Passive fire protection requirements achieved by fixed firefighting systems in façades

CFD studio and test protocol

Fire Engineering and Ad-hoc testing

- 2025
- **Bellaterra, Barcelona**

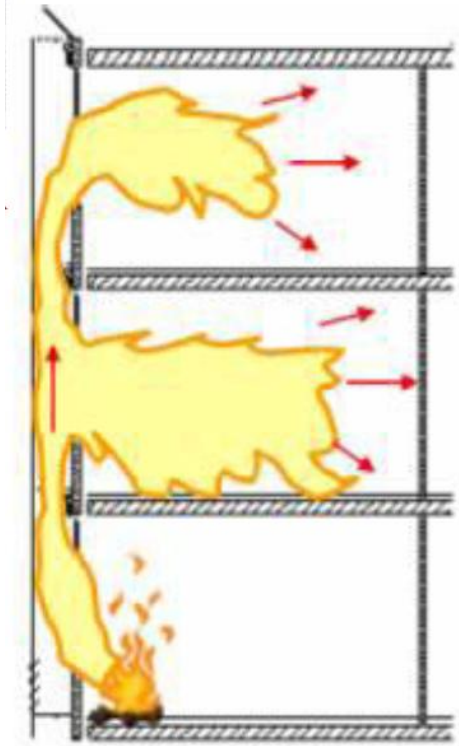
The problem: façade fire propagation in existing buildings.

Recent high-rise fires highlight the risk of combustible façade claddings in existing buildings that were build without façade fire regulation.

- Energy efficiency compromise: increase of combustible insulation with better energy performance but higher fire risk.
- Legacy constraints: façades installed under older rules are non compliant and replacement is costly, restricted or technically complex.
- Façade cladding replacement can be non-viable or restricted due hight cost, technical issues or heritage and architectural value and regulation.

Torre Grenfell, Londres 2017

El Campanar, Valencia 2024



Solution: FFFS could be a solution as a façade fire protection system?

A study is required to evaluate the effectiveness and viability of FFFS as a façade fire protection system and define an ad-hoc testing protocol to assess it.

- Use Fixed Fire Fighting Systems (FFFS) to achieve passive fire protection requirements in façades:
  - Avoid or limit fire propagation in façade with combustible claddings.
  - Guarantee a structural fire resistance – loadbearing capacity on external steel structure under fire exposure.
- CFD-based studio was carried out to:
  - Evaluate the a preliminary effectiveness and viability of FFFS.
  - Define a real scale fire test scenario and ad-hoc testing protocol to evaluate FFFS effectiveness and its field of application.

Proposal and methodology: CFD case studio - FDS

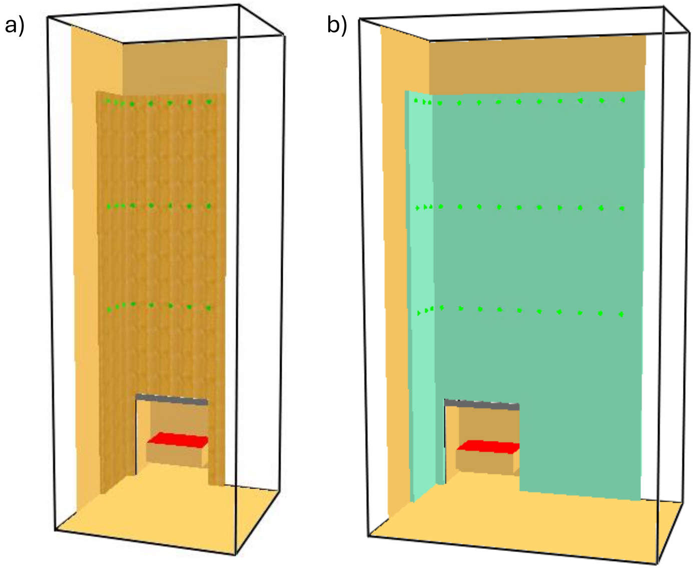
Background: existing buildings that requires reduce and mitigate fire risk on façades and achieve passive fire protection requirements.

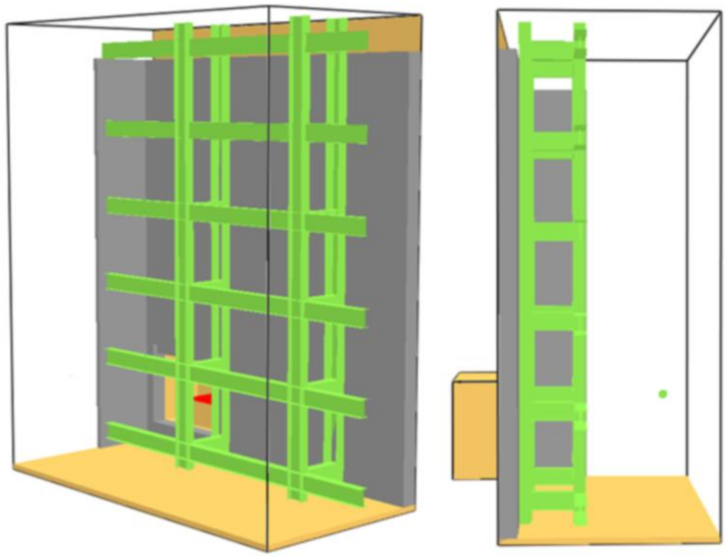
- Case studies:
  - Existing heritage building with façade combustible cladding material.

