Protocols for Mitigating Cladding Risk Support Package

D.03 – Balcony Fires

Version 2

Date: 13 March 2024

Aboriginal acknowledgement

Cladding Safety Victoria respectfully acknowledges the Traditional Owners and custodians of the land and water upon which we rely. We pay our respects to their Elders past, present and emerging. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life. We embrace the spirit of reconciliation, working towards equality of outcomes and an equal voice.

Application of Minister's Guideline 15

These documents contain information, advice and support issued by CSV pursuant to Minister’s Guideline 15 - Remediation Work Proposals for Mitigating Cladding Risk for Buildings Containing Combustible External Cladding. Municipal building surveyors and private building surveyors must have regard to the information, advice and support contained in these documents when fulfilling their functions under the Act and the Regulations in connection with Combustible External Cladding on buildings:

a) which are classified as Class 2 or Class 3 by the National Construction Code or contain any component which is classified as Class 2 or Class 3;

b) for which the work for the construction of the building was completed or an occupancy permit or certificate of final inspection was issued before 1 February 2021; and

c) which have Combustible External Cladding.

For the purposes of MG-15, Combustible External Cladding means:

a) aluminium composite panels (ACP) with a polymer core which is installed as external cladding, lining or attachments as part of an external wall system; and

b) expanded polystyrene (EPS) products used in an external insulation and finish (rendered) wall system.

Disclaimer

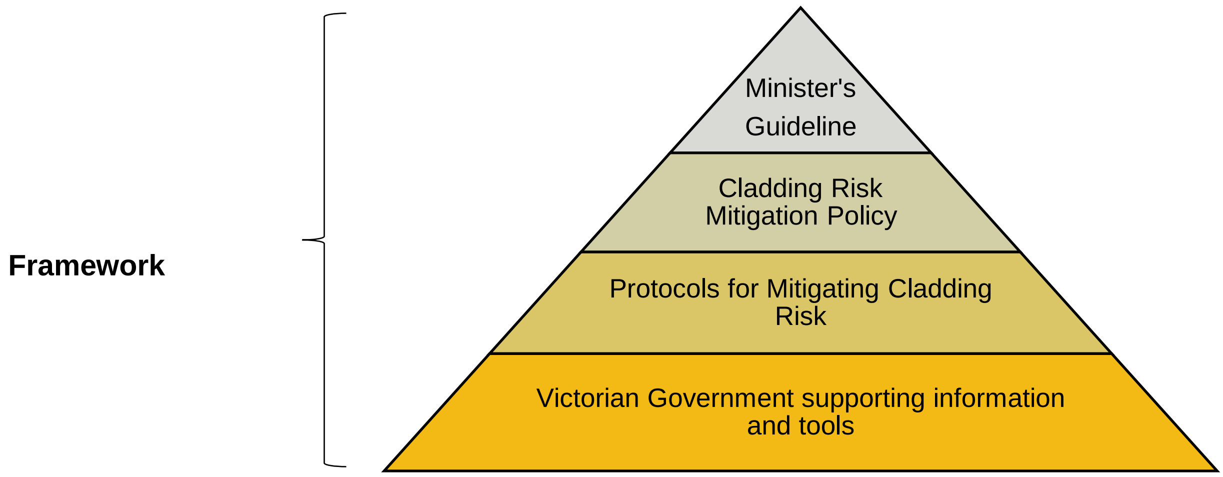
These documents have been prepared by experts across fire engineering, fire safety, building surveying and architectural fields. These documents demonstrate CSV's methodology for developing Remediation Work Proposals which are intended to address risks associated with Combustible External Cladding on Class 2 and Class 3 buildings in Victoria. These technical documents are complex and should only be applied by persons who understand how the entire series might apply to any particular building. Apartment owners may wish to contact CSV or their Municipal Building Surveyor to discuss how these principles have been or will be applied to their building.

CSV reserves the right to modify the content of these documents as may be reasonably necessary. Please ensure that you are using the most up to date version of these documents.

Document Notes

The Protocols for Mitigating Cladding Risk (**PMCR**) is an approach developed by Cladding Safety Victoria (**CSV**) on behalf of the Victorian Government to consistently and systematically address the risk posed by the presence of combustible cladding on Class 2 and Class 3 buildings (being multi-storey residential structures). For many buildings, combustible cladding on the facade:

- does not present a high enough level of risk to warrant substantial or complete removal of the cladding; but
- presents enough risk to warrant a tailored package of risk mitigation interventions to be introduced that provide a proportionate response to the risk.



A set of documents have been assembled to describe the purpose, establishment, method, findings and application of the PMCR. The full set of PMCR documents and their relationship to each other is illustrated in a diagram in Appendix A – PMCR document set and flow

There are **seven** related streams of technical document in the PMCR document set:

A. Authorisation	Codifies the Victorian Government decisions that enable PMCR activation.
B. CRPM Methodology	Specifies the Cladding Risk Prioritisation Model (CRPM) method used for assessing cladding risk and assigning buildings to three risk levels.
C. PMCR Foundation	Defines the PMCR method, objectives and the key design tasks.
D. Support Packages	Captures the relevant risk knowledge and science-based findings necessary to systemise and calibrate PMCR application.
E. CSV Cladding Risk Policy	Establishes key CSV policy positions in relation to cladding risk.
F. PMCR Interventions	Identifies and describes the interventions that the PMCR method can employ to mitigate risk associated with combustible cladding.
G. Implementation	Specifies the standards and procedures that guide PMCR application.

This current document is one of a suite of supporting research papers that provides the findings and analysis that act to inform the PMCR design.

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Abbreviations

Term	Meaning
ACP-PE	Aluminium Composite Panel with a polyethylene core
CFSR	Cladding Fire Spread Risk
Cladding Cluster	A group of SOUs being connected with combustible cladding as identified by IF-SCAN.
CRMF	Cladding Risk Mitigation Framework
CSV	Cladding Safety Victoria
EPS	Expanded Polystyrene
FFL	Finished Floor Level
FR	Fire Retardant
Framework	Cladding Risk Mitigation Framework (CRMF)
MBS	Municipal Building Surveyor
MG-15	Minister's Guideline 15
IF-SCAN	Initial Fire Spread in Cladding Assessment Number
NCC	National Construction Code
PMCR	Protocols for Mitigating Cladding Risk
RWP	Remediation Work Proposal
SOU	Sole Occupancy Unit as defined in the National Construction Code

1 Summary

This report has been developed to analyse the incident heat flux upon balcony returning walls with combustible cladding installed. The radiative heat flux is induced by a simulated flashover fire, venting through the balcony area to the external parts of the building. The research strengthens Cladding Safety Victoria's (CSV) risk reduction decision making processes through targeted cladding removal by resolving the following key **research questions**:

- When and to what extent should cladding be removed from balcony returning walls to effectively reduce cladding risk?
- Does an overclad solution sufficiently reduce risk and is it viable and practical?

The research methodology in this support package is predominantly based on numerical simulations incorporating the Fire Dynamics Simulator software [9], laboratory testing and experimental analysis of cladding materials, expert judgements and literature reviews combining publications, publicly available industry data and relevant operational data from CSV. A full list of references is provided at the end of the document.

Returning wall cladding removal

Remove cladding from returning walls of balconies to reduce cladding fire spread through the following mechanisms:

- Reduce the likelihood of cladding ignition directly from a balcony fire source;
- Reduce the likelihood of a cladding fire externally spreading into balcony areas; and
- Reduces the likelihood of a flashover fire from balcony openings (doors and windows) connecting with external walls.

Removal of cladding should be considered where construction facilitates relative ease of removal where the installation of sprinklers is challenging due to bounding construction (at the balcony/SOU threshold).

Overcladding/encapsulation

Overcladding of combustible cladding material with non-combustible shielding materials to provide an additional protection for 20 mins to 30 mins should be considered in isolated instances. Fibre cement sheet of varying thicknesses were subject to computational fluid dynamic analysis to assess the transfer of heat through the material when exposed to fire. The objective of the analysis was to understand the surface temperature expected on the external side of the overclad that would be installed directly against the combustible cladding.

Fibre cement sheet of varying thicknesses were subject to computational fluid dynamic analysis to assess the transfer of heat through the material when exposed to fire. The objective of the analysis was to understand the surface temperature expected on the external side of the overclad that would be installed directly against the combustible cladding. Results show the following:

- Thickness of 9mm, 14mm and 23mm thickness were subject to Fire Dynamic Simulations. The results show that reduced and practical thicknesses of 9mm, 14mm and 23mm analysed in this report would not reach the critical ignition temperatures of polystyrene or polyethylene for a period of 30 minutes on the overclad materials unexposed side.

Sprinklers

The performance of sprinklers is discussed at length in Support Package D.05. There is not conclusive evidence around the reduced performance of balcony sprinklers; CSV is of the view that extending of sprinklers into balconies may sufficiently address the risks associated with cladding installed on balconies providing balconies are considered fully covered with only one side open.

Where combustible cladding is to be removed from the balcony returning walls, **250mm from the finished floor level (vertically) can be retained**. This is to prevent potential damage to the delicate waterproofing membrane and the resulting ingress of water to the structure (identified as a key risk in balcony rectification work).

Rectification work must consider the detrimental impact that such work can have on the external wall systems of a building. A great deal of care should be taken to ensure that the integrity of the condensation management systems, the weatherproofing/waterproofing systems and the structural wall systems are maintained. Striking a balance between the competing objectives of fire safety issues and structural issues can be difficult and is critical to the intervention method chosen.

2 Introduction

When a building has combustible cladding on the facade, an **intervention** may be necessary to enhance life safety and reduce cladding fire risk to an acceptable level.

The level of risk created by the presence of combustible cladding varies substantially from building to building. Accordingly, a decision to **intervene** and the extent of **intervention** required must also vary.

The Victorian Government has authorised the use of **15 interventions** to mitigate cladding risk. The authority for their use is contained in *Minister's Guideline 15* (**MG-15**) and supported by the *Cladding Risk Mitigation Framework (***Framework***)*.

