SYMPOSIUM DAY

Padova, 22 Novembre 2017

How to deal with the fire safety of facades in Croatia: research and experiences from the University of Zagreb

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POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI DI PADOVA

Comando Provinciale VVF Di Padova

CONTENT OF PRESENTATION

1. INTRODUCTION – link between energy efficiency and fire protection of façades
2. MECHANISMS OF FIRE SPREAD ACROSS FAÇADES
3. FIRE FAÇADE TEST
4. CROATIAN LEGISLATION REGARDING FIRE PROTECTION OF FAÇADES

Introduction – paradox?

- **1666: Great Fire of London**
  - Fire in the entire London that lasted for 4 days
  - Displacement of 70 000 people (out of 80 000 of all population)
  - 6 verified deaths

SOURCE: https://libcom.org/news/council-blamed-tower-blaze-deaths-14062017

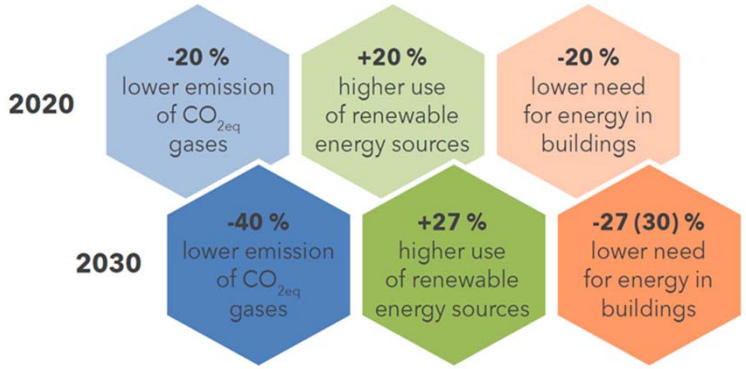
- **2017: Fire in Grenfell Tower**
  - Fire in a single 24-storeys building
  - 80 deaths

SOURCE: https://libcom.org/news/council-blamed-tower-blaze-deaths-14062017

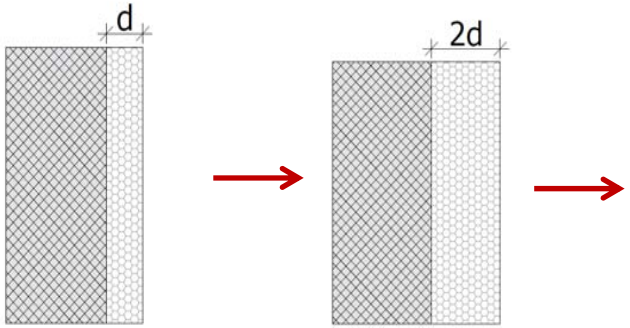
351 years of improving fire safety engineering ???!!!!

Introduction – link between energy efficiency and fire safety

Comparison of 2020 and 2030 goals for set by EU for energy efficiency in buildings:

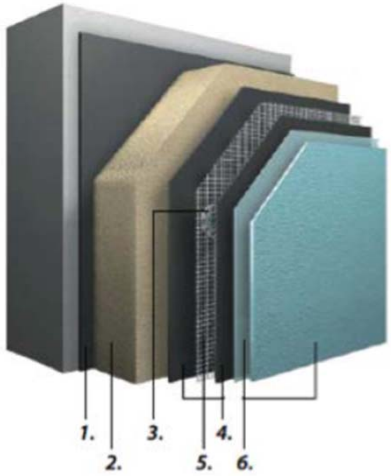


In order to satisfy above requirements, one of the modes is to **thermally enhance building envelopes.**



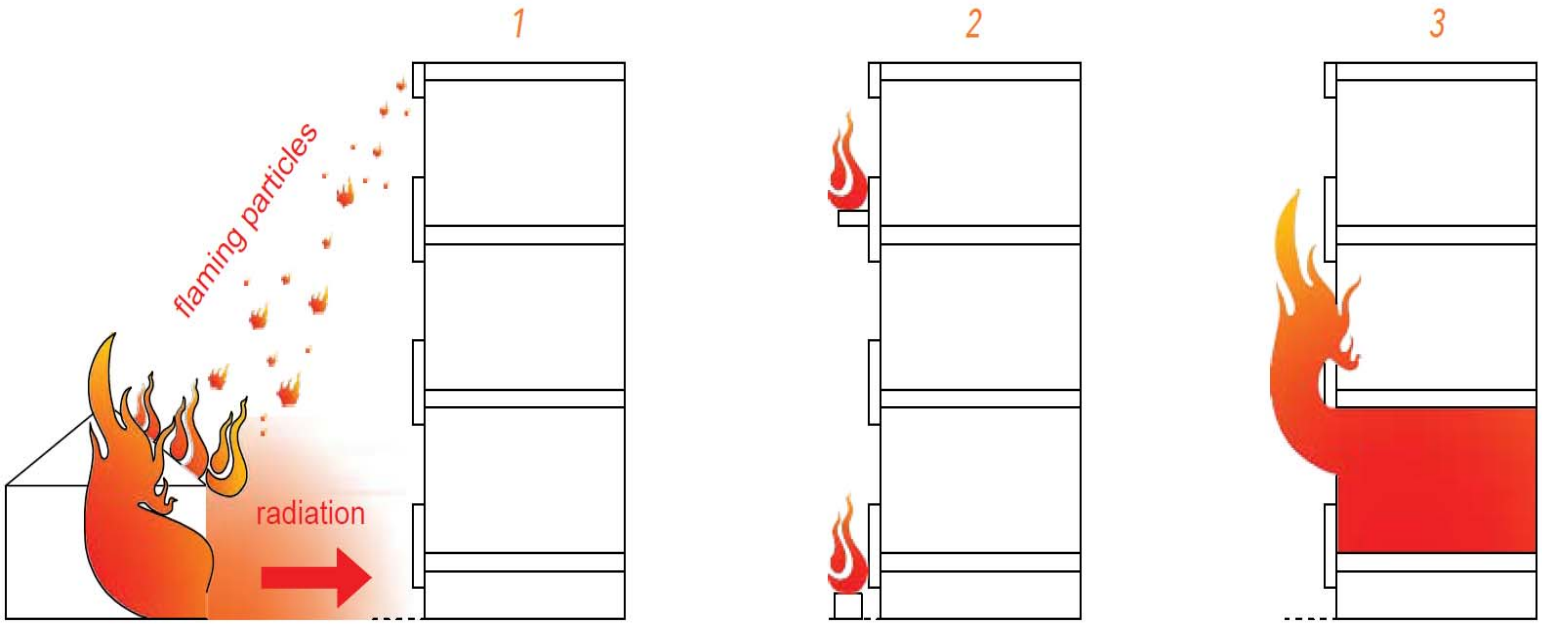
If combustible insulation materials is used, it leads to **increased risk of vertical fire spread across façades, especially in tall buildings**

