ASPECTS REGARDING THE USE OF ALUMINIUM FOAMS AS MATRIX FOR SOME FIRE-RESISTANT MULTI-LAYER MATERIALS

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In the present study, the authors have proposed the use of commercially available aluminium foam as a matrix for obtaining fire-resistant multilayer materials. Representative samples were made from the following components: ALUHAB closed cell aluminium foams, PROMASTOP intumescent paint, SuperPro furnace kit, Texxor double-woven Kevlar textile. These have been tested by exposure to the open flame in order to obtain initial fire resistance assessment data by following the sealing and insulation criteria according to SR EN 1363-1.

Keywords: fire-resistant, multi-layer material, aluminum foam matrix.

1. Introduction

According to the literature, a fire barrier system, assimilated in the present study with the fire-resistant multi-layer concept, comprises at least one layer of any of the following: an insulation layer, an intumescent layer, a layer of foam, a layer of bonding material (adhesive), a reflective surface layer, a layer of alkaline silicone resin composition and a reinforcement material [1]. Such a fire barrier system provides improved fire resistance, a thermal barrier, an oxidation barrier when used in conjunction with a substrate such as wood, polymer, etc.

In the case of civil and industrial buildings, one of the essential requirements for their design and execution is fire safety, which includes conditions relating to the location and performance of fire behavior of structures, construction products and related facilities. One of the recent changes that reflect the new European concept for testing and classification of construction products

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in terms of fire behavior is that contained in Commission Decision 2000/147 / EC of 2000 which, together with other decisions, had the effect of developing a coherent, unitary and complex system of fire and fire resistance euro-classes respectively [2, 3].

The concept of reaction to fire defined by European documents is much broader than indigenous fuel grades, as it includes not only combustion behavior, but also evolved heat flow, smoke and burn gas emissions, heat radiation, flame propagation, a.s.o. [4]. Thus, the way of fitting the building materials into the performance classes regarding the fire behavior is made on the basis of the following performance criteria: Reaction to fire, External fire performance and Fire resistance.

Reaction to fire is the behavior of a material which, by its own decomposition, supplies a fire to which it is exposed under specified conditions. External fire performance typically defines the behavior of a roof or a roof covering for situations where, under final use conditions, it is exposed to a fire outside the structure. Fire resistance is the ability of a product to preserve for a specified time the stability to fire, the fire integrity, imposed thermal insulation and or any other required function specified in a standardized fire resistance test [5].

Metal foams are a relatively new class of materials, characterized by low density and new physical, mechanical, thermal, electrical and acoustic properties. These materials offer the possibility of obtaining light structures, but they respond to demands as well as those previously standardized structures, the most commonly used being foams made of aluminum alloys. The production method of these foams varies greatly, in the commercial production area being used the following:

1. bubbling the metal melt (Al-SiC, Al-Al2O3) with gas,
2. mixing a foaming agent (TiH2) in the metal bath (usually Al alloy) and strictly controlling the pressure during cooling,
3. mixing a metallic powder (usually aluminum alloy) with a foaming agent (TiH2) and bringing the mixture into the molten state by heating to the temperature at which the sponge releases the hydrogen (Al, Zn, Fe, Pb, Au). [6]

In the present study, the authors have proposed to use commercially available aluminum foam as a matrix for obtaining multi-layer fire-resistant materials. After obtaining the representative samples, they were tested by exposure to the open flame in order to obtain some initial data to assess their fire resistance. According to the Romanian standard SR EN 1363-1 „Fire resistance tests, General Conditions”, two of the performance criteria applicable to the non-loadbearing’s elements in this study are:

1. Sealing capacity: the time in minutes in which the specimen continues to retain its distinct functions during the test without:

a) determine the carbonization of the cotton (according to art. 10.4.5.2); or
b) allow the penetration of a hole measuring apparatus; or
c) result in sustained flame.

