Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

FIRE SAFETY OF ETICS BASED ON EPS TYPE POLYSTYRENE

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Abstract

Due to the requirements to reduce energy consumption, the thermal rehabilitation of existing buildings has gained momentum in recent years, both in Romania and at the European level (Petcu et. al., 2023). The most accessible and used technical solution for the thermal rehabilitation of residential buildings, is represented by the external cladding systems with polystyrene thermal insulation. For this type of buildings thermal insulation system, the most unfavourable and most common external actions are represented by compartment fires. The researchers of the Fires Research Laboratory within the INCERC Bucharest Branch, have carried out a series of experimental studies on a natural scale, in order to develop a method of testing ETICS systems for fires generated from fire compartments. Through these studies and experimental research, conclusive results were obtained regarding the development of compartment fires, the evolution of temperatures inside the combustion chamber and the propagation of fire on the combustible facades of buildings.

Key words*: experimental research, fire resistance, fire behavior, ETICS.*

INTRODUCTION

Internationally, there are a number of full-scale or intermediate-scale testing methods for assessing the fire performance of external thermal insulation composite systems (ETICS) based on EPS type polystyrene (Lalu et al., 2017). All these methods define fire exposure scenarios inside buildings, which are characterized by different thermal loads that generate flames that propagate on building facades (Yoshioka, 2011). In Romania, full-scale tests are not yet accepted through which to test the fire resistance of ETICS (Simion et. al., 2019). In this context, it is necessary that a full-scale testing method for ETICS be adopted in our country, so as to demonstrate the fulfilment of fire safety requirements in accordance with the harmonized testing standards at European level. To meet this objective, the Fires Research Laboratory within the INCERC Bucharest carried out, for the first time in our country, a series of theoretical studies and experimental tests within a research project funded by the Ministry of Research, Innovation and Digitalization, which reproduced as closely as possible to reality, the propagation phases of compartment fires on building facades. Through this testing method, conclusive experimental results were obtained regarding the development of the compartment fire and the evolution of temperatures on the combustible facade of a building. The general purpose of the project was to conduct experimental research on the fire safety of the built environment: concepts and methods of fire resistance testing, new materials and solutions, including fire-built environment interaction (Ovadiuc et al., 2024).

The objectives of the project were the following: construction of a full-scale test stand for fire resistance of ETICS; adoption of a full-scale test method similar to one of the most commonly used test methods internationally; justification of the choice of the test model for conducting the experimental test; conducting an experiment on the newly built test stand in order to evaluate the mode of compartment fire propagation on the combustible facade of a multi-storey building; provision of protection measures against compartment fires that can be adopted when putting into operation the exterior cladding systems of buildings;

proposals for the extension of the experimental study.

MATERIALS AND METHODS

The fire resistance test stand for ETICS was designed by the engineering team from the INCERC Fires Research Laboratory based on the provisions of the British test method standard BS 8414 and was built at the facade tower of the laboratory in several stages. The research test stand for testing the fire resistance of exterior cladding systems of buildings, was designed by the team of researchers after an analysis of the fire testing concepts of ETICS at European and even worldwide level. Thus, a stand was put into operation with characteristics similar to the stand regulated in BS 8414, with one difference (BS 8414-1, 2002). This difference lies in the fact that in the continuation of the side wing and 2 m opposite the combustion chamber, a reinforced concrete diaphragm is additionally placed over the entire height of the stand (8.5 m), which has the role of both accentuating the chimney effect during the experiment and protecting the combustion phenomenon from possible wind from the North (Figure 1).