Most common system to thermally enhance the building envelope in EU is **ETICS**



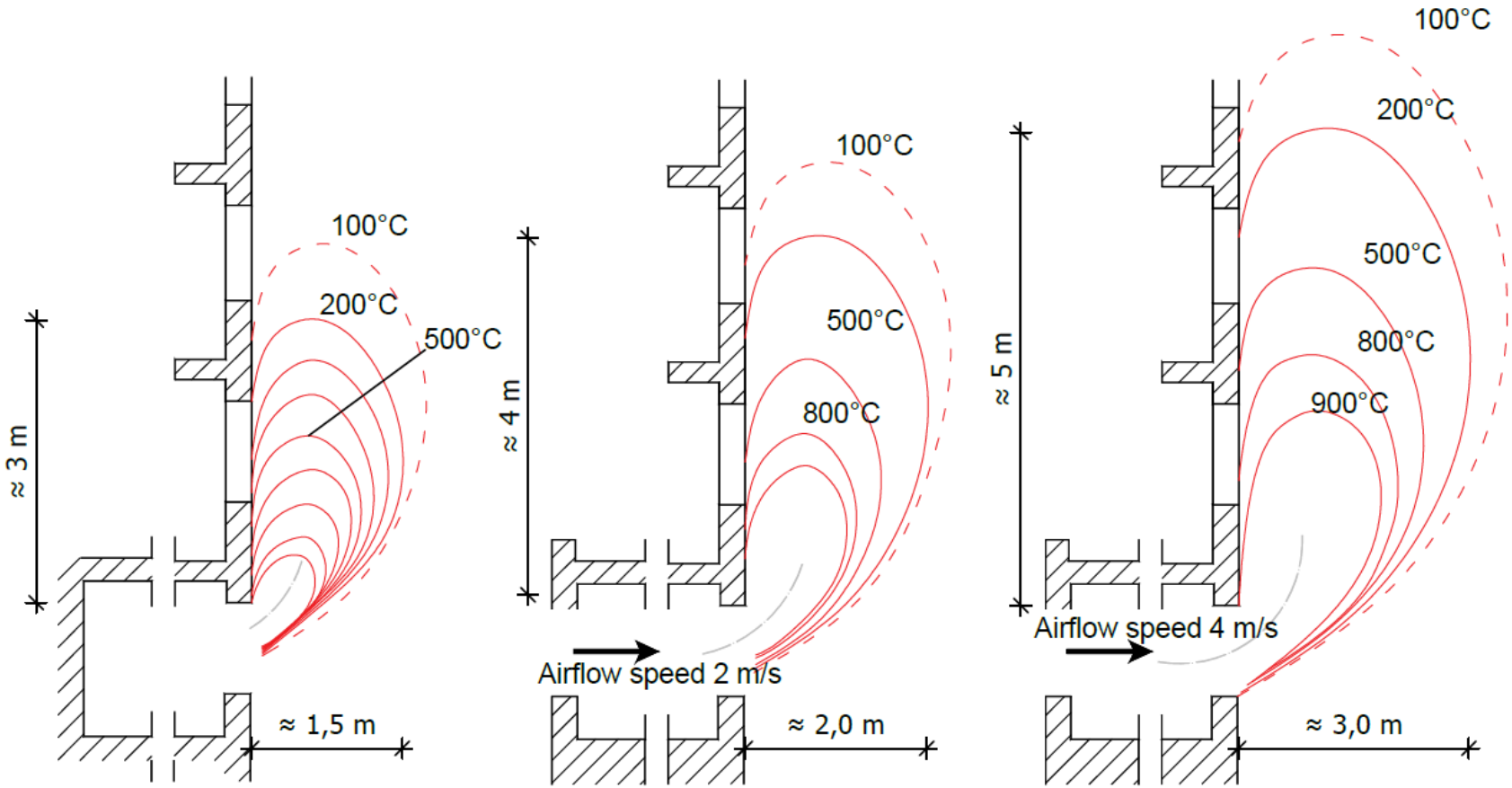
1. adhesive mortar
2. **thermal insulation material (combustible or non-combustible)**
3. mechanical fixings
4. mortar for reinforcement layer
5. glass fibre mesh
6. finishing layer

Three typical scenarios of fire spread across facades



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 or lower floors which is the most often case.

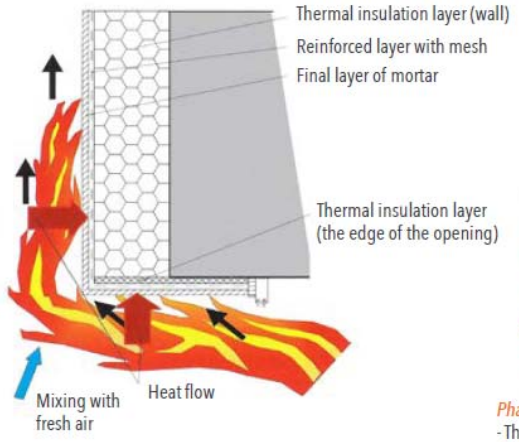
Flame heights with temperatures across façade depending on airflow



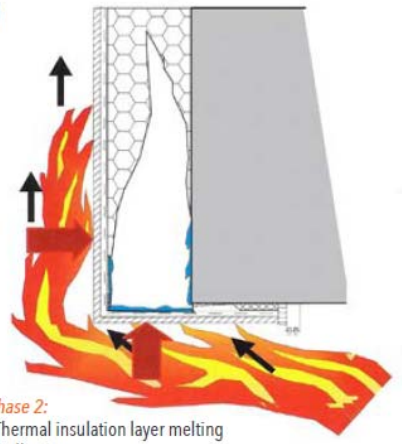
SOURCE: K. Kordina, C. Meyer-Ottens, *Holz Brandschutz Handbuch.* Deutsche Gesellschaft für Holzforschung e.V. (Hrsg.): Ernst & Sohn Verlag, 1995.

