A Novel Non-Linear Homogenization Approach for the Analysis of TRM Reinforced Double Curvature Masonry Structures

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ABSTRACT

In the context of historical heritage, curved masonry structures as arches, vaults and domes represent the most distinctive and charming feature. Since 17th century, several approaches have been developed in order to analyze their behavior, achieving nowadays techniques enable to combine ancient and current methods [1]. As these elements act as a weak point of the structures during seismic events, their vulnerability could be faced with the application of innovative composite material as TRM (Textile-Reinforced Matrix). The behavior of single and double curvature masonry structures, even more when reinforced with TRM, is still not deeply investigated in literature as the high number of variables and uncertain involved in the analysis. This latter should be preferably non-linear in order to reproduce properly the evolution of the damage and so the activation of the strengthening.

In this paper a novel user Abaqus implementation of a simple holonomic homogenized model with curved units cell for non-linear analysis of masonry vaults is presented. At meso-scale level a curved running bond elementary cell is taken as representative element of the volume (REV). The REV is discretized through 24 triangular curved shell elements (for bricks) and linear interfaces with zero thickness (for mortar). An elastic behavior is accounted for bricks, whereas a holonomic behavior with softening is addressed for the mortar joints, reducing by far the variables and allowing a semi-analytical evaluation of the homogenized stress-strain relationship [2].

At the structural level a shell approach with on-thickness integration is used. The method is able to take into account the typical in-and-out-of-plane coupled behavior exhibited by masonry vaults. The transition from meso-scale to the macro-scale is a procedure implemented in a user-defined UMAT function. The strengthening, made of cementitious matrix and fibers is then modeled directly on the homogenized model in a second step[3].

With the aim to validate the proposed approach, some non-linear simulations are carried out on examples of unreinforced vaults, of which experimental and numerical data are available[4]. Then FRCM reinforced structures are analyzed, showing the reliability of the method and the accuracy of reproducing the evolution of the damage with a limited computational burden.

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