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ДРУШТВО НА ГРАДЕЖНИТЕ КОНСТРУКТОРИ НА МАКЕДОНИЈА

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ПРИДОНЕС НА ПОЖАРНИТЕ БАРИЕРИ ВО ПОЖАРНОТО ОДНЕСУВАЊЕ НА КСИНТИ ФАСАДИТЕ СО ЗАПАЛЛИВИ МАТЕРИЈАЛИ

РЕЗИМЕ

Во случај на пожар, запалливите изолациони материјали во склоп на фасадните системи ја зголемуваат опасноста од ширење на пожарот, вертикално по фасадата како и на соседните објекти. Овој труд дава преглед на проблемот со ширење на пожарот низ фасадите, но и начини за заштита со апликација на пожарни бариери за згради со висина до 22 m, во согласност со барањата на регулативата во Р. Хрватска. За да се докаже ефикасноста на пожарните бариери за временско одложување на ширењето на пожарот, прикажани се резултатите од пожарни тестирања спроведени на реални модели на КСИНТИ примероци на база на EPS со и без пожарни бариери.

Клучни зборови: пожарна безбедност, фасади, пожарни бариери, КСИНТИ системи

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CONTRIBUTION OF FIRE BARRIERS IN FIRE PERFORMANCE OF ETICS FAÇADES WITH COMBUSTIBLE MATERIALS

SUMMARY

In case of fire, application of combustible insulation materials in façade systems increases the risk of fire spread vertically across façade and to adjacent buildings. This paper gives an overview of a problem related to fire spread across façades and modes of its protection, which are, in accordance to regulatory requirements set in the Republic of Croatia, based on the application of fire barriers for buildings with height up to 22 m. Further on, to demonstrate effectiveness of fire barriers to delay the spread of fire, results of large scale fire testing performed on EPS based ETICS specimens with and without fire barriers are shown.

Keywords: fire safety, facades, fire barriers, large-scale testing, ETICS systems

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1. INTRODUCTION

Having joined EU, Croatia has accepted the entire acquis, including all the obligations and regulations on energy efficiency in building construction. Current plans on energy renovation of buildings in the Republic of Croatia are aimed at gradual and systematic energy renovation of the existing buildings. The main assessment criteria are the reduced CO_2 emission and the reduced consumption of energy used for heating, cooling, air-conditioning, ventilation and water heating in buildings.

Among several possible technologies to thermally enhance building envelopes, *External Thermal Insulation Composite Systems* (ETICS) are the most commonly used façade systems in Croatia, as in entire Europe [1]. Thermal insulation materials used in ETICS systems can be either non-combustible or combustible.

With the goal of reducing energy consumption, the regulations are constantly getting stricter on thermal properties of construction elements in façades. Since the thickness of the insulation layer has been at least doubled, compared to former requirements, with a tendency of further increase (with the aim to reach the goals in 2020), total fire loads have been increased, especially if combustible thermal insulation materials are installed on a façade. Thus, the duration of fire and its extinguishing is extended, which ultimately increases the risk of fire spread on façades, and its transfer into the interior of buildings, respectively, onto surrounding buildings.

The objective of fire protection measures regarding façades is the prevention of fire spread to more than two floors above the floor where the fire started before the firefighters' intervention. The firefighters' intervention should prevent falling of the combustible parts of a façade or larger parts of an external wall [2].

Lately, there are a lot examples of fire spread across façades, where the worse one was fire occurred in west London tower block. In Croatia, fire incident that caused a lot of debate about proper use of combustible insulation materials in façades is fire occurred at Cvjetno Naselje student dormitory in February 2017 (Figs. 1a and 1b). The exact cause of this fire is not yet known. However, per the photographs of the fire, it can be claimed that the fire started on the roof of the lower building and vertically spread along the façade of the adjacent building towards upper three floors. Combustible thermal insulation material installed in the ETICS façade system and a strong wind promoted the spread of flame and smoke across the façade. Luckily, fire occurred during the day, when most of the students were outside the building and because of fast firefighters intervention, it was extinguished without any human victims.