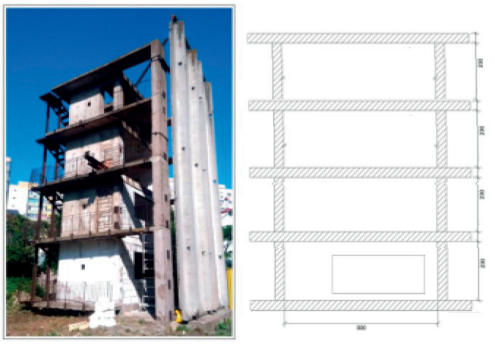

Figure 1. The construction used for the test stand

The ETICS installed on the two wings of the stand was made of 10 cm thick expanded EPS polystyrene (is a minimum thickness taken into account in current energy calculations that are made before thermal insulation of buildings), glued with adhesive and fixed with dowels to the BCA support layer (Michalak, 2021). The polystyrene was fireproof type EPS 80 – AF 80 with a density of 14.5 kg/m³ and was classified for reaction to fire according to SR EN 13501-1, class B-s2, d0. Over the EPS, a reinforcement layer consisting of an exterior fiberglass mesh (145 g/m²) embedded in adhesive mortar for plastering was installed with a crowbar. After the plastering mass had dried, a primer and a layer of structured decorative plaster type 2R were applied to it (Figure 2).

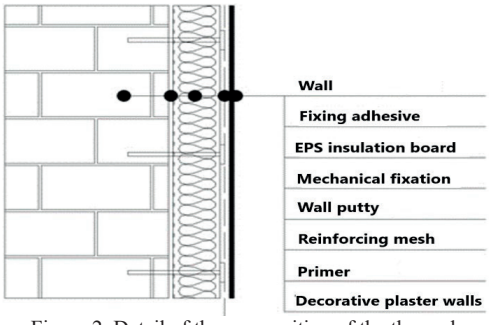

Figure 2. Detail of the composition of the thermal insulation system tested for fire resistance

The ETICS performed on the building for fire resistance testing was installed without non-combustible barriers between floors. Also, the polystyrene boards were installed in the worst case, namely on mortar beads, as is often done in current construction practice on site (Figure 3).

Figure 3. Test stand with ETICS prepared for fire resistance testing generated from the fire compartment

The ceiling of the combustion chamber was lined with 10 cm thick ceramic wool and the walls with 5 cm thick wool. The ceramic wool was fixed with high temperature resistant

refractory anchors. A 1.0 cm thick ceramic board was placed on the floor of the combustion chamber. In the test stand, researchers from the INCERC Bucharest conducted an experimental test to determine the compartment fire behaviour of an ETICS mounted on the facade of a building. During the fire resistance test experiment of the ETICS, a series of qualitative parameters were measured in order to evaluate the response of the construction materials from which the system was made up, to the propagation of fire in height. These parameters are: the moment of ignition of the system, the variation of temperatures in the fire compartment and in height, the variation of the mass of the thermal load, the height of the flames, detachment of elements from the system, losses of local stability and the amount of smoke released. The thermal load consisted of a softwood stack measuring 1.5 m (L) × 1.0 m (W) × 1 m (H) (Figure 4).

Figure 4. Wood stack

The wood was conditioned before combustion to reach a moisture content between 13 and 17% (Figure 5).

Figure 5. Wood conditioner

From the records presented above, the evolution of temperatures during the experiment results. The temperatures recorded under the specific conditions of the test (composition of the ETICS, choice of thermal load, geometric conformation of the stand as well as environmental conditions), highlight and provide data on the mode of propagation of fire in the combustion chamber, starting with the moment of initiation of the fire and ending with its regression (Figure 6).

Figure 6. Fire ignition

During the test, the variation in time of the following parameters was recorded:
- The temperature of the outer surface of the thermal insulation at 2.5 and 5 m above the combustion chamber (of the fire compartment);
- The temperature inside the thermal insulation at 5 m above the combustion chamber;
- The temperature inside the combustion chamber.

Also, during the test, the moment of ignition of the ETICS, the development of the fire on the facade and the moment of flash-over, the maximum height of the flames, the detachment of burning elements from the ETICS, the regression and extinguishing of the fire were monitored (Malgorzata et al., 2022).

The height of the flames in the fire compartment varied during the experiment and it was found that their maximum height was reached approximately in the 15th minute, when the flames propagated above the combustion chamber to a height of approximately 2.5 m (Figure 7).

