Composites: Part B 42 (2011) 692–704

Contents lists available at ScienceDirect

Composites: Part B

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

Masonry columns confined by composite materials: Experimental investigation

Ciro Faella [a], Enzo Martinelli [a,*], Sergio Paciello [a], Gianpietro Camorani [a], Maria Antonietta Aiello [b], Francesco Micelli [b], Emidio Nigro [c]

[a] Department of Civil Engineering, University of Salerno, via Ponte don Melillo, 84084 Fisciano, SA, Italy
[b] Department of Innovation Engineering, University of Salento, Via per Monteroni, 73100 Lecce, Italy
[c] Department of Structural Engineering, University of Naples Federico II, via Claudio 21, 80125 Naples, Italy

ARTICLE INFO

Article history:
Received 16 June 2010
Received in revised form 18 January 2011
Accepted 7 February 2011
Available online 19 February 2011

Keywords:
A. Carbon fibre
A. Glass fibres
B. Strength
D. Mechanical testing
Masonry

ABSTRACT

The present paper deals with the mechanical behaviour of masonry columns confined by using fibre-reinforced polymer (FRP) composites. In particular, it presents the key results of a wide experimental program jointly carried out at the Laboratories of the Universities of Salerno and Salento (Italy).

Several kinds of masonry, made out of either natural or artificial bricks having different dimensions, have been tested in this experimental programme. A total number of 54 column specimens have been built and tested in pure compression.

Moreover, several composite systems (mainly based on glass fibres) have been utilised as confining device by applying a variable number of layers that allow to develop different levels of lateral pressure.

The present paper reports the complete information about the geometric and mechanical parameters related to the tested specimens as well as the key aspects of the structural behaviour observed during the compression tests. In particular, the maximum load levels and the corresponding axial stresses and (average) strains are clearly reported.

Finally, the main differences in terms of structural response due to the behaviour of the various materials utilised for both masonry and external wrapping are highlighted. Moreover, the same experimental results, along with further experimental data already available in the scientific literature, will be quantitatively analysed in a companion paper with the aim of calibrating a design formula for determining the axial strength of masonry columns confined by FRP.

1. Introduction

A significant part of the existing buildings in Europe as well as elsewhere in the World are made out of masonry. Beyond the general principles formulated in the classical technical theories (i.e. [1–4]), global analysis of masonry structures, especially in the widely common case of earthquake-induced actions, is still an open issue. Both practical rules for assessing the performance of masonry structures and design-oriented formulae for dimensioning traditional strengthening interventions aimed at improving their capacity are collected in [5]. They generally belong to the educational background of structural engineers.

However, rather innovative techniques are available nowadays for structural strengthening of existing members and structures: fibre-reinforced polymers (FRP) as well as other composite materials are among those innovative techniques ([6,7]) that received an increasing interest in the past decades.

In particular, wrapping either reinforced concrete or masonry columns with FRP sheets is one of the most common strengthening techniques for enhancing their overall performance under axial loads. Although several analytical proposals are currently available for evaluating the so-called "confinement" effect (whose theoretical foundations date back to [8]) in terms of both strength and ductility for concrete columns (for a comparative study see [9]), no analytical formulation has been established so far for determining the confinement effect induced by FRP sheets on masonry columns. The huge variability of the mechanical properties of masonry is one of the key reasons for this delay in defining sound design rules and formulae for confined masonry members. Such a variability is mainly induced by the nature of the brick elements, the quality of the mortar layer, the dimension of the member and the texture of the masonry brickwork as a whole. Nevertheless, the experimental results, currently available in the scientific literature, are mostly focused on clay-brick masonry columns ([10–12]). Few studies are currently available for stone masonry columns [13–15].

The present paper is firstly aimed at providing the scientific community with a series of experimental results carried out on segments of masonry columns confined with different amount of

* Corresponding author. Tel.: +39 089 96 4098; fax: +39 089 96 4045.
E-mail address: e.martinelli@unisa.it (E. Martinelli).

1359-8368/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compositesb.2011.02.001

composite materials. The experimental campaign, carried out within the framework of a joint research activity at the Structural Laboratories at the Universities of Salerno and Salento (Italy), covers a wide range in terms of experimental variables. In particular, masonry columns made out of natural stones have been tested as well as similar specimens built by using clay bricks. The former ones have been chosen considering the most common materials utilised in existing buildings in the regions of Southern Italy. Anyway the considered masonry specimens can be assumed as representative of a wide class of natural building materials which are common throughout the Mediterranean Basin as a whole.

On the contrary, clay bricks are widely utilised all over Europe and other countries. Consequently, the types of masonry considered in the present experimental campaign cover a really broad range of materials. Furthermore, the specimens are realised by considering two different shapes for the cross section and variable dimensions for their geometry. The choice of variable features for both the brick texture and the rounding fillet radius of the edges in confined columns further broaden the range of variation of the tested parameters and, consequently, the significance of the experimental programme.

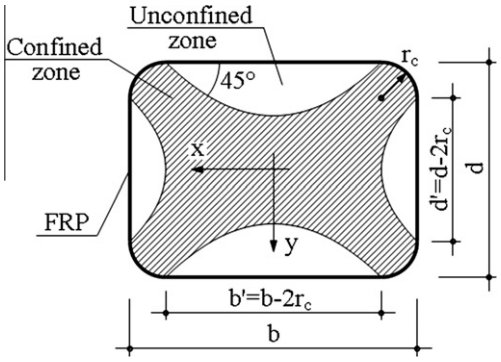

Fig. 1. Definition of the geometrical parameters of the cross section and derivation of the effective confined area in rectangular columns.

Glass fibre composites (GFRP) were mostly used for wrapping the tested specimens, carbon fibres (CFRP) were also applied. Several layers of fibres are considered in the various tests in order to obtain a reasonably wide variation of the lateral pressure due to the different amount of elastic reinforcement.

After an in-depth report of the geometric and mechanical properties characterising the above specimens, the paper reports the results of the tests carried out within the framework of the mentioned experimental campaign. The key features of the observed structural behaviour are highlighted also by comparing the different groups of specimens. Finally, the experimental results in terms of maximum strength will be compared with the predictions of the corresponding formula provided by the National Research Council (CNR) Italian Guidelines [16], recently issued for addressing the use of FRP material as external strengthening of both concrete and masonry members. Further analytical calibration of a more refined design formula based on both the experimental results presented in this work and the others currently available within the scientific literature will be proposed within a companion paper [17].

2. Description of the experimental campaign

The experimental campaign reported in the present paper consisted of 54 masonry specimens tested in compression and characterised by having different dimensions, brick nature and texture, type of FRP and number of external layers. A generic rectangular cross section of a confined column is represented in Fig. 1 emphasising its key geometrical properties. The figure shows the concept of "effective" confined area, namely, the part of the cross section which can be really considered under the confinement action in columns with rectangular cross section. According to this model it is defined by four parabolic branches, starting from either the section edges or the end of the round fillets, having a slope of 45°. The radius r_c of such fillets plays a double role and often controls the behaviour in compression of confined columns. On the one hand, it affects the effective area, while on the other hand it controls the possible stress concentrations in fibres around

(a) test-setup (University of Salerno) *(b) test setup (University of Salento)*

Fig. 2. Compression tests on masonry columns: test setup.