Fig. 1. a) student dormitory during fire b) the façade after the fire was extinguished [3,4]

2. MECHANISMS OF FIRE SPREAD OVER FAÇADES

There are three typical scenarios of fire spread across façades [5]:

1. Spread of the external fire onto combustible façade by radiation from the neighboring, separate building,

2. Spread of the external fire onto combustible façade from the source of fire located next to the façade, with the consequence of radiation or direct exposure to fire (litter on the balcony, parked cars etc.),
3. An internal fire that has started in a space inside a building spreads through openings in the façade (windows, doors etc.) onto higher and lower stories.

The most often, fire initiates inside buildings and spreads through the openings across its façade. Namely, if there is a fast intervention (either by firefighters or by a sprinkler system) a fire in an indoor space can develop to flashover phase, when the flame is most likely to come out through the openings on the façade (windows or doors). By the time glass breaks and a fire breaks outside, flames can reach up to 5 m above the edge of the opening regardless of the façade system and the type of material used, which is very influenced by airflow speed in the vicinity of building.

The ″weakest″ part of façade presents the one located directly above the opening, lintel. Once the fire breaks outside through the window of the building with combustible insulation material built into the façade, it will cause the damage of the lintel and spread further across façade in accordance to mechanism presented in Fig. 2. That is why, one of the ways to slow down fire spread across façade till firefighter's intervention is to install fire barriers as it will be shown in the next section of this paper.

