The safety of reinforced concrete structures

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The Safety of Reinforced Concrete Structures.

Zur Frage der Sicherheit im Eisenbetonbau.

La sécurité des constructions en béton armé.

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If a review is made of the increasing use of high tensile structural steels in reinforced concrete structures, numerous reports on experiments with such steels will be found in the literature dating from soon after the War.

It is proper that attention should be directed first to the problem which is of most frequent occurrence and admits of easiest experiment: namely that of bending. In this connection, the most important and interesting of the experiments made to date are those to establish a comparison with St. 37, the type of steel hitherto customary for reinforcement. One of the best of the few summaries of such experiments that have appeared is that by *Dr. Emperger*, which led to the discovery that when various specimens containing samples of steels with abnormally high yield points were tested, much greater breaking strengths were obtained than was to be expected from the usual calculations for bending. It was found that the coefficient of $n = 15$ usually adopted in the bending calculations was too high for the ordinary steel St. 37. (In Switzerland and Yugoslavia $n = 10$ is employed.)

A certain variability in the coefficient n had already been recognised in Great Britain by making its value depend on the cube strength. In Austria a correction of the concrete stress, where high tensile steel is used, has been permitted since 1928 for a special cold stretched steel with a yield point of 3600 kg/cm^2 and similarly in Bulgaria an increase in the concrete stress of 15 % has been sanctioned. Very recently a New York regulation has authorised an increase in the concrete stress of 15 % in reinforced concrete beams containing high tensile steel.

In Germany, also, the knowledge now available has not been neglected, and since 1932 the Ministry of Public Welfare has allowed the concrete stress to be increased by 15 % where the special steel mentioned above is employed. The Ministry of Finance in Berlin, in view of various problems which are still outstanding in this connection, has accepted the proposal put forward by the German Committee for Reinforced Concrete that special regulations should be considered, and these are expected to be ready in the spring of 1937 after the conclusion of the relative experiments now in hand by that Committee. When the results of these experiments are available, the authorities concerned will, no doubt, amend the relevant regulations in accordance with them as has been done in the latest

Austrian standard or "Oenorm". In the latter, the increase in breaking loads established by *Dr. Emperger*'s survey in comparison with the loads calculated on the basis of n = 15 has been accepted as justifying the use of higher steel stresses in the calculations (and also higher concrete stresses) than where ordinary steels are used, and these increases vary from 15 % for ordinary steels to 25 % or more for high tensile steels.

From this point of view the proposal made by *Dr. Friedrich* of Dresden before the present Congress is no doubt a welcome advance, involving, as it does, the substitution of a rectangular distribution of the compressive stress due to bending for the impracticable triangular distribution assumed at present. The proposal carries all the more weight because other workers — such as, for

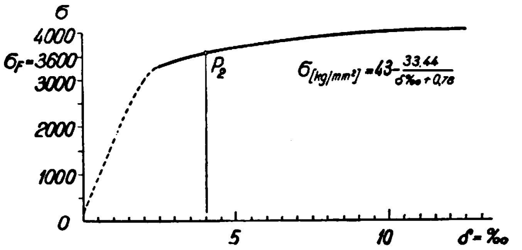

Fig. 1.
Isteg-Steel

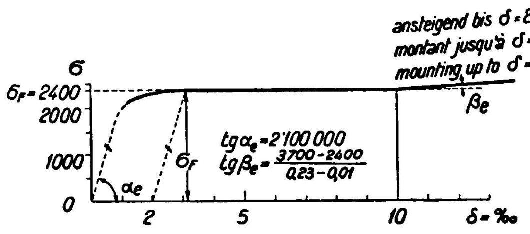

Fig. 2.
Steel St. 37.

instance, Hofrat *Saliger* of Vienna, Professor *Brandtzaeg* of Trontheim and *Dr. Bittner* of Vienna — have also arrived at this form of distribution of stress. By such a method the calculation is rendered very easy, *but in view of the many experimental results obtained in Germany, Austria, Switzerland, Czecho-Slovakia. U.S.A. and other countries, it would still appear expedient to make use of n = 10 for ordinary steels and n = 15 for high tensile steels in calculating the neutral axis assuming that the yield point of the steels is not less than 3600 kg/cm².*

