Fire resistance of walls made of soil-cement and Kraftterra compressed earth blocks

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SUMMARY

This study presents the results of fire resistance tests on walls made of soil-cement and Kraftterra compressed earth blocks (CEBs). The purpose of this work was to evaluate and compare the fire resistance of CEB walls with and without cellulose pulp derived from the recycling of cement sacks. This article describes the Kraftterra mixture and its production processes as well as the fire resistance test campaign. The fire resistance performance of CEB walls produced with Kraftterra and soil-cement blocks is analysed. Copyright © 2012 John Wiley & Sons, Ltd.

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1. INTRODUCTION

At present, the construction sector is moving towards the development and optimisation of more sustainable solutions, from the materials used to the energy consumed in the construction process. Additionally, the energy consumption involved in the heating/cooling of dwellings is a topic of great concern. Thus, the number of earth-based construction solutions is increasing. The compressed earth block (CEB) is the modern descendent of the moulded earth block \cite{1}, more commonly known as the adobe block \cite{2}. Presses are used in CEB production to compact the soil particles, thus increasing density. According to Rigassi \cite{2}, adding fibres to reinforce the soil is very common in traditional adobes but is incompatible with the CEB compression process because it complicates production.

Plant and vegetable fibres have been used extensively in traditional earth construction to improve the mechanical properties of soil-based constructive components. To improve the durability of adobes, strength should be increased, and water absorption should be decreased. The most effective method to modify the adobe is to compact the earth and stabilise it with additives \cite{3}. Fibre, cement, bitumen, lime or cow dung can be used to stabilise the adobe \cite{4}. Natural fibres from bamboo, coconut husk and sisal \cite{5} or artificial fibres such as plastic or polystyrene fabrics \cite{6} are examples of efficient stabilisers.

Analyses of a new composite material, Kraftterra, have has encouraging results. Kraftterra proved to be an excellent material for the production of CEBs, as demonstrated by the compressive strength, diagonal compression strength, shrinkage and fire resistance of walls made with Kraftterra CEBs.

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Tonnes of cement are used every year in civil construction. Most of the cement sacks are thrown out without any environmental treatment, causing an enormous negative environmental impact. In 2008, cement production in Brazil reached 51.9 million tonnes. Of this, 73%, or 37.3 million tonnes of cement, was packed in sacks [7]. Cement in Brazil is typically packed in 50-kg sacks. It is estimated that in 2008, 747.3 million cement sacks were used in Brazil, which corresponds to a consumption of 112.0 tonnes of Kraft paper.

The fibres of these sacks have excellent mechanical and physical properties. The fabrication of these sacks is guided by strong specifications demanded by the cement industry. Sack fabricators use high-resistance long-fibre sulphate cellulose, mainly in its pure form. After the cement is used, the sack, which has desirable characteristics, ends up not being accepted by the recycling industry because it has been ‘contaminated’ by the cement. However, there is great potential for reusing the sacks in the production of new construction materials or for improvements in the technical, economical and sustainable properties of some traditional components utilised in dwelling construction.

The fire risk in a dwelling may be high, as there may be several ignition sources (chemical, mechanical, thermal or even electrical). Additionally, catastrophic events, such as impacts, explosions and earthquakes, are commonly associated with the occurrence of fires. These building fires may have very severe consequences (loss of human life [8]), which justify society’s increasing attention.

Kraftterra blocks have raised doubts regarding their fire resistance, limiting their application in practice. This study presents the results of fire resistance tests on walls made with soil-cement and Kraftterra CEBs. The walls were tested without additional loads apart from their deadweight. This represents the typical loading conditions of these walls when inserted in single dwellings. The purpose of this work was to assess and compare the fire resistance of CEB walls with and without cellulose pulp derived from the recycling of cement sacks. Moreover, the eventual decay of the CEB masonry during its lifecycle may affect the fire performance of the walls. This aspect was not analysed in this research.

2. MATERIALS DESCRIPTION

One possibility for the use of earth in construction is the CEB. The idea of compressing earth to improve the performance of adobe blocks is not new. The first CEBs were produced with a heavy wood rammer, a process that is still used today in some regions of the world [9–11].

