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# Design and testing of innovative composites for passive fire protection

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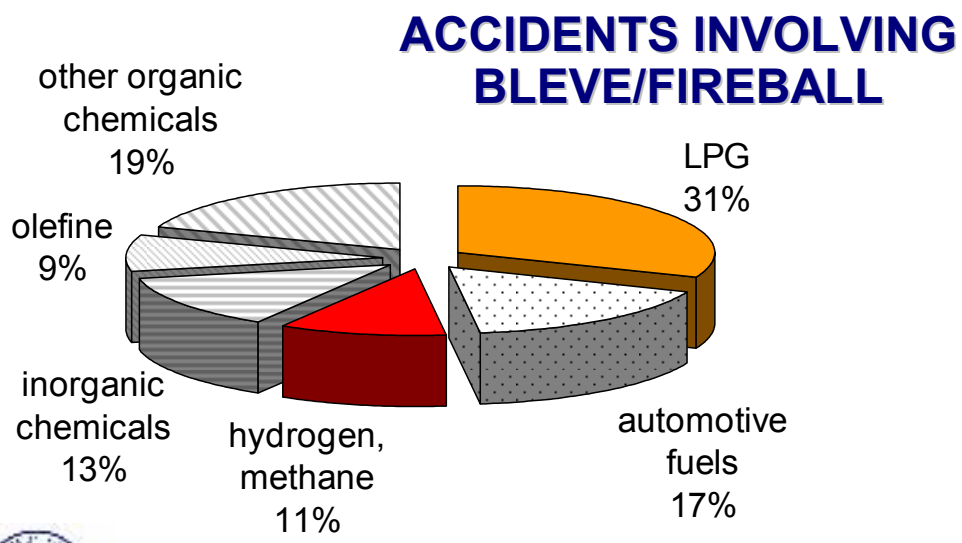
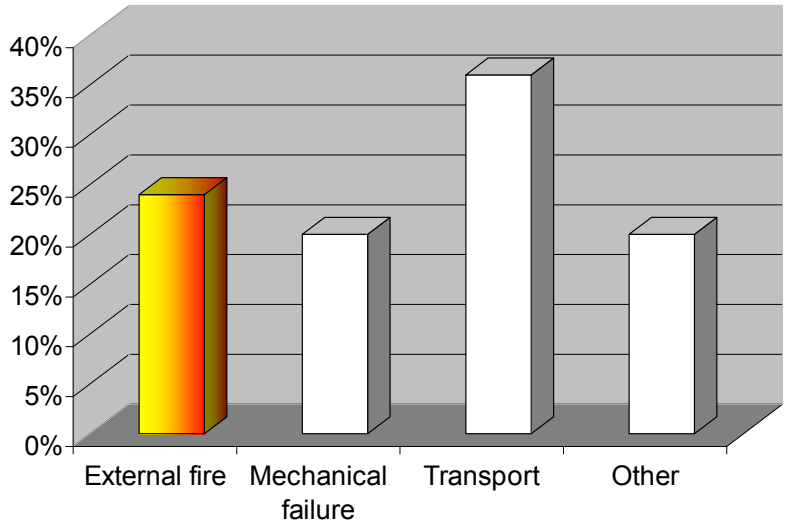
# Introduction

- Ignition of accidental releases may trigger the escalation of the domino effect, involving process equipment
- More severe consequences if pressurized gases are involved
- Past accident data analysis: external fire is a common primary cause for mechanical explosions and fireballs (MHIDAS DATABASE)



# Passive fire protection systems

- Consequences mitigation is crucial for safety based design: passive fire protection (PFP)
- Thermal shields and equipment insulating coating are reliable and simple solutions
- Design and testing of PFP materials is critical: implementation of innovative materials

# Basalt fibers

| Compound | % in basalt rocks |
|---|---|
| $SiO_2$ | 49.58 |
| $TiO_2$ | 2.08 |
| $Al_2O_3$ | 14.48 |
| $Fe_2O_3$ | 4.42 |
| FeO | 9.43 |
| $K_2O$ | 1.89 |
| $Na_2O$ | 2.1 |
| MgO | 5.1 |
| CaO | 8.5 |
| MnO | 0.17 |

| Thermal Properties | SI Units | Basalt Filaments | Fiberglass | Silica filaments |
|---|---|---|---|---|
| Maximum application temperature | (K) | 1255 | 923 | 1640 - 2070 |
| Sustained operating temperature | (K) | 1093 | 753 | 1470 |
| Minimum operating temperature | (K) | 15 | 210 | 100 |
| Thermal conductivity | (W/m K) | 0.035 | 0.034-0.04 | 0.035-0.04 |
| Melting temperature | (K) | 1720 | 1390 | 2070 |
| Thermal expansion coefficient | (1/K) | 8.0E-06 | 5.4 E-06 | 0.05 E-06 |
| Qualitative price Comparison | | $ | $ | $$$$ |

