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Proposal of an innovative solution for partition walls: Mechanical, thermal and acoustic validation

G. Vasconcelos [a,*], P.B. Lourenço [a,1], P. Mendonça [b,1], A. Camões [b,1], R. Mateus [b,1], L. Bragança [b,1], A.G. Brito [c,2], E. Poletti [a,1]

[a] ISISE, Department of Civil Engineering, University of Minho, Azurém, P-4800-058 Guimarães, Portugal
[b] C-TAC, Department of Civil Engineering, University of Minho, Azurém, P-4800-058 Guimarães, Portugal
[c] Department of Polymer Engineering, University of Minho, Azurém, P-4800-058 Guimarães, Portugal

HIGHLIGHTS

- The composite blocks were produced with a mixture of three distinct by-products.
- The composite blocks were designed to allow the placement of infra-structures.
- The composite blocks present a very ductile behaviour under compression.
- The partition wall presents a ductile behaviour under distinct loading conditions.
- The thermal performance of the proposed partition walls is very good.

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ABSTRACT

Nowadays, there is an increasing need for alternative construction technologies that allow, among others, reducing construction wastes and energy consumption during the buildings' life-cycle. In this context, this paper presents results of a research project which goal is to develop an innovative solution for partition walls. This solution is based on a masonry block made of an eco-efficient new composite material. The composite material used in the production of the blocks results from the combination of three industrial by-products, namely: flue-gas desulfurization gypsum; granulated cork; and textile fibers resulting from the tyre recycling process. Besides the raw materials, the innovation of the solution results also from the new design of the block, whose shape enables the positioning of the infra-structures during the assembling of the indoor wall.

In this paper, details of the design process of the block and both the optimization of the composition of the material and construction technology are provided. The validation of the partition wall solution in the point of view of mechanical, thermal and acoustic performance was also carried out.

From the results obtained, it is possible to conclude that the solution fulfils all the requirements of structural stability adequate for this type of wall. In terms of thermal performance, the proposed solution presents very good behaviour, being the acoustic performance slightly lower than the traditional solution.

1. Introduction

In Portugal, the construction of partition walls in residential and commercial buildings is still dominated by solutions based on hollow brick masonry units, mainly with horizontal perforation, even if some evolution for brick masonry with vertical perforation has been recorded. The use of the latter solution for brick masonry units is essentially associated with the aim of using these units for both structural and non-structural purposes with improved thermal insulation properties [1]. Other solutions, such as lightweight concrete blocks or gypsum blocks, were scarcely used in Portugal in the past for partition walls, even if they have been used in many other European countries. Reasoning for this is that the Portuguese construction market is much conservative and therefore some resistance is found in relation to innovative and new construction materials and construction solutions. With respect to lightweight construction solutions, the lack of acceptance is also due to the fact that, associated with a low thermal and acoustic mass, there are usually functional performance related problems.

* Corresponding author. Tel.: +351 253 510 200; fax: +351 253 510 217.
E-mail address: graca@civil.uminho.pt (G. Vasconcelos).
[1] Tel.: +351 253 510 200; fax: +351 253 510 217.
[2] Tel.: +351 253 510 320; fax: +351 253 510 339.

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These problems demand some specific strategies to implement on temperate climates, such as in the case of Portugal [2,3].

Only recently, the construction market has been given clear signs for the systematic use of lightweight partition solutions, such as drywalls. Besides the weight, the drywalls have the advantage of making the incorporation of the installations easier, contrarily to the usual brick masonry walls, in which grooves must be made to include electrical, communication and hydraulic installations. The reduction of the waste during the construction phase represents a significant advantage under the economical and environmental point of views as it eliminates or substantially reduces the transportation costs of wastes and contributes for lower accumulation of wastes in sanitary landfills. In fact, the construction market is responsible for 50% of the total wastes accumulated in landfills, for the production of 30% of the total CO_2 emissions and for the 40% of the total energy consumption during the buildings operation. The environmental impacts resulting from the production of wastes and energy consumption together with the increasing problems with environmental changes are in the basis of most of the R&D efforts that the scientific community is developing to find alternative and more sustainable construction solutions.

