CREEP-DAMAGE COUPLING

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The failure of quasi-brittle materials under mechanical loading can be divided into two different parts. Initially, diffuse microcracking (damage) occurs in the Fracture Process Zone (FPZ) due to heterogeneities at the micro-scale. Further on micro-cracks coalesce into a macro one yielding strain localization. As the size of the FPZ is related to the microstructure, this type of fracture yields a size effect extensively studied by Bazant since the 70's [1]. For prestressed concrete structures for which permanent load level is large, the influence of creep on the fracture process should be taken into account. We tackled the coupling between creep and failure properties from experimental, analytical and numerical point of view keeping in mind the perspective of size effect. Therefore, several analyses have been performed on three point bending tests on a notched beam of three homothetic sizes.

We first put experimentally in evidence the coupling between creep and damage with several levels of sustained load. Tertiary creep yielding failure has eventually been observed for some of the largest beams and loaded at the highest level. For surviving beams a residual capacity test has been performed to evaluate peak load and fracture energy after three months of creep at different load levels. The conclusion of this study is that the bearing capacity is slightly influenced by creep whereas the fracture energy decrease is not negligible. Therefore we observe a shift towards the LEFM response in the size effect plot.

In a second stage to get some insights of the bifurcation problem we perform an analytical analysis [2]. The conditions for localization in a rate-independent material described by a non-local damage based constitutive relation coupled with a Kelvin type creep relation are derived in a closed form. The inception of a localized mode is considered as a bifurcation into a harmonic mode. The criterion of bifurcation is reduced to the classical form of singularity of a pseudo acoustic tensor; Based on the wavelength of the localization mode, a shift on the size effect plot towards the strength criterion, i.e. towards ductility, is found when the fraction of creep release energy which contributes to damage is decreasing. Moreover, the normal to the localization band depends only upon the elasto-damage state of strain.

Finally, we numerically simulate the experimental tests with a finite element code using the coupling between the Benboudjema's creep model [3] and the Mazars' damage model [4]. Experimental results are qualitatively reproduced in terms of failure due to tertiary creep, fracture energy reduction.

References

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