Summary of discussion: session 1, part 2

Objekttyp: **Group**

Zeitschrift: **IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen**

Band (Jahr): **34 (1981)**

PDF erstellt am: **22.05.2024**

DISCUSSION

Session 1, part 2: Modelling of Material Behaviour

Introductory Report by Gerstle, U.S.A.

Kotsovos (U.K.): In the report cracked concrete is discussed. In the cracked state however, the plane stress assumption is not valid any more. This should be explained.
On the other hand, simplified methods have to be found for structural design.

Gerstle: Threedimensional approach of cracked concrete is complicated. A simplification for structural design is necessary.

Bazant (U.S.A.): No categorical distinction can be made between bond-slip relevance in microscopic and macroscopic approaches. The bond-slip behaviour is important in both.

Gerstle: I agree with the statement, in principle. However, it would be practical to have criteria to distinguish cases when the bond-slip should be considered from those when it can be neglected. In case of cyclic loading the bond-slip behaviour is to be taken into account in the macro-approach as well as in the microscopic approach.

Schnobrich (U.S.A.): Should Peter's tests be considered as micro- or as macro-tests? There are some doubts with respect to these tests, concerning the edge constraint and strain measurements.

Gerstle: Peter's tests are to be understood as element (macro) tests. Peter's dissertation gives more information on details as mentioned.

Braestrup (Denmark): The reason of putting steel in concrete is to prevent the cracks from opening. Its yielding should not be called premature.

Gerstle: I agree. The term "premature" may be inappropriate in this case; the yielding steel has done the job.

Paper by Gambarova, Italy

Braestrup (Denmark): The paper consideres one crack. To have shear stresses in the plane of that crack the principal stress axes must be different from those corresponding to the stresses that have produced the crack. As a consequence, these further stresses may cause new cracks in different directions: a complicated model should be necessary to describe the different systems of cracks!

Gambarova: The Rough Crack Model, which is considered in this paper, was conceived with the aim of analysing the shear stiffness and the shear strength of primary (preformed) cracks, when further loads are applied, with shear in the plane of the crack. It is completely true that any load combination, not related to the primary cracks, may produce "secondary" cracks in the solid concrete between the "primary" cracks: this fact is going to be introduced in the Rough Crack Model. However, also in the case of principal axes aligned with the crack axes (normal and tangent), the aggregate interlock is exploited, provided that the bars are not symmetric with respect to the axis normal to the crack. The same is true when the principal axes coincide with the axes of the bars.

Bazant (U.S.A.): I agree with Dr. Gambarova. A recent model developed at Northwestern University shows that not only cracks perpendicular to the direction of the maximum principal tensile stress matter. This model involving solely an elastic matrix, plus rough cracks of all directions, gives a complete description, also for plain concrete. A current work is dedicated to the description of different cracks.

Paper by Walraven, The Netherlands

Bazant (U.S.A.): I am surprised that there is, in your opinion, no rubble in the crack. I think that there is some evidence which points the contrary. For example: if it is tried to return the shear displacement to zero and then to close the crack, it will turn out that this is impossible. The same is observed in rock mechanics.

Walraven: After the tests on the specimens with external bars, the specimens were opened, and then only a negligible amount of powder was observed. That was my evidence that the behaviour is principally governed by irreversible deformation of the matrix between the particles, and not by the action of loose aggregate particles, rotating between the crack faces. If it is tried to close the crack after opening, this is indeed not perfectly possible without any normal compressive stress. However, this may also be due to microcracking under the level of the crack faces,resulting in a deformation of these faces.

Kotsovos (U.K.): It is known that on the tip of the crack there are very high stress concentrations, and these stress concentrations are of the order of magnitude equivalent to chemical forces or even physical forces. What would be the contribution of the state of stress on the tip of the crack on the overall strength behaviour?

Walraven: The behaviour at the crack tip was not studied in detail. The model that was developed was meant to be used for finite element analysis, where we distinguish in general between cracked and uncracked elements, so that we do not have to deal with this question. To my opinion the influence of the state of shear at the crack tip on the behaviour of most concrete structures is not very great.

Mehlhorn (F.R.G.): I wonder why the diameter of the aggregate does not influence the relations between stresses and displacements very much.

Walraven: If I compare two mixes, one with a maximum particle diameter of 32 mm and the other of 16 mm, these mixes contain the same total aggregate volume. So actually every large particle is replaced by a number of smaller ones. Apparently these effects compensate each other.

Gambarova(Italy): With reference to your tests with embedded bars, you said that a mechanism based on the information of concrete struts occurs. These struts, which are at an angle to the crack plane, improve the crack shear stiffness. What is in your opinion the nature of these struts? Do they consist of concrete rubble (aggregate particles detached from the crack faces during the loading process) or are they made of solid concrete in between the secondary cracks originating from the bar deformations? Have you noticed any remarkable amount of concrete rubble at the crack interface, after each test?

Walraven: This aspect of the behaviour was most surprising. We knew that tests of Mattock, conducted at the University of Washington D.C., showed inclined cracking at the outside of the specimen. However, the only thing that we saw, was that the crack opening was constant, independent of the reinforcement ratio, which raised the supposition that also here inclined struts had been active. As we did not realize in advance that such a mechanism was possible, we had not made any arrangement to study the behaviour inside the specimen. A reasonable explanation is that the crack in the direct vicinity of the bars has a smaller width than elsewhere, which will attract stress concentrations and result in internal cracking, attended with solid concrete struts, which are invisible from outside. It is true that after opening of the specimen, after testing, concentrations of rubble were found in cratershaped holes, directly around the bars, but this may have been caused by the opening procedure itself, since a considerable pull-out of the bars is necessary before the specimen halves can be separated.
A definite answer may be found by injecting the cracks during testing with a fluorescent fluid and studying the micro-cracking pattern after the tests.

Paper by Nilsson/Glemberg, Sweden

Braestrup (Denmark): Experiments have shown that brittle failure can occur even when the corresponding stress is zero or even compressive. Can your model take account of such a phenomenon?

Nilsson: It is possible when the tensile strength is greater than or equal to zero, but not in other cases.

Paper by Dieterle/Bachmann, Switzerland

Flesch (F.R.G.): Did you use a constant bond stress in your calculations?

Dieterle: As a first assumption a bond stress is assumed that is constant over the length of the beam. In a second calculation the real bond stress is used, as can be calculated from the paper by Rehm, published by the Deutscher Ausschuss für Stahlbeton. Also the height of the load was considered calculating the real bond stress.

Flesch: My paper is quite in accordance with your results, given in reference [2], e.g. showing the high damping for small amplitudes and a decrease of damping, with increasing amplitudes; further an increase with the percentage of reinforcement, etc.

Paper by Roelfstra/Wittmann, Switzerland

Bazant (U.S.A.): In your model creep recovery is due to the elastic recovery of the aggregate. Does this mean that in cement paste there will be no creep recovery?

Roelfstra: The elastic energy stored in aggregates contributes to the total creep recovery of concrete. Hardened cement paste is far from being a homogeneous material. There are unhydrated clinker particles and weak zones randomly distributed in the microstructure. Therefore even in hardened cement paste locally elastic energy is stored during time-dependent deformation and therefore even in hardened cement paste creep recovery is observed.