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Editors:
João Paulo C. Rodrigues
George V. Hadjisophocleous
Luís M. Laím
Hélder D. Craveiro

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PREFACE

On behalf of the Organising and Scientific committees, as well as the CIB W-14 Commission on Fire Safety it is our pleasure to welcome you to the International Fire Safety Symposium - IFireSS 2015, which is organised by the CIB's Commission W14-Fire Safety, ALBRASCI and University of Coimbra. The Symposium aims to contribute to the exchange of ideas and knowledge in the area of Fire Safety and assist in planning future research activities in this area.

CIB W14-Fire Safety is a Working Commission of CIB (International Council for Research and Innovation in Building & Construction) and its main objectives are:

- To create an ongoing research and innovation focus for the development of a comprehensive, coherent, rational and empirical basis for a safe and sustainable built environment, which includes fire science and engineering practices and design methodologies;
- To promote the acceptance of Fire Science and Engineering Practices, Procedures and Design Methodologies worldwide, and to encourage their use in Building and Fire Safety Legislation, Codes, Regulations and Standards;
- To provide technical input, from a Fire Science and Engineering Perspective, to other relevant CIB Working Commissions and Task Groups;
- To facilitate the transfer of state-of-the-art Fire Science and Engineering Technology at international level;
- To encourage capacity building for Fire Science and Engineering worldwide.

The Luso-Brazilian Association for Fire Safety (ALBRASCI) was established recently by Portuguese and Brazilian specialists in the area of Fire Safety to create a platform for the development of Fire Safety in Portugal and Brazil.

The University of Coimbra (UC) is a reference in higher education and research in Portugal, due to the quality of the courses taught and to the advances achieved in pure and applied research in various areas of knowledge. UC is also well-known around the World due to the research and training in Fire Safety with an MSc and PhD in the area.

The Symposium has participants from researchers around the world and covers a wide variety of research areas including: Structural Fire Safety; Mechanical and Thermal Properties of Materials; Fire Chemistry, Physics and Combustion; Fire Reaction; Fire Safety in Vehicles and Tunnels; Fire Risk Assessment; Smoke Control Systems; Firefighting and Evacuation; and Fire Regulations, Standardization and Construction Trends.

Joao Paulo C Rodrigues
President of the Organizing Committee

George Hadjisophocleous
President of the Scientific Committee

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FIRE REGULATIONS, STANDARDIZATION AND CONSTRUCTION TRENDS

IFireSS – International Fire Safety Symposium
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FIRE BEHAVIOUR OF TABIQUE WALLS

Alexandre Araújo
Student
IPB - Bragança

Elza Fonseca
Professor
IPB - Bragança

Débora Ferreira*
Professor
IPB - Bragança

Paulo Piloto
Professor
IPB - Bragança

Jorge Pinto
Professor
UTAD – Vila Real

ABSTRACT

This paper present a study on the behaviour of *tabique* walls, concerning its fire resistance. This work is based on the experimental analysis of real scale *tabique* panels. Such walls were made in pine wood with an earth-based mortar finishing. In order to assess the earth-based mortar thickness effect on the fire resistance of the wall, three specimens were tested with three different mortar thicknesses of 15 mm, 10 mm and 5 mm. The earth-based mortar was previously analysed in the laboratory. The wooden structures were constructed based on traditional *tabique* technique. The experimental models were tested in a fire-resistance furnace, according to the ISO 834 standard fire. Temperatures were recorded using two data acquisition systems (spot measuring and field measuring). Fire resistance of test elements is expressed as the time during which the appropriate criteria have been satisfied so that one can predict the time before collapse, increasing both people and property safety. The obtained results are of great importance as they allow to improve the knowledge on *tabique* walls behaviour subjected to fire conditions. Two performance criteria were verified: the integrity criteria and the insulation criteria.

