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

Band: 2 (1936)

Artikel: General report

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DOI: https://doi.org/10.5169/seals-3239

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General Report.

Generalreferat.

Rapport Général.

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Economic construction demands that the available margin of safety should be fully utilised. It was formerly the practice to base the calculations of structures on the hypothesis of permissible stresses determined from the factor of safety which in turn was governed by the breaking stress, but this practice gave a completely false picture. In the course of the last ten years the yield point strength in the stress-strain diagram obtained by the tensile test has become of ever increasing importance in the evaluation of material and, therefore, in the determination of the degree of safety.

Experience on completed works has shown that under certain conditions stresses may be present which considerably exceed the permissible values, and which may even exceed the yield point strength, without the structure being thereby endangered. As examples one may cite the secondary stresses present in trussed lattice girders, the conditions of stress in riveted connections, the effects in continuous girders, attributable to settlement of the supports, etc.

It is well known that in hyperstatic systems stresses are allowed to exist under certain conditions which exceed the yield point stress without prejudice to the factor of safety assumed.

These observations call for a fundamental revision of the concept of the factor of safety in steel structures, for the yield point stress no longer constitutes an adequate criterion of the material to the designing engineer.

When a bar subjected to pure tension reaches the yield point stress its resistance is destroyed, except in so far as the elongation may be hindered through the material forming part of an internally hyperstatic system and the interplay of forces within this system being altered. In beams exposed to bending, or to bending combined with a normal force, it is possible for the load to increase, even if the deformation is not hindered, after the yield point stress is reached in the extreme fibres, because in such a case the stresses are of a hyperstatic nature.

Les us consider the case of a rectangular beam subjected to bending. According to the old hypothesis of plasticity the "permissible moment" is to be explained on the assumption of a regular yield which takes place in layers, until a completely plastic condition has been reached or until a plastic joint has been formed. In accordance with the new theory of plasticity, however, the matter is to be explained on the assumption of an increase in the yield point stress followed by abrupt and complete plastification over the whole section, or by the abrupt formation of a plastic joint.

From the point of view of the designer and engineer neither theory is more than an interesting explanation of the nature of a process of development devoid of importance so far as the final result is concerned — the latter being the formation of a plastic joint, and, therefore, a modification in the statical composition of the structure.

The plastic behaviour depends largely on the type of section, and particularly on the system of multi-axial stress. The phenomena which occur are very difficult to explain mathematically on the basis of our present knowledge.

In none of the large number of researches hitherto carried out in reference to the theory of plasticity has account been taken of the influence of time. It is likely enough, however, that a better explanation of the conditions which exist will be reached by considering the problem as being properly a dynamic one, that is by introducing a new variable "t".

It is a matter of common knowledge that the "yield point stress" as determined by the ordinary tensile test does not depend only on the shape of the section of the specimen, but also on the manner of execution of the test in relation to time.

The fact that the properties of ductility possessed by steel allow of its being dimensioned with greater economy in hyperstatic structures has exerted an influence on the German regulations, and on other regulations relating to structural steelwork. In the design of continuous girders it is, in fact, necessary to allow for the circumstance that an equalisation of the moments occurs over the supports and in the spans (though the allowance may perhaps not correspond exactly with the true conditions). *Kazinczy* in Hungary and *Kist* in Holland have suggested that the design of hyperstatic systems should be based on a new definition of the factor of safety.

A more exact understanding of the problem has only been rendered possible by the very full and interesting works carried out by *Grüning,* who was the first to suggest an analytical conception of the relationship with which we are concerned. *Grüning* confined his investigations at first to the action of a permanent super-load on the supporting system, but *Hans Bleich* has taken account also of differences in the arrangement of the load, and has introduced the idea of self-stress lines to serve as a basis for calculation based on plastic equilibrium ["carrying capacity method"].