    Combustible cladding material represents a high fire risk for occupancy and fire brigade (egress and tenability conditions) and for building fire compartmentation.

  - Existing steel exoskeleton 1 m from façade with degraded protection.

    Degraded protection doesn't guarantee the minimum structural fire resistance required.

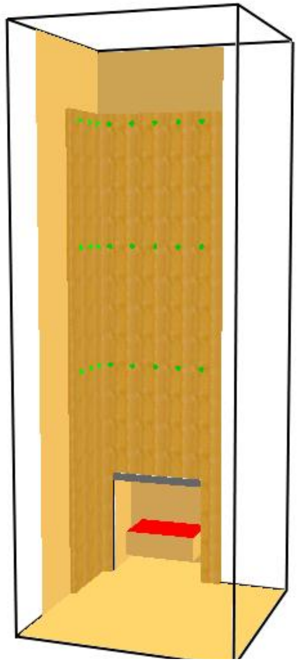




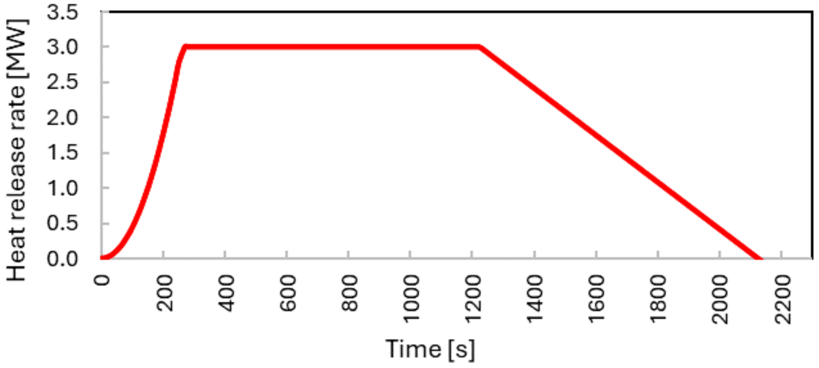
Proposal and methodology: CFD Simulations setup

Setup based on BS 8414-1:2020 *Fire performance of external cladding systems. Test method for non-loadbearing external cladding systems fixed to, and supported by, a masonry substrate.* Fire propagation performance.

- Test setup



- Fire load



In all cases, cell size is 0,1 m throughout the entire simulation domain.

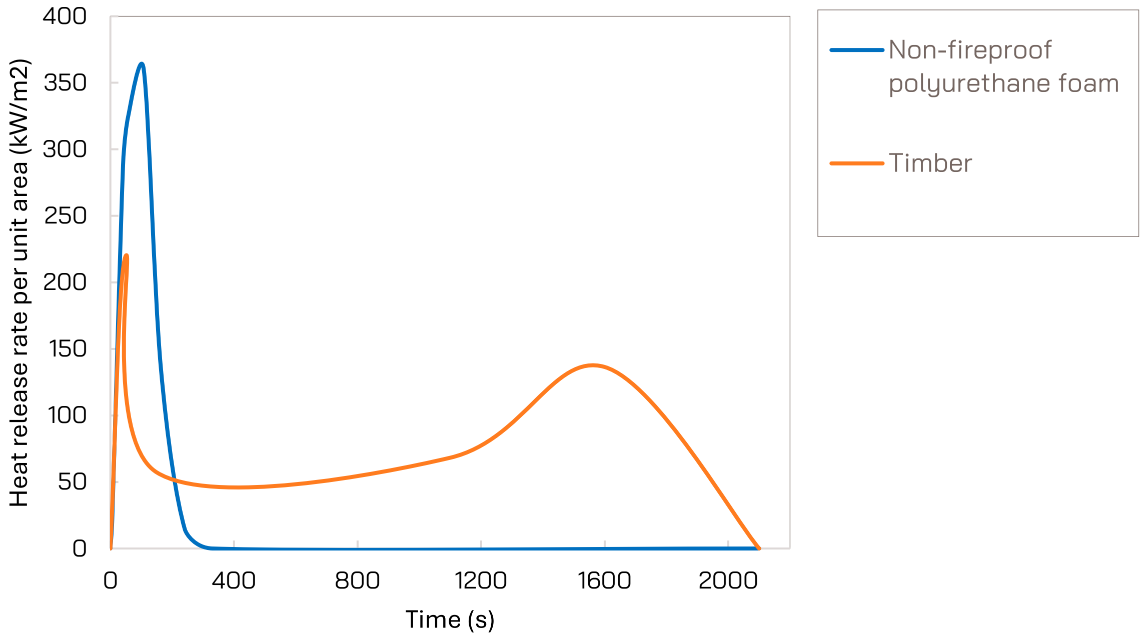
$D^* = \left(\frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{g}}\right)^{\frac{2}{5}} = 1.46,$ using $\partial x = 0.1$ m the ratio $D^*/\partial x$ equals 14.6

Proposal and methodology: CFD Simulations setup

Façada cladding materials. Fire propagation performance.