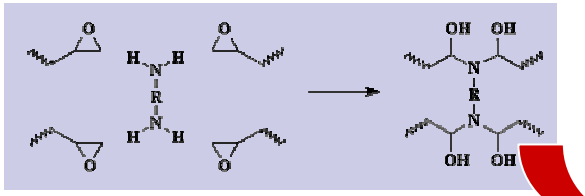
# Aims:

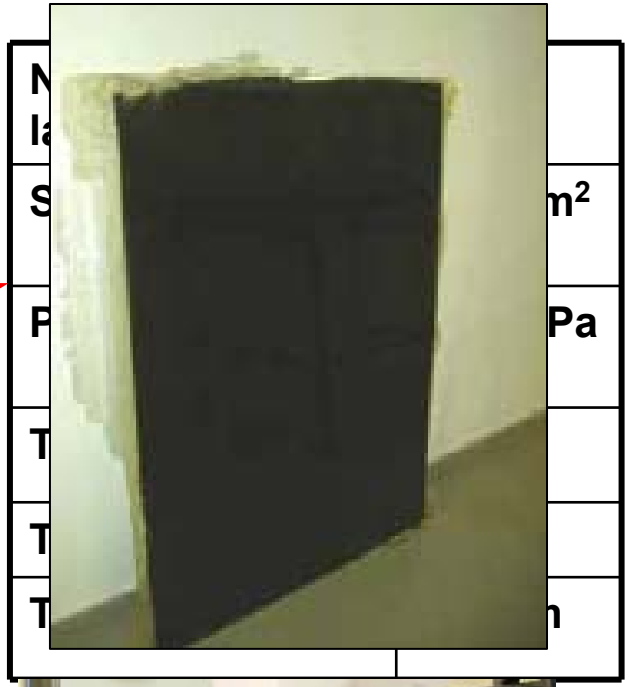
- Design and production of innovative composites for passive fire protection (PFP)
- Development of a small scale fire test for thermal characterization of PFP materials
- Comparison between innovative and commercial materials for thermal insulation

