Fire Safety Risks of External Living Walls and Implications for Regulatory Guidance in England

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safety in numbers

Acknowledgements

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  - Dr Zhaozhi Wang,
  - Dr John Ewer,
  - Dr Fuchen Jia
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Fire safety risks of external living walls and implications for regulatory guidance in England

- Special thanks to Dr Wojciech Węgrzyński and his team from the Building Research Institute (ITB), Poland for providing access to LW fire test data.

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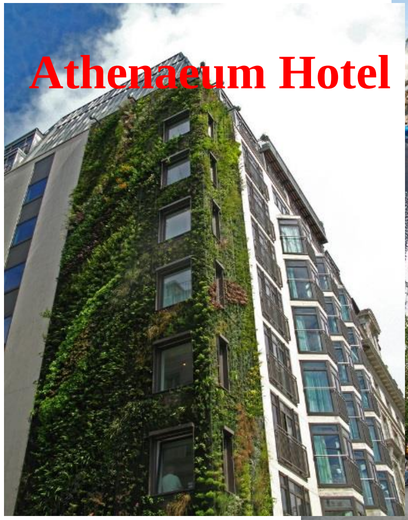
Introduction

Living walls (Green walls)

- LWs introduce biodiversity into cities, improve public health and wellbeing, as well as air quality and thermal environment.
- **100 AD Rome:** Origins date back to Romans training grape vines on trellises and villa walls
- **1930s USA:** Stanley Hart White introduced a modular architectural system made up of ‘botanical bricks’ that could be built to any height
- **1986 France:** Modern LWs pioneered by botanist Patrick Blanc who developed and installed the first successful large indoor LW at the Paris Museum of Science and Industry
- **2006 UK:** First LW in the UK
- **2009 UK:** First UK LW dies.
- **While LWs have aesthetic and environmental appeal, these characteristics must not compromise fire safety.**



Introduction

Living wall fire incidents

- **Beer garden fire, Sydney, 2012**

The LW caught alight in a semi enclosed beer garden when a patron used a candle to light a cigarette and one of the ferns caught alight resulting in fire spread across the wall in a few seconds.

- **Mandarin Oriental Hotel fire, London, 2018**

The fire is believed to have been caused a by-product of arc welding landing on the felt lining of the planting façade.

- **Fire at Block of Flats, Ealing, London, 2018** (twitter by @Miss_AnitaRaj)

This fire destroyed a LW and decking on the 7th floor of a residential building. The external fire gained entry into the building damaging parts of the 7th and 8th floor corridors.

- However, reports of LW fires are relatively rare. Not clear why -
  - limited number of installed LWs around the world?
  - incidence of fire in LWs is a rare event?
  - LW fires are under-reported because they are not significant?

Amy McNeilage, 2012

Lake, 2018

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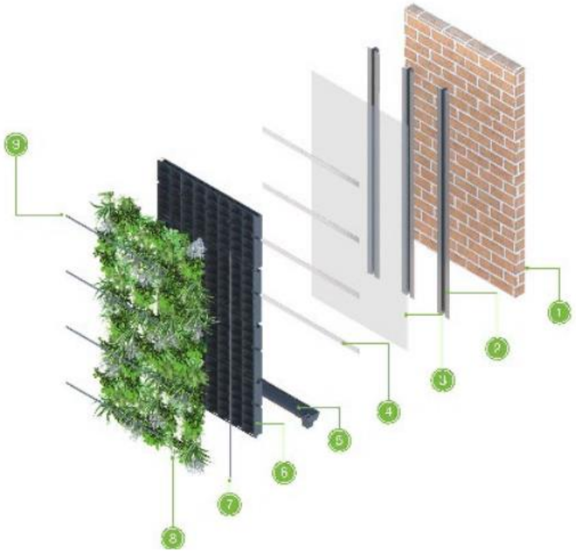
Living Wall Fire Risk

Fire risk factors for LW components include:

- **Individual materials** - The use of combustible materials such as plants, growth media, plastics for the modules (e.g. Polypropylene – PP) and backing layers, wood, etc.
- **Combination of materials** - The integration of these materials into a composite LW system which may increase fire spread and severity;
- **Spatial arrangement of materials** – Including gaps and air pockets within the system itself and the supporting structures, which may hinder or exacerbate fire spread;
- **Facade design** – For example where LW abut windows or wall penetrations, fire can spread from within to the LW and from LW to the interior.



https://www.ansgroupglobal.com

Living Wall Fire Risk

One particular fire retarded (FR) polypropylene (PP) currently used in LWs (i.e., achieved a Class B rating) has a …..

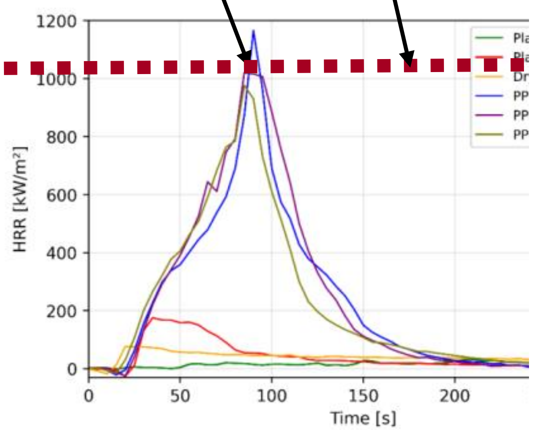
- ….. higher HoC (~ 44.6 MJ/kg) and greater mass/m^2 (~ 3.80 kg/m^2) than the Grenfell ACM core (Polyethylene) (~ 43.3 MJ/kg, ~ 2.91 kg/m^2).
- This FR PP LW module represents 34% more fire load per m^2 than Grenfell ACM
- This FR PP has quite similar fire behaviour (cone calorimeter experiment) as PE ACM

FR PP used for LW module

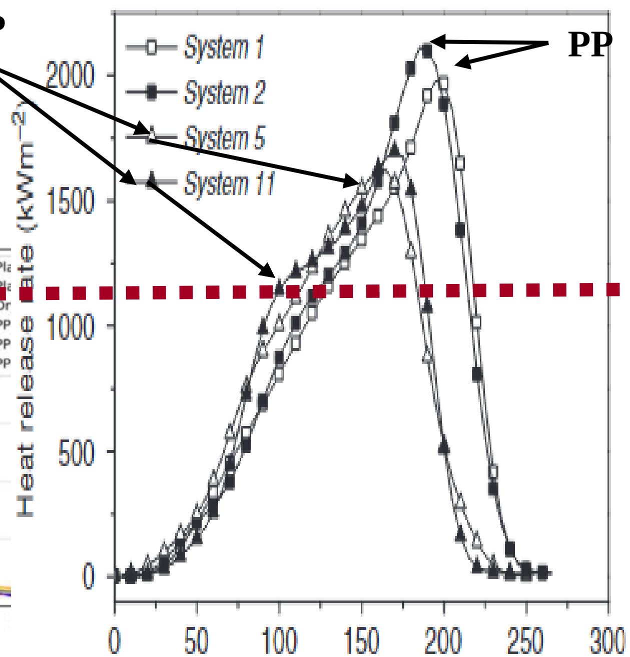
FR PP

PP

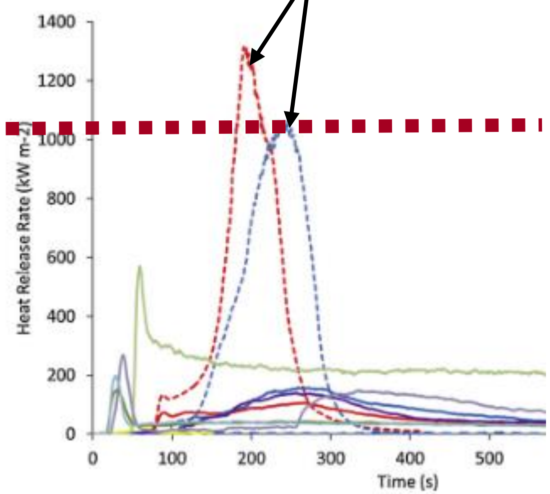
PE ACM



Węgrzyński et al., 2023



Marney et al., 2007



McKenna et al., 2019

Living Wall Fire Risk

LW structure and installation – The design of the system can affect fire spread;

Defective installation – Poor quality implementation can exacerbate fire spread;

Moisture levels – Moisture levels within the system growing medium and irrigation network can greatly influence flammability and fire spread;

Maintenance – Lack of maintenance, e.g., neglected accumulation of dry matter and litter can affect flammability and fire spread;

Environmental factors – Factors beyond control e.g.,

- wind can dry plants and can support fire spread,
- climate change is also a consideration as weather patterns change, e.g., increased periods of drought and increases in wind velocity.

http://www.landmarklivingroofs.co.uk/

LW Regulatory and Guidance in England

Approved Document B (ADB) 2022

The Building Regulations 2010

Fire safety

B

12.3 The external walls of buildings other than those described in regulation 7(4) of the Building Regulations should achieve either of the following.

a. Follow the provisions given in paragraphs 12.5 to 12.10, which provide guidance on all of the following.

i. External surfaces. → **Table 12.1**

ii. Materials and products.

iii. Cavities and cavity barriers.

b. Meet the performance criteria given in BRE report BR 135 for external walls using full-scale test data from **BS 8414-1** or **BS 8414-2**.

12.8 Best practice guidance for green walls (also called living walls) can be found in *Fire Performance of Green Roofs and Walls* published by the Department for Communities and Local Government. Where regulation 7(2) applies, that regulation prevails over all the provisions in this paragraph.

2013

LW Regulatory and Guidance in England

- Prior to 2019, wall material fire performance was defined by the ‘disputed’ **Diagram 40**.
- From **ADB 2019**, the questionable Diagram 40 was deleted and wall material fire performance requirements were defined using **Table 12.1.**
- Wall materials are classified in terms of their reaction to fire performance in accordance with **BS EN 13501-1: 2018**.