Fire spread onto facade throught openings

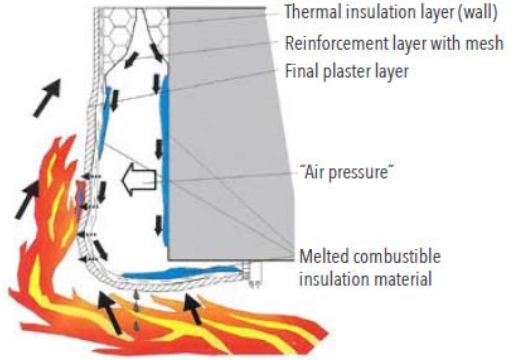
Figure Development of fire across a façade due to combustible thermal insulation *(J. Mayr, L. Battran, Handbuch Brandschutzatlas Grundlagen – Planung – Ausführung. FeuerTrutz, 2014)*



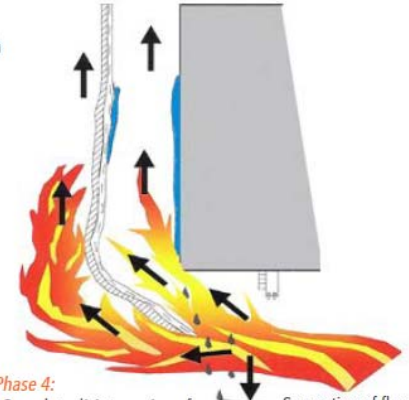
Phase 1:
Thermal effect on a façade from the bottom and front side into the ETCS system.



Phase 2:
- Thermal insulation layer melting
- Hollowing
- Accumulation of melted material on the external wall
- Accumulation of melted insulation layer along the upper edge



Phase 3:
- Occurrence of compressive stresses behind the outer plaster layer (due to hot air and pyrolytic gases)
- Release of pyrolytic gases through plaster
- Burnout of organic plaster
- Bending and cracking of the outer layer of plaster
- Disintegration of the ETICS system along the edge of the opening under the weight of the dissolved substance
- Occurence of flaming droplets



Phase 4:
- Complete disintegration of the ETICS system at the edge of the opening
- Penetration of flame behind the plaster
- Burnout of the system on the inside and external sides
- Flaming droplets falling

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

Figure spreading of fire across facade (Source: Khotoff, 2015)

FIRE FACADE TEST (FFT)

– Conducted on 28.5.2014. www.grad.unizg.hr/fft

- Organisers:

- Partners during testing:

- The testing was performed in accordance to: BS 8414-1:2002

Experimental testing

- **The main aim the experimental testing was twofold:**
  - To provide **deeper understanding** of the fire performance of ETICS systems with **combustible insulation**
  - To investigate whether and how the **fire barriers** constructed above openings **influence fire performance** of ETICS systems with combustible insulation

Results of testing are presented in the following scientific paper:

1. *D. Bjegović, I. Banjad Pečur, B. Milovanović, M. Jelčić Rukavina, M. Alagušić, "**Comparative full-scale fire performance testing of ETICS systems**", Građevinar, vol. 68, no. 5, pp. 357–369, 2016. doi: https://doi.org/10.14256/ JCE.1347.2015*
2. *Bjegović, Dubravka; Banjad Pečur, Ivana; Messerschmidt, Birgitte; Milovanović, Bojan; Alagušić, Marina. **Influence of fire barriers on fire performance of facades with combustible insulation** // 2nd International conference Fire Safety of Facades - FSF2016 / Vallerent, Stephanie (ur.). Lund: MATEC Web of Conferences, 2016. 05006-p.1-05006-p.11*
3. *Banjad Pečur, Ivana; Bjegović, Dubravka; Boström, Lars; Milovanović, Bojan; Hajduković, Milan. **ETICS Fire Performance Test** // Fifth International Workshop on Performance, Protection & Strengthening of Structures Under Extreme Loading "Response of Structures Under Extreme Loading" : proceedings / Kodur, Venkatesh K.R. ; Banthia, Nemkumar (ur.). East Lansing : DEStech Publications, Inc., 2015. 964-971…….*

Experimental methodology and set-up

- **BS 8414-1 test method** used as a ''guide'' (fire scenario: fire occurs inside a building and spreads to the facade due to venting through an opening)
- **Two tests performed** on identical test specimens

repeatability of testing → comparability of obtained results → confirmation of fire performance of tested systems

