Fire behavior and fireproofing of building facade elements – Multi-scale study

Comportement au feu et ignifugation d'éléments de façade pour le bâtiment – Étude multi-échelle

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Project

- ANR project FRENETICS (Fire REsistaNce of External Thermal Insulation Composite Systems)

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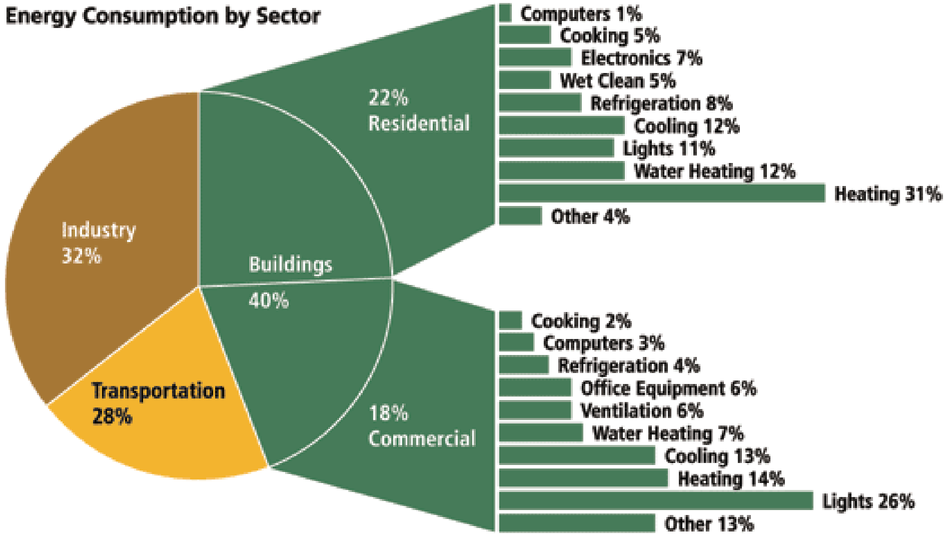
CATALOGUE

- Context
- ETIC System
- Test in lab-scale
- Test using test bench in small scale
- Test using test bench in intermediate scale
- Full-scale test
- Conclusion

Contexte



Increasing energy performance → Increasing building insulation

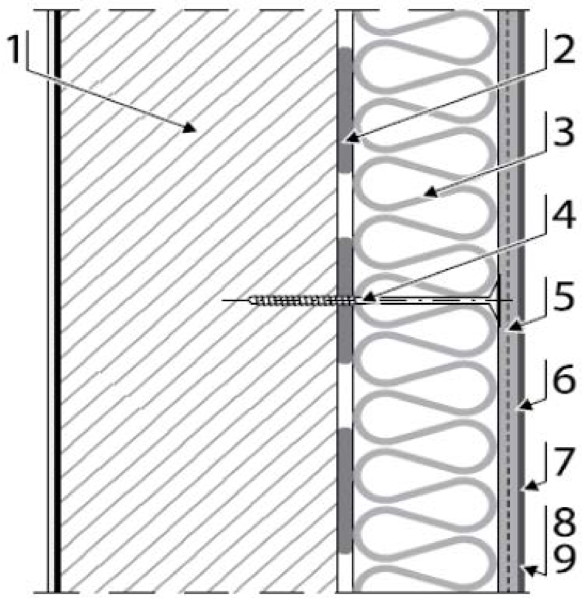
RT2012 et 2020

External Thermal Insulation (ETI)
plastic (PE, EPS, PIR. etc.)

- Limiting the thermal bridges between environment and building interior space
- Increasing the fuel mass

* https://www.seas.ucla.edu/~pilon/PCMIntro.html

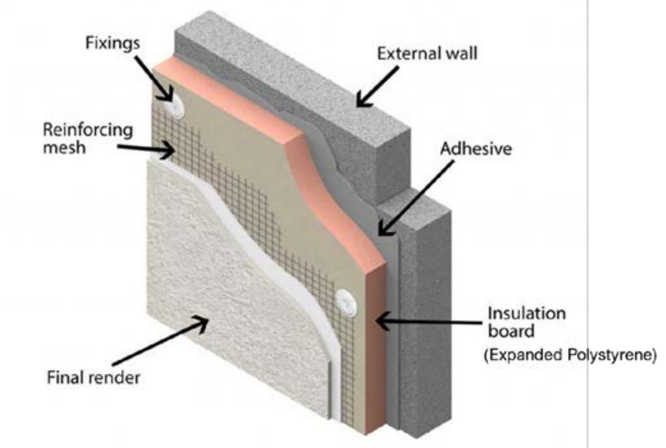
ETIC System Components

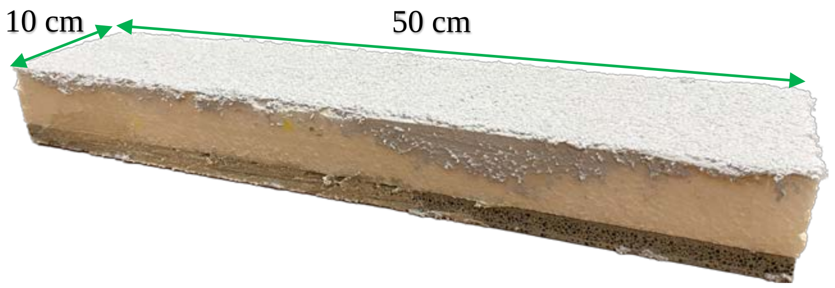


Category	Component Description
1. Wall structure (substrate)	Panel consisting of a cement core lightened by EPS beads
2. Adhesive	Cement-based adhesives modified with redispersible polymers, fibers, and mineral fillers
3. Insulation	Prefabricated EPS board
4. Anchor	If necessary, additional fixing
5. Reinforcement layer	Base coat with glass fiber mesh embedded
6. Key coating	If necessary
7. Finishing coat	Mineral render/ Acrylic render/ Silicone render/ Silicone-silicate render
8. Primers	Optional
9. Decorative coats	Optional

* Building Research Insitute. National Technical Approval ITB-AT-9090/2016 Zestaw Wyrobów do Wykonywania Ociepleˊnˊ Scian Zewn˛etrznych Budynków Systemem Atlas ETICS; Building Research Insitute: Warsaw, Poland, 2016

External Thermal Insulation (ETI)





Finishing coating	1.5 mm
Base coating	1.5 mm
EPS	40 mm
Cement board	12 mm

Finishing coating → Cement, silicone resin, mineral fillers and additives (68%Si, 14%Al, 9%Ca, 6%Mg)

Base coating → Sand, acrylic binder, mineral fillers and additives (53%Ca, 24%Si, 11%Al, 7%Ti)

} Incombustible

EPS → Expanded Polystyrene — Combustible

In lab-scale

- Investigation of thermal decomposition of ETI

STA (TGA+DSC)