Keywords: Fire, *tabique*, traditional building techniques

* Corresponding author – Applied Mechanics Department of the High School of Technology and Management of the Polytechnic Institute of Bragança. Campus de Santa Apolónia 5300 – 253 Bragança. PORTUGAL. Telef.: +351 273 303061, Fax: +351 273 313051. e-mail: debora@ipb.pt

1. INTRODUCTION

The *tabique* is one of the main portuguese traditional building techniques, which is based on raw materials as earth and wood. In general, a *tabique* wall is formed by a simple timber structure covered by an earth-based material. The later material plays an important role in this building system since it improves the fire resistance of the wood-based structures. The northeast region of Portugal is very rich in terms of *tabique* construction heritage. Nowadays, the existing *tabique* constructions show a generalized and advanced stage of deterioration [1, 2, 3]. This concern, along with the fact that there is still a lack of scientific studies in this field, motivated this research work which main goal is to experimentally study the behaviour of this solution against fire using different earth-based mortar thicknesses. Moreover, it is intended to motivate and to give guidance for future rehabilitation works in this field. In relation to the earth-based mortar, and based on previous studies [4, 5], it was shown that it is a material with adequate fire resistance. When exposed to fire, the wood inside *tabique* shows a decomposition process (pyrolysis) and produces a surrounding charring depth layer. On the fire exposure side a charcoal layer without effective mechanical resistance causes the reduction of the element cross-section. However, the charring layer depth can delay the heating process, from the exposed side, acting as an excellent insulating material. When compared to steel or concrete structures, wooden structures have therefore an improved structural behaviour [6].

2. EXPERIMENTAL PROGRAM

2.1 *Tabique* walls construction

The construction system of *tabique* walls is based in a lightweight wooden structure. The fabrication of *tabique* walls relies on a timber structure assembled with pine planks (170×25 mm^2) placed vertically on which horizontal battens (30×25 mm^2) separated 37 mm are nailed on both sides [7]. In order to evaluate the earth-based mortar thickness effect, three walls (nominal dimensions: 990×975 mm^2) with different mortar layer thicknesses (th, refer to see Figure 1) of 15 mm, 10 mm and 5 mm were tested. Once the earth-based mortar has been applied, the specimens remained in hygrometric controlled conditions in the laboratory for 30 days and dried naturally.

2.2 Tabique walls instrumentation

The thermal behaviour of *tabique* walls exposed to the fire action was evaluated using several thermocouples meant for measuring both internal and external temperatures of the wall. The entire procedure is based on EN 1364-1 [8]. The goal of this study is to examine the behaviour of the earth-based mortar layer that protects the timber structure which constitutes the wall.

Hence, thermocouples have been placed at different depths in order to obtain temperature records inside the mortar (TA) and in the wood (TM). The unexposed surface was also instrumented with thermocouples disks (TD) placed according to Figure 1.

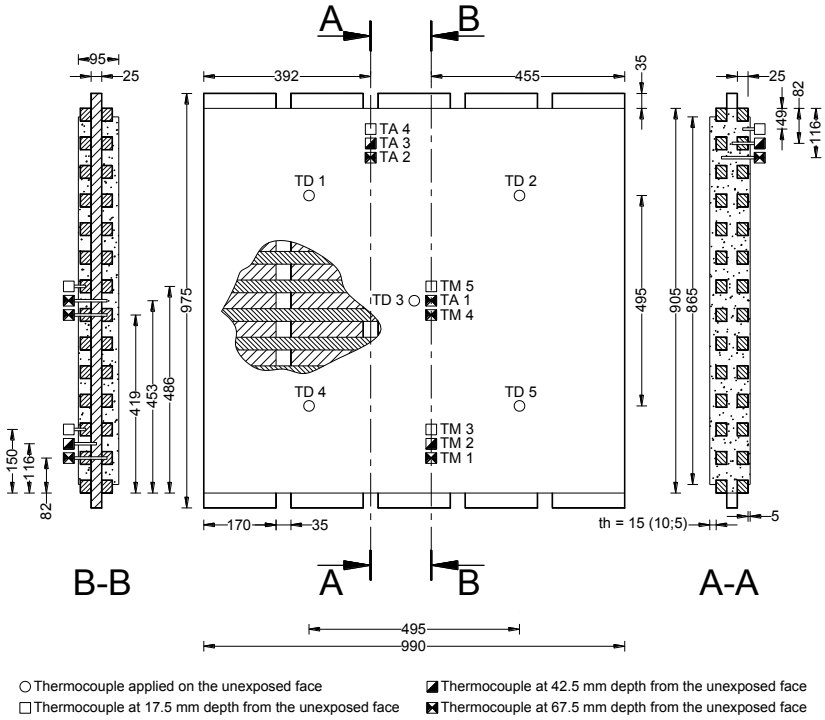


Figure 1: Panels geometry and thermocouples location (dimensions in mm)

