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Influence of confinement reinforcement on the compression stress–strain of grouted reinforced concrete block masonry boundary elements

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ABSTRACT

Reinforced masonry (RM) shear walls are widely used in medium- to high-rise masonry buildings as part of the lateral force resisting system to provide the lateral strength, stiffness and energy dissipation capacity required to resist lateral loads arising from earthquakes or wind. In the past few decades, there has been considerable advancement in the design of RM shear walls for new construction with variable types of confinement of the compressed boundaries of the wall for increasing ductility level. Recent codes and standards for design of masonry structures are introducing the use of Ductile Reinforced Masonry (DRM) Shear Walls with column-like boundary elements for the improvement of the ductility capacity of the walls. A key component in the evaluation of the ductility capacity of shear walls is evaluating the compressive response of their boundary elements. This paper presents an experimental and analytical investigation on the compression stress–strain behavior of fully grouted unconfined and confined reinforced concrete block masonry boundary elements. Full scale boundary elements were constructed and tested under concentric axial compression. An analytical stress–strain model was proposed that can be used in the design and assessment of DRM walls with boundary elements.

1. Introduction

Moderately ductile reinforced masonry (RM) shear walls are considered an economical seismic force resisting system for masonry buildings in low- to moderate-seismicity zones. However, in regions with high seismicity, an economical RM shear wall system necessitates achieving higher ductility levels. Because RM shear walls are expected to undergo high inelastic response during severe ground motions, special consideration must be given to detailing of the horizontal and vertical reinforcement, especially at the ends of such walls in order to resist the high curvature ductility demands. Confinement of the wall end section is an efficient approach to enhance the curvature ductility capacity in RM shear walls. A key component in the evaluation of the ductility capacity of RM walls is the evaluation of compression stress–strain behavior of the confined ends. A number of different methods of confinement have been studied for application to masonry, including providing steel plates and seismic combs in the bed joints, steel rings and spirals around vertical reinforcing bars within the block cells and more recently the addition of confined boundary elements (Fig. 1).

Priestley and Elder [2] investigated the compressive stress–strain characteristics of reinforced concrete masonry containing steel confinement plates placed in the mortar bed joints. The researchers concluded that the confinement plates produced a more gradual failure and improved the ductility of the concrete masonry prisms. Hart et al. [3] studied confinement reinforcement in concrete masonry prisms using seven different types of steel confinement reinforcement including Priestley plates, ties, closed wire mesh, seismic combs, steel ring cages, spirals, and spiral cages. The researchers concluded that confinement improved the displacement ductility and decreased the slope of the post-peak portion of the compressive stress–strain curve. Shing et al. [5] presented experimental work with prisms and walls demonstrating that ring, comb and spiral steel confinement reinforcement within the grouted cells of masonry units was effective in increasing the ultimate strain of the descending branch in masonry. Dhanasekar and Shrive [7] employed welded wire steel meshes to unreinforced masonry prisms which resulted in increased strength and enhanced post-peak behavior. Laursen and Ingham [6] integrated steel confinement plates for post-tensioned concrete masonry walls. More recently, Shedid et al. [1] and Banting and El-Dakhakhni [8] integrated confined boundary elements in the form of thickened wall ends that contained a double row of vertical reinforcement with closed hoops to improve the ductility and drift capacity of RM shear walls. Cyrier [9] investigated the ductility capacity of shear walls with integrated reinforced concrete boundary elements.

Recent codes and standards for design of masonry structures are introducing the use of Ductile Reinforced Masonry (DRM) Shear Walls with column-like boundary elements for the improvement of the ductility capacity of the walls. The 2013 Building Code Requirements and Specifications for Masonry Structures [10] allows the use of confined

