FE-ANALYSIS OF THE BEAVIOUR OF CONCRETE ELEMENTS WITH COUPLED ELASTO-PLASTIC-DAMAGE MODELS WITH NON-LOCAL SOFTENING

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1. General

The analysis of concrete elements is complex due to their stiffness degradation during cyclic loading caused by strain localization in the form of cracks and shear zones. The determination of the width and spacing of strain localization is crucial to evaluate the material strength at peak and in the post-peak regime.

The aim of the present paper is to show the capability of two different coupled elasto-plastic-damage continuum models to describe strain localization and stiffness degradation in concrete elements subject cyclic loading during bending, uniaxial compression and extension. First, a coupled elasto-plastic-damage model based on the idea by Pamin and de Borst [1] was used [2]. Second, a coupled elasto-plastic-damage model using the formulation proposed by Carol et al. [3] and Hansen and Willam [4] was taken into account.

To describe properly strain localization, to preserve the well-posedness of the boundary value problem, to obtain FE-results free from spurious discretization sensitivity and to capture a deterministic size effect, a integral-type non-local theory was used as a regularization technique in a softening regime [5]. It was achieved by weighted spatial averaging over a neighborhood of each material point of a suitable state variable. Thus, the stress at a certain material point depended not only on the state variable at that point but also on the distribution of the state variable in a finite neighborhood of the point considered.

2. Coupled models for concrete

The first coupled model [1], [2] combines non-local damage with hardening plasticity and assumes that total strains are equal to strains in a undamaged skeleton. Plastic flow can occur only in a undamaged specimen, thus an elasto-plastic model is defined in terms of effective stresses. As a consequence, the damage degradation does not affect plasticity.

In the second coupled model [3], [4], plasticity and damage are connected by two loading functions describing the behaviour of concrete in compression and tension. The model assumes that the damage approach simulates the behaviour of concrete under tension while plasticity describes the concrete behaviour under compression. According to this assumption, a failure envelope is created by combining a Drucker Prager formulation in compression with a damage formulation based on a conjugate force tensor and pseudo-log damage rate in tension. Both models require only few material parameters. Except of the Young modulus and Poison's ratio, the following parameters need to be defined: initial value of strain when damage starts, two parameters describing the damage growth and ratio between the compression and tensile strength to define the equivalent strain measure (when using a modified von Mises definition) in the first model, and the internal friction angle, dilatancy angle, softening function in compression and fracture energy with its elastic part to describe the resistant function in tension in the second model.

3. FE-simulations

The mesh-independent FE-results for concrete beams under cyclic loading were compared with corresponding laboratory tests [6], [7]. They show that the both models were able to proper describe the behaviour of concrete under cyclic loading. Fig.1 shows a comparison with experiments on concrete beams under bending subjected to cyclic loading [6] using the first coupled elasto-plastic–damage model. The numerical result fits the experimental data quite well.

However, both models have also some disadvantages. In the fist model is hard to properly define all parameters to control both plasticity and damage at the same time. In addition, there is no clear distinction between elastic, plastic and damage strains. In turn, the second model is not able to reproduce plastic strains in compression during cycling loading. So it implies a necessity to improve the models to couple damage and plasticity more realistically in one formulation.

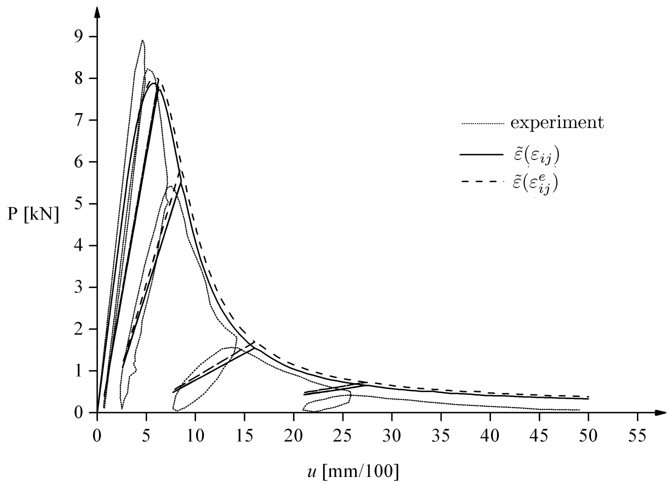

Fig. 1: Calculated load-displacement curves for a coupled elasto-plastic-damage model with non local softening during cycling loading compared with experimental data [6]

4. References

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