Non-linear static analysis of masonry structures

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ABSTRACT

Vibration induced damage to structures due to sources of low and moderate amplitude, such as road traffic and construction activities, is subject to persisting controversy. Current guidelines to assess damage in structures due to vibrations are largely based on heuristics. Therefore, a numerical model is proposed to model damage in masonry structures.

The propagation of damage in masonry structures primarily occurs in the mortar layers. Therefore, the masonry is modelled at the mesoscopic scale, where continuous solid elements are used for the masonry blocks and interface elements are used for the mortar layers. The non-linearity of the model is concentrated in the interface elements which consists of two faces corresponding either to the faces of two solid elements bound through a mortar layer or to adjacent faces of solid elements for a single brick. An elasto-plastic contact law that follows a Mohr-Coulomb criterion is used to model failure in tension and shear, taking into account the softening behaviour of masonry [1].

Because of the brittle nature of masonry, special attention has to be paid to the global solution strategy. Sharp snap-backs are observed in the global static solution when cracks develop in the structure [1, 2]. Traditionally, a standard arc-length method is used to trace the static non-linear equilibrium path. However, for many materially non-linear problems the global norms used in these methods are inappropriate and a different constraint equation has to be used. Therefore, two alternatives are studied. Verhoosel *et al*. [3] proposed a dissipation based arc-length method. The constraint equation is based on the rate of energy dissipation which is equal to the exerted power minus the rate of elastic energy. This method is only applicable for dissipative parts of the equilibrium path. A second alternative is an adaptive path following scheme [2] where, for every load increment, a control region is identified where control parameters in the constraint equation are evaluated. This region changes with the propagation of damage.

Multiple numerical experiments are performed on different masonry brick wall configurations. A direct shear test under normal compression is performed on a small brick assembly (2×1.5). Initially, the sample behaves elastic and a standard arc-length method is used. When the interface elements start yielding, the solution method switches to the dissipation based arc-length method. The externally applied horizontal force reaches a maximum value after which softening is observed. The yield function evolves to a standard Mohr-Coulomb slip criterion and a horizontal crack develops in the wall. When performing numerical tests on larger samples, the dissipation based method fails after a number of load increments depending on the configuration of the bricks. In order to obtain a robust solution scheme, an adaptive path following scheme is also considered. Presently, the analysis is extended to incorporate the dynamic response of masonry structures.

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