# New materials for PFP: basalt fibers

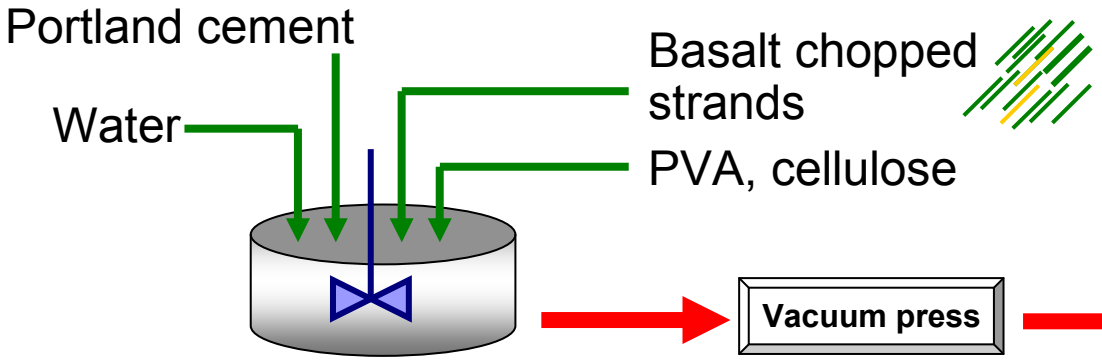
- Organic based materials

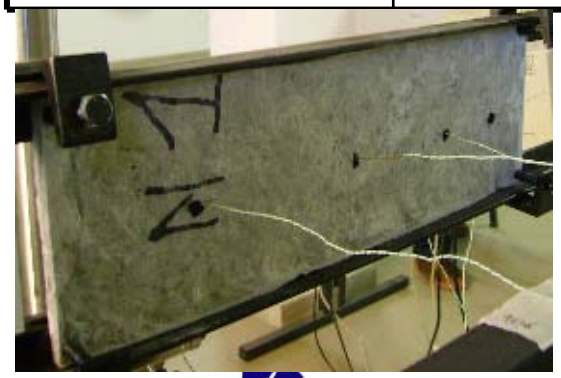
**Epoxy-fenolic resin**



- Inorganic based materials



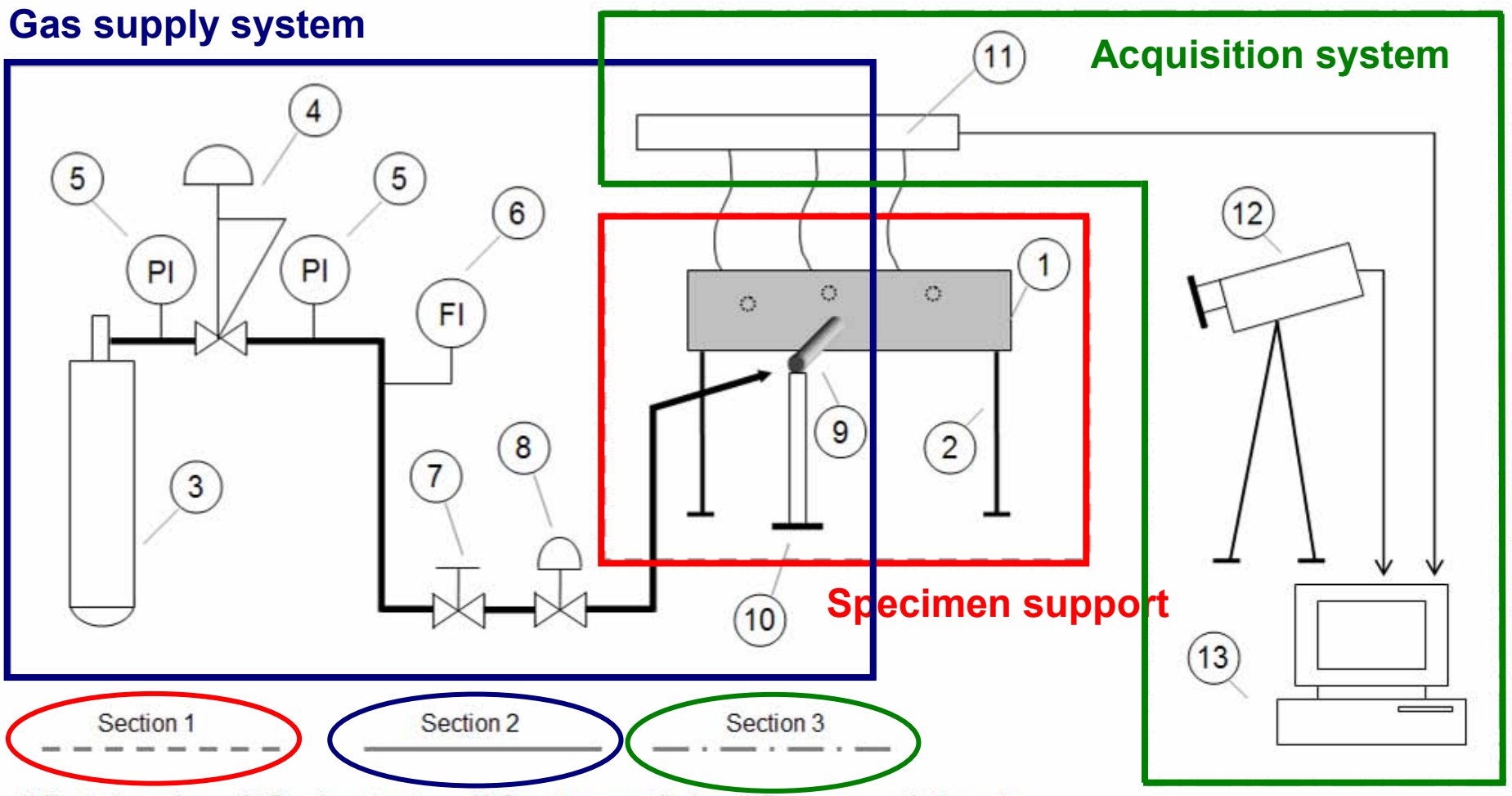
# Reference standards for fire tests

- ASTM and other standard are devoted to the determination of flame spread among surfaces

ASTM E162

- A more detailed analysis o ue to jet fire impingement are ne
- Material testing in more se tive conditions and heat expos

# Experimental set up scheme




1) Tested specimen; 2) Bearing structure; 3) Gas storage cylinder; 4) Pressure regulation valve;

5) Manometer; 6) Flow indicator; 7) block valve; 8) regulation valve; 9) welding torch; 10) burner support;

11) Thermocouples and data logger; 12) IR camera; 13) computer connection and data collecting

# Experimental set up

CPTM
Consorzio Polo Tecnologico Magona



## System

premix transition for start-up

thicknesses (< 25mm)

# Presentation of results (1)

Different materials were considered and compared.