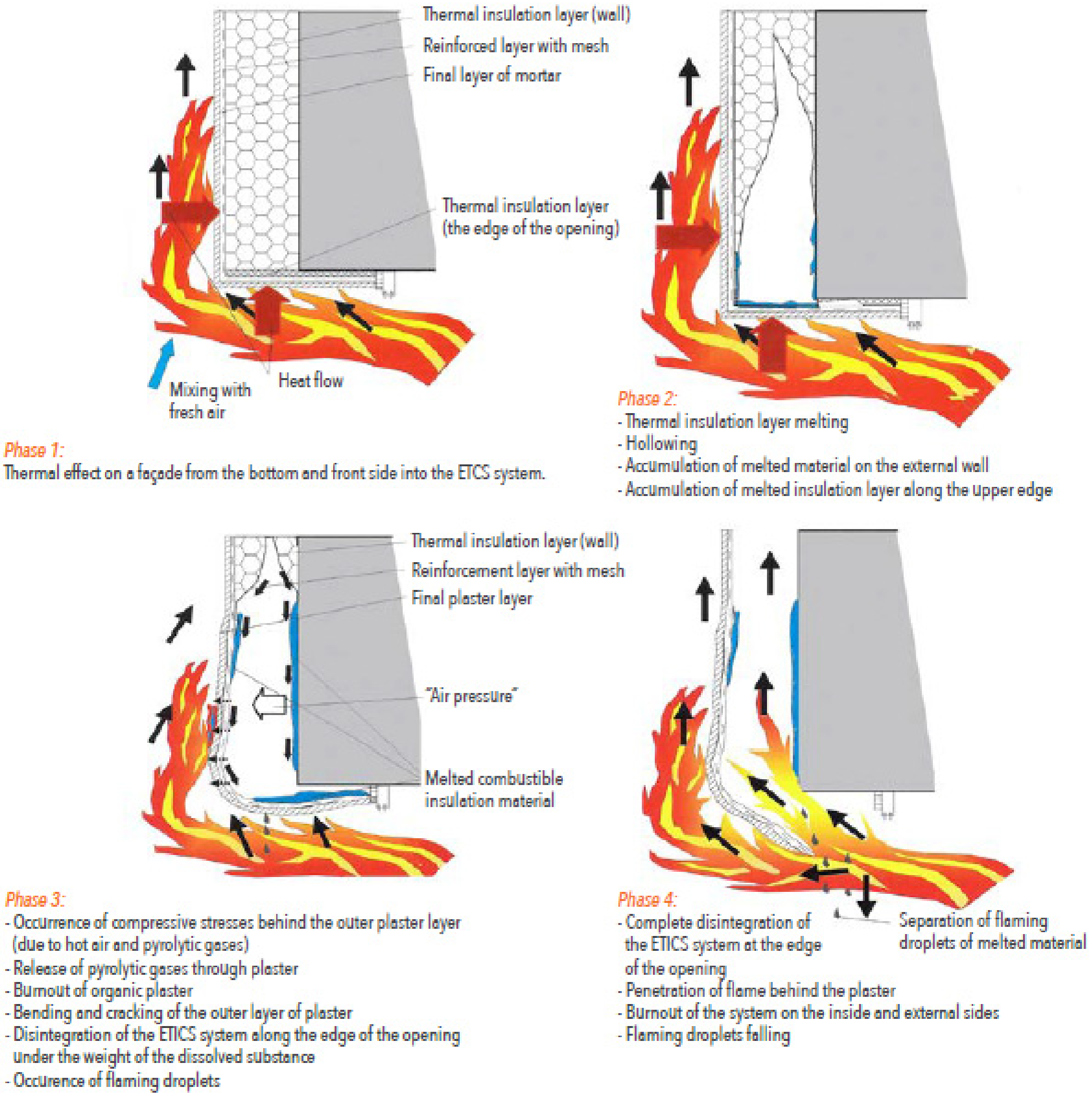

Fig. 2. Fire spread across façade above the opening [6]

3. CROATIAN REGULATIONS REGARDING FIRE PROTECTION OF FAÇADES

In the Republic of Croatia, the design of buildings in the area of fire protection in buildings is regulated by the Building Act (Official Gazette 153/13, 20/17), Fire Protection Act (Official Gazette 92/10) and a number of bylaws, the recognized rules in technical practice and standards (Fig 3.).

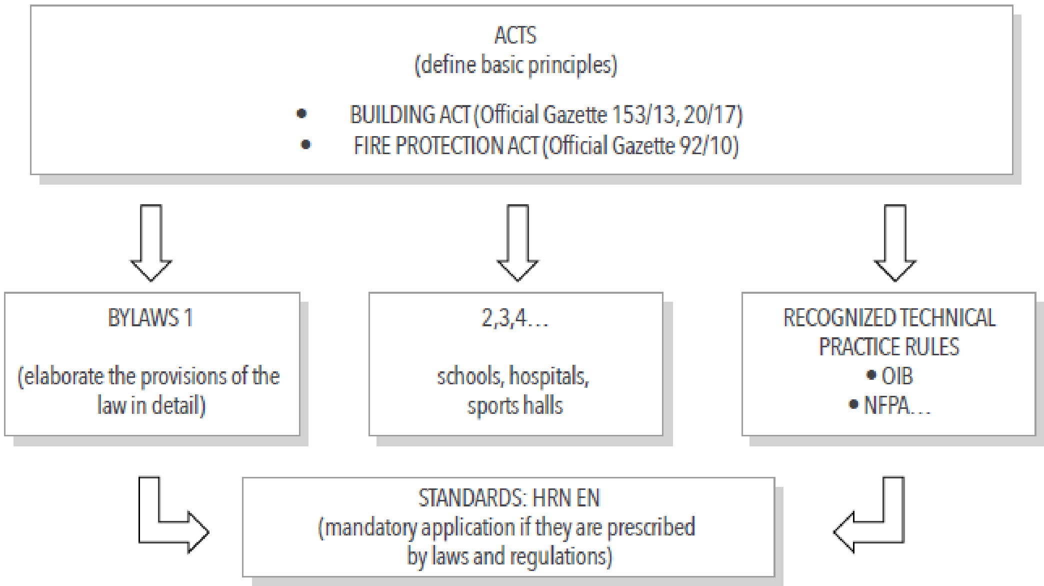

Fig. 3. Schematic representation of the Croatian regulations regarding fire protection of buildings

There are still some areas of fire protection, for instance, requirements for design of hospitals, schools, retirement homes etc. which have not yet been covered by Croatian legislation. *Ordinance on fire resistance and other requirements for buildings in case of fire* (Official Gazette 29/13 and 87/15, (hereinafter Ordinance), passed in 2013 and amended in 2015, is the basic bylaw for fire protection in buildings. It is harmonized with the European requirements. The Ordinance was defined as a basic module which has to be upgraded with the modules for the buildings of the above mentioned purposes (schools, hospitals, nursery homes, etc.). Recognized rules in technical practice will be applied for these purposes until relevant Croatian regulations are brought, of which most often NFPA 101, *Life safety code* (NFPA – National Fire Protection Association) [7] or Austrian guidelines OIB Richtlinie 2 (*OIB - Österreichisches Institut für Bautechnik*) [8]. These regulations define fire protection measures that have not been regulated by Croatian legislation, for instance, when determining the maximum allowed area of fire and smoke compartments or the need for systems of active protection (sprinklers, fire alarms etc.). However, if there exists Croatian legislation for fire protection, it is mandatory to apply thereof. Thus, the requirements from the above-mentioned Ordinance regarding reaction to fire of insulation materials for façades are applied.