The Guideline and Framework are intended to:

- support Municipal Building Surveyors (**MBS**) in rating the cladding risk of a building; and
- inform owners about how their building is assessed with regard to cladding risk and the structured way in which Remediation Work Proposals are developed to bring their building to an acceptable level of cladding risk.

Cladding Safety Victoria (**CSV**) is assisting MBSs and owners by providing information about the cladding risk associated with each building and the steps necessary to remedy that risk. This information is provided in the form of a Remediation Work Proposal (**RWP**), that applies the cladding risk methodologies developed by CSV over three years.

A threat barrier analysis can be used to represent how risk-mitigating actions can function to respond to a problem. The CSV method employs this analysis technique to identify the central problem (the 'top event'), in this case a cladding fire, and depict how risk associated with the problem can be mitigated through the implementations of barriers (interventions) designed to control the key hazards identified.

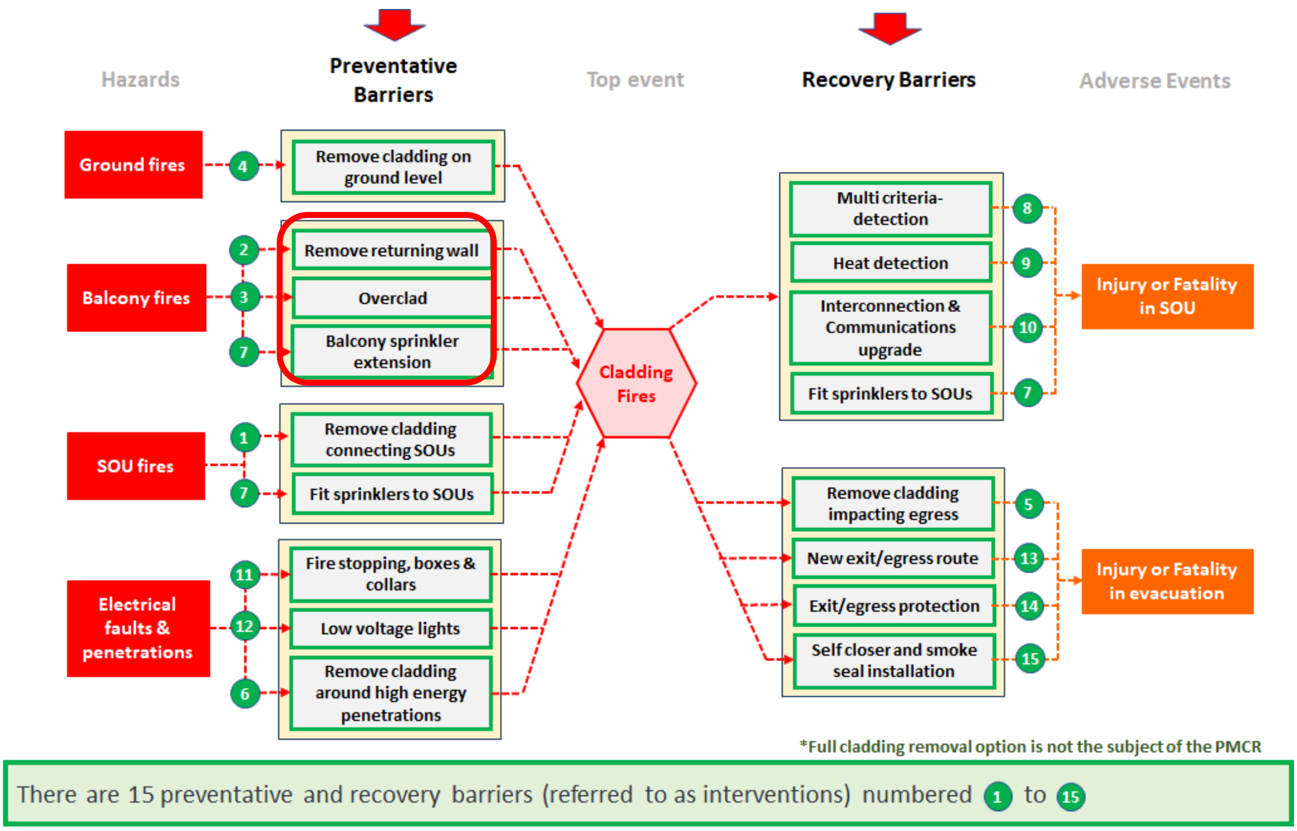


Figure 1: Threat barrier analysis

The 15 interventions in the threat barrier analysis act in different ways to mitigate cladding fire risk.

Each intervention may:

- Respond to one or more of the four identified hazards;
- Function to prevent an ignition source from spreading fire to cladding (i.e. interventions that reduce the likelihood of a fire igniting cladding); and/or
- Function to reduce the adverse impacts for building occupants once a fire has reached cladding (i.e. interventions that reduce the consequences of a cladding fire).

Any risk mitigation solution designed under the Framework must target credible hazards on a building and balance both cladding ignition likelihood and consequence considerations.

2.1 Purpose of this report

Where combustible cladding is installed to the walls of private balcony areas, there is the potential for the ignition of these cladding elements and increased opportunities for fire spread. Combustible cladding can both enhance the ability for fire to spread from an internal SOU flashover event to the external walls of a building, as well as providing a mechanism for external wall fires spreading into apartments. Additionally, it is notable that balcony geometries can vary from small open spaces to large enclosed spaces acting as an extension to internal living areas. The storage of items associated with the latter, when combined with the recreational activities that commonly occur on balconies (such as smoking and cooking) can increase the number of plausible fire ignitions and the risks associated with these ignitions.

Research is required to inform PMCR judgements about:

- The scenarios under which a balcony intervention is most/least meaningful in risk mitigation;
- The situations under which cladding removal (or overcladding) on balconies is of most benefit (and least benefit);
- The requirements of overclad solution so that cladding could be isolated from other fire sources; and
- The extent of cladding removal that is necessary to affect a safe PMCR solution.

Research Question 1	When and to what extent should cladding be removed from balcony returning walls to effectively reduce cladding risk?
Research Question 2	Does an overclad solution sufficiently reduce risk and is it viable and practical?

The research methodology in this support package document combines numerical simulations, experimental analysis, expert judgements and literature reviews incorporating publications, publicly available date and CSV operational data. A full list of references is provided at the end of the document.

3 Literature review

3.1 Balcony fire frequency/spread

For the last three decades, large-scale facade fires across the world have been occurring at an ever-increasing rate [1]. In particular, between 2005 and 2017, 19 fires specifically involved combustible cladding worldwide [2]. Information regarding the location of ignition for all combustible cladding fire events is not readily available within the current literature, however we can look towards general building ignition data to gain insight into the general statistics of balcony fires and the spread of these fires along building facades. Data obtained from the London Fire Brigade (LFB) shows that, between 2017 and 2020, 587 balcony fires occurred within the LFB service area [3]. Of these, 291 fires were started by the unsafe disposal of a heat source (e.g., lit cigarette) and 44 fires spread from the balcony of fire origin.

A paper by Clare & Garis shows that between October 2006 and October 2011, 2,638 fires occurred in multi-residential buildings within British Columbia, with 255 of these fires originating from an outside area (either balcony or court/patio/terrace) [4]. Fires that commenced on the building exterior were 3.3 times less likely to have burned out on their own, 3.5 times less likely to have been controlled by sprinkler systems, 1.9 times more likely to spread to different levels and 1.5 times more likely to require both the application of water by firefighters and be controlled by makeshift firefighting aids by civilians. This information shows the threat balcony fires pose to the safety of building occupants, with a higher chance of spread between levels and a higher risk of homeowners putting themselves in danger of attempting to stop the spread of an uncontrolled fire.

3.2 Cooking appliance fires

In Great Britain, 873 balcony fires occurred between 2017 and 2020, with 420 of these fires being smoking related and 19 being a result of a barbeque fire [5]. The significance of barbeque fires should not be understated. Research published by the National Fire Protection Association shows that of 10,600 barbeque related fires in the US between 2014 and 2018, 46 percent of them resulted in a structure also catching fire [6]. Of these, just 10 percent began with the ignition of exterior wall coverings, however these fires caused 45 percent of barbeque fire related structural property loss. This information shows the danger posed by the large heat load associated with barbeque fires, and the disproportionately high monetary loss associated with cladding fires initiated by such means.

3.3 Other balcony ignition sources

There have been multiple incidents where discarded smoking material has ignited balcony furniture, resulting in the ignition of combustible cladding installed to the returning walls and re-entrant corners of balconies [7] [8]. Electrical fires and barbeque fires are also common balcony ignition threats, leading to a combined 10% of balcony fires in Great Britain between 2021 and 2022 [9]. Air conditioners also pose a significant fire risk to cladding as the electrical connection for the condensing unit is likely to pass directly through the cladding, exposing combustible layers to flame in the event of a catastrophic condensing unit fire. A report published by the Singapore Civil Defence Force shows that 51.6% of air conditioner fires in Singapore started with either the external condensing unit or its associated wiring catching fire [10].

3.4 Balcony usage

An initial hypothesis was formed that enclosed balconies would be more likely to be used as storage areas as they are more protected from weather than open balconies, and as such contain much higher fuel loads than their counterparts. A study by Bryant et al. has provided information contrary to this however, showing that open balconies actually contained higher fuel load energy densities than enclosed balconies, although to a statistically insignificant amount [11].

This data is not necessarily applicable to the buildings within Victoria, however, due to a variety of circumstances. As discussed in a post incident analysis report on the 2014 Lacrosse Docklands cladding fire, higher than expected fuel loads were seen on balconies due to a high occupancy rate within SOUs [7]. During investigations conducted after the fire, some 2-bedroom apartments were identified as having sleeping arrangements for up to eight people. This not only leads to people being much more likely to use the balcony as a storage space, but also impacts the safe evacuation of the occupants in the event of an emergency.