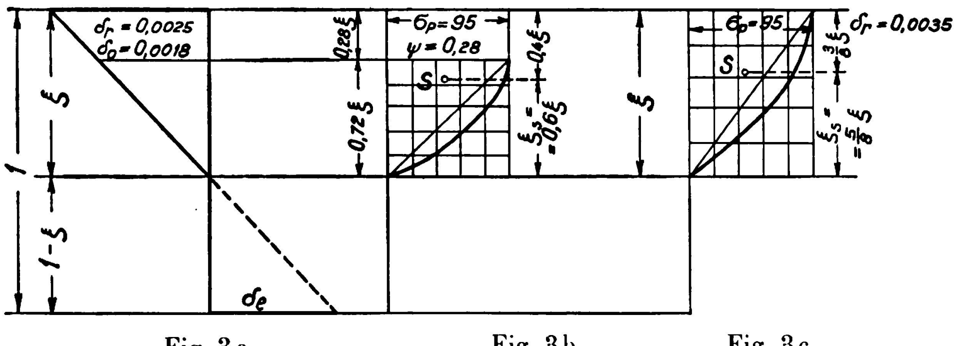

Fig. 3 a. Fig. 3 b. Fig. 3 c.

In order to give the proposal a more definite form, advantage might be taken of the regularity of the stress-strain curve for structural steels under tensile stress by adopting the suggestion made by *Klockner* of Prague that the relationship in question is best represented as a hyperbola connecting to the straight line of *Hooke*'s Law (Fig. 1). The resulting curve for ordinary steel is shown in Fig. 2, and the elongations when the cross section is assumed to remain constant in Fig. 3. Fig. 3b shows the stress-strain curves plotted as parabolae and indicating an increase in compressive strain towards the edge of the beam but without any corresponding increase in stress in the final portion. Fig. 3c shows a similar parabolic shape of the stress-strain curve for concrete.

Adopting the hyperbolic form of equation for the shape of the stress-strain curve of the steel, and the parabolic form for that of the concrete (or a parabola combined with a rectangle), it becomes possible, on purely theoretical grounds, to calculate the curve of $\frac{M}{bh^2}$ in relation to the percentage of reinforcement.

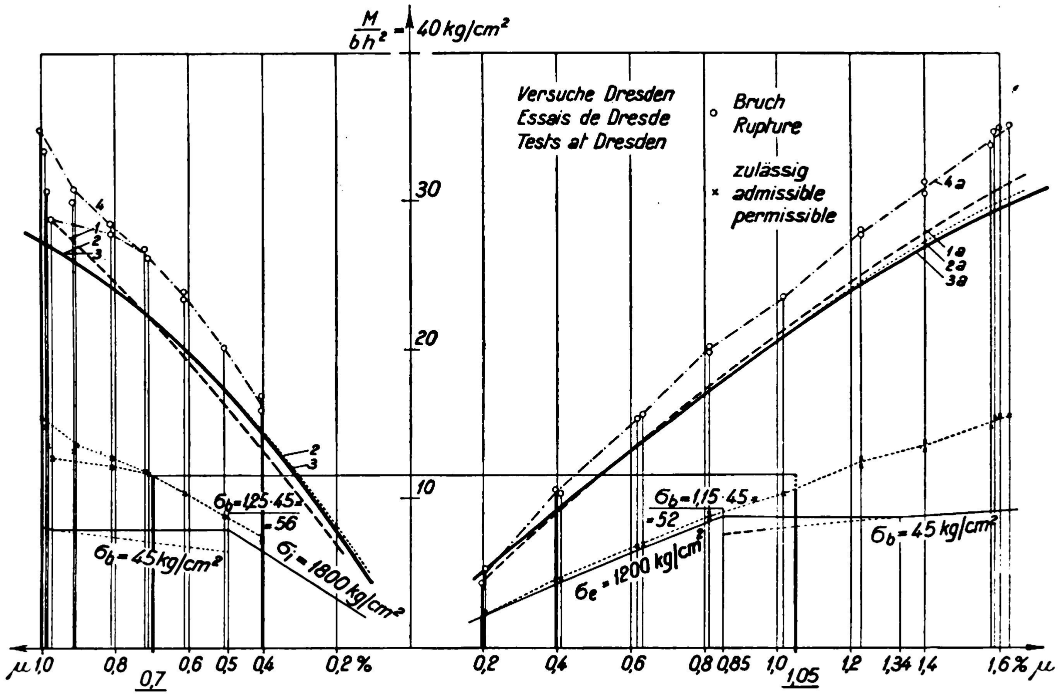

Fig. 4.

Isteg. St. 37.