The first machine used to compress the earth probably dates to the 18th century. In France, Francois Cointeraux, inventor and supporter of the new pisè, designed the crecise, a device derived from a grape press for wine production. However, only in the early 20th century did the first designs appear for mechanical presses with heavy caps for moulding earth. The decisive moment for the adoption of presses in the production and consequent use of CEBs for construction and execution of specific architectural demands arrived only in 1952, with the invention of the famous CINVA-RAM press, designed by the Engineer Raul Ramirez [2].

Since the 1970s, different models of manual presses have been developed. Mechanical and motorised presses enabled the extension of the market for the production and use of CEBs in construction. The decision regarding the type of press to use for CEB production is of extreme importance because the greater the compaction imposed on the soil or composite, the better the CEB performance will be.

The presses compact the soil or composites in moulds that define the dimensions and shape of the CEB. Today, in addition to the varied equipment available for the production of CEBs, there are several types, forms, styles and designs for CEB blocks (see examples in Figure 1): solid, cast, smooth, with and without inserts, curved, half-block, corner, and so on.

Among the types of CEBs available, solid and smooth blocks were chosen for analysis in this study. The choice of these types of blocks simplifies the laboratory procedures by reducing the occurrence of any deviation in the test results associated with the consistency in the form and location of the holes. These blocks also allow the study of wall elements constructed with mortar bed-joints.

Barbosa [12] comments that, in general, CEB quality depends on the type of soil, amount of moisture during moulding, type of CEB machine, choice of curing process and type and quantity of binder.
Currently, the most commonly used composite for the production of CEBs is the soil-cement mixture. As the name implies, these blocks consist of soil stabilised with cement, normally Portland cement.

The main binder in the new composite Kraftterra, which is studied in this work, is dispersed Kraft fibres obtained from the recycling of cement bags. Other materials such as cement and lime may also be used as supplementary stabilising agents in Kraftterra. However, depending on the characteristics of the soil used in the mixture, these additional agents may be omitted.

3. FIRE RESISTANCE TESTS

Fire safety regulations and codes are prescriptive in nature. Most of these regulations are both extensive and complex, making their interpretation difficult. In reality, Brazil has a national fire code, which consists of a general document and does not contain detailed fire safety requirements. Therefore, detailed regional fire safety regulations are applied on a daily basis and vary from city to city. Despite these regional regulations, some required systems for buildings are analysed and certified on the basis of national standards [13].

These regulations are based on international standards such as ASTM E119, ISO 834 and BS 476, among others [13]. The typical fire resistance required for the structural frame is defined by regulations NBR 5628 [14] and NBR 14432 [15]. The fire resistance of load-bearing and non-load-bearing walls is regulated by NBR 10636 [16]. Regarding the European standards, Eurocode 6 [17] gives the design procedures for obtaining fire resistance in masonry walls.

The Laboratory for Structures and Fire Resistance at the Department of Civil Engineering of the University of Aveiro, Portugal, uses the European Standards for testing fire resistance (e.g. EN 1363-1 [18] and EN 1364-1 [19]).

In comparing the Brazilian standard NBR 10636 [16] with the European Standard EN 1363-1 [18], many similarities in their descriptions, recommendations and procedures are observed. Both are aimed at evaluating the fire resistance of vertical non-load-bearing partition elements. These properties are characterised by the ability of the construction element to maintain its load-bearing capacity, integrity and thermal insulation.

Load-bearing capacity refers to the ability of the wall or partition to maintain its mechanical strength (load-bearing capacity) without collapsing. Integrity refers to the ability of the separating element to prevent the passage of flames or hot gases from the compartment with the fire to another compartment. In addition, thermal insulation refers to the ability of the partition element to resist heat transmission, keeping the temperature increase on the face not exposed to fire within allowable limits.

A test specimen is considered to maintain its load-bearing capacity when, during tests involving the application of loads, it does not deform at a rate higher than the limits prescribed in the aforementioned standards.

A test specimen is considered to guarantee fire integrity when, during a test, it does not present openings that permit the passage of hot gases or flames lasting for more than 10 s from the fire-exposed face to the opposite face (not exposed).
A test specimen is considered to be thermally insulated when the average temperature increase does not exceed 140°C on the unexposed face and when the temperature increase is always lower than 180°C at any thermocouple of the same face [16,18].