In accordance to the Ordinance, all buildings are classified into subgroups according to the required level of fire protection, as presented in Table 1.

Buildings of special fire safety concern are those that belong to subgroup 5 and which include buildings which mostly consist of underground stories, buildings where immobile users or users with reduced mobility capabilities reside, users that cannot be independently evacuated (hospitals, retirement homes, psychiatric institutions and the like), and buildings with users with limited mobility for security reasons (prisons etc.), and/or single spaces where more than 300 users can gather.

Requirements /Subgroup	ZPS 1	ZPS 2	ZPS 3	ZPS 4	ZPS 5	High-rise buildings*
Height, h [m]	7	7	7	11	< 22	≥ 22
Total floor area, m^2	≤ 400	≤ 1200	No limit	No limit	No limit	No limit
Gross floor area of single business units/apartments	≤ 400	≤ 400	No limit	No limit if there is one residential or business unit ≤ 400 per residential/business unit	No limit	No limit
Maximum number of units	1	≤ 3	No limit	No limit	No limit	No limit
Number of users	≤ 50 total	≤ 100 total	≤ 300 total	≤ 300 total	≤ 300 total in single space	No limit

- special bylaw for high-rise building is under preparation

Table 1. Requirements for classification of buildings into relevant subgroups according to the required fire protection

Regarding to fire behavior of façades or façade elements, requirements are set upon reaction to fire properties as shown Table 2, where requirements for thermal contact systems of façades or ETICS system is shown.

Requirements /Subgroup	ZPS 1	ZPS 2	ZPS 3	ZPS 4	ZPS 5	High-rise buildings
Thermal contact systems of façades						
Classified system	E	D	D-d1	C-d1	B-d1	A2-d1
or						
Components of layers with the following classified element						
Finishing layer	E	D	D	C	B-d1	A2-d1
Insulation layer	E	D	C	B	A2	A2

Table 2. Required classes of reaction to fire in façades

As can be seen from the table, there is a difference depending whether the entire façade system has been tested and classified according to reaction to fire properties or whether the designer has planned the use of the individual tested and classified components of façade systems for which there are special requirements for the reaction to fire class.

Due to special fire safety problems related to high-rise buildings (i.e. prolonged evacuation, rescue is not possible from outside, risk associated with vertical spread across façades, firefighting difficult from inside of the building etc.), there is requirement for usage of only non-combustible materials for façade application, while for the buildings belonging to other subgroups, the use of combustible materials in façade systems is allowed.

In addition to requirements based on reaction to fire classes presented by the table 2, in case of buildings that belongs to subgroup 4 and 5, when combustible materials in façades are used, it is further required to use fire barriers (materials of reaction to fire class A1 or A2-s1,d0). Dimensions and positions of fire barriers on the façades depends of many factors, but the most important is whether each floor of the building is considered as one fire compartment or the whole building is one fire compartment. In the latter case, fire barriers in the form of lintel protection above each opening (window, door etc.) or bands around building perimeter on each alternate floor are required. Positions and dimensions of mentioned fire barriers are presented in Figs. 4a and 4b [5].