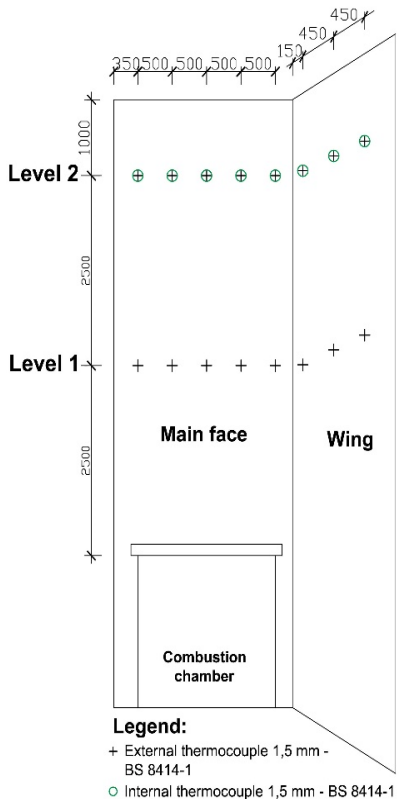
Table *Description of test specimens*

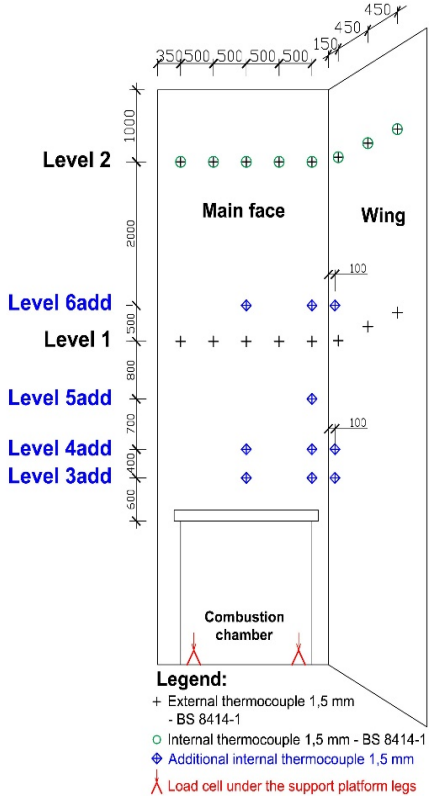
TEST SPECIMEN	Thermal insulation material and thickness	Render	Fixing method	Reaction to fire classification
TS_1	Expanded polystyrene (EPS) – 150 mm	Basic render reinforced with glass fibre mesh and final organic (acrylic) render – 5 mm	Bonded and mechanically fixed	B-s2,d0
TS_2	Expanded polystyrene (EPS) – 150 mm + fire barrier 150 mm thick x 200 mm high; right above fire chamber			B-s2,d0 (A2-s1,d0) barrier
TS_3	Mineral stone wool (MW) – 150 mm			A2-s1,d0

Lintel protection (TS_2)

Experimental methodology and set-up

- **Deviations** from BS 8414-1 test method: tests were performed outside and additional measurements were performed in addition to the standard temperature measurements defined by BS 8414-1





Experimental methodology and set-up

- Wood crib of TS_1 and TS_2 has been ignited at the same time with the aim that the fire development and fire spread on both test specimens could be visually comparable
- Weather conditions were monitored in order to be able to take into account their possible influence on testing and obtained results

Table *Weather conditions during Test 1 & Test 2*

Test	Air temperature	Air velocity	Wind direction
Test 1	11.2 – 12.3°C	1.8 – 5.4 m/s	N - E
Test 2	20.5 – 22.2°C	2.2 – 4.5 m/s	N, N - W

Test results

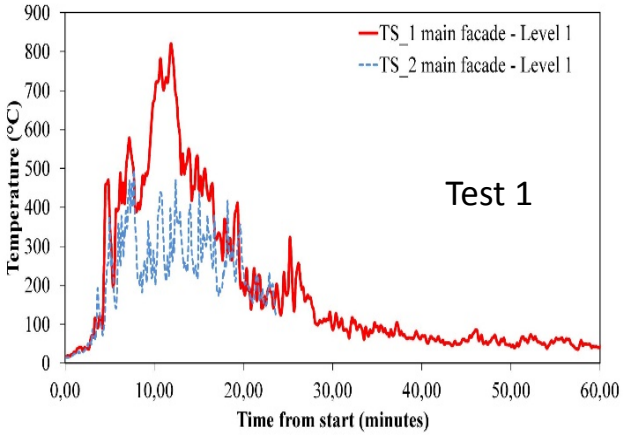
1. **Visual appearances on test specimens**
2. **Developed temperature profiles**

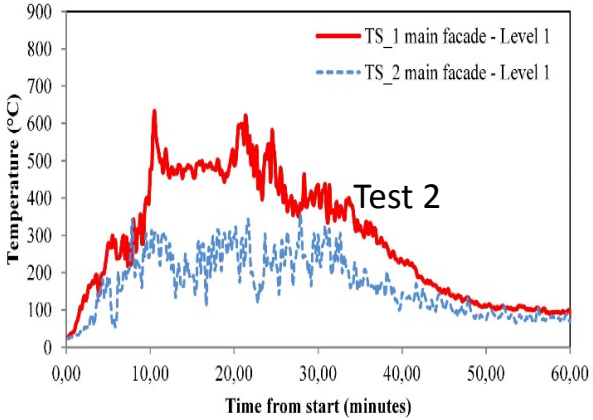
Indicating fire performance of ETICS systems with combustible thermal insulation, with and without SW fire barrier

- Comparison of test specimens TS_1 & TS_2 → influence of SW fire barrier on the fire performance of ETICS system with combustible thermal insulation

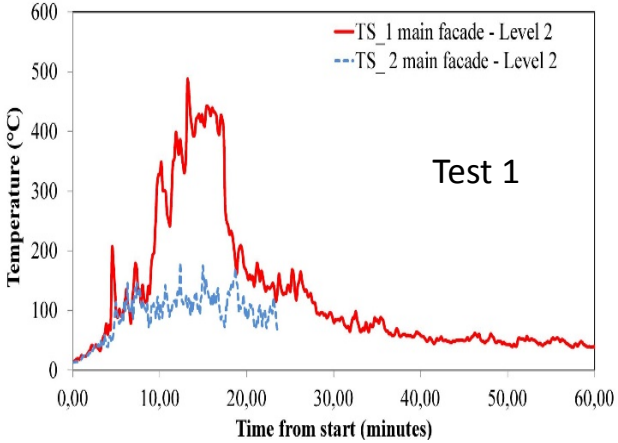
- Comparison of tests Test 1 & Test 2 → pattern of fire behaviour