- Considered façade cladding materials and fire propagation analysis:
  - Non-fireproof polyurethane foam to analyse vertical and horizontal fire propagation.
  - Timber cladding to analyse vertical propagation.

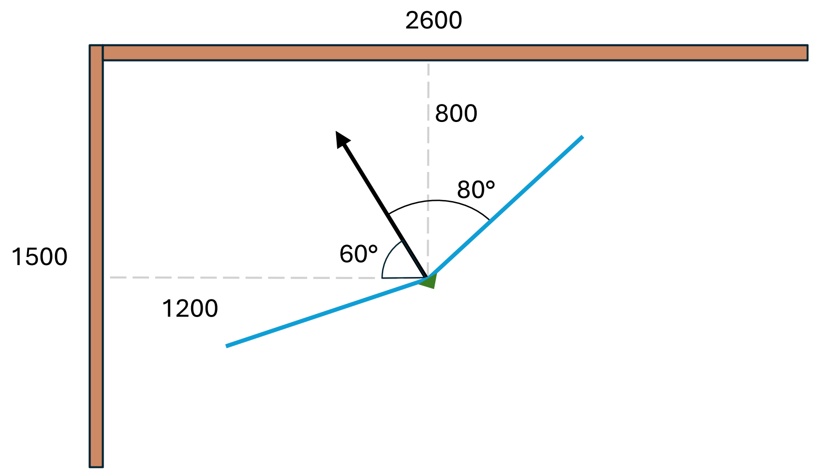
	Polyurethane	Timber
Thermal conductivity, k, [W/(m°C)]	0.025	0.12
Specific heat, c_p, [J/(kg °C)]	1.4	1.53
Density, ρ, [kg/m3]	40	550
Ignition temperature, T_{ig}, [°C]	350	350



Proposal and methodology: CFD Simulations setup

Fixed firefighting system characteristics.

- Different FFFS and design has been considered in order to evaluate the feasibility and effectiveness of FFFS as a façade fire protection system:
  - Conventional sprinkler system and water mist system.
  - Low pressure (most conservative).
  - Single/various sprinkler and nozzle per test setup.
  - Different sprinkler and nozzle locations.
  - Automatic / non automatic systems (activation termperature 68°C) and deluge systems.