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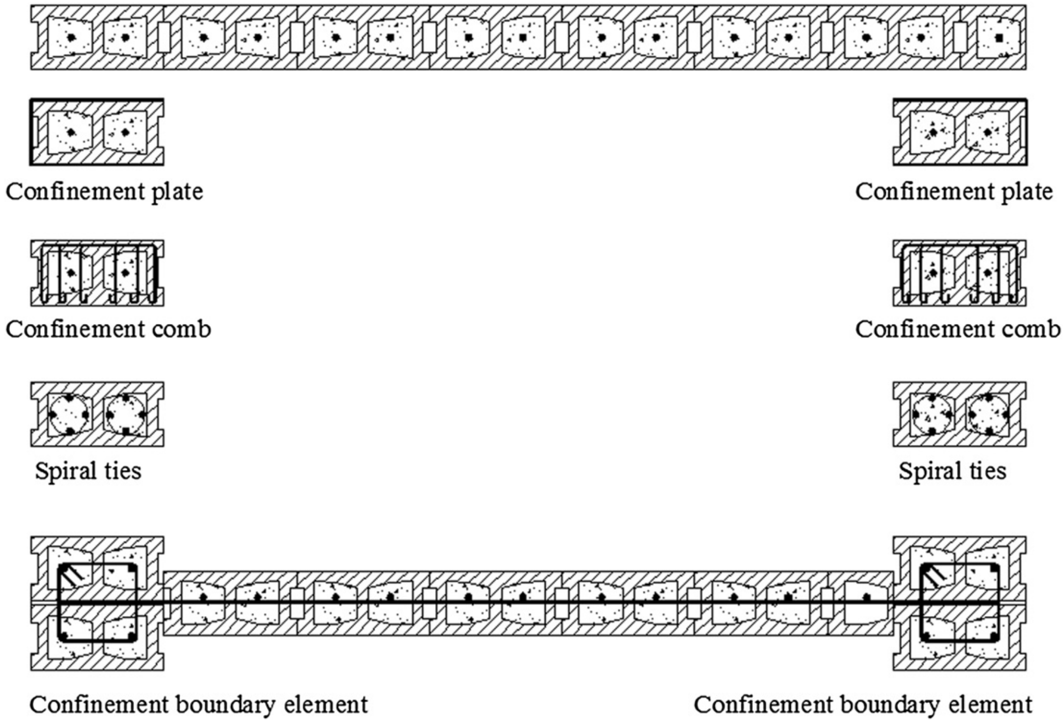

Fig. 1. Examples of confinement methods of reinforced masonry construction.

boundary elements by only imposing some geometrical rules but provides no guidelines for reinforcement detailing and requires that testing be conducted to verify that the detailing provided shall be 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 S304-14 [12] also allows the use of confined boundary elements with prescriptive detailing requirements. However, these detailing requirements need more experimental verifications for reliable application to RM shear walls. Such experimental studies are scarce in the literature.

This paper presents an experimental and analytical investigation on the compression stress–strain behavior of confined reinforced concrete block masonry boundary elements. Axial compression tests are conducted on 17 full-scale unconfined and confined boundary element columns with variable confinement ratios. A simplified analytical stress–strain model is proposed for unconfined and confined boundary

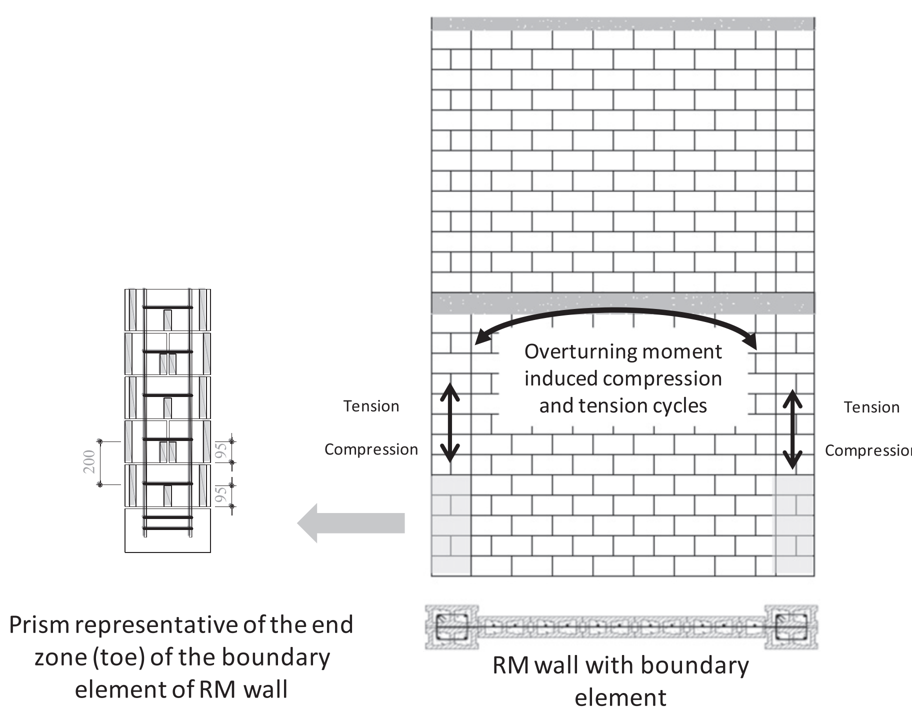

Fig. 2. Illustration of a RM wall with confined boundary elements and the tested prism that is representative of the end zone (toe) of the wall.