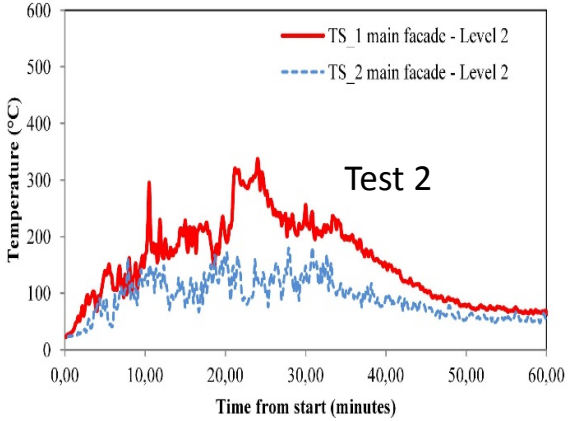
Test results – external thermocouples





Average surface temperatures at Level 1 on main facade





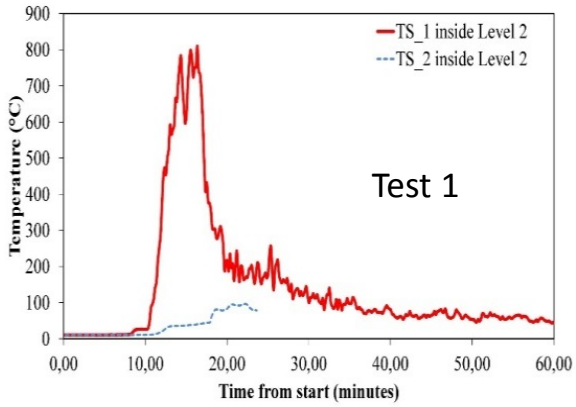
Average surface temperatures at Level 2 on main facade

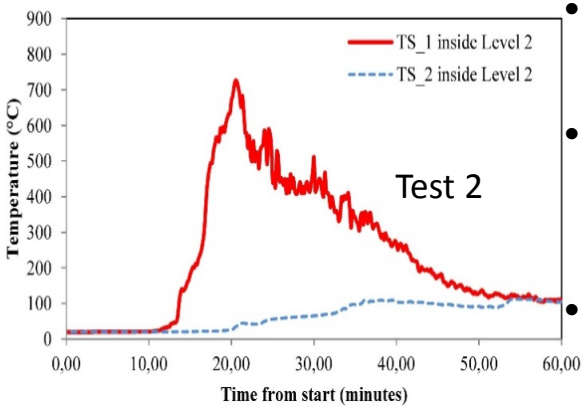
**Average temperatures imply an average of several thermocouples at the same level*

- Higer surface temperatures on TS_1 compared to TS_2
- Temperature profiles of TS_1 characterized with stronger peaks compared to TS_2
- Differences in developed temperatures during the Test 1 and Test 2 reach up to 200°C (Level 1) for TS_1 and up to 150°C (Level 1) for TS_2
- Differences in developed temperatures during the Test 1 and Test 2 reach up to 150°C (Level 2) for TS_1 and remain practically the same at Level 2 for TS_2

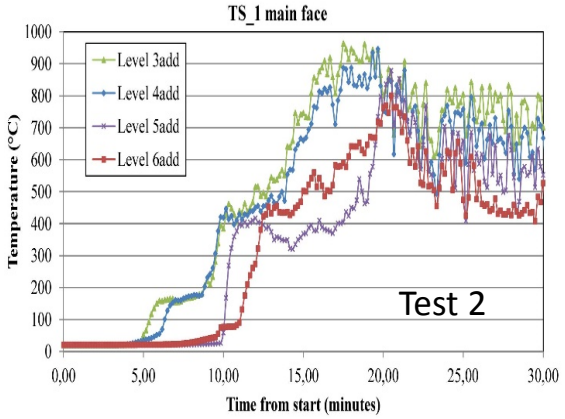
Caused by changes in weather conditions and different burning rate of fire source

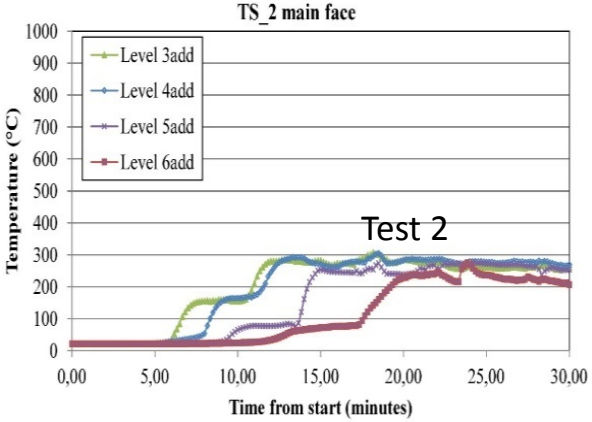
Test results – internal thermocouples





Average temperature within thermal insulation layer at Level 2 on main facade





Average temperature within thermal insulation layer at additional levels on main facade from Test 2

- TS_2 has considerably lower temperatures compared to TS_1
- Fire barrier has limited the fire development within the insulation of TS_2
- Peak temperature reached 800°C (Test 1) and 720°C (Test 2) within insulation of TS_1
- Time shift of first peak occurrence on TS_1 when comparing Test 1 and Test 2
- The same value of average temperature within insulation of TS_1 and TS_2 up to 8 min (Test 1) and up to 10 min (Test 2)
- Fire barrier caused the temperatures within insulation to stay below 300°C up to Level 6add (3 m above combustion chamber)

Conclusions of the fire test

- **Safety margin of ETICS systems with fire barrier are limited**
- 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.
- Results showed that the fire barrier has function to delay 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.
- **Thus, fire barriers are not recommended for all building types, especially in buildings with users of reduced mobility capabilities as hospitals, retirement homes, kindergartens etc.**

General scheme of Croatian legislation regarding fire protection

LAWS
(define general principles of fire safety)

- **Building Act** (NN 153/13)
- **Fire Protection Act** (NN 92/10)

Bylaws
(work out law provisions in details)

schools, hospitals, kindergardens etc. → recognized codes of technical profession (OIB, NFPA)

Standards: HRN EN
(compulsory if prescribed by regulations, optional otherwise)