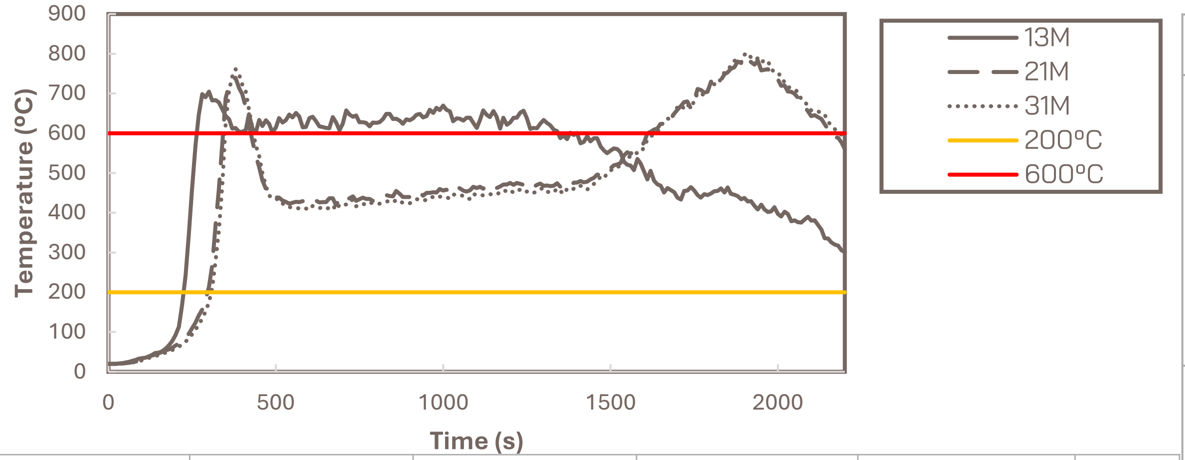


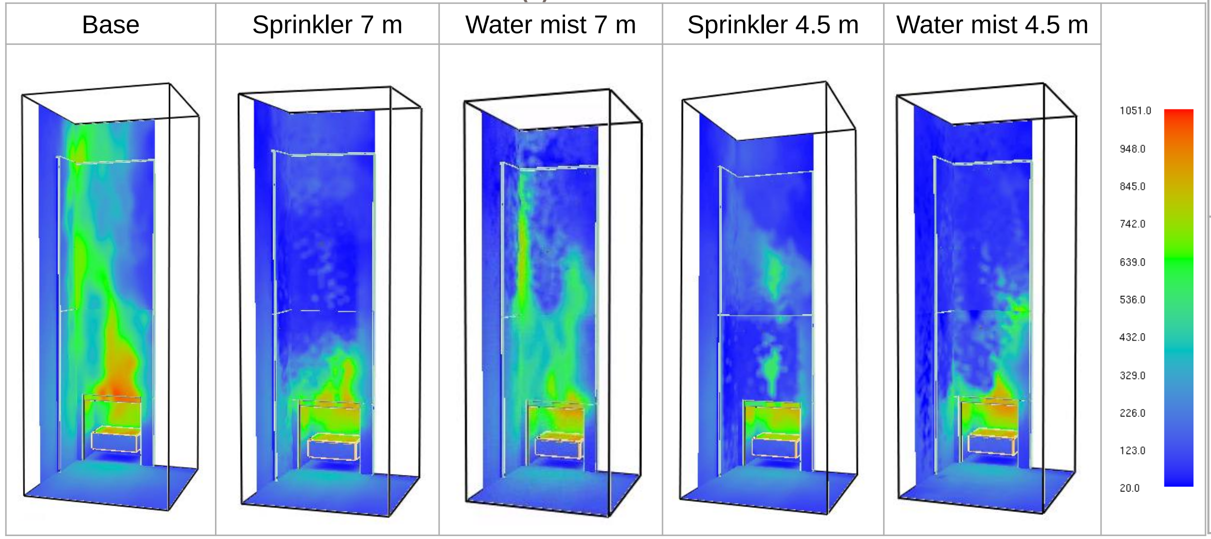
	Sprinkler	Water mist
Droplet diameter, µm	2000	200
Response Time Index, $(m \cdot s)^{1/2}$	50	50
C-factor, $(m \cdot s)^{1/2}$	0.7	0.7
