Contributions on the fire performance assessment of ETICS systems

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Abstract. The Romanian norms and technical regulations do not provide the obligation of compartment fire tests for composite facade insulation systems “ETICS”. Unfortunately, only after these tests can result reliable data on the performance evaluation of ETICS under the effects of compartment fires, and there is still no harmonized European standard requiring such tests (in 2018 the first part of a European project that aims to harmonize the fire exposure test of façades was completed). In this context, researchers from the INCERC Fire Security Research and Testing Laboratory in Bucharest, tested experimentally the exposure to compartment fire of two types of ETICS, according to the test method set out in BS 8414. The climate test conditions of both systems were similar, and after the tests (for the first time in Romania) a series of data were obtained on the behaviour of ETICS under the action of compartment fires. With these results, the Romanian fire research aims to bring its contribution at European level, for the large-scale fire performance assessment of ETICS and the identification of innovative solutions for limiting fire propagation on building facades.

1. Introduction

Building materials contribute to the initiation and development of fires that can be fatal for both the occupants of buildings and those who intervene for their extinction. In Romania, the vast majority of living quarters are thermally insulated on the outside with composite thermal insulation systems based on expanded polystyrene (ETICS) that are relatively easy to apply on exterior walls, do not add loads to the structure, are energy efficient and have low costs compared to mineral dry wool [1]. Also, composite thermo-insulation systems describe an elegant way to isolate buildings from outside. These allow to conserve the initial appearance of the façade (the finished surface being made of plaster) and constitute a thermo-insulating covering on the whole surface, thus eliminating the formation of heat bridges. Unfortunately, some owners and builders, to increase productivity and reduce the production costs, do not respect design projects by using inexpensive materials and poor quality during the coating process of buildings facades with composite thermal insulation systems. Those facts, coupled with the legal shortcomings regarding the immediate firing of those who inadequately build the
ETICS, is the main cause of the tragic fires that cause great material damage and even loss of human life[2]. In this paper we present a comparative analysis regarding the behavior of the compartment fire of two ETICS that were built in different ways of forming and gluing into the support layer of the research stand. Through the results obtained, the researchers from INCERC Bucharest put at the disposal of specialists who work in the fire-safety of the residential buildings, a series of data that will warrant the necessity of introducing in Romania the mandatory testing of the fire performance of the ETICS.

2. Experimental procedures
Researchers from the INCERC Fire Safety Research and Testing Laboratory, conducted two experimental tests to assess the fire performance of ETICS systems exposed to the compartment fire action. Tests were performed according to BS 8414 standard (Figure 1) and performed under the following conditions:
- The ETICS tested with compartment fire had a 10 cm thick polystyrene from the same manufacturer. The fire reaction class declared by the manufacturer for the polystyrene used in Test no. 1 was B-s2, d0 and the polystyrene fire reaction class used in Test no. 2, was class E;
- In the test no. 1, the polystyrene sheets were bonded to the BCA masonry wall by adhesive mortar points and in test no. 2, each polystyrene plate was glued to the wall with adhesive mortar, both perimetral (all over the borders) and in the center by three bonding points;
- Both types of polystyrene boards were secured to corners with PVC clamps;
- In the test no. 2, the ETICS had protective fire propagation barriers, 10 cm thick and 30 cm wide basalt mineral wool which were mounted both along the shell of the combustion chamber and the floor planes from floors 1 and 2, across all the widths of the two wings of the ETICS;
- In both ETICS, it was built a reinforcement layer consisting of a glass fiber mesh (145g /m²) embedded in the glue mortar. After the spattering was dried, a primer and a decorative plaster layer of 1.5 mm grit and a fire reaction class A2 were applied there;
- The two experiments were instrumentalised with the same apparatus and equipment;
- The thermal loads (≈450 MJ) of the combustion chamber for each test consisted of a stack of 50 x 50 mm resinous wood that was conditioned with a humidity up to 12 to 15%;
- The experiments were recorded with a thermal camera and a 4K camera;

Figure 1. Large-scale cladding test facility (dimensions in mm) [3].
- For both tests, measurements of the temperatures in the 1st and 2nd floor levels (at 2.5 and 5 m above the combustion chamber) were performed. Also, there were measured for both tests, the temperatures inside the polystyrene at a height of 5 m above the combustion chamber. For this purpose, K-type thermocouples with a diameter of 1.5 mm were used;
- The ceiling of the combustion chamber was lined with ceramic mineral wool, 10 cm thick and the walls with ceramic mineral wool, 5 cm thick. Ceramic wool was attached to the support layer with high temperature resistant refractory anchors. A 10 mm thick magnesium oxide plate was placed over the floor of the combustion chamber, over which the wooden stack was placed for each test;
- For the purpose of assessing flame propagation height in the combustion chamber for each test, on the edge of the thermo-system located above the combustion chamber, lines were drawn with a step of 100 mm, over a distance of 1000 mm;
- The weather conditions during the tests were: air humidity 81.6%, air temperature 18°C, wind speed 0.4 m/s (for the first test), air humidity 62%, air temperature 20°C and wind speed 0.4 m/s (for the second test).