During the experiment, an increasing evolution of the temperatures along the height of the

tested system under the action of the fire is observed.

Figure 7. The beginning of the fire propagation on the height of the ETICS on the front wall

It is also found that the propagation of the fire along the height and especially after the polystyrene thermal insulation began to burn generalized, influenced the increase in temperatures both on the external surface of the ETICS and from inside it (Figure 8).

Figure 8. The beginning of the fire propagation on the height of the ETICS on the side wall

During the test, component elements of the system were detached and burning particles fell from the system. Following the action of the fire on the thermal system, the expanded polystyrene thermal insulation layer did not withstand in terms of mechanical resistance and fire tightness over the entire height of the test stand (Figures 9, 10).

The amount of smoke released into the atmosphere was relatively constant, increasing slightly around the flash-over moment (Figure 11).

Figure 9. Complete combustion of the ETICS on the side wall to the fire compartment

Figure 10. Burning particles detached from the thermal system

Figure 11. Smoke plume stock

RESULTS AND DISCUSSIONS

Following the correlation of the temperature recording times presented in the tables above, with the photo-video recordings corresponding to the time points of the most important stages of the experiment, it results that a series of conclusions can be drawn regarding the behaviour of ETICS in the event of compartment fires, which can contribute to increasing the degree of fire safety of the built environment.

Following the action of the fire on the ETICS, it was found that the thermal insulation layer made of EPS polystyrene was burned and melted down to the support structure, in the area of direct action of the fire.

After the thermal insulation ignited, a significant amount of black and gray smoke was released. The tested system favoured the propagation of the fire both vertically and laterally. During the duration of the fire, burning detachments of the thermal insulation system were found.

The maximum temperatures were recorded in the combustion chamber was over 920°C. The maximum temperatures recorded 2.5 m above the combustion chamber was over 740°C (Figure 12).

Timp / Termocuplu	TF7	TF8	TF9	TF0	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8
Minute / °C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
0	12	16	16	16	17	17	17	17	17	17	17	17
13.30	37	798	783	196	77	234	430	152	202	189	78	32
20.30	29	634	595	283	276	413	746	598	184	175	82	52
25.06	25	367	362	55	76	115	163	113	115	104	45	23
29	36	772	770	219	82	227	476	157	189	184	82	35
32	28	717	605	394	150	305	410	327	244	202	261	95
36	29	720	616	430	212	347	318	228	222	238	452	149
38.40	29	777	693	487	214	337	287	194	246	275	288	161
44.50	29	770	547	396	105	163	228	215	210	205	258	188
48.30	26	927	576	360	109	191	204	149	181	171	193	109
51.20	22	495	315	221	72	110	153	126	125	126	151	83
57.20	18	233	178	145	43	69	64	57	78	80	94	60
59.10	17	193	135	101	36	55	60	67	76	79	89	61

Figure 12. Temperatures recorded in the combustion chamber and 2.5 m above the combustion chamber

The maximum temperatures recorded 5.0 m above the combustion chamber was over 820°C (Figure 13).

The temperatures measured at the height of the thermally insulated facade with ETICS during the experimental test indicate that around 20 minute by ignite the fire, the fire became generalized and encompassed the entire ETICS above the combustion chamber, resulting an additional heat input compared to the heat released following the combustion of the wood stack

Timp / Termo-cuplu	2 1	2 2	2 3	2 4	2 5	2 6	2 7	2 8	2 9	2 10	2 11	2 12	2 13	2 14	2 15	2 16
Minute / °C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
0	17	17	18	17	17	13	17	17	15	14	15	15	13	17	13	14
13.30	80	137	156	107	115	24	72	44	320	199	399	43	31	118	17	16
20.30	759	821	747	622	614	83	113	72	786	816	731	614	596	250	31	33
25.06	375	437	393	325	324	261	270	77	382	454	455	325	330	268	249	74
29	389	402	357	316	292	290	277	278	392	405	366	317	296	294	270	282
32	252	267	289	283	266	259	274	245	254	266	287	286	269	271	256	230
36	287	277	276	276	281	278	369	371	285	276	274	275	283	296	409	358
38.40	258	249	250	234	227	226	261	249	258	248	250	237	230	230	251	250
44.50	159	165	170	171	173	171	188	195	160	164	172	171	172	176	192	205
48.30	146	152	165	147	129	125	154	158	147	153	168	152	130	128	158	172
51.20	109	116	119	115	108	102	130	133	110	116	121	118	107	102	133	144
57.20	65	66	64	60	65	61	89	89	65	67	66	62	64	59	91	95
59.10	63	62	61	58	69	65	85	84	63	62	62	60	67	63	87	90