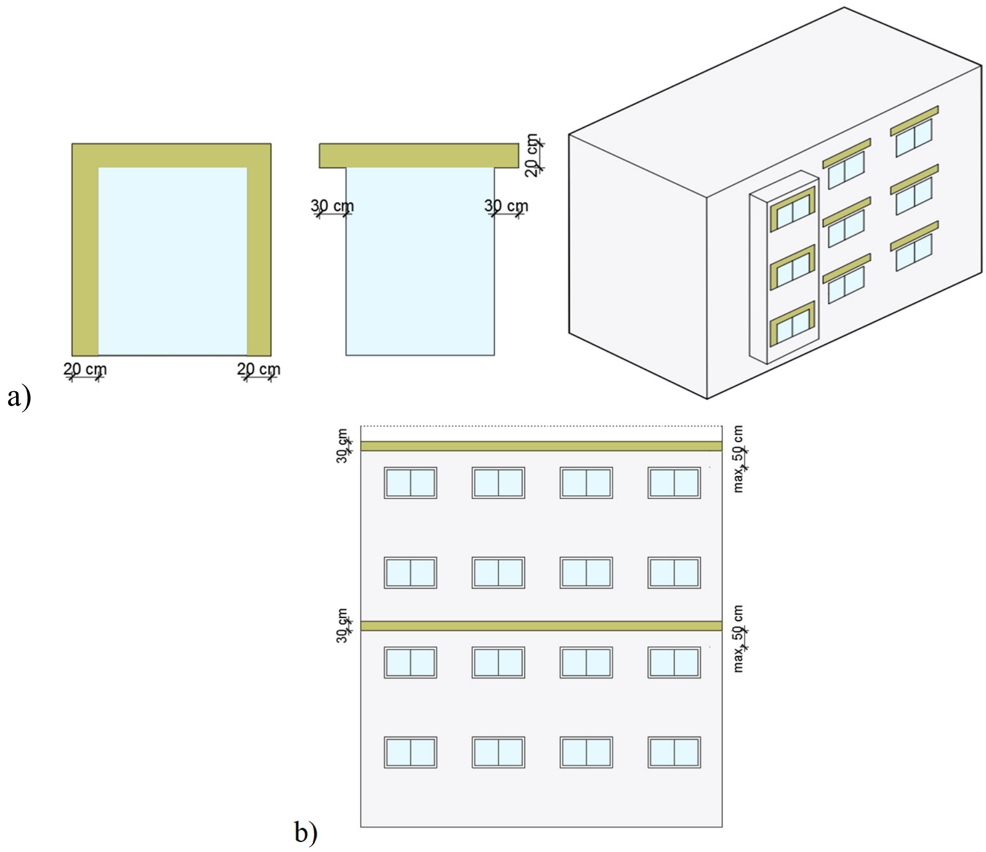

Fig. 4. Prevention of vertical fire spread by using fire barriers made of non-combustible insulation materials in the form of a) lintel protection b) continuous band around the building perimeter

4. EXPERIMENTAL TESTING

To confirm effectiveness of fire barriers made of non-combustible materials (reaction to fire classes A1 or A2-s1,d0) in delay of fire spread across ETICS façades with combustible insulation, fire behavior of two large-scale specimens were assessed. The only difference between test specimens was the fire barrier made of non-combustible material (stone wool in this case) that was installed as lintel protection above the opening of one test specimen (as presented in Fig. 4a).

4.1. Test set-up

Composition of test specimens and their classification according to the reaction to fire properties, as declared by the manufacturer, is shown in Table 3.

Test specimen	Thermal insulation material and thickness	Render	Fixing method	Reaction to fire classification
TS_1	Expanded polystyrene (EPS) – 150 mm	Basic render reinforced with glass fibre mesh and final organic (acrylic) render – 5 mm	Adhesive and mechanical fixing	B-s2,d0
TS_2	Expanded polystyrene (EPS) – 150 mm + fire barrier 200 mm high; directly above combustion chamber			B-s2,d0 (A2-s1,d0 barrier)

Table 3. Description of test specimens

In the absence of a harmonized EU standard for large scale façade fire testing, fire performance of ETICS system in these tests was performed according to standard BS 8414-1 [9]. This standard describes a method of assessing the behavior of façade systems applied to the face of a building with a masonry wall as substrate and exposed to external fire under controlled conditions.

Both test specimens were L-shaped, 8 m high, with one leg 2.6 m long forming the main test wall (main face) and the other leg 1.5 m long forming the return wall (wing) as shown in Fig. 5. The L-shape of the specimen represents an internal corner of a building.

External thermocouples were positioned on the main face of the façade and on the wing, both at Level 1 and Level 2 (Fig. 5b) in accordance with BS 8414-1. Internal thermocouples were positioned at Level 2, on the main face of the façade and on the wing. Internal thermocouples required by BS 8414-1 were positioned at Level 2, on the main face of the façade and on the wing [10].

Since the tests were performed outside, the weather conditions, i.e. wind speed, wind direction and air temperature, were monitored in order to be able to take into account their possible influence on testing and obtained results. Air temperature during the test was within the range of 20.5 – 22.2 °C and the air velocity was within the range of 2.2 – 4.5 m/s in N, N – W direction. Direction of north is shown in Fig. 5a.

