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Literature Review on Fire Safety of Exterior Insulation Finish Systems and Insulated Sandwich Panel as External Wall Systems

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Executive summary

CSIRO has been engaged by the Victorian Building Authority to conduct a literature review and draft an advisory report to identify the fire safety issues regarding exterior insulation finish systems (EIFS) and insulated sandwich panel (ISP) systems applied to external walls for Class 2-9 buildings.

This report presents the detailed results of the literature review.

This review is based on publicly accessible publications, research and test reports. Confidential test reports for specific products or systems have not been reviewed and cannot be included for reasons of confidentiality.

This review has also drawn upon generalised information from Victorian Statewide Cladding Audit (by Victorian Cladding Taskforce, VBA and DELWP).

The general conclusion of this report is:

- EIFS and ISP are not permitted by the National Construction Code (NCC 2019) Deemed-to-Satisfy (DTS) provisions for use on external walls of buildings of Type A and B construction. DTS provisions generally require External walls for Type A and B construction to be non-combustible and this has been the case for more than 20 years of previous National Construction Code / Building Code of Australia versions.

- EIFS and ISP, particularly having expanded polystyrene (EPS) insulation, appear to have been installed on external walls of buildings of Type A and B construction in numerous cases without adequate certification or approval via a Performance Solution assessment process.

- There is currently insufficient test (or other) evidence available regarding façade fire spread performance of EPS cored EIFS and ISP systems as typically installed in Australia for Type A and B construction buildings to conclude that these products can perform suitably. The limited evidence that is available indicates that they are very unlikely to perform suitably in terms of façade fire spread performance if presented with a large ignition source.

- Based on the above, it is recommend that EIFS and ISPs should not be not be applied to any new Type A and B construction buildings from this point forward without suitable demonstration of NCC compliance via full scale façade testing and performance-based assessment.

The report has covered the following topics:

1) What is EIFS and ISP.
2) How EIFS and ISP are used in Australian buildings.
3) Construction quality and maintenance.
4) Component material fire properties.
5) Mechanisms of fire spread on external walls for EPS and ISP.
6) EIFS and ISP related fire incidents buildings.
7) Building code requirements.
8) Certification.
9) EIFS and ISP Industry bodies, guidelines and standards in Australia.
10) Fire tests and experimental research applicable to EIFS and ISP external walls.
11) Fire safety rectification of existing EIFS or ISP external walls.

Knowledge gaps regarding EIFS and ISP fire performance applicable to Type A and B residential construction in Australia have been identified. This report has made suggestions on opportunities to address the identified knowledge gaps. These address:

1) Building industry education.
2) Improved regulation of EIFS and EPS.
3) Improved Certification.
4) Audit and inspection of existing EIFS and ISP buildings and recording of fire incidents.
5) Further testing and experimental research.

1 Introduction

1.1 Background

CSIRO has been engaged by the Victorian Building Authority to conduct a literature review and draft an advisory report on the fire safety of Exterior Insulation Finishing Systems (EIFS) and Insulated Sandwich Panels (ISP) applied to external walls of Class 2-9 buildings as façade or cladding material.

1.2 Objective

To identify the fire safety issues regarding EIFS and ISP systems applied to external walls for Class 2-9 buildings.

1.3 Scope of work

CSIRO will undertake a literature survey to gather information on the fire safety of EIFS and ISP systems. This information will form the basis of the document "Literature Review on Fire Safety of Exterior Insulation Finish Systems and Insulated Sandwich Panel as External Wall Systems". The work is applicable to Class 2-9 building external walls.

The scope of this work is expected to deliver a preliminary summary of findings on the fire safety of EIFS and ISP based on literature survey and any industry information provided by the VBA. These findings will be documented as an "Advisory report" intended to be published and accessible by the building and regulatory industry.

The literature review will cover the following topics

1. EIFS and ISP building systems typically used – Australia and world (USA and Europe).
2. Methods to identify if EIFS and ISP systems are installed to an existing building.
3. EIFS and ISP component material information and known fire properties – focus will be primarily on EPS and fire retarded EPS core material and typical render systems, however other types of foamed polymer insulation core less frequently used may also be briefly considered.
4. Mechanisms of fire spread on complete EIFS and ISP systems.
5. EIFS and ISP related fire incidents and case studies in Australia and around the world. Within Australia, only EIFS fire incidents in Victoria have been identified and summarized, incidents in other states were not identified or focused upon, but it appears that major EIFS fire incidents resulting in extensive multistory fire spread or fatalities has not occurred in Australia. However, there are examples of such EIFS fire incidents internationally
6. An overview of the relative risks that each type of product presents to a building occupant. This information may be presented in a table format and will attempt to range generic product types in order of overall risk. In most cases, it is noted that the quality of construction will have the most significant impact on the level of risk. Therefore core materials, facing materials and quality of construction may be ranked separately.
7. A summary of current BCA fire safety requirements applicable to EIFS and ISP.
8. A summary of typical regulation of EIFS and ISP in Australia over the past 10 years. Identify if an EIFS and ISP industry association has been developed in Australia and its contribution to control or regulation of EIFS and ISP use for external walls in Australia.

9. A summary of regulation of EIFS and ISP in USA and Europe, including building code requirements and industry association standards, guidelines or accreditation systems. This will include review of what regulators have issued by way of guidance material regarding the use of EIFS and ISP.
10. A summary of EIFS and ISP related fire test methods applied in Australia, USA and Europe. Will include small scale, intermediate scale and full-scale tests. Summary of known fire performance of complete EIFS and ISP systems (expect a range and almost all from overseas) available from existing published full-scale façade tests.
11. Identification of EIFS and ISP fire safety knowledge gaps not addressed in the literature review and opportunities for further research or testing that could address these gaps. The work may be undertaken by the VBA as a future additional scope of work.

1.4 Sources of information

CSIRO has sourced literature addressing the above scope of work from sources including:

- Scientific and industry journals and conference papers.
- Library searches, specifically on key fire engineering and materials flammability books such as the SFPE handbook, etc.
- Online searches.
- Searches of product accreditation schemes and specific product supplier information.
- Newspaper articles.
- Request for any fire incident information from MFB and CFA.
- Information and discussion provided from international fire safety researchers including Anja Hofmann (BAM Federal Institute for Materials Research and Testing, Germany).

From 2017-2019 CSIRO has acted as a fire safety engineering representative in various Advisory Reference Panels (ARP's) under the Statewide Cladding Audit on behalf of the Victorian Cladding Task Force, VBA and DELWP. This role has involved:

- Panel review of inspection reports by others of numerous buildings with combustible cladding in Victoria.
- Panel risk assessment of the buildings reviewed, and
- In several cases, in person inspection of buildings with combustible cladding has been carried out by panel members including CSIRO.

VBA, DELWP and the Victorian Cladding Task Force has not provided CSIRO with detailed statistical or summary data from this ARP process beyond that contained in The Victorian Cladding Taskforce interim[1] and final[2] reports. Other fire engineering consultants have also participated in the ARP process, so CSIRO has only been exposed to a significant portion (but not the whole) of the buildings inspected. CSIRO's observations from ARP's have helped to inform the understanding and knowledge of typical application of EIFS and ISP in Australia. However, due to confidentiality, CSIRO cannot include details of specific buildings reviewed via ARP's. Instead this knowledge is drawn upon as a generalised knowledge based on CSIRO ARP involvement and is used to supplement or fill gaps in information available from published literature.

CSIRO has extensive experience in application of a range of fire test methods to building products including EPS, EIFS and ISP. CSIRO testing is on behalf of clients and is client confidential, therefore CSIRO cannot include specific details sourced from this work, unless already publicly available.

1.5 Limitations

The reader's attention is drawn to the following limitations with respect to this literature review:

a. This review deals with the fire safety of EIFS and ISP systems described in Section 2 only and does not directly provide detailed review of other non-fire related matters such as durability, weather performance, acoustic performance and thermal insulation performance, etc. However, this report does where matters such as durability or construction quality may have an impact on fire performance.
b. This review does not focus on other types of combustible external wall materials or systems.
c. In particular, the scope of this review does not extend its focus to the use of EPS or other rigid foamed polymer insulation boards applied as cavity insulation within other types of wall systems such as rain-screen cladding systems etc.
d. This review is based on publicly accessible publications and journals. Confidential test reports for specific products or systems have not been reviewed and cannot be included for reasons of confidentiality.
e. This review is limited in extent by the time and resources available to CSIRO. It is not exhaustive, and some relevant literature may not have been identified and included.
f. In reviewing the literature, CSIRO has attempted to identify cases where published literature appeared to be not based on peer reviewed scientific data and such literature has been excluded from this report except for cases of manufacturer product technical data etc.
g. The scope of this preliminary review has excluded communication with industry bodies to explore information they may be able to provide or related industry activity. The scope of this review has also excluded detailed site inspections or audits. These items have been recommended as further work.

1.6 List of Terminology

Different countries and sections of the construction industry have differing terms for systems and materials. For examples ETICS and SIPS are acronyms not commonly used in the Australian construction industry.

External wall Assemblies – Outer wall of a building which is not a common wall. May include a curtain wall or a panel wall system as defined by the NCC, and is the external vertical or near vertical wall system of a building, either structural or non-structural, including the façade, skin and all substrates along with finishes, attachments and cavities.

Non-combustible means—

a. Applied to a material — not deemed combustible as determined by AS 1530.1 — Combustibility Tests for Materials; and
b. Applied to construction or part of a building — constructed wholly of materials that are not deemed combustible.

Ignitability – The measure of the ease with which a material can be ignited. This is typically defined as the minimum temperature or heat flux condition needed to sustain combustion under specified conditions. Such conditions include the availability of air (ventilation), ambient temperature and atmospheric pressure. Ignitability also depends on the thermal and physical properties of the material.

Fire Severity – The combination fire size (HRR) and exposure duration of the fire at high HRR defines fire severity.

Flame Spread –The process of progressive ignition along a continuous surface. The rate and extent of flame spread depend on ignitability, heat release rate of the material and the available ventilation conditions. This definition also extends to the spread of fire between spatially separated occurrences of combustible material or spread of fire through a barrier from one compartment to another.

Heat Release Rate (HRR) – The characteristic that quantitatively describes the size of a fire is the Heat Release Rate. The HRR is a measure of the rate of heat energy output in kilowatts (kW).

Lightweight construction –wall or roof frame constructed of either timber or steel members that form the structural support of a building. It also provides the framework for non- structural cladding.

Solid construction – Masonry or concrete construction or the like.

Rigid Cellular Foamed Polymer–Cellular structured foam that is rigid (non-flexible) containing dispersed air pockets. This type of material is manufactured using petroleum-based polymers.

1.7 List of Abbreviations

Table 1. List of abbreviations

Abbreviation	Definition
AAC	Autoclaved Aerated Concrete
ABCB	Australian Building Code of Australia
ACP	Aluminium Composite Panel
ANSI	American National Standard Institute
ARP	Advisory Reference Panels conducted in Victoria on behalf of either VBA, DELWP or the Victorian Cladding Taskforce . Panel typically includes a fire engineering representative, a building surveyor representative and a fire brigade representative. The purpose of the panel is to review inspection reports and other information provided on specific building identified to have combustible cladding, risk assess the building and make recommendations to the municipal building surveyor.
AS	Australian Standards
ASTM	American Society for Testing Materials
BA	Breathing Apparatus
BAB	Building Appeals Board (Victoria, Australia)
BAL	Bushfire Attack Level as defined by AS 3959.
BAM	Bundesanstalt für Materialforschung und –prüfung (German research and testing authority)
BB	Building to Building (external wall classification as defined by AS 5113-2016)
BMK	Bauministerkonferenz (German Building Authority)
BRAC	Building Regulations Advisory Committee (Victoria, Australia)
BRANZ	Building Research Association of New Zealand
BRE	Building Research Establishment Limited (UK research and testing authority)
BS	British Standard
CFA	Country Fire Authority (fire brigade for rural and outer urban areas of Victoria, Australia)
CHF	Critical Heat Flux for sustained ignition.
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DELWP	Department of Environment, Land, Water and Planning, Victoria
DIBt	Deutsches Institut für Bautechnik – German Institute for Building technology
DIN	Deutsches Institut für Normung (German Testing Standard)
EAE	European Association for ETICS
EIFS	Exterior Insulated Finishing Systems
EIMA	EIFS Industry Members Association (USA)
EOTA	European Organisation for Technical Approvals
EPAQ	European Panels and profiles Assured Quality
EPDM	Ethylene propylene diene monomers
EPS	Expanded Polystyrene
EPSA	Expanded Polystyrene Australia Incorporated (Australian EPS industry body)
EPS-FR	Expanded polystyrene with flame retardant additive
EPSMA	EPS Molders Association (USA)
ETAG	European Organisation for Technical Approvals
ETICS	External Thermal Insulation Composite Systems (alternative name for EIFS)
EU	European Union

Abbreviation	Definition
EW	Eternal Wall classification as defined by AS 5113-2016
EWFA	Exova Warringtonfire Assessment (Australian testing laboratory)
FM Global	American mutual insurance company with offices worldwide, that specializes in loss prevention services primarily to large corporations in the Highly Protected Risk (HPR) property insurance market sector. "FM Global" is the communicative name of the company, whereas the legal name is "Factory Mutual Insurance Company". The company employs a non-traditional business model whereby risk and premiums are determined by engineering analysis as opposed to historically based actuarial calculations.
FPA	Fire Propagation Apparatus as defined by ASTM E-2085
FRL	Fire Resistance Level - means the grading periods in minutes determined in accordance with NCC Specification A2.3, for the following criteria— (a) structural adequacy;and (b) integrity;and (c) insulation, and expressed in that order. Note: A dash means that there is no requirement for that criterion. For example, 90/–/– means there is no requirement for an FRL for integrity and insulation, and –/–/– means there is no requirement for a FRL.
FZ	Fire zone (e.g. Bushfire Attack Level BAL-FZ) as defined by AS 3959 and AS 1530.8.2
GRP	Glass Reinforced Plastic
HBCD	Hexabromocyclododecane. The flame retardant predominately used for EPS.
HBO	German model building code for high rise buildings (Musterhochhausrichtlinie 2008 with amendments 2012, known as HBO).
HDPE	High Density Polyethylene
HFC	Hydrofluorocarbons
HPL	High Pressure Laminate
HRR	Heat release rate. A measure of the rate of heat energy output in number of kilojoules per second, kJ.s-1 or kilowatts (kW).
HRRPUA	Heat release rate per unit area (kW/m^2)
IBC	International Building Code (North American Model Building code)
ICA	Insurance Council of Australia
ICC	International Code Council (USA)
IMP	Metal skinned ISP panels (alternative name for ISP)
IPCA	Insulated Panel Council of Australasia Ltd.
ISO	International Standards Organisation
ISP	Insulated Sandwich Panel
JAS-ANZ	Joint accreditation system of Australia and New Zealand
LF	Large (sized) Fire – Large sized fire façade exposure test under consideration by the European façade test harmonisation project.
LPCB	Loss Prevention Certification Board (UK)
LPS	Loss Prevention Standard (UK)
MBO	German model building code for low and mid-rise buildings (Musterbauordnung MBO, from 2002 with recent amendments from May 2016).
MCA	Metal Construction Association (USA)
MDI	Methylene diphenyl diisocyanate
MF	Medium (sized) fire - Medium sized fire façade exposure test under consideration by European façade test harmonisation project.
MFB	Metropolitan Fire Brigade (Urban fire brigade, Victoria, Australia)
MgO	Magnesium oxide.
MHCLG	Ministry of Housing, Communities and Local Government (United Kingdom)
MW	Mineral wool fibre insulation (note – MW also denotes the units MegaWatts)
NCC	National Construction Code (Australia)

Abbreviation	Definition
NFPA	National Fire Protection Association (USA)
NICNAS	National Industrial Chemicals Notification and Assessment Scheme (Australia)
NZFS	New Zealand Fire Service
OSB	Oriented strand board
PACIA	Plastics And Chemicals Industries Association (Australian industry body)
PIP	Polystyrene Insulated Panels (alternative name for ISP)
PIR	Polyisocyanurate foam
POP	Persistent Organic Pollutants
PUR	Polyurethane
PVC	Polyvinyl chloride
QT	"Quick 'n' Tuff" (commercial brand for an EPS in cement matrix product)
SBI	EN 13823 Single Burning Item test
SIPS	Structural Insulation Panel Systems. Compared to metal skinned ISP these have a facing that has some structural loading capability. Facings are typically oriented strand board, concrete etc.
SPS	Expanded Polystyrene with Phenolic resin (Syntactic)
TGA	Thermal Gravimetric Analysis
UBC	Uniform Building Code (older USA building code)
UL	Underwriters laboratories (USA)
uPVC	Un-plasticised Polyvinylchloride. Commonly known as rigid PVC
UV	Ultra violet
VBA	Victorian Building Authority (Victoria, Australia)
XPS	Extruded Polystyrene

2 What is EIFS and ISP?

This chapter introduces what EIFS and ISP are and clarifies their difference from other common types of combustible external wall systems such as Aluminium Composite Panels (ACP). Section 3 contains detailed information on the typical system components and installation methods for EIFS and ISP.

