Mazar's Damage Model for Masonry Structures: A Case Study on an Italian Church

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Abstract

Structural safety assessment of cultural heritage masonry structures plays an important role in safeguarding their integrity and conservation.
In this regard, masonry modeling is one of the most challenging tasks, since an accurate reproduction of its mechanical behavior is necessary to assess the overall bearing capacity of the structures. In Finite Elements Methods, a realistic constitutive relation for the materials must take into account their brittle nature, their asymmetric behavior in tension and compression and their damage upon reaching their ultimate strength. A classic plasticity model is not well suited for simulating masonry materials, which are characterized by a low tensile strength and by fractures and discontinuities. Such behavior is better implemented through a damage model, where material properties are modified by the load history.
One of the models available for limited tensile strength materials is the Mazars' damage model, which belongs to the isotropic damage material class. Its essence can be summarized by the introduction of a Damage Status Variable, D, that keeps track of fracture strains and reduces the effective Young modulus as a function of maximum tensile strains experienced by the material throughout its load history. Such constitutive relation is implemented by COMSOL Multiphysics® as external material model. This functionality allows COMSOL to call an external dynamic link library (DLL), written in C language, that contains the relationships between stresses and strains in the material.
In this paper, the Mazars' model is applied to a case study regarding a masonry church in center Italy. In a first step, an accurate solid 3D geometry is built within a 3D modeling software, starting from architectural drawings and site photography. The model is then simplified and cleaned using both CAD surfacing tools and COMSOL geometry preprocessing tools, such as repair features and virtual topology operations.
Solid Mechanics physics is applied to the geometry and the Mazars' damage model is used to determine the structure's static configuration under self-weight condition, by gradually ramping gravity loads with the auxiliary sweep feature. Various configurations are analyzed, taking into account also the contribution of tie rods, whose purpose is to limit the horizontal thrust of vaults and arches on the adjacent structures.
Damage and crack opening can be visualized by plotting the damaged Young Modulus. The results display the advantages of the tie rods in containing the horizontal thrust of vaulted structures, leading to a reduced crack opening in the masonry. Modal analysis is then performed in the deformed configuration, showing how cracking development leads to a reduction in structural stiffness, providing lower eigenfrequency values compared to the

undamaged case.

In conclusion, Mazars' damage model allows assessing damage contribution in low tensile strength materials such as masonry and concrete in static and dynamic analyses. COMSOL has proven as a valuable tool to perform analyses with custom material models. Its solver flexibility has allowed estimating the damaged structure's dynamic properties.

Figures used in the abstract

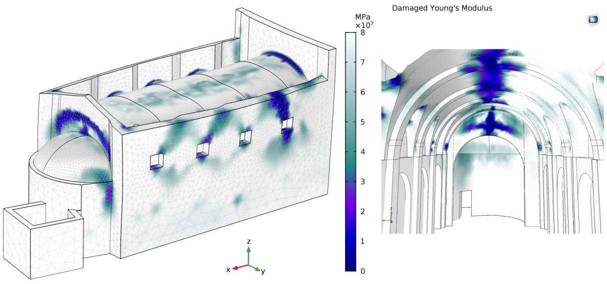

Figure 1: Damaged zones computed with Mazars' model.