Diagonal compression of masonry panels : Identification of non-linear parameters via Digital Image Correlation

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Abstract

During seismic events, masonry walls are subjected to in-plane loadings, which predominantly induce compression along the wall diagonals. The ASTM-standardized diagonal compression test simulates these conditions on a square masonry panel to analyze failure mechanisms and determine its compressive strength. This method has been widely applied to study both unreinforced and reinforced masonry, facilitating direct comparisons of their strength under identical loading conditions. Traditionally, deformations along the vertical and horizontal diagonals are measured using Linear Variable Differential Transducers (LVDTs). This measurement approach may limit the accuracy of strain analyses in heterogeneous materials like masonry.

To address this limitation, Digital Image Correlation (DIC) has been increasingly adopted for measuring displacement fields, providing a contactless method for tracking displacement fields and crack development. Studies have demonstrated that DIC enhances insight into displacement fields, strain distribution, and crack propagation. In diagonal compression tests on unreinforced masonry elements, cracking typically occurs along the mortar joints, forming a characteristic staircase pattern. To observe these mechanisms in greater detail, multi-view DIC is used, namely, two cameras are positioned at an angle to capture the overall 3D kinematics of the specimen, while three additional cameras focus on key regions. Specifically, two cameras monitor the upper and lower boundary conditions, and a third focuses on the specimen center, where initial cracking is expected to initiate and subsequently propagate across the sample. This approach reduces uncertainties in the zoomed regions, allowing for a more precise observation of localized phenomena (1).

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Diagonal compression tests are simulated using the Finite Element Code Cast3M (https://www-cast3m.cea.fr/). Two types of models are considered in this study, both are based on an isotropic damage model that incorporates friction and unilateral effects, namely, a macroscale law with a detailed representation of block and mortar elements using the nonlinear Vassaux et al. model (2), and a volumetric homogenized nonlinear model (3). Initial simulation results show that both models effectively replicate the expected behavior of a masonry panel. The objective, therefore, is to identify the parameters of these models

throughout the test. While extensive research has been conducted on diagonal compression tests, only few studies have considered full-field measurement techniques, such as DIC with the identification of nonlinear parameters. Transitioning from measured data to identifying meaningful physical parameters requires careful consideration of numerous variables. A recommended approach is to begin by virtually designing the experiment (4). This process involves initially positioning cameras in areas of interest, followed by conducting virtual tests in Blender (https://www.blender.org/) to simulate experimental conditions that closely approximate reality. In this virtual setup, a fully parameterized image correlation environment is created, integrating nonlinear Finite Element simulations with animation tools. Sensitivity analyses and uncertainty quantifications are then conducted to ensure that model parameters can be precisely calibrated prior to the actual experimental campaign.

The study proceeds with a description of the experimental campaign on individual block and mortar elements, followed by details of the diagonal compression test setup. Results, including force-displacement curves and post-processing of multi-view DIC data are then presented. Employing a Finite Element Model Updating (FEMU) approach, the objective is to use full-field displacement data from DIC to accurately define the boundary conditions within the simulations. By integrating this data with force measurements, the study seeks to identify and calibrate the nonlinear parameters of the masonry model effectively.

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