All EIFS and ISP are systems (consisting of multiple materials). These systems are often marketed as products, for example EIFS are often marketed as products but are still constructed on site.

2.1 External Insulation Finishing Systems (EIFS)[3-5]

Exterior Insulation Finishing Systems are also referred to as:

- External Thermal Insulation Composite Systems (ETICS).
- Rendered EPS.
- Synthetic stucco (USA terminology).

EIFS is the term most commonly used in North America and ETICS appears to be the term most commonly used in Europe. This report shall use the term EIFS for consistency. These systems are very common in the cold climate continents where they a popular due to the high thermal insulative properties. In Australia the main driver in adopting these systems for buildings are for their relative low cost and lightweight.

The International Building Code (IBC) and American Society for Testing Materials (ASTM) define EIFS as a non-load bearing, multi-layer external wall cladding system that consists of an insulation board attached either mechanically or adhesively or both to a substrate, a reinforced base coat and textured protective finish coat.[4]

In general terms, the EIFS system consists of the following main components:

1) A layer of Insulation (Insulation board); usually made of a rigid cellular foam plastic. The most common type being Expanded Polystyrene (EPS). The insulation layer thickness can vary from 30 -300 mm where the thicker layers are used in colder (overseas) climates. Layer thickness in the range 50-100 mm appears to be most typical in Australia. Refer to Section 4 for other types of core material.
2) A render system that seals the raw insulation board. The render system typically consists of two to three layers (one or two base coats and finish coat) with an alkali resistant reinforcing mesh (typically a fibreglass mesh) that is embedded within rendered layers to provide a water-resistance, durable and crack resistance finish.

The insulation board and render system in EIFS encapsulates the building envelope and forms the weatherproofing protective surface of the façade. EIFS places the main insulating material on the exterior of the wall structure. This contrasts with traditional building systems where the insulating element is internal; within wall cavities and often between the structural elements.

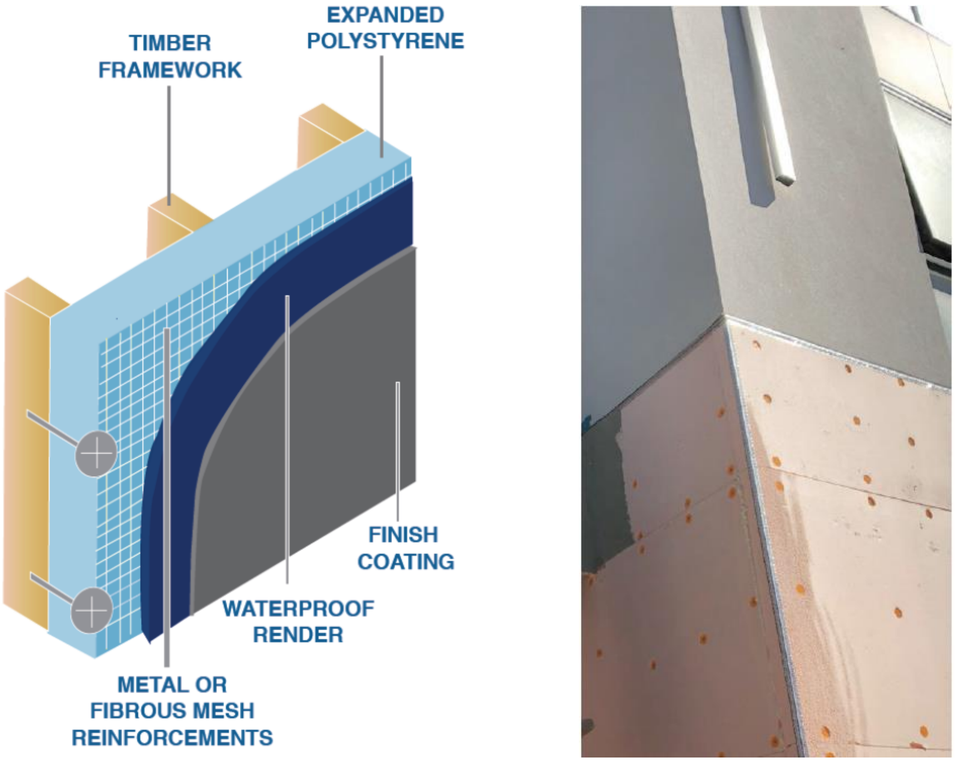


Figure 1. Typical EIFS installation

EIFS is typically selected for installation to buildings for a combination of the following:

- It increases the energy efficiency of a building due to:
    - Enhanced thermal insulation.
    - Placing the lower thermal density material on the outside of the building envelope and higher thermal density material on the inside of the building envelope.
    - Reduced air movement through the building envelope and therefore less heat loss.
- Ease and cost effectiveness of installation.
- Light weight – may reduce cost of supporting structure (for example on upper levels) compared to solid or heavier construction.
- Design flexibility and aesthetic choice.

However, EIFS has been identified to present the following problems, particularly in cases of poor design, installation or workmanship:

- Poor external wall fire spread performance.
- Prone to surface damage.
- Problems relating to moisture ingress.
- Moisture condensation and ineffective drainage or ventilation.

2.2 Insulated Sandwich Panels (ISP)[6-8]

Insulated Sandwich Panels (ISP) are defined as a building construction panel system made from:

- A low-density thermal insulation core material. Cores are typically in the range 40-200 mm thick but thicknesses outside this range do occur.
- A facing/skin material bonded to each face which has increased density, tensile and compressive strength and provides a barrier against impacts and moisture ingress. Steel sheet of 0.4-0.7 mm thick with painted/colorbond type external coating is most commonly used.
- Skins are typically bonded to the core by a thin layer of two-part heat polymerising adhesive via a continuous laminating and roll forming process. An interlocking tongue and groove style joint by roll forming the steel skins is typically provided at the edges of the panels.

The lightweight core keeps the two faces in the correct position, resists shear forces and provides insulation. The two external faces provide durability, weather and impact resistance, and resist in-plane forces of tension and compression.

ISP's are also known as:

- Sandwich Panel.
- Structural Insulation Panel Systems (SIPS).
- Metal skinned ISP panels can be referred to as Insulated Metal Panels (IMP).
- Polystyrene Insulated Panels (PIP).

For consistency this report shall use the term ISP.

By far the most common type of ISP's used in Australia are steel faced with either an EPS, EPS-FR (EPS with fire retardant) or PIR (Polyisocyanurate) core. This literature review mainly focuses on steel faced ISP's with foam polymer insulation cores.

Figure 2. Typical ISP with interlocking slip joints, EPS core (left), PIR core (right). Photos by CSIRO

However, the following alternative types of skin and core materials may be used to a lesser extent in Australia.

Alternative skin materials:

- Aluminium.
- Pre-cast concrete.
- Cement board.
- Glass fibre reinforced polypropylene.
- Poly vinyl chloride (PVC).
- Magnesium oxide board (MgO).
- Plywood.
- Oriented strand board (OSB).
- Glass reinforced plastic (GRP).
- Cardboard.

Alternative Core Materials – To EPS, EPS-FR or PIR

- EPS in a phenolic resin matrix (Syntactic) (SPS)
- Extruded polystyrene (XPS).
- Mineral wool (rock fibre) (MW).
- Phenolic foam.
- Folded metal, paper, aramid and carbon fibres. See Foldcore for more information.
- Honeycomb materials (such as Polypropylene).
- Straw.

2.3 EIFS AND ISP in comparison to other combustible external systems[9]

The scope of this report is to focus on EIFS and ISP only. However, there are several other types of combustible external wall systems that have been used in Australia. Some of these systems may include similar foamed polymer board insulation materials but arranged in a different manner to EIFS or ISP systems.

For further clarification, some of the more common combustible external wall systems are compared to EIFS and ISP systems. However, these other systems are not reviewed further in this report. The main material which has been involved in large fires around the world has been Aluminium composite panels (ACP). Other reports provide information on this material. A brief summary is included below.

2.3.1 ALUMINIUM COMPOSITE PANEL (ACP)

Description

ACP typically consists of two 0.5 mm thick aluminium sheets with a core material sandwiched between. The core material thickness typically ranges from 2-6 mm. The core material is typically either polyethylene (PE) or a mineral filled core which commonly consists of polyethylene with a percentage of mineral filler. A high ratio of mineral filling provides significant improvement in fire performance. The surface is typically coated with a fluorocarbon surface coating in a range of different colours. These panels are significantly less expensive than solid metal panels and are manufactured at a thickness required to achieve the same flexural stiffness.

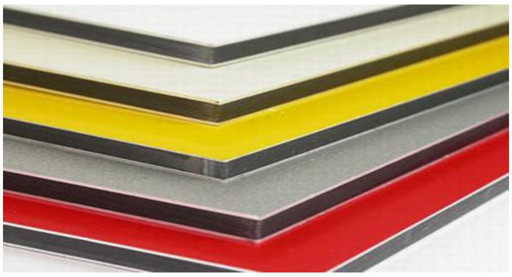


Figure 3.Typical Metal Composite Claddings [10]

The percentage of PE content of ACP can typically be categorised into 4 general categories.

The Insurance Council of Australia, Engineers Australia and Fire Protection Association (Australia) have published a protocol which categories ACP core materials as per the table below. Note this classification was first published in November 2017 and has since undergone several revisions. The table below also references the categories as identified by BRE through the screening test BS ISO 1716:2010.

Table 2. ICA protocol and BRE ACP core ranking[11, 12]

ICA Category	Polymer percentage by mass (%)	Inert filler percentage by mass	Similar category in BRE Appendix	Colloquial Naming
A	30-100%	0-70%	3 (> 35 MJ/kg)	PE
B	8-29%	71-92%	2 (>3 MJ/kg and ≤ 35 MJ/kg)	FR, Plus or rated Class B per EN 13501
C	1-7%	93-99%	1 (≤3 MJ/kg)	A2, rated as Class A2 per EN 13501
D	0%	100%	1 (≤3 MJ/kg)	Non-combustible

ACP is typically installed to external walls on steel channels or battens/top hats. This typically creates an air gap between the cladding and the insulation, sarking or wall structure behind. The panels are typically fastened to the steel battens by either of the following two methods.

- Flat stick method – panels adhered to steel battens using double sided adhesive tape.
- Cassette mount method – the edges of the panels are folded at right angles and are rivet or screw fixed to aluminium or steel channels or clips which are in turn screw fastened to the external wall.

Sealant is normally applied to the gaps between panels. The above type of installation typically forms a ventilated façade/rain screen with an air gap separating the ACP from the supporting wall behind

PE ACP has been involved in several large façade fires around the world including Grenfell tower fire (UK), Lacrosse apartment fire (AUS) and in several fires in the Middle-East.

Key differences from EIFS

- ACP is a completely different system which contains a thin 4-6 mm layer of solid PE or other core material sandwiched between aluminium skins compared to EIFS which is a thick 30-200 mm foam polymer insulation board (typically EPS) with render on its external face.
- ACP is typically selected due to its light weight, strength and aesthetics but not for its thermal insulation. Although it can provide thermal shading as part of a ventilated façade, EIFS is typically selected for its thermal insulation.

Key differences from ISP

- ACP is a completely different system which contains a thin 4-6 mm layer of solid PE or other core material sandwiched between aluminium skins compared to ISP, which is a thick 40-200 mm foam polymer insulation board sandwiched between steel sheet skins
- ISP provides increased strength and thermal insulation compared to ACP and can be a structurally self-supporting non-load bearing wall.
- ISP is available in larger panel lengths than ACP and is installed, joined and fixed in a completely different manner to ACP.

2.3.2 HIGH PRESSURE LAMINATES (HPL)

Exterior grade High Pressure Laminate (HPL) panels are typically layers of phenolic resin impregnated cellulose fibres (typically up to 70% cellulosic fibre content) with one or more decorative surface layers. HPLs are manufactured by pressing these layers at high temperature and pressures of typically >1000lb per square inch (70 kg/cm^2). This high pressure and temperature are required for the thermosetting poly-condensation process of the resin used. A wide range of colours, patterns and surface textures for the decorative surface layer are possible. The resulting panel is dense with a good strength to weight ratio and is weather resistant. HPL panels are typically available in thicknesses ranging from 3mm to 14 mm. HPL panels are typically applied as ventilated facades/rain screens, balcony panels and sun louvres.

HPL panels are typically installed over the existing wall surface using metal channels (battens or top hats) to separate the panel from the supporting wall. The panels are fixed to the metal channels either by exposed screws or rivets or on thicker panels (8 mm or thicker) concealed screwing of mounting clips to the inside of the panel is possible.