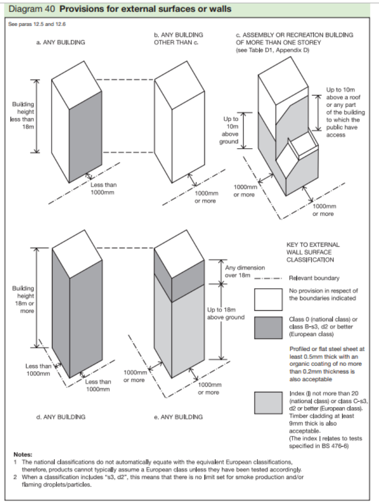


Table 12.1 Reaction to fire performance of external surface of walls

Building type	Building height	Less than 1000mm from the relevant boundary	1000mm or more from the relevant boundary
‘Relevant buildings’ as defined in regulation 7(4) (see paragraph 12.15)		Class A2-s1, d0[1] or better	Class A2-s1, d0[1] or better
All ‘residential’ purpose groups (purpose groups 1 and 2)	More than 11m	Class A2-s1, d0[2] or better	Class A2-s1, d0[2] or better
	11m or less	Class B-s3, d2[2] or better	No provisions
Assembly and recreation	More than 18m	Class B-s3, d2[2] or better	From ground level to 18m: class C-s3, d2[3] or better From 18m in height and above: class B-s3, d2[2] or better
	18m or less	Class B-s3, d2[2] or better	Up to 10m above ground level: class C-s3, d2[3] or better Up to 10m above a roof or any part of the building to which the public have access: class C-s3, d2[3] or better[4] From 10m in height and above: no minimum performance
Any other building	More than 18m	Class B-s3, d2[2] or better	From ground level to 18m: class C-s3, d2[3] or better From 18m in height and above: class B-s3, d2[2] or better
	18m or less	Class B-s3, d2[2] or better	No provisions

BS EN 13501-1:2018

BSI Standards Publication

Fire classification of construction products and building elements

Part 1: Classification using data from reaction to fire tests

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 and	$\Delta T \leq 30$ °C; and $\Delta m \leq 50$ %; and $t_f = 0$ s (i.e. no sustained flaming)	-
	EN ISO 1716	$PCS \leq 2{,}0$ MJ/kg and $PCS \leq 2{,}0$ MJ/kg and $PCS \leq 1{,}4$ MJ/m² and $PCS \leq 2{,}0$ MJ/kg	-
A2	EN ISO 1182 or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ s	-
	EN ISO 1716 and	$PCS \leq 3{,}0$ MJ/kg and $PCS \leq 4{,}0$ MJ/m² and $PCS \leq 4{,}0$ MJ/m² and $PCS \leq 3{,}0$ MJ/kg	-
	EN 13823	$FIGRA_{0,2\,MJ} \leq 120$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production and Flaming droplets/particles
B	EN 13823 and	$FIGRA_{0,2\,MJ} \leq 120$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production and Flaming droplets/particles
	EN ISO 11925-2 : Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
C	EN 13823 and	$FIGRA_{0,4\,MJ} \leq 250$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 15$ MJ	Smoke production and Flaming droplets/particles
	EN ISO 11925-2 : Exposure = 30 s	$F_s \leq 150$mm within 60 s	
D	EN 13823 and	$FIGRA_{0,4\,MJ} \leq 750$ W/s	Smoke production and Flaming droplets/particles
	EN ISO 11925-2 : Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
E	EN ISO 11925-2 : Exposure = 15 s	$F_s \leq 150$ mm within 20 s	Flaming droplets/particles
F	EN ISO 11925-2 : Exposure = 15 s	$F_s > 150$ mm within 20 s	

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LW 'Best Practice' Guidance: Issue 1/3

- The LW 'best practice' fire safety guidance document, **Fire Performance of Green Roofs and walls**, was published by DCLG in **2013**.
- The guidance states that LWs must comply with the requirements as specified in Diagram 40 of ADB **2013** and yet, the materials must be of **limited combustibility** – these requirements were contradictory even in 2013.

Department for Communities and Local Government

Fire Performance of Green Roofs and Walls

Page 27

'In a building with a storey 18m or more above ground level any material used in the external wall construction should be of **limited combustibility**'

August 2013
Department for Communities and Local Government

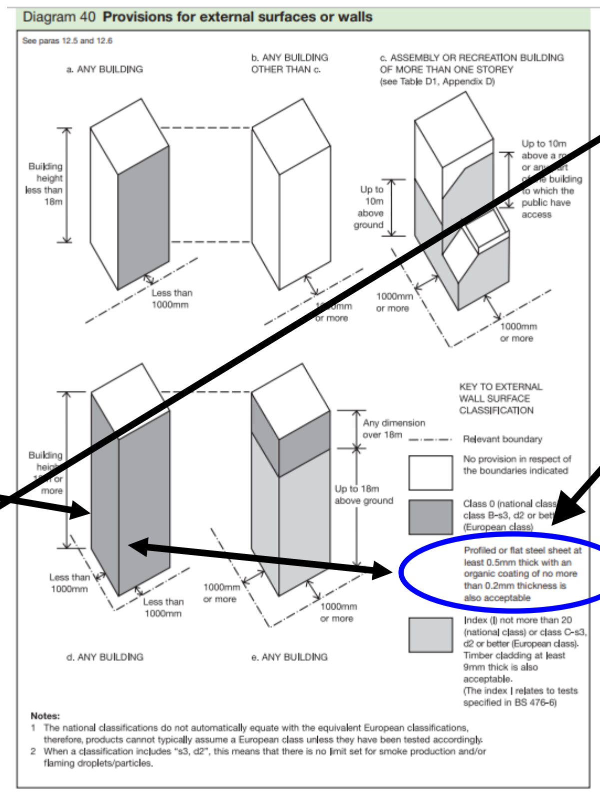


Diagram 40 (ADB, 2013)

Limited Combustibility implies Class A2 or better

But Diagram 40 suggests a requirement of Class B or better

From 2013 construction industry assumed guidance intended Class B

LW 'Best Practice' Guidance Issue 2/3: Inconsistent with ADB 2022, e.g. 1
Any building (other than recreation or assembly) < 18 m, boarder > 1m

LW 'best practice' Guidance 2013

Department for Communities and Local Government

Fire Performance of Green Roofs and Walls

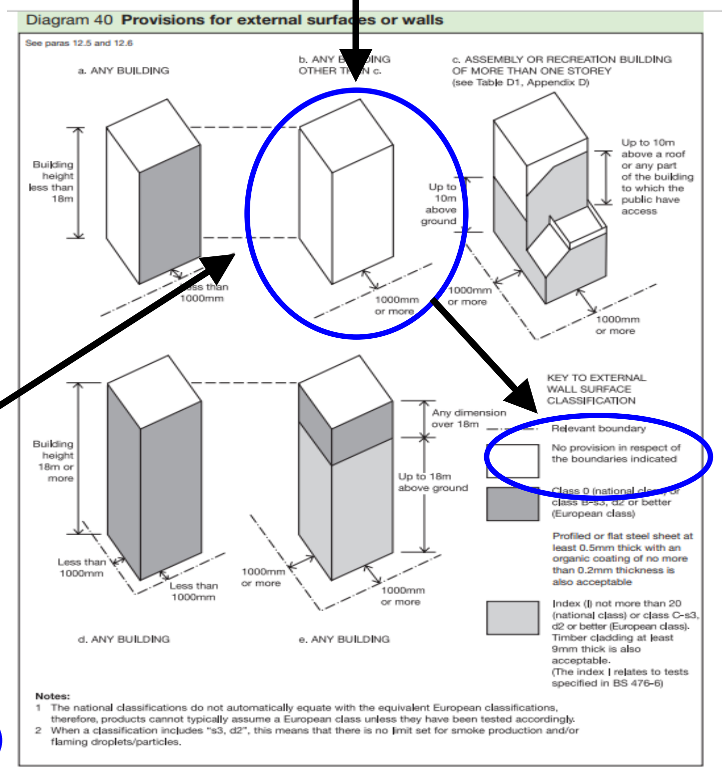
NO restriction on LW for residential or office buildings in 2013 'best practice' LW fire guidance (<18m high, boarder >1m)

Department for Communities and Local Government

August 2013

ADB 2013

Residential or Office buildings
< 18 m high with a façade > 1m from the boundary – NO restriction



ADB 2013 and 2020

- Residential or Office: NO restriction - **consistent with LW BP**

ADB 2022

- Office: NO restriction - **consistent with LW BP**
- Residential <11m: NO restriction - **consistent with LW BP**
- Residential >11m: Class A2+ (irrespective of boundary distance) **NOT consistent with LW BP**

LW 'Best Practice' Guidance Issue 2/3: Inconsistent with ADB 2022, e.g. 2 Residential or Office (any building) > 18 m, boarder < 1m

LW 'best practice' Guidance 2013

Department for Communities and Local Government

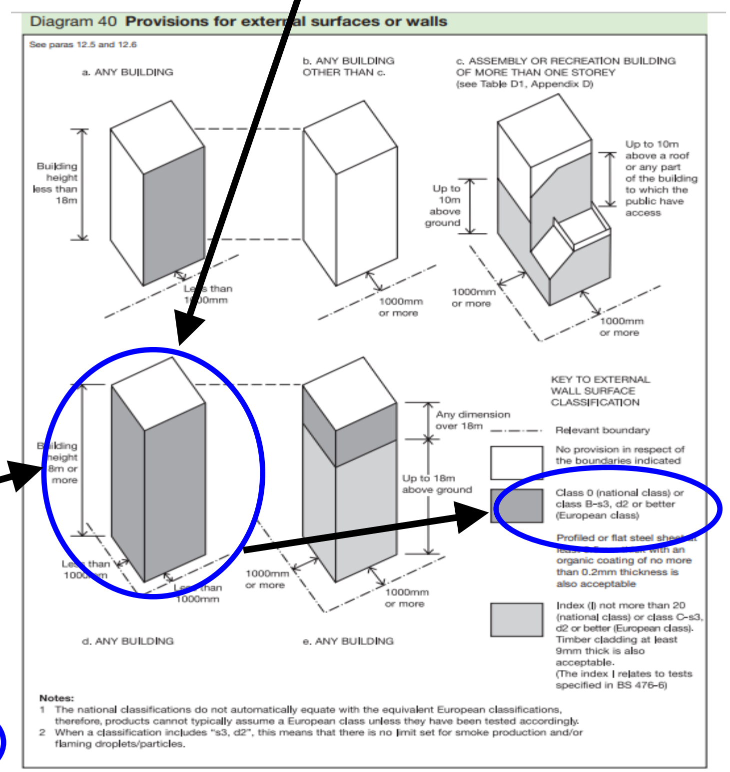
Fire Performance of Green Roofs and Walls