A difference between these standards can be observed regarding the heating conditions used to define the temperature–time curve imposed during the test. NBR 10636 [16] uses in its formula (expression 1) $T_0$, which refers to the furnace initial temperature in °C, with $10°C \leq T_0 \leq 40°C$. EN 1363-1 [18] adopts the ISO 834 fire curve (expression 2), which considers a constant value equal to 20°C and allows variations of 20°C ± 10°C in the initial temperature.

\[
T - T_0 = 345 \log_{10}(8t + 1) \tag{1}
\]

\[
T = 345 \log_{10}(8t + 1) + 20 \tag{2}
\]

The other procedures and recommendations provided by the two standards are similar, particularly with regard to temperature tolerance, pressure conditions, temperature measurements of the furnace and of the unexposed face of the test specimen, average and maximum allowable temperature, and the installation and dimensions of the test specimen.

In Brazil, it is recognised that the city of São Paulo has the most advanced standards regarding the prevention and control of fire in buildings; these standards are often used as a model for the development of standards in other Brazilian cities [13].

Technical Instruction 8/2004 of the São Paulo Fire Department [20] includes a table of masonry fire resistances, which provides the minimum performance requirements for some types of masonry and structural sealing. As a reference, the performance values for ceramic brick walls, concrete hollow blocks (14 and 19 cm thick), clay bricks with eight holes and uncoated reinforced concrete walls are presented in Table I.

In this technical reference [20], a table with fire resistance time requirements (TRRF, from the original Portuguese name) that depend on the type of occupation and use of the building is also presented. This regulation proposes that the required fire resistance is determined as a function of several parameters, including the type of occupation: residential, service hosting, retail trade, professional services, personal and technical, educational and physical culture, public meeting, automotive services, health services and institutional industrial and deposits. The TRRF required for buildings with a height of up to 80 m is 120 min.

This study was not conducted under ideal temperature and pressure conditions, under which six different specimens of $3.1 \times 3.1\ m^2$ would be tested for each of the three configurations (without plaster, with plaster on the face exposed to the fire and with plaster on both sides) for the two materials.

The concurrent construction of six different specimens, with dimensions $3.1 \times 3.1\ m^2$, was not possible because of limitations of the number of frames available in the laboratory. Otherwise, the construction of the six specimens on different dates would influence their behaviour because of the differences in the curing conditions of each specimen.

<table>
<thead>
<tr>
<th>Tested wall</th>
<th>Time to fulfil each of the criteria (h)</th>
<th>Fire resistance (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load-bearing</td>
<td>Integrity</td>
</tr>
<tr>
<td>Ceramic brick $5 \times 10 \times 20\ cm$</td>
<td>≥2</td>
<td>≥2</td>
</tr>
<tr>
<td>Concrete hollow blocks $14 \times 19 \times 39\ cm$</td>
<td>≥1½</td>
<td>≥1½</td>
</tr>
<tr>
<td>Concrete hollow blocks $19 \times 19 \times 39\ cm$</td>
<td>≥2</td>
<td>≥2</td>
</tr>
<tr>
<td>Clay bricks with eight holes $10 \times 20 \times 20\ cm$ with cement-mortar coating of 1.5 cm</td>
<td>≥2</td>
<td>≥2</td>
</tr>
<tr>
<td>Uncoated reinforced concrete, thickness 11.5 cm</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table I. Masonry fire resistance [20].

4. TEST CAMPAIGN AND PROTOTYPES DESCRIPTION

A TERSTARAM Appro-Techno press was used for the CEB production (Figure 2). This machine produces two CEBs at each pressing and has a system to adjust the height and volume of the mould with steel plates (Figure 2c).

This press produces CEBs with dimensions of $22 \times 11 \times 5.5$ cm. For the construction of the wall, vertical and horizontal joints with a thickness of approximately 1.5 cm were adopted. To conduct the fire resistance test, a CEB wall was constructed in a surrounding reinforced concrete frame, with dimensions $3.10 \times 3.10$ m, which constituted the oven cover.

A test to characterise the fire resistance of Kraftterra masonry was carried out. Comparative analyses were performed on the wall panels constructed with soil-cement blocks and on those constructed with Kraftterra blocks. Different plastering conditions were also studied. To that end, the wall was constructed in two different phases corresponding to two distinct horizontal bands: the bottom half-height wall with traditional soil-cement CEBs and soil-cement mortar in the joints and the top half-height wall with Kraftterra in the CEBs and mortar.