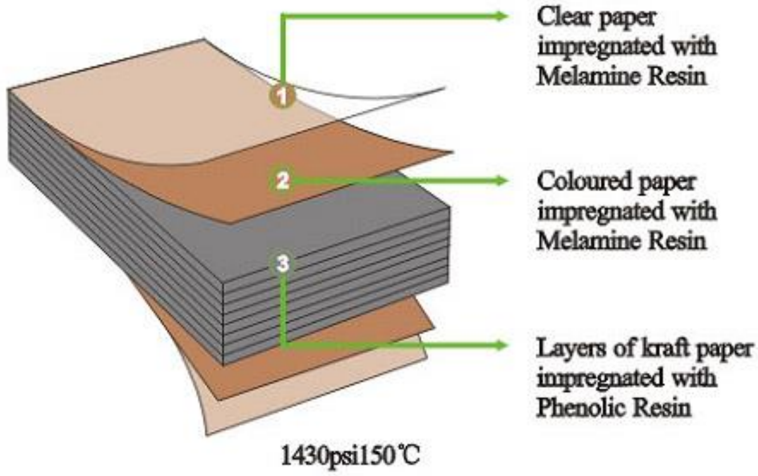


Figure 4.Typical HPL construction [13]

2.3.3 TIMBER

Motivation for increased use of timber-based materials exists due to increase in the renewable composition of buildings.

Timber external wall systems can include:

- Timber cladding ranging from traditional weatherboards to hard wood screening etc.
- Light weight timber framed construction.
- Massive timber construction including cross laminated timber (CLT).

Figure 5. Typical CLT Panels (left), Forte 10 storey residential CLT building in Melbourne (right), Typical hard wood cladding (bottom).

2.3.4 GLASS REINFORCED PLASTICS (GRP)

GRP is a composite material made of a solid polymer resin matrix reinforced with fibres. The fibres are usually glass (in fibreglass), carbon (in carbon-fibre-reinforced polymer), aramid, or basalt. Rarely, other fibres such as paper, wood, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic. Phenolic resins can be used to improve fire performance.

GRP appears to be used to a significantly lesser extent on building facades in Australia compared to ACP, EIFS and ISP. However, it is known to be used in some cases to be used in areas requiring complex curved geometric surfaces whereby the GRP can be moulded (by hand layup) into complex shapes.

The fire performance of GRP can be strongly influenced by the resin type used and any fire-retardant additives (typically Antimony tri-oxide).

2.3.5 WEATHER RESISTIVE BARRIERS AND SARKING

Weather resistive barriers are typically installed within the wall cavity to control air and moisture transmission and in some cases provide insulation to radiant or conducted heat transfer. Weather resistive barriers come in the following forms:

- Mechanically attached membrane known as sarking or building wrap. Typically, this is made from woven bonded polyethylene fibre.
- Self-adhering membranes.
- Fluid/paint applied membranes which include polymeric and asphaltic based materials.
- Spray applied polymeric foams such as polyurethane which also provide insulation.
- Board type barriers which includes plywood (typically up to 12 mm thick) or foamed plastic boards such as EPS or phenolic up to 25 mm thick (sometimes with a foil facing).

- Cellular insulation wraps which typically are made of polyethylene and have an air bubble structure much like bubble wrap. These often come with a reflective foil facing. They are typically 4-10 mm thick.
- Weather resistive barriers/ sarking are typically installed as part of the wall system behind EIFS (in Australia). They less often installed as part of an ISP wall system.

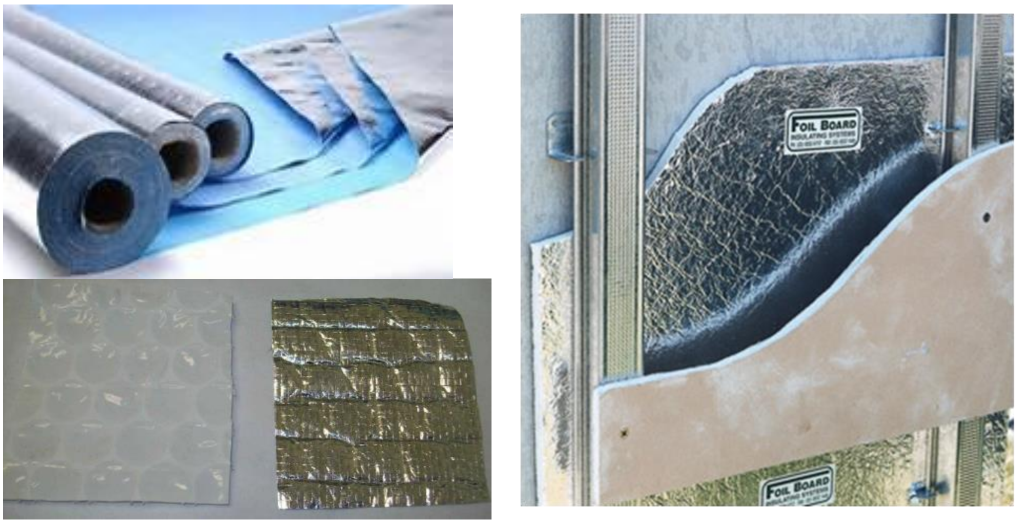


Figure 6. Typical weather resistive barriers including sarking (top left), air cell insulation (bottom left) and foil faced EPS board (right).

2.3.6 WALL CAVITY INSULATION

Insulation material typically installed within external wall cavities to increase thermal insulation and sound insulation include:

- Non-woven polyester blanket, batts or board.
- Glass fibre insulation.
- Mineral fibre insulation.
- Foamed plastic insulation including EPS, PIR, Phenolic foam, PUR etc.

Figure 7. Polyester blanket insulation (left), Fibreglass insulation (centre) Phenolic foam insulation (right).

2.3.7 RAIN SCREEN OR VENTILATED FAÇADE SYSTEMS

Rain screen cladding, sometimes referred to as a ventilated façade, is a type of façade construction which typically includes the following elements

- The structural wall /substrate – this may be solid masonry or concrete construction, or a light weight framed wall lined with an exterior grade sheeting product such as gypsum or cement board or timber board products with a water proof membrane. In many cases no solid substrate board is installed and only a moisture control membrane/sarking is installed to prevent moisture ingress into the light weight stud wall cavity.

- Insulation – Mineral fibre based insulation or foamed phenolic, polyisocyanurate (PIR), expanded polystyrene (EPS), polyurethane (PUR) or phenolic foam may be adhered or mechanically fastened to the exterior of a solid substrate. In some cases, a spray-based insulation may be applied. In many other cases, insulation is placed internally within the stud framed wall cavity with no insulation in the ventilation cavity.
- Moisture control membrane to keep rain and moisture out of the insulation and structural elements.
- Ventilation cavity and supporting brackets – a ventilation cavity (air gap) of at least 25 mm typically exists between the insulation and the rain screen external cladding. The cladding is supported by aluminium or steel brackets which bridge across the air gap.
- Rain screen cladding panel – A wide range of materials are typically used including ACP, HPL, timber products, metal sheeting, ceramic tiles, and cement board products. The cladding may include gaps between edges of panels and usually includes openings at the top and bottom of the wall to promote ventilation and drainage though the cavity.
- Cavity barriers are sometimes installed as fire/smoke barriers and/or moisture drain barrier

The above description describes a “Stick build” which is installed layer by layer onsite.

Rain screen cladding can be applied during primary construction or as refurbishment to existing construction.

Rain screen cladding systems are usually installed due to the following possible benefits;

- Improved protection against moisture ingress into buildings.
- Improved thermal performance through solar shading, ventilated cooling of wall cavities, increased insulation and reduced thermal bridging.
- Aesthetics.
- Cost.

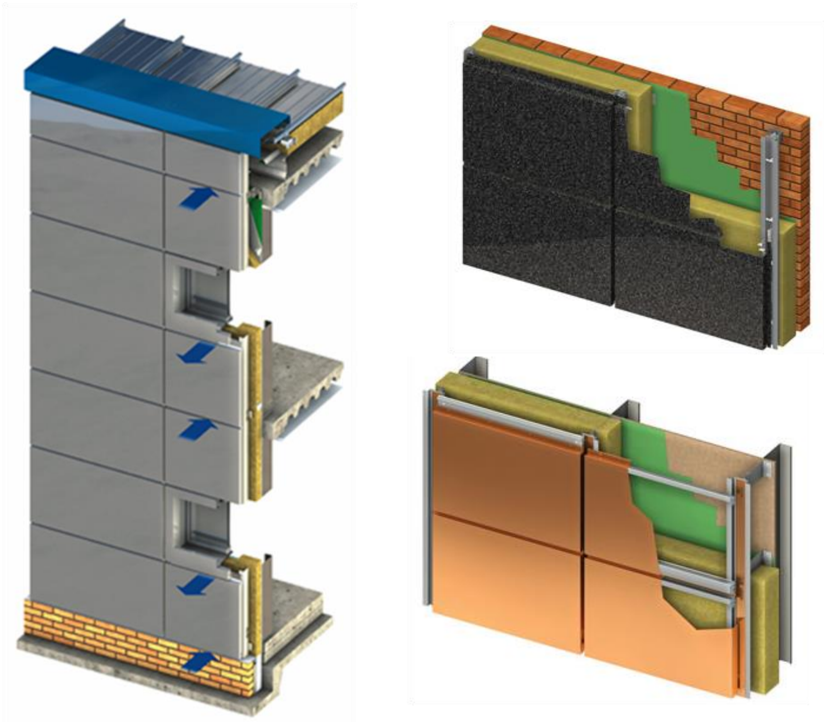


Figure 8.Typical rain screen cladding installation arrangements- from Linear Facades Catalogue[14].

2.3.8 PRE-MANUFACTURED UNITISED CURTAIN WALL FAÇADE PANELS

Unitised facades are factory pre-manufactured and installed as large complete curtain wall panels which may be up to 12 m in length[15]. They are typically installed on metal curtain wall brackets or framework supported off the slab edge or building structure. They lock into and seal against adjacent unitised panels.

Unitised façade panels may include integrated glazing. Unitised façade panels typically include the following key elements:

- Panel edge frame – typically aluminium or steel.
- External cladding panel – this may be sheet steel, aluminium or ACP.
- Internal air cavity.
- Internal insulation - which may be combustible or non-combustible.
- Rear back pan – Typically thin sheet steel.
- Edge sealing gaskets.

Some systems may adopt a ventilated rain screen design whilst others may be fully sealed.

Whilst these are pre-manufactured panels with an insulation component, they are clearly not ISP's.

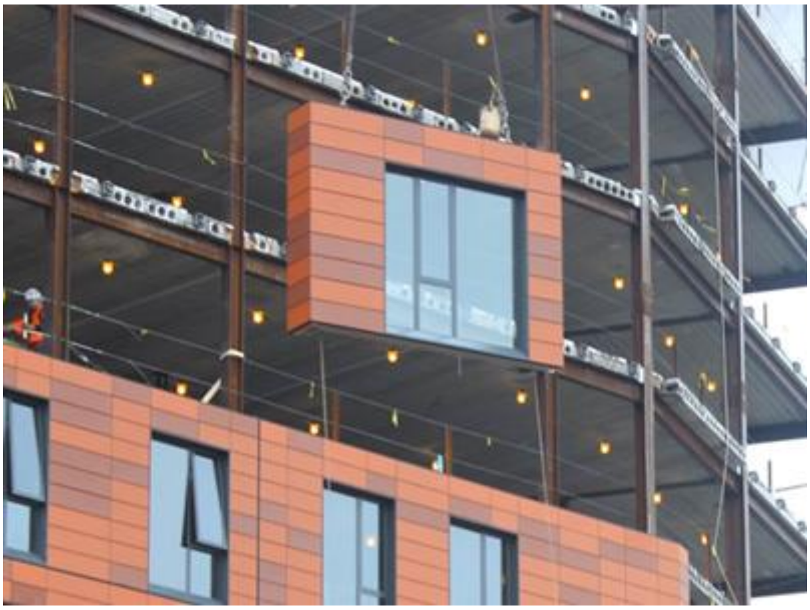


Figure 9. Unitised façade panels

3 How are EIFS and ISP used in Australian building industry?

This chapter discusses the introduction of EIFS and ISP into the Australian building industry, typical construction methods in Australia in comparison to Europe and/or US, onsite identification methods and Certification of EIFS and ISP via CodeMark certificates of conformity and other certification/approval processes.

3.1 Background and application to Australian Buildings

3.1.1 EIFS[16, 17]

EIFS systems were first designed and manufactured in Europe to increase the energy efficiency of masonry buildings during the 1950s. They were subsequently introduced to the United States in the 1960s and were initially mainly retrofitted to existing masonry buildings, however by the 1990s the main application of EIFS in the US was as external cladding to light weight wall construction. EIFS appear to have been introduced to Australia during the early 1980s. EIFS systems were adopted in the build for government commissioned homes (Class 1) located in the suburbs of Preston and Chadstone in 1984.[18]

Since their introduction to the Australian market, EIFS have mainly been used within the residential Class 1 construction market. However, due to its design flexibility it is now also being applied to a significantly lesser extent into façade design of structures belonging to other building classifications.

EIFS systems are most commonly installed on:

- Low rise residential Class 1
- Low to mid rise Class 2 and 3 buildings typically 2-4 storeys in height
- Upper storey extensions to existing buildings (typically of solid existing construction)

EIFS appear to be less commonly applied to taller buildings of 5 storeys or more where other cladding types such as ACP appear to dominate (perhaps due to height access and manual labour for the render installation). However, EIFS have been applied to taller buildings to a lesser degree.

3.1.2 ISP

ISPs have been used in Australia for the past 50 years. ISPs were originally devised for use in commercial refrigerated food storage applications. By far the most common type of ISPs used in Australia are steel faced with either an EPS, EPS-FR (EPS with fire retardant) or PIR (Polyisocyanurate) core. However other core types including mineral fibre and EPS in a phenolic resin matrix (Syntactic) are also used. ISP's are not only applied as wall panels but also as ceiling and roof panels.

ISP systems are commonly applied to (Based on CSIRO experience, IPCA code of practice and typical supplier brochures):

- External walls and roofs of Class 7b storage/warehouse buildings, typically low rise.
- External walls and roofs of Class 8 Production/Manufacturing buildings, Data Centres and the like, typically low rise.
- Internal rooms/compartments such as cool rooms or clean rooms within other building classes.
- Class 10 sheds.
- All the above are low rise, typically Type C construction.

However, with increasing energy efficiency requirements over the past 10 years there has been some application of ISP as external walls or roofs to other building classes, although the extent of application in other building classes is significantly lower. Examples, based on CSIRO experience and ARP's include:

- Class 6 – retail shopping centres.
- Class 9a – hospitals[19].
- Class 9b – sports stadia and swimming complexes.
- Data Centres etc.
- Class 1 – extensions and granny flats/portable homes.
- Temporary construction hoarding.

It is unclear from this review if ISP have been significantly applied as external walls of Class 2 and 3 residential buildings. However, based on the range of buildings reviewed by Advisory Reference Panels (ARPs) under the Statewide Cladding Audit, the extent of any use of ISP as external walls to Class 2 and 3 buildings is significantly less compared to ACP and EIFS.

3.2 Typical construction installation methods

This section summarises typical construction and installation of EIFS and ISP wall systems.

This has been based on a review of various manufacturers' instruction manuals, industry guidelines and technical papers. The level of adherence to construction methods and quality recommendations is unknown and can only be fully ascertained by conducting a site inspection.