2. Insulation: the time in minutes in which the specimen continues to retain distinct functions during the test, without developing the unexposed face temperature which:

a) increase the average temperature above the initial average temperature by more than 140°C; or

b) grow at any point (including the mobile thermocouple) above the initial mean temperature above 180°C.

These two criteria were monitored during the tests by directly observing the fulfillment of points b) and c) in the case of sealing capacity, respectively by recording the temperature in different areas of the samples and the test stand.

2. Materials and methods

In this study, three types of fire-resistant multilayer materials were made on a matrix of aluminum foam, with the following components:
- ALUHAB commercial aluminum closed cells foam manufactured by Aluinvent Hungary with a bubble size of about 5 mm and a sample thickness of 10 mm (Fig. 1a);
- PROMASTOP water-based intumescent paint (manufactured by Promat SEE Slovenia) classified according to reaction to fire in Class C - s2 d0 according to EN 13501-1 ("in addition to Class D: products which present a limited lateral flame propagation under the action of a single burning product, criteria according to EN ISO 11925/2 and EN 13823 "[6] with a expansion temperature of about 300 ° C and a expansion rate of about 1:22;
- SuperPro furnace kit, by ProInvest Romania, with a maximum use at 1200°C;
- "Texxor" double knit Kevlar textile, BIG Arbeitschutz GmbH, Germany.

The samples were produced by immersing the aluminum matrix in the intumescent paint and applying a textile layer on one side using as an adhesive material the furnace kit (Sample 1 - Fig. 1c, d), respectively on both sides (Sample 2 - Fig. 1e, f), and a sample without textile material (Sample 0 - Fig. 1b). Table 1 shows the proportions of the components used for the three samples.

Table 1

Components of the studied multilayered materials

Material Sample	Sample 0/mass [g]	Sample 1/mass [g]	Sample 2/mass [g]
Aluminum foam	1 pcs / 4,28 g	1 pcs / 3,96 g	1 pcs / 3,14 g
Intumescent paint	10,08 g	8,86 g	8,25 g
Kit for furnaces	-	1 side / 16,95 g	2 sides / 30,52 g
Kevlar textile	-	1 side / 1,23 g	2 sides / 2,34 g
Total mass	14,88 g	31 g	44,25 g

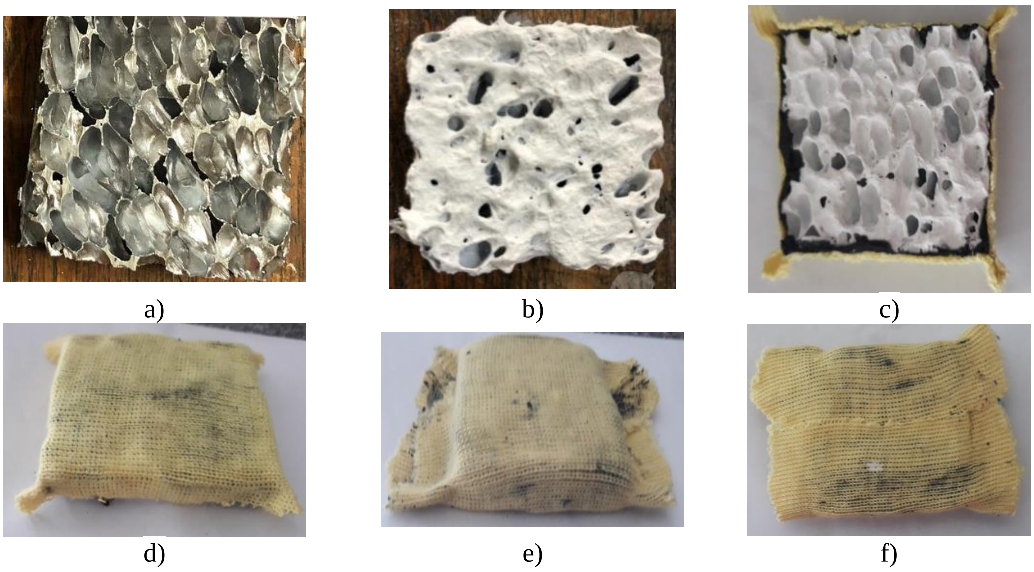


Fig. 1. The appearance of: a) the aluminum foam used as a matrix; b) Sample 0; c, d) Sample 1 on both sides; e, f) Sample 2 on both sides.