K-factor, $L/(min \cdot bar)^{1/2}$	80.5	25.5
Pressure, bar	1	16
Spray angle, °	80	80
Particle velocity, m/s	5	5
Pattern shape	Uniform	Uniform

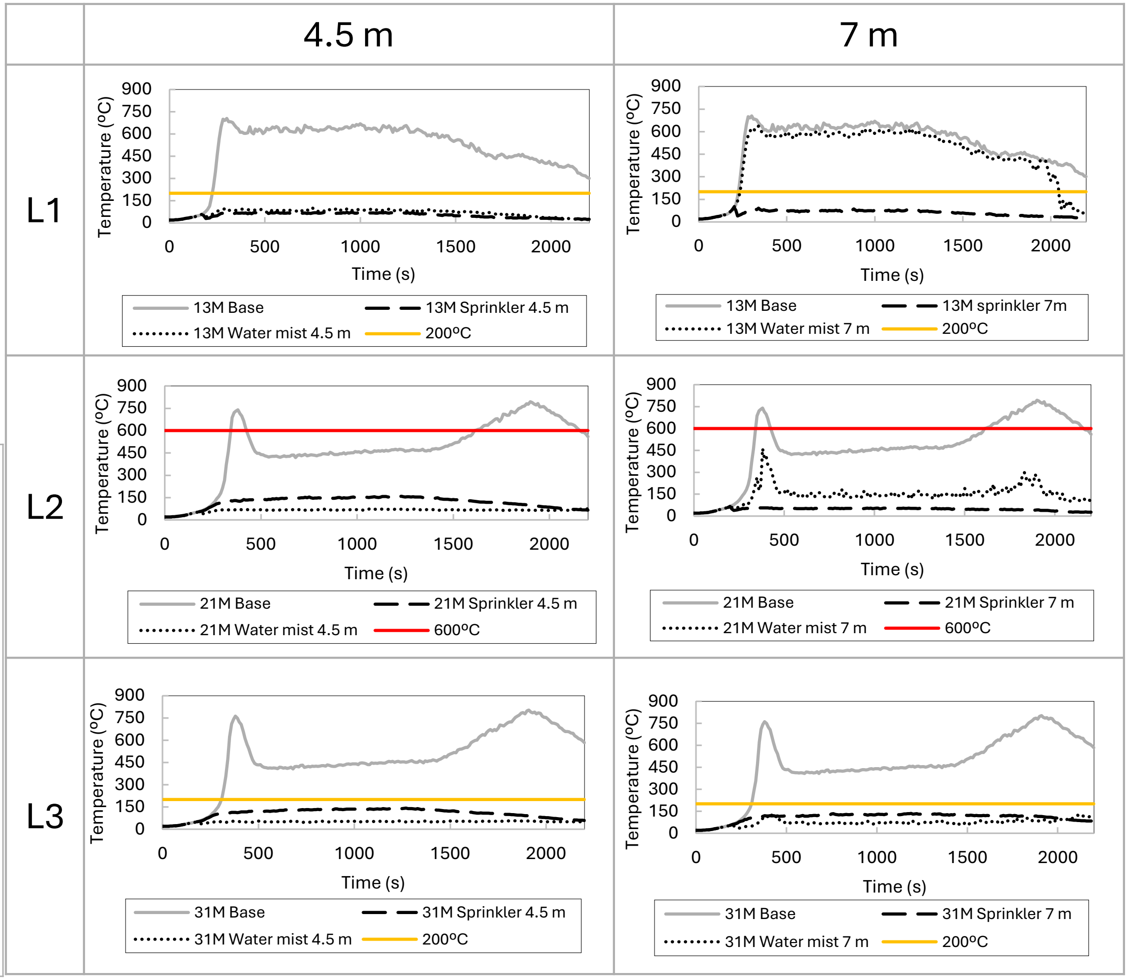
Results: façade claddin

Timber cladding – 1 automatic (68º) device.

