Seismic fragility of historical masonry constructions: A variational-based non-smooth contact dynamics formulation

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Abstract

Historical masonry constructions represent a valuable part of the architectural heritage, whose structural safety in seismic regions could be endangered by earthquakes. Ensuring their preservation thus requires a reliable assessment of their seismic vulnerability, which depends on accurately predicting their dynamic response under ground acceleration.
Due to the occurrence of impacts, i.e., of events producing velocity discontinuities, the rocking motion of block masonry structures represents a non-smooth dynamic problem. Following Housner's pioneering work on the rocking motion of a single rigid block (1), the dynamics of masonry structures has been extensively investigated using event-driven numerical schemes. However, these schemes are challenged by numerical issues arising from the need of precisely detecting the events in time by some root-finding procedures, such as a sub-stepping.
As an alternative, the attention is focused here on the Non-Smooth Contact Dynamics (NSCD) method (2), originally proposed as a time-stepping scheme to investigate the dynamic behavior of collections of rigid bodies. The fundamental idea of the method is to address a discrete version of the time-integrated version of the equations of motion. The resulting impulse-theorem format has the crucial advantage that, by interpreting the hard-contact laws between the bodies in a time-averaged sense and by introducing suitable contact gaps in the contact relationships, the need for a precise identification of the event times is circumvented and the solution can advance in time with a fixed time step.
Several applications of the NSCD method have proven its merit when considering historical masonry block structures modeled as systems of rigid blocks in unilateral and dry-frictional contact with each other (3–5). In (6), a variational-based NSCD approach has been proposed to investigate the dynamic behavior of 3D masonry block structures subject to seismic excitation. As a merit of the formulation, large-scale problems can be robustly and efficiently addressed thanks to the convex framework of the time-step optimization problem, specifically formulated as a second-order conic programming problem. By leveraging those computational potentialities and considering a broad database of natural earthquake records, a systematic and critical investigation of the seismic fragility of historical masonry constructions is presented, providing valuable engineering insights for their seismic preservation.
References

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