To test the fire resistance of these samples it was chosen to apply a non-standardized test, which consists of exposure to open flame samples [7]. For this purpose, on a support of refractory brick was made an orifice in which the three samples were mounted in turn, representative images being shown in Fig. 2.

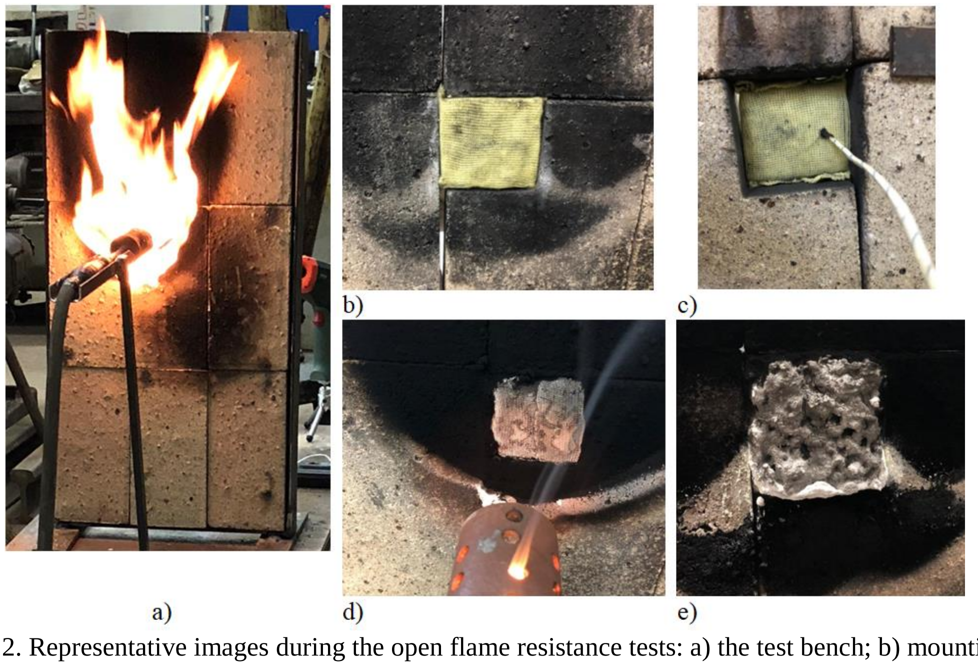


Fig.2. Representative images during the open flame resistance tests: a) the test bench; b) mounting of Sample 1, front view exposed directly to the flame; c) mounting of Sample 2 and thermocouple,

view from face not exposed to direct flame; d) the appearance of Sample 2 during the test; e) the appearance of Sample 0 after open flame weaving.

The open flame to which each of the samples was subjected for 180 minutes was obtained by combusting a GPL (butane 87% + propane) fuel by means of a 5 cm diameter burner head mounted at a fixed distance of 10 cm from the sample surface, as can be seen in Fig. 2a.

