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SUMMARY OF DISCUSSION - SESSION 5

1. Brittleness and Plastic Design

The discussion focused on some problems of major practical interest where the theory of plasticity does not seem applicable.

Both K.H. Gerstle and J. Blaauwendraad discussed the structural response of a substance of brittle nature. The latter reported on a cooperation established in the Netherlands between researchers on the mechanical behaviour of the constituent materials and on numerical modelling. This has led to the development of a finite element computer programme incorporating the effects of cracking. This so-called micro-model had been applied successfully to several structural elements on which tests had also been performed, e.g. the well-known wall-beam experiments performed by Leonhardt and Walter. A connection was drawn to session 4 on numerical methods by discussing the advantages of applying hybrid displacement methods when developing such numerical methods for structural design.

K.H. Gerstle referred to at least three problems discussed where failure is initiated by brittle tension, i.e. punching (presented by M.W. Braestrup), splitting and anchorage (presented by U. Hess), and flexural shear in beams without shear reinforcement (presented by M.P. Nielsen). He therefore asked the Danish group whether elastic or elasto-cracking analysis had been carried out to compare with the plastic solutions and the tests.

Such investigations have not been performed, but M.P. Nielsen further mentioned the scepticism of the Danish research group when they found that in the application of plastic analysis to problems apparently so brittle in nature as anchorage, splitting, corbels, punching etc., excellent results were found when comparing with tests. Until further investigations have been made, the assumption at present is that the stress-strain relationship for concrete in tension is of the same nature as in compression, including a falling branch of considerable length, and that the application of plastic analysis to these problems is a fully reasonable and rational approach. As reported by M.W. Braestrup, the theory also holds excellently for the lok-test.

2. Effectiveness Factor

J. Witteveen supplemented his discussion to Session 2 on the origin and magnitude of the effectiveness factor ν , and made the criticism that the value of ν in the different cases depends much on the intuition of the individual designer. M.P. Nielsen supported further research on the determination of ν for the individual cases considered, but at present the formula $\nu = 2/\sqrt{\sigma_c}$ (MPa) seems to be a fair guess on the safe side, as values lower than these had seldom been found. He further reminded the discussion group that the elastic stress distribtuion in certain cases can be very wrong, e.g. when stress concentrations occur.

3. Safety Levels and Codified Plastic Design

A.B. Sele had applied the beam-shear model presented by J.F. Jensen in Session 2 to survey data from the UK. Extensive computer calculations were made in order to determine the level II reliability based on the BS CP 110, the ACI

318-77, the DIN 1045 (1972) and the rules of Det Norske Veritas for off-shore structures.

The results showed good agreement between the different rules. However, the absolute level of calculated reliability depends heavily on the codified loadings adopted. The relative picture may be altered significantly for other load types.

4. Bond and Anchorage

The tensile strength of concrete is often overlooked in our models. This simplification is in several cases unsatisfactory and leads to wrong results, e.g. in punching, and in splitting in the anchorage zone, as pointed out by R. Tepfers. In the anchorage tests performed by Rathkjen and further treated by U. Hess, an upper bound solution was applied, and transverse friction at the supports was neglected though some friction must have been present in the tests. It was furthermore pointed out that in the presentation by U. Hess only the last test series contained stirrups in the anchorage zone, all other series had no stirrups.

5. Optimal Design

Based on many years experience with the development of precast, reinforced slabs, A. Sawczuk presented his recommendations on the rational reinforcing of such slabs. Economy was assured by seeking maximum load carrying capacity for minimum reinforcement. Favourable service performance was reached by allowing minimal redistribution of sectional forces. Simple and quick execution was achieved by following certain technological conditions concerning welding, producing simplified reinforcing nets.

In R. Maquoi's interesting presentation it was stated that considerable economy was achieved when applying inclined stirrups as compared to vertical stirrups. As pointed out by M.W. Braestrup, this is only the case when the shear stresses are high and the concrete strength thus determining, whereas the advantage disappears when low shear stresses are exhibited. R. Maquoi supplemented this by emphasizing that codes such as the CEB-FIP Model Code should contain supplementary information such as the information he had given, instead of just giving the two limiting values of the stirrup inclination.

It seems obvious that the various manuals of CEB for example should profit from such valuable practical information, so clearly exemplified by R. Maquoi.

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