Pyrolysis reaction: EPS – 1 step, Coating – 2 steps

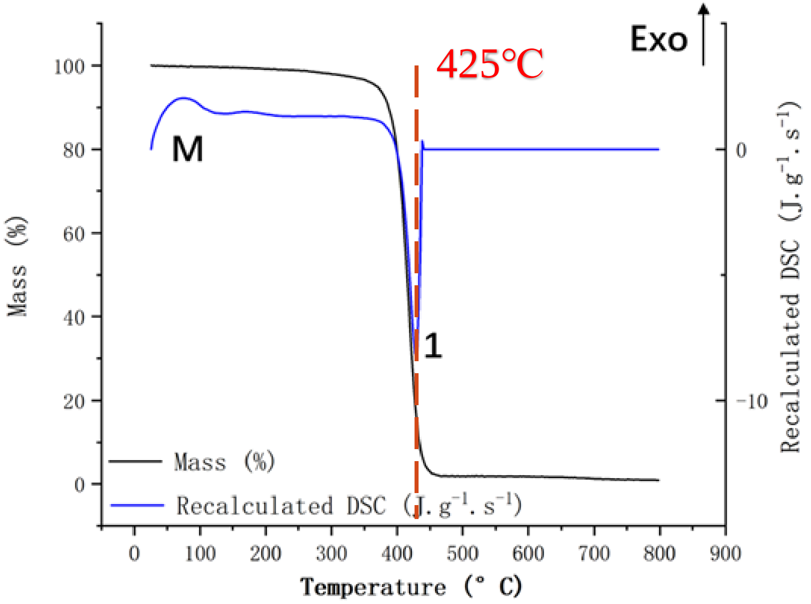


Fig.1 TGA/DSC curves of EPS in 10K/min in N2

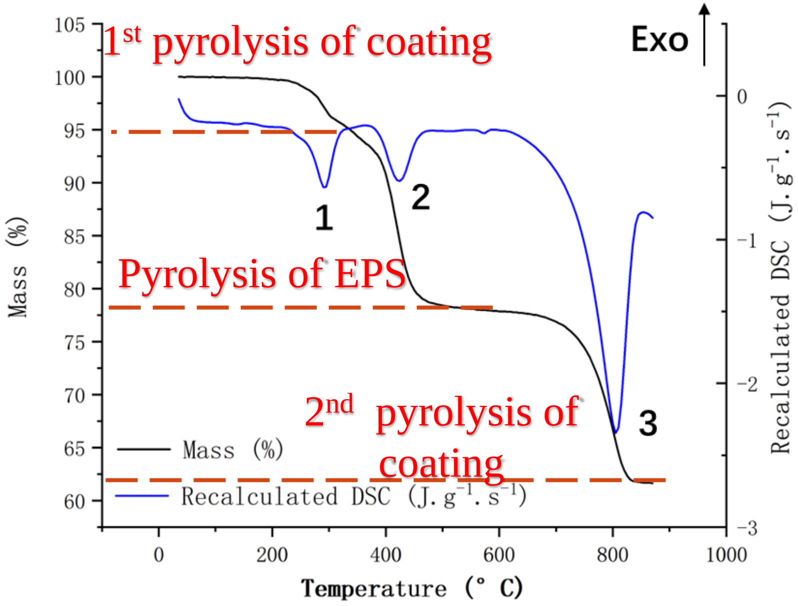


Fig.2 TGA/DSC curves of ETI in 10K/min in N2

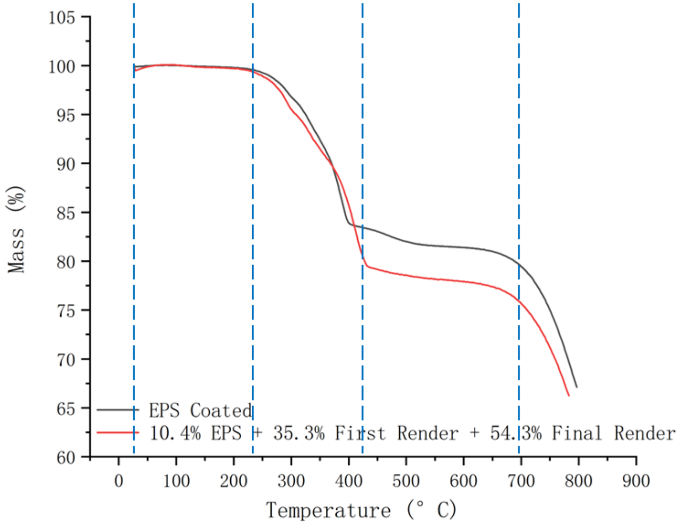
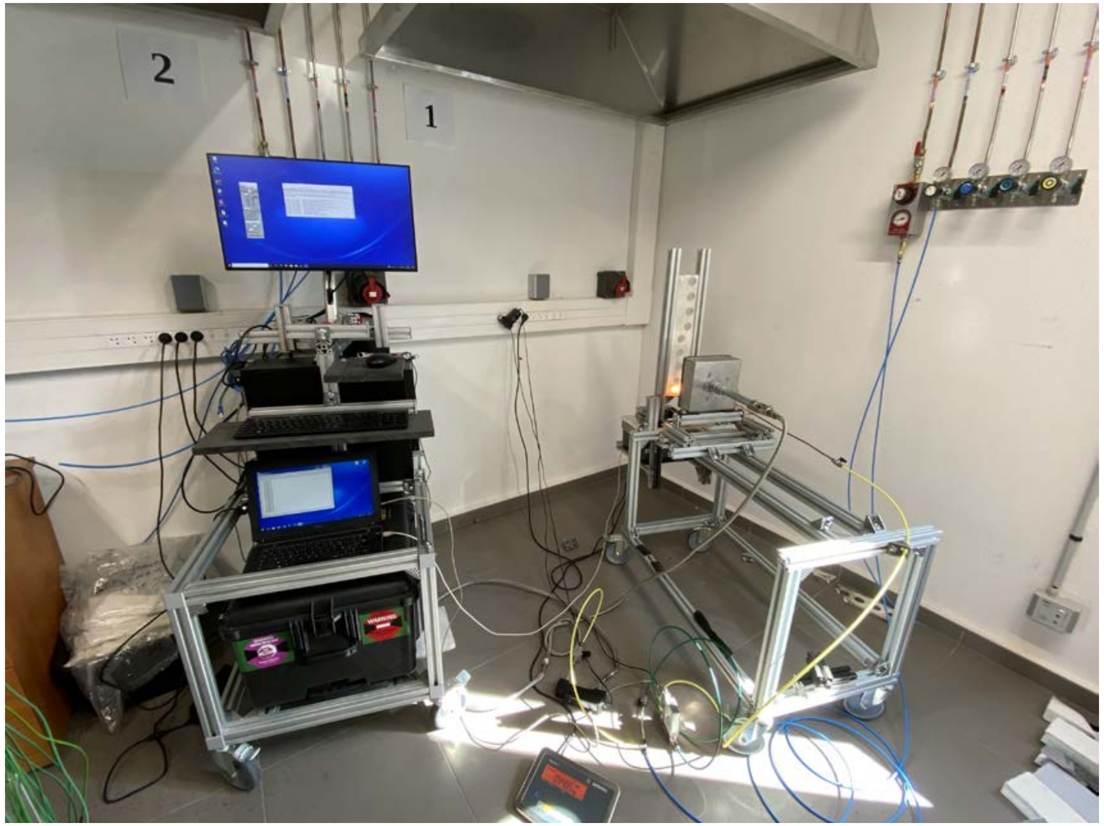


Fig.3 Comparison of TG measured and calculated

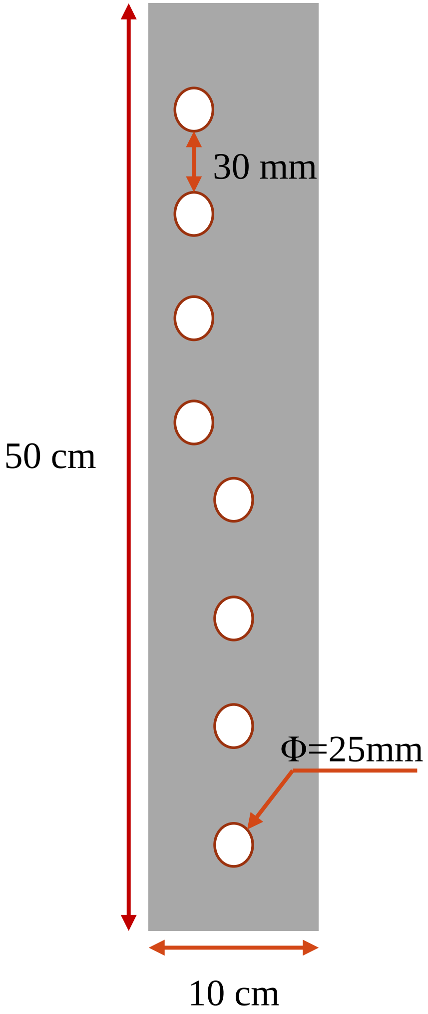
In small scale

- A test bench, with a horizontal and rotational motion, is developed to study the fire-facade interaction under controlled heat condition.

