Nonlocal three-dimensional continuum damage model for failure analysis of timbers

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ABSTRACT

Timber is an environmentally-friendly construction material with anisotropic mechanical properties and complex nonlinear hardening/softening behavior and various interacting failure modes under multi-axial stress state. In structural/construction engineering applications, the nonlinear response and failure of timber are typically predicted by phenomenological models cast in the framework of continuum damage mechanics (CDM) or plasticity-based models. Regardless of the framework adopted for the constitutive law, the negative slope of stress-strain curve or softening behaviour of material in the framework of continuum mechanics is associated with instability of the materials which in turn is manifested by localisation of strain and spurious mesh sensitivity (lack of objectivity) in finite element simulations. Accordingly, the last three decades have witnessed efforts to develop localisation limiters such as crack/crush band approach and viscus regularisation methods that alleviate mesh sensitivity of continuum-based finite element models [1-3]. Among different localisation limiters proposed so far, nonlocal integral and/or gradient-based models have proved to be effective in restoring the objectivity of finite element simulations and treating the mesh sensitivity associated with softening of materials.

In this study, an integral-type nonlocal average technique is incorporated into the CDM-based timber model developed by Gharib et. al. [4] and the model is implemented in an ABAQUS-UMAT subroutine. In the implemented nonlocal model, the strain components of a point in continuum media are replaced by their weighted average over a spatial neighbourhood of that point and the damage indices are calculated using the nonlocal strains. Finite element simulations of timber elements with softening behaviour are carried out to demonstrate the accuracy of the proposed nonlocal model for predicting the softening behaviour of timber. Moreover, the problem of locking in the nonlocal models are addressed and it is shown that the nonlocal model proposed in this study is free of locking.

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