Fire-resistant behaviour of some cellular materials treated with intumescent solutions

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Abstract. Cellular materials are a very wide range of materials characterized by a hollow structure. These materials exhibit various thermo-mechanical properties, which recommend them for the creation of ultra-light structures, both singular and as part of complex systems. In this paper we have studied the possibility of providing fire resistance properties of some cellular materials, using them together with intumescent solutions. A good response of these systems to the direct flame exposure tests conducted under laboratory conditions has been observed, which recommends them for further investigations.

1. Introduction

The burning process that characterizes a fire is accompanied by a series of very complex phenomena, because the transformation of the reactants into the final combustion products is realised by means of a series of intermediate reactions that generates middle reaction products whose formation and evolution speed are unknown. This is a very important issue because it is known that the vast majority of the victims of a fire are caused by poisoning with the gas generated during the fire [1]. For these reasons it becomes necessary that the efforts of the specialists and the researches in the field have as a goal to ensure the appropriate levels and criteria of performance both by applying the regulations as well as by innovating new materials. In the case of construction products, the new European rules define the concept of fire reaction much broader than the domestic fuel classes, which includes not only combustion behaviour but also the flow of heat released, the smoke and combustion emissions, heat radiation, propagating his flame [2].

In an attempt to innovate materials to successfully meet the new regulations and conditions imposed by the Decision 00/147/EC that establish the performance euro-classes regarding the reaction to fire of the construction products [3-5], we initiated a study on the reaction to fire of a system composed of a matrix of cellular material and a intumescent solution.

Cellular materials are a relatively new class of materials characterized by the presence of inner voids. Depending on how these voids are formed, several types of materials are distinguished:
- with open or closed cell, depending on the degree of communication established between the voids,
- with cell matrix, when space is divided into distinct cells,
- porous materials containing a plurality of pores with a smooth inner surface,

- metal foams formed by the introduction and dispersion of gas bubbles in the melt,
- metal/ceramic sponge composed of particles forming a continuous network. [6]

An intumescent material is a combination of various compounds (acrylic resins and solvents, with or without water) that in the event of fire react at the heat together and increase their volume to form carbon foam. This foam attains a thickness of 10 to 100 times of the originally applied coating and insulates the substrate material through its low thermal conductivity.

2. Experimental setup

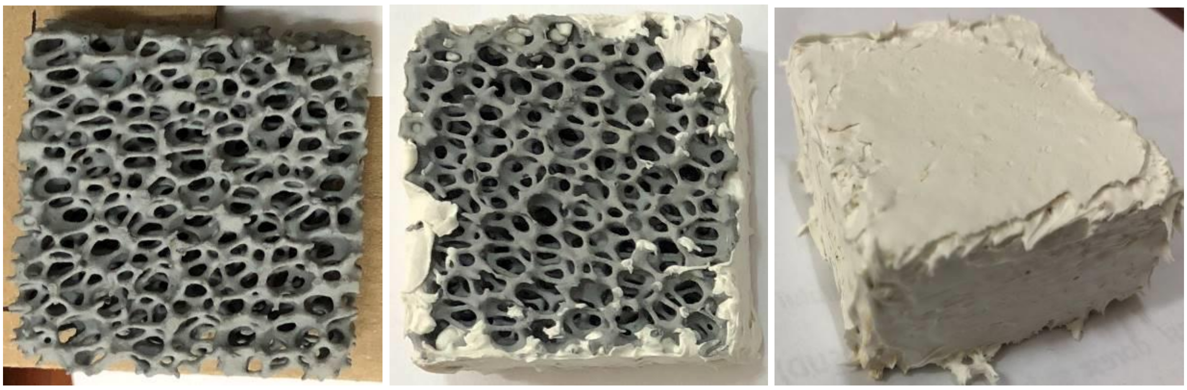
In the present study, the following materials have been used as forming materials for the fire-resistant system:

a) a SiC-based ceramic sponge cell material with Al_2O_3 and SiO_2 additions (commercially known as Vukopor S [7] produced by Lanik Foam Ceramics) in the form of a parallelepiped having the dimensions 50x50x15mm and a porosity of 10 ppi (see Figure 1a);

b) a intumescent solution for concrete, masonry and plasterboard wall – Hilti Firestop Acrylic Sealant CFS-S ACR (manufactured by Hilti AG), classified based on the reaction to fire in Class D - s1 d0 according to EN 13501-1 ("*products that resist for a long period of action of a small flame and are able to withstand the thermal action of a single burning product with a limited heat output, criteria according to EN ISO 11925/2 and EN 13823*"[3])

c) a water-based intumescent paint - PROMASTOP (manufactured by Promat SEE Slovenia) classified based on the reaction to fire in Class C - s2 d0 according to EN 13501-1 *("in addition to Class D: products that present a limited lateral flame propagation under the action of a single burning product, criteria according to EN ISO 11925/2 and EN 13823"*[3]) with an expansion temperature of about 300°C and an expansion rate of about 1:22.

Two sets of samples were prepared: sample 1 (P1) in which the Firestop Acrylic Sealant was applied on one side and on the laterals of the ceramic matrix (see figure 1 b) and sample 2 (P2) in which the paint was applied to all faces of the ceramic matrix until full sealing (see Figure 1c). The amounts of intumescent material deposited by brush application were as follows: Firestop Acrylic Sealant - 21.4g, water-based intumescent paint - 33.2g.



a) b) c)

Figure 1. The aspect of the materials / samples: a) cellular base material; b) P1; c) P2.

Testing of the samples was carried out by exposure to the open flame, and a refractory brick test support was built for this purpose, in which a special hole was prepared for mounting the prepared samples, as can be seen in Figure 2a. This type of test was chosen as a previous testing stage of systems that prove to be effective according to *SR EN 1364-1-2002 - Fire resistance testing of non-bearing elements*. The open flame is provided by combusting a gaseous mixture from butane (87%) and propane with the help of a fixed burner mounted at a distance of 10 cm from the test sample surface, as can be seen in Figure 2c.

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Measurements of the temperatures are carried out both on the non-exposed posterior face of the test sample using a thermocouple (see Figure 2b) and on the face exposed to the flame by means of a digital infrared measurement thermometer.

a) b) c)

Figure 2. Aspects of the testing stand: a) anterior sight; b) posterior sight; c) image during the test.

Subsequent to the tests, detailed observations of the samples were performed in the cross-section using a stereomicroscope at 40x magnification.

3. Results and discussions

In case of sample 1, the test was run only for 9 minutes, being interrupted when the flame appeared on the back of the sample, in the area not exposed to the flame, which caused the stopping of the recordings. The appearance of the intumescent effect was observed within the first three minutes of open flame exposure when the temperature of the surface directly exposed to the flame went up to about 400°C, as can be seen in Figure 3a. This phenomenon was also accompanied by a rapid increase in temperature on the posterior face of the sample (see Fig. 6) followed by the flame, as can be seen in Figure 3b. During this time, the temperature of the refractory bricks on the rear face increased from 30°C (in the first 2 minutes) to 90°C (at the end of the test).

a) b)

Figure 3. Aspects observed during the open flame test of sample 1: a) apparition of the intumescent layer on the anterior side, b) apparition of the open flame on the posterior side.

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As a difference from the behaviour of sample 1, sample 2 had a very good resistance to exposure to the open flame, the experiment being stopped after 180 minutes for objective reasons that did not reflect the quality of the experiment. As can be seen on the temperature variation graph recorded during the experiment shown in Figure 5, at the moment 1 the appearance of the intumescent layer (thermo-foam), which was slightly increased in height, was observed. After about 10 minutes (25 minutes - moment 2 on figure 5) it was observed that a very low thickness thermo-foam was developed on the posterior side. Another important moment was the one marked with 3 in Figure 5 when a new small area (white, circular in Figure 4a) appeared in the intumescent layer. It reached the final dimensions at moment 4, when a new increase to the size of about 20 mm occurred, as can be seen in Figure 4a. Towards the end of the experiment, a temperature stabilization recorded on the two sides of the P2 sample was recorded, while the temperature of the refractory bricks began to increase slightly.

