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3D FINITE ELEMENT ANALYSIS OF TIME-DEPENDENT STRUCTURAL FAILURE OF CONCRETE BEAMS IN BENDING DUE TO NONLINEAR CREEP

Alexander Dummer*, Matthias Neuner and Günter Hofstetter

University of Innsbruck, Faculty of Engineering Sciences,
Unit of Strength of Materials and Structural Analysis,
Technikerstraße 13, 6020 Innsbruck, Austria, www.uibk.ac.at/bft

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In order to assess the structural integrity of concrete structures for the complete service life by means of 3D finite element analyses, the appropriate description of the highly nonlinear and time-dependent material behavior is crucial. In particular, the realistic representation of the creep behavior is of special importance: While for moderate stress levels the creep strain rate is approximately proportional to the acting stress, for higher stress levels the relation between the creep strain rate and the acting stress becomes nonlinear. Furthermore, a high sustained acting stress leads to an increase of the creep strain rate due to growth of microcracks, which potentially results in structural failure.

For representing this complex material behavior of concrete in numerical simulations, an extended material model for concrete is presented. It is mainly based on (i) the damage-plasticity model by Grassl and Jirásek [1] and (ii) the solidification theory by Bažant and Prasannan [2], formulated within the theory of the gradient-enhanced continuum. Novel approaches are proposed for modeling a nonlinear dependence of the creep strain rate on the acting stress as well as the evolution of material damage due to sustained loads. Since both aforementioned phenomena strongly depend on the acting stress level, a novel measure for the degree of material utilization is proposed which is formulated within the plasticity framework of the model.

For demonstrating the predictive capabilities of the extended constitutive model, a 3D finite element study is performed based on the flexural creep rupture tests on concrete beams conducted by Zhou [3]. It is shown that time-dependent failure of concrete beams subjected to high sustained loading can be captured very well by the proposed model in a mesh-objective manner.

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