To experimentally assess different plastering conditions commonly adopted in building construction using CEBs, the wall was divided into three vertical strips, each 1 m wide, to produce three different plastering configurations for each type of wall (soil-cement and Kraftterra). Figure 3 shows views of the finished wall, particularly the external face not exposed to fire (Figure 3a) and the inner surface before exposing it to fire (Figure 3b). The nomenclature adopted for each wall panel is presented in Figure 4. The central strip was not plastered on both sides (P2 and P5 for the panels with Kraftterra and soil-cement blocks, respectively). One lateral strip was plastered only on the face exposed to the fire (P1 and P4 for the panels with Kraftterra and soil-cement blocks, respectively). The other lateral strip was plastered on both sides of the...
Thus, six different panels were studied. The plaster, a soil-cement mortar, had the same composition in all of the panels, and the same soil was used in the production of the CEBs and 12% cement (in mass). The average thickness of the plaster was 2.0 cm, which resulted in a wall with a total thickness of 15 cm (for the panels plastered on both faces). Before plastering, the wall was wet to prevent rapid water absorption from the mortars and to reduce shrinkage.

Figure 3. (a) External face and (b) inner surface of the constructed wall infilled in a reinforced concrete frame mounted to test for fire resistance at the Laboratory for Structures and Fire Resistance.

Figure 4. Test instrumentation set-up, thermocouples and points where displacements were measured.
5. TEST MEASUREMENTS

The test was conducted at the Laboratory for Structures and Fire Resistance in two distinct stages (heating and cooling) with a total duration of 6 h 54 min. Figure 4 presents the external thermocouple position on the test specimen in each panel and the points used for measuring displacements. The position of the internal thermocouples used to measure the temperature evolution within the wall behind panels P2 and P5 can also be observed in Figure 4.

A neutral pressure plane (a pressure of zero) was imposed 500 mm above the floor level.

During the first 2 h of the test, the average temperature values for all of the furnace thermocouples followed the ISO 834 fire temperature evolution curve, defined by expression (2), where $t$ is time in minutes and $T$ is the average temperature of all furnace thermocouples.

After the first 2 h of the test, the furnace was turned off, but all of the connected external thermocouples continued to measure the temperature evolution during the cooling phase.

Some additional observations were noted: thermocouple 28 did not provide temperature values throughout the test; humidity, caused by water evaporation inside of the blocks and subsequent condensation on the plastered surface not directly exposed to fire, was observed during heating in different cracks (Figure 5b); and 1 h 53 min after the beginning of the test, a vertical fissure developed on the face that was not exposed to the fire, initially in the middle of the panel P2, as shown in Figure 5. It is noteworthy that the wall integrity was not at risk, and no hot gases or flames passed through the test specimen.

The crack ran vertically along the centre of the wall (panels P2 and P5) and was more visible on the face directly exposed to the fire (see Figure 6). On the exposed face, detachment of the plaster was observed in some locations.

6. TEST RESULTS AND COMPARISON

The room temperature recorded in the laboratory at the beginning of the test was 22.8 °C. After 120 min, the temperature increased to 23.0 °C. At the end of the test (after 414 min, including the wall cooling), the recorded room temperature was 31.2 °C (see Table II), which is in the range of the ambient temperature condition limits prescribed by EN 1363-1 [18].

The graph in Figure 7 illustrates the furnace temperature evolution corresponding to the ISO 834 curve up to 120 min. After 120 min, the furnace was turned off to reproduce the cooling phase of a natural fire. It was decided not to account for the ignition phase of real fires [21] to make it possible to determine the fire resistance time as prescribed in fire resistance tests standards [16,18].

According to the behaviour criteria proposed in EN 1363-1 [18], insulation is defined by the time in minutes during which the wall maintains its separation function without developing high temperatures
on the unexposed surface. This property is evaluated by limiting the increase in the average temperature to 140 °C or by limiting the increase of temperature at any point to 180 °C.

The mean initial temperature value recorded was 22.8 °C. Thus, the materials studied will be considered insulators until the instant when the average temperatures on the surface not exposed to fire reach 162.8 °C or until a temperature above 202.8 °C is recorded.

In Technical Instruction No. 08/2004 of the São Paulo Fire Department [20], the structural safety of a building is evaluated according to the fire resistance of its elements. In that document, values are proposed for the TRRF.

Table II. Room temperature recorded during the fire resistance test.