Class B on LW for residential or office buildings in 2013 'best practice' LW fire guidance (>18m high, boarder <1m)

August 2013
Department for Communities and Local Government

ADB 2013

Residential or Office buildings
> 18 m high with a façade < 1m from the boundary – Class B



ADB 2013

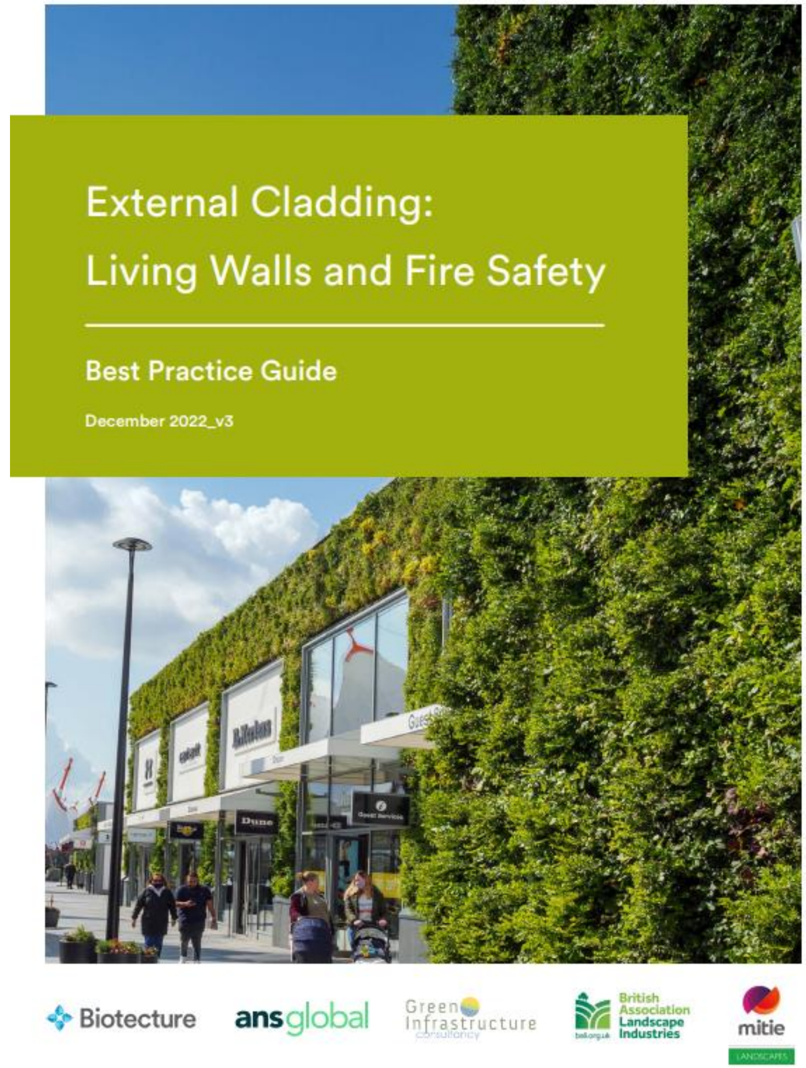
- Residential or Office: Class B - **consistent with LW BP**

ADB 2020 and 2022

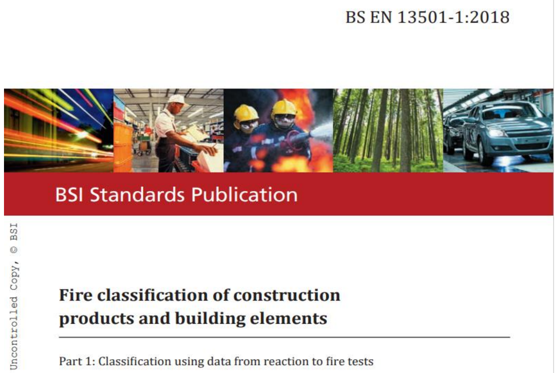
- Office: Class B - **consistent with LW BP**
- Residential: Class A2+ (irrespective of boundary distance) **NOT consistent with LW BP**

Recently Published LW Fire Safety Document

- **As the official 2013 LW 'best practice guidance' provides contradictory information and is not consistent with ADB 2022, it must be removed from the ADB or be brought up to date.**
- **A recently published industry guidance document that proclaims to be a 'best practice guide' for LW is at least compliant and consistent with ADB 2022.**
- **However, it still recommends that LW fire performance can be assessed using 'destructive testing' of the same type recommended in the 2013 LW guidance i.e., SBI testing (Issue 3).**



LW ‘Best Practice’ Guidance Issue 3/3: Appropriateness of current fire test methods


BS EN 13501-1:2018

BSI Standards Publication

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Fire classification of construction products and building elements

Part 1: Classification using data from reaction to fire tests


BS EN 13823:2020

BSI Standards Publication

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Reaction to fire tests for building products — Building products excluding floorings exposed to the thermal attack by a single burning item


BS EN ISO 11925-2:2010

BSI Standards Publication

Reaction to fire tests — Ignitability of products subjected to direct impingement of flame

Part 2: Single-flame source test

- Wall materials are classified in terms of their reaction to fire performance in accordance with **BS EN 13501-1: 2018** (classes summarised in the right table).
- LW industry, as recommended by the 2013 Guidance (and ADB) utilise the **SBI test (EN 13823)** test for the whole system and the **ignitability test** for solid components.
  - The SBI test is an intermediate-scale fire test representing an internal corner formed with two faces of product, 1.5 m high with 1.0 m and 0.5 m wide surfaces.
  - The SBI test is successfully used to assess building products used in the construction of walls for Euro classification from A2 to D.

Appropriateness of Current fire test methods

SBI LW fire test examples

Sample before product test

Sample before product test

Sample during product test

Sample after product test

Test sample undergoing research – this product has achieved Class B in an official SBI Test - Węgrzyńskia et al.

Issues Relating to the Current LW fire test

- **Heat source:** The small **SBI** heat source (30 kW) is inappropriate for assessing the fire performance of LW organic matter under wet conditions.
- **Size:** The standard SBI test requires that specimen surfaces are flat or regularly corrugated with a thickness of no more than 0.2 m.
- **Consistency:** The tested sample may not be representative of the original LW module as the plants are usually trimmed to fit in the test facility.
- **Moisture:** SBI test specimens must be conditioned to a temperature of 23±2 ^{O}C and a relative humidity of 50±5%. This is impossible for LW as they must be wet!

LW test specimen during and post SBI test

SBI test with untrimmed plants

SBI test with plants trimmed back to the compost

Two extremes of test specimen preparation for SBI testing

Issues Relating to the Current LW fire test

Moisture Issues:

- Test results are dependent on the level of moisture within the module (plants, growth medium and support structure).
- Moisture levels will be dependent on the preparation of the particular product sample tested and so cannot be standardised as a predetermined test requirement.
- Thus repeatability of test results is doubtful.
    - **A sample of 5 LW fire tests** had moisture levels (mass fraction) of 45%, 70%, 14%, 27% (excluding water in the plants), and ‘wet’ (described in the test report) respectively.
    - **RECOMMENDATION:** To avoid potential biasing of test results, the moisture level tested should be representative of the minimum levels expected for the installation and **MUST** be specified as a condition for the achieved product test performance.

SBI test with dead plants - 150 s after test start Węgrzyńskia et al 2023

Flame from cavity between LW and support wall Węgrzyńskia et al 2023

Gaps:

- The gap between the modules and cavity between the module back and support wall and any barriers within the cavity are highly likely to impact fire development.
- Indeed, it is arguable whether it is even possible to assign a living product a Euro Class fire performance rating.

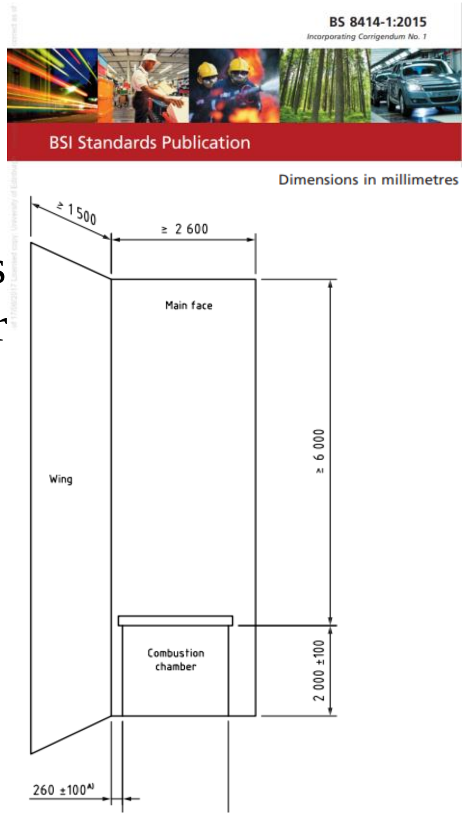
Potential approaches to address moisture issues of LW fire assessment methodology

Assessment using SBI test (EN 13823)

- **Abley et al**. (RISCAuthority) suggest that assessing LW systems using the SBI test while including succulent plants and irrigated growing medium is an abuse of the small-scale tests in BS EN 13501-1 as the moisture effectively protects combustible components.
- **Abley et al**. recommend simply testing the module and backing layer, excluding plants, growth medium and all moisture.
- However, this does not test the complex system that is intended to be installed.
    - Clearly, moisture levels tend to improve fire performance of the system, and plants may have a negative impact while growth medium may have a negative or positive impact.
- Rather than test a LW in its optimal state, the state of the test module, including plants, should reflect that of the minimum acceptable condition.
    - This way test results identify the expected performance of the maximum degraded LW system which is still considered acceptable.