Different criteria were used for the comparison:

1. **Maximum wall temperature**: thermal insulation effectiveness
2. **Weight losses**: material loss during the fire exposure; definition of a synthetic index
3. **(Eventual) rupture time**: material resistance to the fire impingement.

$$I = \frac{w_i - w_f}{V_i}$$

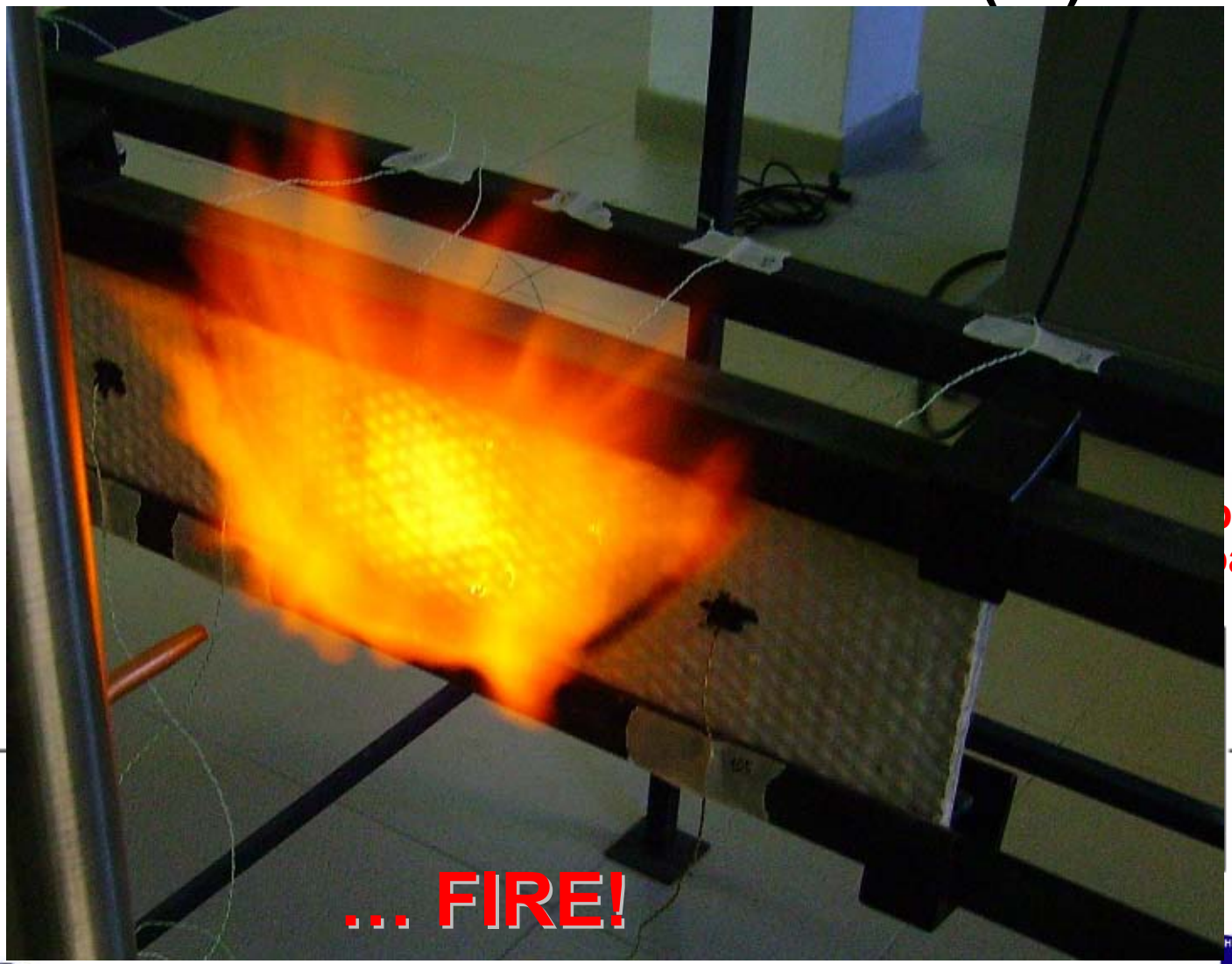
Initial weight

Final weight

Initial volume

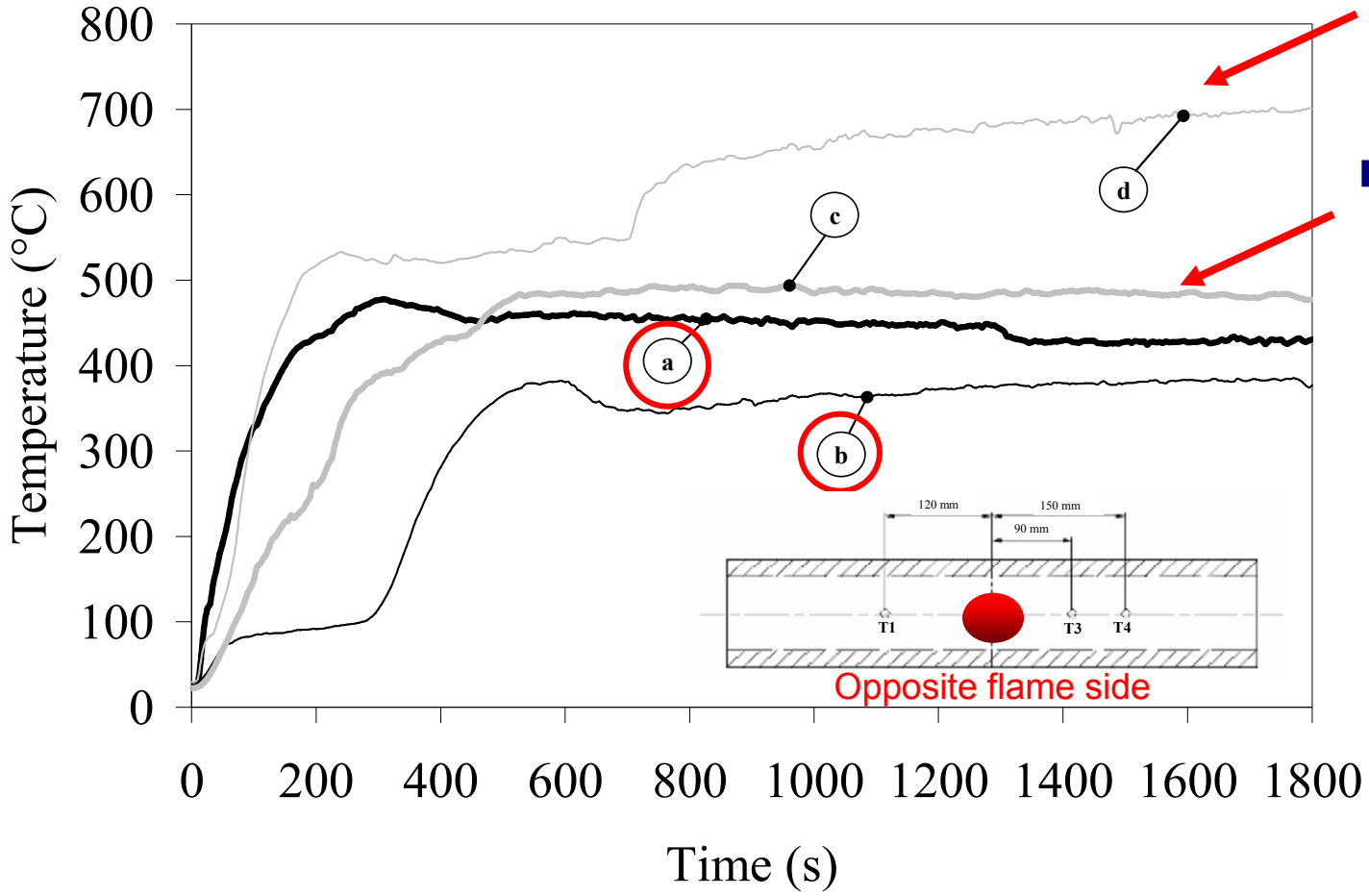
**The index is aimed to consider the geometrical features of the panels and not only the relative weigh loss**

