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Fire Performance of the Thermo Insulant Facade Systems of the Buildings

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Abstract. The purpose of this research: The large-scale use of the external cladding systems with polystyrene thermal insulation, for rehabilitation of existing and new buildings, requires the experimental determination of the fire performance of these thermal insulating systems, both as wholes, and from the materials point of view, which they are constituted from. This study aims to present the evaluation of the fire performance of some polystyrene thermosystems and of the elements that make up these systems. Methodology: Experimental tests are carried out related to the fire behavior of polystyrene thermal insulation systems used in building renovation, in order to determine the mechanisms of flames initiation and propagation on the surface of combustible facades under natural ventilation conditions, the behavior of thermosystems in different fires scenarios and determining the fire performance of the constituent elements of these thermosystems. As a result of the performed tests, it was found that the overall performance of the thermal system against the fire action during the testing was mainly influenced by the value of the thermal load density parameter, and by the way the thermosystem is built and put into operation. The contribution of the components of the thermal system to the ignition, burning, development and propagation of flames and smoke differed on a case-by-case basis, depending on the materials used to cover the polystyrene, and the time elapsed, since they were put into operation. In the direct fire area of the fire test, temperatures above 1000 ° C have been recorded that have led, in some cases, to complete damage to the thermosystem. It is intended to establish a concordance between the parameters resulting from the tests on the facades of buildings, and those measured during the fire reaction tests of the elements which the facades were made from. This highlights the need to introduce the requirement of performing fire performance tests for building façade systems, following a harmonized testing methodology across the European Union.

1. Introduction
Thermal insulation of buildings is a complex and continuous challenge that requires a serious analysis of the physical aspects of building exploitation, the economic aspects of the construction and operation of the thermal insulation systems and environmental aspects [1-4]. When discussing the thermal insulation of a building, a multitude of parameters must be taken into consideration to ensure its functionality, durability and final appearance. Among these parameters, the fire performance plays a crucial role in ensuring high fire security for existing buildings and occupants.

2. Methodology
The assessment of fire response for polystyrene thermal insulation systems is based on the results of fire tests of these thermosystems. The researchers from INCERC Bucharest- Fire Safety Research and Testing Laboratory designed a stand for a research and fire tests of the buildings´ external plating systems. The test stand was designed after an analysis of the fire test concepts of thermo-insulating systems at European level. Thus, a test stand with characteristics similar to the test stand provided in BS 8414 has been built [5], with the exception that in the continuation of the lateral wing and at 2 m opposite to the combustion chamber, a reinforced concrete diaphragm on the whole height of the stand (8.5 m) is also placed there, which has a role of both increasing the effect of the chimney during the experiment and of protecting the burning phenomenon from the possible wind blasts from the North direction.

In order to assess the action of compartmental fires on the combustion exhaust systems of polystyrene-based buildings, an experimental test was performed at the above-mentioned test bench as follows:

- On the two wings of the test stand, a thermal insulation system consisting of expanded polystyrene EPS 80, with a thickness of 100 mm, was applied, and a spatula mass and an organic decorative plaster with a grain size of 1.5 mm were applied there as well, as can be seen in figure 1;

Figure 1. The thermosystem prepared for compartment fire testing

- The polystyrene boards were glued on the facade with adhesive mortar, both perimetral (all over the contour) and in the center by three bonding points;
- All polystyrene boards have been secured to the corners with clamps as can be seen in figure 2;
- The thermosystem had barriers made of 10 cm thick and 30 cm wide basalt mineral wool (see figure 2), which were mounted along the side of the fire compartment and on the floors of levels 1 and 2 on all the widths of the two wings of the thermosystem;

Figure 2. Bordering with mineral basalt wool

- During the experiment, the variation in the mass loss of the wood material in the fire compartment during burning was recorded;
- The experiment was instrumental and equipped to measure temperatures in the combustion chamber and the thermosystem facade;
- The thermal load consisting of 5x5 cm resinous couscous wood was purchased in advance, so that the wood was able to reach the point of ignition at a very close humidity as set forth in BS 8414, as can be seen in figure 3;

Figure 3. Thermal load made of resinous cousins

- The experiment was fully recorded with a thermal imaging camera and a 4K camera (figures 4-7);