BS 8414 Test

- **Larger size:** The BS8414 (2015) test represents an external building corner formed by two faces at least 8.0 m high with 1.5 m (wing) and 2.6 m (main face) wide surfaces.
- **Large fire:** The fire chamber is represented by a 2.0 m wide by 2.0 m high chamber in the main face and the fire source is a wood crib producing **3 MW peak** output and 4500 MJ over 30 min.
- **System test:** BS8414 test attempts to treat the building façade as a complex system taking into consideration how each component of the façade system reacts to a representative fire threat.
- It is recommended in ADB (Item 10.3 b) as one of the methods to assess external building walls using the performance criteria given in BRE report **BR 135** .
- The current BS8414 2020 test methodology has some improvements:
    - Detail requirements for the distance between cavity barriers
        - Increase of test facility height from 8m to 9.7 m
    - Additional temperature measurement at level 3 (7.5m high)

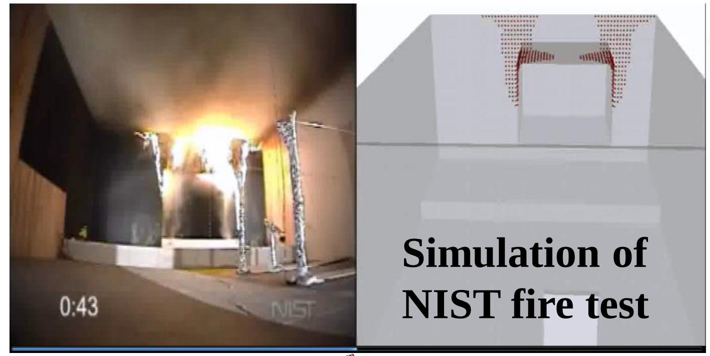


Potential Alternative LW fire assessment methodology

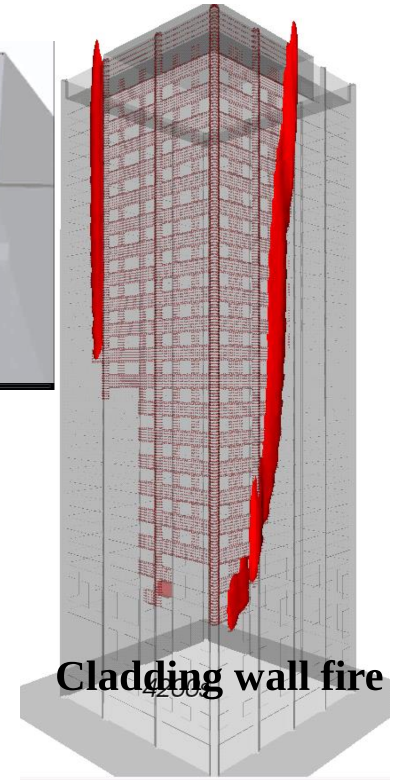
- No publicly available reports describing BS8414 tests for LW systems.
- While not specifically mentioned in ADB 2022 (or the 'best practice' guidance) as a test protocol for LW systems, the BS8414 test could be used to assess LW installations and is arguably more appropriate than the reduced-scale SBI test.
    - Larger LW module size that can be accommodated by the BS8414 test compared to the smaller SBI test
    - More appropriate fire source (2.5-3.5 MW) used.
    - No need to assign a Euro Class categorisation
    - However, still need to address issue of state of sample tested
- There are additional 'general' limitations of the BS8414 test that should also be addressed if this approach is to replace the SBI test, such as:
    - inconsistency of the fire source (wood crib fire),
    - inappropriateness of simple pass-failure criteria and associated lack of monitoring data,
    - impact of wind.

SMARTFIRE CFD FIRE SIMULATION SOFTWARE

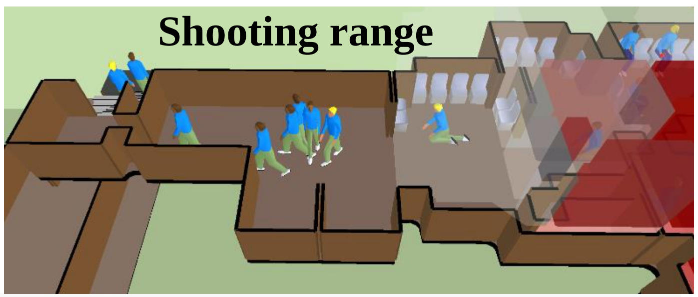
- Developed by FSEG
- Applications in buildings, aviation, marine and rail environments
- https://fseg.gre.ac.uk/smartfire/



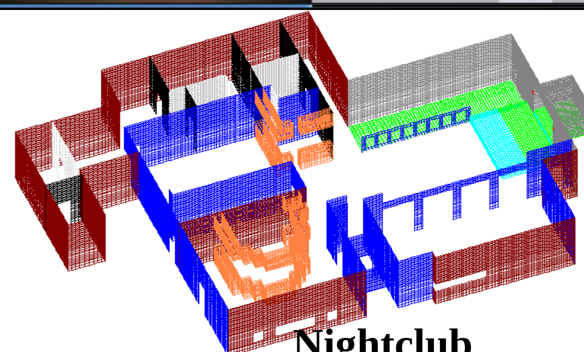
Simulation of NIST fire test



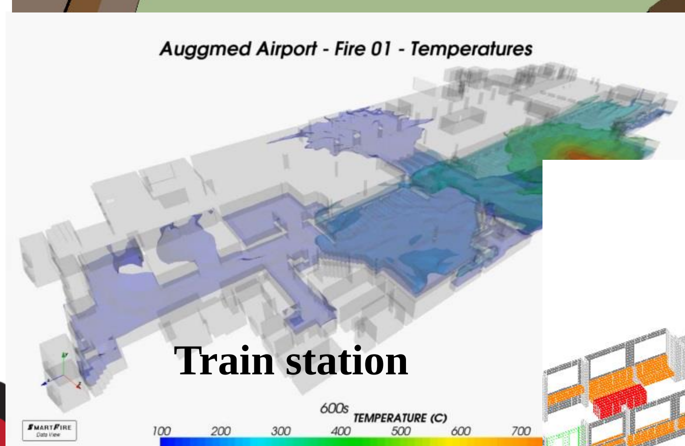
Cladding wall fire



Shooting range

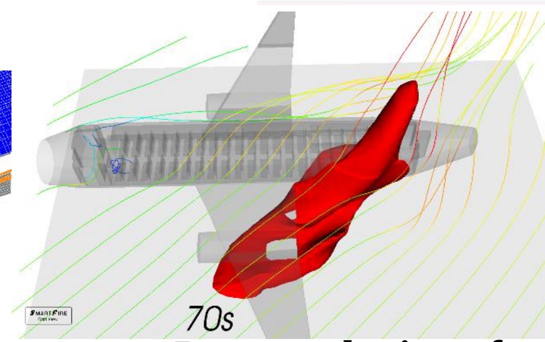


Nightclub



Train station

Underground train

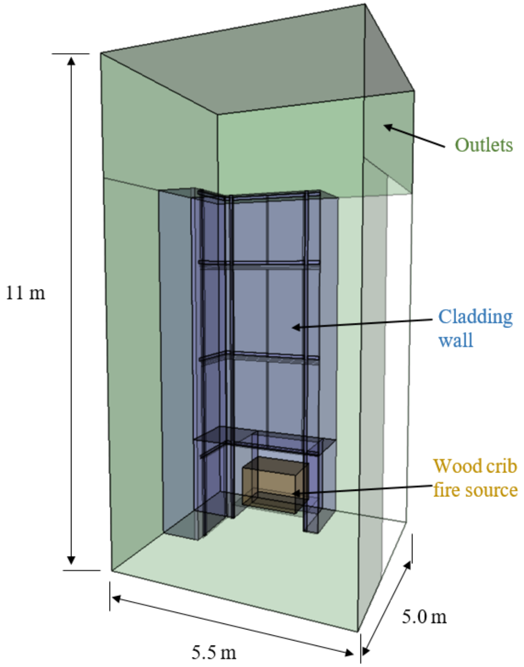


Post-crash aircraft

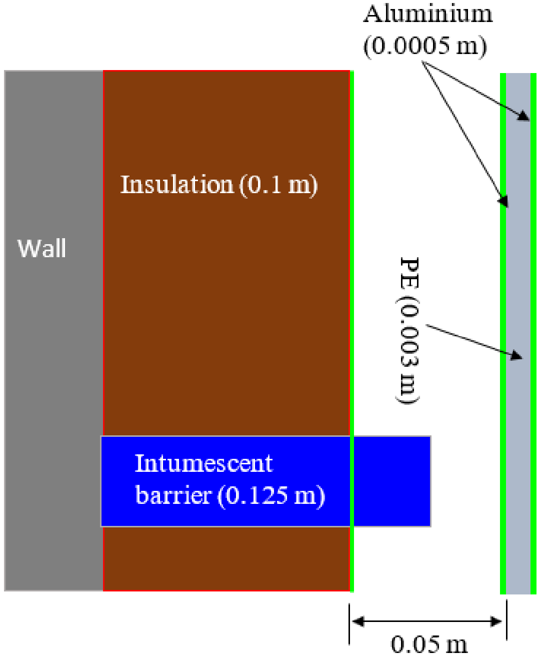
BS8414 SMARTFIRE CFD Fire Simulator

Developed by FSEG using SMARTFIRE, capable of predicting:

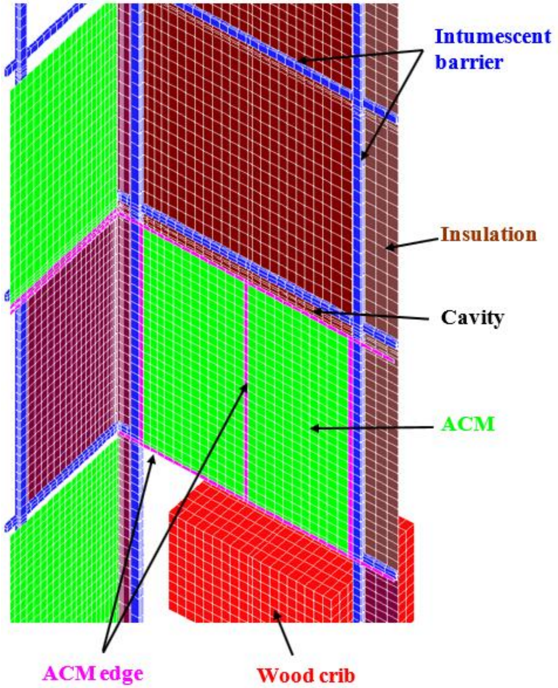
- burning rates of individual materials such ACM panels, insulation, etc;
- temperature and toxic gas profiles as function of time at locations of interest;
- Burning/burnt off locations
- Typical mesh consists of 600,000+ cells, smallest cells are 0.01m
  - 6 min sim required 11hrs with varying time step (3.6 GHz, 12 core CPU)