3.5 Balcony fuel loads

Studies into the fuel loads observed on multi-storey residential balconies are unfortunately quite rare, however such studies have occurred. Kose et al conducted a movable fire load survey in Japan, finding the average equivalent Fire Load Energy Density (FLED) observed on balconies to be 223 MJ/m^2, however this data may not be comparable to modern balconies seen in Australia due to the age of this data, having been published in 1989 [12].

A more recent study by Bryant et al. [11] found the average FLED observed among balconies to be 67.4 MJ/m^2, with an 80th percentile value of 110 MJ/m^2. The calculation for this value includes the 0 MJ/m^2 value seen on 43 percent of balconies surveyed, skewing the average FLED downwards as a result. By removing these empty balcony values from the data set, we get an average FLED of 118 MJ/m^2. The average Heat Release Rate (HRR) density for all balconies, including empty, was found to be 105 kW/m^2.

It should be noted that the average fire load observed on balconies is not the main consideration in the risk evaluation of a cladding fire initiated by a balcony fire. Once again taking the Lacrosse Docklands case as an example, only a single balcony containing a high fuel load and an ignition source is needed for a fire to burn hot enough to set the cladding on the building’s facade alight [7]. Consideration must be made, for the instance of any single balcony potentially containing a higher than average fuel load.

3.6 Numerical simulations

Numerical simulation of fire scenarios provides a relatively inexpensive method for investigating fire dynamic behaviour. Modelling of fires extending from openings developed in Fire Dynamics Simulator (FDS) for external flame heights have been validated with prominent correlations and key authors in the field, through a range of opening dimensions [13]. The effect of the flames extending from openings adjacent to returning walls with combustible cladding installed will be considered for this intervention.

4 Numerical analysis

4.1.1 Numerical set up

The numerical simulations were developed to analyse two scenarios being:

1. ***Returning wall analysis*** – investigating the radiative impacts of a flashover fire on combustible cladding installed to private balcony areas; and
2. ***Overcladding analysis*** – investigating the heat transfer through varying thicknesses of fibre cement sheet when installed to protect and encapsulate retained combustible cladding on balconies.

Balcony dimensions

A substantiated geometry is required to analyse fire dynamic behavior within an apartment/balcony enclosure. It is considered that for conservative numerical analysis, the balcony should be covered and enclosed on all sides except for the main balcony opening, maximizing the impact of a flashover fire on the balconies returning walls. It was established that openings at the threshold between the subject balcony and the SOU should be close to full height, representing typical threshold glass doors installed to permit access to private balcony areas.

The subject returning wall (test wall) is to be located on the left at a small distance from balcony openings. The proximity of the openings to the test wall has been verified as the worst-case scenario, as highlighted in Figure **2**.

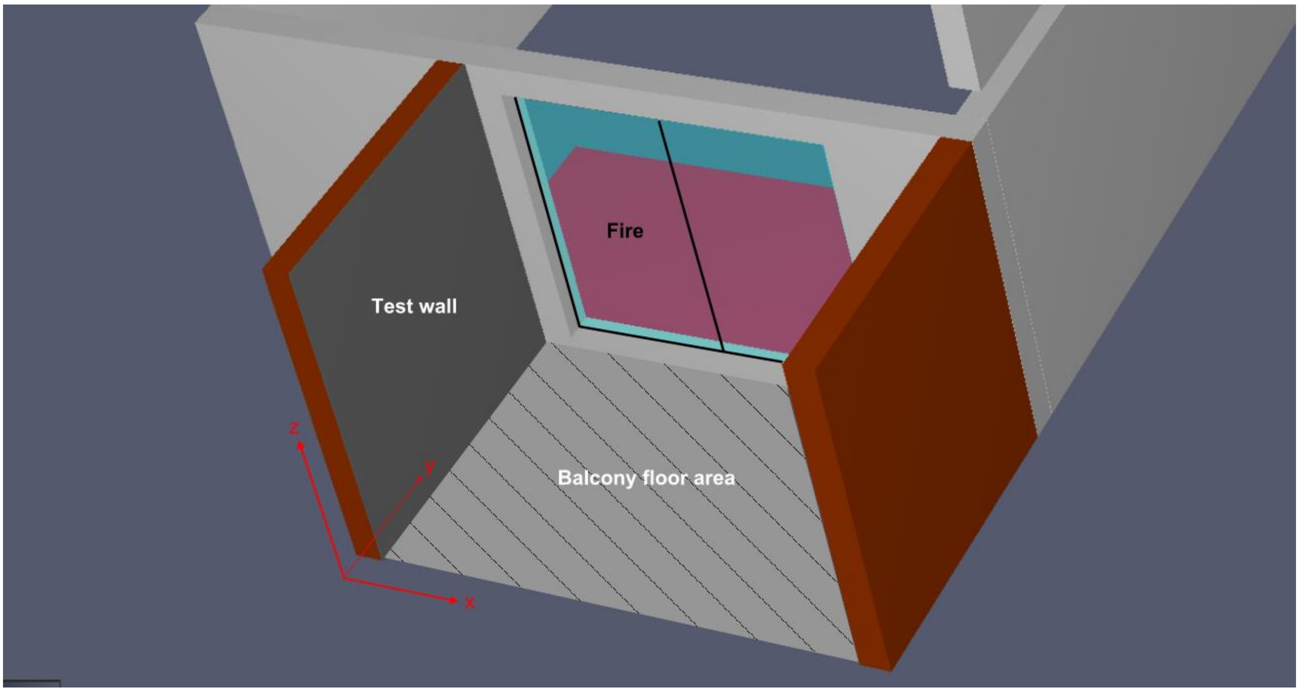


Figure 2: Modelled balcony area

The general dimensions for the enclosed balconies floor area are informed by state government apartment design guidelines where the following is recommended [14]:

Table 1: Victorian state government apartment design guidelines

Dwelling type	***Minimum balcony area***	***Minimum balcony depth***
1-bedroom dwelling	8.0 m^2	1.8 m
2-bedroom dwelling	8.0 m^2	2.0 m

4.1.2 Fire prescription

Fire size

The HRR of the design fire projecting from the SOU and on through the covered balcony area was prescribed at 6.9MW. Several calculations implementing various apartment sizes and calculation of the design fire through the McCaffrey and Quintiere method [15] were considered appropriate, as this would provide consistency for fire selection and investigation into the fire dynamics attributable to an apartment's geometry, i.e., floor area and ventilation.

As it is a requirement of the PMCR that the generated solutions must be applicable to apartments of varying floor areas. The fundamental choice for the size of a flashover fire in an apartment is required in order to understand the implications this has on radiant heat flux values impinging upon a balcony's returning wall. An apartment size of approximately 70m^2 with a floor to ceiling height of 2.7m is used to provide support for fire size decision making. Using these apartment and dimensions, the calculated design fire with a design safety factor of 1.5, that resulted in a 6.9MW Design Fire is utilised conservatively for this research.

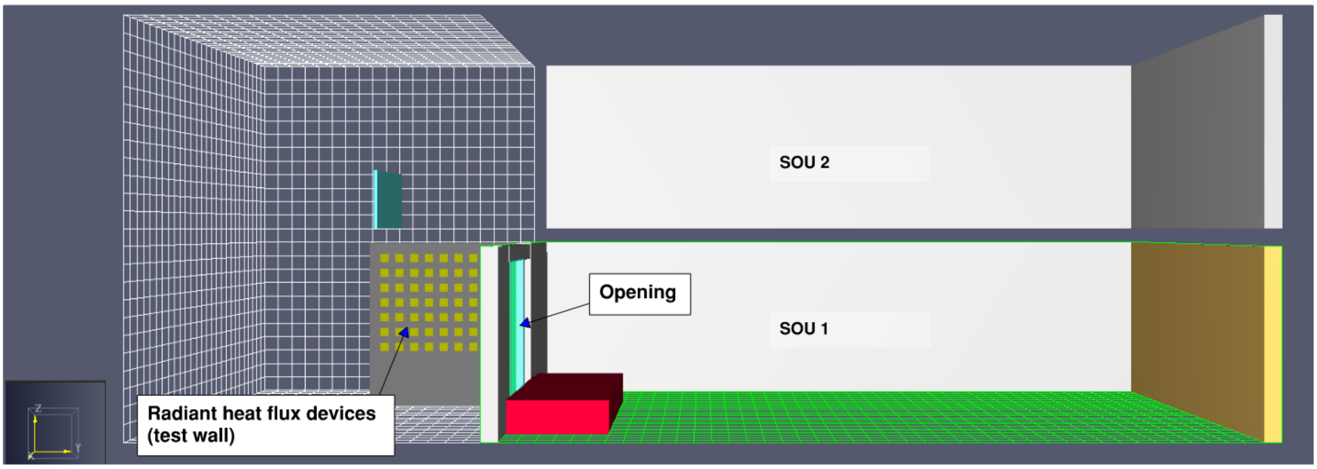


Figure 3: Sole Occupancy Unit (SOU) geometries (generated in Pyrosim)

Computational meshes

The recommended grid size was estimated using the following equation [9]:

$$D^* = \left(\frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{g}}\right)^{\frac{2}{5}}$$

where D* is the characteristic fire diameter, $\dot{Q}$ is the total heat release rate of the fire, ρ_∞ is the air density, c_p is the specific heat of air, T_∞ is the ambient temperature, and g is gravity. A grid with a ratio of the fire's characteristic diameter to the nominal cell size (D*/ δX) between 4 and 16 is desirable.

An acceptable grid size in the current study is 0.25 m for the fire with a calculated and conservative HRR of 6.9MW. The resulting D*/ δX value is 8.3 for the simulation, falling within the acceptable range of 4 to 16.

Opening area

The opening area used for the enclosed balcony was **2.75m x 2.50m**, simulating the large sliding glass doors that would be expected on a residential balcony.

4.2 Returning wall analysis (FDS)

Fire scenarios

For the purposes of identifying the location of the critical heat flux received by balcony returning wall clad in combustible cladding, the following scenario is developed.

