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Two-dimensional computational framework of meso-scale rigid and line interface elements for masonry structures

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ABSTRACT

In this paper, rigid elements along with nonlinear line interface elements are utilized to model masonry structures. The modeling approach focuses on two dimensions (2D) whereby the in-plane behavior of components is represented by rigid elements and nonlinear interfaces instead of modeling by a traditional finite element method. In this approach, the component will be allowed to crack in predefined paths which have more likelihood for propagation. The paper discusses the model derivation and implementation. Moreover, the mesh sensitivity of this method is assessed by using different mesh sizes, and it is shown that the model captures response obtained by the experimental tests. The traditional finite element method is indeed capable of predicting the behavior of large scale masonry component, but the computational time is very high. In this study it has been shown that using rigid elements along with nonlinear line interfaces leads to a reduced number of degrees-of-freedom, which consequently reduces the computational time. The material model is implemented in a user-defined subroutine that is compiled with DIANA. The algorithms and material models are validated with well-documented experimental studies, and results clearly show the capabilities of the proposed procedures.

1. Introduction

Masonry structures have been used for centuries in building construction and with all the knowledge base and complexity of the behavior of masonry components, masonry buildings are still in demand. Whether the masonry structure constitutes the whole structural system or used as an infill in a concrete or steel frame, the complex failure modes often pose a significant challenge for computational models. Although novel structural technologies are often utilized in new buildings, masonry components are not omitted from structural usage and masonry components are still usable especially for infill walls. These masonry components have an important contribution in the behavior of the buildings in earthquakes.

Simulating the behavior of masonry structures is one of the most complex problems in computational mechanics; especially because of sliding of the bricks relative to each other, and consequently, formation of new contacts and stress concentration at the corner of bricks. In order to simplify the computational methods while accurately modeling masonry, different ideas have been implemented both for the in-plane and out-of-plane behavior of masonry walls [1–5]; however, the use of traditional finite element (FE) methods requires extensive computational resources and significant processing time.

Different types of computational methods have been presented to assess the behavior of masonry structures under static and dynamic loading. These computational methods are categorized in three groups – namely, micro-, macro-, and meso-scale analysis. In micro-scale analysis the accurate behavior of structure is important and exact path of cracks in the nonlinear behavior of components are often of great interest. In the macro- and meso-scale analysis of components the global behavior of components is important, not the detailed behavior of each component. Although there exist gaps in the knowledge in the micro-scale approach, the prediction of these types of analysis is relatively acceptable. The main problem in micro-scale analysis is the significant computational demand that will be required to model large scale structures. Therefore, for large structures, it is more reasonable to use meso- and macro-scale analysis.

Analysis methods that are based on meso- and macro-scale approaches, utilize some simplifications to improve the computational efficiency. However, it is important to note that the accuracy level to, some extent, will be impaired by these simplifications. In this paper, some simplification has been performed to reduce the computational time. Then the results of the numerical simulations were compared with experimental results to validate the robustness and accuracy of the proposed method. Finally by using different sizes of mesh, the issues pertinent to mesh sensitivity were explored.

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