<table>
<thead>
<tr>
<th>t (min)</th>
<th>Room temperature (°C)</th>
<th>t (min)</th>
<th>Room temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22.8</td>
<td>80</td>
<td>22.3</td>
</tr>
<tr>
<td>10</td>
<td>22.0</td>
<td>90</td>
<td>22.6</td>
</tr>
<tr>
<td>20</td>
<td>22.0</td>
<td>100</td>
<td>22.8</td>
</tr>
<tr>
<td>30</td>
<td>21.8</td>
<td>110</td>
<td>22.7</td>
</tr>
<tr>
<td>40</td>
<td>21.8</td>
<td>120</td>
<td>23.0</td>
</tr>
<tr>
<td>50</td>
<td>22.1</td>
<td>220</td>
<td>28.7</td>
</tr>
<tr>
<td>60</td>
<td>22.1</td>
<td>310</td>
<td>30.0</td>
</tr>
<tr>
<td>70</td>
<td>22.5</td>
<td>414</td>
<td>31.2</td>
</tr>
</tbody>
</table>

Figure 7. Furnace temperature evolution.
According to the values proposed in the document, it is possible to verify that the maximum fire resistance required for all buildings is 120 min, with the exception of Group M (labelled ‘special’), where 150 min is required.

The global behaviour of the wall was excellent. The temperature on the external surface did not increase more than 80°C at any point until the furnace was turned off (120 min after the test began). This demonstrates that CEB walls perform adequately against fire, considering the performance criteria outlined previously. After 120 min, wall behaviour during the cooling phase was also characterised.

It is noteworthy that the different analysed walls showed adequate performance for consideration as firewalls to be eventually used in stairs or in partitions.

As presented in Figure 4, thermocouples t25 and t26 measured the temperature evolution at different depths of Kraftterra panel 2, and thermocouple t29 (thermocouple t28 was damaged during the test) measured the temperature evolution for the soil-cement panel 5. Figure 8 presents the temperature evolution at these thermocouples and for the corresponding unexposed surface thermocouples (t4 for panel 2 and t16 for panel 5). The maximum temperature recorded in the interior of panel 2 (from thermocouple t26), which is inferior to the corresponding thermocouple from panel 5 (t29), was approximately 75°C.

Although the maximum furnace temperature was achieved at 120 min, the wall temperature continued to increase afterwards because of the heat transfer process.

From the graph in Figure 8, it is also possible to observe along the wall the differences in the occurrence of total water vaporisation. This vaporisation process decelerates the temperature evolution on the unexposed to fire surface. Figure 9 presents the temperature profile evolution in panels 2 and 5. It can be observed that in both panels, the heating on the unexposed surface is faster and the cooling is slower when compared with the corresponding temperature changes inside the blocks. For the Kraftterra blocks, the vaporisation occurs at 120 min on the surface that was not exposed to the fire.

From the temperature evolution curves in Figures 8 and 9, a rough estimation of the materials’ thermal properties can be made mainly on the basis of comparisons between Kraftterra and soil-cement. It can be observed that Kraftterra may have a slightly lower thermal conductivity and specific heat. Future works will focus on the analysis of these parameters.

To evaluate the insulation performance of the different materials, the average temperature and the maximum temperature increases were calculated.

The average temperature increases for the six panels were compared within the limit of 140°C. For each panel, only the thermocouple located in the panel centre was considered. Figure 10 presents the average temperature evolutions for the six panels. The temperature increase limit (140°C) is not reached in any panel during the first 120 min of the test with the ISO fire curve.

![Figure 8. Temperature evolution throughout the wall cross section.](image-url)
Graphs in Figures 11–16 show the temperature evolution recorded in each thermocouple for each panel tested. By individually analysing the results for each panel, it is concluded that Kraftterra CEBs present slightly better performance than soil-cement BTCs, especially in the conditions without plaster and

Figure 9. Temperature profile evolution in the cross section of the panel: (a) Kraftterra, (b) soil cement.

Figure 10. Averages temperature increase in the unexposed surface of the six panels during the fire resistance test.