Vertical propagation



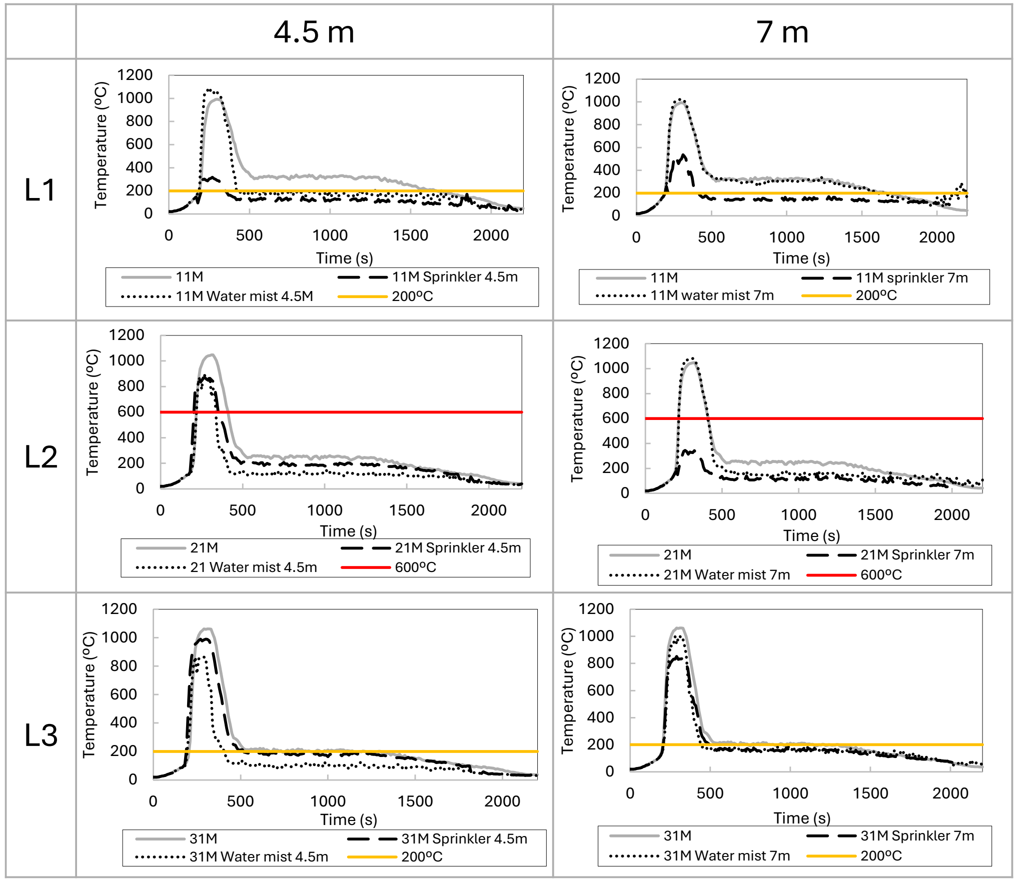




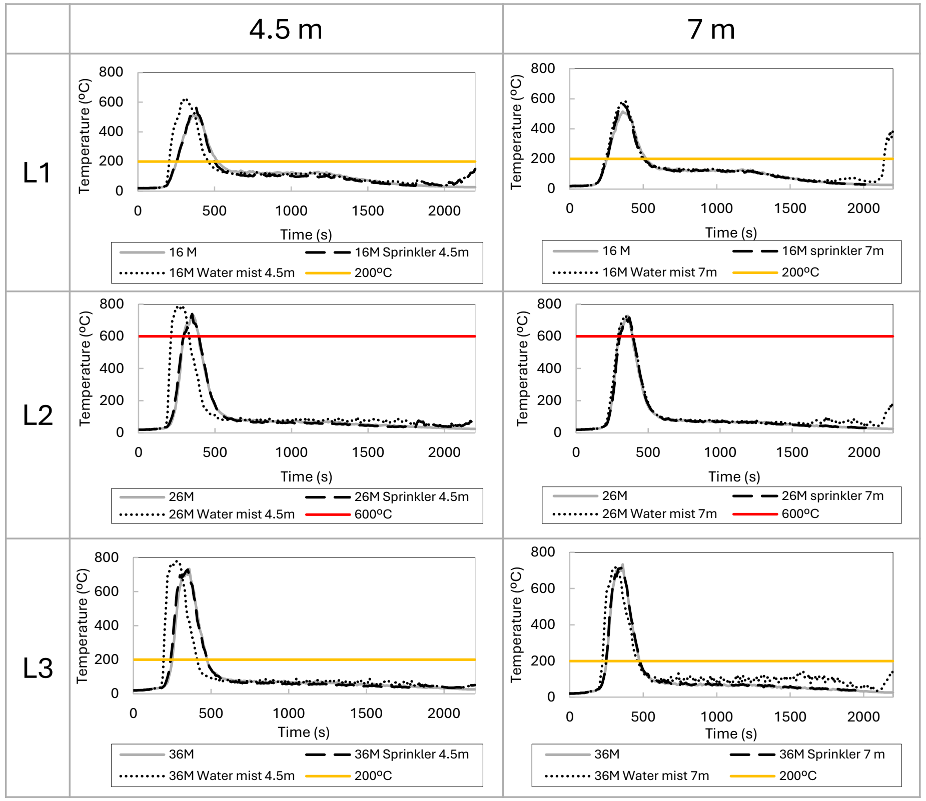
Results: façade cladding

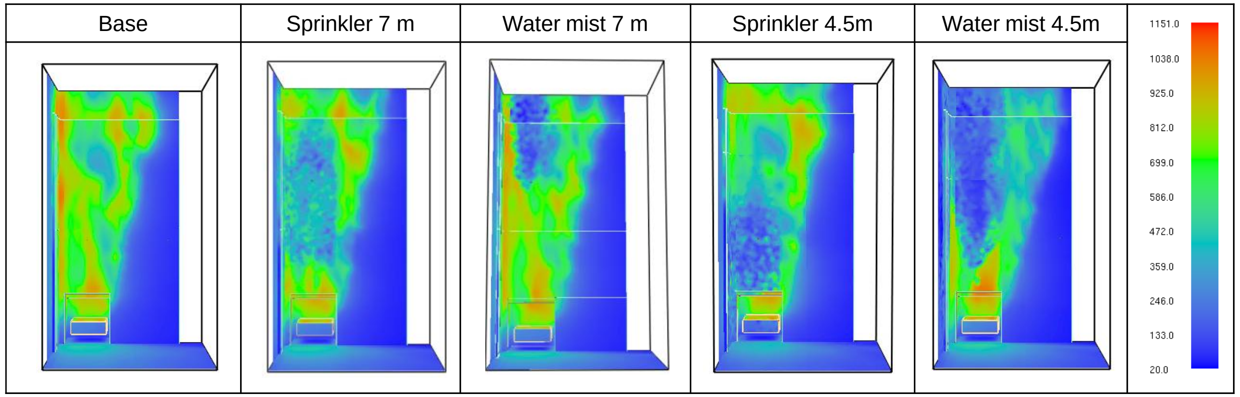
Polyurethane cladding – 1 automatic (68º) device.