3.2.1 EIFS[17, 20]

In Australia most manufacturer's installation instructions mainly address installation to light weight timber or steel framed construction and specify the following two options for EIFS installation:

Direct fix system

A direct fix system is where the foam polymer insulation is screw fixed directly to the stud wall frame with only sarking in between.

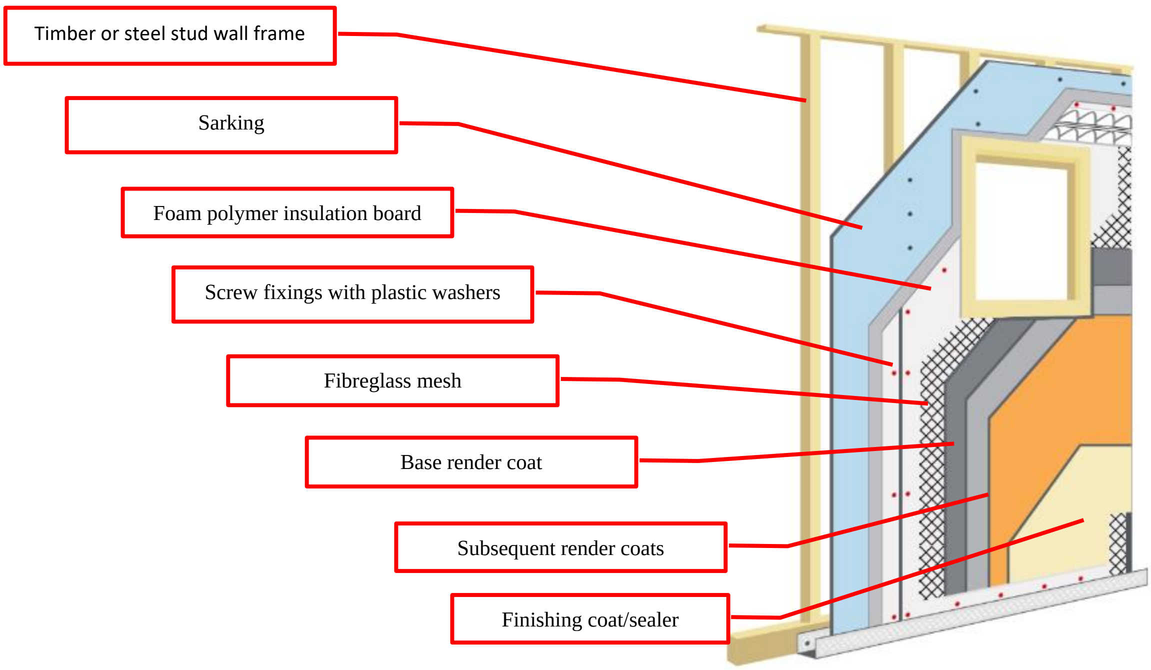


Figure 10. Typical EIFS direct fix system (image taken from Cova Wall website [21])

The key components of a direct fix system in order of installation are:

- Timber or steel stud wall frame.
- Sarking – typically a permeable or non-permeable foil faced building wrap such as woven polyethylene fibre.
- Foam polymer insulation board – EPS or EPS-FR is by far the most common used in Australia, however XPS, phenolic foam, PIR and PUR can also possibly be used.
- Screw fixings with plastic washers – Steel screws fix through the foam insulation board to the supporting frame. Installation guides typically specify maximum fixing spacing's along studs of ~ 300 - 400 mm or less dependent on stud spacing and wind design category. Plastic washers are typically high-density polyethylene (HDPE) or polypropylene with a diameter of ~ 40 mm.
- Fibreglass mesh – An alkaline resistant fibreglass reinforcing mesh is placed over the foam insulation board surface and sits within the base coat render layer. Its purpose is to improve strength and cohesion between the render system and insulation board and to resist cracking of the render due to building movement or thermal expansion and contraction.
- Render system – Most manufacturer's instructions specify acrylic polymer modified render with a minimum of:
    - Based coat.
    - Subsequent coat.
    - Finishing coat/sealer.

  The base coat is sometimes a special formulation with increased adhesion. The purpose of the subsequent render coats is to build thickness, strength and texture. The finishing coat is typically a membrane/paint/sealer applied with brush or roller that protects against weather, moisture, UV stability and provides some durability enabling washing etc. Various EIFS system manuals specify minimum total render thickness of 5-6 mm with some specifying 10mm or more.

Cavity System

The cavity system has all the same components as the direct fix system except that the battens/cavity spacers are placed between the sarking and the rear face of the foam insulation board, creating a~ 25 mm air gap. This air gap helps drain and dry out any water ingress that may occur via any moisture penetration, condensation or wicking/ capillary action.

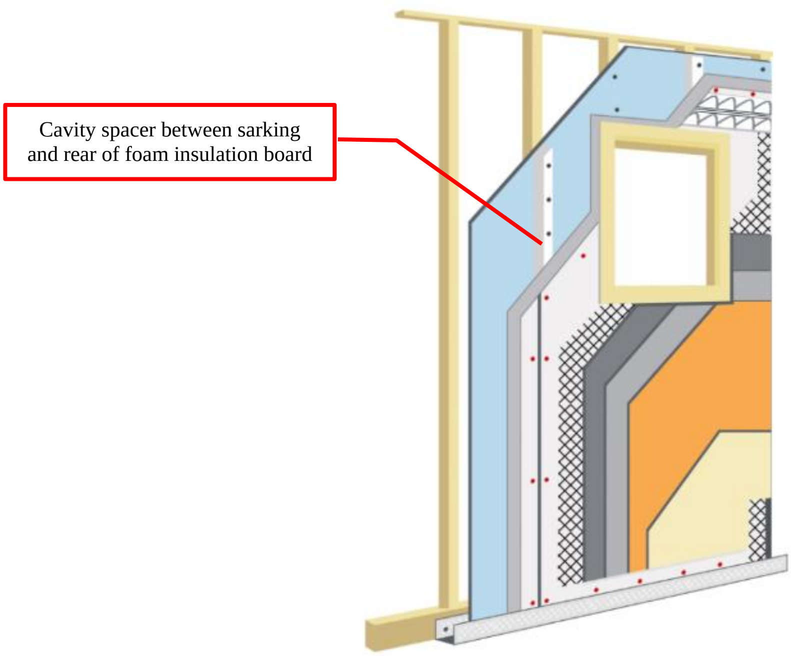


Figure 11. Typical EIFS cavity system (image taken from Cova Wall website [21])

The cavity spacers/battens are typically narrow strips of EPS (denser grade than main EPS board) but may also be timber or steel battens.

Other components/installation steps commonly specified for both direct fix and cavity installation include:

- Ground clearance - EIFS typically must be installed with a ground clearance of 75 mm or more above finishing grades such as ground or lower level roof lines. The adjacent finished grade must slope away from building. EIFS typically must not be installed in areas where it will remain in contact with standing water or where there is backfill around its base. However, some EIFS system installation manuals do specify a damp proof course as a membrane to form a barrier, if this is the case.
- Starter channel – Many EIFS system manuals specify a starter channel with weepholes, typically aluminium or PVC. Placed at the base of the wall cavity, these function as a cavity closer that enables adequate drainage to the exterior. However in practise, the bottom edge of the EIFS system are either unfinished (minimal to no render application) or is installed without a starter channel. In both cases, the edge foam insulation board can be seen upon close inspection.
- Damp proof course – installed at base behind EIFS to slab edge rebate to protect against moisture ingress.
- Expanding PU foam – foam is typically sprayed from a can and spread with a spatula to seal gaps between edges of EPS foam insulation boards prior to render application.
- Flashing or weather proof flashing tape – installed around window and door rebates and at top of EIFS systems.
- Corner angles – perforated aluminium or PVC corner angles or sometimes just additional re-enforcing fibreglass mesh is embedded in render at corners to improve strength and durability.
- Render Expansion joints – Different EIFS system manuals specify different maximum vertical or horizontal spacing's for expansion joints. Good practice appears to be to place expansion joints at weak points where potential cracking may occur such as in line with large windows and doors and between floor levels. Expansions joints are typically filled with flexible joint sealer and/or U-PVC control joint bead.

Some variations to the above systems offered by some EIFS system suppliers include:

- Pre-rendered Insulation board – Insulation boards supplied pre-rendered on exposed side to reduce onsite finishing rendering required.
- Insulation board with grooves moulded to rear surface – to improve moisture drainage.

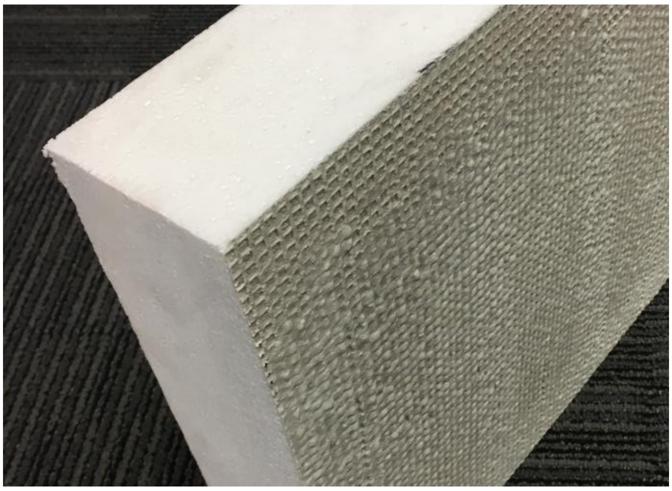


Figure 12. Example of pre-rendered EPS. Photo by CSIRO

Literature indicates that in Europe and USA, installation of EIFS directly to solid masonry substrates and to light weight framed construction with a solid substrate board such a plywood or cement sheet is much more common. For such installations the insulation board appears to be either glued with adhesive, mechanically fixed or a combination. However, this type of installation in Australia appears to be very uncommon.

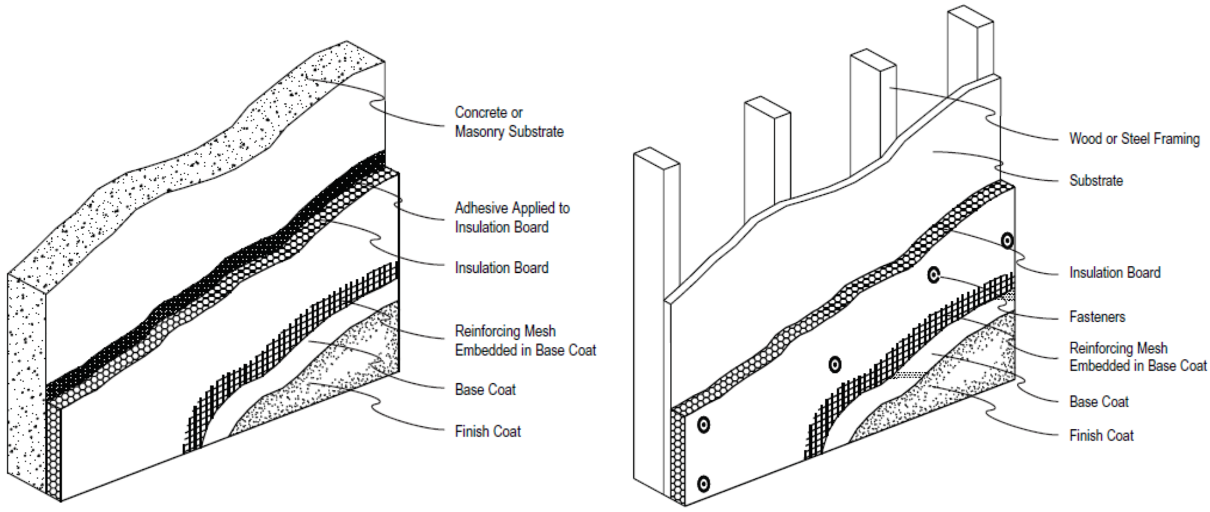


Figure 13. EIFS construction more typical in Europe and US (fixed to concrete, masonry or solid substrate board)[5]

In Europe and the US, two typical types of EIFS installation are described as[16]:

- Face-Sealed EIFS - System relies completely on the render, insulation and flashing preventing moisture ingress and has no provisions for drainage of moisture behind the EIFS. These systems have been prone to result in moisture damage such as mould, wood decay and corrosion, which has been a major issue in New Zealand and known as “leaky building syndrome”[22].
- Drainable EIFS – System includes a drainage gap between the rear face of the insulation board and the supporting substrate or frame. The gap can be created via grooves in the insulation board, plastic/EPS spacers or concertinaed material etc. This provides significantly improved moisture control.

In Europe and the USA, the building codes and EIFS industry codes of practice[23, 24] specifically address facade fire performance of EIFS and specify protection measures which include accreditation via façade fire testing, minimum requirements for render thickness and inclusion of fire resistant cavity barriers embedded within EPS and cavities above windows or between levels.

In Australia the NCC does not specifically address EIFS façade fire performance except for generalised DTS requirements such as non-combustible external walls for Type A and B construction and generalised performance-based requirements. In Australia the presence and application of an EIFS industry code of practice[25] is very limited (and possibly no longer active) and it does not directly address requirements to achieve a suitable level of fire performance. Australian EIFS system installation manuals reviewed generally do not specify any requirements to achieve suitable vertical façade fire spread performance (such as fire-resistant barriers above windows or between levels). However, it is noted that many manufacturers state that they use EPS-FR rather than non-fire retarded EPS. In some cases, they specify requirements where a given bushfire attack level (BAL) or external wall fire resistance level is specified.

3.2.2 ISP

Steel faced ISP are made with rolled tongue and groove inter-locking slip joints along edges.

The Insulation Panel Council of Australasia (IPCA) code of practice[26] states minimum requirements for ISP installation however this is focused on large internal rooms/compartments (cool rooms) within Class 7 and 8 buildings and rooms < 20m^2 internal to other building classes. The installation requirements appear to be based on minimum fixing requirements needed for EPS-FR core steel faced ISP to achieve Group 1 when tested to AS/ISO 9705. It does not provide installation requirements specifically for external wall façade applications. The IPCA code of practice includes the following key installation requirements:

- All ISP cores where EPS is used are to be 100% EPS-FR, fully cured to ensure EPS-FR is free of residual pentane or other blowing agents and must be minimum SL grade.
- ISP must have steel skins.
- Other ISP with other core types are permitted provided they have achieved Group 1 when tested to AS/ISO 9705 or FM approval 4880 class 1 classification.
- Walls and ceilings are to be fully supported by steel fixings to surrounding building construction, which is typically steel portal frame construction. Sandwich panel compartments are not to be self-supporting.
- All fixings, rivets and channels and capping are to be steel. Aluminium or plastic rivets, fixings, channels or capping is not permitted.
- ISP slip joints and channels and capping are to be sealed with a suitable mastic sealant.
- Steel channels and capping of at least the same thickness as the ISP facing are to be installed at every corner joint formed by wall to floor, wall to wall and wall to ceiling.
- 4 mm diameter steel rivets to be applied at 300 mm centres along all slip joints, steel channels and capping.

