II. Free discussion

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Freie Diskussion.

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a)

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Qualifying his contribution to the discussion on Group IIa the author observes, on the one hand, that hitherto little has been done to investigate the subject of shrinkage stresses, and especially the changes undergone by these after a reinforced concrete structure has been in existence for a long time. On the other hand it is necessary that the method followed in the design of reinforced concrete should be as simple as possible and should rest upon an assured foundation, in order that the scope for such construction having a definite degree of safety may be promoted.

In the author's opinion the ideas which have found expression fail to correspond with the new status of scientific knowledge on the subject. Ultimately there is no difference between the behaviour of lightly and of heavily reinforced cross sections (Report ot the 2nd Congress: *Saliger,* page 316, last paragraph). Hence design according to the "n" method does not allow a correct estimate to be found of the factor of safety possessed by a structure. (Same reference: page 323, last paragraph.) Consideration of the test diagrams obtained with either lightly or heavily reinforced beams shows that calculation based upon permissible stresses has lost its significance. The calculation of beams must be referred, like that of columns, to the properties of the material used, and therefore to the conditions of equilibrium existing at the moment of failure, in which respect the yield point of the steel and the strength of the concrete are the determining values. These principles can be inferred from all the experiments that have hitherto been carried out, always provided that the beams have been reinforced accordingly. In particular this is indicated by the experiment mentioned by the author at the second meeting which relates to reinforcement between 0.5 % and 6.5 %.

In reference to his contribution under Group IIa the author would summarise the conclusions of the Congress in the following terms: —

An examination of the experimental results obtained with beams exposed to bending indicates that, with light and with heavy reinforcement alike, failure ultimately occurs through cracking of the concrete, and that the stresses in the steel exceed the yield point therein. Design can, therefore, be based upon the conditions of equilibrium at the moment of failure, account being taken of the desired degree of safety. Special attention is necessary in the constructional arrangement of beams wherein the steel bars are bent up at an angle. The "n" method of design, based upon the assumption of permissible stresses, does not afford a correct picture of the degree of safety secured in a reinforced concrete beam, and this method of calculation should be abandoned.

The experiments prove that the full carrying capacity, especially in the case of lightly reinforced beams, is not developed until the yield point of the steel is considerably exceeded, and a need arises for more exact investigations to interpret the reasons for this. Pending the attainment of further knowledge of this matter by research, the possibility of exceeding the yield point in the steel reinforcement should not be taken into account when making calculations for practical purposes.

b)

Dr. Ing. h. c. M. Roš,
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The author makes the following further observations in summing up the discussion on Group IIc: —

In the case of properly designed and carefully executed reinforced concrete structures experience supports the retention of the classical theory of elasticity as regards stresses within the permissible limits.[1]

Reinforced concrete structures which are suitably calculated, properly reinforced and carefully built show a practically elastic behaviour within the limits of the permissible stresses now usual,[2] namely $\sigma_{zul} = 0.4$ to $0.5\,{}_p\beta_d$.

The reconciliation of theory with actuality is a matter which must be referred to fundamental principles, account must be taken of the properties of the concrete or reinforced concrete as the case may be.

In regard to the technical properties of the concrete as such, attention must be paid to the total deformations divided as between elastic and plastic; to the influence of continued stresses on the deformation (time effect); to the effect of repeated loading (fatigue); to the changes undergone by the mechanical properties and power of deformation in the course of time, and to the consequences of shrinkage and temperature change. The influences of forces which exert their effect for a short period of time only (traffic load, wind, snow) should be separated from that of permanent loading (the dead weight of the structure itself) when considering the matter.

The effects, under these two headings, of the external load (the dead load and live load) and of temperature changes and shrinkage on the conditions of stress and strain, and therefore on the safety of the structure, should be worked out. Shrinkage and temperature are not external loads but exert an effect on the internal stresses alone.

It is only by making this separation in principle that clarity may be secured, allowing the theory of elasticity to be retained as a basis for the design dimensioning of reinforced concrete structures while making due allowance for the power of plastic deformation possessed by the concrete, so that as regards the

[1] *M. Roš:* Versuche und Erfahrungen an ausgeführten Eisenbeton-Bauwerken in der Schweiz 1924—1937. Report N° 99, Swiss Federal Testing Institute, Zürich 1937.

[2] *M. Roš:* Vereinheitlichung der material-technischen Erkenntnisse und des Sicherheitsgrades im Stahlbeton. — Monatsnachrichten des Österreichischen Betonvereins, Festschrift, Vienna 1937.

factor of safety the significance of stresses due to shrinkage and temperature may not be confused with that effect of stresses due to the external loads (dead load and live load) — for the former may be diminished or may entirely disappear when the condition of failure is reached.

The statical and fatigue failure to which the factor of safety is referred is not dependent on the value of n, but upon *the compressive strength of the concrete* $_{p}\beta_{d}$, *the yield point of the reinforcing steel* σ, *the fatigue strength under pulsating load of the concrete* $_{t}\beta_{u}$, *the corresponding value for the steel* $_{e}\sigma_{u}$, *the percentage of reinforcement* μ *and the shape and dimensions of the cross section.*[2]

The endeavour to utilise the whole of the capacity for plastic strain possessed by the concrete in determining the degree of safety must be regarded as too far reaching. The material should not be deprived of its last reserves of strength; reserves which are not always present even under conditions of statical stress and which are only doubtfully present under conditions of repeated dynamic stress.[3]

c)

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In reference to this discussion the author desires to make the following additions:

1) In the calculation of reinforced concrete sections for bending a distinction should be drawn between the first zone of lightly reinforced beams (the usual case) wherein the exceeding of the yield point of the steel is attended by failure, and the second zone in which the criterion for breakage is the compressive strength of the concrete. As regards the first of these zones there is no justification for making any change in the method of calculation hitherto usual.
2) As soon as the limiting amount of reinforcement which separates these two zones shall have been determined by experiment, it will be possible for the first zone to be extended in practice right up to this limit. According to the Dresden experiments the limiting value in question has been determined for rectangular cross sections as $\mu_G = 1{,}8\,\%$, with a cube strength of $W_{b\,28} = 160\ \mathrm{kg/cm^2}$ and with steel St. 37, and as $\mu_G = 1{,}0\,\%$ with Isteg steel.
3) In the second zone, where failure is determined by the compressive strength of concrete, the usual method of calculation does not correctly indicate the factor of safety obtained. It is desirable, therefore, that a new method of calculation depending upon more complete utilisation of the material should be introduced.

[3] In the Swiss Regulations for Concrete and Reinforced Concrete of 14th May, 1935, plasticity has properly been taken into account in the case of hooped concrete columns and of beams subject to bending stresses.