# Presentation of results (2)




**les positioning**
**anel**

# Temperature profiles (1)



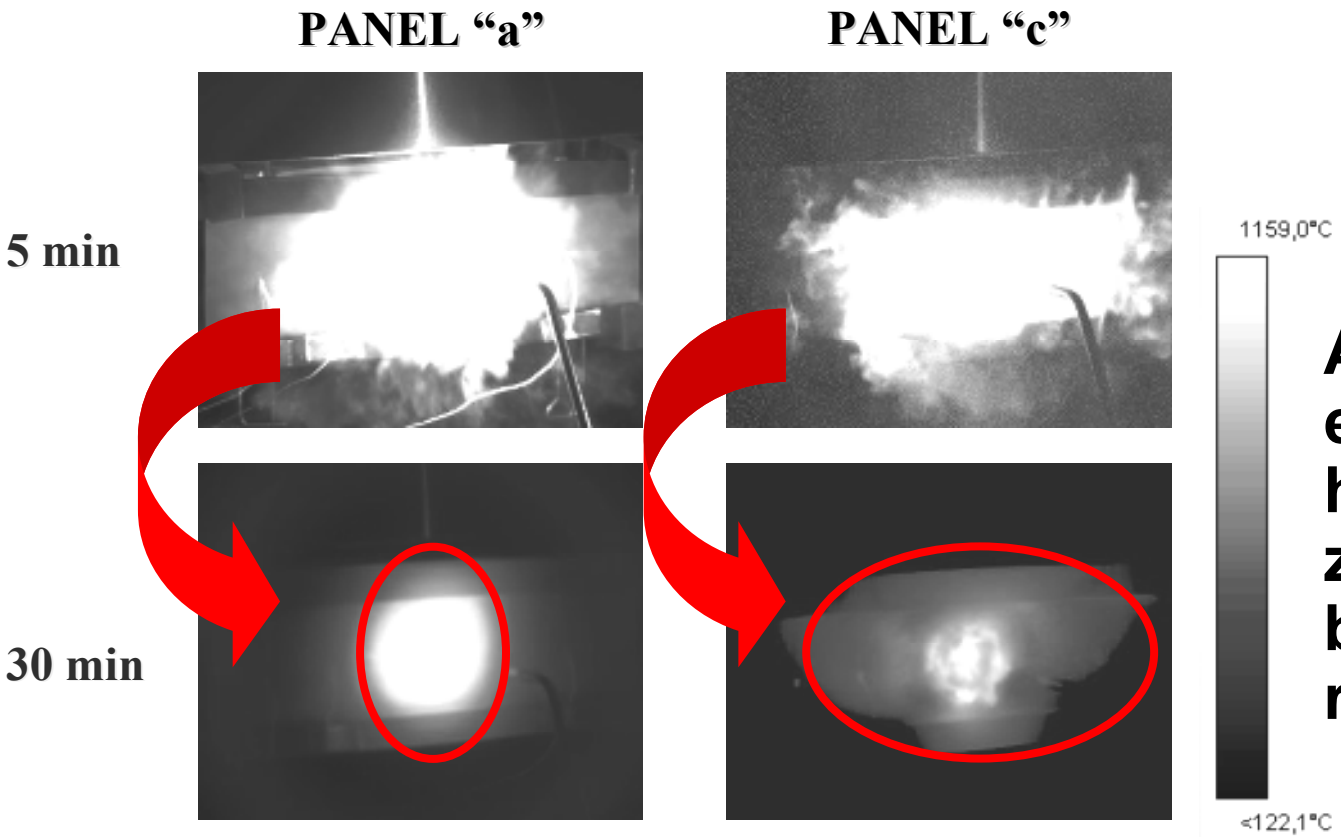

- Civil thermal insulation is not adequate
- Fiberglass results in higher temperatures

