Multiscale formulations for in-plane and out-of-plane analysis of masonry elements

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ABSTRACT

Masonry is a heterogeneous composite material largely used in historic constructions, made of bricks and/or blocks bonded together by cementitious mortar layers. Development of numerical procedures to efficiently describe its mechanical response is a hard, yet important, task, due to the nonlinear brittle behavior of the constituents and debonding phenomena occurring at interfaces.

Discrete element methods, discontinuous deformation analysis and finite element (FE) models are the most used methods for the numerical simulation of masonry structures. Among them, FE models based on multiscale approaches are a modern and promising tool, representing a fair compromise between a detailed description of masonry micromechanical mechanics and computational burden. In these approaches, the constitutive response of the continuous medium at the higher geometric scale (macroscale) is determined by evaluating the response of a Unit Cell (UC) at a lower geometric scale (microscale). Different homogenization procedures [1, 2] can be used to link the two scales, based on properly defined average and boundary conditions.

This work presents a two-dimensional Timoshenko beam finite element for the in-plane and out-of-plane nonlinear analysis of masonry elements. The model is obtained by exploiting a multiscale procedure that links the beam model at the macroscale to a UC at microscale. The beam at the macroscale is defined equivalently considering a straight or curvilinear axis [3], while the UC is described by an equivalent straight Timoshenko beam and is made of a linear elastic brick and a nonlinear mortar layer. The nonlinear constitutive relationship considered for the mortar accounts for the evolution of damage, friction, and unilateral effect. A homogenization procedure relates the general quadrature cross-section at the macroscale to the UC at the microscale and, thus, the generalized section constitutive response for the beam at the macroscale is evaluated by homogenizing the response of the UC.

Nonlinear analyses on experimentally tested masonry specimens are performed and the numerical results are compared with experimental outcomes and micromechanical FE models.

REFERENCES

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