- *A fully developed flashover fire in an SOU with flames extending from the internal parts of the building through balcony openings and impinging directly upon the balcony returning walls.*

A computational fluid dynamic simulation using Fire Dynamics Simulator (FDS) software version 6.7 was developed to analyse the effects of flashover fire conditions impinging on the returning wall of an enclosed balcony, as it is expected that a flashover fire scenario would be considered worst case for cladding ignition on the test wall obstruction.

Conservatively, a canopy or covered balcony was used in the balcony architecture for the simulation, ensuring maximum heat retention, with heat and flames transferred through the balcony area and released to the open sky at the outermost of edge to the balcony covering.

Objectives

The following are the objectives of the simulations and analysis:

Scenario 1 ***Returning wall analysis***	The objective of the simulation was to provide numerical evidence to support the retention of small areas of combustible cladding at the finished floor level of a balcony.
Scenario 2 ***Overcladding analysis***	The objective of the simulation was to provide numerical evidence of the thermal performance of fibre cement sheet as a protective layer between a fire hazard and installed combustible cladding.

Both scenarios employ the same overall balcony geometry and design fire scenario.

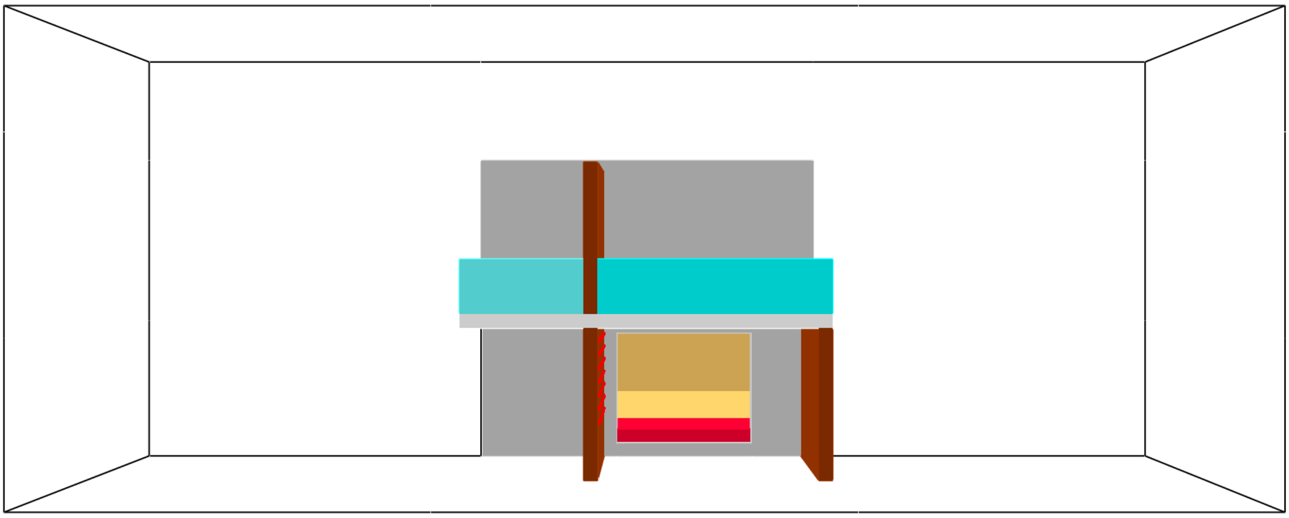


Figure 4: Covered balcony geometry (Fire Dynamics Simulator)

Obstructions

The key objective of the simulation is to extract the impinging heat flux data that is experienced by the test wall (balcony returning wall) resulting from a flashover fire extending through openings and through the balcony to the external building facade. Nil properties were attributed to the obstructions in the model.

Fire ramp

It is considered conservative that the burner achieves the peak heat release rate from the beginning of the simulation through to the end (as opposed to reconstructing empirical flashover curves. The results are reviewed from the earliest timestamp of perceived fire stability (approximating steady state conditions). The preheating of the material is not considered, only the heat flux impinging upon the material.

Devices

The balcony returning wall (test wall) is installed with gas phase radiant heat flux measurement devices. Radiant heat flux devices were installed from finished floor level and continuing up the wall at 0.25m increments through to the balconies canopy and installed at 0.25m increments moving away from the subject opening (0.25m x 0.25m grid).

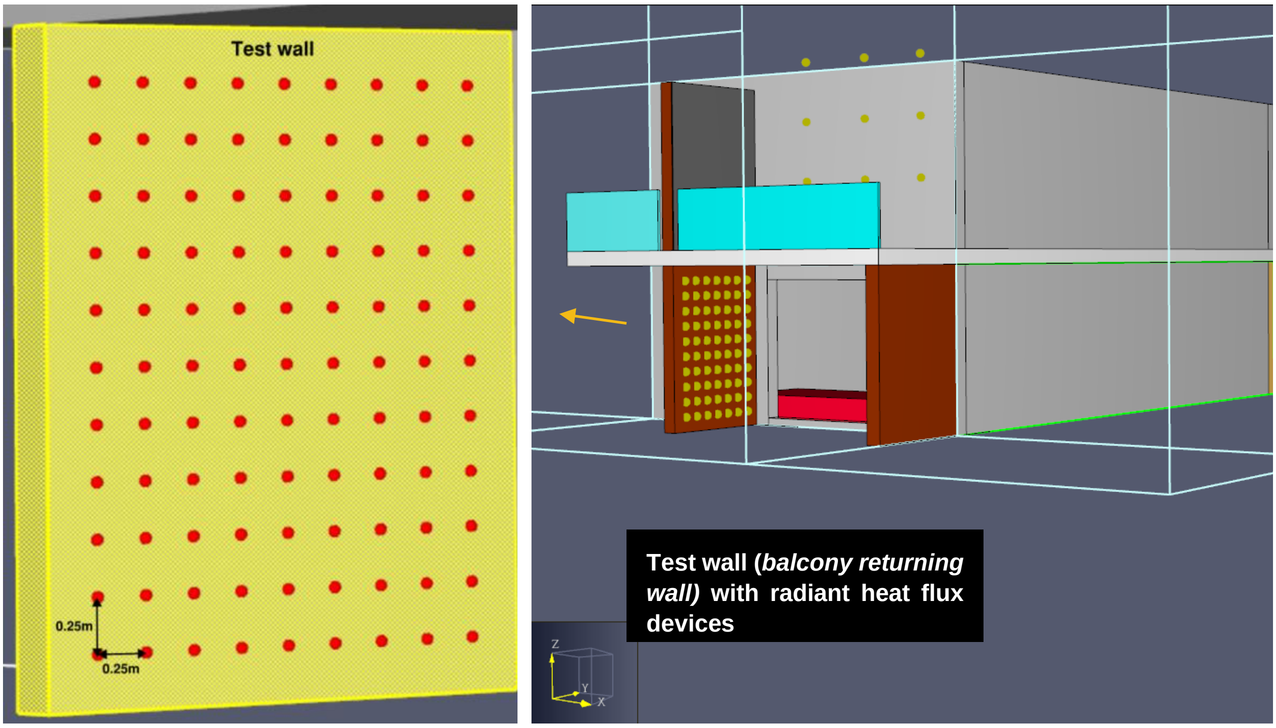


Figure 5: Indicative balcony geometry modelled in FDS (right) highlighting test wall adjacent balcony openings with radiant heat flux device grid simulated (left)

4.2.1 Heat flux exposure to balcony returning walls

The following images from the CFD simulations highlight the heat flux experienced by the balcony returning wall as a result of a fire occurring internally and projecting out through the balcony area. The black marker lines in Figure 6 highlight radiant heat flux at 10kW/m^2 increments, ranging from 10kW/m^2 through to 60 kW/m^2.