BS8414 CFD simulation domain



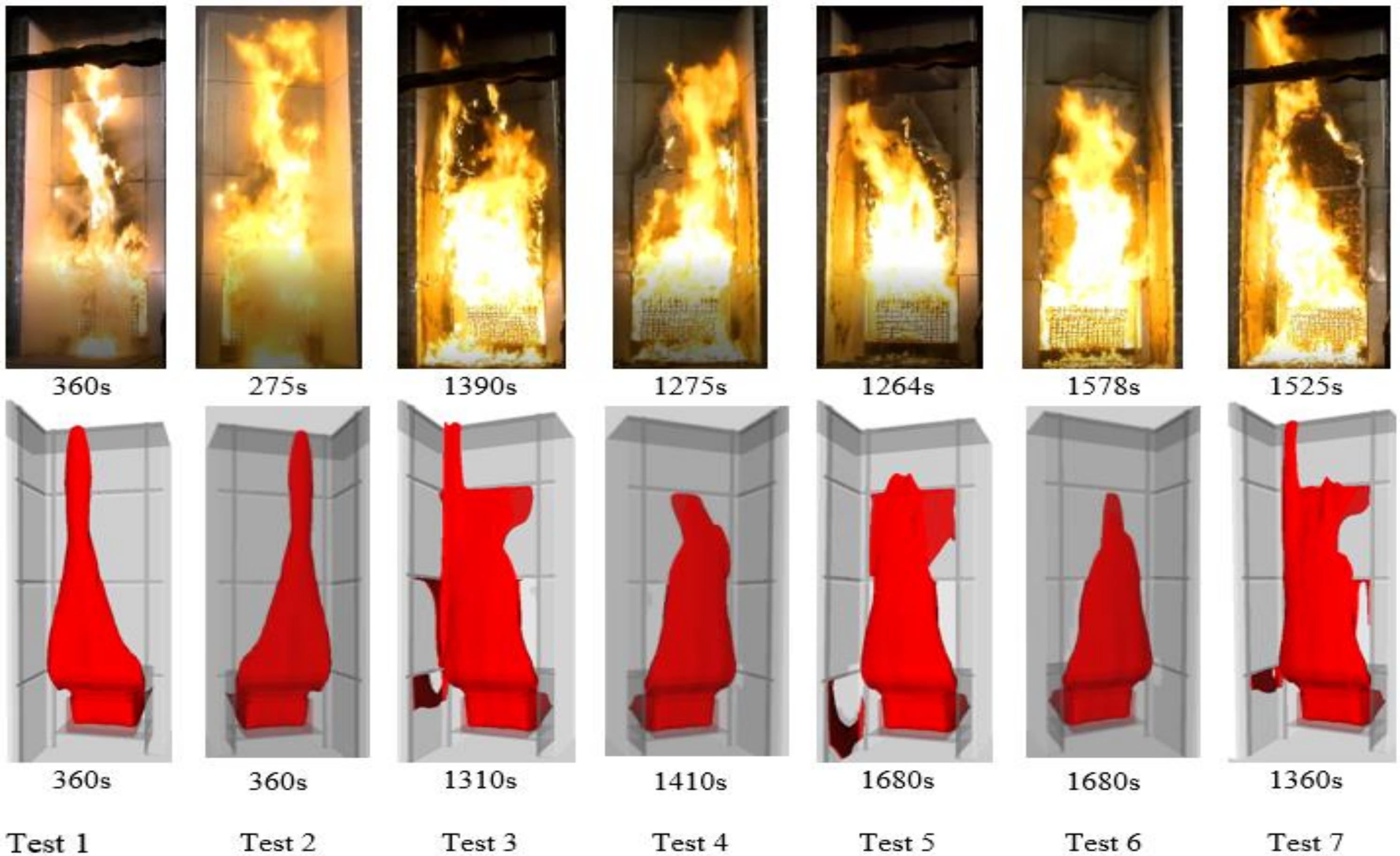
Side view of the cladding system (element size adjustable)



Details of ACM panel, insulation and barriers

BS8414 Fire Simulator

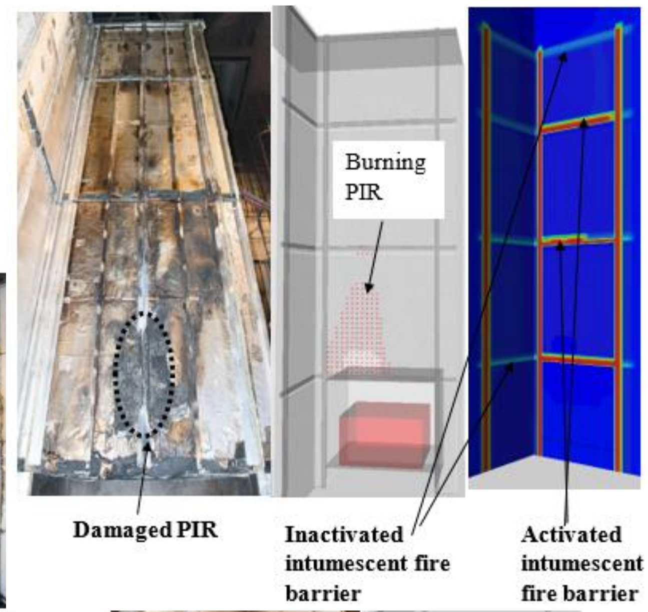
- Validated by reproducing the seven BS 8414 tests conducted by DCLG in 2017 following the Grenfell fire.

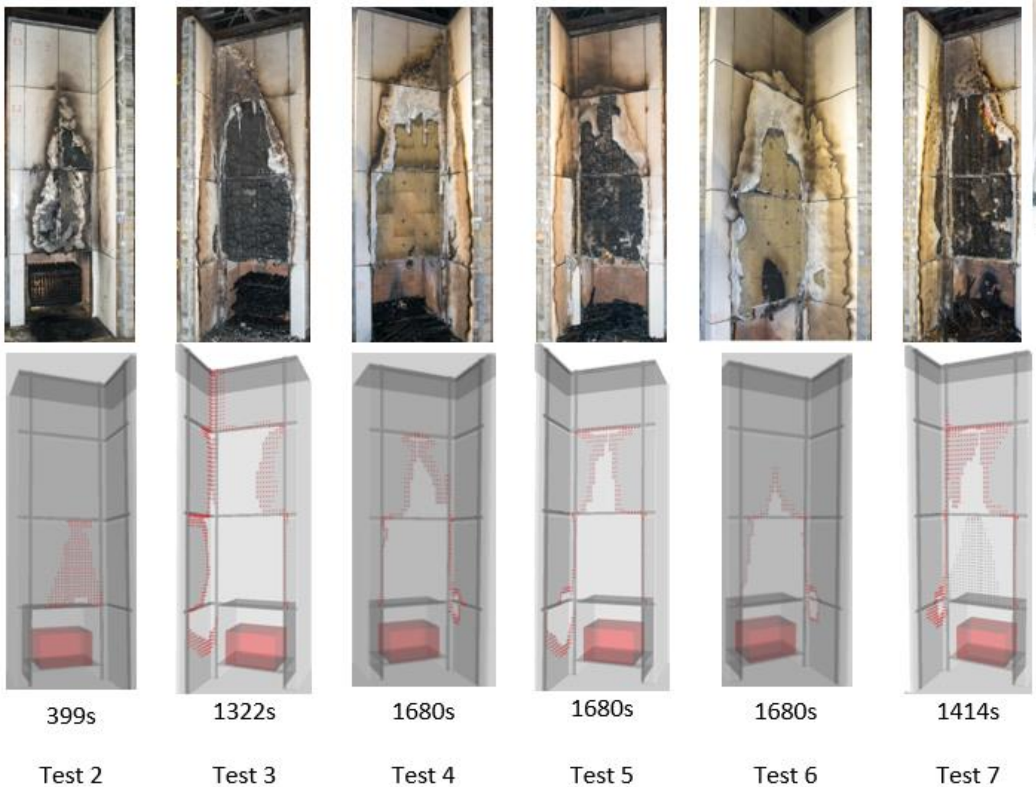


Observed and simulated flames at failure or at the end of test (if passed)

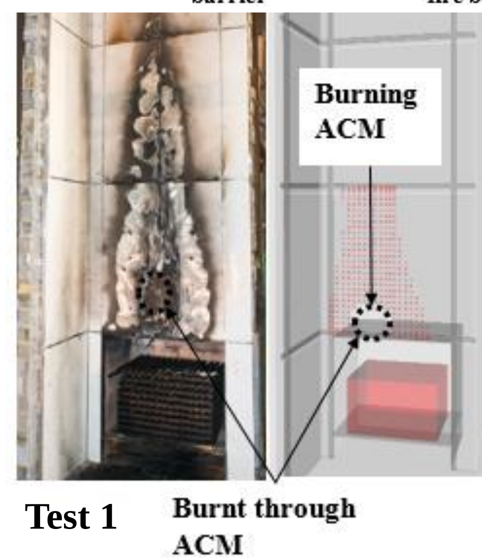
BS8414 Fire Simulator

- Validated by reproducing the seven BS8414 tests conducted by DCLG in 2017.