A more sustainable construction can be achieved mainly from the reduction of energy consumption during the operation of the buildings. Additionally, the use of materials with low-embodied energy is other design principle that can result in lower building life-cycle impacts. For instance, this principle can be archived through the use of alternative raw materials such as industrial by-products. With this respect, several studies reporting the use of recycled materials of industrial by-products in mortar and concrete are available in literature. Most of them are related with the use of by-products as aggregates or the use of alternative binders to the Portland cement, which allows reducing the amount of needed cement and the corresponding impact on the CO_2 emissions [4–6]. An example of the introduction of more sustainable raw materials in mortars is the use of gypsum and cork for applications in construction [7]. In this work, good compatibility between gypsum and cork was recorded. Nevertheless, the mechanical properties can be improved by the addition of glass fibers. This composite material has been used in pre-fabricated elements for partition walls [8]. The granulated cork was also used in the past in polymeric mortars aiming at obtaining a more durable material and with higher ductility relatively to conventional mortars [9]. It can be also used as aggregate in lightweight concretes for non-structural applications [10–12].

The use of natural gypsum is widely used in the construction as plaster or binder, but it is possible to use gypsum resulting from other sources such as red gypsum [13] and flue-gas desulfurization gypsum [14,15].

This work presents and discusses the results of an experimental campaign designed for the assessment of the mechanical, thermal and acoustic performances of a solution for partition walls based on blocks produced from a composite material that results from the combination of three industrial by-products, namely: flue-gas desulfurization gypsum; granulated cork; and textile fibers resulting from the tyre recycling process. The use of these three by-products resulted from the aim of different industries to value their by-products, until the moment without any valuable direct or even indirect application. The flue-gas desulfurization gypsum comes from a Portuguese thermoelectric power station, the granulated cork comes from cork industry that produces black agglomerate cork boards and the textile fibers were provided by a company dedicated to the tyre recycling process.

Besides the presentation of the geometry and shape of the blocks, some details about the materials and construction technology of the partition walls are provided. The mechanical validation of the construction solution encompasses the mechanical characterization of the blocks and masonry assemblages submitted to different loading configurations, namely uniaxial compressive and flexural tests. The mechanical validation is completed by considering impact loading and eccentric compressive loading. Finally, the functional performance of the innovative partition wall is evaluated based on thermal and acoustic tests made in a test cell especially designed for this typology of tests.

2. Composite blocks

2.1. Shape and geometry

Aiming at proposing an innovative solution for non-loadbearing partitions walls, composite blocks with an innovative shape and geometry were designed. The definition of the geometry was based on two main ideas, namely: (1) to obtain a block that results in an easy construction technology and decreased construction times and (2) to make possible the installation of infra-structures during construction of the walls and therefore to reduce the production of wastes. In fact, even if in case of partition walls the reduction on the compressive strength of masonry due to the opening of grooves is not a real issue [16], it results in a huge amount of wastes that need to be removed from the construction site, which implies additional costs and environmental impacts.

The block has a rectangular shape and is composed of two equal halves (Fig. 1), that are connected through and adhesive material to form a complete block with vertical and horizontal perforations. As presented in Fig. 1b the block is thus adequate to an efficient integration of the infra-structures.

Aiming at having a block with a weight not higher than 16 kg (8 kg per half block), it was decided to consider for the length a value of 600 mm, for the height a value of 300 mm and a total thickness of 140 mm, resulting from the connection of the two 70 mm thick halves with. It should be noticed that the weight is an ergonomic feature that can influence the construction times. For this reason, one of the aims of this project was to reduce the weight of masonry units in order that they can be easily handled by the workmanship in the construction site.

Each block consists of an association of two halves with distinct shapes: (1) an external part with rectangular shape of a constant thickness of 20 mm and (2) an internal part of variable thickness (with a maximum thickness of 50 mm) formed by curvilinear concave and convex shapes aiming at defining the horizontal and vertical internal perforation of the blocks (Fig. 1b). The concave shapes aim also at reinforcing the connection between the two halves and to confer a monolithic behaviour after the connection of both halves. Besides the concave parts, the connection between the half blocks is also made along the continuum perimeter (Fig. 1b). The connection between each half should be made by using an adhesive material that ensures an adequate compressive and flexural behaviour to the blocks. Additional polymeric pieces can be also used during the construction phase to enhance the connection between the half blocks before the hardening of the adhesive material during the construction (Fig. 2). Along the perimeter the block has chamfered hook and eye notches, being continuous at the vertical joint and discontinuous at the bed joints. The horizontal discontinuity is justified by the aim of making the introduction of the infra-structures easier. The notches are important to make the construction of the walls easier and to avoid the use of any mortar at the head joints.

2.2. Composite material – an overview of the mechanical behaviour

As already mentioned, the composite material used in the production of the blocks results from the combination of the three