Applying a second gradient theory on reinforced concrete structural elements

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Strain localization is a common phenomenon in solids which have suffered severe loadings and can lead to fracture and failure of the medium. From a practical point of view, it is important to predict the possible occurrence of such phenomena (location threshold), but also to be able to simulate the behavior of a structure (e.g. reinforced concrete buildings, dams, nuclear power plants) beyond this point (post-localization behavior). It is well known that continuum mechanics models that do not have an internal length are not suitable for this type of engineering problems.

A rather natural way of introducing (indirectly) a length parameter in a continuum model is to somehow account for the microstructure of the material. The general class of so called microstructured models or higher order continuum models allows for the description of the kinematics of the microstructure by using an additional tensor in the displacement field. Higher order continuum theories can be traced back to the works of the Cosserat brothers and have been generalized and properly formulated by Mindlin and Germain using the method of virtual power.

The local second gradient model developed by Chambon et al. [1] can be seen as a particular case of a higher order continuum and has been often used to regularize problems involving localization in soils. In this work, it adopted to simulate localization problems in reinforced concrete structural elements. More specifically, a two dimensional nine-node node second gradient finite element is used [2] and the constitutive laws for the first gradient part are based on damage mechanics [3], [4].

Experiments on a reinforced concrete beam (three point bending test) and a reinforced concrete shear wall (static monotonic loading) were studied within the French National Program CEOS.fr (Behaviour and Assessment of special R.C. works - cracking & shrinkage), www.ceosfr.org. Global (force-displacement curves) and local results (strains in concrete and steel, crack propagation using the Digital Image Correlation technique) were monitored and are compared with the numerical results of the second gradient approach.

The results show that the model is able to reproduce the force-displacement curve obtained experimentally. Damage localizes into bands whose width is controlled by the model parameters. The uniqueness of the solution is however not restored.

These results are encouraging and represent the first steps toward a wider use of the local second gradient method for concrete structures.

References

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