Fig. 4 shows curves of resisting moments calculated by Professor *Roš* in accordance with the Swiss regulations mentioned above, using either of the above assumptions — on the left for Isteg steel which is chosen as an example of the high tensile steels, and on the right for St. 37, these being represented by the lines marked 1, 2 and 3 and 1a, 2a und 3a respectively, which it will be seen practically coincide. Lines 4 and 4a contain points representing a series of comparative experiments carried out at Dresden in which concrete of the lowest possible cube strength of 110 kg/cm² was purposely used, and in which the minimum cube strength required by the regulations, 160 kg/cm² was reduced by two-thirds, corresponding to twice the *degree of safety* in the steel and to three times that in the concrete. It is concluded that by halving the ordinates of the curve of resisting moment, values are obtained which represent the minima to be allowed.

The curves in bold lines show the effect of a correction of 25 % in the concrete stress where high tensile steel is used in accordance with the Austrian standards.

Fig. 5 indicates that assuming, for instance, a 15 % increase on account of high tensile steel, the degree of safety thus obtained is in no way less favourable than with round bars under the ordinary regulations. It is clear, however, that the degree of safety calculated in accordance with the regulations varies a great deal according to the percentage of reinforcement provided. This goes to show

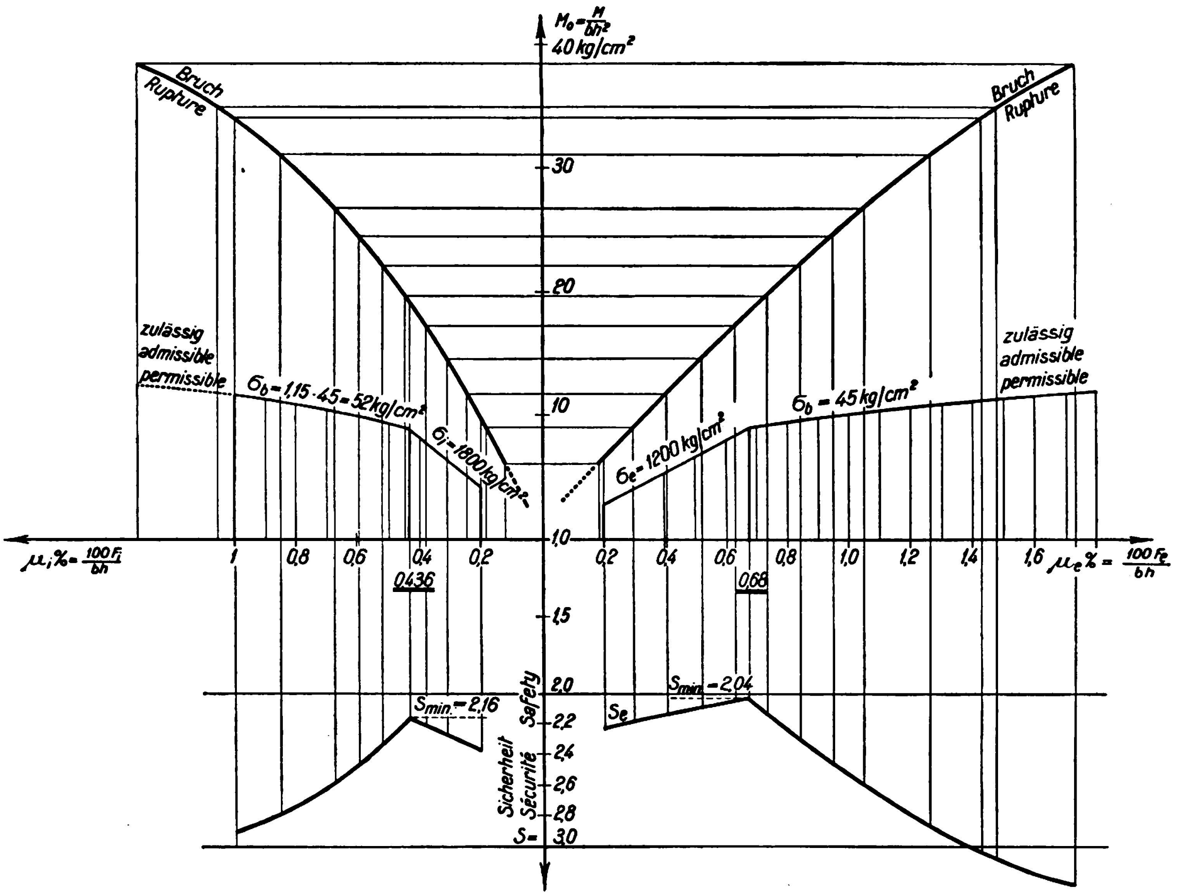

Fig. 5.

Isteg. St. 37.

how very important it is that methods of calculation should be adapted in such a way as to ensure the possibilities of high tensile steel being utilised to their full economic advantage, when designing members to resist bending, and at the same time to obtain closer agreement with the latest experimental knowledge than is possible with the present methods.