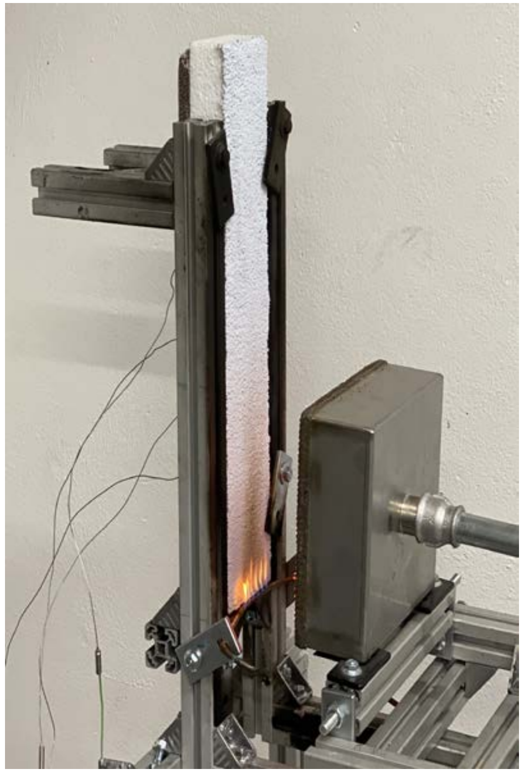


Measurement

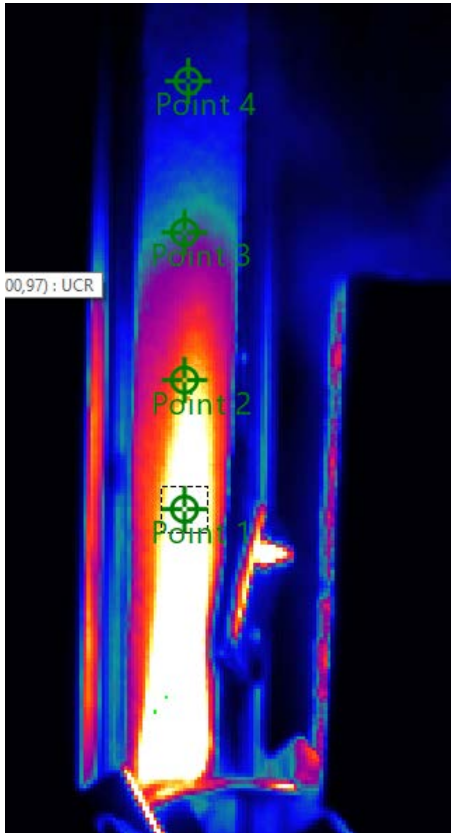
- Heat flux calibration



- Temperature monitoring



Thermal couple



IR Camera

Results

- Intensity of heat flow – 0° ,10cm

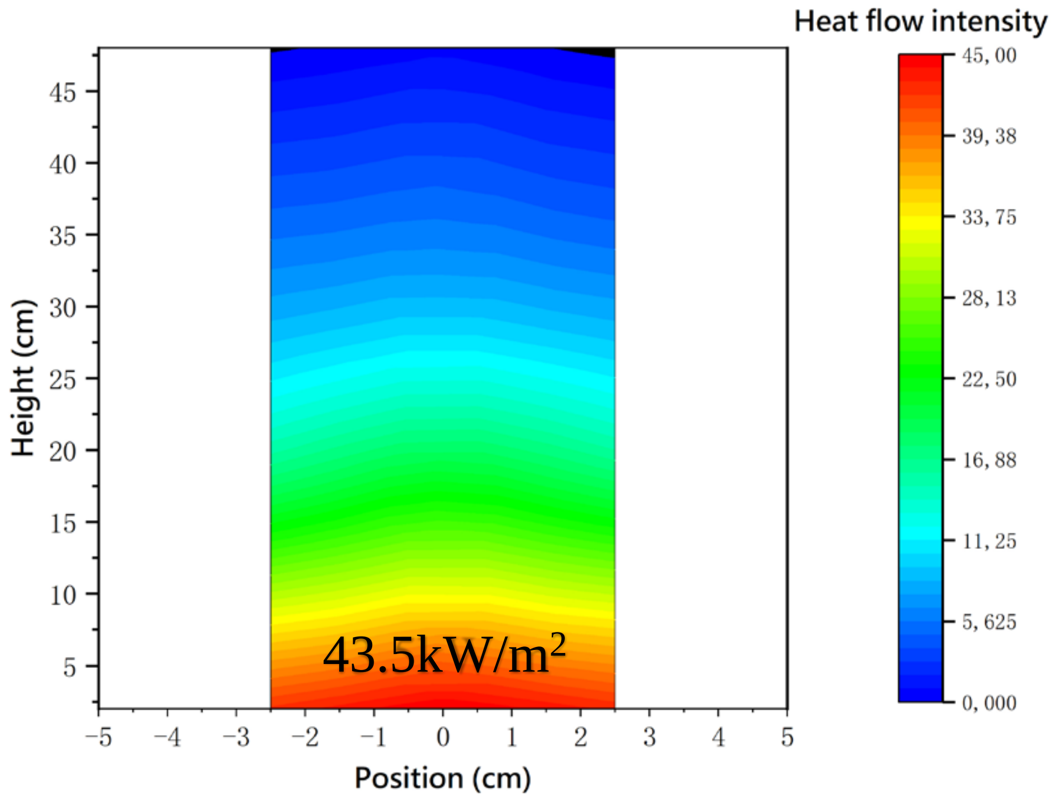


Fig.4 Intensity distribution of heat flow – 0° ,10cm

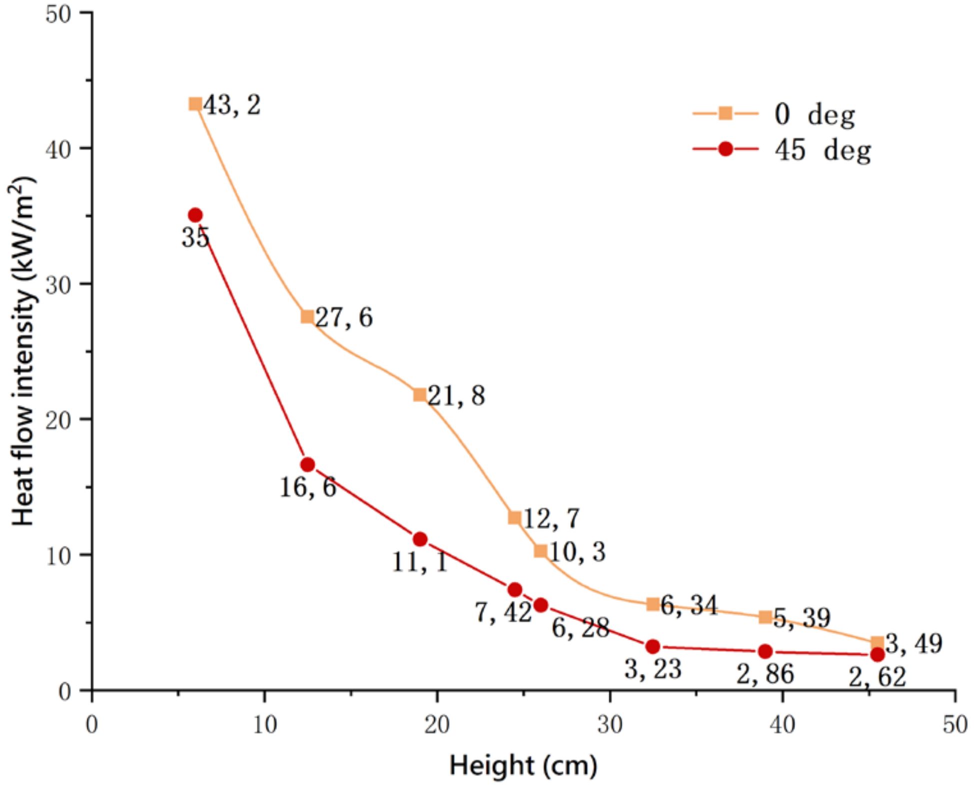
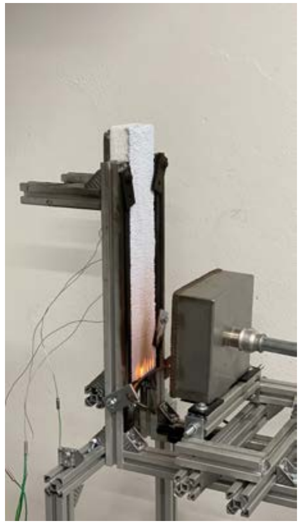


Fig.5 Intensity contrast of heat flow – 0° and 45°

Results

- ETI STO – 0°,10cm, 43.2 kW/m²

Finishing coating
Base coating
EPS
Cement board



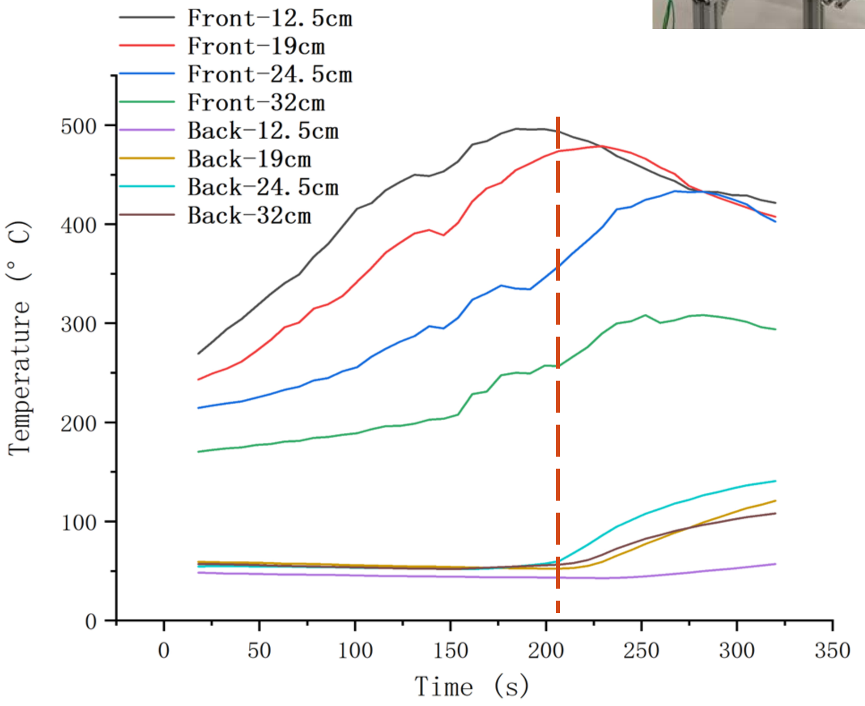


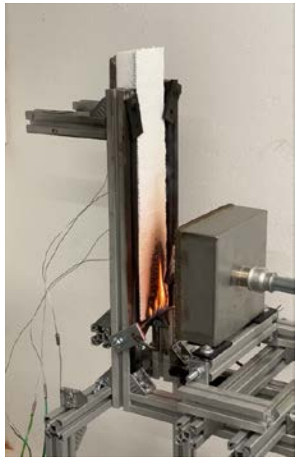
Fig.6 Temperature changes of ETI STO

Ignition observed
Initial mass: 294.23g (EPS 31.80g)
Mass after test: 265.54g -28.69g

Results

- ETI FlameOFF – 0°,10cm, 43.2 kW/m²

FlameOFF
Finishing coating
Base Coating
EPS
Cement board



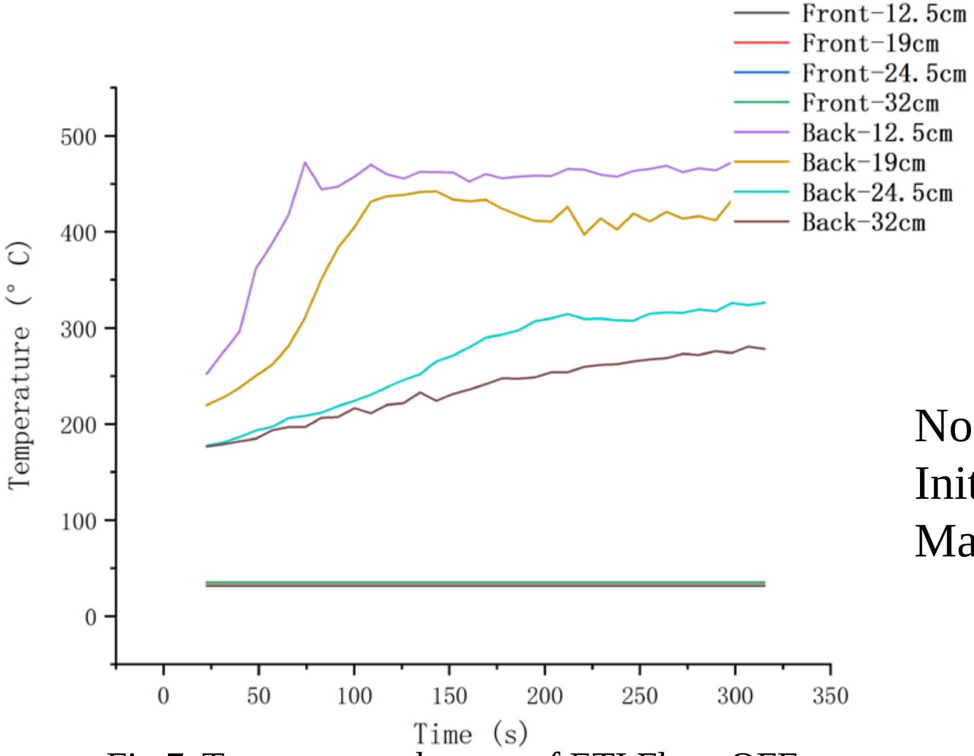


Fig.7 Temperature changes of ETI FlameOFF

No ignition

Initial mass: 294.63g (EPS 30.02g)

Mass aftertest: 288.19g -6.44g

Results

- ETI EG – 0°,10cm, 43.2 kW/m²

Finishing coating + Graphite
Base coating
EPS
Cement board

Component	Finishing coat STO	EG	Clay	Water
Concentration (Masse)	70%	6% => 8 %	4% =>5%	20%

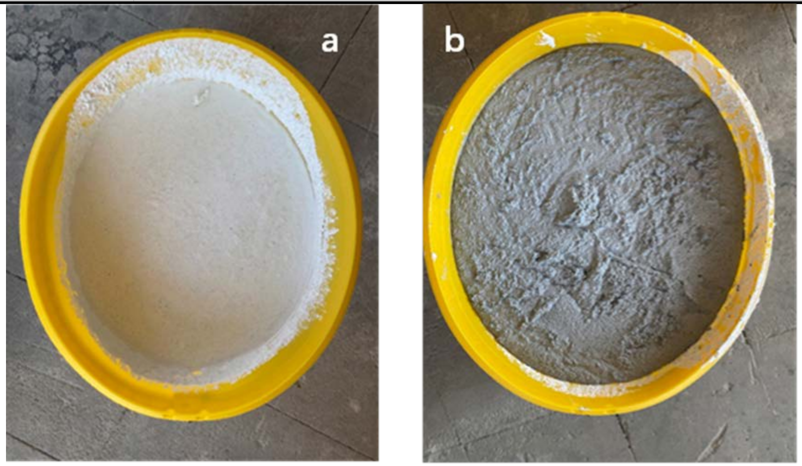
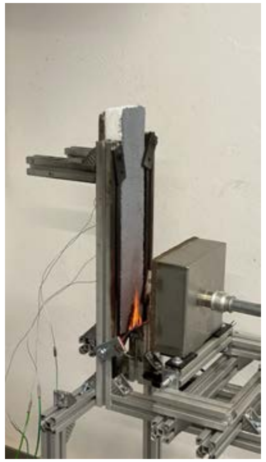
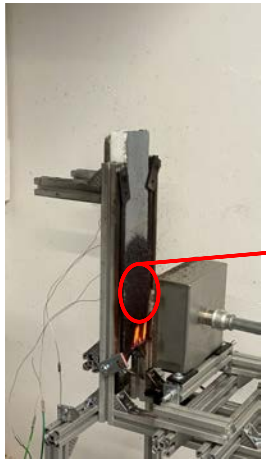