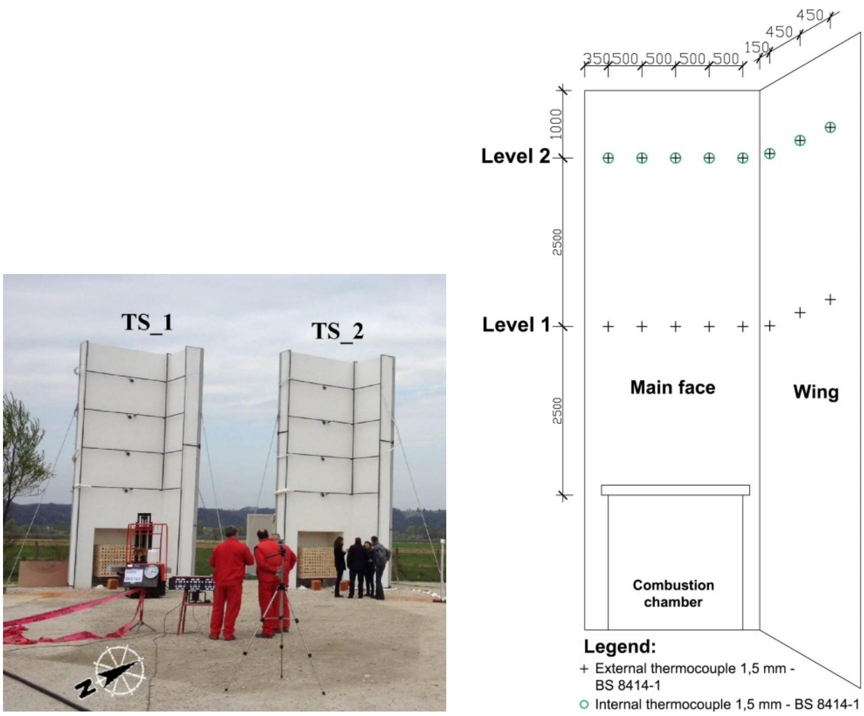

Fig. 5. a) Test specimens before the start of the testing and b) positioning scheme of thermocouples required by BS 8414-1

4.2. Test results

Test results will be presented in terms of developed temperature profiles and visual appearances of test specimens during and after the test. Figs. 6a and 6b present temperature profiles based on the average temperatures, measured according to the used standard with the external thermocouples embedded in test specimens at Level 1 and Level 2, respectively. Fig. 7 presents the average temperature measured within the thermal insulation layer at Level 2. Average temperatures in all figures imply an average of several thermocouples at the same level.

From Figs. 6 a and 6b, higher average surface temperatures can be observed on test specimens without fire barriers, TS_1 at both Level 1 and Level 2. As expected, obtained differences are higher at Level 1 (up to 300°C) compared to Level 2 (cca 150°C) because of the proximity of fire source, i.e. combustion chamber.

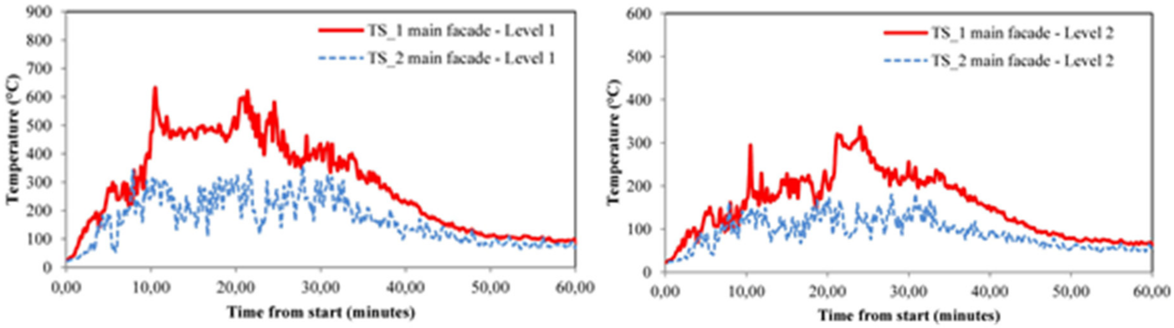

Fig. 6. Average surface temperatures on main façade at a) Level 1 and b) Level 2

Analysis of average temperatures within the thermal insulation layer shows that test specimen TS_2 has considerably lower temperatures compared to test specimen TS_1. Obviously, fire barrier has limited the fire development within the insulation material in test specimen TS_2 and temperatures remained below or around 100°C at Level 2. The adverse effect occurred on TS_1, i.e. the thermal insulation in this specimen was caught by fire where temperature peak rose up to 720°C (Fig. 7).

