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Behaviour of non-loadbearing *tabique* wall subjected to fire – Experimental and numerical analysis

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ABSTRACT

Tabique construction is one of the most used traditional building techniques and it can be found almost everywhere in Portugal with special incidence in the northeast region. *Tabique* construction elements can be described as a timber structure filled on both sides with an earth-based render. *Tabique* elements can be found in ancient buildings, from simple construction as rural dwellings to more urban sophisticated ones. This paper presents a study of the behaviour of *tabique* walls, concerning its fire resistance. Therefore, an experimental analysis was performed using *tabique* wall panel specimens. Such wall panels were made in pine wood with an earth-based render finishing. In order to assess the thickness effect of the earth-based render on the fire resistance of the wall, three specimens with different render thicknesses of 15 mm, 10 mm and 5 mm were tested in a fire-resistance furnace according to the ISO 834 [1] standard fire curve. Fire resistance is a measure of the ability of a building element to resist a fire, usually the time for which the element can meet appropriate criteria during exposure to a standard fire resistance test. By this way it is possible to increase the safety of people and property. Two performance criteria were verified which are the integrity and the insulation. In addition, a numerical model was also developed in order to assess the *tabique* wall behaviour under fire conditions, which was validated using the obtained experimental results.

1. Introduction

In the historic city centres of the north of Portugal, most of the existing buildings are ancient and they were built using techniques that have fallen in disuse due to the natural technological progress of the construction sector. Several of these buildings are abandoned and show an advanced state of degradation. Thus, it is important to perform rehabilitation and conservation processes of this heritage.

The usage of natural materials such as wood, earth and stone has evolved to industrialized solutions that result in environmental impacts. In recent decades, the sustainable construction concept has been developed based on the principles of recycling and maximizing resources, protecting and stimulating the creation of healthy environment, leading to the reduction of the environmental impact of the construction sector. In order to support the different stakeholders in the above referred sector, research projects and knowledge dissemination on sustainable development construction have been conducted [2].

The *tabique* is one of the main Portuguese traditional building techniques based on raw materials such as earth and wood, which was extremely relevant until the introduction of the reinforced concrete technique in the beginning of the 20th century. The *tabique* building technique consists of using natural and non-processed building materials, with simple procedures. In general, a *tabique* wall is composed by a simple timber structure covered with an earth-based material. The timber frame elements are nailed to each other and the most common timber frame solution is formed by vertical boards linked to each other by horizontal elements. In general, both materials are locally available in abundance, can be recycled, and are consequently more sustainable [3].

Tabique walls may be key structural elements because they connect horizontal structural elements located at different levels of a building. They contribute for bearing capacity during the occurrence of an earthquake, due to energy dissipation. For instance, during the earthquake that occurred in Lisbon in 1755, constructions built with *tabique* walls (or similar) had presented better structural behaviour under seismic action compared than the ones built with masonry walls.

Some research studies have highlighted the advanced deterioration level of this type of construction and the recommended the need for retrofitting actions [4–6]. At the same time, it was also stated that there is still a lack of publications related to *tabique* constructions which may

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be available to scientific and technical communities.

Therefore, the main goal of this research work is to study experimentally and numerically the behaviour of real-scale *tabique* walls subjected to fire conditions using different earth-based render thicknesses. Thus, three wall panels with different render layer thicknesses of 15 mm, 10 mm and 5 mm were tested. The overall dimensions of the panels are 990×975×95 mm^3. It was concluded that the earth-based render works as fire protection of the timber frame which allows the *tabique* wall to present adequate behaviour under fire conditions. The obtained results may give guidance for rehabilitation actions in buildings with a significant state of deterioration [7,8] and also provide new information about the behaviour of this *tabique* non-loadbearing wall under fire.

2. *Tabique* panels and construction details

The timber structure of the *tabique* panels is formed by vertical boards which are connected to each other by laths placed on both sides [9]. It was used *Pinus pinaster* and taking into account that it corresponds to a current applied solution [3]. These timber elements are nailed. This timber structure was then covered with an earth-based render corresponding to a traditional building solution. Fig. 1 shows some building details of typical *tabique* walls.

In order to evaluate the behaviour against fire, three *tabique* panels were manufactured by this way in the Strength of Materials Laboratory at Polytechnic Institute of Bragança.

2.1. Timber structure

As it was stated above, vertical boards and laths are the main elements of the timber structure. Both elements are separated to each one 35 mm. The respective cross section is 170×25 mm^2 and 30×25 mm^2. These dimensions correspond to average values obtained from [9]. Fig. 2 shows some stages of the manufacturing of the timber structure of the panels. Meanwhile, Fig. 3 schematically presents the geometrical detail of the timber structure.

2.2. Earth-based render

The timber structure of the panels was covered with an earth-based render applied on both sides. At a first stage, it was adopted the render composition delivered in previous studies [4] which do not considered lime or cement necessary. However, in this case and after some preliminary tests, it was concluded that it was convenient to include a 8% mass content of cement CEM II/B-L-32,5 R (white). The application of the render was performed in two main stages. In the first stage, the empty spaces of the timber structure were filled with the render (Fig. 4). In the second stage, the final coating was applied (Fig. 5). After this procedure, the panels remained in hygrometric controlled conditions of the laboratory for 30 days and they dried naturally at a room temperature around 18 °C and air humidity of about 75%.

2.3. Tabique *wall instrumentation*

The thermal behaviour of *tabique* walls exposed to the fire was evaluated using several thermocouples for measuring both internal and external temperatures of the wall. The entire procedure is based on European standard for the general requirements for fire testing [10] and the specific requirements for the fire testing of non-loadbearing walls (testing conditions, specimen preparation, specimen fixation, conditioning and instrumentation) [11]. According to these standards two performance criteria should be evaluated through all tests: the insulation and integrity criteria.

The insulation criterion is the time, in completed minutes, for which the test specimen continues to maintain its separating function during the test without developing temperatures on its unexposed side which increase the average temperature above the initial average temperature: i) by more than 140 °C, ii) or increase more than 180 °C at any location of the unexposed side above the initial average temperature.

The integrity is the ability to prevent the fire and the smoke transmission through the element. The integrity criterion will be verified throughout the experiments by employing a cotton wool pad saturated in ethyl alcohol.

As it was stated above, the main goal is to study experimentally and numerically the behaviour of *tabique* walls subjected to fire conditions using different earth-based render thicknesses. Hence, wire type K thermocouples have been placed at different depths in order to obtain temperature records inside the render (TA) and the wood (TM). The unexposed surface was also instrumented using type K thermocouples welded on copper discs protected by plasterboard (TD) used for measuring temperatures at specific panel points in order to assess and to verify the insulation criterion. The thermocouples were placed according to Fig. 6.

2.4. Tabique *panel coupled to the fire-resistance furnace*

Before coupling the panel, a 50 mm thick rock wool was nailed along the perimeter of the panel in order to avoid gas or flame escaping between the rim and the panel, Fig. 7. The *tabique* panels were then fixed into a support and coupled to the furnace, Fig. 8.

3. Experimental tests

The experimental *tabique* panels were tested in the fire resistance furnace existing in the Strength of Materials Laboratory at Polytechnic Institute of Bragança, which is able to carry out ISO 834 [1] standard fire tests, as defined in Fig. 9.

At the beginning of the tests, the *tabique* wall panels were at the

Fig. 1. *Tabique* wall building details.