Engineering Structures 33 (2011) 1377–1389

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Parametrical study of masonry walls subjected to in-plane loading through numerical modeling

Vladimir G. Haach [a,*], Graça Vasconcelos [b], Paulo B. Lourenço [b]

[a] School of Engineering of São Carlos, University of São Paulo, Department of Structures, Av. Trabalhador Saocarlense, 400, 13566-590, São Carlos-SP, Brazil

[b] ISISE, Department of Civil Engineering, University of Minho, Azurém, 4800-058 Guimarães, Portugal

ARTICLE INFO

Article history:
Received 26 September 2009
Received in revised form
15 January 2011
Accepted 17 January 2011
Available online 17 February 2011

Keywords:
Shear
In-plane behavior
Numerical analysis
Parametrical analysis
Masonry walls

ABSTRACT

This paper deals with the numerical assessment of the influence of parameters such as pre-compression level, aspect ratio, vertical and horizontal reinforcement ratios and boundary conditions on the lateral strength of masonry walls under in-plane loading. The numerical study is performed through the software DIANA® based on the Finite Element Method. The validation of the numerical model is carried out from a database of available experimental results on masonry walls tested under cyclic lateral loading. Numerical results revealed that boundary conditions play a central role on the lateral behavior of masonry walls under in-plane loading and determine the influence of level of pre-compression as well as the reinforcement ratio on the wall strength. The lateral capacity of walls decreases with the increase of aspect ratio and with the decrease of pre-compression. Vertical steel bars appear to have almost no influence in the shear strength of masonry walls and horizontal reinforcement only increases the lateral strength of masonry walls if the shear response of the walls is determinant for failure, which is directly related to the boundary conditions.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Masonry is an excellent structural system when compressive stresses control the ultimate response. Though, it is well known that the low tensile strength of masonry might lead to an inadequate response when lateral forces reach high values. Reinforcement appears to be a solution to increase the tensile strength and thus to improve the mechanical behaviour of masonry under lateral loading.

Masonry shear walls exhibit a complex structural behavior since masonry is a composite material with anisotropic behavior and shear walls are subjected to a bi-axial stress state. Several experimental studies on masonry shear walls have been carried out in order to evaluate and better understand their behavior under seismic loads [1–17]. However, a number of drawbacks occurs in experimental analysis since the test setups are usually complex (the real boundary conditions are hard to be known and represented), experimental setups are generally expensive, and results are sometimes scarce and limited to the conditions in which they have been obtained. Complementarily to experimental analysis, numerical modeling of masonry walls under horizontal loads contributes to increasing knowledge about their behavior, once it is validated variations of parameters that can influence the in-plane behavior can be analyzed.

There are basically two numerical approaches that have been adopted by researchers to describe the mechanical behavior of masonry: macro-modeling and micro-modeling [18,19]. In macro-modeling, masonry is considered as a composite and homogeneous material while in case of micro-modeling masonry is considered as a discontinuous assembly of units connected by joints simulated by appropriate constitutive laws.

For the macro-modeling approach, Lourenço et al. [18] presented a failure criterion for masonry based on an extension of conventional formulations for isotropic quasi-brittle materials to describe the orthotropic behavior. Another macro-model was developed by El-Dakhakhni et al. [20] to predict the in-plane behavior of concrete masonry. It is a multilaminate model where the masonry assemblage is replaced by an equivalent material which consists of a homogenous medium intersected by two sets of planes of weakness along the head and bed joints. Related to macro-modeling there are still other models in the literature [21,22].

For the micro-modeling approach, Lourenço and Rots [19] proposed an interface cap model based on modern plasticity concepts, capable of capturing all masonry failure mechanisms, namely tensile cracking, frictional slip and crushing along interfaces. Similar cap models were proposed by Sutcliffe et al. [23] and Chaimoon and Attard [24], with the consideration of a linear compression cap model, which seems to be an interesting simplification that can be applied in complex analysis of masonry structures.

Numerical modeling of masonry structures can effectively be useful for a better understanding of the mechanical behavior

* Corresponding author. Tel.: +55 16 33739455; fax: +55 16 33739482.
E-mail addresses: vghaach@sc.usp.br (V.G. Haach), graca@civil.uminho.pt (G. Vasconcelos), pbl@civil.uminho.pt (P.B. Lourenço).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.01.015