Special issue on compressive failure of concrete and rock

J.G.M. van Mier
Delft University of Technology, Faculty of Civil Engineering and Geo-Sciences, Stevin laboratory and M2L laboratory, PO Box 5048, 2600 GA Delft.

Concrete is a complicated multi-phase material. Under mechanical load its behaviour is far from linear elasticity. The same holds for other heterogeneous materials like many types of rocks and soils. Generally such materials are gathered under the name 'Geo-materials'. At the macroscopic level, we are interested in measuring the complete stress strain behaviour, which is the necessary input information for structural engineers.

From uniaxial compression tests it is concluded that the definition of a unique stress-strain curve is not a simple task, see for example the work of the RILEM Technical Committee "Strain-Softening of Concrete" [1]. The stress-strain curve is to a large extent influenced by boundary restraint and specimen geometry and size. Friction between loading platen and specimen leads to a size dependent strength. A higher strength is measured when the friction increases and when the specimen slenderness decreases. In addition, the slenderness has a significant influence on the post-peak behaviour, and experiments have shown that localisation of deformations occurs in the post-peak regime, [2], [3]. Such phenomena are found for multiaxial compression as well, [4], [5]. Moreover, similarities exist for the mechanical behaviour of rocks, [6]. Structural engineers attempt to include these far reaching consequences of these observations in such a way that the analyses have a predictive character. Essentially the observations indicate that in the pre-peak regime stress-strain diagrams should be used, whereas after the peak where localisation of deformations occurs and a stress-deformation diagram should be used in the spirit of fracture mechanics of concrete. Based on these observations, the introduction of fracture mechanics concepts for compressive failure was proposed [7], for example for analyzing the rotational capacity of reinforced concrete beams.
The future will have to learn whether such attempts will be successful or not.

On a more scientific level, we are also interested for the conditions that determine the failure of the material at a lower level of observation. Many mechanisms have been proposed in the past, such as the growth of splitting cracks from pores, debonding cracks between aggregates and matrix, the growth of wing cracks and their interactions from pre-existing flaws in the material, etcetera. From a mechanical point of view, any disturbance in the material structure, be it a pore, flaw or inclusion, will lead to fluctuations in the local stresses. The situation may be severe and local tensile stress concentrations are found, which eventually will trigger macroscopic failure. The true conditions are only partly known, but the information is essential in particular when we are interested in engineering new strong and ductile cement-based composites. In this issue of HERON, three interesting

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papers are included in which it is attempted to come to an improved understanding of compressive failure.

In the first paper by Küntz, new experiments are presented which show the similarity between fluid flow along inclined obstacles and the growth of wing cracks from inclined flaws in a solid. Clearly similarities between solid and fluid mechanics seems to exist. The flow of the fluid seems to indicate the direction of crack propagation. Also on the effect of wing cracks from inclined pre-existing flaws is the contribution by Dyskin. He is pre-occupied with the effect of the presence of many randomly distributed flaws in the material, which cause a fluctuating stress field. These stress fluctuations from the interacting cracks causes the onset of global failure. Finally, Bongers points to the effect of pore collapse in the interfacial transition zone between aggregate and matrix as a reason for the typical shape of the pre-peak compressive stress-strain diagram under multiaxial compression. The effects are analyzed with a numerical model. The three contributions are a step in further understanding compressive failure. Many mechanisms have still to be elucidated. The stay of Dr. Küntz and Dr. Dyskin at TU Delft in 1998, and the interaction with the researchers at Eindhoven University was very enjoyable, and the contributions gathered in this HERON issue hopefully helps to formulate new and interesting directions for new research in the field of compressive failure. The results seem to point to a direction where renewed interest in basic fundamental mechanisms responsible for compressive failure should be gathered in order to define more reliable – physically based – models for structural engineering. In addition, such models may also be helpful to engineer new improved cement-based composites.

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