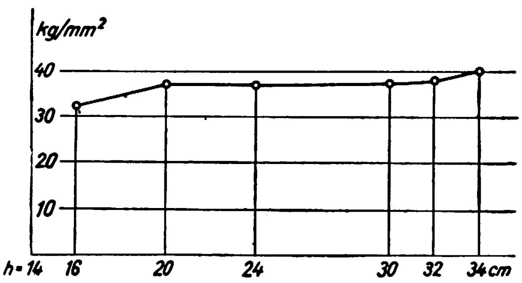

Fig. 6.

the joist. The influence of the stiffeners on the deformation of the joist becomes more marked in proportion to their depth. It follows that the resistance of the joists to bending where stiffeners were provided was on the point of being used up, and that fracture was imminent. On the other hand in the joists which had no stiffeners failure due to bending was still a long way off, and failure actually occurred on account of the buckling of the flange under the concentrated load. The collapse observed in the deep joists without stiffeners when the stresses σ were still relatively low appears to indicate that it is not these stresses which play the predominant role, but rather the normal stresses present in the horizontal section of the web immediately below the flange underneath the concentrated load, to which Professor *Huber* has given the name of transverse stresses, and has devoted several chapters of his book.[1] The present author will give a more detailed study of these transverse stresses elsewhere, and will here merely summarise the results.

[1] *M. T. Huber:* Investigations of I-beams double T. Proceedings of the Technical Society of Warsaw, 1925.

1) The reinforcing of an I-joist by means of stiffeners welded to the web below the concentrated load has the effect of increasing its resistance to bending, the increase being more marked in proportion to the depth of the joist, and

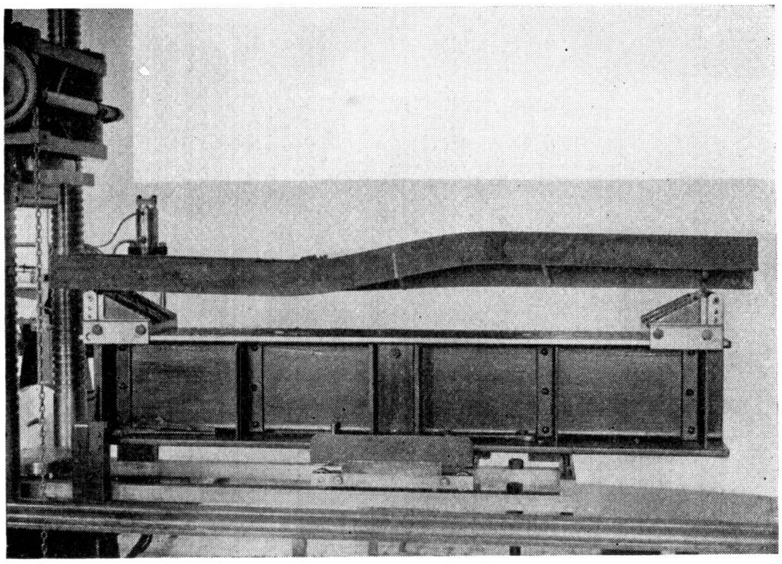

Fig. 7.

being inappreciable in a joist PN 16 but amounting to 40 % in the case of a joist PN 30. The provision of stiffeners welded to the web at other points than the concentrated load also increases the resistance of the joist, though to a smaller extent.

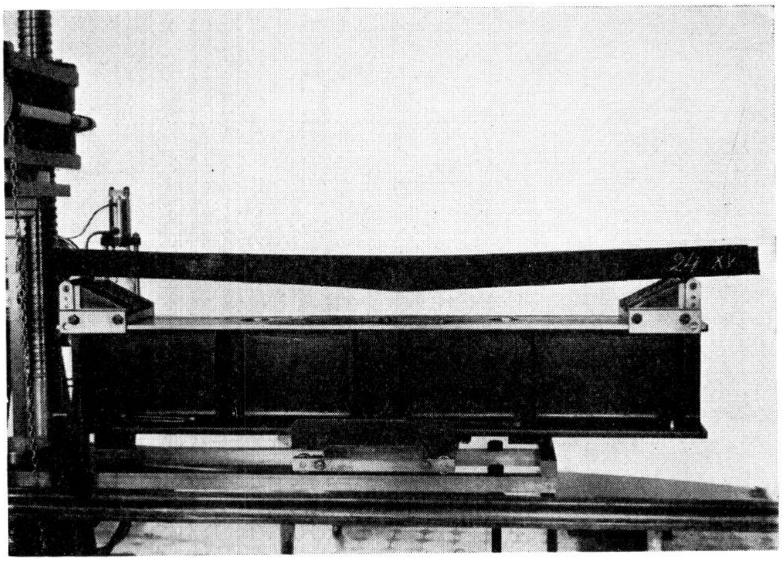

Fig. 8.

2) The maximum stresses calculated from the formula $\sigma = \frac{M}{W}$ must be reduced in the case of very deep joists. This formula cannot be used to determine the strength of joists in excess of a certain depth when subjected to concentrated loads, as such joists fail not by bending but by crushing of the flange where the load is applied. By welding on stiffeners underneath the concentrated load the failure by buckling is delayed and the formula as given may continue to be used.