**End of test:**
30 min

- Basalt based materials present lower temperatures

# Temperature profiles (2)

- Infrared camera registrations – front of the panel




**After the initial exposition the high temperature zone among the basalt panel is restricted**

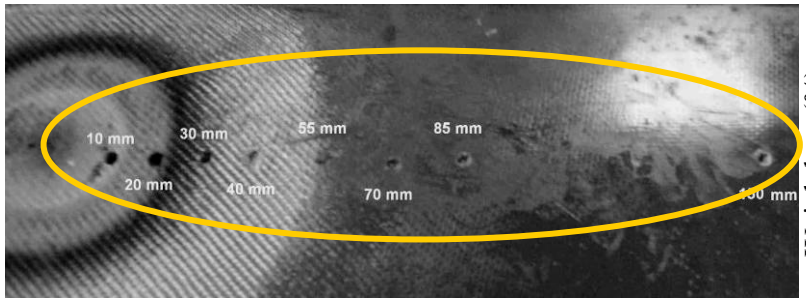
# Weight losses

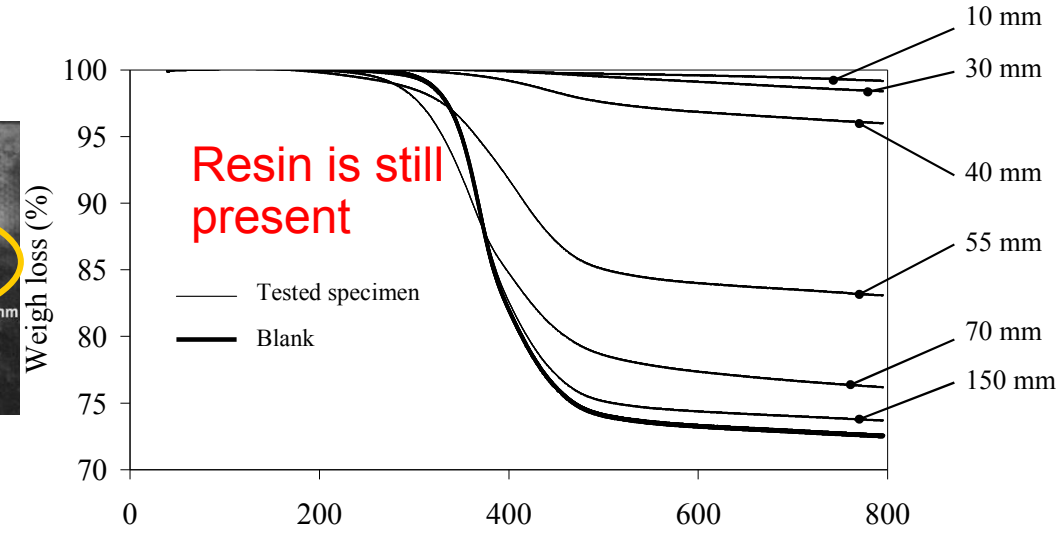
| Material | Maximum wall temperature (°C) | Average wall temperature (°C) (after 15 min test) | Time for rupture (min) | Weight loss (%) | Weight loss index I (g/L) |
|---|---|---|---|---|---|
| **Panel a** | 478 | 438 | - | < 10 | 160÷180 |
| **Panel b** | 385 | 375 | - | ≈ 10 | 60÷80 |
| **Panel c** | 494 | 485 | 20 | ≈ 15 | ≈ 220 |
| **Panel d** | 701 | 680 | 5 | ≈ 4 | 40 |

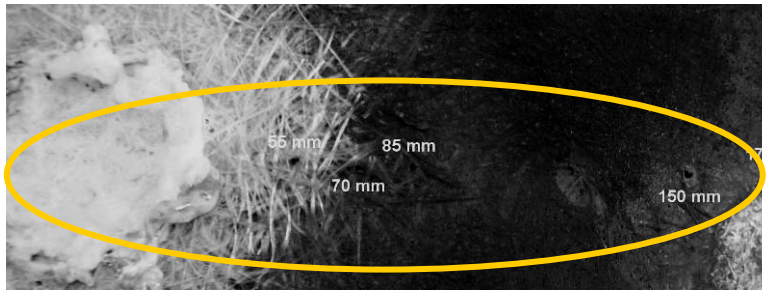
- Basalt based panels presented no rupture after 30 minutes
- Weight loss index is greater in the case of organic matrixes due to resin combustion
  - A more detailed analysis is required: **TGA**