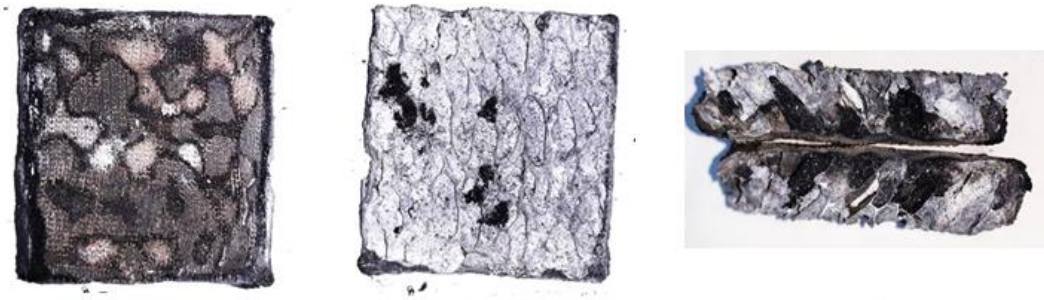
The temperatures achieved during the tests were measured using a thermocouple mounted on the face opposite to the open flame (see Fig. 2c). The temperatures on the face exposed directly to the flame or on the brick side from the immediate vicinity of the sample were measured using a portable infrared digital thermometer.

3. Results and discussions

After 180 minutes of open flame exposure of each of the three samples, they were extracted from the special hole designed in the refractory brick wall and directly observed. Their appearance after the test is shown in Figs. 3, 4 and 5. In the case of Sample 0 shown in Fig. 3, it is observed that all surfaces are covered with expanded thermo-foaming paint residues, which began to react visibly from the minute 50, at a temperature of approx. 520 ° C (see Fig. 4), which coincided with a gradual decrease in the temperature recorded on the unexposed area of the sample.

a) b) c)

Fig.3. Aspect of Sample 0 after testing: a) face exposed to flame; b) unexposed face; c) fracture.



a) b) c)

Fig.3. Aspect of Sample 1 after testing: a) face exposed to flame; b) unexposed face; c) fracture.

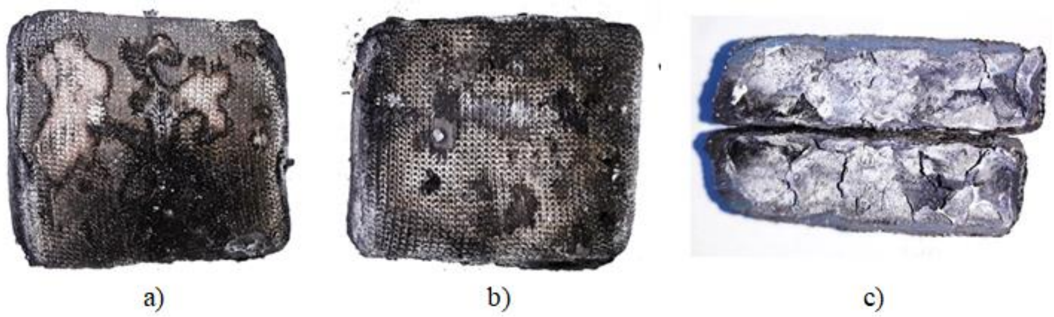


Fig.5. Aspect of Sample 2 after testing: a) face exposed to flame; b) unexposed face; c) fracture.

In the fracture, the expansion effect of the thermo-foaming paint that has penetrated most of the open holes can be noticed, but it can also be observed that the closed cells of the sample have a brilliant appearance indicating the lack of oxidation of the material in that area.

In case of Sample 1 it was observed that the fabric resisted without losing its integrity after direct exposure to the open flame, but the color of the surface was changed. On the unexposed side, as in Sample 0, the presence of intumescent material, which in this case expanded incomplete, was observed, a probable explanation being related to the fact that the temperature recorded in the test of this sample did not exceed 500°C, as it can be seen in Fig. 4. However, full intumescent material (Fig. 6) is observed in the fracture, but also enclosed cell areas whose interior aspect is specifically non-oxidized.

The appearance of Sample 2 suggests that it was not severely affected by the direct flame exposure test because the textile material resisted and did not present disintegration zones. However, in the fracture, we observe both the expanded intumescent material and the oxidized surfaces of the aluminum foam cells, consistent with the fact that in this sample the highest temperatures during the test were observed, as can be seen in Fig. 6.