Burnt off ACM panel in the experiments and the predictions (white area)



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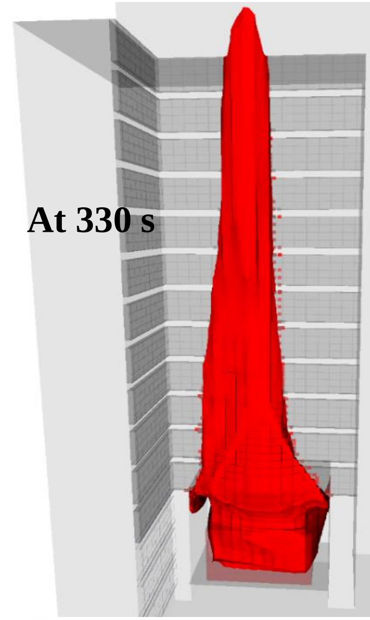
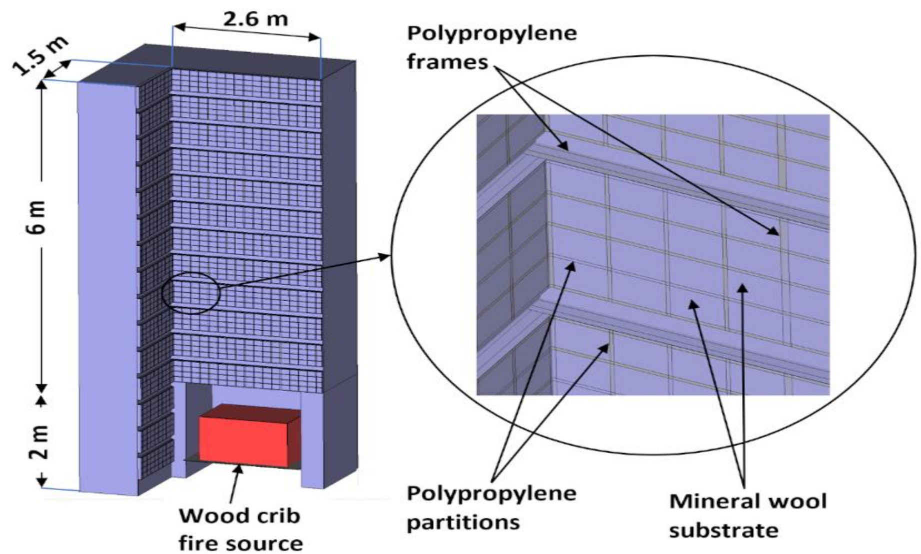
Potential LW fire assessment methodology

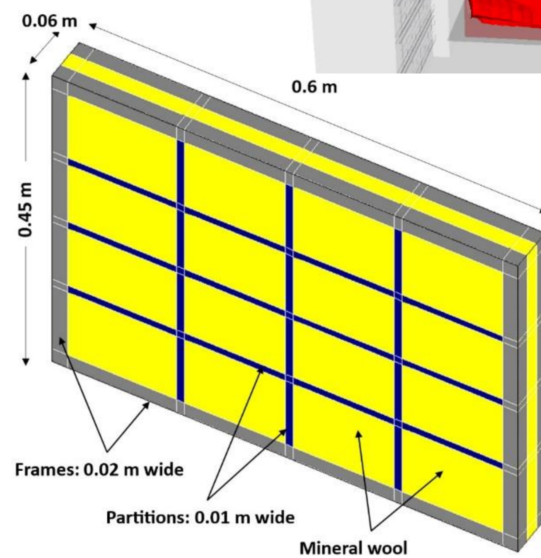
BS8414 fire simulator for LW structure fire

- Hypothetical dry LW excluding plants and irrigation system;
- The HRRs for the exposed part of polypropylene planting modules refers to data by Marney et al., 2007;
- The back of the modules attaches directly to the wall (fixtures are not modelled);
- This hypothetical LW fails the BS8414 test with the simulated fire plume beyond the test facility at 330 s.





LW Assembly



Module details

LW Fire Sub-Models

Common CFD sub-models include

- k-epsilon turbulence model;
- The multiple ray radiation model;

Flame spread model for the pyrolysis of solid structure such as LW module plastic panels;

- Ignition using surface ignition temperature or specified flame spread rate;
- Once ignited, fuel is released based on prescribed HRRs;

LW fire model for the pyrolysis of the plant and growth medium

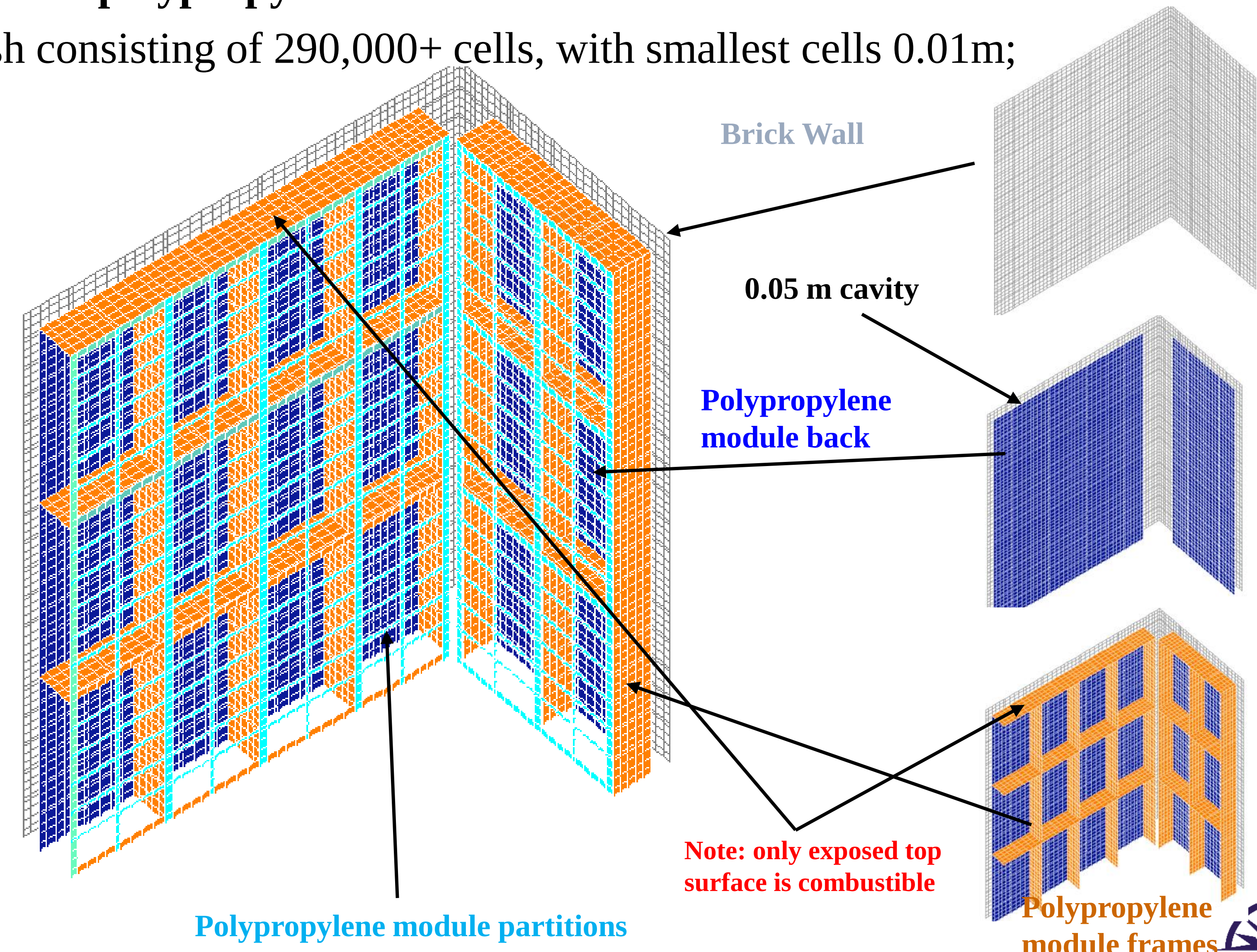
- Plants and growth medium are modelled as porous medium with key parameters of moisture content; volume fraction of plants; surface to volume ratio of plants, ignition temperature, pyrolysis heat and heat of combustion.
- Water contained in the plants/medium in a computational cell is evaporated when the medium temperature reaches 100 ^{O}C;
- After the material in a computational cell is dried (water evaporated), when the ignition temperature is reached, plants/medium start to release gaseous fuel at a calculated fuel release rate (incident heat flux and pyrolysis heat dependent);

Combustion model

- The eddy dissipation combustion model predicts the heat release rate of the combustion of the gaseous fuel released from the pyrolysis of the solid materials (solid structure and plants/medium).

SBI LW Structure

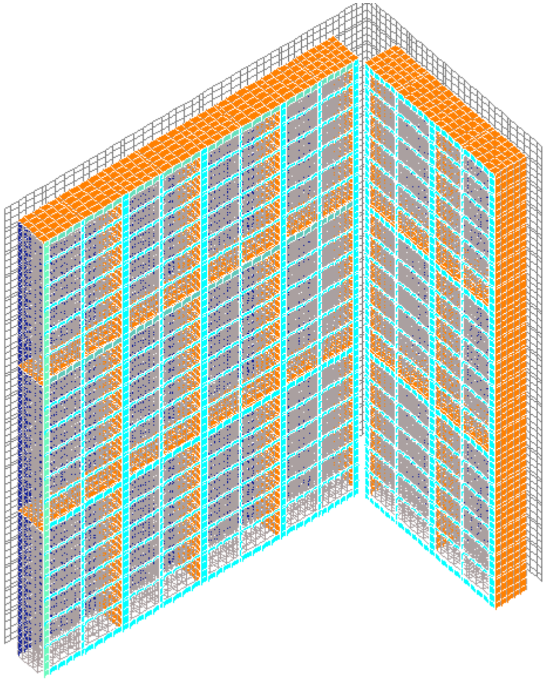
- **SBI LW assembly**
- **Exposed polypropylene surfaces are combustible**
- Mesh consisting of 290,000+ cells, with smallest cells 0.01m;



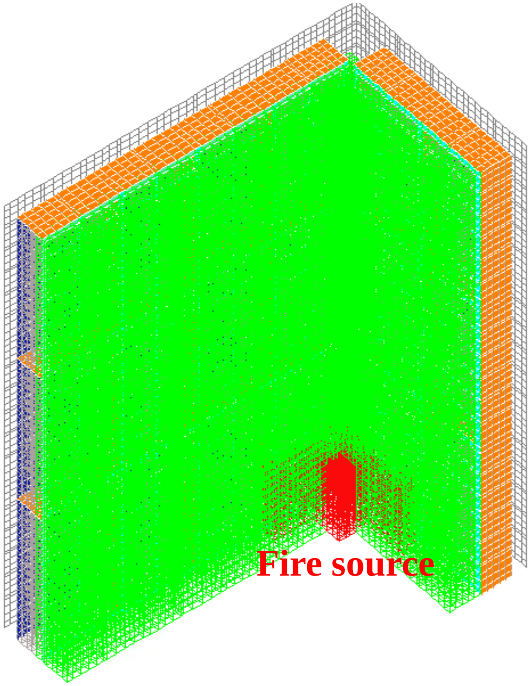
SBI LW Fire Simulation

SBI LW system

- Plants, growth medium and module panels are combustible;
- A 2-cm gap between modules in the corner is modelled;
- Module collapse is not modelled.