2.3 Experimental tests

The experimental *tabique* panels had the appropriate geometry to be tested in the fire resistance furnace at Polytechnic Institute of Bragança (Figure 2), which is able to carry out ISO 834 standard fire tests. At the beginning of the test, the *tabique* wall was at ambient laboratory temperature of about 21°C. During the test, the integrity of the wall has been evaluated throughout the cotton wool pads test and gap gauges as well as monitoring the test specimen regarding evidence of sustained flaming. However there only was a significant amount of smoke release from burning wood at final stage of the test, Figure 3. At the end of the test, it was found that the exposed mortar had cracked and wood was burning (refer to Figure 4).


Figure 2: Experimental *tabique* panels model

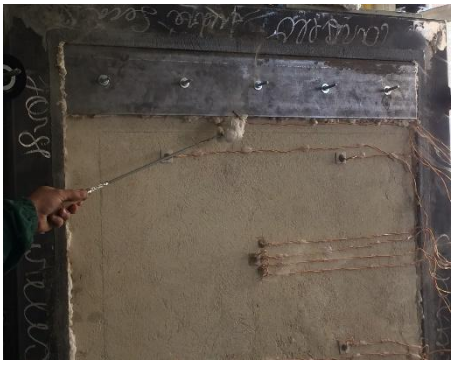
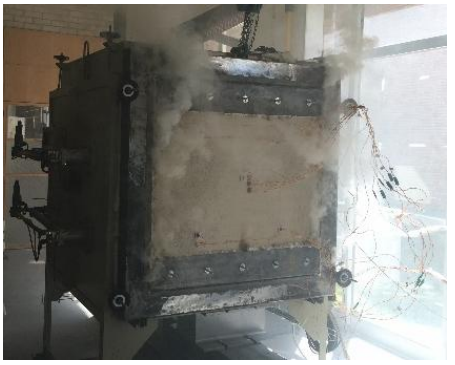
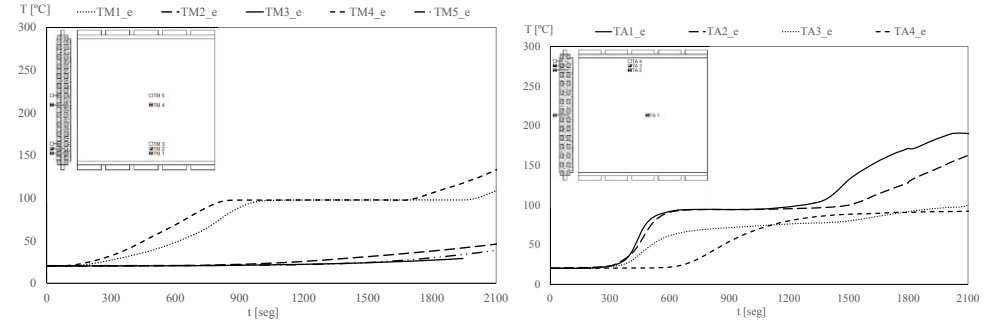