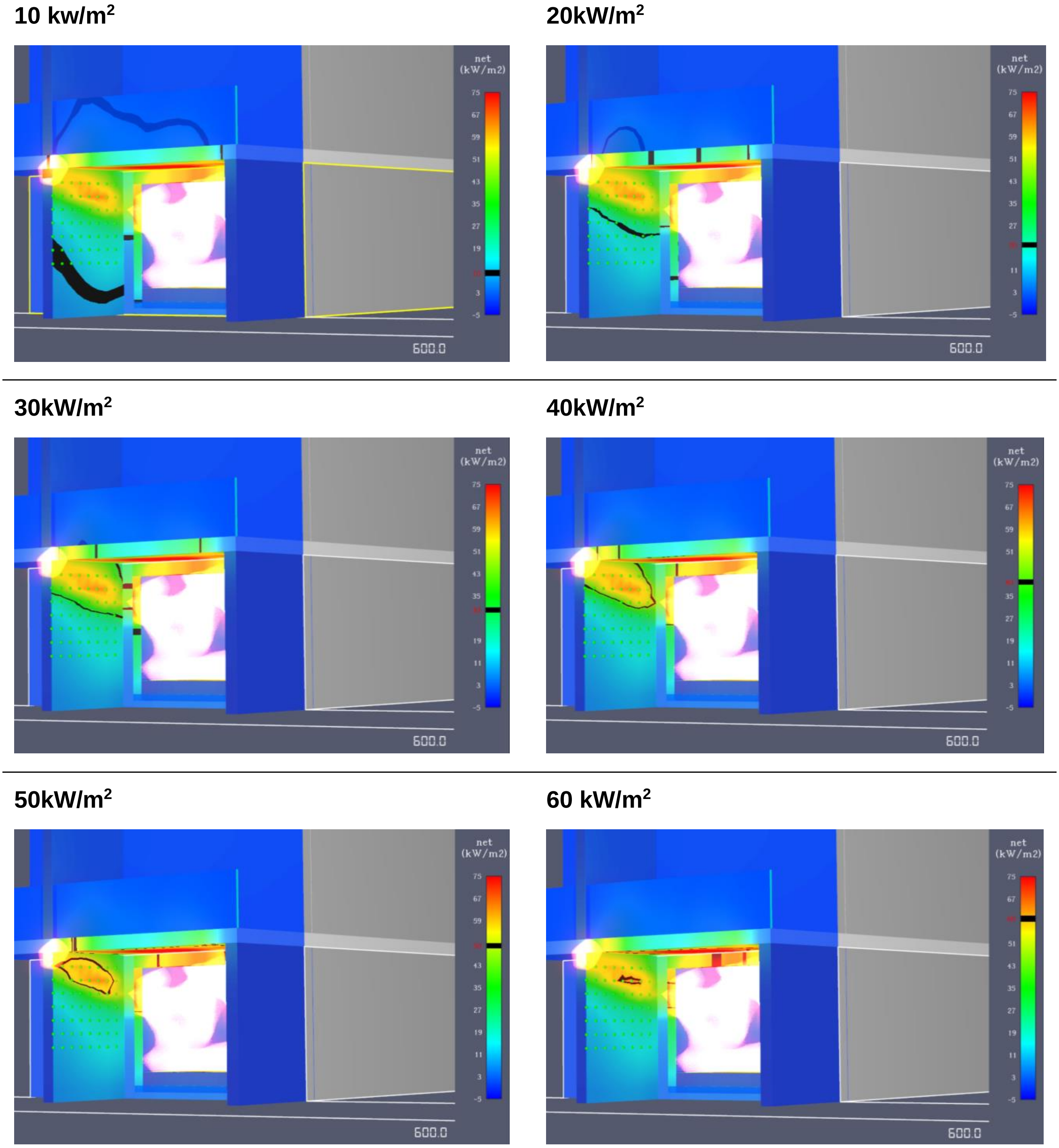


Figure 6: Radiant heat flux incident upon the balcony returning wall

As can be seen in Figure 6 above, the upper regions of the balcony returning wall receive the greater radiant heat flux, with the shape of the heat flux map on the balcony returning walls reflect the shape of the flames extending through the balcony and out into open air, with the heat flux map reflecting a sharp increase in radiative heat flux occurring from 1.5m right through to the returning wall and canopy intersection.

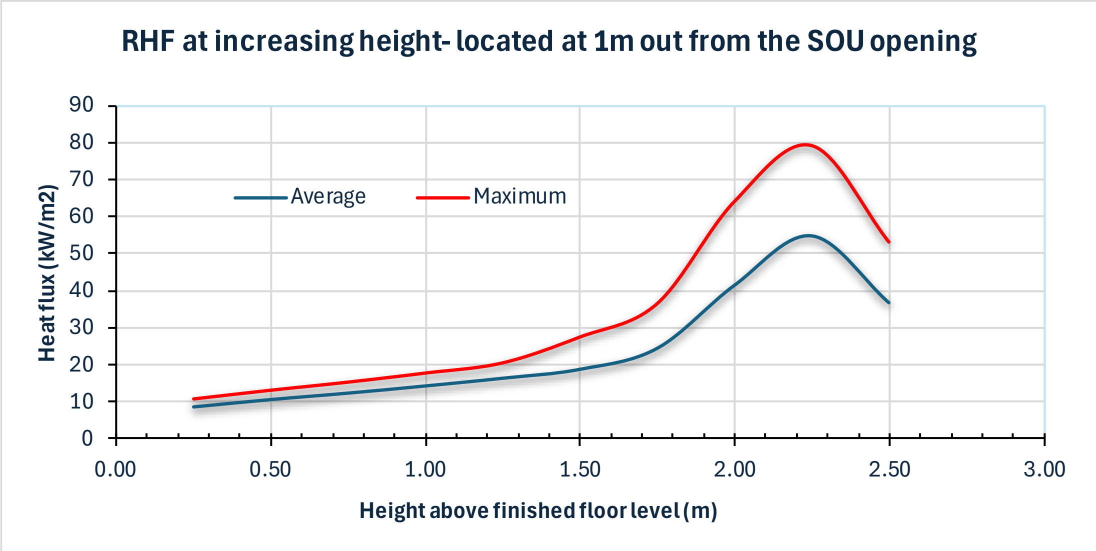


Figure 7: The plot right reflects the radiant heat flux incident upon the wall from 0.25m to 2.5m above the balcony FFL

The above graphical representations reflect the maximum and average RHF experienced at the balcony returning wall at a -y distance (-y value) of 1m out from the opening.

As highlighted in Figure 7, the RHF experience begins to increase dramatically at approximately 1.6m above floor level.

The following graphical representations reflect the maximum and average RHF experienced at the balcony returning wall at a -y distance of 1m out from the opening.

The maximum RHF value is registered at the topmost thermocouple located 1m out from the opening at approximately 80kW. The results show that that the highest average RHF experienced is at a height of 1.0m on the returning wall and is generally less than 18kW/m^2. For perspective, average RHF experienced at or below a height of 1.5m above FFL sits somewhere between the piloted ignition of timber (after a long time) and the unpiloted ignition of timber after a long time as referenced in AS 1530.4 [16]. It can also be seen that the average heat flux experienced by the wall at 1m is approximately 14.19kW, lower than our critical heat flux value for polyethylene.

4.2.2 Numerical results and discussion

As highlighted in the experimental analysis of Support Package D.02, analysis of the cladding samples showed that the ACP failed to ignite after 30 minutes exposure to 10 kW/m^2, and that after an exposure time of 96.15 ± 12.66 s at 15 kW/m^2, PE polymer cores can start to ignite.

It is proposed that when removal of the cladding is to occur, a small strip of cladding be retained close to the finished floor level of the balcony, as there is the potential for the waterproofing membrane to be damaged when removal occurs at this interface.

Heat flux devices were added to the lower parts of the test wall and the simulations generated to provide results pertaining to the lower parts of the test wall. Devices installed in a 0.25m x 0.25m grid on the test wall, beginning at 0.25m above finished floor level and continuing vertically up the wall at 0.25m increments through to the balconies canopy, and at 0.25m increments moving away from the subject opening.

Figure 8 shows that the test wall receives the critical ignition heat flux values in the upper parts of the wall. Where the radiant heat flux devices are located in rows at 0.25m and 0.50m above the finished floor level of the balcony, the maximum radiative heat flux received is approximately 5kW/m^2.

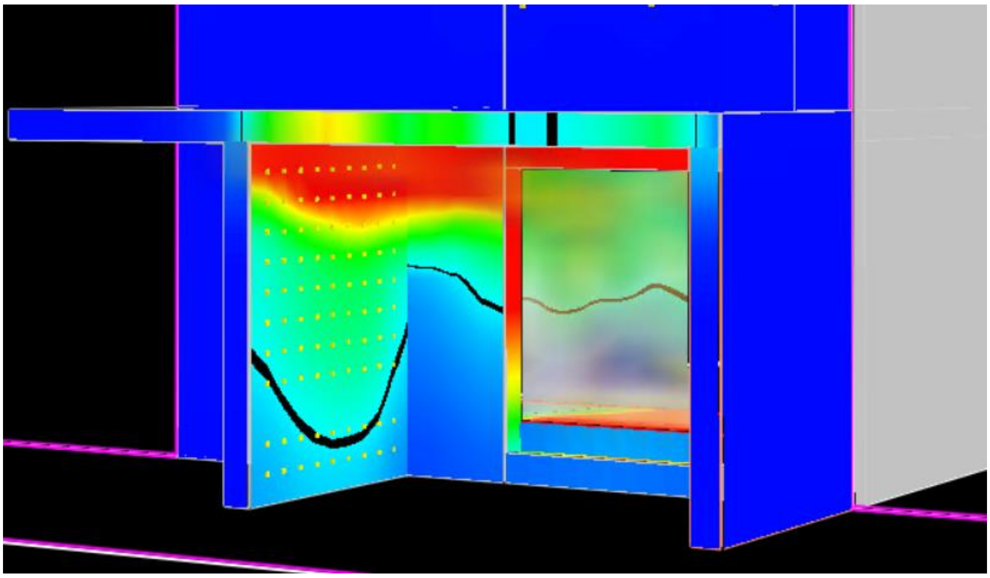


Figure 8: Smoke view representation of incident RHF (5kW/m²) incident upon areas close to the finished floor levels of the balcony

The results of the 8 devices located at 0.25m above the balconies finished floor level are as follows:

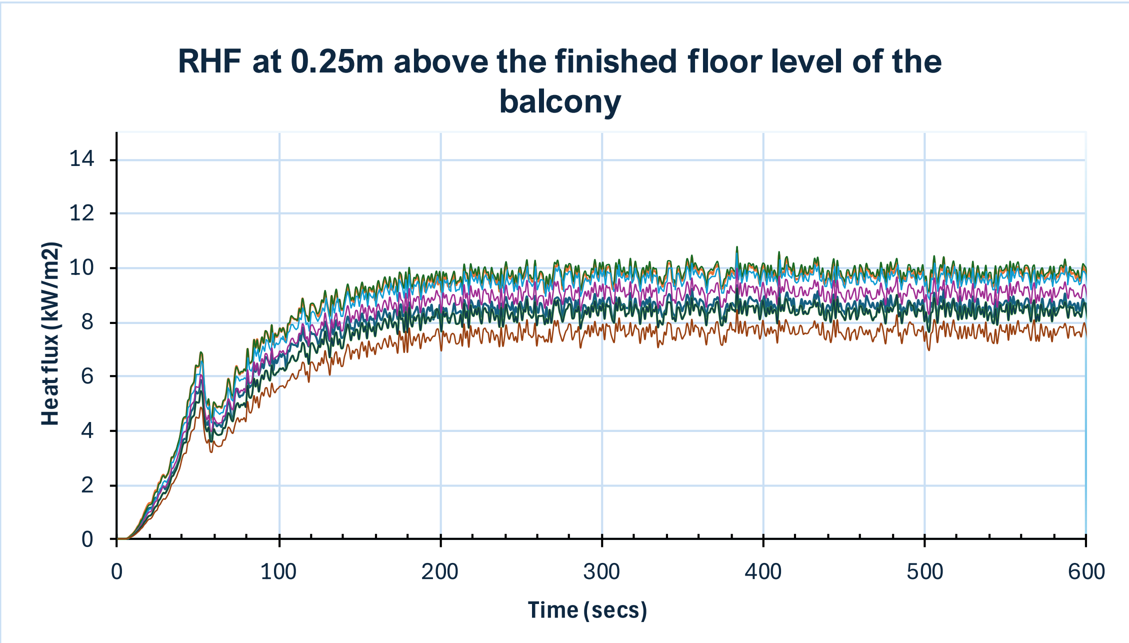


Figure 9: Radiant heat flux experienced by the test wall at a height of z=0.25m above the finished floor level of the balcony- with devices mi

Numerical analysis suggests that with the radiant heat flux experienced from a 6.9MW flashover fire at < 250mm above FFL would likely be insufficient to ignite the small volume of cladding retained.