Modules filled with growth medium



Modules including plants

SBI Mock up (Węgrzyńskia et al. 2023)

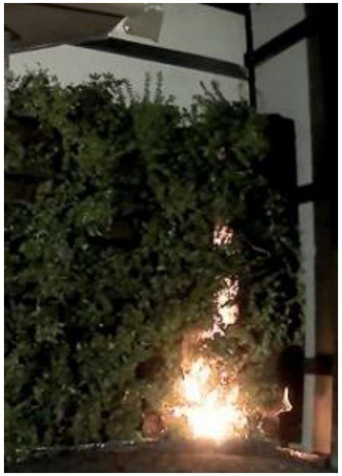
SBI and Large-scale LW Fire Test conducted by ITB

- SBI and large-scale LW fire tests have been conducted by Węgrzyńska et al., Instytut Techniki Budowlanej (ITB), Poland, as reported in:

  An exploratory investigation into moisture content and wind impact on the fire behaviour of modular living walls, to be presented at IAFSS 2023.

- ITB SBI test – LW module that has been certified
  - $FIGRA_{0.4MJ}$ is over 1500 W/s in the test while the criterion for Class D is < 750 W/s
  - The tested LW was assessed to be Class B based on the SBI certification test.
  - The significant difference in performance between the ITB test and the certification test suggests that test conditions were different.

- **ITB Large-scale test – LW modules that have been certified**
  - The wall is 2.5 m high, 1.75 m wide consisting of 35 modules
  - Higher and wider than SBI test, with larger ignition source.

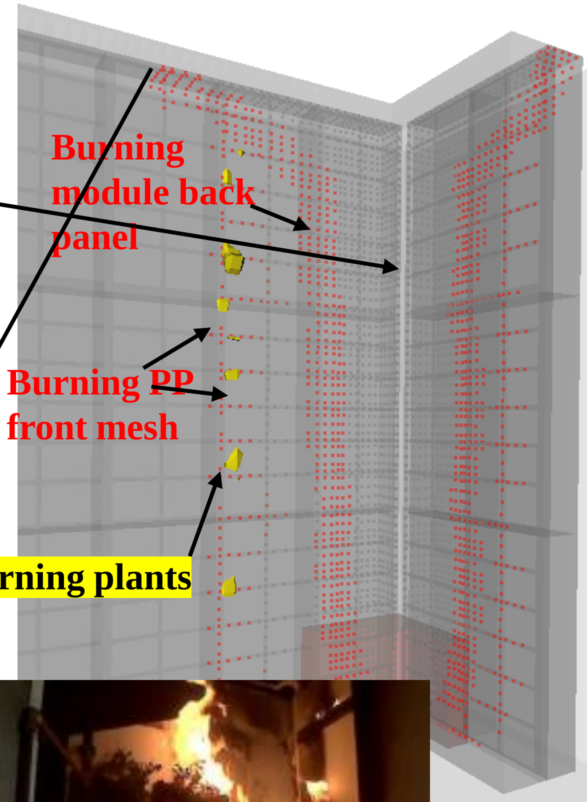


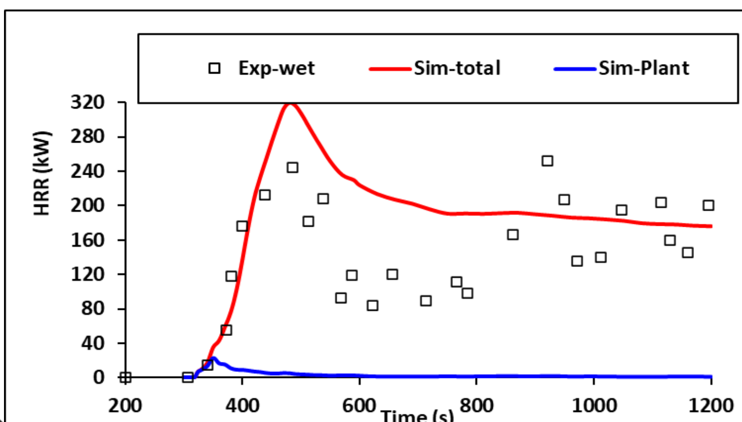
SBI test

Full-scale test

SBI LW Fire Simulation Demonstration

- **Simulation**
  - HRR data for polypropylene is by Węgrzyńskia et al.,
  - Dry plant mass per module of 0.05 kg is derived from the work by **Matthew Allen Newcomer**, 2022
  - Assumed 2-cm gap between the modules at the corner
  - Moisture content is 285%;
  - Module collapse is not modelled
- **Results**
  - The simulated HRRs follow the measured trends; the maximum HRR from plants is only 23 kW;
  - Polypropylene module structure is the key fire load;
  - There is a large fire within the cavity due to burning module backs

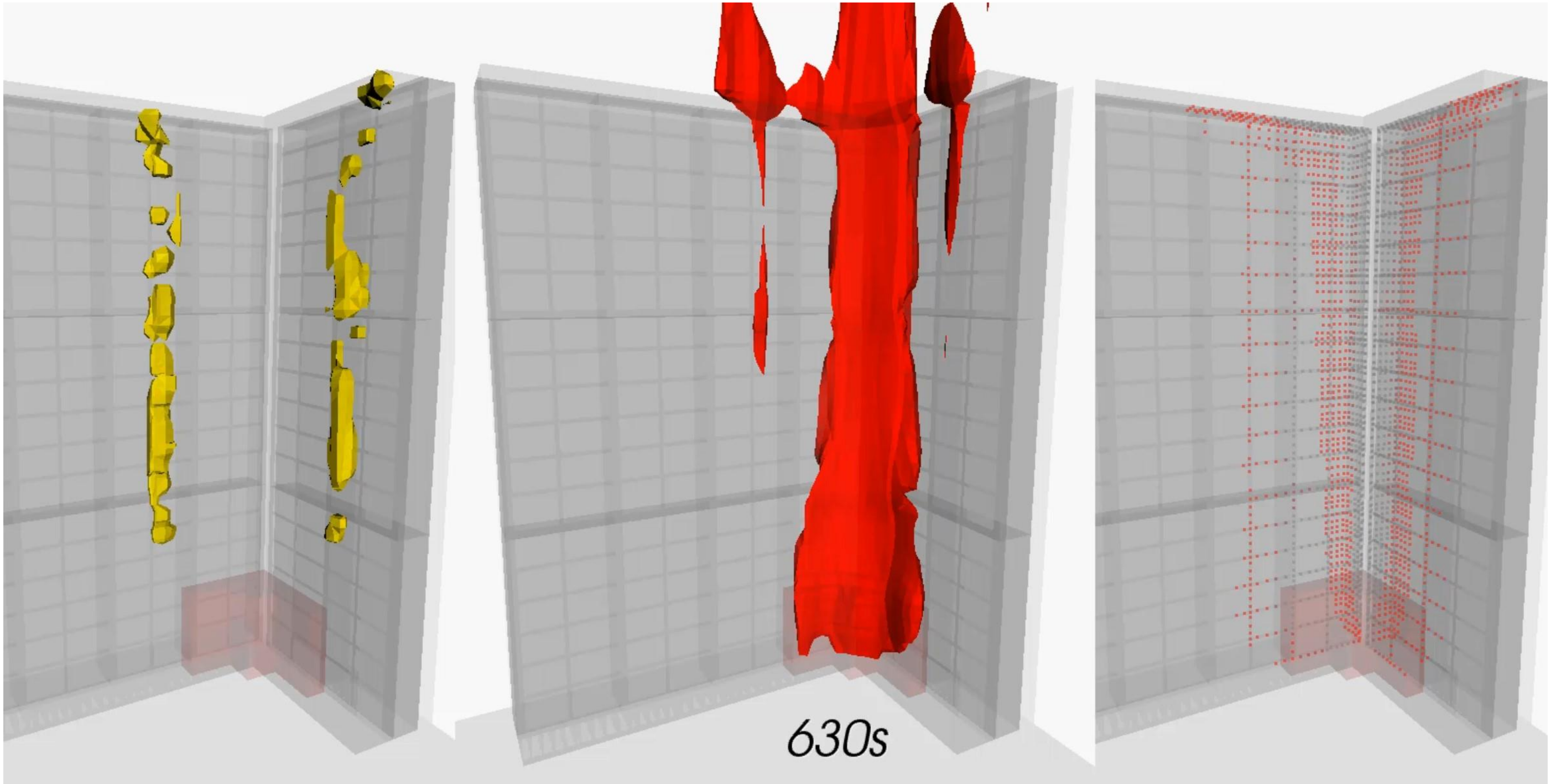




Measured and simulated HRR

Węgrzyńskia et al 2023

SBI LW Fire Simulation Demonstration



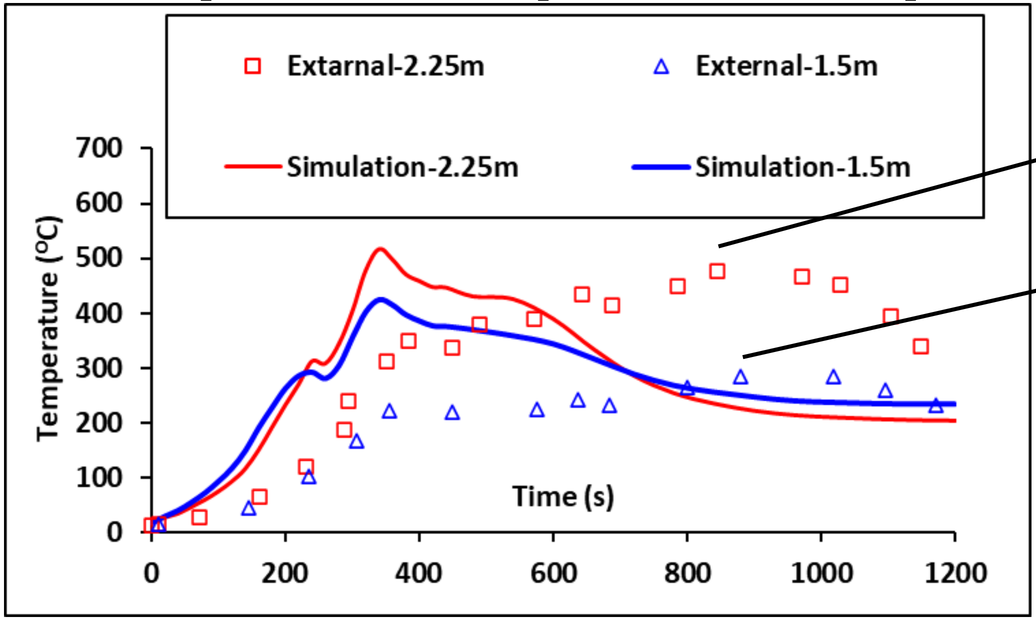
Burning plants
(yellow volume)