When designing and executing a building, fire protection must be provided, as one of the essential requirements for buildings prescribed by a special regulation regulating physical planning and construction, so
that in case of fire:

1. *the load-bearing capacity of the construction can be assumed for a specific period of time,*
2. *the generation and spread of fire and smoke within the works are limited,*
3. *the spread of fire to neighboring construction works is limited,*
4. *occupants can leave the works or be rescued by other means,*
5. *he safety of rescue teams is taken into consideration.*

The most important: *Ordinance on Fire Resistance and other Requirements for Buildings in Case of Fire (Official Gazette 29/13, 87/15)*

Jelcic Rukavina M., Carevic M., Banjad Pecur, I.: **Fire protection of façades – Guidelines for design and execution**

- In accordance to ***Ordinance on Fire Resistance and other Requirements for Buildings in Case of Fire*** (Official Gazette 29/13, 87/15)
- Publication with overview of existing Ordinance, provisional proposals of new amandments and points of interest for the design and execution

University of Zagreb
Faculty of Civil Engineering

MINISTRY OF INTERIOR
CROATIAN FIRE PROTECTION ASSOCIATION
Student Association for Promoting Energy Efficiency and Consulting

Ministry of Construction and Physical Planning
MINISTARSTVO GRADITELJSTVA I PROSTORNOGA UREĐENJA

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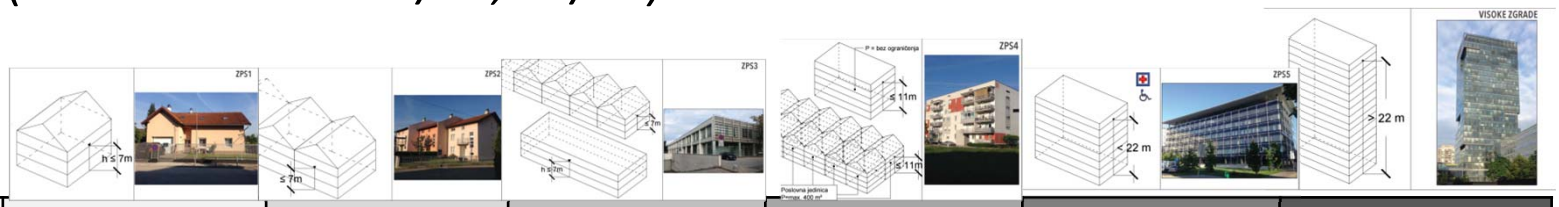
In accordance to Ordinance on Fire Resistance and other Requirements....(Official Gazette *29/13, 87/15)*: BUILDING SUBGROUPS



	ZPS 1	ZPS 2	ZPS 3	ZPS 4	ZPS 5	High-rise buildings
Height of the highest residence floor, h	7 m	7 m	7 m	11 m	< 22 m	≥ 22 m
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 a unit	No limit

In accordance to Ordinance on Fire Resistance and other Requirements....

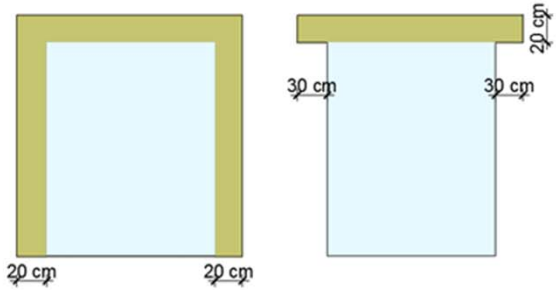
(Official Gazette *29/13, 87/15)*: REQUIREMENTS FOR FACADES **REACTION TO FIRE CLASSIFICATION**

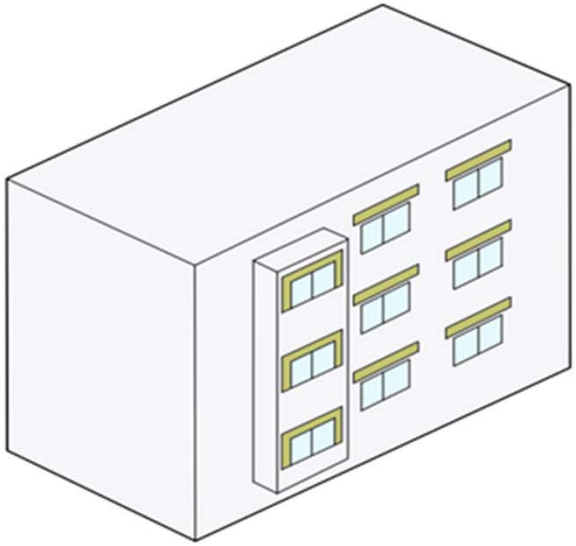
Building elements	**ZPS1**	**ZPS2**	**ZPS3**	**ZPS4**			**ZPS5**	**High-rise buildings**
Suspended ventilated façade systems								
Classified system	E	D-d1	D-d1	C -d1			B -d1	A2-d1
or								
Installation with the following classified components								
Finishing layer	E	D	D	A2-d1	or	B-d1	B-d1	A2-d1
Substructure								
– lined	E	D	D	D		D	C	A2
– pointed	E	D	A2	A2	or	A2	A2	A2
Insulation	E	D	D	B		A2	A2	A2
Thermal contact façade system								
Classified system	E	D	D-d1	C-d1			B -d1	A2-d1
or								
The composition of the layers with the following classified components								
– finishing layer	E	D	D	C			B-d1	A2-d1
– insulation layer	E	D	C	B			A2	A2

Additional requirements for ETICS facade of buildings that contain combustible insulation and belong to subgroup ZPS 4 and ZPS 5:

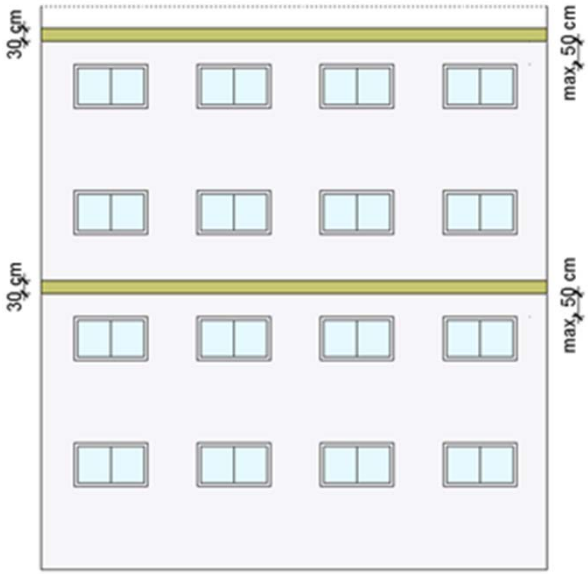
FIRE BARRIERS is a non combustible (reaction to fire classes A1 or A2-s1,d0) insulation structure used to break up continuous combustible insulation panel to hinder fire spread.