In the papers before the I.A.B.S.E. great importance has been attached to the principle that the questions outlined above should be discussed only by persons fully competent to do so, in order that as adequate as possible a review of the problem might be obtained. The works by *Fritsche, Freudenthal* and *Rinagl* are concerned mainly with questions relating to the technical aspects of materials, while another group of writers, including *Melan, Kohl* and *Lévi,* have treated the problem from a theoretical point of view supported by an idealised stress-strain diagram.

It is clear that test results play a part of paramount importance in explaining questions of plasticity. *Maier-Leibnitz* in his paper refers to this subject, and bases his arguments regarding methods of calculation on tests. In a recent issue of the journal "Stahlbau", *Maier-Leibnitz* has described a series of more complete tests for determining the effective resistance of continuous girders and has arrived at simplified hypotheses for their interpretation which are likely to be very useful. Finally, there is a paper by *Bleich* in which the statical design of continuous girders and frames by reference to the theory of plasticity is explained.

The influence of plasticity on the dimensioning of structural steelwork is one which appears to be of great importance, in view of the urge towards greater economy in such structures without prejudice to their safety. This aim is capable of attainment, under certain limitations, by having recourse to the principle of plastic equilibrium [carrying capacity method] when dimonsioning hyperstatic systems. The limitations in question have reference, for instance, to frames and continuous girders, which according to the theory of elasticity are already fully utilised over the wohle of their sections, and which consequently possess a very small reserve of strength due to the transformation of the system which results from a plastic joint being introduced. The same is true of lattice girders, at any rate so far as these are at present understood, and in this instance account has also to be taken of the instability of elements stressed in compression.

So far we have tacitly confined our discussions to the subject of plasticity in girders and rigid structures, but the plastic behaviour of the material also plays a very important part in problems of unstable equilibrium, and from this point of view it is necessary to pay careful attention to what is already known. The theory of plasticity enables us to simplify the study of the stability of a bar, taking due account of the shape of its cross section and also of widely varying conditions of support. It will very soon be possible to establish practical methods of calculation for studying problems of the stability of bars and slabs on a greatly simplified basis.

Hitherto the methods followed in dimensioning the members of hyperstatic systems with regard to the plastic properties of the steel have usually taken no account of the contingency of breakage by fatigue effects, and neither the tests nor the experience at present available are sufficient to show how far, when alternating stresses have once exceeded the yield point stress and plastic joints have been formed, it is permissible to treat any subsequent excess of purely elastic stress in the same way as in structures where no local equalisation of moments occurs, from the point of view of fatigue.

Even if the design of hyperstatic systems be performed without reference to the theory of plasticity it remains true to say that the knowledge obtained from the solution of these problems will play a very important part in determining the form of structures. For instance, in the light of this knowledge the misgivings that have been entertained regarding the construction of continuous girders on account of the possibility of settlement of the supports would not appear to be justified. Economical structures of statically indeterminate nature are now possible where previously only statically determined structures could have been adopted in view of the risk of settlement of piers or the elasticity of supports.

Hitherto it has been customary to attribute too great an importance to secondary stresses, although *Engesser* showed more than forty years ago that such stresses are in fact diminished by the ductility of the steel. Examples in relation both to the resistance and the stability of metal structures might be multiplied indefinitely. We are, in fact, now in the middle of a revolution of our ideas as to the local critical stresses affecting structures, and we are demanding that the technique of testing materials shall yield better criteria, enabling the designer to dimension his structures with due regard to the degree of safety which is actually necessary. Our knowledge of these matters is continually increasing, and at many points its scope extends beyond the concepts hitherto entertained, but neither the new methods of calculation nor the new constructional ideas can do more than elucidate the details and peculiarities of any one element of structure.

A job as a whole is made up of a mass of details which act reciprocally upon one another, so that the complex problem which results is one which calls for all the attention of the engineer to resolve it. It behoves the designer worthy of his task to draw upon the new knowledge now available of the properties of materials, and upon the new methods of calculation based on the tests of the ductility of steel, in order to achieve steel structures which shall be at once reliable and economical.