a) b) c)

Figure 4. Aspects of sample 2 after the open flame test: a) apparition of the intumescent layer on the anterior side; b) apparition of the intumescent layer on the posterior side; c) sample 2 aspect after removing the intumescent layer

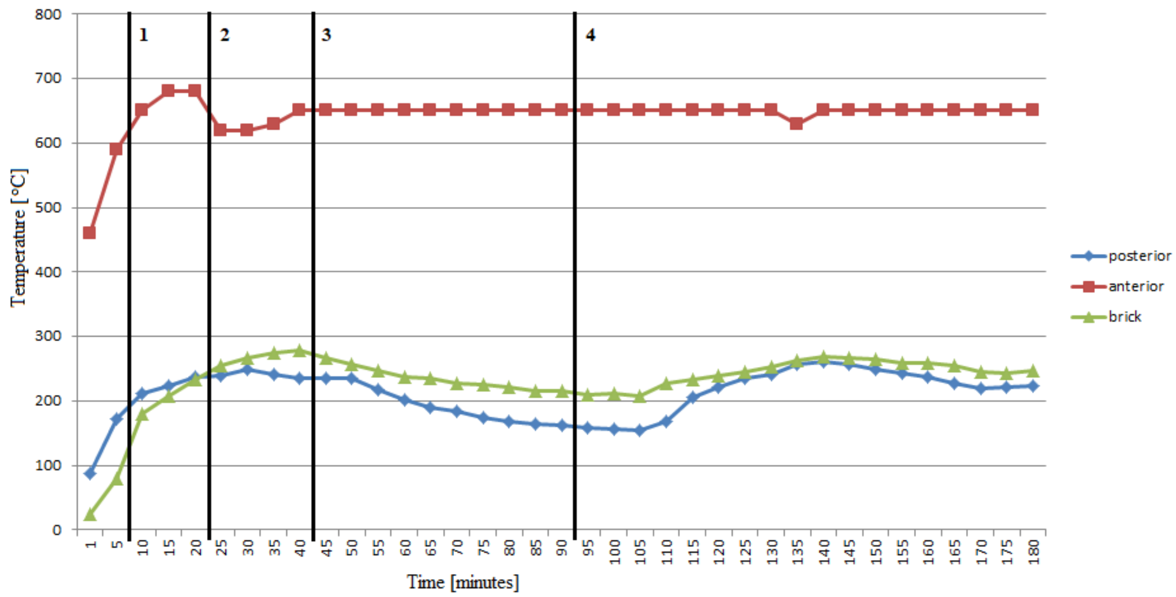


Figure 5. Variation graphs of the temperatures registered during the experiment on sample .

Regarding the comparative behaviour in the first 10 minutes of the experiments of the two samples presented by plotting the temperature curves in Figure 6, it is observed that the P1 sample records a rapid increase in temperature by 3 minutes before ignition, while sample P2 records increases with low speed and constant rate, which recommends it for use in future tests.