Figure 3: Integrity criteria proofing and smoke release


Figure 4: Final aspect of *tabique* panel

2.4 Experimental results

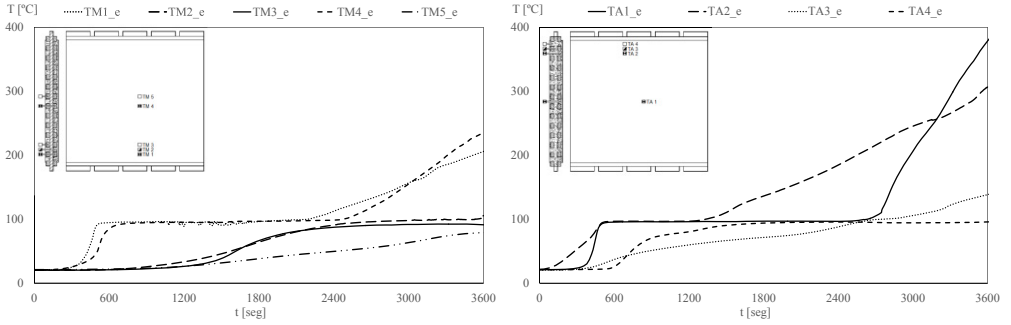
Graphs below (Figure 6 to Figure 8) show the obtained experimental fire exposure (T_e) responses in *tabique* walls for 15 mm, 10 mm and 5 mm mortar thicknesses, both for thermocouples located on wood structure (TM) and earth-based mortar (TA).



Temperatures on wood Temperatures on earth-based material

Figure 6: Results obtained in *tabique* panel with a 15 mm thick mortar layer

Regarding the panel with a 15 mm thick mortar layer (Figure 6), it can be seen that thermocouples TM 1 and TM 4 (which are placed on wood at 67.5 mm depth from the unexposed surface) recorded the highest temperatures of approximately 100°C. Regarding the thermocouples located near the unexposed surface (17.5 mm deep), the temperature remained nearly unchanged. Concerning earth-based mortar, the higher temperatures of about 180°C were recorded near to the fire exposed side. The lowest temperature (about 80°C) was registered at 17.5 mm depth in the mortar.

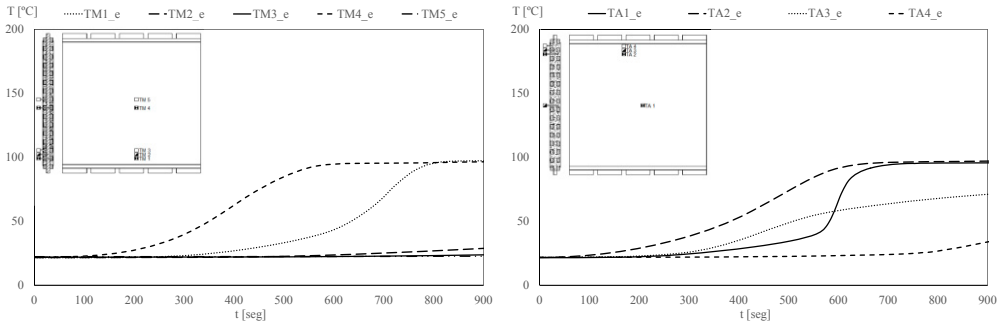


Temperatures on wood Temperatures on earth-based material

Figure 7: Results obtained in *tabique* panel with a 10 mm thick mortar layer

In Figure 7, it can be seen that thermocouples TM 1 and TMA 4 recorded the highest temperatures of approximately 240°C, but for t = 2100 s the same temperature of approximately 100ºC as *tabique* wall with 15 mm of mortar thickness was obtained. Regarding the thermocouples located near the unexposed surface, 17.5 mm deep, the temperature remained practically unchanged until t = 1200 s, increasing to around 100ºC at the end of test. As regards earth-based mortar, the higher temperatures of about 380°C were recorded near to the fire exposed side for t = 3600 s, but for t = 2100 s it recorded 180ºC which is the same registered temperature as with 15 mm of mortar thickness. The lowest temperature (about 100°C) was recorded at 17.5 mm depth in the mortar.

Concerning the 5 mm thick mortar layer, it can be seen in Figure 8 that thermocouples TM 1 and TM 4 recorded the highest temperatures of approximately 100°C. Regarding the thermocouples located near the unexposed surface, 17.5 mm deep, the temperature remained practically unchanged. With reference to earth-based mortar, the higher temperatures of about 80°C were recorded near to the fire exposed side. The lowest temperature (about 50°C) was registered at 17.5 mm depth in the mortar.

