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Review article

Compression behavior of confined concrete masonry boundary elements

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ABSTRACT

The seismic performance of reinforced masonry (RM) walls can be enhanced by integrating confined boundary elements at the end zones of the wall. The evaluation of the compression behavior of the boundary elements is essential to the reliable assessment of displacement ductility and the seismic performance of the walls. Complementary to the experimental evaluation of the compression behavior, finite element numerical simulations are particularly useful in assessing the influence and sensitivity of various design parameters. In this study, experimental and numerical investigations are conducted to evaluate the compression stress-strain behavior of confined C-shaped reinforced concrete masonry block boundary elements (C-RMBEs). Compression tests are conducted on 16 full-scale confined C-RMBEs with different configurations of confinement reinforcement. A finite element modeling (FEM) procedure using the ABAQUS software is employed to simulate the compression behavior of a C-RMBE. The FEM procedure is validated with experimental results on a full-scale confined C-RMBE. Comparative compression stress-strain curves and damage progression are presented and discussed. The study shows the significance of the confinement reinforcement in the improvement of the compression strain capacity of the C-RMBE. Moreover, the proposed FEM procedure provides a good approximation of the compression stress-strain behavior in the elastic and inelastic regions and captures the influence of the confinement reinforcement ratio on the compression response of the C-RMBE.

Contents

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1. Introduction

Reinforced masonry (RM) shear walls are commonly used in medium-rise and high-rise masonry buildings as the lateral load resisting system to provide the lateral strength, stiffness and energy dissipation capacity required to resist seismic loading. RM walls are expected to exhibit an inelastic response during severe ground motions. Furthermore, the end zones of the RM wall will be subjected to cycles of tension and compression, arising from seismic overturning moments, as seen in Fig. 1. Therefore, ductile detailing of the horizontal and vertical reinforcements, especially at the end zones of the walls (toe region), is required. Typical rectangular RM walls would have only a single vertical reinforcement bar placed in the masonry block cells without violating the maximum reinforcement and spacing requirements specified in masonry design standards (e.g., MSJC-2013 [1] and CSA-S304 [2]). Consequently, this single bar disallows the placement of confinement hoops at the end zones of the wall, which are subjected to high inelastic strains during earthquake-induced cyclic loading (Fig. 1a). On the other hand, adding boundary elements at the wall ends allows the placement of at least four vertical reinforcing bars enclosed by hoops (Fig. 1b and c), thus enhancing the wall performance by providing core confinement to the wall ends through the reinforcement cage. As such, RM walls constructed with boundary elements at the end zones ensure stability under high compression loading and demonstrate an enhanced curvature ductility for the wall. The compression strain capacity can be increased using confinement reinforcement [3]. Therefore, compared to a rectangular wall, adding a confined boundary element will increase the width of the RM wall end. As such, the sustainable compression strain will be increased, and the compression zone depth will be decreased [4]. Hence, adding boundary elements will enhance the curvature capacity of the wall cross-section.

The use of ductile reinforced concrete masonry shear walls with column-like boundary elements has been introduced in recent North American codes and standards for the design of masonry structures to improve the ductility capacity of walls. The US Building Code Requirements and Specifications for Masonry Structures (MSJC, 2013) [1] allows the use of confined boundary elements and only imposes some geometrical rules. The code requires testing to be conducted to verify that the detailing provided is capable of developing a strain capacity in the boundary element that would be in excess of the maximum imposed strain. The most recent Canadian Standard for the Design of Masonry Structures (CSA S304, 2014) [2] also allows for the use of confined boundary elements. However, this design standard does not provide a correlation between specific detailing for confinement reinforcement and the corresponding improvement in the strain capacity and required testing and analysis to satisfy the level of required strain. Experimental studies that quantify the compression strain ductility of concrete masonry boundary elements are scarce in the literature.

The evaluation of the compression behavior of the confined end zones of an RM wall is a key component in the assessment of the curvature and displacement ductility capacities of RM walls. Recent experimental investigations on RM shear walls with confined boundary elements (e.g., [5,6]) have concluded that the geometry of the boundary element allows for more than one layer of vertical reinforcement enclosed by hoops, which delays or prevents buckling of the vertical reinforcement, confines the compression zone, and limits the damage at the ends of the RM wall. Integrating the boundary element enhances the seismic performance of RM walls by improving the compression strain capacity

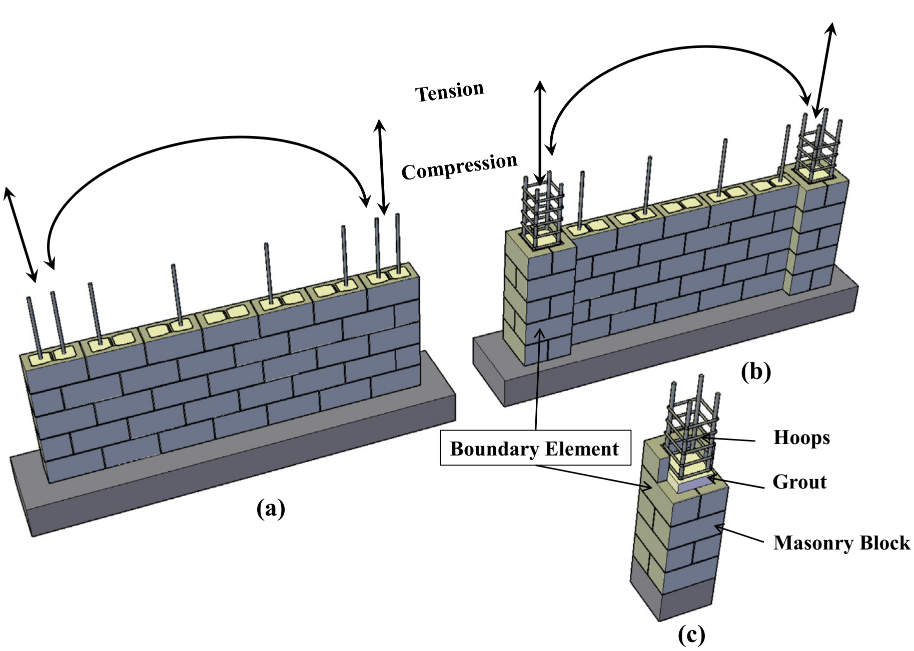

Fig. 1. Schematics of a masonry building: (a) Rectangular RM wall; (b) RM wall connected with boundary elements; and (c) RM boundary element.