Fire plume
(525º C iso-surface)

Burning polypropylene
(red dots)

Large-Scale LW Fire Simulation Demonstration

- Model parameter values are the same as that for the SBI simulation
- Wood crib fire source is modelled as a t^2 function with peak HRR of 200 kW at 300 s (peak HRR is the estimated average HRR from the test);
- Only left half of the wall is simulated due to symmetry;
- Mesh consists of 275,000+ cells with smallest cell 0.01m;
  - 20 min sim required 16 hrs with 1 s time step (3.6 GHz, 12 core CPU)
- Simulated temperatures at locations 0.125 m to the symmetry axis, at 1.5m and 2.5m high follow the measured trends.
- Predicted temps are 5 cm from plant surface – temps are very sensitive to location



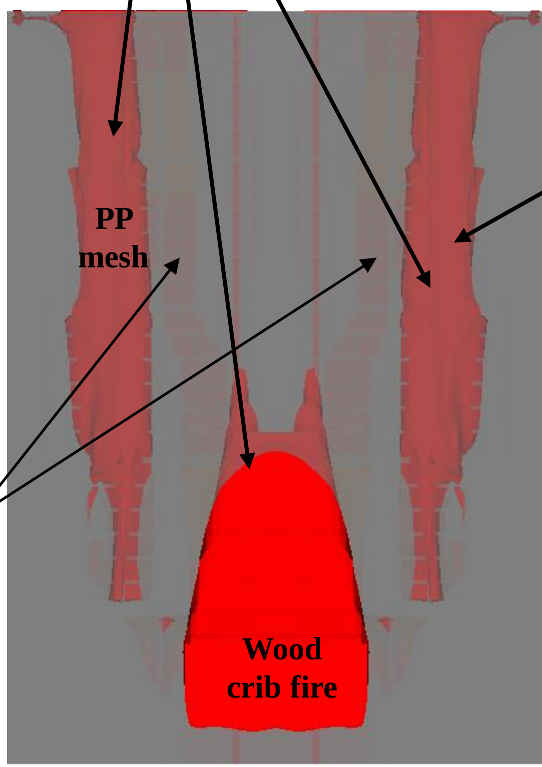
Measured and simulated temperatures

Węgrzyńskia et al., 2023

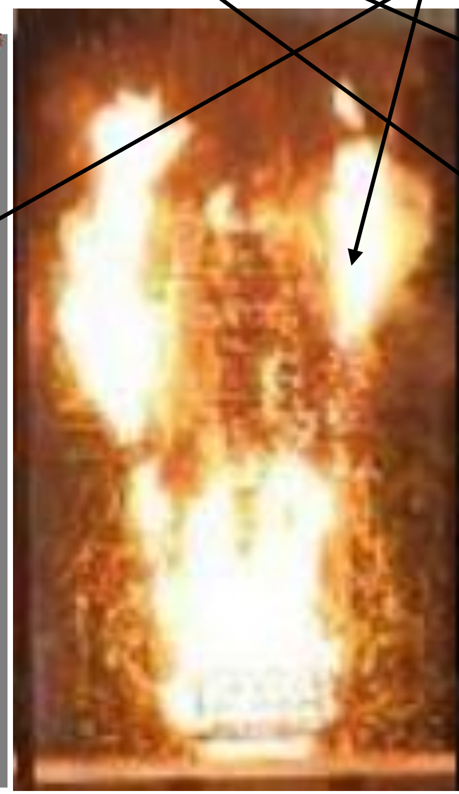
Large-Scale LW Fire Simulation

- **The simulated fire plume** (525°C temperature iso-surface, the minimal visible temperature) and **burning locations** of plants at 1200s are comparable with the experimental observation
- Main contribution to the fire is the burning of **polypropylene modules**

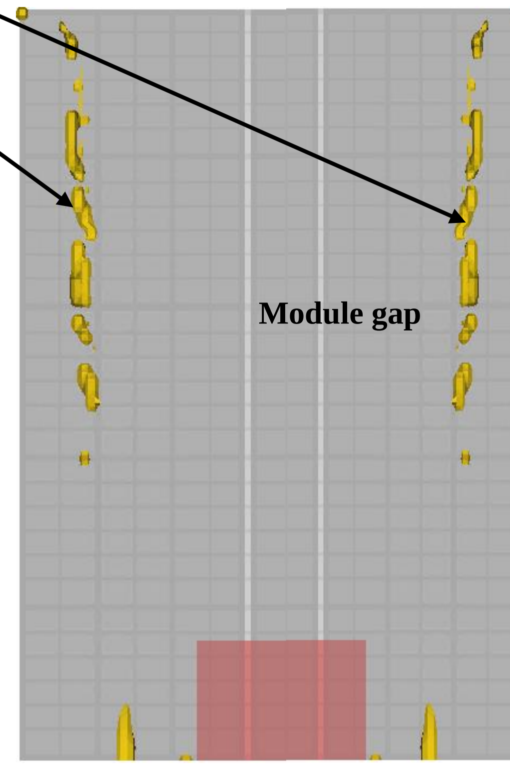
Cavity fire



Simulated fire plume at 1200 s



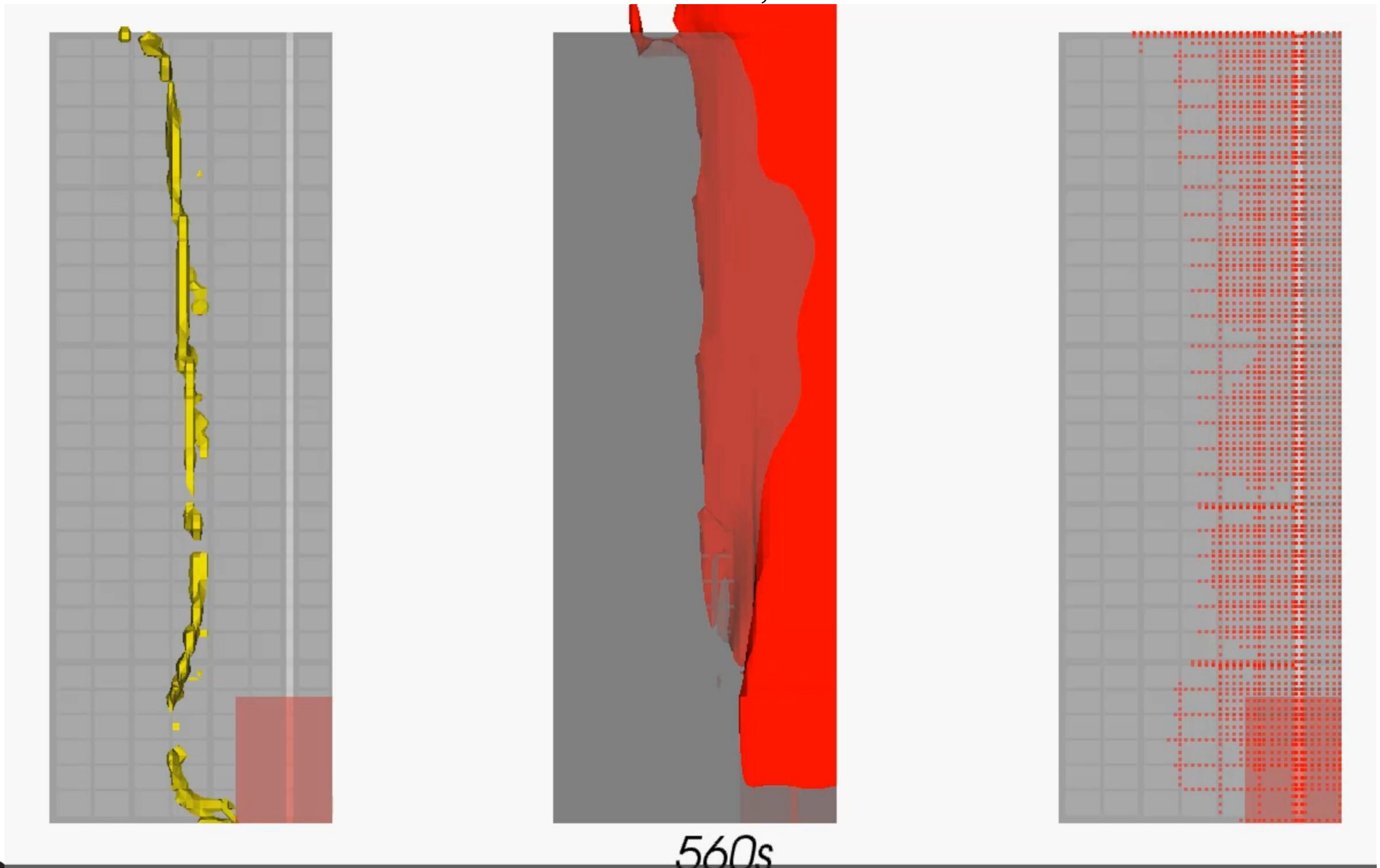
Flame at 1152 s
Węgrzyńska et al 2023



Simulated burning plants at 1200 s

Large-Scale LW Fire Simulation

Front Elevation, left half



Burning plants (yellow volume)

Fire plume (525^o C iso-surface)

Burning polypropylene (red dots)

Conclusions

Key take aways:

- The fire guidance for living walls in UK, **Fire Performance of Green Roofs and walls 2013**, is outdated, inappropriate and confusing.
- The current reaction to fire testing methodology, using the **SBI test (EN 13823)** for wet living wall systems is inappropriate.
- The **BS8414 full-scale test** addresses many shortcomings of current test methods, considering the scale of the test facility and larger ignition source.
- **CFD fire modelling** has the potential to reduce costs associated with BS8414 testing, but is challenging given the complexity of the LW system.

Recommendations:

- There is an urgent need to update the 2013 ‘best practice’ guidance for LWs, including recommended fire test methods. Until the guidance document is updated it should be removed from the ADB.
- A modified BS8414 test could be introduced as a more appropriate test for LW
- To reduce costs of BS8414 testing for LW systems, we propose pretesting candidates using CFD fire modelling, or a modified SBI test (with dry growth medium excluding plants and irrigation), to identify candidate LW products likely to pass BS8414 testing;
- Given the inherent variable nature of LWs and associated fire properties, regular maintenance **MUST** be considered an essential component for compliance with fire safety requirements.