Vertical propagation



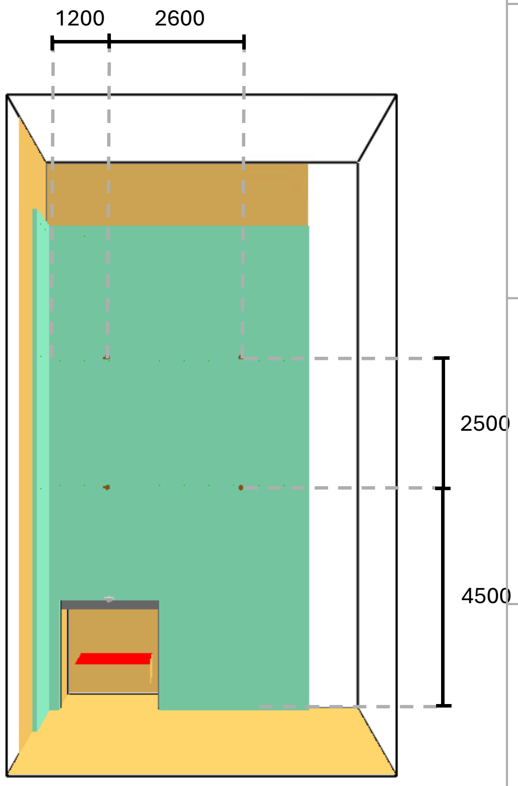
Horizontal propagation



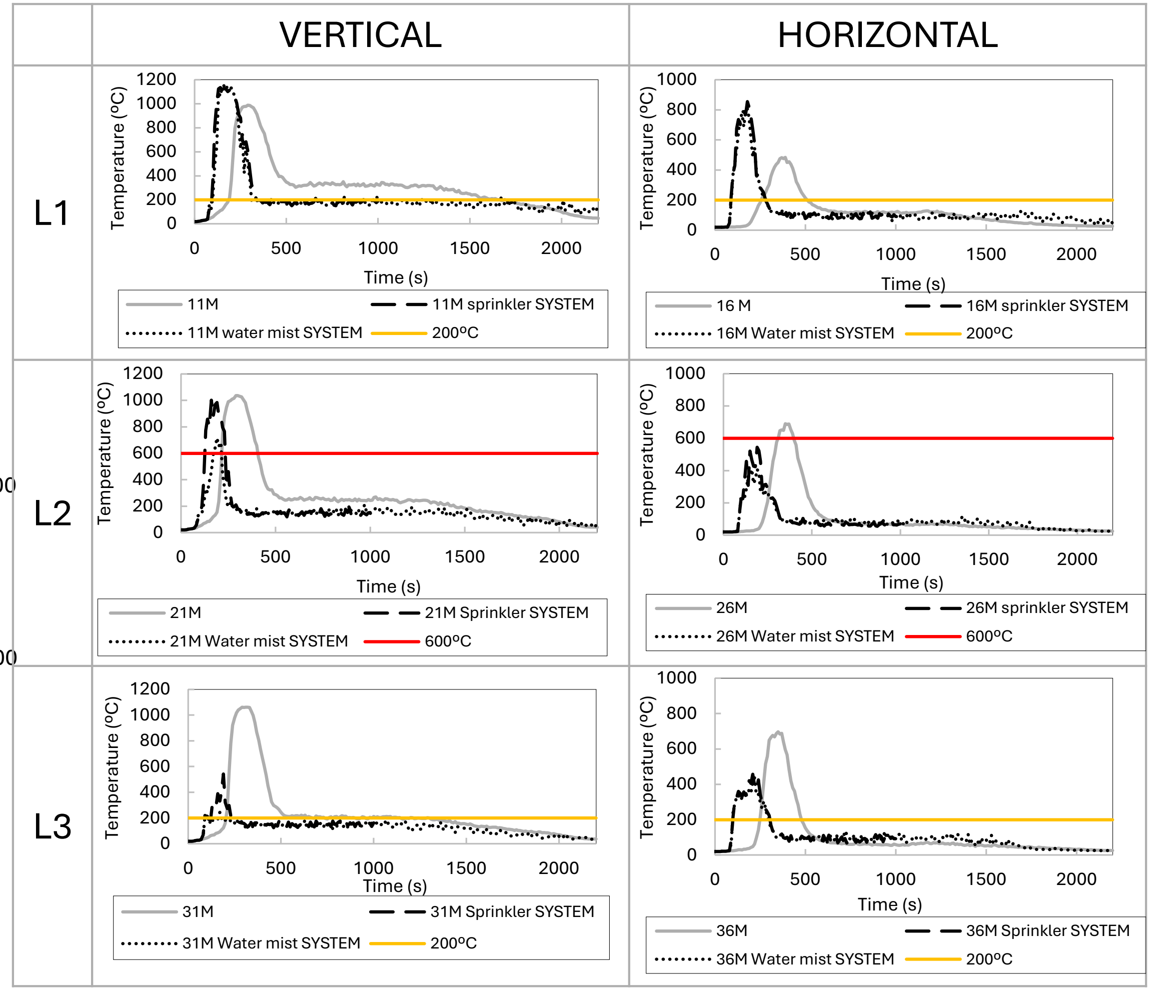


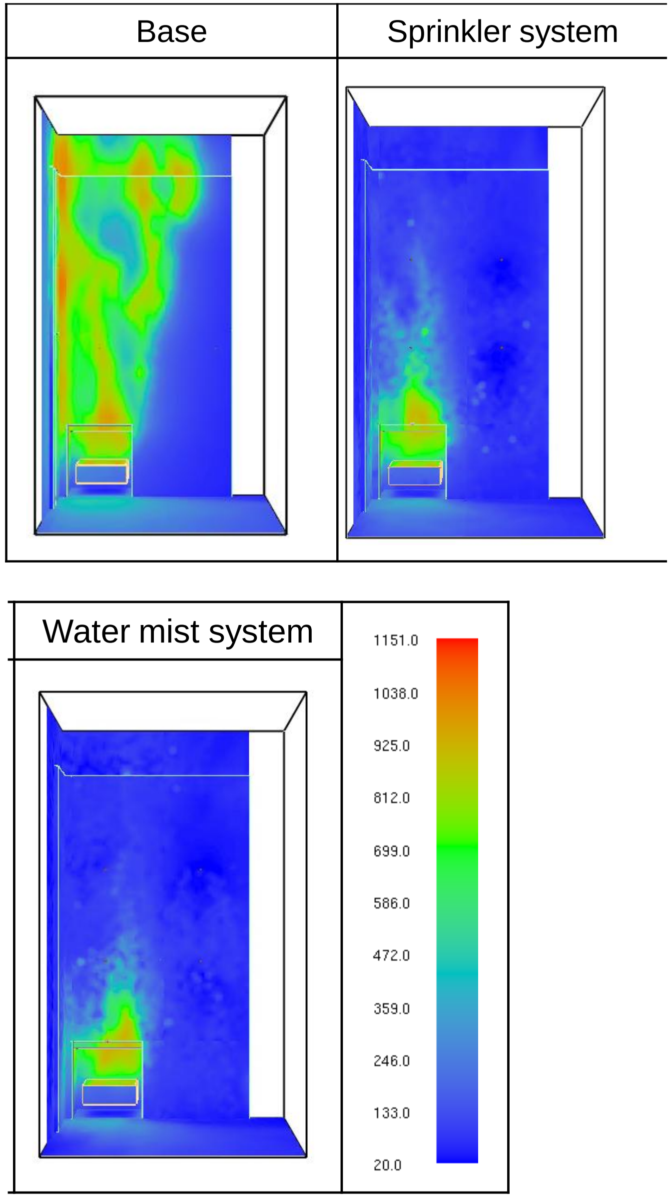
Results: façade cladding

Polyurethane cladding – 4 non automatic (detection 68°C) devices



FFFS configuration with 4 devices





Test Protocol for the Fire Performance of Façade Systems with FFFS protection

Based on reference standards and the CFD study, fire test protocol *Fixed firefighting systems – Test protocol for external façade systems* is defined and proposed.

- Objective: evaluate the effectiveness of Fixed Firefighting Systems (FFFS) as a fire protection system on combustible façade cladding.
- Scope:
  - Façade systems with FFFS independent of the façade cladding solution.
  - Façade system with FFFS integrated into the façade cladding system such as ventilated façades.
  - External steel structure separated from the façade.

This fire test protocol is applicable to automatic and non-automatic nozzles.

- Test setup based on BS 8414-1:2020 fire test scenario, measurements and test criteria.

Test Protocol for the Fire Performance of Façade Systems with FFFS protection

Fire test protocol *Fixed firefighting systems – Test protocol for external façade systems*

- Measurements:
  - Temperature
  - Fire propagation
  - Structural façade integrity
  - FFFS performance
    - Activation monitoring
    - Water flow and pressure
    - Water distribution
- Performance criteria:
  - Vertical fire propagation
  - Horizontal fire propagation
  - Structural façade integrity
  - Load-bearing capacity
  - Others depends on authority having jurisdiction and/or national building and fire code regulation.

Vertical propagation	Criterion
Level 2	T > 600°C for 30s in t < ts+15min
Level 3	T > 200°C for 30s

Horizontal propagation	Criterion
Level 1	T > 200°C for 30s
Level 2	T > 200°C for 30s
Level 3	T > 200°C for 30s

Test Protocol for the Fire Performance of Façade Systems with FFFS protection

Fire test protocol *Fixed firefighting systems – Test protocol for external façade systems*
Test results field of application

- Test results will be directly applicable to external façades taking into account the following considerations:
  - The **same façade cladding material**.
  - Façades geometry similar to that tested, **fully vertical without obstruction**.
  - External steel structure at **equal or higher distance than the tested distance** between the structure and top centre of the opening of the combustion chamber.
  - External steel structure different than the tested structure if the section factor of the structural elements is equal or lower than the of the tested
  - **Same FFFS design and parameters** than the tested (nozzle model, coverage pattern, water and flow conditions).
