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FAST-DYNAMIC RESPONSE AND FAILURE OF MASONRY STRUCTURES OF NON-STANDARD GEOMETRY SUBJECTED TO BLAST LOADS

Masonry structures are often characterized by non-standard geometries, consisting of arches, vaults, and domes. This is also the case for historical and monumental structures, which are often primary targets of accidental and deliberate explosions.

The main goal of this work is to shed light on the dynamic behavior and failure modes of monolithic and non-standard, curvilinear masonry geometries subjected to blast loading. This is, first, accomplished through simplified analytical tools and advanced numerical simulations relying on the Discrete Element Method (DEM). Then, a simplified macroscopic modeling approach, using the Finite Element Method (FEM), is presented as an engineering tool to be used in the investigation of complex, large masonry buildings, such as monuments.

In particular, new analytical, closed-form solutions for the rocking response and the overturning domain of slender, monolithic structures are derived and validated against existing experiments and detailed numerical simulations. Rocking mechanism is found to be predominant over sliding, up-lifting, and direct damage modes.

DEM is used to investigate the response of non-standard masonry structures, e.g. arches and vaults, and the influence of various mechanical parameters (e.g. dilatancy angle, tensile strength and cohesion of the masonry joints, and building blocks size). The approach allows considering the detailed mechanical and geometrical characteristics of masonry, as well as the inherent coupling between the in- and out-of-plane motion.

Relying on DEM numerical results, we develop a macroscopic FEM modeling approach, based on simplified upscaling techniques and the smeared cracking model, to make preliminary predictions of the structural response of masonry assets at large scale. The proposed, simplified model assumes isotropic behavior and allows taking into account the strain softening phenomenon.

With the aim of developing more accurate and detailed material models of the aforementioned simplified approach, a new class of Artificial Neural Networks (ANNs) is also proposed as a robust, thermodynamics-based, tool to derive constitutive models, at the material point level, in the framework of physics-based multiscale analyses. Thermodynamics-based Artificial Neural Networks (TANNs) are applied-and their superiority with the respect to classical ANNs approaches is proved-for the case of materials displaying softening behavior.

Finally, we propose new scaling laws for the response of masonry structures subjected to explosions. Our aim is to design future experimental, reduced-scale experiments, which are of paramount importance to further improve current understanding and corroborate the proposed models. Indeed, at present, experimental tests of masonry structures subjected to explosions are limited, compared to tests under different dynamic conditions, such as earthquakes.

Mots-clés: Masonry; Blast loads; Fast-dynamics; Discrete Element Method; Finite Element Method; Artificial Neural Networks; Scaling laws.

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