Editorial

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A growing interest in the conservation of historic masonry structures has led to the development of detailed analyses of the structural behaviour of masonry vaults, which are widely diffused in the architectural heritage. For such doubly curved structural elements, the assessment of their load-bearing capacity is crucial, as well as the evaluation of some typical mechanical behaviours. For these reasons, several approaches have been proposed in the last decades to analyse the behaviour of vaults under static and dynamic loads, depending on different parameters such as shape, mechanical properties of masonry and brick patterns, loads and boundary conditions, etc.

This special issue collects a selection of the papers presented in the second edition of the mini-symposium *Nonlinear Behaviour of Vaulted Masonry Structures* of the International Conference on Nonlinear Solid Mechanics – ICoNSoM 2022, held in Alghero, Italy from 13 to 16 June 2022. Among the themes that characterise the conference, the mini-symposium focused on the evaluation of the nonlinear behaviour of vaulted masonry structures and aimed to stimulate a discussion on the different approaches to the study of their structural behaviour.

The discrete element model is a very useful tool for the numerical analysis of masonry structures as it is particularly suitable for representing the non-linear behaviour of masonry, which is governed by shear and separation along joints and discontinuities. However, in the case of domain dynamic analysis, the choice of damping is critical. Lemos (2024) compares the standard Rayleigh damping model with an alternative damping model based on the use of Maxwell elements in the contacts between blocks. The performance of these two alternative formulations is discussed by means of comparative analyses for arches and vaults under static and dynamic loading.

Zucca et al. (2024) analyse the static behaviour of an historic masonry sail vault, characterised by a complex brick pattern and a segmental shape, belonging to a characteristic typology of masonry vault widely spread in the area of Cagliari, Italy.

Attention is focused on the construction techniques, in particular the role played by the arrangement of the bricks. On the basis of a complete laser scanner survey, a Finite Element model is proposed to carry out a stage-by-stage analysis, in order to study the evolution of the stresses acting on the different parts of the vault during the construction process, assuming that no formwork has been used.

Despite their widespread use, experimental and numerical analyses of masonry arches and vaults exposed to fire are still not well developed. Fantilli and Burello (2024) present experimental tests on masonry barrel vaults made of solid clay bricks and cement-lime mortar, subjected to a standard fire in the intrados and different loads in the extrados. Two vaults were also insulated with fireproofing materials to mitigate the effects of elevated temperatures. A simplified numerical model, introduced previously and improved here, is used to calculate the fire resistance; the comparison between the test data and the numerical results provides a more reliable prediction.

Hemispherical domes and square cloister vaults subjected to concentrated vertical loads in the upper crown are quite common in practice, for example in lantern domes and cloister vaults of historic buildings loaded in the middle span. For such cases, Milani (2024) hypothesises a failure mechanism and derives the analytical expressions for the different contributions of internal and external energy dissipation. The collapse multiplier can then be obtained by applying the principle of virtual forces. The proposed method is benchmarked here on two experimentally tested case studies for which several numerical results from different models are already available.

Barsi et al. (2024) propose a parametric analysis of the safety level of masonry domes subjected to their own weight. Based on the well-known Heyman hypotheses, statically acceptable stress fields inside the dome are sought. The dome is modelled as a thin shell, where both membrane forces and bending moments can occur, in order to explore a wider set of possible equilibrium states with respect to several analysis techniques found in the literature. The equilibrium problem is solved by the collocation method and a convex optimisation problem is developed to find the best stress field distribution. The cases of spherical domes and equilateral conical domes with a top opening are analysed, for which the minimum allowable thickness and the corresponding stress field are given.

Gerges et al. (2024) assess the seismic vulnerability of the Beit-El-Din Hammam, a Lebanese masonry monument characterised by vaults pierced with holes. Hammams with multi-hole vaults are typical structures in Arab countries, and their behaviour has not yet been studied. Thanks to environmental modal tests, the natural frequencies of such a structure are measured and a detailed 3D model is identified. The authors perform nonlinear dynamic analyses under spectrum-consistent earthquakes, adopting a concrete damage plasticity model to describe the inelastic behaviour of the masonry. Possible damage patterns that could affect the monument are predicted. In addition, a twin model was used to assess the effect of holes on the tensile damage of vaults.

Addessi et al. (2024) provide numerical simulations considering a small-scale specimen of a masonry dome. A micromechanical modelling approach is adopted, where each masonry constituent is separately modelled and all the information about the microstructure are considered. Linear elastic bricks are discretised with 3D solid Finite Elements, joints are modelled as interfaces, for which a damage-friction constitutive law is assumed, able to track the microcracking evolution due to tensile and shear states. Sensitivity to masonry texture is investigated. The experimental response of the dome is studied first under vertical load, considering ideal symmetry conditions, then under horizontal actions, mimicking seismic excitation.

For materials such as masonry, where the tensile capacity is negligible, designing a purely compressed form allows the structure to work efficiently through membrane action, resulting in minimum structural thickness. Most shell and vault form finding methods are based on discrete approaches, where the solutions are linked to the initial discretisation or mesh estimates, and typically do not prioritise the optimal internal stress state of the shell. To overcome the challenge of inefficient mesh discretisation in a form-finding process for shell or vault forms with boundary arches, Olivieri et al. (2024) propose an optimised and continuous form-finding approach based on Pucher's membrane equilibrium formulation. Considering four case studies, the authors define a compressed configuration with minimum principal stresses as vertical loads, plan shape and geometric constraints vary.

In the case of historic buildings, architectural and/or functional rearrangements can lead to critical seismic hazard issues that require careful assessment of the impact of structural modifications and the need for retrofit interventions. Meloni et al. (2024) consider the effect of new openings in masonry walls, accompanied by local reinforcements, on their behaviour under cyclic loading. They propose a Finite Element model that takes into account plasticity and stiffness degradation, calibrated using literature results from experiments on full-scale unreinforced rubble masonry walls subjected to cyclic shear loading. The fine-tuned model is used for numerical investigations of different configurations incorporating a new opening and a reinforcing steel frame.

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