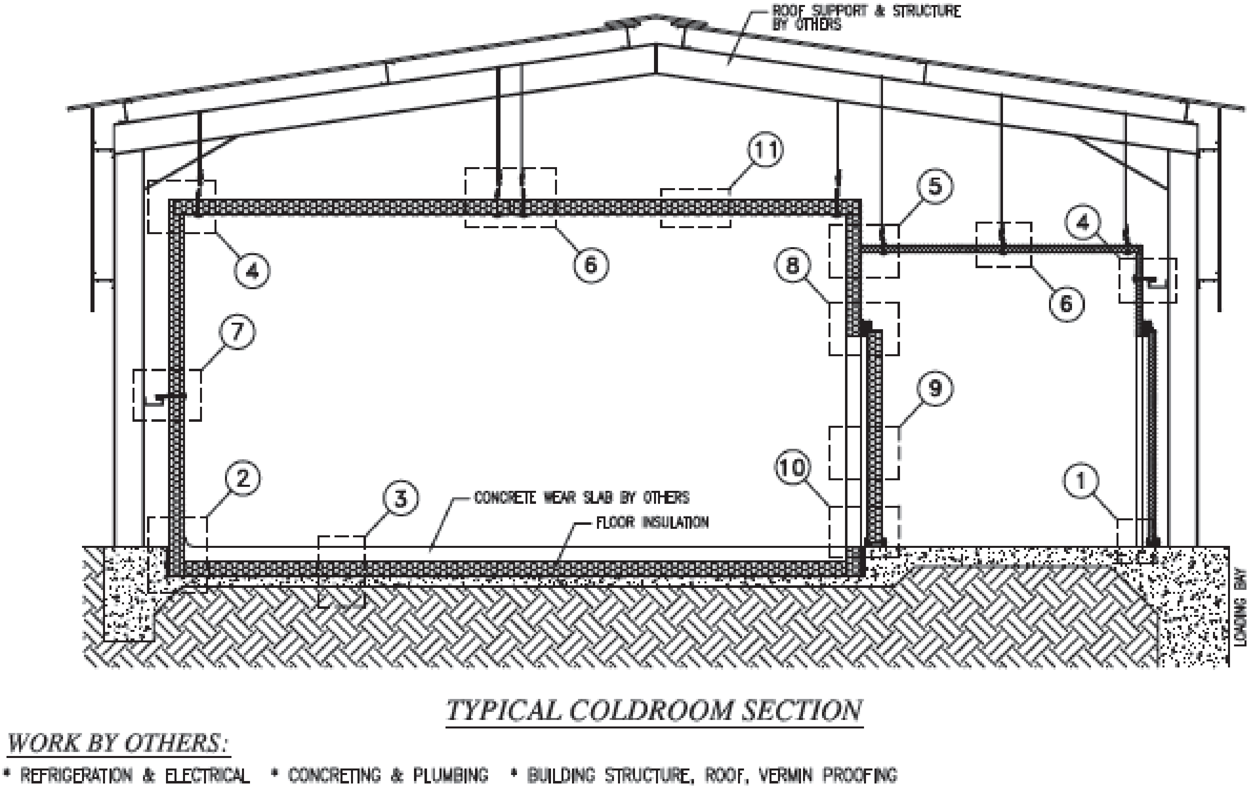


Figure 14. Example of IPCA code of practice installation of ISP for internal cool room[26].

Typical installation of ISP for external walls (and roofs) have been drawn from the review of manufacturer installation manuals for ISP external wall systems. Key elements of ISP installation to external walls are:

- ISP are typically supported at their rear by a steel frame structure. Spacing between steel supports can typically be large (1.5-2.5 m depending on system).
- ISP can be installed in either horizontal or vertical panel orientation. Horizontal is likely to be the more popular panel orientation due to ease of installation and alignment of hidden screw fixing at slip joints with vertical steel support elements.
- Most systems have a support channel which supports the ISP at its base along the slab edge and creates a drainage gap between the base of the ISP and the slab edge.
- A damp course membrane or flashing is typically placed at the base of the wall between the ISP support channel and the slab edge.
- Polyethylene or EPDM strips are typically placed at contact points between the rear of the panel and the supporting steel frame. Plastic packer/spacers may also be used as required.
- The ISP's are typically screw fastened to the steel frame however the exact details of the screw fastening vary with specific ISP systems.
    - Many use a hidden screw which screws through the recessed edge of the slip joint through the outer and inner ISP facings and into every steel purlin. The screw head is then hidden when the next panel is slipped over this joint.
    - Some simply specify exposed/visible screws through the outer and inner ISP facings into the steel frame.
    - Some use joint clips/channels/top hats which fasten against the outside and inside ISP facings at the edges of the ISP which are then screwed into the steel frame.
    - Some appear to require only screw fixing from the rear of the supporting steel frame into the rear face of the ISP.
    - Most appear to use a combination of at least some of the above fixing methods.
- Sealant is generally applied along slip joints.
- Metal capping channels, angles and top hats are typically required to be installed along the tops of walls systems, external faces of wall corners and between panel joints on non-slip joint edges. Some manufactures specify these to be steel and others permit aluminium.
- ISP installation manuals vary regarding requirements for riveting or screw fixing to ISP external facings along slip joints, capping, angles and top hats. Some require fixings as close as 300 mm centres and others do not specify any fixings along slip joints at all. Some permit aluminium fixings.

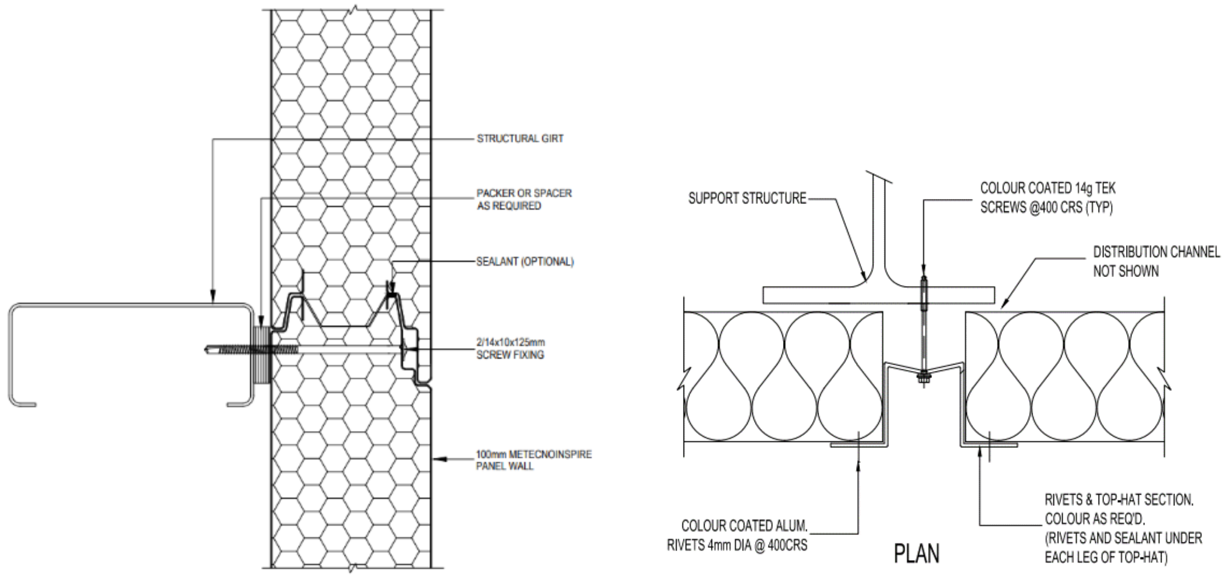


Figure 15. Hidden screw fixing through outer and inner facings at slip joint (left) (Image from Bondor Metecnoinspire[27]) and top hat fixings at non-slip joint edges (right) (image from Bondor Equitilt[28])

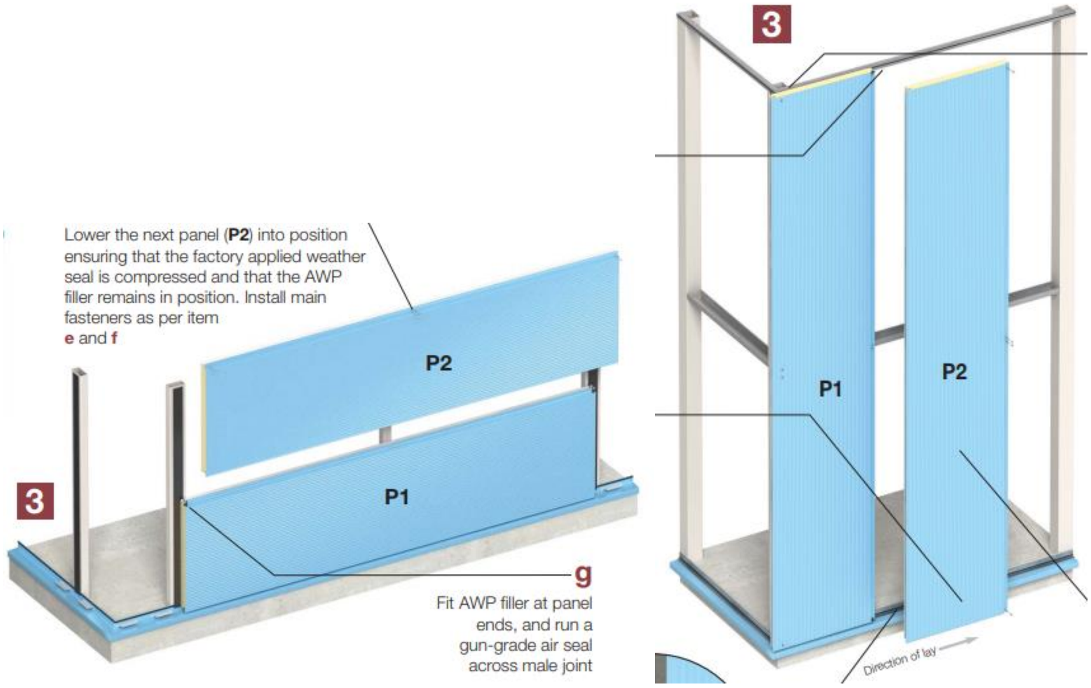


Figure 16. ISP panels installed horizontally or vertically (from Kingspan external wall system installation guide[29])

3.3 Identification on existing buildings[30]

3.3.1 EIFS

EIFS systems installed to existing buildings can be identified onsite using the following non-destructive methods.[31]

- Rebates of 50 mm depth or more around windows and doors and over hanging edges above awnings or balconies can provide a preliminary indication that EIFS may be installed. However further inspection is required for confirmation.
- In comparison to a hard-surfaced wall (such as brick or cement) a hollow sound is made when tapping on the surface of EIFS by hand or using a tool or golf ball. The returned energy from a golf ball bounced from wall surfaces at hard to reach locations will typically be significantly reduced for EIFS with thin render compared to render over solid substrate. All these effects are more pronounced when the render is thin. Where a thick render of 6-10 mm or more has been applied it can become difficult to differentiate between rendered EIFS and rendered cement sheet via the above effects.
- The wall cladding slightly gives when you apply pressure to the surface with your hands. This is more pronounced for thin render layers and for thick render it can become difficult to differentiate between rendered EIFS and rendered cement sheet.
- Typically, the bottom of an EIFS wall cladding at surrounding ground level or surrounding roof surfaces is stopped short to provide a clearance gap to reduce moisture ingress. The bottom edge of this gap is often not finished with render. Visual inspection of this location can be difficult, but a finger can be used to feel/probe the bottom edge, or a mirror or mobile phone camera can be used to view the hidden layers. In some cases, a plastic or metal channel with weep holes may be installed along the bottom edge.

Figure 17. Example of bottom edge of EIFS exposed (photos by CSIRO)

- Inspect the wall for any damaged render which reveals the core materials behind. Often damage occurs at areas prone to impact such as corners or at grade areas where there is movement of occupants or materials such as bins. Damage also occurs at stress concentration areas such as panel joints at edges of windows and doors.

Figure 18. Damage to EIFS system with inappropriately thin render systems and poor maintenance (example photo extracted from ARP building audit report).

- Inspection or removal of service penetrations can enable visual inspection of core and cavity materials. Appropriately licenced trades can remove power points or other services that may penetrate the render.
- External wall attachments can cause EIFS surfaces to compress causing a deflection at the wall's surface. A simple instrument like a pencil or a straight edge can be used to visibly inspect the deflection at the location of the attachment (see Figure 19)

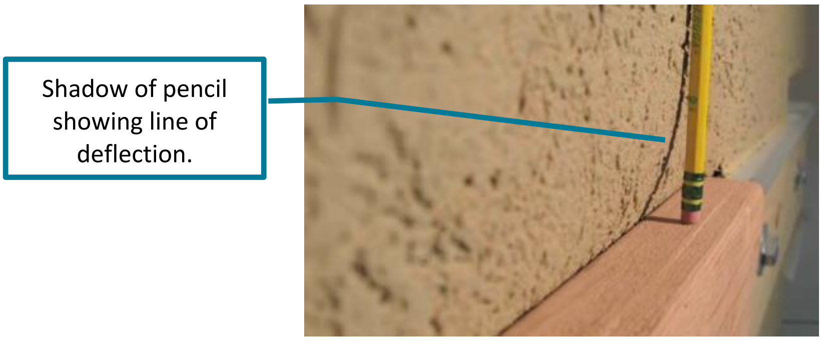


Figure 19 – Straight edge of pencil highlights deflection of EIFS system at location of the wall attachment (photo from Gramico, 2016)

- When there is a transition into a new façade wall cladding system; such as EIFS to brickwork, if there is flashing present this can sometimes be moved to reveal the core materials.
- Penetrating the render with a sharp pointy metal probe can determine if the render has a solid (concrete/masonry) substrate or if it is EPS with minimal damage. Once the probe is removed EPS may be able to be visually confirmed. However thick renders can be difficult to penetrate and initially appear like compressed cement sheet. Aerated concrete and QT may also be penetrated with a probe but provide more mechanical resistance than EPS.

Figure 20. Probe used to penetrate EPS EIFS system render. In this case the render was ~ 5-6 mm thick and felt like compressed cement sheet based on external knocking only and was initially difficult to penetrate with probe. Thinner renders will have a different feel and be easily penetrated. (Photos by CSIRO)

Usually with careful inspection the above methods can verify the presence of EIFS. However, if this is not possible, then cutting/coring through the rendered surface provides a destructive inspection method.

3.3.2 ISP

ISP installed as external walls to existing buildings can be identified via the following methods:

- The panels will have a metal external and internal facing but when tapped will have a dulled insulated sound rather than a metallic ringing sound.
- The panels will visually have long run lengths of several meters with widths of ~ 900-1200 mm.
- They will have regularly spaced slip joints.
- Exterior surface may be flat or profiled.
- Screw/bolt fixings to supporting structure may be visible from exterior or not visible from exterior if the fixings are hidden within slip joints. Visual inspection of fixings is best made from location where the interior side of the panels is exposed such as within plant rooms etc.
- In some cases, manufacturer product details may be printed on rear of panels.
- Look for any areas of unfinished capping, penetrations or damage to steel skin where the core material can be visually confirmed.
- A magnet can be used to determine if skins, capping/channels and fixing brackets etc. are steel or aluminium (where these are coated and raw metal surfaces are not easily visually inspected).
- If the above methods fail then cutting or coring through the metal skin provides a destructive inspection method but this should be done with caution so as not to create sparks, over heat or ignite the core and with appropriate portable fire extinguishers or water suppression on hand.