# TGA for organic materials

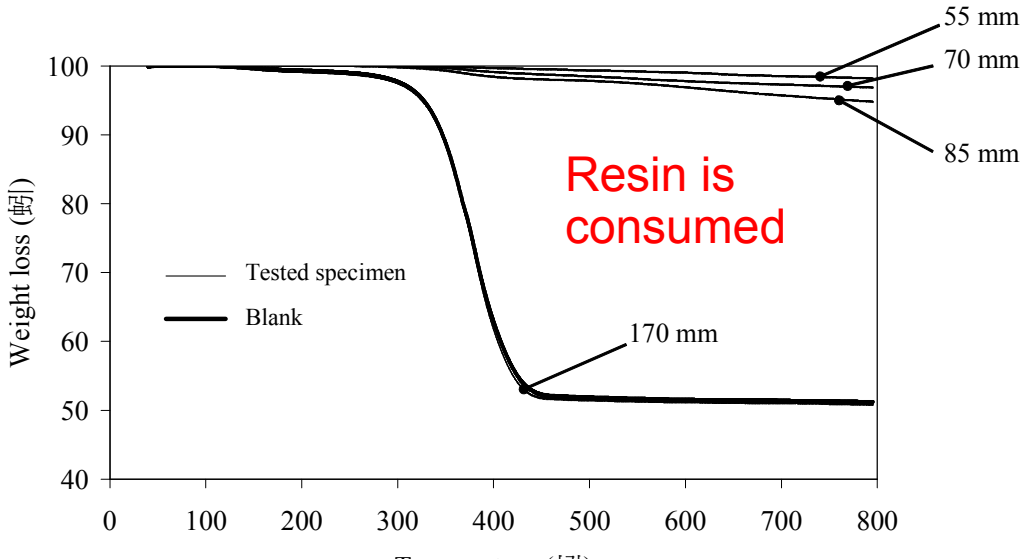
## Basalt organic



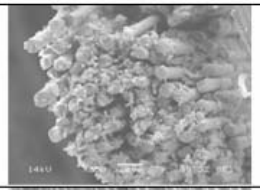
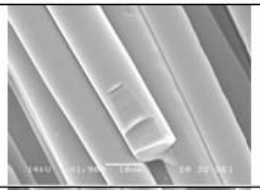
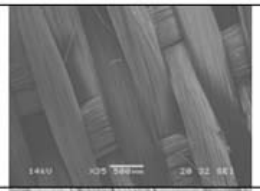
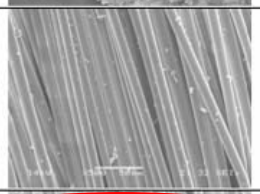
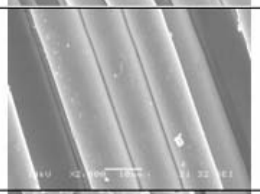
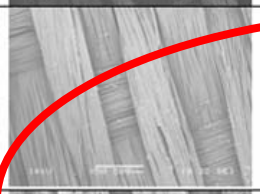
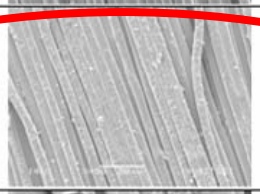
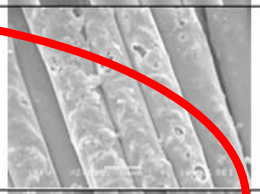
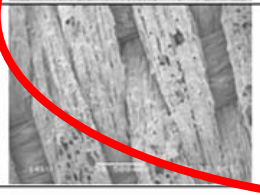
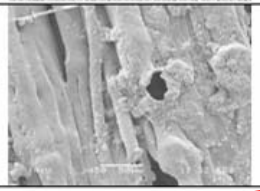
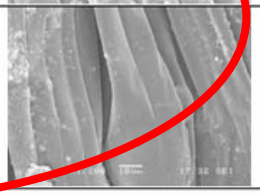




## Fiberglass



# Micro-structure analysis (SEM)

| | Magnification | | |
|---|---|---|---|
| | 45 x | 450/500 x | 1900/2000 x |
| Blank | - |  |  |
| 40 mm |  |  |  |
| 20 mm |  |  |  |
| 10 mm |  |  |  |

**SEM images for basalt fibre panels with organic matrix.**

- Fibres result damages only close to the flame impact zone;
- Good thermal resistance

# Conclusions

- Innovative composite materials for passive fire protection have been developed
  - based on basalt fibers
  - Organic and inorganic matrix
- Small scale jet fire test aimed to the lab characterization at high temperatures severe conditions
  - Comparison between different materials, innovative and commercial
  - Temperatures profiles were determined with thermocouples and IR camera measurements.
  - Weight losses, TGA, SEM
- Basalt based panels showed better thermal behaviour, lower weight losses, due to the surface flame propagation, and full structure integrity.

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# Thank you for your attention

Any question?