Nonlinear analysis of masonry arches adopting a multiscale curved beam finite element model

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Abstract

Arches are widely used structural elements in masonry constructions, as their shape reduces tensile stresses in the materials and increases the carrying capacity with respect to vertical loads. By contrast, horizontal actions due to seismic loads easily produce damage, micro-cracks and bond loss at the interfaces between bricks/blocks and mortar joints, leading to structural collapse and making the arch mechanical behavior hard to simulate.

Many numerical approaches have been proposed to reproduce the response of masonry arches in structural analysis. Among them, multiscale finite element models have been often preferred, as these result computationally efficient, robust and enough accurate, compared to more complex approaches, such as micromechanical and discrete element methods.

This work presents a two-dimensional Timoshenko beam finite element with curved axis for the nonlinear analysis of masonry arches. The model is derived by introducing an arch-to-beam multiscale procedure in the force-based formulation proposed in [1] and considering three different parametrizations of the axis planar curve to exactly describe the element geometry. To evaluate the integrals along the curved axis that appear in the element governing equations, specific quadrature techniques are applied. These are also exploited to detect the formation of the nonlinear hinges characterizing the arch collapse mechanisms.

A homogenization procedure relates the general quadrature cross-section to the Unit Cell (UC) at the lower geometric scale (microscale) [2]. This is made of a linear elastic brick and a nonlinear mortar layer and is described by an equivalent Timoshenko straight beam model. Hence, the generalized section constitutive response for the curved beam at the macroscale is evaluated by homogenizing the response of the UC at microscale.

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

Keywords: **Masonry arch, multiscale model, force-based finite element, curved beam**

References

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