Figure 21. Example of ISP with PIR core as external wall on multi-storey building viewed from exterior and interior within plantroom. (Photos by CSIRO)

3.4 Site construction quality and maintenance of installed system

The fire behaviour of EIFS and ISP can be strongly influenced by construction quality and maintenance.

3.4.1 EIFS

In Australia, EIFS systems available appear to be predominantly intended for application to Class 1 (detached, single occupancy dwellings) or Type C construction. This is based on review of CodeMark certificates. There are minimal fire safety requirements for this class of building. However there appears to have been a spill over of these types of systems being applied to Type A and B, multi storey construction which requires non-combustible external walls as DTS. It appears likely that many systems used have not had appropriate performance-based assessment or certification for this intended use. The end result is that systems designed and intended for Type C construction are likely to have been applied to Type A or B construction without any additional design changes or measures to achieve a suitable level of fire performance. The above is indicated by ARP building audits, review of EIFS systems marketed in Australia and review of existing CodeMark certificates (see Section 3.5.1).

A recent Norwegian experimental and field investigation of durability of EIFS[32] concludes "*systems generally perform satisfactorily if thoroughly designed and carefully erected. However, according to the survey, the systems are not very robust. Even minor errors in design techniques and/or craftsmanship can lead to rendering defects*". Although installation practices and systems are different in Europe (more likely to have solid or board substrate) compared to Australia, the Norwegian study lists the following construction quality and maintenance issues which are likely to be relevant to Australia:

- Defects associated with flashings against precipitation - Defective forming and/or execution of cornice, horizontal, parapet, and window sill flashings are repeated items.
- Incorrect reinforcement mesh – includes insufficient mesh or placement of mesh within render too close to insulation or too close to exposed surface. Insufficient mesh at cut outs and stress points.
- Insufficient thickness of render.
- Faulty render mix or undesirable application and setting conditions
- Shrinkage and temperature movements within render – can be exacerbated by deficient expansion joints.
- Incorrect end laps against adjoining structures – insufficient transitions to balconies and other façade structures can lead to cracking and moisture ingress.
- Moisture from the ground (or other horizontal surfaces and bottom of EIFS). EIFS finished too close to these surfaces can draw up moisture via capillary action.
- Faulty anchorage of the system – insufficient or incorrectly located fixings can lead to cracking of render.
- Micro-organism growth in/on the render - Biological growth is not unusual in damp and mild climates. Render with large quantities of organic additives have proved to be highly vulnerable as growth can cause swelling of such render.
- Variations in render thickness over the insulation boards. -Large divergences in render thickness can cause cracking.
- Vibrations, movements in the substructure, settling - Vibrations and other movements in the wall behind can easily cause cracking of the render.
- Incorrect choice of paint or incorrect cleaning prior to painting - Moisture accumulation behind the paint layer or deficient cleaning prior to painting can cause defects in the form of flaking.
- Insufficient impact resistance - Ground-level zones readily accessible to the public may be especially vulnerable to hard body impacts and to perforation.
- Leaching of pigment - Heavy water exposure may cause leaching of pigment if the rendering is insufficiently composed.
- Mould growth behind the EIFS - Mould growth is often caused by the accumulation of moisture in organic materials in the primary wall. This can particularly be a problem if a moisture drainage cavity is not provided behind the EIFS.

The following other potential construction and maintenance issues for EIFS have been identified from review of manufacturers installation manuals for systems available in Australia [17, 20] [33]:

- For Pre-coated panels – the use of incorrect render that is not the recommended render by the proprietor can cause delamination of the pre-coated render layer.
- Overdriving mechanical fasteners that damage the surface of the EPS – this can create weak points for adhesion of render.
- EIFS is glued directly on to the substrate (stud wall or solid substrate) without mechanical fixings.
- Insufficient application of fire rated sealant to wall penetrations.
- Panels not rendered within 7-10 days of being installed. A dusty film develops on the EPS surface due to the oxidation of the surface with exposure to sun’s UV rays. This film needs to be removed with a wire brush or stiff broom, then washed/hosed down with water and 100% dry prior to any rendering to begin. This ensures adhesion of the render to the surface of the insulation board.
- Raw polystyrene insulation board must not be exposed any moisture or water and must be dry prior to rendering.
- EIFS must have a ground clearance of 100mm or greater above paving or soil to avoid ground the potential for water capillary action.

As installation of the render system is typically the most labour intensive and costly part of the EIFS installation process it is more likely prone to on-site poor workmanship such as insufficient render thickness. Once the render is installed, it can be difficult to detect deficient application by visual inspection alone.

The items listed above describe the points of failure within an EIFS wall that compromise the quality. These qualities may directly or indirectly affect the fire safety properties of the system.

The surface of rendered rigid cellular foam is prone to getting surface damage. Unlike other external wall assemblies such as steel panels, cement sheet or Aluminium Composite Panels that have a hard-tactile surface, a regular maintenance of any damage as it occurs is required to preserve the rendered barrier.

EIFS has had some significant problems relating to water and mould intrusion in the past. There are numerous web pages, articles and journal papers which discuss this and some of the product installation guides also address this.

This appears to be a problem particularly in high humidity/rainfall areas and includes:

- EIFS was one of the problem claddings in the NZ leaky buildings crisis[34].
- Early EIFS used in USA and Europe from 1980s - 1990s[16] was typically "Face Sealed" (sealed around all edges with no cavity or weather proof membrane behind EIFS). These had some significant moisture related failures. In these areas they have more recently adopted "drainable" EIFS systems which have a drainage gap and weather proof membrane (sarking) behind the EIFS to address this problem.

Some key factors that contribute include:

- Cracks in render which can allow moisture in.
- Poor flashing or capping at tops of EIFS, around gutters, at windows and other moisture collection points.
- EIFS systems without suitable drainage gaps or sarking can result in moisture collecting behind EIFS causing rotting/corrosion of building structure, mould and moisture wicking into building interior.
- EIFS must typically be installed with a gap between the bottom of the EIFS and the surrounding ground level for two reasons ;1) to let any moisture drain away and 2) to prevent moisture wicking into EIFS from surrounding ground level via capillary action between EIFS material layers. If this is poorly constructed or disturbed by post construction landscaping/garden beds etc. this can cause problems.
- Numerous other possible problems with poor construction controls as discussed above can contribute.

3.4.2 ISP

Compared to EIFS, the encasement system for ISPs is factory manufactured rather than constructed layer by layer onsite. This has the effect of significantly reducing onsite build quality issues that can be detrimental to the encasement of the combustible insulation component. However the following possible construction and maintenance issues have been identified primarily from review of manufacturers' installation manuals and the IPCA *Code of Practice* document[26].

- Panels are to be kept dry and stored off the ground when kept onsite, with slight incline to allow for adequate drainage and ventilation of panel stack. Ingress of water inside the ISP core can lead to reduced thermal performance and possible delamination of skins.
- Onsite substitution of approved panel system for a different (poorer performing) system.
- Use of aluminium fixings, channels, flashing and capping.
- Insufficient fixing of panels to supporting structure with low number of fixings or fixings not "through bolted/screwed" through both facing but rear facing only.
- Slip joints not pressed together and sealed adequately.
- Panel facing joints/seams not riveted at required spacings with required (steel) rivet types.
- Exposed edges of cores not capped and flashed as required.

- Penetrations through ISP not suitable sealed and capped.
- Inappropriate “high temperature” services penetrations.
- Steel faced ISP are generally more resilient than EIFS to impact damage, but this can still occur with sufficient force or sharp objects (for example vehicle impacts or scrapes). When panels are damaged exposing core this requires suitable maintenance.

3.5 Certified or approved systems.

The following certification, appraisal or approval systems have been identified as having some relevance to EIFS and ISP systems in Australia. Some certification systems such as CodeMark cover a broad range of performance requirements (such as energy efficiency, weather proofing and structural performance) in addition to Fire performance. Other approval systems such as FM Approvals have specific focus on fire performance. The range of fire tests and acceptance criteria that each certification, appraisal or approval system relies upon varies as detailed below.

3.5.1 CODEMARK

The CodeMark Certification Scheme is a voluntary third-party building product certification scheme that provides certification for the use of products in specified circumstances in order to facilitate compliance with Volumes One and Two of the NCC. CodeMark issues a Certificate of Conformity for products, which is one of several options available for meeting the ‘evidence of suitability’ requirements of the NCC.

The ABCB maintains oversight of the scheme on behalf of the Commonwealth and all States and Territories. The Joint Accreditation System of Australia and New Zealand (JAS-ANZ) is responsible for both accrediting Certification Bodies and administration of the Scheme.

The CodeMark Certification Scheme has considerable criticism from the building consultant industry regarding the adequacy and application of CodeMark certificates in the wake of recent ACP fire incidents both in Australia and internationally. The Shergold-Weir report[35] states *“There have been criticisms of the CodeMark system. The BMF (Building Ministers Forum) has been aware of these issues for some time. Indeed it has already tasked the ABCB with making recommendations to address shortcomings with the CodeMark system*.”

The CodeMark Register of certificates of conformity is located at the following website:

http://www.jas-anz.org/our-directory/codemark-certified-organisations

This register was reviewed to identify all EIFS and ISP systems currently listed to have CodeMark certification. A detailed summary of the CodeMark certificate for each identified product is given in Appendix A . The review of CodeMark certificates was conducted by CSIRO in March 2019. Although this report has been further revised in response to stakeholder comments in August 2019, CSIRO review of CodeMark certificates was not updated at this date.

An aggregate summary of details addressed in identified CodeMark certificates for EIFS is given in Table 3 and for ISP in Table 4

Table 3. Aggregate Summary details addressed in identified CodeMark certificates for EIFS products

CodeMark Certificate details			**Number of products**	**Percentage of total number of products**
Total number of Products/Systems identified to have CodeMark certificates			17	-
Certificate Available		Yes	17	100%
		No	0	0%
Certificate Withdrawn*			2	12%
Certificate stated applicable Building Classification		Classes 2-9	9	53%
		Class 1 & 10	5	29%
		Not Specified	3	18%
Certificate stated applicable Building Type of Construction		Type A/B	1	6%
		Type C	5	29%
		Not Specified	12	71%
Certificate Addresses NCC Structural Provisions (Impact Resistance) (Performance Requirements and/or DtS)		Vol 1	12	71%
		Vol 2	17	100%
Certificate Addresses NCC Weatherproofing Provisions (Performance Requirements and/or DtS)		Vol 1	11	65%
		Vol 2	16	94%
Certificate Addresses NCC Energy/Thermal Provisions (Performance Requirements and/or DtS)		Vol 1	12	71%
		Vol 2	17	100%
Certificate addresses NCC Fire Safety Provisions	Combustibility Test (1530.1) Or assessment as suitable for use where non-combustible material is required	Y	0	0%
		Not Specified	17	100%
	NCC Clause C1.10 Internal wall and ceiling lining Material group number assessment/Test	Group 1	0	0%
		Group 2	0	0%
		Not specified	17	100%
	AS 1530.3 test	Stated	11	65%
		Not Specified	6	35%
	Bushfire AS 1530.8 (part 1 or part 2 tests)	BAL 29	12	71%
		BAL 40	1	6%
		BAL FZ	1	6%
		Not Specified	3	18%
	FRL Tests	≤60/60/60	1	6%
		90/90/90	0	0%
		180/180/180	0	0%
		Not specified	16	94%
	External Façade Fire Spread Test (AS 5113 EW test or similar)	completed	0	0%
		Not specified	17	100%

* Note – The following certificates were withdrawn as stated in a VBA Industry alert dated 20 February 2019 but copies had been obtained by CSIRO prior to withdrawal. The date of withdrawal does not appear to be published on the JAS-NZ website.

- CM40138 Dulux Exsulite TM Thermal Façade non-cavity system (Date of Issue – 06/02/15 & Date of Expiry – 06/02/18)
- CM40082 Dulux Exsulite TM Kooltherm Façade System (Date Certified – 23/02/2018 & Date of Expiry – 16/11/2019) – Note this was the only product certificate that included BAL-FZ and FRL tests (but included a layer of fire-resistant plasterboard and phenolic foam insulation) and stated applicability to Type A and B construction.

Table 4. Aggregate Summary details addressed in identified CodeMark certificates for ISP products

CodeMark Certificate details			**Number of products**	**Percentage of total number of products**
Total number of products			12	
Certificate Available		Yes	10	
		No	2	
Certificate stated applicable Building Classification		Classes 2-9	8	80%
		Class 1 & 10	2	20%
		Not Specified	0	0%
Certificate stated applicable Building Type of Construction		Type A/B	0	0%
		Type C	1	10%
		Not Specified	9	90%
Certificate Addresses NCC Structural Provisions (Impact Resistance) (Performance Requirements and/or DtS)		Vol 1	8	80%
		Vol 2	10	100%
Certificate Addresses NCC Weatherproofing Provisions (Performance Requirements and/or DtS)		Vol 1	5	50%
		Vol 2	7	70%
Certificate Addresses NCC Energy/Thermal Provisions (Performance Requirements and/or DtS)		Vol 1	8	80%
		Vol 2	10	100%
Certificate addresses NCC Fire Safety Provisions	Combustibility Test (1530.1) Or assessment as suitable for use where non-combustible material is required	Stated	2	20%
		Not Specified	8	80%
	NCC Clause C1.10 Internal wall and ceiling lining Material group number assessment/Test	Group 1	4	40%
		Group 2	3	30%
		Not specified	3	30%
	AS 1530.3 test	Stated	10	100%
		Not Specified	0	0%
	Bushfire AS 1530.8 (part 1 or part 2 tests)	BAL 29	0	0%
		BAL 40	8	80%
		BAL FR	2	20%
	FRL Tests	Not specified	7	70%
		≤60/60/60	3	30%
		90/90/90	2	20%
		180/180/180	1	10%
	External Façade Fire Spread Test (AS 5113 EW test or similar)	Completed*	1	10%
		Not specified	9	90%

* Note – Only one product (MetecnoPanel) certificate referenced an AS 5113 EW test report. However, results of this test or acceptable performance related to external wall fire spread were not stated on the CodeMark Certificate.

Some common issues identified with the CodeMark certificates reviewed are:

- The certificates typically only address a subset of the NCC Requirements relevant to a particular product but not all of the relevant requirements. For example, for EIFS it is common that energy efficiency, weather proofing and structural performance are addressed but not fire safety. It is possible that building practitioners could mistakenly rely upon a certificate of conformance for a product as evidence of compliance against fires safety requirements when this is not actually addressed by the certificate.