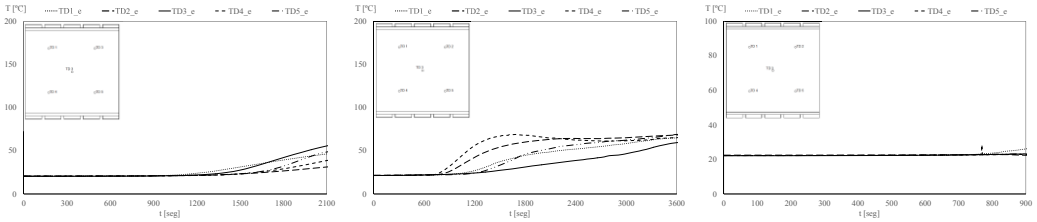


Temperatures on wood Temperatures on earth-based material

Figure 8: Results obtained in *tabique* panel with a 5 mm thick mortar layer

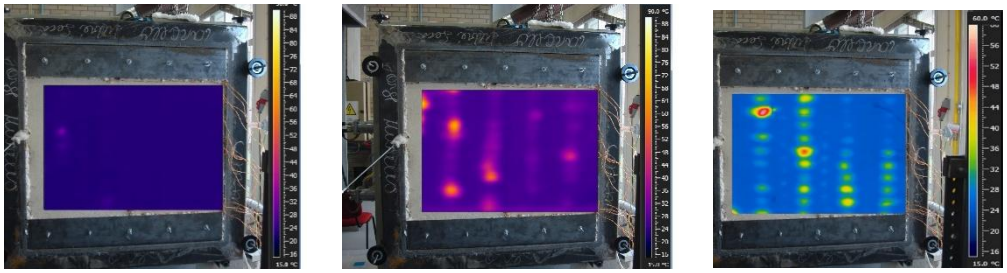
The three performed tests had different durations. Taking for reference the shortest experiment, which lasted for 900 s, one can observe that the recorded temperature for the three panels at that time was 100ºC which was recorded both in the mortar and in the wood structure. Nevertheless, with increasing duration of the test, one can verify that the temperature in the mortar was higher than the one recorded in the wood. Therefore, it can be pointed out that the mortar thickness did not influence significantly the protection of *tabique* panel against fire.

Figure 9 shows the temperatures recorded in the thermocouples applied on the unexposed face of *tabique* panels and Figure 10 depicts the results measured with infrared thermography (IR) at time t = 900 s.



15 mm thick mortar layer 10 mm thick mortar layer 5 mm thick mortar layer

Figure 9: Obtained results in *tabique* panels on TD (unexposed face) thermocouples



15 mm thick mortar layer 10 mm thick mortar layer 5 mm thick mortar layer

Figure 10: Obtained results in *tabique* panels with infrared thermography (t = 900 s)

From the analysis of Figure 9 one can observe that the temperatures of the unexposed face remained practically unchanged at around 21ºC until t = 900 s. However the wood isolation was visible as well as the effect of the different thicknesses earth-mortar considered, see Figure 10. At time t = 3600 s, the surface temperature increased up to 80ºC, which means the insulation criteria was fully verified since the average temperature increase in relation to the initial average temperature did not exceed 140°C. Moreover, the maximum temperature at any point of the unexposed face did not surpass the final temperature of 180°C. Therefore, it can be concluded that the earth-based mortar acted as a fire exposure protecting layer for the wood structure improving the overall fire performance of this building element.

3. CONCLUSIONS

The obtained experimental results allow the authors to point out that the performance criteria (insulation and integrity) defined according to the European standard for fire resistance tests [8] and was fulfilled for the whole test duration of the three *tabique* panels.

The insulation performance criteria shall be automatically assumed not to be satisfied when the integrity criterion ceases to be fulfilled. The insulation criteria verification was conducted

according to the relation of the average temperature increase to the average initial temperature, which was not higher than 140°C. Also, the maximum temperature at any point of the unexposed face did not exceed the final temperature of 180°C.

The integrity criteria was observed throughout the experiments by employing a cotton wool pads saturated in ethyl alcohol. No flame or ignition of the cotton have been identified. However, a significant amount of smoke release from burning wood was noticed at final stage of the test.

Finally, the earth-based mortar acted as a fire protection exposure layer to the wood structure improving significantly the fire resistance of this building construction element.

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