Fig.10 a) Enduit finition STO; b) Enduit modifié





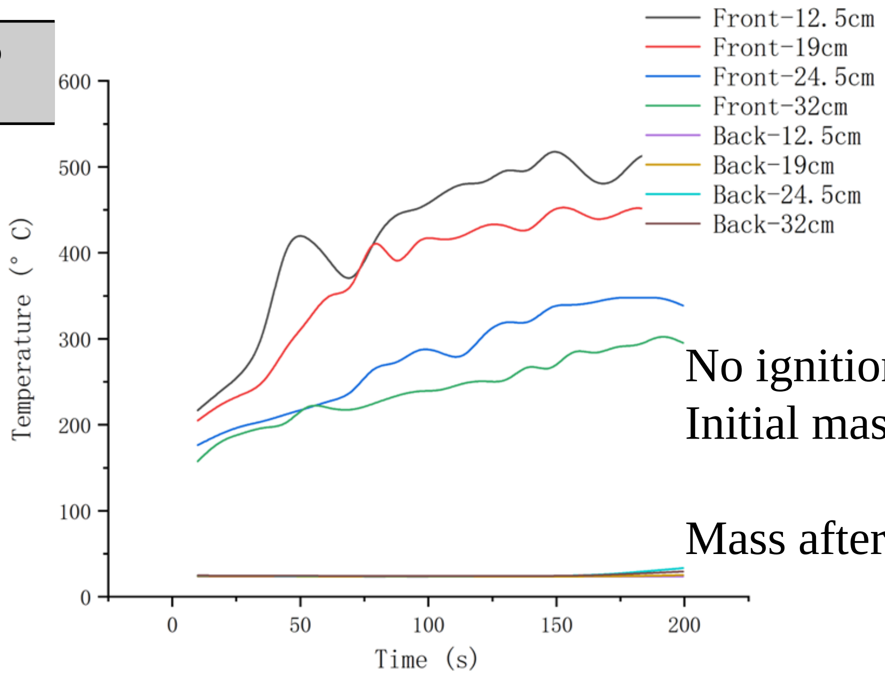


Fig.8 Temperature changes of ETI EG

No ignition

Initial mass: 285.05g (EPS 32.25g) (EG 23g)

Mass after test: 245.7g -39.35g

Discussion of flame retardant application

- Mixture of finishing coating and FR (Nitrogen-phosphorus based flame retardant)

APP 766 ✗

ADEKA ✗

- Painting FR **FLAMEOFF** ✓

FlameOFF
Finishing coating
Base Coating
EPS
Cement board

- Adding a FR layer **FLAMEOFF** ✗

Finishing coating
FlameOFF
Base Coating
EPS
Cement board

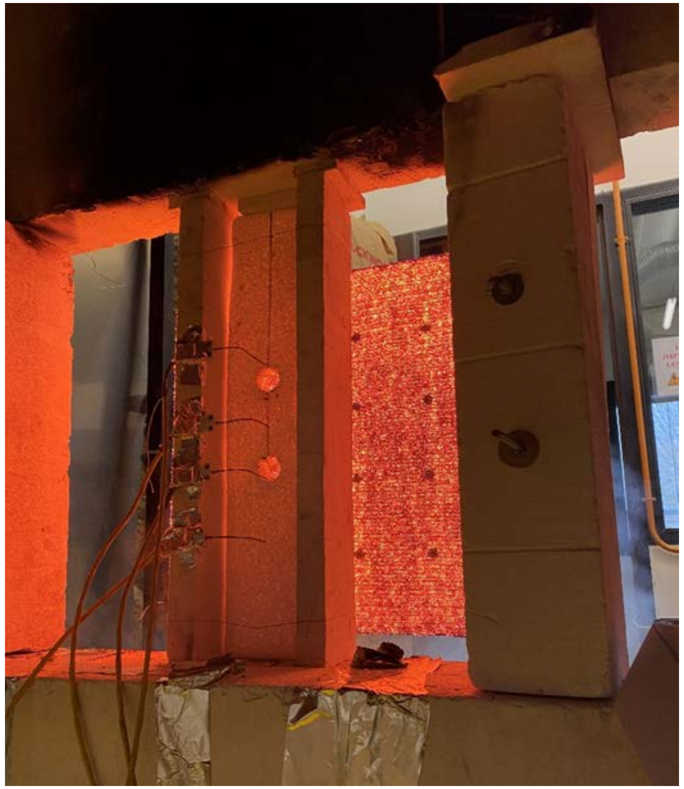
- Blending **expandable graphite** in the finishing coating ✓

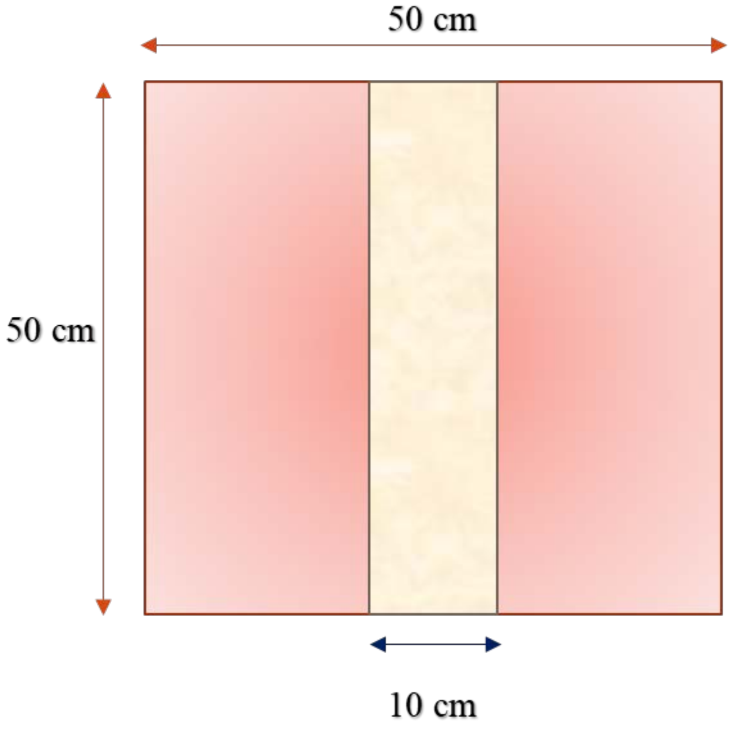
Finishing coating + Graphite
Base coating
EPS
Cement board

In intermediate – scale

- Conducting several intermediate-scale test in using the bench of *Pprime*

The distance from the radiant panel to the sample is 29 cm.





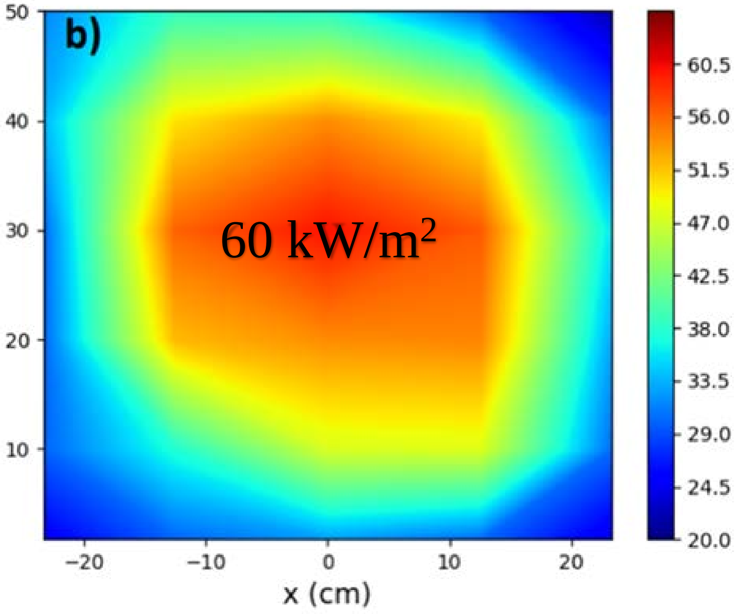


Fig.10 Intensity distribution of heat flow

Fig.9 Test bench of *Pprime* and a sketch

Results

- Surface Temperature

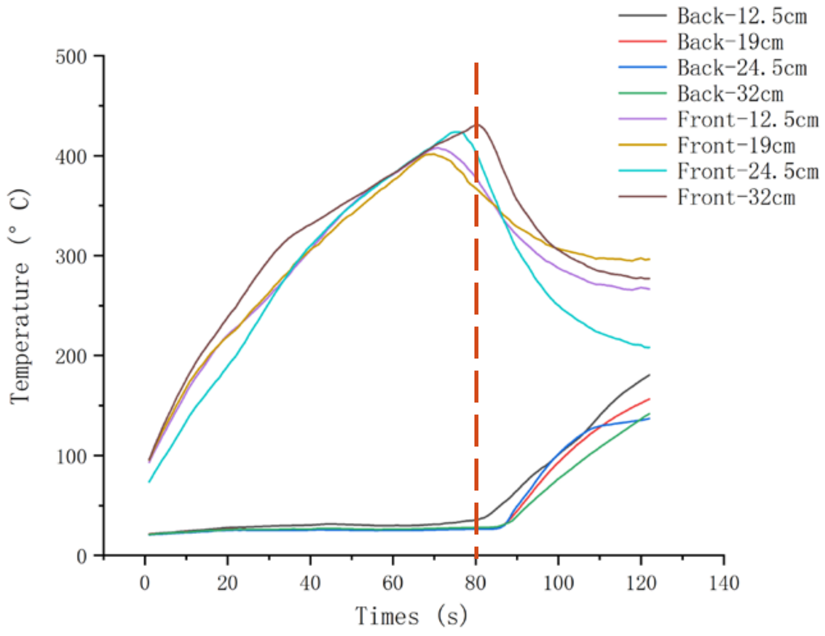


Fig.11 Temperature changes of ETI STO

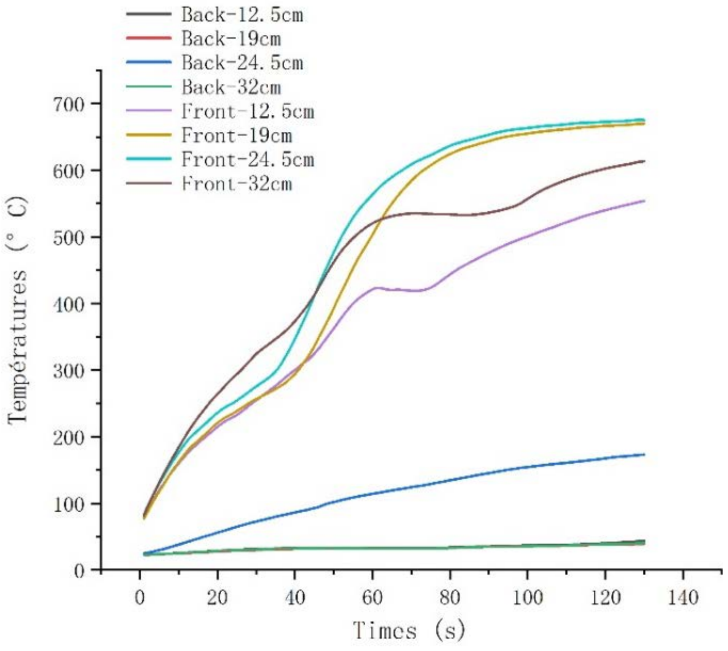


Fig.12 Temperature changes of ETI FlameOFF

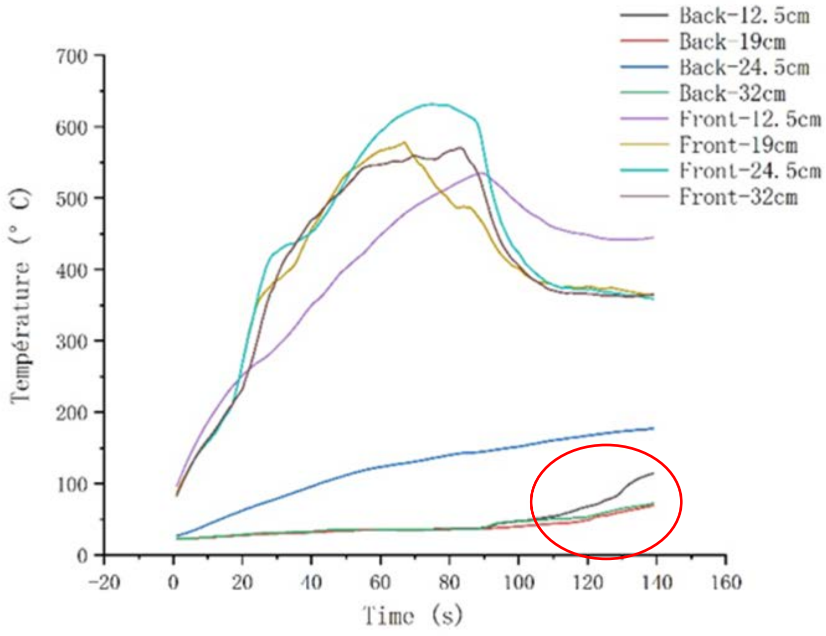


Fig.13 Temperature changes of ETI EG

When the surface temperature reaches 425℃, EPS melts quickly in ETI STO, indicating that the majority of heat passes through the coating. FlameOFF or EG forms a char layer that effectively block heat transfer.