The most suggestive images during the two experimental tests are shown in Table 1.

**Table 1. Comparative images from the important moments of the two tests.**

| Test no. 1 | Test no. 2 | Test no. 1 | Test no. 2 |
|------------|------------|------------|------------|
| Min. 1 - Ignition stacks of wood | Min. 23 - Full combustion of the ETICS on the façade of the combustion chamber (Test no. 1) | Min. 10 - Fire development | Min. 24 - Beginning of fire propagation on the side facade of the ETICS (Test no. 1) |
| Min. 16 - Beginning of fire propagation on the height of the ETICS (Test no. 1) | Min. 38 - Full combustion of the wing thermal system (Test no. 1) |
Min. 19 - Propagation of fire across the entire ETICS (Test no. 1)

Min. 43 - Fire regression and burning elements detached from the ETICS (Test no. 1)

For the two experimental tests, the evolution of the temperatures measured on the outside and inside of the ETICS are shown in Figure 2.

**Figure 2.** Outside and inside temperature evolution: a) test no. 1; b) test no 2.
3. Results and discussions
Evolution of temperatures on the ETICS facades during the tests provides information on the fire propagation height, from the start of the test to the ending with the regression of the fires. For the two compartment fire scenarios presented above, the maximum flame height was about 2.5 m and was reached in both cases after 30 minutes after the thermal loads were ignited. Following the analysis of the temperatures measured during the test no. 1, it is noted that in the 16th minute of the test, the temperature inside the polystyrene at the 2nd floor level reached 443°C, indicating that the fire reached this level. At test no. 1, vertical fire propagation was amplified by the chimney effect through the gap left between the polystyrene and the support wall as a result of discontinuous bonding of the polystyrene through adhesive mortar points. Following the total combustion of polystyrene from the test no. 1, maximum temperatures of about 800°C were recorded both on the outside and within the ETICS. During this experiment, burning elements resulted at the base of the test stand and continued to burn even after complete combustion of the heat load. The amount of smoke released into the atmosphere during test no. 1, was amplified by the combustion of polystyrene. Compared to test no. 1, the outer coating of the ETICS from test no. 2, resisted the fire action throughout the experiment and prevented the ignition of the polystyrene from inside, even if the maximum temperature on its exterior façade exceeded the direct flash point of the flame, the polystyrene ignition point (∼350°C). In this area, due to lack of oxygen in the atmosphere, the polystyrene could not ignite and only melted due to thermal phenomena from the outside to the interior of the thermo-system [4]. It has been found that the basalt mineral wool barrier with which the combustion chamber has been flanked prevented the ignition of polystyrene and fire propagation on the height of the ETICS [5]. Considerably lower temperatures on the façade of the ETICS from test no. 2 compared to test no. 1, is due to the fact that they were generated only by the compartment fire.

4. Conclusions
It can be concluded that the bonding of polystyrene boards to the BCA masonry substrate by adhesive mortar points without the use of non-combustible barriers to interrupt thermal insulation is a wrong solution that favours the propagation of fires on ETICS facades in a short time. On the other hand, the solution chosen for the perimeter bonding (on the entire border) to the support wall of polystyrene boards with adhesive mortar together with the solution of planking the windows and doors with non-combustible barriers having a width of at least 300 mm and a thickness equal to of polystyrene, provides a high degree of fire safety for ETICS used for external thermal insulation of buildings. It is noted that the polystyrene used in the ETICS in test no. 2 had a much lower fire reaction class than that of the polystyrene used in the ETICS in test no. 1. It results that the fire reaction of the polystyrene used in the ETICS does not major influence the behaviour of ETICS to the compartment fire actions as long as the polystyrene is in a fuel class, it is not glued with perimetal adhesive mortar to the support wall and is not protected by non-combustible barriers. Regarding the different weather conditions of the two experimental tests, they did not have a decisive influence on the different behaviour of the two ETICS systems at the action of the fire.

5. References:
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