    Distance between nozzles shall be equal or less than that tested.
    In case that just one nozzle is to be tested, FFFS shall comply:
    - In height, the maximum distance between nozzles shall be equal or less than the tested distance between the nozzle and the centre of the opening of the combustion chamber.
    - In wide, the maximum distance between nozzles shall be equal or less than 2600 mm.

Test Protocol for the Fire Performance of Façade Systems with FFFS protection

Fire test protocol *Fixed firefighting systems – Test protocol for external façade systems*
Test results field of application

- **Others façade cladding materials** are allowed if they have a better fire reaction performance than the tested. Additional small-scale or mid-scale fire tests could be required to verify fire reaction performance of the material (combustibility, ignition temperature and fire propagation).

- FFFS on **ventilated façades or curtain wall** can be tested according to this test protocol as a component of the façade system and considering **FFFS as a part of the façade system**. Test results are applicable to the same façade system. Direct extrapolation of the test results is not permitted.

- To extrapolate the tests results for **singular façade** cladding materials, external steel structure geometries or configurations, it is necessary a performance-based design using a CFD simulation. This method requires that the **numerical model has to be previously validated against the experimental data**.

Conclusions – CFD studio and test protocol proposal

In existing buildings with combustible façades claddings or exterior steel structures, FFFS can be a realistic and valid solution to achieve passive fire protection requirements.

- Combustible façade claddings, **FFFS contributes to preventing vertical and horizontal fire propagation**.
- External steel structure, FFFS has been proven to be an **effective solution for reducing both radiation and steel temperature** by creating a water curtain between the structure and the façade.
- System design characteristics such as the position of the nozzle or sprinkler relative to the fire are identified as critical, as they can significantly influence overall system performance. No generic solution, **specific FFFS solution must be designed and tested**.
- The presented **test protocol based on BS 8414-1:2020 fire test is useful** to test and evaluate the effectiveness of FFFS.
- **Computational CFD simulation is an effective tool** for a preliminary **FFFS design and for the extrapolation of test results** to specific building geometry and configuration, provided it is based on a **validated numerical model**.

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