Results

- Mass Loss

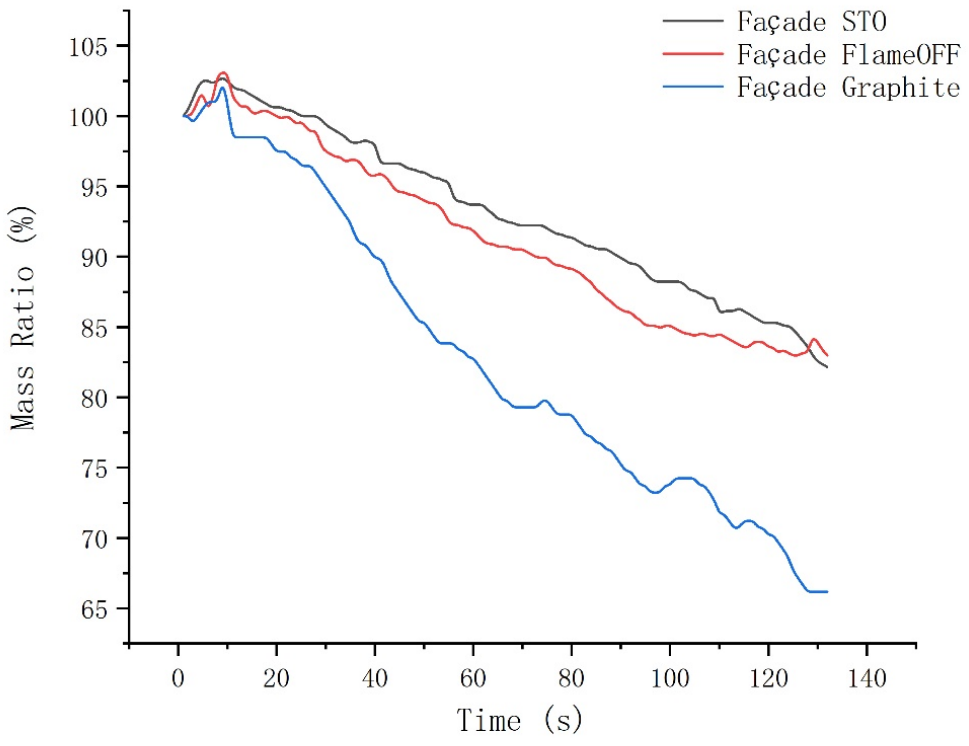


Fig.14 Mass loss of facade

The char layer formed by EG is scattered and unstable, prone to falling or dispersing with airflow, leading to a decrease in protection.

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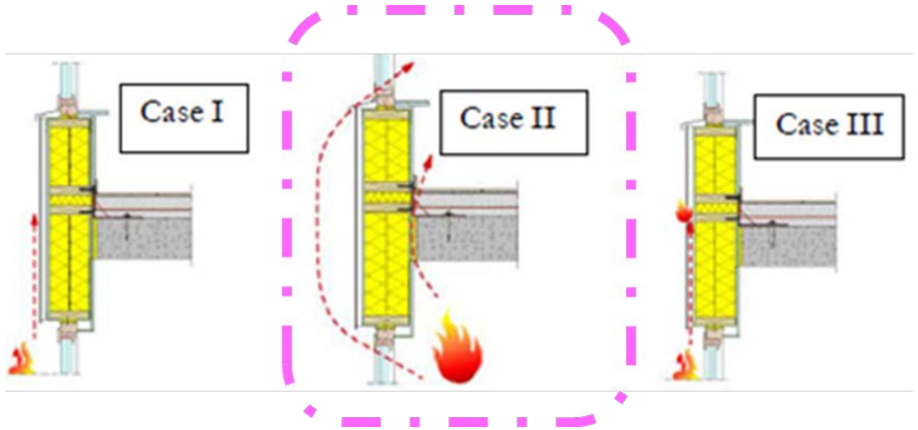
Full-scale test

- Conducting full-scale trials with fire retardant treatment proposal (expandable graphite), in cooperation with *Efectis*

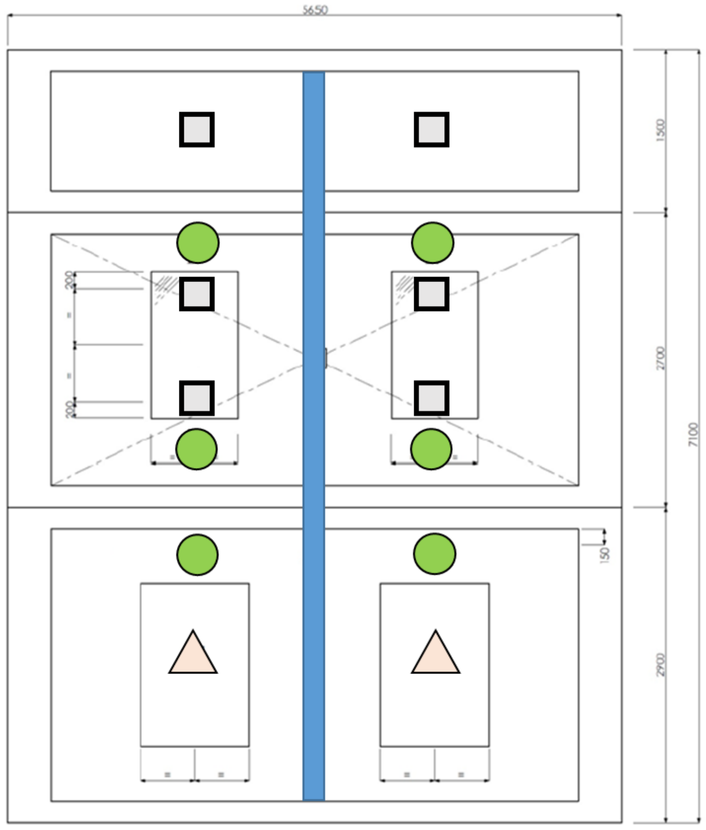
Oak piles



Typical Case 2 Scenario:
Compartment Fire with Flame Exit

Instrumentation

- 9 TC in room
- 6 TC facade (3 per ½ façade)
- 8 PT (4 per ½ façade)



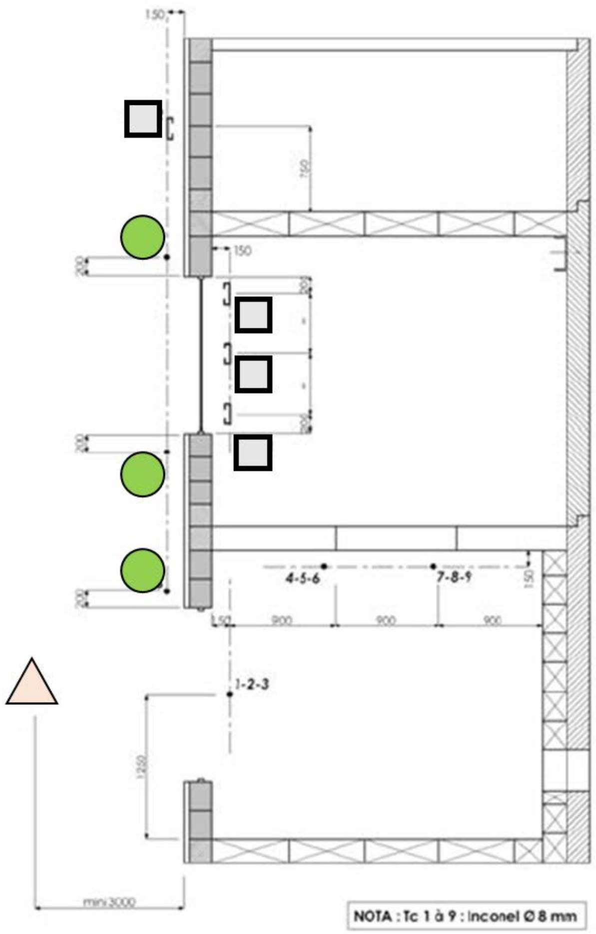
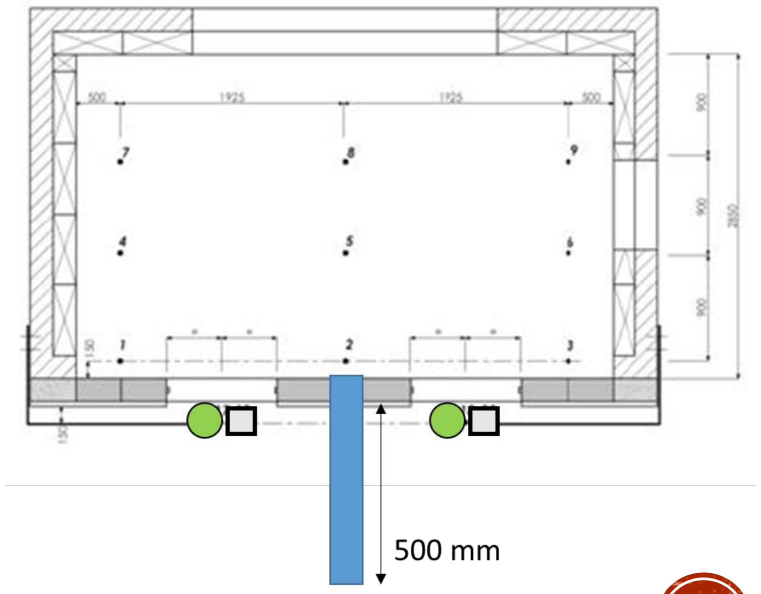