It is important to note that:

- Analysis considers the polyethylene and polystyrene as exposed (in reality, the polymers are protected by an aluminium skin and render, for ACP and EPS respectively).
- The received radiant heat flux at 250mm stabilises at approximately 10kW (no ignition as tested in Support Package D.02).
- The small piece of retained ACP PE or EPS will be flashed to maintain the flow of water as designed at the drainage surface balcony floor level.

4.3 Overcladding material analysis

The external side of fibre cement sheeting (FCS) as an overcladding material was analysed. The objective of the simulation was to determine if the heat transferred through the overclad material, being fibre cement sheeting, is sufficient enough to ignite the polystyrene of EPS or the polyethylene core of ACPs.

4.3.1 Heat flux exposure to balcony returning walls

The following images highlight the heat flux experienced by the balcony returning wall as a result of CFD simulations of a 6.9MW fire occurring internally and projecting out through the balcony area.

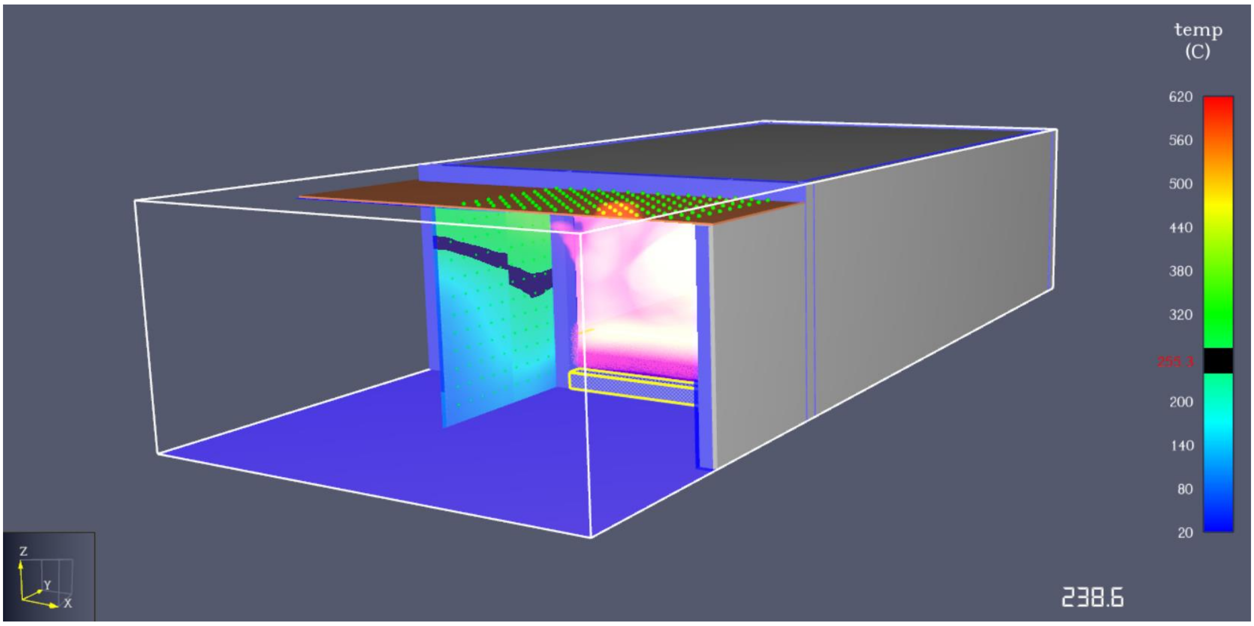


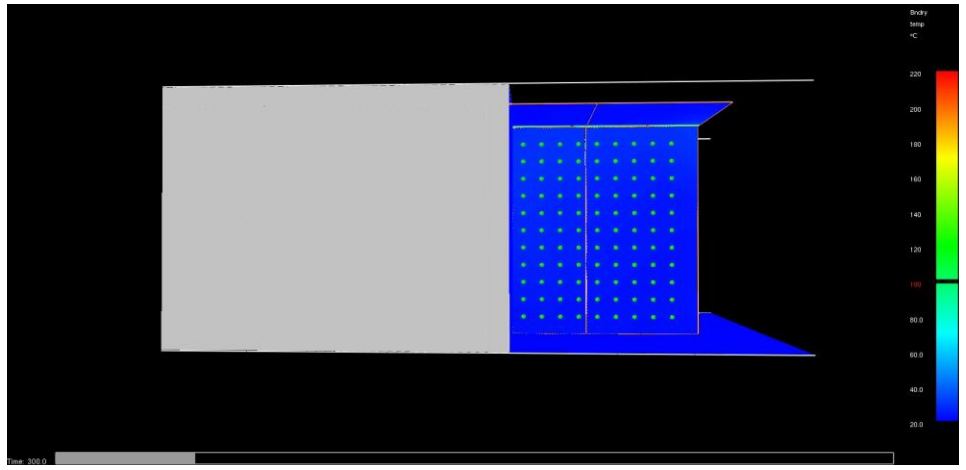
Figure 10: Smokeview image – marker highlighting the fibre cement sheets surface temperature when exposed to a flashover fire

23mm FCS as overclad material

The following images are FDS/Smokeview renders showing the surface temperatures of the unexposed side of the FCS over a period of 30 minutes, indicating the transfer of the heat from flashover fire through protective overclad material (FCS) over time. It is important to note that the exposed side (not visible) surface temperatures at the 10-minute mark sit between 500°C and 580°C.

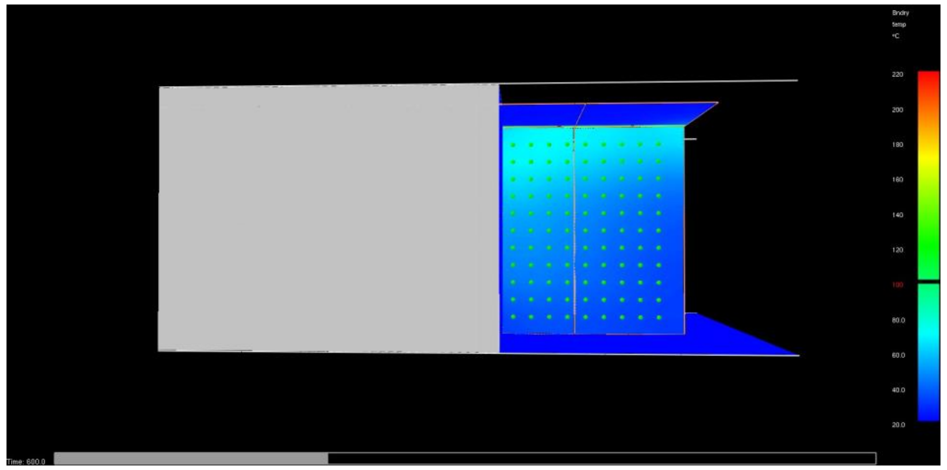
The maximum surface temperature on the internal side of the 23mm FCS is generally less than 170°C after 30 minutes exposure.

5 minutes



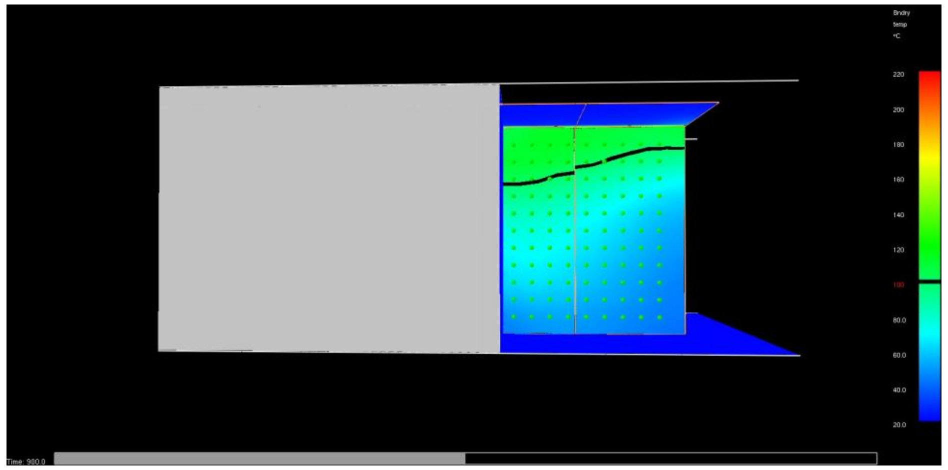
No indication of any heat transfer through the fibre cement sheet (FCS).

10 minutes



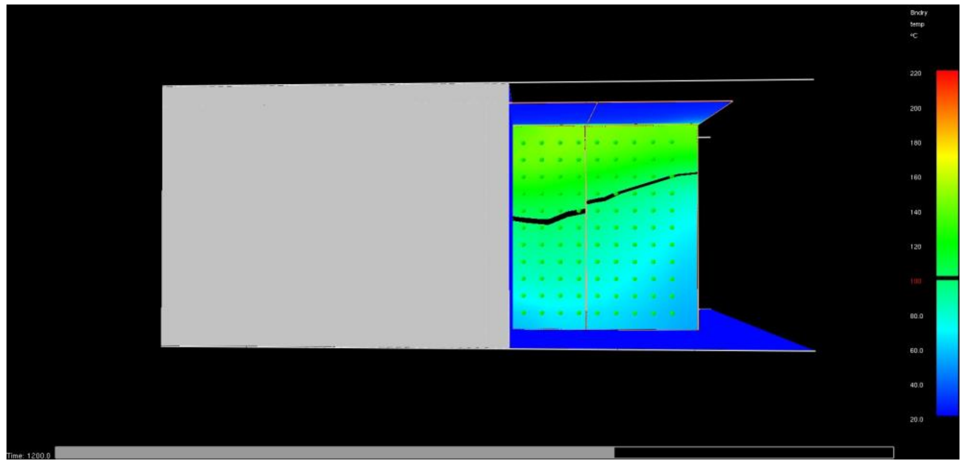
At 10 minutes, the surface temperature of the non-exposed side of the FCS is approximately 80°C to 100°C.