Figure 13. Temperatures recorded 5.0 m above the combustion chamber

It is also noted that in a relatively short period of time (10 min) the entire thermal insulation facade located above the combustion chamber was destroyed by the fire.

Specialists draw attention to the results obtained, that in the case of installing ETICS on high-rise buildings, without installing non-combustible barriers between floors, there is a very high risk that combustible facades will burn along their entire height when exposed to compartment fires (Lalu, 2016).

CONCLUSIONS

Based on the experimental research carried out, unique results were obtained in Romania regarding the development of a fire on the combustible facade of a building, with results that can be transposed to a normative level and with applicability from the design phases of the buildings. Also, a unique stand was created in Romania for carrying out experimental research testing the compartment fire action of ETICS, open to both the academic and the economic environment.

In this way, INCERC Bucharest contributes to the development of a database that will support the establishment of criteria and performance levels for ETICS used to enclose residential

buildings, so that they can ensure a high degree of fire safety.

ACKNOWLEDGEMENTS

This research work was carried out with the support of the Ministry of Research, Innovation and Digitalization and was financed from Project PN 19 33 02 01.

REFERENCES

British Standards Institution (2005). *BS 8414-1: Fire performance of external cladding systems applied to the face of the building* (pp. 4–6). London: BSI.Yoshioka, H., Yang, H.-C., Tamura, M., Yoshida, M., Noguchi, T., Kanematsu, M., Koura, K., & Ozaki, Y. (2011). Study of test method for evaluation of fire propagation along façade wall with exterior thermal insulation. *Fire Science and Technology, 30*(1), 27–44.

Lalu, O. (2016). *Cercetări privind elaborarea unor soluții durabile de reabilitare termică a anvelopei clădirilor. Comportamentul la acțiunea focului, soluții de securitate la incendiu* [Doctoral thesis, Universitatea Tehnică de Construcții București].

Lalu, O., & Bubulete, L. (2017). Termosistem pentru placări exterioare utilizat pentru anveloparea construcțiilor. Răspuns la acțiunea focului. *Revista Construcțiilor, 133*, 8.

Malgorzata, N., Wieczorek, M., & Borkowicz, K. (2022). Fire safety of external thermal insulation systems (ETICS) in the aspect of sustainable use of natural resources. *Sustainability, 14*(3). https://doi.org/10.3390/su14031224.

Michalak, J. (2021). External Thermal Insulation Composite Systems (ETICS) from Industry and Academia Perspective. *Sustainability*, *13*(24), 13705. https://doi.org/10.3390/su132413705

Ovadiuc, E. P., Calotă, R., Năstase, I., & Bode, F. (2024). Integration of phase-change materials in ventilated façades: A review regarding fire safety and future challenges. *Sustainability, 7*(7), 244. https://doi.org/10.3390/fire7070244.

Petcu, C., Hegyi, A., Stoian, V., Dragomir, C. S., Ciobanu, A. A., Lăzărescu, A. V., & Florean, C. (2023). Research on thermal insulation performance and impact on indoor air quality of cellulose-based thermal insulation materials. *Sustainability, 16*(15), 5458. https://doi.org/10.3390/ma16155458.

Simion, A., Anghel, I., Dragne, H., & Stoica, D. (2019). Contributions on the fire performance assessment of ETICS systems. *IOP Conference Series: Materials Science and Engineering, 572*, 012112.