Plate Thermometer
Thermocouple
Flow gauge



Instrumentation

- Infrared camera

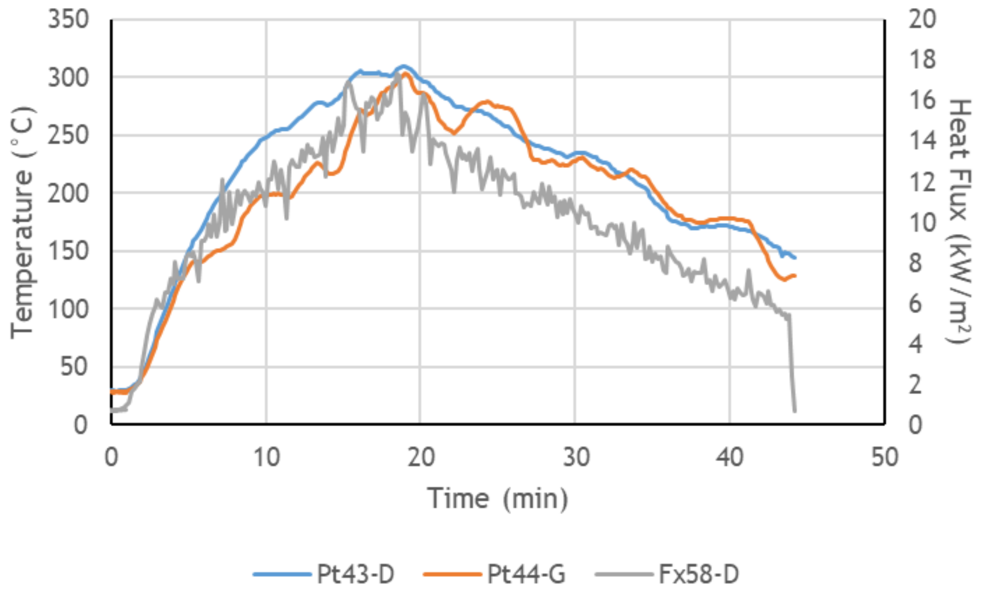
Caméra	FLIR X6540sc
Image Format	640*512
Input Power	24V
Housing Colling system	Forced convection external cycle
Pitch	15µm
Band	1.5-5.1µm
Lenses	25mm
Filtre	NA-3970-60 %

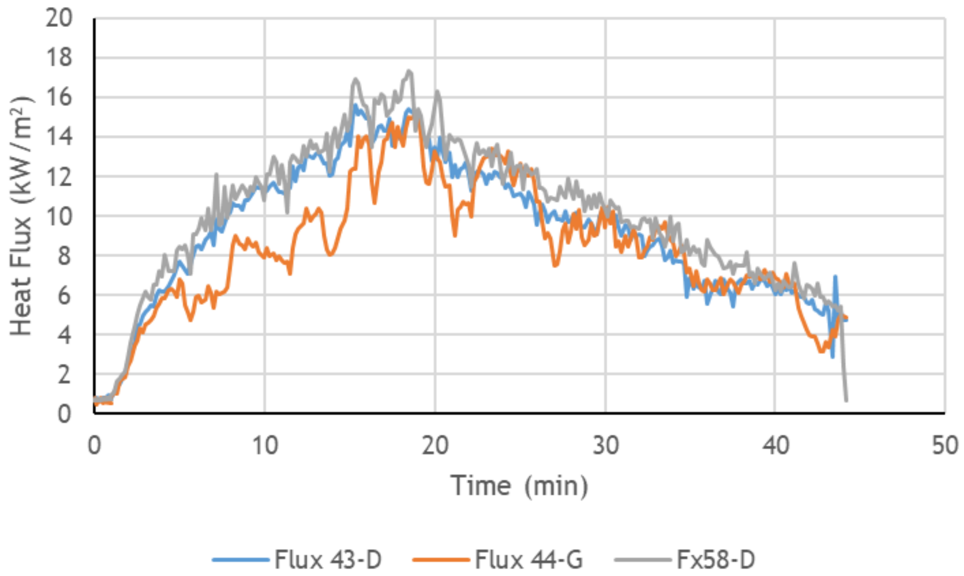
Emissivité	0.6
Distance (m)	14
Reflected temperature (°C)	20
Temps d'allumage	10h53min04s

Results

Results

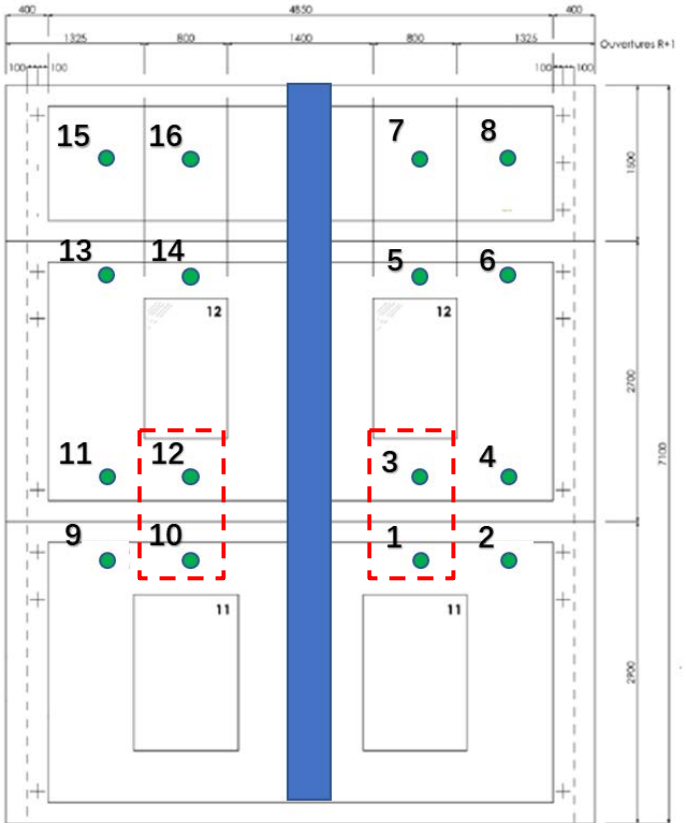
- Intensity of heat flow (2 PTs + heat flow meter 3m from façade)



