On Finite Element Modelling of Compressive Failure in Brittle Materials

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Modelling of brittle softening materials requires suitable regularization techniques. This has been long recognized for the modelling of cracking, i.e tensile failure, in brittle materials such as for instance concrete. The crack band approach represents the classical method how to address this problem of proper energy dissipation in the modelling of the tensile failure in the finite element calculation. The paper presents the straightforward extension of this approach for the modelling of compressive failure in brittle materials. This approach was first used in Červenka, et. al. 1998, but more rigorous treatment is necessary and will be the subject of this paper presented.

It has been recognised by experimental work by Van Mier 1986 and Tatematsu and Nakamura 1997, 2001 that in compression failure similar size effect as in tensile behaviour can be observed. In finite element modelling of brittle materials such as concrete, the compressive behaviour is as important as the tensile response. The compressive failure is often a critical behaviour, which may control the ultimate limit state of the investigated structure The regularization techniques for the modelling of cracking in brittle materials has been extensively investigated in the past and various approaches have been proposed such as: crack band method, nonlocal averaging, higher order continuum theories, etc. All these approaches can be applied to the compressive softening as well, however, it is not usually done, mainly due to the fact that the experimental evidence is limited.

The paper discusses the importance of an appropriate modelling of compressive failure in concrete structures on several examples with experimental data involving shear and compressive crushing of concrete. The crush band approach is proposed for the modelling of the mesh objective energy dissipation during the crushing process. The crush band size is calculated as a finite element size projected into the direction of the minimal principal stress. The crush band size is in addition adjusted based on the finite element shape and the crush band direction.

One example of practical application will be presented, which involves modelling of ultimate limit states and fatigue states in grouted connection in offshore wind farms. In this grouted connection significant tensile and compressive stress concentration occurs, which makes it difficult to use standard design approaches based on checking of stress levels. Global assessment based on nonlinear analysis can be successfully applied if proper modelling of the nonlinear effects in the high stress concentration zones is used.

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