15 minutes



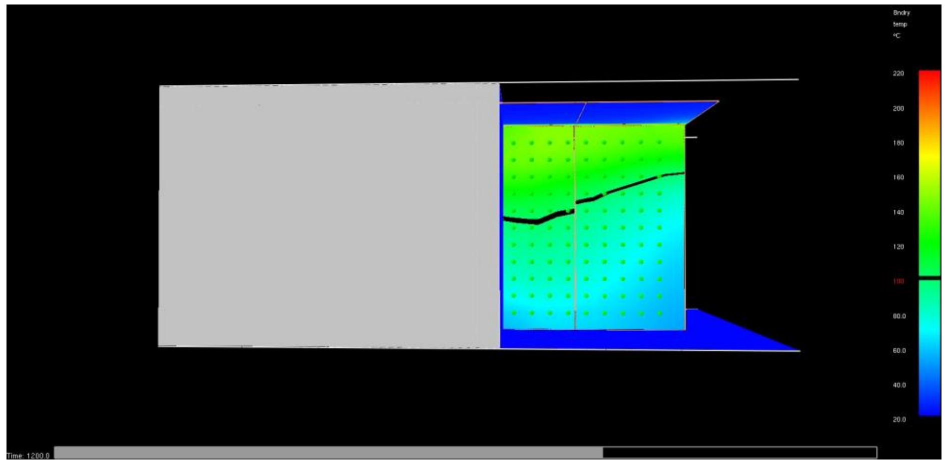
At 15 minutes, the surface temperature of the non-exposed side of the FCS is approximately 120°C to 140°C. The temperature marker (set at 100°C) begins to descend.

20 minutes



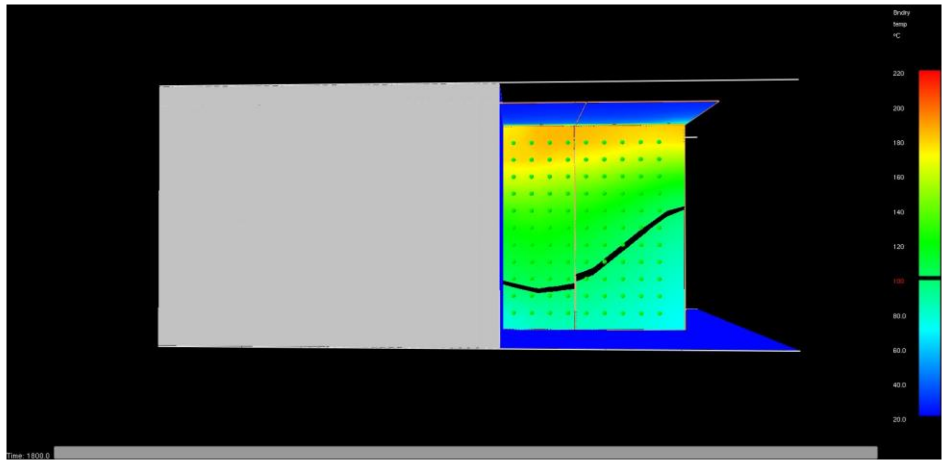
At 20 minutes, the surface temperature of the non-exposed side of the FCS is approximately 140°C to 160°C.

25 minutes



At 25 minutes, the surface temperature of the non-exposed side of the FCS is approximately 140°C to 160°C.

30 minutes



After 30 minutes exposed to a 6.9MW fire extending through the openings of the balcony area, the radiative heat flux impinging upon the FCS resulted in an unexposed surface temperature of approximately 160° to 180°C.

4.3.2 Numerical results and discussion

Surface temperatures – exposed side

The following analysis considers the effectiveness of fibre cement sheet as a theoretical protective overclad treatment where combustible cladding is to be retained.

Figure 11 represents the temperatures of the internal surface of the FCS when installed to cover cladding that is to be retained. The surface temperature of the internal side is reflective of 30 minutes exposure to a 6.9MW flashover fire extending through the balcony area.

Three thicknesses were evaluated – 9mm, 14mm and 23mm (to represent 9mm and 14mm FCS combined), the analyse over-cladding thicknesses that would resist reaching critical polymer temperatures on the external side of the overclad (closest to the internal side of the combustible cladding encapsulated).

The surface temperatures on the exposed side were assessed to ensure that the exposure was identical in the 3 cases. The resulting internal surface temperatures are represented in Figure 11 below:

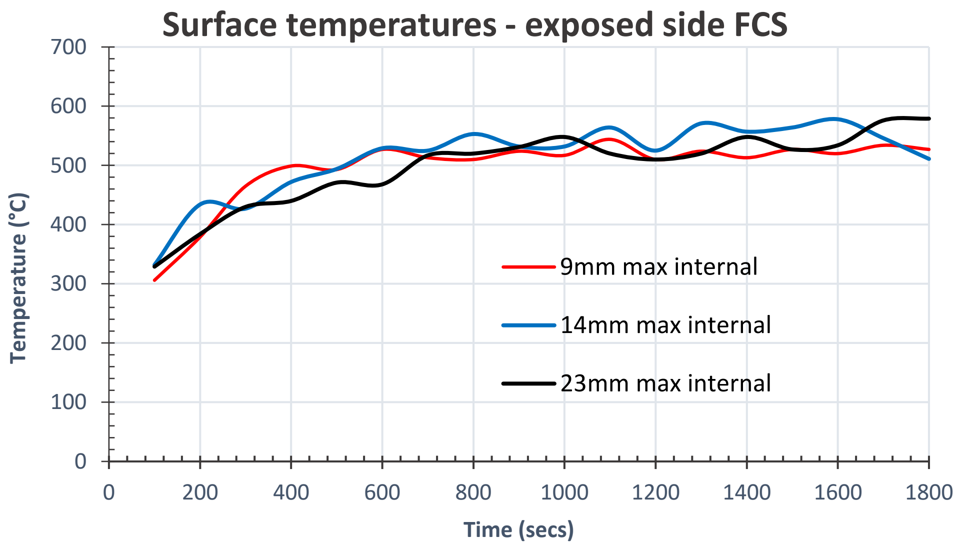


Figure 11: Internal exposed surface temperature of FCS when exposed to a 6.9MW flashover fire

The temperatures of the exposed surfaces were in alignment for all 3 cases.

Comparison

The resulting temperatures of the over claddings unexposed side were compared to the autoignition temperatures of polystyrene and polyethylene. The benchmark temperatures used were as follows [16]:

Table 2: Polymer autoignition temperatures

Polymer	***Autoignition temperature***
Polystyrene	427°C
Polyethylene	330-410°C

The individual results for the unexposed side, for the three FCS thicknesses were as follows:

9mm fibre cement sheet

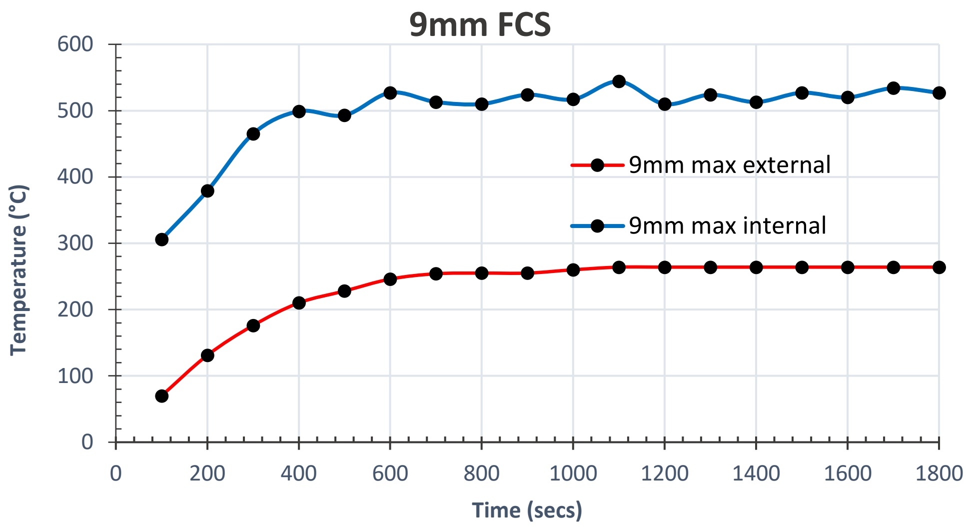


Figure 12: Internal and external surface temperature of 9mm FCS when exposed to a 6.9MW flashover fire

<u>Observations</u>:

- Temperature differential between both internal and external surfaces is reasonably consistent at an approximate **Δ 280°C** (i.e. 540°C – 260°C).
- The maximum surface temperature reached on the unexposed side over the 30 minute period is approximately **264°C**.