1. buildings considered as one fire compartment:



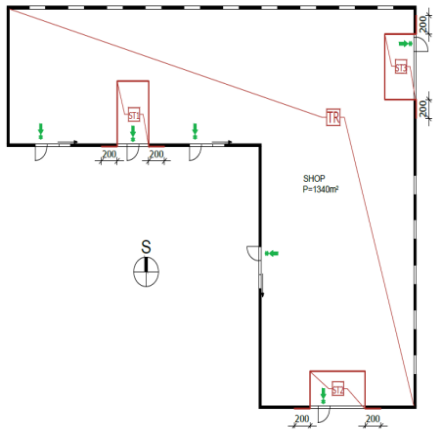


or

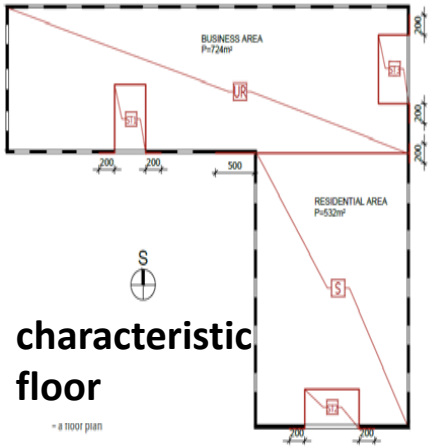


NON-COMBUSTIBLE INSULATION

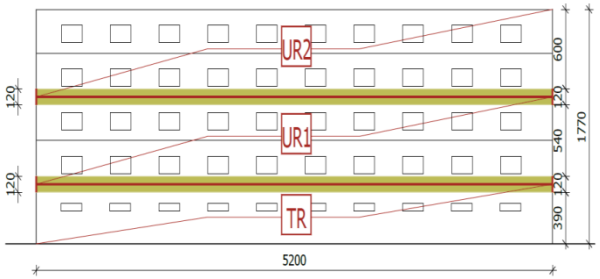
2. buildings with multiple fire compartmens