Graphs in Figures 11–16 show the temperature evolution recorded in each thermocouple for each panel tested. By individually analysing the results for each panel, it is concluded that Kraftterra CEBs present slightly better performance than soil-cement BTCs, especially in the conditions without plaster and
with plaster on both sides. However, it is also clear that, in general terms, both types of blocks showed similar performances, with the major difference being the lower heat transfer showed by the walls with Kraftterra blocks. In fact, as can be observed in the graphs of the previous figures, after switching off the furnace, lower temperatures were recorded for the panels with Kraftterra blocks. This difference is more pronounced when comparing the two panels without plaster (P2 and P5).

The recorded plateau temperature on all of the thermocouples, which varied by 60°C to 80°C, was induced by material moisture. All of the moisture evaporation occurred in the cooling phase, when it was possible to observe rising temperatures, mainly in the panels without plaster.

It can also be concluded that the plaster had a positive effect on fire resistance. Separation between the plaster and the wall was observed in both the surfaces exposed to fire and the surfaces not exposed to fire. The separation of the plaster induced the emergence of air flow zones, which does not favour a temperature increase.

The cooling phases in fire scenarios are gaining increasing importance in fire safety design. In fact, the test results showed that the cooling phase is strongly related to delays in temperature increases.
(in Figure 8, see the temperature recorded in thermocouples t29 and t26). It can be observed that the maximum temperatures were achieved in the cooling phase, after approximately 240 min in the panels with no plaster and approximately 340 min in the panels with plaster on one side. The results show that these temperature increases never reached 180 °C, which is the prescribed limit for the ISO curve and is not directly applicable to this phase.

The lateral displacement evolution was also measured during the test. During the ISO fire, the wall, which was subjected to its own weight, was able to maintain stability, and the maximum lateral displacement recorded was 20 mm.

The horizontal displacements recorded in all positions have small values and do not affect the stability of the wall. The low values for these displacements do not invalidate the fire resistance characterisation test.

Illustrations of the displacement evolution at different levels are presented in Figures 17 to 19.

It is observed that the centre points of the soil-cement panels (D, E and F) showed a more pronounced horizontal displacement than the corresponding points of the Kraftterra panels. The
Figure 15. Temperature increase evolutions in the thermocouples of panel P3, Kraftterra blocks with plaster on both surfaces.

Figure 16. Temperature increase evolutions in the thermocouples of panel P6, soil-cement blocks with plaster on both surfaces.

Figure 17. Evolution of the measured horizontal displacements profiles for the Kraftterra panels.
points closest to the interfaces between different materials, namely points H, J and L on the soil-cement panels, showed larger displacements than those for the Kraftterra panels.

The concave shape of the deformed wall, which deviated towards the inner part of the furnace because of the thermal gradients across the wall thickness in the early stages of the heating process, is consistent with the observations that have been made in other similar tests. At the later stages, the deformed shape evolved in the opposite direction because of a reversal of the thermal gradients within the wall, which occurs because of the thermal inertia of the wall (see Figures 17 and 18).

Figure 18. Evolution of the measured horizontal displacements profiles for the soil-cement panels.

Figure 19. Evolution of the measured horizontal displacements profiles for the non-plastered walls with Kraftterra and soil-cement blocks.
SOIL-CEMENT AND KRAFTTERRA CEBs

7. FINAL COMMENTS

The application of this constructive technique is increasing in many countries, both in developing regions and in developed regions where sustainable solutions are enforced and optimised. The mechanical characteristics of CEBs may guarantee its use in certain applications, such as dwellings, in which structural safety and comfort are required. Walls made of Kraftterra blocks, which incorporate cement sacks, has raised doubts regarding their fire resistance, limiting their application in practice.

With the fire resistance test performed, it is concluded that the inclusion of Kraft paper fibres from the recycling of cement bags in the production of CEBs resulted in panel elements with adequate performance and fire resistance. The test results confirm that the walls with Kraftterra CEBs, with or without plaster, can be used as partition walls.

As discussed, all of the walls built with CEBs composed of soil-cement and Kraftterra showed adequate performance and fire resistance. For all of the panels, the stability was guaranteed, and the different compositions guaranteed wall integrity until the conclusion of the ISO fire test (120 min duration). The walls also prevented the passage of flames, smoke and hot gases. In regard to thermal insulation, the wall with Kraftterra CEBs showed a better performance.

It is noteworthy that for all of the walls (made with soil-cement and Kraftterra CEB blocks), the temperature rise on the external face was far below the values recommended in the standards. The performance of the studied walls made with CEBs was comparatively better than required for other types of partition masonry walls.

REFERENCES