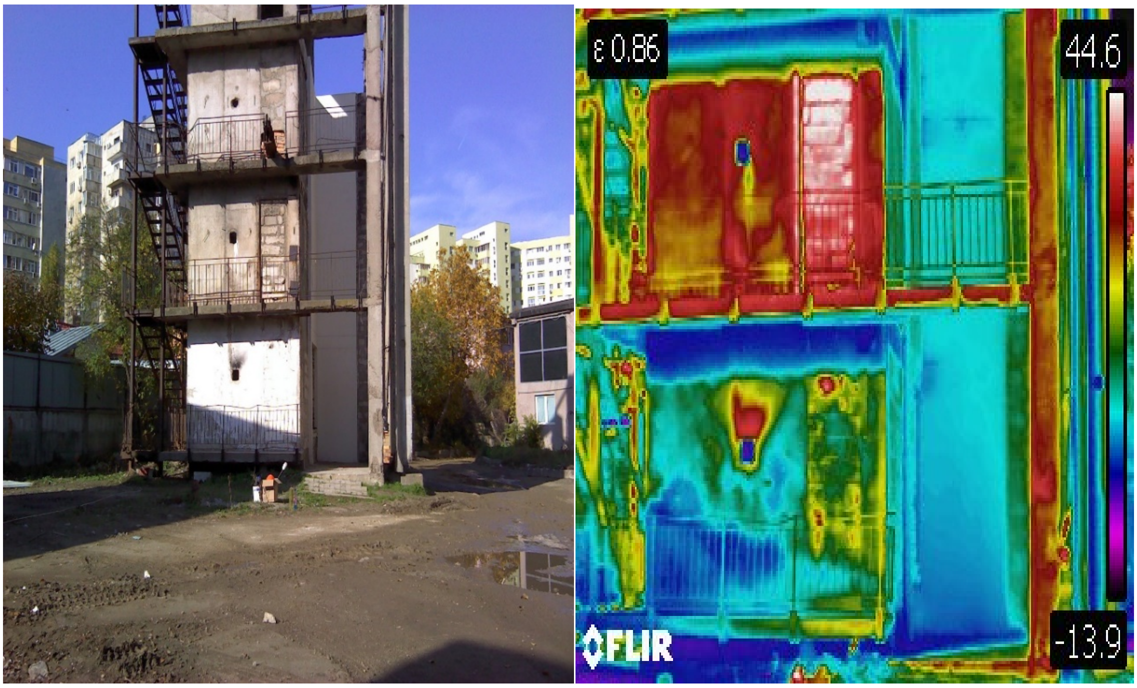

Figure 4. Images (photo and thermal) before the test begins

Figure 5. Images (photo and thermal) during the development of the compartment fire

Figure 6. Images (photo and thermal) during flash-over

Figure 7. Images (photo and thermal) at the end of the test

- Data acquisition was performed during the experiment with mass loss in the fireplace so that the experimental data can be validated as closely as possible with the numerical results from subsequent simulations;
- Measurements of the temperatures in the combustion chamber were made at 2,5 or 5 m above the combustion chamber. For this purpose K-type thermocouples with a diameter of 1.5 mm were used.

Existing theoretical studies and research have highlighted the fact that each fire has its own evolution that individualizes it, with no two fires of identical evolution. The uniqueness of the event should be understood as referring to the whole set of factors and consequences of fire.

The most important way to evaluate the behavior of the thermal load underlying the fire scenario of an experiment is to measure the variation of the wood material mass (the loss of mass) during the burning phenomenon.

In this regard, an industrial scale with a maximum load of 600 kg was purchased (figure 8), which was delivered together with a data acquisition system (PC unit) and an electronic display unit. The scale was placed in the fire compartment and protected against fire with two mattresses of 5 cm thick ceramic wool.

Over the mattresses were arranged in order: 5 bars of PC 52 with the diameter of 18 mm, the plate of 1.5 mm thick sheet and the surface of approx. 1.5 sqm, 5 BCA elements with the height of 200 mm and a STNB net (8 mm in diameter, mesh size 100x100 mm and area 1000x1500 mm).

A stack of resinous wood with the volume of 0.75 m^3 was set over the metal net. The 8m-long transmission cable was passed through the BCA wall of the combustion chamber to the PC unit installed on the 1st floor of the test tower.

During the experiment, an operator performed the measurement of the variation of the heat load mass as it burned in real time, minutes per minute.

Figure 8. Industrial scales with a load of 600 kg protected with ceramic wool mattress

The resulting values will be the basis for validating the experimental test with the numerical simulations to be performed both the variation of the parameters in the fire compartment as well as the surface of the thermosystem.

3. Results and discussions

During the test, a series of qualitative parameters were measured to assess the response of the materials from which the thermosystem was formed to the compartment fire action. These parameters are: system ignition time, flame height, detachments of system components, local stability losses, burning drops, amount of smoke released and variation in the heat load mass during combustion.

The height of flames varied over the 60 minutes of the test and their maximum height was reached at 30 minutes (≈ 2.5 m high). During the test, system components have not been detached and burning particles have not fallen from the thermosystem. The amount of smoke released into the atmosphere has increased around the flash-over moment. During the experiment, temperatures on the façade of the thermosystem had a uniform evolution. Propagation of fire in height has mainly influenced the temperatures of the outer surface of the thermosystem and, to a lesser extent, those inside the thermosystem, except for the direct action of the flame.

As a result of the action of the compartmental fire in the thermosystem, it is observed that the outer layer, consisting of adhesive mortar and decorative plaster of the thermal insulation, resisted the entire height of the thermosystem, but suffered a slight phenomenon of buckling in the central area above the combustion chamber (direct action of flames). The test thermoset did not favor the spread of fire vertically and laterally. The maximum recorded temperatures were in the combustion chamber above 1000ºC and on the facade above the combustion chamber exceeded 600ºC. Based on the results obtained, it results that the chosen solution for putting the thermosystem in operation and discontinuing the thermal insulation of the system tested with incombustible barrier solutions, made up of basalt mineral wool, ensures a high degree of fire safety.

4. Conclusions

The large-scale use of the external cladding systems with polystyrene thermal insulation, for rehabilitation of existing and new buildings, requires the experimental determination of the fire performance of these thermal insulating systems, both as wholes, and from the materials point of view, which they are constituted from.

A concordance between the parameters resulting from the tests on the facades of buildings, and those measured during the fire reaction, from which the facades were made, highlights the need to introduce the requirement of performing fire performance tests for building façade systems, following a harmonized testing methodology across the European Union.

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