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Results of experiments on compression members composed of two unequal angle bars.

Ergebnisse von Versuchen mit Druckstäben aus zwei ungleichschenkligen Winkelstählen.

Résultats des essais de compression sur des cornières à ailes inégales.

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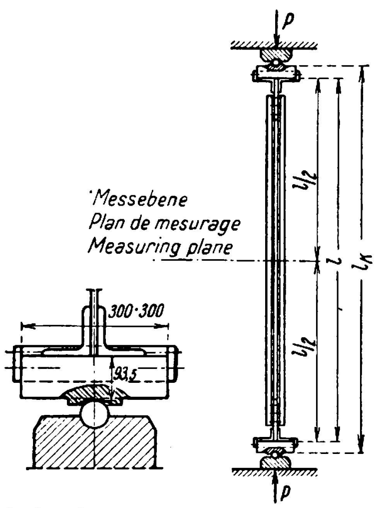
Bars composed of two angles with unequal legs are frequently used in trusses as, for instance, in those of roofs, both for the chords and diagonals. In the case of the chords, the angles are usually made continuous over the gussets. With compressed diagonals the forces are transmitted as a rule by means of gusset plates. The clearance between the angles is either constant throughout, or is wider at the middle.



l = Stablänge - Longueur de la barre - Length of test piece
l_K = Knicklänge - Longueur de flambage - Buckling length

Fig. 1.
Disposition of test.

In the case of compressed members composed of two parts, according to DIN 1050 (Version of July 1937), the "ideal ratio of slenderness" λ_{yi} has to be used for checking the buckling tendency in the phase x — x (see fig. 4).

In developing the formula for λ_{yi} it is assumed that the axis x — x of the bar consisting of two parts is an axis of symmetry of the total cross section, but in the case of bars composed of two angles connected to one another by packing pieces this assumption is not correct. Theoretical investigations relating to such bars have apparently not been carried out up to the present time; nor have any values been made available of the buckling resistance of such bars as determined by experiment.

In 1936 the author accordingly carried out experiments[1] on nine double bars and also on two single bars serving for comparison, and a summary and supplementary discussion of these experiments will be given below.

[1] See the journal „Der Stahlbau". Vol. 9 (1936), p. 166 foll.

The tests were made with the bars arranged in a vertical position, as shown in Fig. 1, wherein it should be noted that the load was imposed through hinges and pressure plates. The tested bars were arranged in such a way as to make the geometrical axis through the centre of gravity coincide as nearly as possible with the axis of the testing machine. After more or less heavy initial loads had been imposed these were removed from the bar and the latter was shifted parallel to the axis of the machine a sufficient number of times to ensure that on again being loaded the deflection at the middle of the bar would be reduced to a minimum. The tested maximum load P_k was usually accompanied by a sudden bending out of the middle of the bar. Fig. 2 represents the „slender" test bars; Fig. 3 the „forced" bars and test bar ⑧ which consists of one angle.

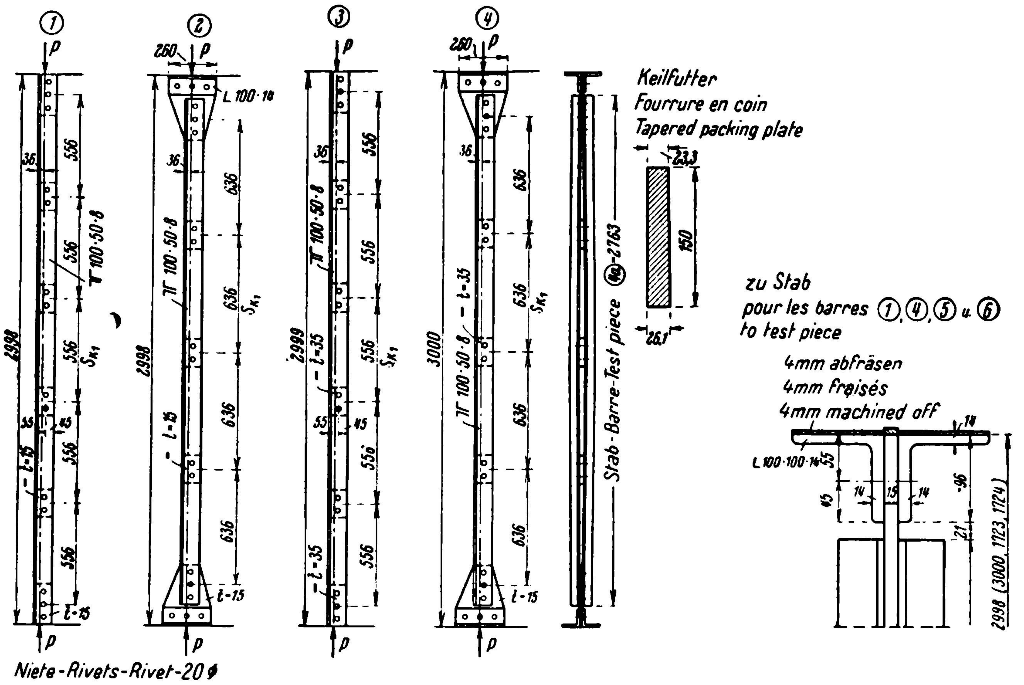


Fig. 2.

Slender bars.

The *buckling load* (in german tons = t) may be seen from the diagram in Fig. 4 which shows the bar (4a) which was formed from the bar ④ after testing, and also the second specimen ⑩ consisting of one part. The end surfaces of this bar bore against the horizontal pressure plate of the testing machine which has been secured against tilting.