- Many certificates do not clearly state the specific building classes and Type of construction (A, B or C) to which the certificate is applicable and limited to. It is possible that this may result in practitioners relying upon certificates of conformance for use on building types that the product is not clearly demonstrated as being suitable for.
- For EIFS Systems, none of the certificates address external wall façade fire spread or the use of a combustible material where non-combustible materials are required. Therefore, their use should be limited to Type C construction but in many cases this is not clearly stated. Given that the primary use of EIFS and ISP systems in external walls, the lack of direct assessment of suitable external wall fire spread performance combined with no clear restriction to Type C Construction is a significant omission.
- For EIFS systems, 11/17 certificates refer to AS 1530.3 test results. This test is not relevant for the specific product and end use application as an external walls system. It is not required by the NCC for external wall systems and does not suitably predict façade fire performance (see Section 9.1.3).
- For EIFS Systems, 14/17 certificates address building in bushfire prone area requirements. This appears to be the main area of fire testing applied to EIFS in terms NCC fire safety requirements.
- For EIFS Systems, only 1/17 certificates address FRL (and BAL-FZ) requirements. However, this system includes a fire-resistant plasterboard layer component combined with phenolic foam insulation. The certificate for this product has recently been withdrawn.
- It is noted that where fire test reports are referenced for EIFS, they generally state that a thick (≥ 5 mm) render layer was included in the tested specimen.
- For ISP systems, most certificates are applicable to Class 2-9, but 9/10 certificates do not clearly state the applicable Type of construction (A B or C).
- For ISP, most certificates (7/10) address material group number requirements. Therefore, certificates have focused on internal wall and ceiling lining requirements rather than external wall combustibility or fire spread performance for Type A or B construction.

A VBA Media release dated 20 March 2019 urges practitioners to take care when relying upon CodeMark Certificates of Conformity clarifying an awareness of Validity and limitations is required[36].

3.5.2 BUILDING REGULATIONS ADVISORY COMMITTEE (BRAC)

The Building Regulations Advisory Committee (BRAC) is a committee of building industry representatives that has two roles set out in the *Building Act 1993*. It provides advice to the Minister for Planning on draft building regulations and also accredits building products, construction methods and components or systems connected with building work. BRAC is an independent committee which is not managed by VBA however VBA provides secretariat support. BRAC Accreditation only applies to building products or systems that demonstrate compliance on a performance basis and does not apply to building products or systems that comply with DTS provisions of the NCC. An application for BRAC accreditation of a product may require submitting relevant test and other design performance evidence. BRAC may require a building product appraisal to be undertaken by a third party. BRAC then reviews and assesses all evidence submitted on a committee basis when deciding on an accreditation application.

A successful application will be issued a certificate of building product accreditation that is proof that a product meets the performance requirements of the *Building Regulations 2018* (the Regulations) or the Building Code of Australia (BCA). Once a product is accredited, there is no need to prove its suitability each time building work requires a building permit. It is mandatory for a building surveyor to accept the product, method, design, component or system if the use complies with the accreditation.

The BRAC website (https://www.vba.vic.gov.au/building/building-product-accreditation) states that BRAC accreditation is intended for products only for use in Victoria and if the product is to be used in number of states then national certification via CodeMark may be more suitable. However, NCC Vol 1 2019 Clause A5.2 (b) states that current certificate of accreditation issued by a state or territory accreditation authority forms acceptable evidence of suitability and NCC does not limit applicability to the state or territory of origin.

The BRAC Register of accredited products accessed by CSIRO on 14/08/2019 on the BRAC website is a PDF list which provides product names, applicant names, certificate numbers, and date of issue. The BRAC certificates of accreditation for the listed products do not appear to be publicly accessible via the VBA BRAC website. The only way that CSIRO could view BRAC certificates of accreditation for specific products was via suppliers' websites (where they may or may not make these available). CSIRO did not search for all BRAC certificates but did view a selection of them.

In summary:

- The BRAC Register of accredited products currently lists 42 products.
- Based on the product names, approximately 16 of these products appear to be either EIFS or other products incorporating foam polymer insulation.
- Based on CSIRO review of a limited selection of BRAC certificates for EIFS, these generally appear to be limited to class 1 and 10 building use and may only address specific NCC performance requirements (e.g. relating to weatherproofing, thermal or structural performance) but may not fully address all performance requirements that may be relevant to the products' potential end use (such as reaction to fire and fire resistance performance).
- The last product added to the BRAC register of accreditation was an EPS EIFS product with accreditation issued 19/12/2018.

3.5.3 CSIRO APPRAISALS

CSIRO previously operated an appraisals system which was intended to publish appraisal documents for building products providing a technical opinion of the product's compliance with specific building code requirements based upon test reports and other technical information.

The CSIRO appraisals scheme was officially closed on 31st December 2009. All appraisals had an expiry set on (or before) that date. CSIRO wrote to each Appraisal holder, advising that the Appraisal had expired, and the information contained within them should not be relied upon.

It is noted that the expired CSIRO appraisals relating to cladding/external wall systems often addressed limited subsets of building code requirements such as structure performance or energy efficiency but typically did not fully address all building code requirements (including external fire spread and combustibility) that may have been relevant to such at the time. NCC requirements have changed significantly since expiry of this system and CSIRO appraisals should no longer be used or relied upon.

Several Product manufacturers still show CSIRO Appraisal information on their product websites however this information is no longer valid and should not be relied upon.

3.5.4 BRANZ APPRAISALS

BRANZ operates an appraisals system which is intended to publish independent evaluations for building products and systems to be deemed fit for purpose and Building Code compliant. In addition to New Zealand application, BRANZ Appraisals address building products for use in Australia against Australian Building code requirements. It is unclear to what extent the Australian building industry currently applies this system as evidence of suitability of NCC compliance, however it may be possible that BRANZ appraisals are applied under Evidence of Suitability NCC 2019 Vol 1 clause A5.2(f).

As of 13/08/2019 the BRANZ website lists 421 Appraisals, the majority of these do not relate to EIFS or ISP. It is beyond the scope of this literature review to search for or review any BRANZ appraisals relating to EIFS or ISP.

The BRANZ Appraisal website is:

https://www.branz.co.nz/cms_display.php?st=1&sn=328&pg=18388

3.5.5 BRE GLOBAL - BR 135/BS8414 CLASSIFIED EXTERNAL CLADDING SYSTEMS

BS 8414 and BR 135 are the full-scale façade fire test method and acceptance criteria applicable in the UK. See Sections 0, 8.3.4 and 9.5.2.

Following the fire that occurred at Grenfell Tower in June 2017, BRE Global were asked by Ministry for Housing, Communities and Local Government (MHCLG) to publish a summary of external cladding systems tested to BS 8414 by BRE which achieved BR 135 classifications.

Where permission to publish details of a cladding system has been granted by the customer, BRE have published a table that summarises the generic components included within these cladding systems. This list is available at the following website.

https://www.bre.co.uk/regulatory-testing

When reviewed by CSIRO on 27/03/2018 the BRE list included the following

- 55 product systems in total were listed.
- 21 of the listed systems were described as rain screen systems (such as ACP with insulation behind etc.) and were not considered relevant to EIFS or ISP.
- 1 system was an ISP. It had a PIR core.
- EIFS systems were typically labelled by the generic cladding type name of “ETICS” or “rendered system”.
- 26 systems were confirmed to be EIFS with EPS insulation. All these systems included mineral wool fire breaks/cavity barriers.
- All the remaining 8 EIFS systems were identified to have mineral wool insulation with no EPS.
- No EIFS with other foamed polymer insulation types such as PIR, PUR or phenolic foam were listed.

3.5.6 FM APPROVALS

FM Global is an American mutual insurance company with offices worldwide, that specializes in loss prevention services primarily to large corporations in the Highly Protected Risk property insurance market sector (see Section 8.5.1). A strategy for FM Global is providing building product testing and approvals schemes through a section of the company called FM Approvals. FM Global provides testing and approvals of external wall product systems for their insurance purposes applying standards and test methods developed by FM Global including FM 4880 and FM 4881. See Sections 8.5.1, 9.4 and 9.5.5.

FM Global publishes a summary list of companies who have achieved FM 4881 external wall approval for external wall product systems. This is available at:

https://www.approvalguide.com/CC_host/pages/public/custom/FM/login.cfm

CSIRO accessed this website on 25/03/2019 and determined the following summary information.

Seventy-five companies are listed with FM 4881 Approval. However, each company can have several different products listed as having been approved. In some cases, it appears that similar approved products listed under different, but related company names (e.g. Kingspan company name in different countries) may in fact be the same product. However, in CSIRO’s review of the website we have simply treated each product listed as a separate product. All products listed appeared to be ISP. No FM 4881 approved EIFS product systems appeared to be listed. The following table provides an aggregate summary of the details of listed products.

Table 5. Aggregate Summary of FM 4881 External wall system approved products list

Product details		**No. of products**	**%**
Total number of products listed		386	-
Height restriction	Maximum 9.1m (30 feet)	17	4%
	Maximum 15.2m (50 feet)	5	1%
	No Height Restriction	364	94%
ISP Core type	PIR	276	72%
	mineral wool	53	14%
	EPS	0	0%
	EPS in phenolic matrix	6	2%
	phenolic foam	0	0%
	PUR	35	9%
	Number other/unknown core types*	16	4%

* Note – Other/Unknown core types appeared to mainly include glass wool cores, cores that were a mixture of PIR and mineral wool and other core product names that could not be readily identified as one of the other listed core material categories. Other/Unknown core types did not refer to any EPS material content.

4 Component material information and fire properties[37, 38]

This section provides a review of fire properties for the various different insulation core materials. Fire properties for foamed polymer core materials are compared and ranked from poorest to best. EPS is determined to have the poorest performance. Properties of render and steel sheet encasement are reviewed.

4.1 Rigid Foam Polymer Insulation Materials

4.1.1 EXPANDED POLYSTYRENE (EPS) [38-42]

The most commonly used insulation material for both EIFS and ISP systems is expanded polystyrene (EPS), typically with a fire-retardant additive (see next section). EPS is a closed-cell rigid foam insulation made from polystyrene. Polystyrene is an aromatic (ring shaped molecule) hydrocarbon polymer made from the monomer styrene. Styrene is a colourless, oily liquid hydrocarbon with the chemical formula $C_6H_5CH{=}CH_2$. It is produced from petrochemicals, benzene and ethylene.

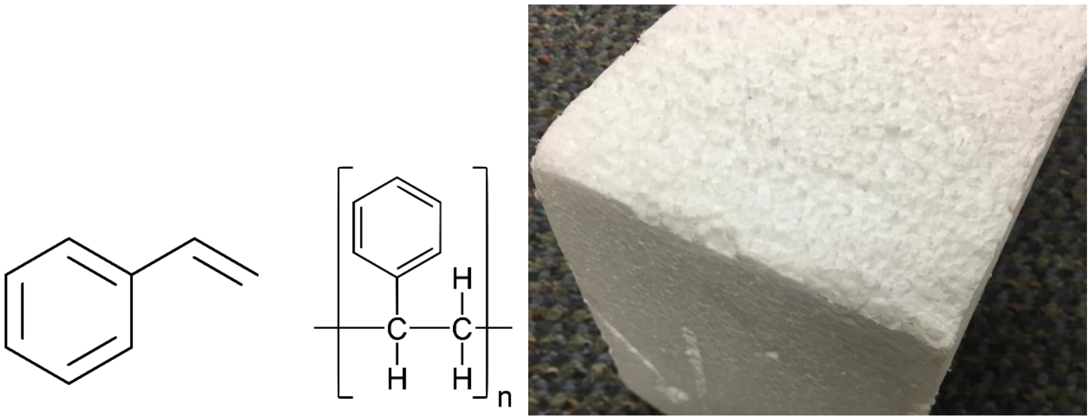


Figure 22. Molecular diagram for styrene monomer (left) and polystyrene (centre). EPS photo (right) by CSIRO.

The polymerisation process produces translucent spherical beads of polystyrene, about the size of sugar granules. During this process a low boiling point hydrocarbon, usually pentane gas, is added to the material to assist expansion during subsequent processing. EPS is then produced in the following 3 stage process[11, 39]:

1. Pre-expansion - Upon contact with steam the pre-foaming agent found within the polystyrene beads (usually a hydrocarbon such as pentane) starts to boil and the beads are expanded to between 40 to 50 times their original volume. The beads are agitated during this process, to prevent fusing together.
2. Conditioning - After expansion the beads undergo a maturing period in order to reach an equilibrium temperature and pressure.
3. Moulding - The beads are placed within a mould and again reheated with steam. The pre-foamed beads expand further to completely fill the mould cavity and fuse together. When moulded, nearly all the volume of the EPS (~98% depending on final density grade of EPS) is air.

"Non-Foamed" polystyrene can also be used in solid plastic form typically for items such as CD cases etc.

Polystyrene is typically clear/transparent in solid plastic polymer form and white coloured in foam insulation form although it is possible to add colouring.

EPS is manufactured in seven grades/classes to Australian Standard AS 1366 Part 3-1992. Grade/Class of EPS is characterised by the following physical properties:

Table 6. EPS Grades/Classes in accordance with AS 1366 Part 3[41]

Physical Property	Unit	Class						Test Method
		L	SL	S	M	H	VH	
Nominal Density (kg/m3)		11	13.5	16	19	24	28	N/a
Compressive stress at 10% deformation (min)	kPa	50	70	85	105	135	165	AS2498.3
Cross-breaking strength (min)	kPa	95	135	165	200	260	320	AS2498.4
Rate of water vapour transmission (max) measured parallel to rise at 23°C	g/m^{2}s	710	630	580	520	460	400	AS2498.5
Dimensional stability of length, width, thickness (max) at 70°C, dry condition 7 days	%	1.0	1.0	1.0	1.0	1.0	1.0	AS2498.6
Thermal resistance (min) at a mean temperature of 25°C (50mm sample)	M^{2}K/W	1	1.13	1.17	1.20	1.25	1.28	AS2464.5 or AS2464.6
Flame propagation characteristics: - median flame duration; max - eighth value; max - median volume retained; - eighth value; min.	S % %	2 3 15 12	2 3 18 15	2 3 22 19	2 3 30 27	2 3 40 37	2 3 50 47	AS2122.1
Nominal Density (kg/m^2) Guide only – physical properties above may be achieved by EPS of other densities	kg/m^2	11	13.5	16	19	24	28	

AS 2122.1 is a small Bunsen burner flame propagation test conducted on a small vertically orientated specimen 255 x 20 x 20 mm in size. This test does not reasonably predict EPS end use fire hazard, particularly for scenarios of higher heat exposure. It is noted that compliance with the small flame propagation test specified by AS 1366 Part 3 appears to be an indicator that EPS has fire retardant additive and may be referred to as EPS-FR.

Raw un-encapsulated EPS typically has the following high temperature and flammability properties:

- EPS is a thermoplastic material.
- EPS has a glass transition temperature of ~ 80-100 °C. At this temperature it begins to soften and contract/shrink away from the heat source due to breakdown of the expanded cellular structure.
- Small flames will ignite EPS (non-FR) readily.
- EPS melting point is ~ 210-250 °C at which point it will become fully liquid.
- Onset degradation temperature = 325 Degradation range 325-425 °C.
- Transfer ignition temperature = 360 °C (370 °C FR).
- Non-piloted self-ignition temperature = 450 °C.

