Contents lists available at SciVerse ScienceDirect

Engineering Structures

Numerical analysis of concrete block masonry beams under three point bending

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

[a] *School of Engineering of Sao Carlos, University of Sao 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

ABSTRACT

A parametrical study of masonry beams through numerical modelling has been performed in order to better understand the mechanical behaviour of these elements. Boundary conditions, geometry and reinforcement ratios are the main parameters analysed in this study. The numerical simulation is performed with DIANA® software, based on the Finite Element Method. A comparison between numerical and experimental results is presented in order to validate the simulation. In conclusion, it was verified that the behaviour of masonry beams is greatly affected by the boundary conditions and geometry, as expected. With regard to reinforcement, it was noted that horizontal reinforcement increases the flexural strength of beams. On the other hand, variation in horizontal reinforcement had no influence on the shear resistance of masonry beams. Finally, the combination of horizontal and vertical reinforcements is shown to enhance the flexural and shear behaviour of masonry beams.

1. Introduction

In masonry buildings, masonry beams are the structural elements responsible for the distribution of vertical loads over openings and they are subjected to shear and flexure stresses. According to several authors, their design can be performed using the ultimate strength design method similar to that used for reinforced concrete beams [1–4]. Nevertheless, the usual presence of cores in units and the anisotropy of masonry, generated mainly by mortar joints which are planes of weakness, make the behaviour of masonry beams more complex. In spite of Eurocode 6, [5] provides the design of masonry beams under flexure and shear, by applying classic formulations used for homogeneous materials; very limited experimental and numerical information is available in the literature about the resisting mechanisms characterising the behaviour of masonry beams under in-plane shear and bending.

Based on experimental research carried out on masonry beams with variable depth to length ratios and variable tensile reinforcement ratios, Khalaf et al. [1] confirmed the assumption that plane sections remain plane during bending and obtained an ultimate compressive strain for masonry of about 0.003. Truss type reinforcement in bed joints was used by Limón et al. [6] in brick masonry beams (span to depth ratio equal to 4.5), which analysed the influence of the depth of the neutral axis, the quantity of reinforcement and the overlap of bars. By comparing the experimental and analytical results on the flexural strength,

it was found that diagonal bars appear to contribute to the flexural resistance of brick masonry beams. According to Jang and Hart [7] and Adell et al. [8], uniform distribution of longitudinal reinforcement leads to the increasing of shear resistance by dowel action. Another important aspect regarding a section in bending is its compressive strength, which can play a significant role in the resisting moment [9]. Note that in the case of masonry beams, compressive stresses act in the direction parallel to the bed joints.

Besides experimental analysis, numerical modelling of masonry beams can provide additional information on flexural and shear behaviour by considering the effect on some parameters. Variables such as geometry, boundary conditions and variation of vertical and horizontal reinforcements can be easily evaluated after the appropriate validation of the numerical model.

In recent years, some numerical approaches have been developed, from which an enhanced understanding of the mechanical behaviour of masonry has been achieved. There are two numerical approaches that have been adopted by researchers for numerical analysis of masonry structures, namely macro-modelling and micro-modelling. It is well-known that both approaches reproduce satisfactorily the behaviour of masonry structures, having specific and particular applications. In the macro-modelling approach, masonry is considered as a homogeneous material and the constitutive models represent the average material properties of masonry as a composite material. Several studies have been developed for the derivation of the homogenised elastic properties of the smeared masonry continuum [10,11] and for the representation of the inelastic behaviour of masonry [12–16].

In the case of micro-modelling, the masonry material is considered as a discontinuous assembly of units connected by