In the case of bars ① to ④, the calculated buckling load P_k is determined by reference to the tabulated values of the cross sections of the bars with the aid of the relationship $\sigma_k = \frac{20726}{\lambda^2}$ t/cm² and in the case of bar ⑤ by the relationship

$$\sigma_k = 2.8905 - 0.008175\,\lambda \text{ t/cm}^2$$

always taking account of the ratio of slenderness λ_{yi} In the case of the single bar ⑧ the value of P_k is determined by reference to the moment of inertia J_η.

Conclusions.

a) In the bars without gusset plates, (1), (3) and (4a), the experimental buckling loads are larger than the buckling loads determined by calculations from λ_{yi}.

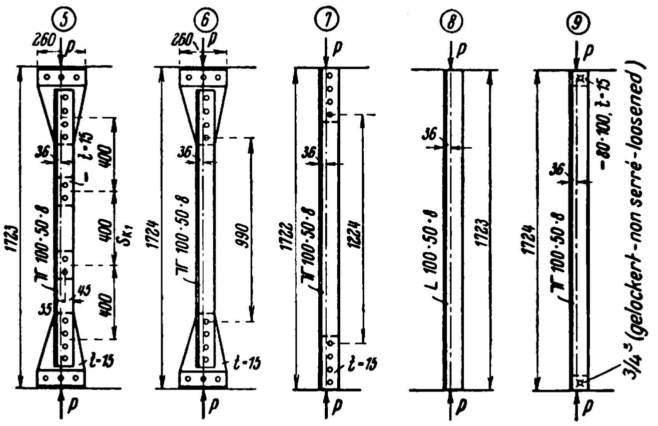


Fig. 3.

Stout bars.

b) Bars with gusset plates, Nos. (2), (4) and (5): the slender bars marked (2) and (4) each showed a buckling load 10 % greater as found by experiment than as calculated in reference to λ_{yi}. The stout bar marked (5) shows a smaller value than that calculated from λ_{yi} despite the fact that its yield point stress 3.27 t/cm² is considerably greater than $\sigma_s = 2.4$ t/cm² which was used as a basis for determining σ_k.

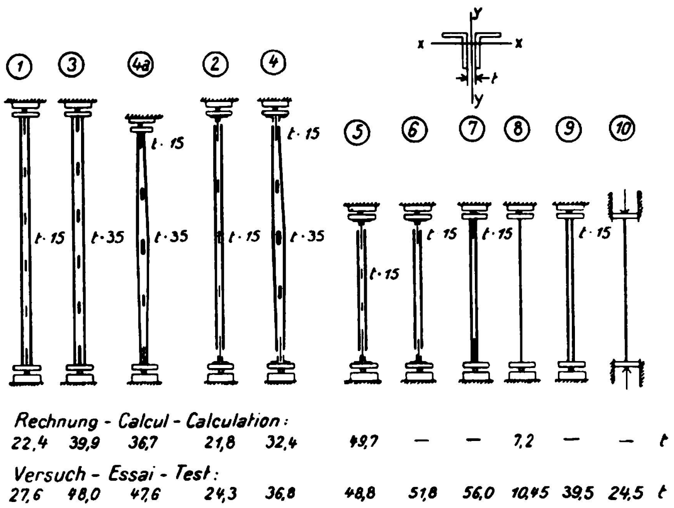


Fig. 4.

The most important results of calculation and test.

c) Bars (6) and (7).

α) In bar (5) the two packings at the points in one third of the total length as required by DIN 1050, have been provided, but in bar (6) these packings have been omitted. In spite of this the maximum buckling load for bar (6) was greater than that for bar (5). It must be concluded from this that the restraint imposed on the ends of the bars by the gusset plates exerts a great influence over the magnitude of the buckling load.

β) Bar ⑦ showed a still greater buckling load than bars ⑥ and ⑤. It may be supposed that the packings provided on bar ⑤ in accordance with the regulations has not increased the buckling load.

d) Bars ⑧, ⑨ and ⑩. The results obtained in these experiments are bound up with questions previously discussed by the author in reference to experiments on timber struts composed of several parts. In the case of the latter the experimental results cannot be applied directly to the conditions of a strut in the actual structure, for the pressure plates generally used at the ends of the bars in compression tests obscure the effect due to the packings intended to ensure the co-operation of the single bars in the making up of a compound bar.[2] Conditions are similar in the case of steel bars made up from two parts.

Bar ⑧ gave an actual buckling load of $P_k = 10.45$ t and the double bar ⑨, which had *no connection of any kind* in the whole length between end plates, gave not merely twice the buckling load of the single bar but 3.8 times as much. The action of this unconnected double bar may be eplained from the circumstance that the projecting legs exert a certain end-fixing effect on the separate bars at the pressure plates. Actually the experiments carried out on the control bar ⑩, the ends of which rested directly against the pressure plates in the machine 1724 mm apart, showed a buckling load of 24.5 t, or rather more than half the buckling load for bar ⑨.

It may be suppposed that in the case of test bars arranged like ①, ③ and (4a), the buckling load depends partly on the nature of the bearing of the compound member against the pressure plates, as explained above. One should beware, therefore, of assuming that the surplus of actual buckling load (found in testing a double bar in the usual way) over the buckling load of two single bars pinned at the end must be attributed to the operation of the connections (packings).

In the case of bars which in the actual structure have their ends connected by gusset plates, the action of the connections can be estimated only by means of experiments arranged as in the case of bars ②, ④ and ⑤.

[2] See. for instance, the journal „Der Bauingenieur" 17 (1936), p. 1.