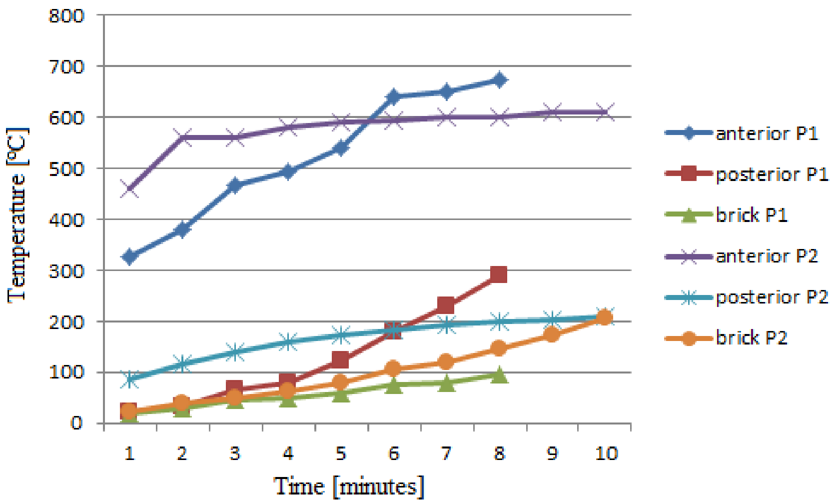
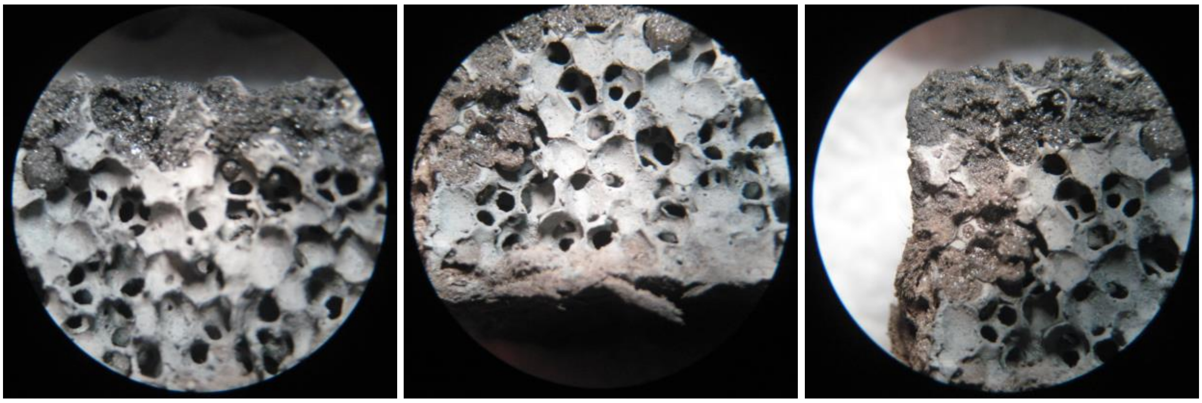


Figure 6. Variation graphs of the temperatures registered in the first 10 minutes of both experiments on samples 1 and 2.

In order to complete and correlate the previous observations with the aspect in the section of the sample P2, cross-sections and image acquisitions were made using a stereomicroscope, which are presented in Figure 7.



a) b) c)

Figure 7. Cross-section images of sample 2: a) on the anterior side; b) on the posterior side; c) on the anterior – lateral side; (40x)

In the details of the P2 sample cross-section presented in Figure 7, one can see how the paint has expanded inside the sponge ceramic matrix and sealed all the spaces, turning it into a compact, fire resistant element.

Based on the visible chromatic changes between the intumescent layer in the anterior area (fig.7a - grey metallic colour) and the one on the rear area (fig.7b – light grey) it can be concluded that long exposure at high temperatures of about 650°C of the intumescent layer modifies the chemical composition but not so much that the entire matrix system - intumescent layer loses its fire resistance.

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4. Conclusions

Even though there is currently a wide range of building materials with good fire resistance properties, it is still necessary that the efforts of the specialists and the researches in the field have as a goal to ensure the appropriate levels and performance criteria both by applying the regulations as well as through the innovation of new materials. One of the possibilities for innovation is that offered by new generations of materials, such as the type of cellular materials that can be used as a matrix to support solutions designed specifically for fire resistance, such as the intumescent solutions. In this study, two types of fire resistant systems consisting of open-cell material and intumescent material were tested, one of these systems successfully achieving standardized fire resistance periods. Following this study, it was observed that there is justification for further research in this direction, and the range of cellular materials with the use of those with metallic matrix can be extended.

5. References

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[6] http://www.metalfoam.net

[7] http://www.insulheat.ro

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