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Hysteresis, damage and moisture effects in quasi-brittle porous materials

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ABSTRACT

Cyclic mechanical tests on concrete specimens show a complex behavior [9; 10]. Cyclic tensile-compressive tests show in the pre-peak region, a nonlinear load-deformation as well as hysteretic loops. In the post-peak region, strain softening occurs when the damage evolves. When unloading, the load deformation is characterized by a stiffness reduction in tensile loading and a stiffness recovery in compressive loading. In addition, permanent deformations and hysteretic loops are formed, which change shape when going from tensile to compressive loading and vice versa. Moreover, the hysteretic behaviour transforms as the damage evolves. These observations correspond with the statements [4; 6] and measurements [11] that the nonlinear, hysteretic response is caused by low-aspect ratio features (e.g. contacts in micro-cracks, macro-cracks, asperities...) present in the material. Since these features are related to damage, it is logical that the nonlinear hysteretic behaviour varies upon damage. [4] propose to model materials with low-aspect ratio features with the Preisach-Mayergoyz space model (PM-model) since the traditional elasticity theory as applied for microscopic elastic materials is not capable to take into account the observed phenomena. The PM-space model is a multi-scale model, whereby the macroscopic behaviour is determined by the mesoscopic elements. Two types of mesoscopic elements are present in the model, non-hysteretic and hysteretic elements. The hysteretic elements are in the PM-model simplified to rectangular hysteretic elements. A physical representation of these elements is the opening and closing behaviour of e.g. microcracks with increasing/decreasing stress. Consequently, the behaviour of the hysteretic elements changes as the damage evolves. The observed permanent deformations are taken into account by hysteretic mesoscopic elements that remain in open state. Physically, this corresponds with the features e.g. microcracks that remain in an open state.
Following [7; 6], the moisture influence on the hysteretic nonlinear behaviour can be implemented as an interaction pressure. With this approach the nonlinear cyclic hysteretic behaviour of the concrete at different saturation states can be simulated as well as hygric swelling/shrinkage experiments of concrete specimens. In combination with the damage dependent hysteretic model, a poromechanical constitutive model is

generated that takes into account the influence of the damage and moisture present in the material.
Subsequently, the behaviour is analysed, conclusions are drawn regarding the evolution of the classical Young's moduli and Biot coefficient with damage, moisture and applied stress.
Finally, the constitutive model is further exemplified by showing the stress-strain behaviour of concrete under varying mechanical, hygric and combined hygro-mechanical loading histories.

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