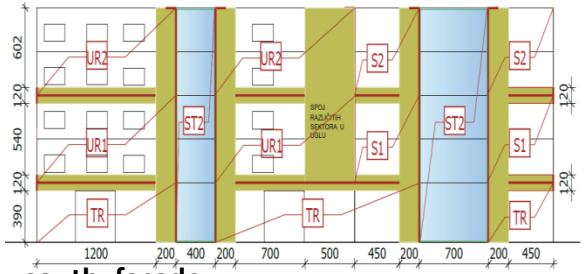
ground floor



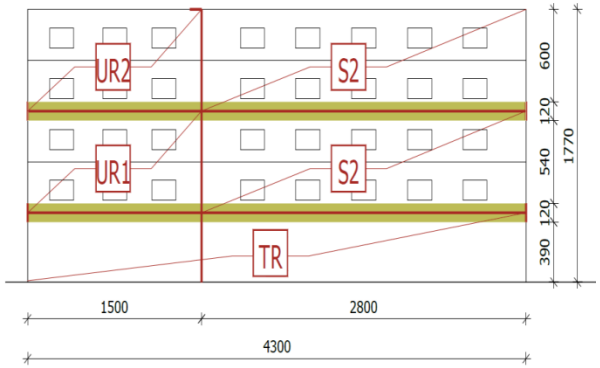
characteristic floor



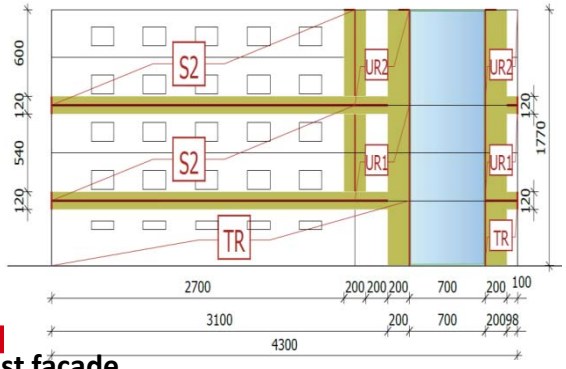
north façade



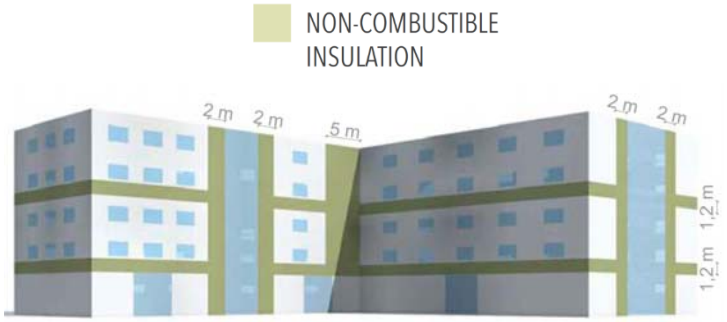
south façade



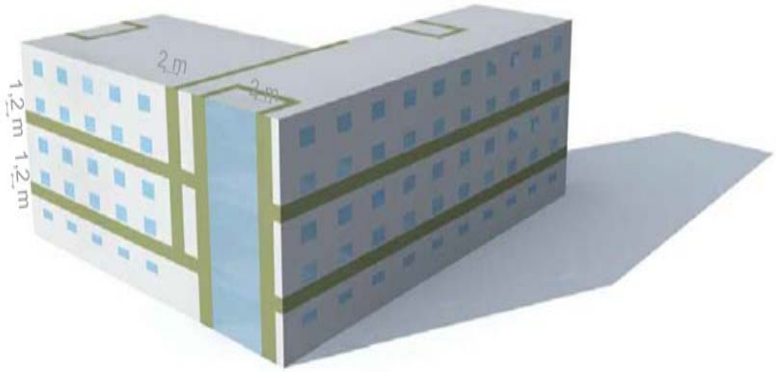
west façade



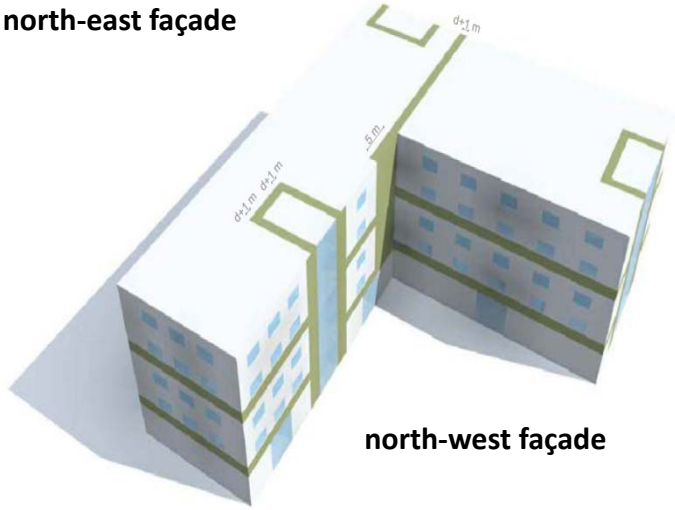
east façade



south-west façade



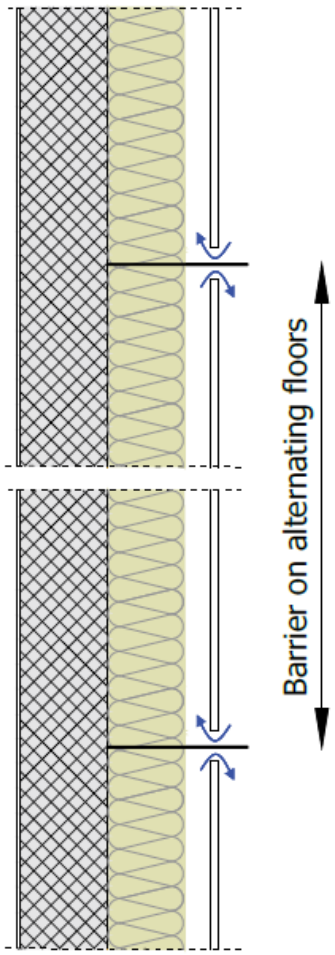
north-east façade



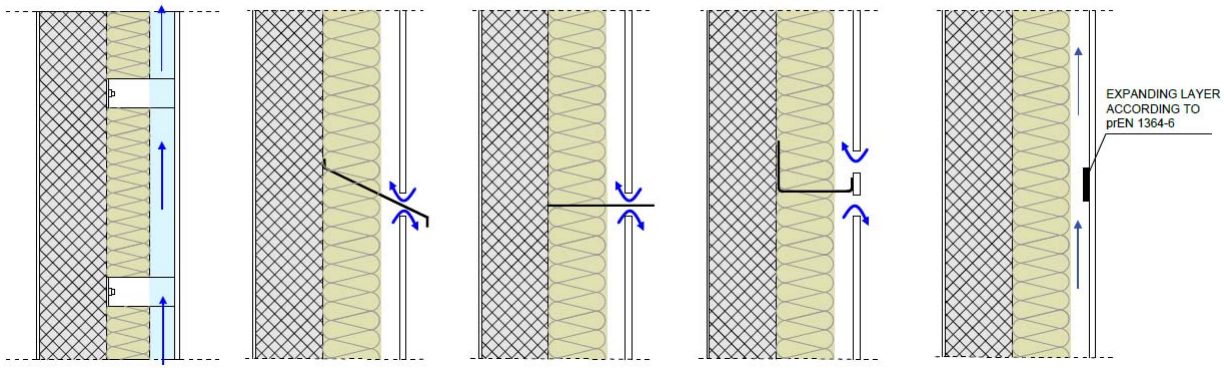
north-west façade

SYMPOSIUM DAY

Suspended ventilated façade systems



- When installing suspending ventilated façade elements it is necessary, when both combustible and non-combustible thermal insulation is used, to prevent fire spread through the ventilating layer through the openings in a façade or at least on every alternate floor along the entire perimeter of the building.
- This barrier in classified façade systems is installed according to the manufacturer's instructions, and in systems with individual components according to the accepted regulations in technical practice.



Example of fire incident in Croatia:

CVJETNO NASELJE STUDENT DORMITORY FIRE, ZAGREB, 2017

- **The fire that started on the roof of a student dormitory vertically spread along the façade of the adjacent building towards next upper three floors**
- **Combustible thermal insulation (EPS)** on **the renovated ETICS façade**
- **Strong wind definitely contributed to the fast spread of fire and smoke**

a)

b)

Figures a) Fire in student dormitory *b)* the façade after the fire was extinguished, source: CROPIX

General conclusions

- **Fire incidents around worls showed that occurence of fires is hard to prevent, but buildings can be designed, built and maintained in a more proper way which would increase safety of their users.**
- **The fire safety regulation unfortunately does not follow the pace of modern technologies and new materials. Things start to speed up only after a tragedy.**
- **There is a need for a close cooperation between political decision makers, researchers, experts, fire fighters and government in order to make sure that gap between fire safety legislation and ˝real-life circumstances˝ is as small as possible.**

Thank you for your kind attention!

Questions?

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