Constitutive modeling of plasticity and elastic degradation coupling in quasibrittle materials

Abstract

The PhD thesis concerns development of thermodynamically consistent constitutive models of elastic plastic damaged materials in the frame of small strain theory. The result is a proposal of a constitutive model suitable for quasibrittle materials, concrete in particular. The introduced model is based on a Helmholtz potential and a dissipation potential. It contains an original yield/damage condition with four material parameters, a non-associative flow rule and a novel form of Helmholtz function, dependent on three scalar damage parameters.

The main aim of the work was to build a new constitutive model of concrete based on a Helmholtz function and a dissipation potential, following the known framework of constructing thermodynamically consistent models of materials. The task was divided into consecutive steps.

After a brief introduction, experimental results available in the literature on the subject are summarized in order to expose the main features of concrete's response to loading and use them to build an adequate model.

Chapters 3 and 4 provide an introduction to the topic of constructing thermodynamically consistent constitutive relationships and contain original examples of formulations of such models. The framework of design of thermodynamically consistent models, drawn from the literature, is described in details.

In the next chapter concrete is considered as an elastic-plastic material. Dissipation rate functions and their Fenchel dual yield conditions are analyzed. Examples of revolving and non-revolving yield surfaces are presented. Novel formulae concerning a dissipation function of a particular form including Ottosen's shape function are introduced.

Chapter 6 discusses an elastic damaged material. A model is presented based on an original Helmholtz function and a dissipation function. Three scalar damage parameters are introduced, representing some observable effects of concrete's deterioration.

In chapter 7 a model coupling elasticity, plasticity and damage is introduced, based on the results from preceding parts of the thesis. Two potentials, Helmholtz energy and dissipation function, are postulated, allowing derivations of all necessary constitutive equations. The proposed model contains ten material parameters and two hardening functions. Two parameters are elastic constants (Young's modulus and Poisson's ratio). Part of the remaining parameters one can determine knowing yield limits for basic experimental tests (uniaxial tension, uniaxial, biaxial and triaxial compression) and the rest of them have clear empirical interpretations, which is a great advantage. Numerical solutions of simple loading test problems prove that the proposed model adequately describes experimental results.

Keywords: concrete, quasibrittle materials, elasticity, plasticity, damage, damage parameter, dissipation function, yield condition, damage condition, nonassociative flow rule, Helmholtz potential, thermodynamically consistent model, Legendre transformation, Fenchel dual