On the temperature variation chart recorded during the experiment, the average values of the other two temperatures were also presented: the temperature on the surface of the samples in the burning zone and the temperature of the brick wall in the immediate vicinity of the tested sample.

The performance of two of the three provisions of the sealing criterion was verified throughout the tests, with the following observations:

- no open flame was observed on the unexposed face of the three samples during the course of the tests,

- no gaps in the material to be assimilated to the damages caused by the burning of the material in any of the three samples were not observed.

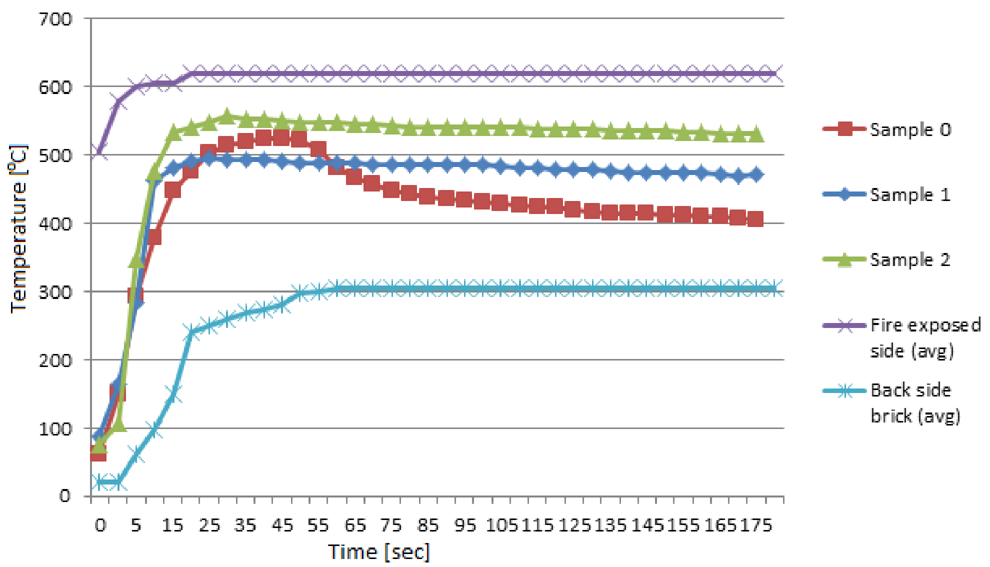


Fig.6. Variation graphs of the temperatures registered during the experiment on samples

By recording the temperatures on non-flame sides the compliance with the insulation criterion was monitored, which stipulates that the specimen continues to maintain distinct functions during the test without developing temperatures on the unexposed side to exceed the initial mean temperature by more than 180°C. As can be seen from the graphs shown in Fig. 6, this criterion was not met because the temperatures recorded on unexposed faces reached values ranging between 400-550 ° C.

4. Conclusions

The way of fitting the building materials into performance classes on fire behavior is based on the performance criteria related to: Fire Reaction, External Fire Performance and Fire Resistance. Fire resistance is the ability of a product to preserve for a determined time the stability to fire, the fire sealing, imposed thermal insulation and / or any other required function, specified in a standardized fire resistance test. According to the Romanian standard SR EN 1363-1”Fire resistance tests General conditions”, two of the performance criteria applicable to non-loadbearing materials are: sealing and insulation.

The following two performance criteria were followed:

- two of the three provisions of the sealing criterion were met: 1. no open flame occurred on the unexposed face of the three samples during the tests, 2. no gaps were observed in the material to be assimilated to the damage caused by burning the material to none of the three samples,

- the temperature requirements specified in the insulation criterion were not met because the temperatures recorded on unexposed sides reached values ranging from 400 to 550°C.

However, based on the results obtained in this study, we can state that there is the possibility of obtaining multilayer materials with aluminum foam matrix. These materials preserve their integrity and functionality after prolonged exposure to the open flame, and no deterioration of the aluminum foam matrix is observed.

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