14mm fibre cement sheet

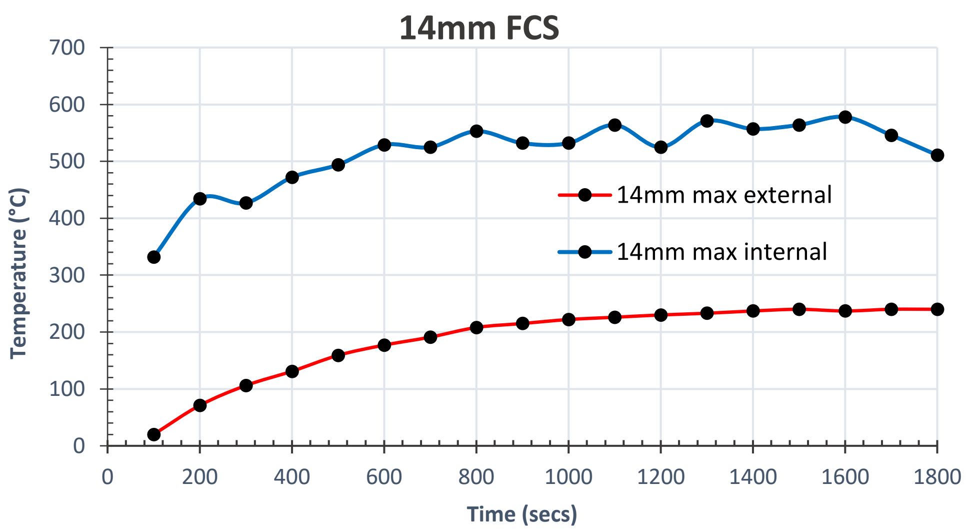


Figure 13: Internal and external surface temperature of 14mm FCS when exposed to a 6.9MW flashover fire

<u>Observations:</u>

- Temperature differential between both internal and external surfaces is reasonably consistent at an approximate **Δ 240°C**.
- The maximum surface temperature reached on the unexposed side over the 30 minute period is approximately **240°C**.

23mm fibre cement sheet

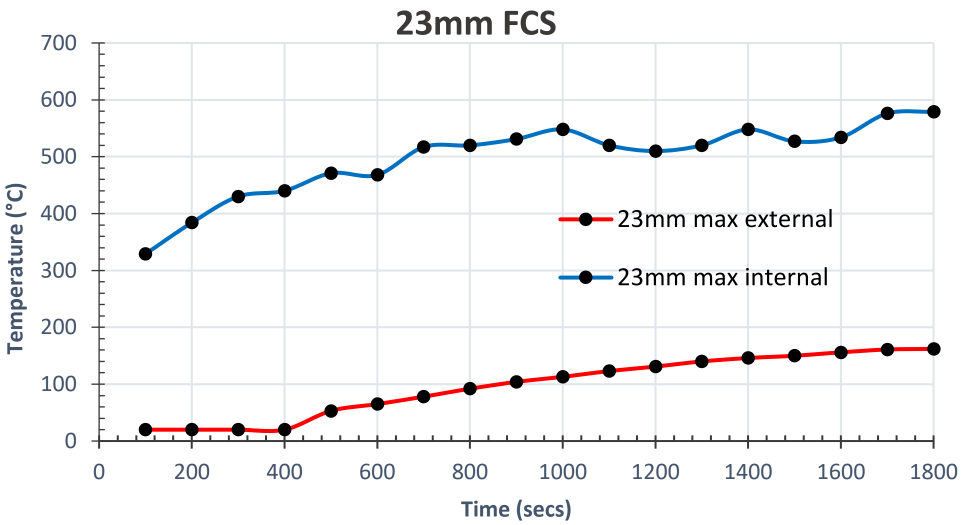


Figure 14: Internal and external surface temperature of 24mm FCS when exposed to a 6.9MW flashover fire

<u>Observations:</u>

It can be seen that the difference between internal and external sides of the overclad material (**delta)** increases with the thickness of the material. The following is noted:

- Temperature differential between both internal and external surfaces is reasonably consistent at an approximate **Δ 300°C**.
- The maximum surface temperature reached on the unexposed side over the 30 minute period is approximately **160°C**.

Comparison of results

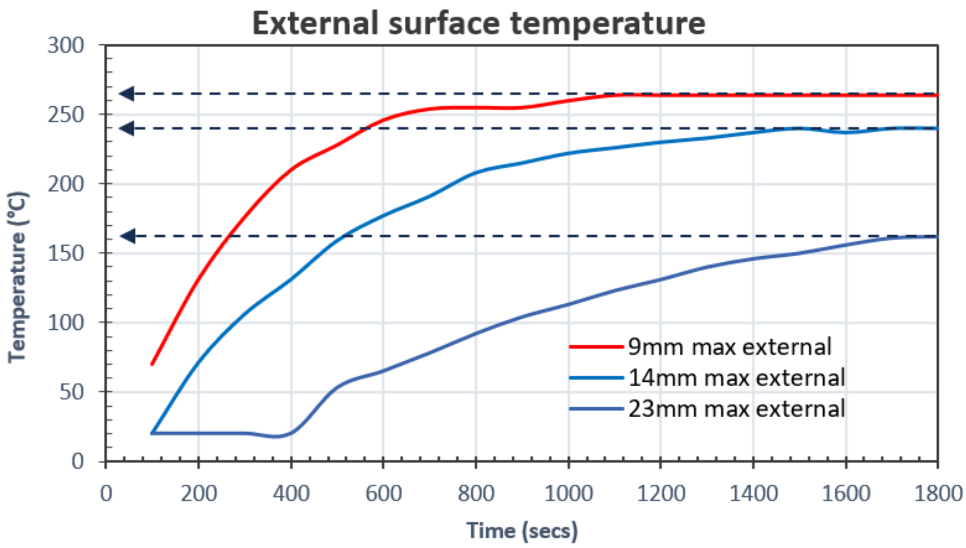


Figure 15: External surface temperature comparison

Where the temperatures on the external side of the protective fibre cement sheet analysed exceed autoignition temperatures of EPS and Polyethylene, careful consideration of the combustible cladding construction will be required before implementing the overclad option instead of removal.

The results have shown that where 9mm, 14mm and 23mm fibre cement sheet is employed as over cladding, temperatures on the unexposed side of the FCS will not reach the autoignition temperatures of the polyethylene and polystyrene.

The following is noted as conservative for the fire dynamic simulations performed:

- Source flashover fire of 6.9MW;
- EPS is considered to be fully exposed and not protected by any render; and
- ACP at the test wall is considered without the aluminium skin, with a 100% polyethylene core fully exposed.

5 Concluding remarks

5.1 Discussion

1. The radiant heat flux experienced by the returning test wall where the height (z) is less than 0.25m is generally below the critical heat flux values required to ignite polyethylene and expanded polystyrene when exposed to a 6.9MW flashover fire.
2. A correlation between balcony geometries, apartment geometries, design fires and height of retainable combustible cladding should be further investigated,
3. FCS overclad materials at thicknesses of 9mm, 14mm and 23mm thickness were subject to Fire Dynamic Simulations. The results show that thicknesses of 9mm, 14mm and 23mm analysed in this report would not reach the critical ignition temperatures of polystyrene or polyethylene for a period of 30 minutes on the overclad materials unexposed side.

5.2 Research responses

Cladding removal

Remove cladding from returning walls of balconies to reduce cladding fire spread through the following mechanisms:

- Reduce the likelihood of cladding ignition directly from a balcony fire source.
- Reduce the likelihood of a cladding fire externally spreading into balcony areas.
- Reduce the likelihood of a flashover fire from balcony openings (doors and windows) connecting with external walls.

1. Removal of cladding should be considered:
   a) Where construction facilitates relative ease of removal.
   b) Where the installation of sprinklers is challenging because of bounding construction (normally at the balcony/SOU threshold).

Over cladding

Fibre cement sheet of varying thicknesses were subject to computational fluid dynamic analysis to assess the transfer of heat through the material when exposed to fire. The objective of the analysis was to understand the surface temperature expected on the external side of the overclad that would be installed directly against the combustible cladding. Results show the following:

- Thickness of 9mm, 14mm and 23mm thickness were subject to Fire Dynamic Simulations. The results show that reduced and practical thicknesses of 9mm, 14mm and 23mm analysed in this report would not reach the critical ignition temperatures of polystyrene or polyethylene for a period of 30 minutes on the overclad materials unexposed side.

Over cladding of combustible cladding material should be considered in isolated instances. The computational fluid dynamic simulations performed provide analysis of a material's ability to resist or delay the transfer of heat from the exposed (balcony fire) side to the unexposed side.

It is important however to note the limitations of the FDS software, particularly in assessing the structural integrity of the material. Actual structural and physical failures, such as cracking or splitting, can occur due to design flaws, material processing inconsistencies, or irregularities, especially under extreme heating conditions. While it's acknowledged that FCS (subject overclad material) can delay heat transfer effectively, it is known to be susceptible to cracking at very high temperatures.

Flashover fire scenarios:

When addressing flashover fire scenarios, it is recommended that greater thickness FCS be considered (i.e. 14mm-23mm). Where 9mm FCS sheeting is proposed, the material must be assessed for its integrity at temperatures above 600°C, as would be expected in flashover fire scenarios.

Balcony fire scenarios:

The use of 9mm FCS as an over cladding material should be reserved as an intervention for protecting against smaller balcony fire hazards only (BBQ's, air conditioning unit failures and penetrations for example).

Where over cladding of the combustible material is preferred to removal, penetrations through the overclad and combustible materials being encapsulated are required to be treated as documented in *Support Package F.03, penetrations to address energy ignitions*.

Sprinklers

The performance of sprinklers is discussed at length in Support Package D.05. While there is not conclusive evidence around the performance of balcony sprinkler, it is the opinion of the authors of this report that extending of sprinklers into balconies may sufficiently address the risks associated with cladding installed on balconies providing balconies are considered to be covered balconies.

5.3 Rule(s)

Where combustible cladding is to be removed from the balcony returning walls, 250mm from the finished floor level (vertically) can be retained. This is to prevent potential damage to the delicate waterproofing membrane and the resulting ingress of water to the structure (identified as a key risk in balcony rectification work).

Note: Rectification work must consider the detrimental impact that such work can have on the external wall systems of a building. A great deal of care should be taken to ensure that the integrity of the condensation management systems, the weatherproofing/waterproofing systems and the structural wall systems is maintained.

6 References

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7 Appendices

7.1 Appendix A – PMCR document set and flow