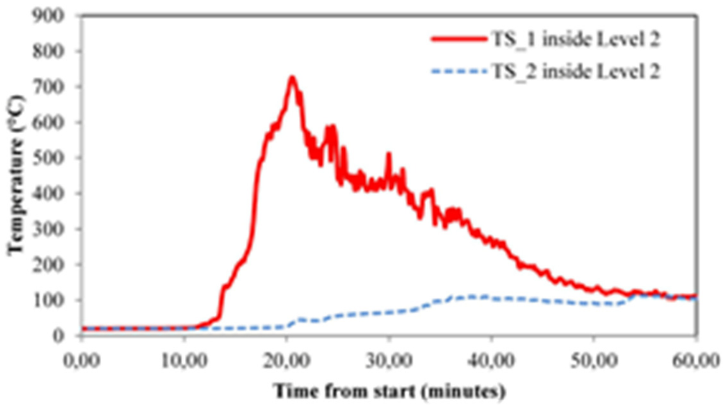

Fig. 7. Average temperature within thermal insulation layer at Level 2 on main façade

More than 60 minutes from the start, firefighters hosed down fire sources and all test specimens for safety reasons. Figs. 8-13 present the course of behavior of two façade systems during testing. From figures, it can be seen that only the glass fibre mesh and finishing render was left of test specimen TS_1, while the entire thermal insulation burned up in less than 40 min after the start of fire. At test specimen TS_2, once the fire propagated over the fire barrier above the combustion chamber, the thermal insulation started to melt and burning droplets fell down. The thermal insulation melted only partially at this test specimen.

Fig. 8. Start of the test

Fig. 9. 9 min from the start

Fig. 10. 19 min from the start

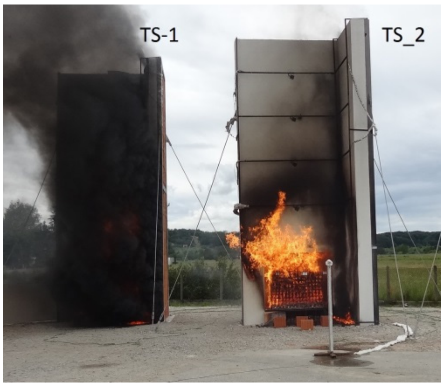

Fig. 11. 28 min from the start

Fig. 12. 37 min from the start

Fig. 13. 57 min from the start – wood crib has burned up

5. CONCLUSION

The first part of this paper present growing problem related to fire behaviour of combustible façade systems which satisfy the requirement for energy efficiency, but impose increased fire loads in buildings. Consequently, the duration of fire and its extinguishing is extended, which ultimately increases the risk of fire spread across façades, and its further spread into the interior of buildings, respectively, onto surrounding buildings. Apart from high-rise buildings for which use of non-combustible materials in façades is demanding, one of the possibilities to delay spread of fire across façades of buildings, in which combustible insulation materials is allowed, is to build in fire barriers at certain locations across façades.

In the second part of paper, the results of large scale testing in which the influence of fire barrier (made of non-combustible material with reaction to fire class A2-s1,d0) positioned above the window opening on the fire performance of an ETICS system with combustible insulation, (EPS), are presented. Results showed that the fire barrier has two major functions during the exposure to fire:

1. keeping the render and mesh in position longer delaying cracking of the render.
2. delaying the spread of fire and falling off the burning droplets.

However, the results also show as whereas a stone wool fire barrier can slow down and decrease the fire spread in EPS ETICS it cannot fully prevent the EPS from contributing in the fire development. Consequently EPS ETICS with fire barriers cannot be considered as fire safe as systems with non-combustible insulation and hence are not recommended for all building types, especially in buildings with users of reduced mobility capabilities as hospitals, retirement homes, kindergartens etc.

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