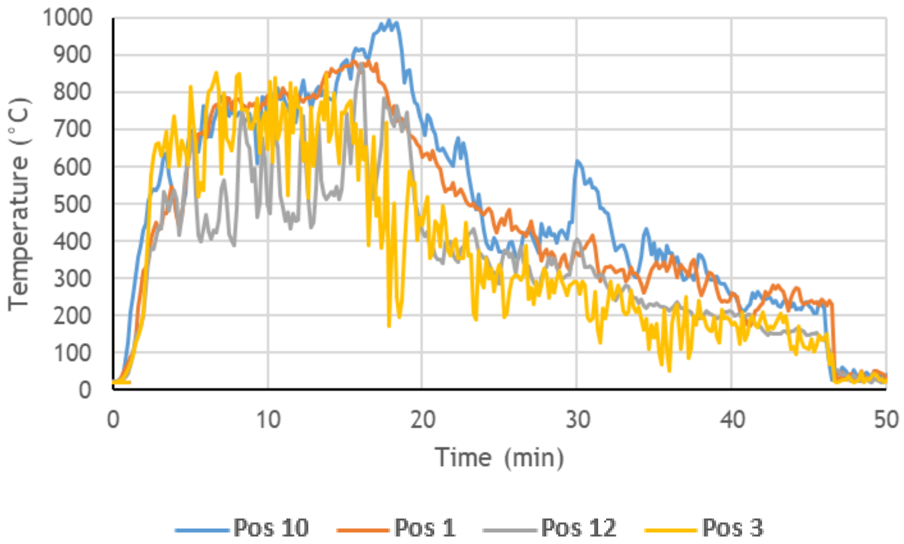


Results

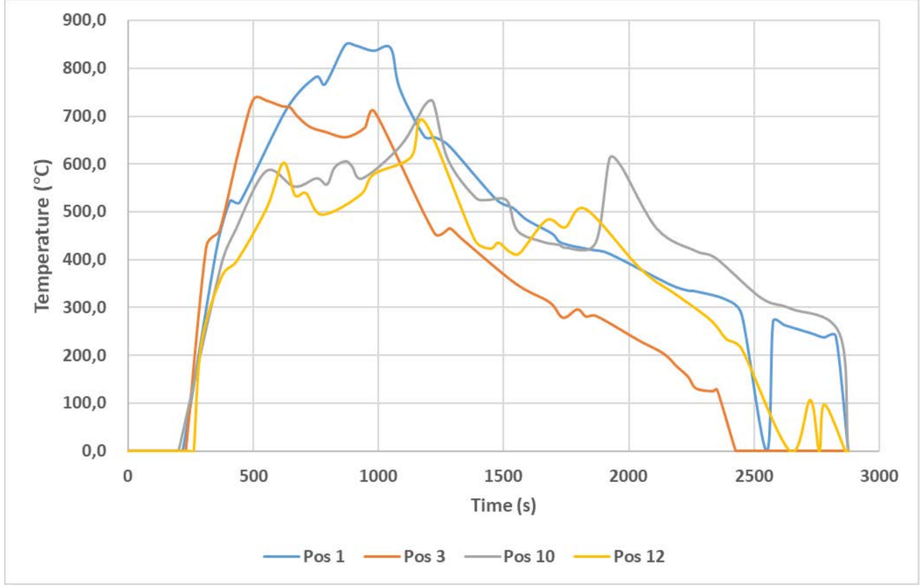
- Surface Temperature



Result of TP Efectis



Result of IR camera

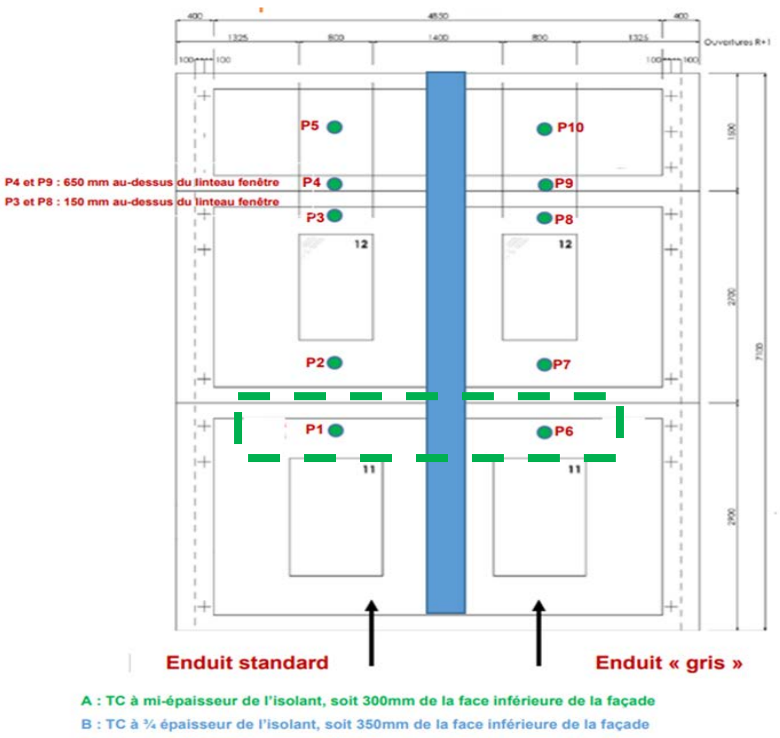


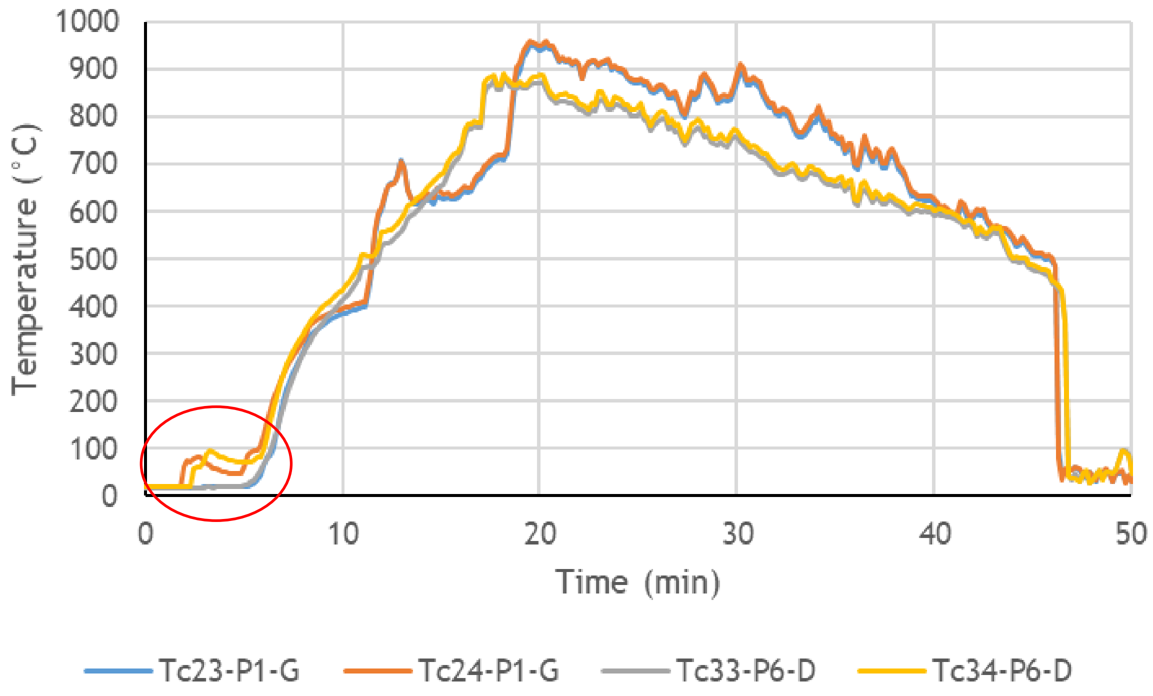
Results

- First floor roof Temperature

Similiar R/L on mid-thickness insulator

Similiar R/L on ¾ thickness insulator





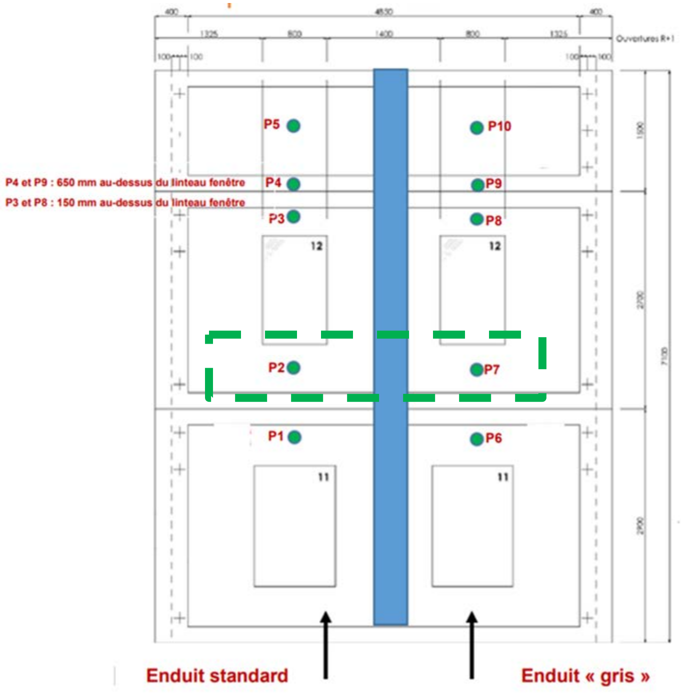
- Right facade: Visible water evaporation for 4 min

Results

- Second floor bottom Temperature

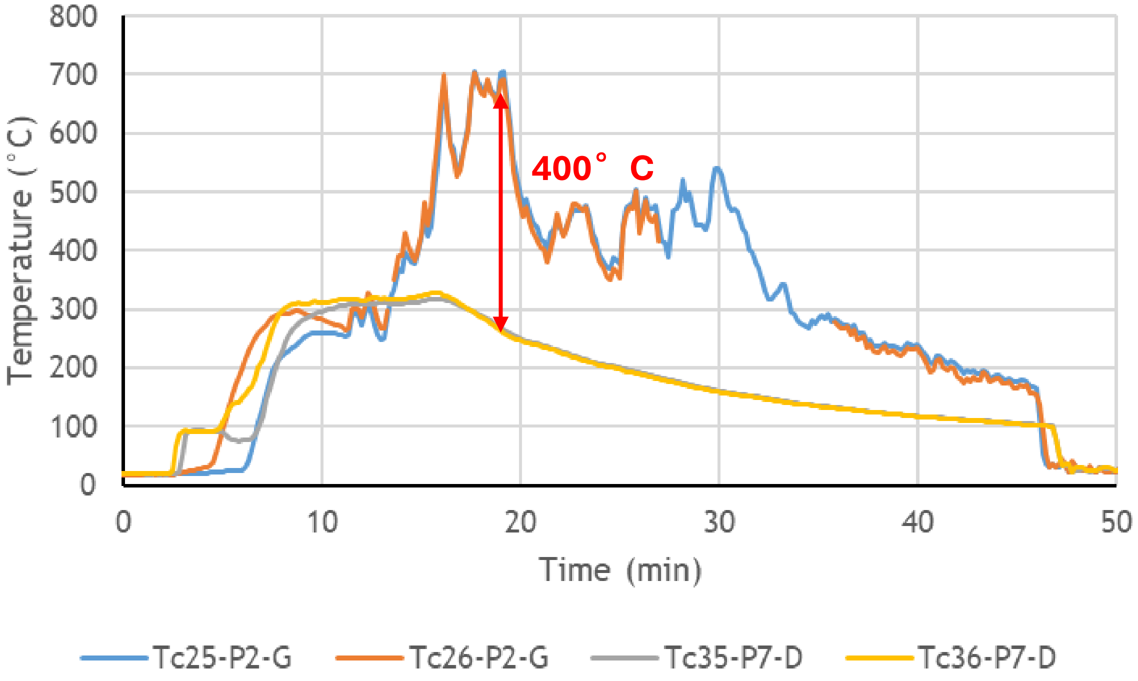
Higher temperature on left mid-thickness insulator

Higher temperature on left ¾ thickness insulator



A : TC à mi-épaisseur de l'isolant, soit 300mm de la face inférieure de la façade

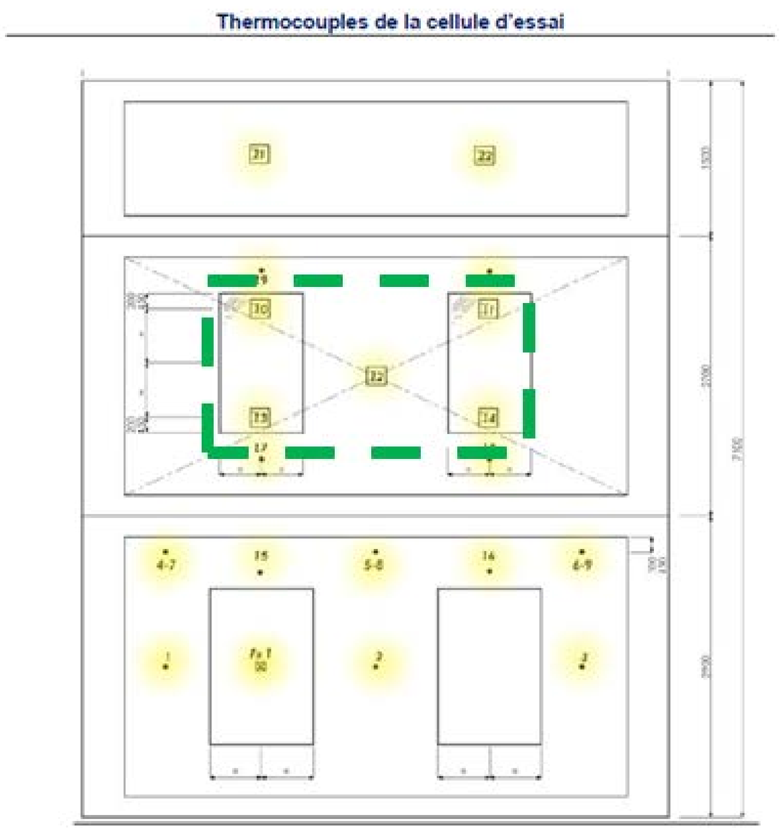
B : TC à ¾ épaisseur de l'isolant, soit 350mm de la face inférieure de la façade

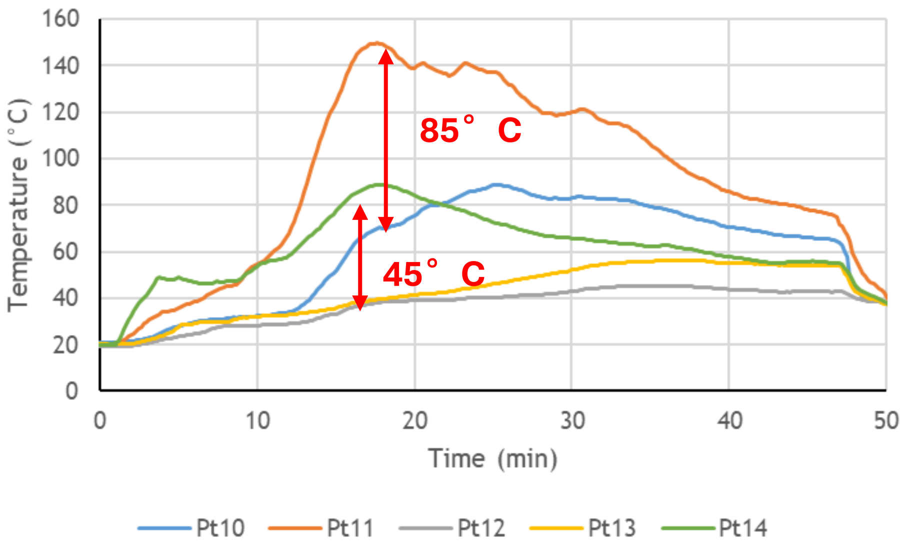


Results

- Second floor windows Temperature

Higher temperature on the right



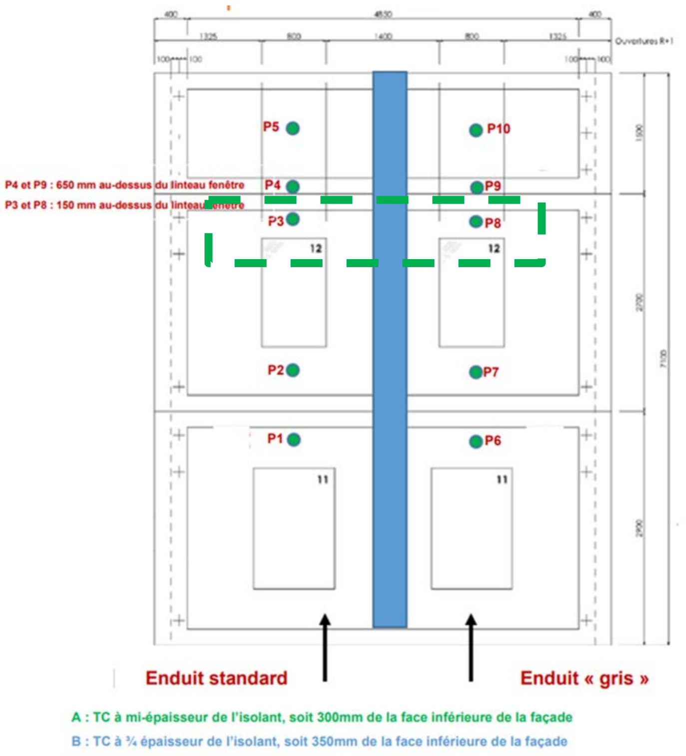


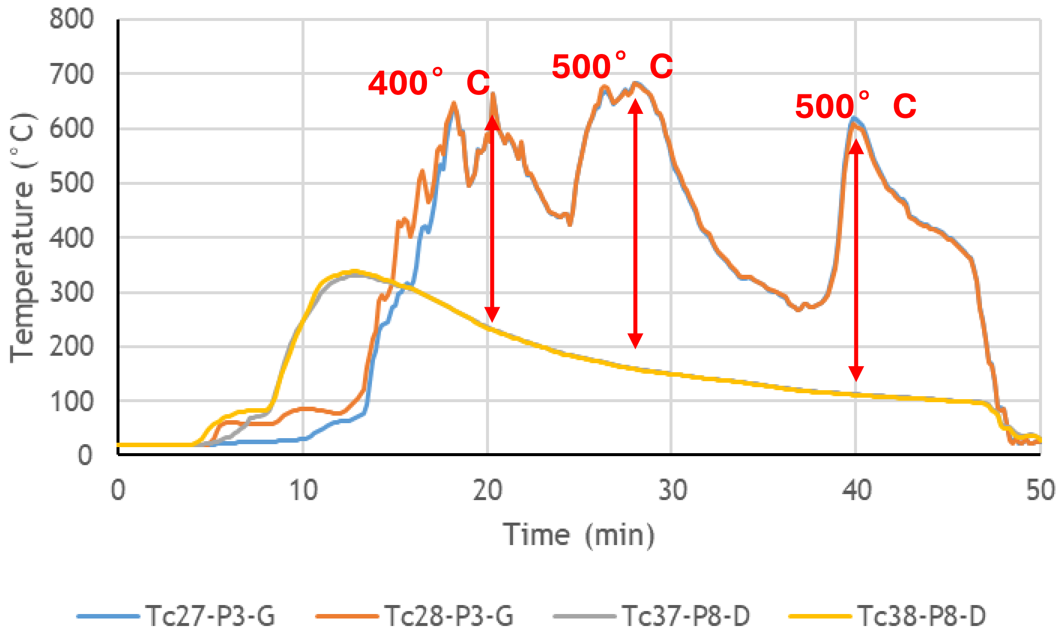
Results

- Second floor roof Temperature

Higher temperature on left mid-thickness insulator

Higher temperature on left ¾ thickness insulator



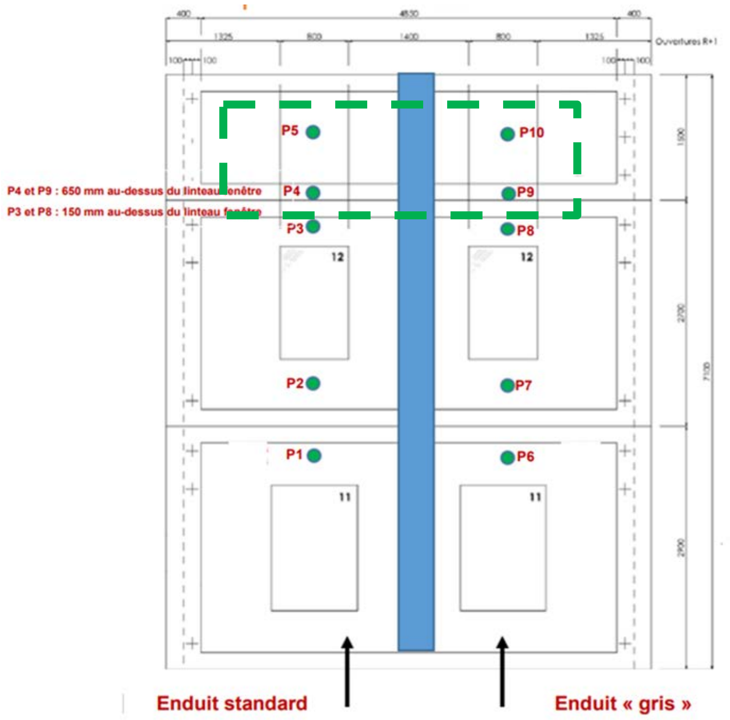


Results

- Roof Temperature

Similiar R/L on mid-thickness insulator

Similiar R/L on ¾ thickness insulator



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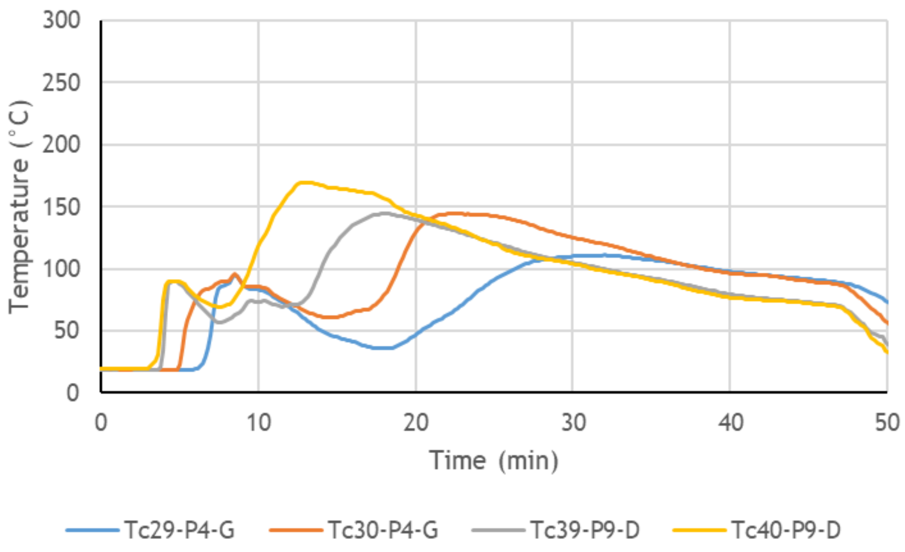
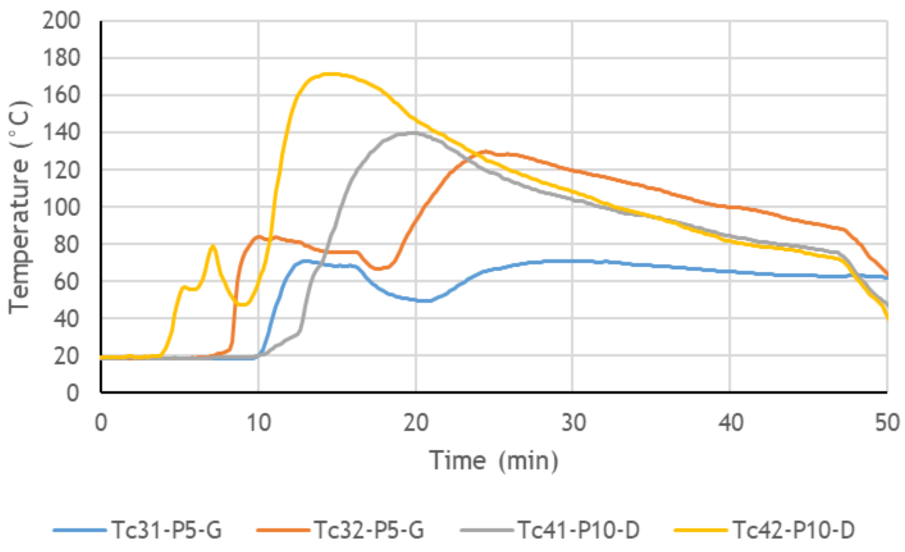
B : TC à ¾ épaisseur de l'isolant, soit 350mm de la face inférieure de la façade





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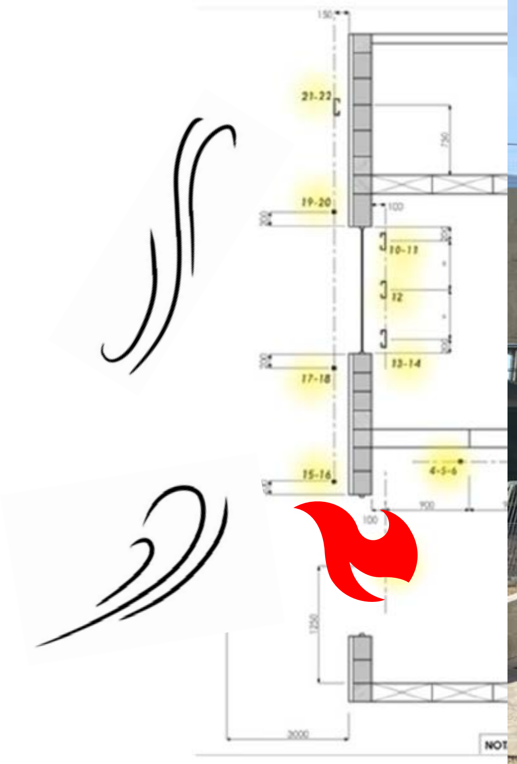

Ignition of the coating occurs at 6 min, on both sides, spanning from the ground floor window to that of the 2nd floor.

When EG is exposed to heat, it generates a loose char layer. The resulting char chips disperse with the airflow produced by the flame, preventing the attainment of intumescence.

EG restricts heat propagation in the cross-sectional direction, but there is an increase in heat propagation in the vertical direction.

Conclusions

- The initial coating is ineffective in blocking heat transfer. When the temperature reaches approximately 425°C, EPS insulation rapidly melt or ignite.
- In small and intermediate scale tests, EG demonstrates effective heat transfer restriction, similar to FlameOFF, but reveals weaknesses in mechanical properties.
- These drawbacks become more pronounced in full-scale tests, particularly with regard to airflow influence. Nevertheless, EG continues to play a certain role in heat insulation

THANK YOU
Q & A