EPS without fire retardant can be prone to ignition from small localised ignition sources and will readily ignite when exposed to flame impingement over a significant area or radiant heat exposure > 10 kW/m^2.

EPS is a thermoplastic material that starts to soften and shrink/contract from the heat source at approximately 100 °C (or 80 °C for prolonged periods of exposure). This softening and contraction away from a heat source can act to delay or prevent ignition from small localised heat sources but can have adverse effects on integrity of rendered surfaces and typically leads to rapid failure in fire resistance tests.

EPS melting point is ~ 210-250 °C at which point it will become fully liquid. This can result in molten material flowing and causing downward fire spread or formation of pool fires at horizontal surfaces.

Molten EPS decomposes into the monomer styrene and carbon monoxide and at higher temperature may further decompose into gaseous oxides of carbon, water and soot. Sustained Ignition of gaseous combustible products will largely depend on temperature of the surface, duration of exposure and ventilation conditions at the combustion zone.

The mass-based net heat of combustion of EPS is 40MJ/kg. By comparison this is significantly greater than the mass-based net heat of combustion for timber (average 18.6MJ/kg). However due to its low density, EPS has a volume based calorific value of 440 MJ/m^3 – 1,200 MJ/m^3 that is 8 - 20 times less than softwood timber (9,300 MJ/m^3 assuming a density of 500 kg/m^3). However, time to ignite EPS with heat fluxes > 10 kW/m^2 is significantly more rapid than that of timber and the Heat Release Rate per unit area (HRRPUA) of EPS tends to be approximately three times greater than soft timber but burns for a shorter period (due to the increased rate of burning).

Protection of exposed EPS by encasement with protective coverings can act to delay or prevent ignition and where the encapsulation system maintains its integrity under fire conditions it can act to minimise spread of fire by molten material and reduce ventilation to the EPS within the encapsulated cavity such that fire spread and melting can be limited to not spread beyond the immediately fire expose/heat effected area. However protective covering such as render, which rely on EPS to provide a stable substrate will typically be compromised once the EPS begins to soften or melt. In the case of metal faced ISP the panel rigidity will be lost once the EPS begins to soften or melt and the performance of the system then becomes heavily dependent on the metal types used, fixing details and joint fastening/riveting details as these can act to minimise panel collapse, openings to interior of panels or outflow of molten EPS from within the panels[42].

4.1.2 EXPANDED POLYSTYRENE WITH FIRE RETARDANT[26, 38, 43] (EPS-FR)

The most preferred fire-retardant additive for EPS (and XPS) is Hexabromocyclododecane (HBCD); a brominated aliphatic hydrocarbon with a bromine content of 74.7%. EPS-FR typically has a HBCD content of ~ 0.5-0.7%. Adding HBCB to EPS significantly improves is resistance to ignition when exposed to small localised ignition sources with no or low levels of radiant heat exposure. When tested in accordance with AS1530.3 or AS1366.3 (small flame test) EPS-FR has demonstrated significantly improved performance compared to non-FR EPS. However, this improved performance is likely to be a combination of the brominated fire-retardant supressing ignition for a long enough period for the EPS to melt or shrink away from the heat source.

EPS-FR reduces the risk of small accidental ignition sources such as electrical sparks, cigarettes or small flames. However, it appears that when EPS-FR is exposed to higher heat flux levels or flame immersion over significant areas the thermal degradation of the EPS is not significantly altered and the effectiveness of the HBCD is depleted resulting in EPS-FR burning in a similar manner and with a similar HRR as for non-fire retarded EPS.

HBCD have also been used in solid plastic, carpets, upholstery and other textiles to achieve flame resistant properties.[44]

HBCB has been identified to be toxic to reproduction and there is some concern regarding its ongoing harm and persistence in the environment. The Australian Government Department of Health National Industrial Chemicals Notification and Assessment Scheme (NICNAS) completed a risk assessment of HBCD as a Priority Existing Chemical in 2012[45, 46]. Key outcomes of this were:

1. The greatest risks are to the environment and workers handling HBCD, thus both need to be managed.
2. Manufacturers and importers of HBCD and flame retarded articles should move away from the import and use of HBCD chemical, and articles containing the chemical, in applications where safer alternatives and technologies are commercially available.
3. Recommended hazard classification of HBCD as follows:
    a. Toxic to reproduction, Category 3, with the following risk phrases:
        i. R63 Possible risk of harm to the unborn child (Toxic to reproduction, Category 3).
        ii. R64 May cause harm to breastfed babies.

In Europe there have been moves to phase out or reduce HBCD. On May 2013 the Stockholm Convention on Persistent Organic Pollutants (POPs) decided to include HBCD in the Convention’s Annex A for elimination, with specific exemptions for expanded and extruded polystyrene in buildings needed to give countries time to phase-in safer substitutes. Japan was the first country to implement a ban on the import and production of HBCD effective in May 2014[43].

4.1.3 EXTRUDED POLYSTYRENE (XPS)[47, 48]

XPS (sometimes referred to as Styrofoam) is also a closed cell rigid insulation material that is made from the polystyrene resin but is manufactured differently from EPS. Polystyrene beads, additives and a blowing agent (CO_2, CO_2/ethanol or HFC) are fed through an extruder. The process combines and melts the mixture to form a viscous plastic fluid that is continuously forced through a die that helps expand the liquid into foam. Unlike EPS, the blowing agent remains in the foam for the lifetime of the material. In comparison to EPS, XPS has a regular, more compact cellular structure giving it a smooth, dust fee appearance. The main differences between EPS and XPS are its improved resistance to moisture and increased compressive strength. The improved resistance to moisture can also improve thermal resistance over time compared to EPS in applications where the material may be exposed to water. XPS is more resistant to damage in freezing conditions where moisture may penetrate EPS, then freeze thereby damaging the cell structure. XPS reaction to fire and material fire properties are like that of EPS although as XPS typically has a higher density than EPS the fuel load per unit volume is increased.

XPS insulation panels are typically used in areas prone to condensation such as for below grade waterproofing or roof system applications. In Europe and USA, XPS is sometimes used for the bottom of the EIFS (900mm within grade level) where exposure to water/snow can occur. XPS can have a natural white colour but commonly has colouring added so that XPS is available in colours such as green, yellow, orange and blue dependant on manufacturer.

AS 1366.4 specifies the required physical properties for XPS. This includes the AS2122.1 small flame test with the following requirements:

- Median flame duration (max) = 1.5 s.
- Eighth value (max) = 2.5 s.
- Median mass retained (min) = 70%.
- Eighth value (min) = 60%.

4.1.4 POLYURETHANE FOAM (PUR)[49-51]

Polyurethane is a generic term covering a wide range of different material formulations based on reacting diisocyanate with a polyol. A polyol is an alcohol with more than two reactive hydroxyl (OH) groups per molecule. Diisocyanates are a chemical group containing Nitrogen, Carbon and Oxygen. Polyether Polyol and Methylene diphenyl diisocyanate (MDI) is used to make rigid polyurethane foam. Rigid polyurethane foam is a thermoset material. Some other forms of polyurethane including some types of flexible polyurethane foam used for furniture can have a thermoplastic melting behaviour.

Polyurethane rigid foam is composed of a highly cross-linked polymeric structure with closed cells formed by adding a blowing agent. Polyurethane foams do not melt in a fire but burn to produce pyrolysis gases, dense smoke and some char. The ease of ignition and rate of burning of polyurethane foams is significantly influenced by the type and concentration of fire retardants present in the foam mix. PUR Foam without fire retardant is very easily ignited by small flame sources.

The most common type of fire-retardant additives used in rigid PUR are phosphorus containing materials (aliphatic chlorophosphates, aliphatic phosphates and aliphatic phosphonates).

Rigid PUR typically does not form a significant stable protective char layer in the same manner as PIR does.

Rigid PUR foam typically has a light brown/tan natural colour but may be available with other colourings such as green.

The benefit of rigid PUR is that it typically has an improved thermal resistance compared to that of EPS or XPS.

AS 1366.1 specifies the required physical properties for PUR. This includes the AS2122.1 small flame test with the following requirements:

- Median flame duration (max) = 8 s.
- Eighth value (max) = 12 s.
- Median mass retained (min) = 55%.
- Eighth value (min) = 50%.

4.1.5 POLY-ISOCYANURATE (PIR)[37, 49, 51]

PIR chemistry uses similar starting materials to PUR and it is manufactured in a similar way. The key differences from PUR are:

- A higher proportion of MDI is used, and,
- A polyester-derived polyol is used instead of a polyether polyol.

The resulting chemical structure is a heavily cross-linked isocyanate ring structure which is significantly different to PUR. This changed structure can result in marginally inferior physical/surface properties compared to PUR but a significant improvement in the ability to form a protective char layer when exposed to fire.

PIR foams behave similarly to fire-retarded PUR foams in the early stages of a fire but once the char formation occurs (at ~ 300 °C) the char layer protects the unburnt polymer behind from heat and can significantly restrict further fire growth and the spread of the fire. The char formed from PIR boards can be brittle and crack easily. Some improvement using glass fibre re-forcing mixed within the PIR can be gained but this does not appear to be commonly adopted.

The colour of PIR is typically orange.

PIR/PUR typically has a recommended long-term maximum working temperature of 90-150 °C.

AS 1366.2 specifies the required physical properties for PIR. This includes the AS2122.1 small flame test with the following requirements:

- Median flame duration (max) = 1 s.
- Eighth value (max) = 1.5 s.
- Median mass retained (min) = 80%.
- Eighth value (min) = 75%.

4.1.6 PHENOLIC FOAM (PF) [51, 52]

Phenolic foam insulation is made by combining phenol-formaldehyde resin with an acid catalyst and blowing/foaming agents such as pentane. The foam typically requires oven curing under pressure.

High quality phenolic foam contains at least 90% closed cell structure, however poor manufacturing can result in higher portion of open cell structure which can degrade thermal performance.

Phenolic foam is a thermoset material which has a high intrinsic fire performance with higher ignition temperature and critical heat flux for ignition, and a lower heat of combustion compared to PIR, PUR and EPS. It also has the benefit of typically having a lower thermal conductivity compared to PIR, PUR and EPS. A disadvantage of Phenolic foam is that it is typically more expensive to produce.

Phenolic foam insulation was manufactured and sold into the North American market in the 1980s and early 1990s, mainly as roofing insulation. However, problems with high moisture absorption potential and residual acid present in the foam allegedly resulted in significant corrosion issues. This issue may have been addressed to some degree in recent times by control on materials and closed cell structure.

Phenolic foam has a natural cured colour of brown/pink. But phenolic foam insulation boards appear to be available in a range of colours from different manufacturers including pink, yellow and blue.

Phenolic foam typically has a recommended maximum working temperature of 180 °C.

Use of phenolic foam in EIFS or ISP appears to be very uncommon. It is more commonly used as an insulation board product in areas such as rain screen cavities etc.

4.1.7 COMPARISON OF MATERIAL AND FLAMABILITY PROPERTIES

Table 7 provides a summary and comparison of key material and flammability properties for EPS, EPS-FR, PUR, PIR and PF.

Many of these properties are likely to vary significantly with product density and product formulation (which can vary with different manufacturers for the same category of rigid foam insulation type). To address this variation, properties from multiple references have been quoted. However, the properties in Table 7 should be taken as generally indicative and not related directly to a specific manufacturer’s product.
It is noted that most manufacturers produce rigid foam polymer insulation in a range of densities to achieve different mechanical and thermal properties.

Table 7. Summary material properties for rigid foam polymer insulation from literature.

Material Property	EPS	EPS-FR	PUR	PIR	PF
Thermoplastic/thermoset	Thermoplastic[53]	Thermoplastic	Thermoset	Thermoset	Thermoset
Density (kg/m3)	11-28[41], 10-30[54]	Note 4	30-35[Note 3]	32[55]	38[55]
Thermal conductivity (W/m.K)	0.039-0.05[41], 0.036-0.046[54]	Note 4	0.027[56],	0.027[57], 0.022-0.028[55]	0.021–0.024[55]
Specific heat capacity (J/kg.K)	1500[54, 55]	Note 4	1500[54, 55]	1500[54, 55]	1500[54, 55]
Glass transition (softening) Temperature (°C)	80-100[54], 100[38]	80-100 °C	N/A	N/A	N/A
Melting temperature (°C)	~ 210-250 °, 240[55]	~ 210-250 °	N/A	N/A	N/A
Onset thermal degradation/pyrolysis temperature (°C)	~300[55]	325 Degradation range 325-425	~250-300[58]	~300-360[55]	~425[55]
Piloted (flash) ignition temperature (°C)	360[38], 345[51], 346[59]	370[38], 366-405[59]	285[51],310[59]	415[51], 445[59]	450[51], 430[59]
Non-piloted self-ignition temperature (°C)	450[38], 490[51], 491[59]	470[59]	500[51], 416[59]	510[51], 575[59]	490[51], 476-614[59]
CHF piloted (kW/m^2)	10-15[53], ~15-16 [Note 1] equivalent to ~6-10[55]	Note 4	13-15[53], 15[59]	10-15[55], 21[59]	20[53], ~22[55], 30[59]
Gross Heat of combustion (MJ/kg)	41.2-42.5[53]	39.7[53]	26.1–31.6[53]	26.3[53], 28.1-31.4[60]	21.6–27.4[53], 26.3-27.2[60]
Net Heat of combustion (MJ/kg)	35.6-40.8[53]	Note 4	23.2–28.0[53]	22.2-26.6[53]	20.2–26.2[53]
Reaction to fire Euro class range (EN13501-1)	E-F[61]	E-F[61]	D-E[61]	C-D[61]	B-C[61]

Note 1- CHF determined via cone calorimeter tests. This value refers to the heat flux at the surface before EPS starts shrinking. Actual heat flux at the bottom of the material where melted material accumulates is expected to be between 6 kW/m^2 and 10 kW kW/m^2.

Note 2 - values of thermal inertia for EPS are not calculated since the material shrinks and melts, becoming a thermally thin element, therefore, the thermal inertia having no physical meaning for this case.

Note 3 – Values taken from general review of manufacturer datasheets.

Note 4 – Values similar for EPS and EPS-FR

The following defines material property terms used in Table 7

Table 7. Summary material properties for rigid foam polymer insulation from literature.:

- Thermoplastic - substances that become soft or melt on heating and harden on cooling and can repeat these processes.
- Thermoset - polymer that is irreversibly hardened by curing from a soft solid or viscous liquid pre-polymer or resin. Curing is induced by heat or suitable radiation and may be promoted by high pressure or mixing with a catalyst. It results in chemical reactions that create extensive cross-linking between polymer chains to produce an infusible and insoluble polymer network. Conventional thermoset polymers cannot be melted and re-shaped after they are cured. When exposed to high heat they tend to char or ignite and burn without melting.
- Density – The mass per unit area of a material. Note that rigid foam polymer insulation material of a given type is generally produced in a range of densities for different applications and by different manufacturers.
- Thermal conductivity (k-value) - is the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area. K-value (W/m·K) is independent of material thickness.

  $$k = q\frac{L}{\Delta T}$$

  Where,
  L – Thickness of the specimen (m)
  T – Temperature (K)
  q – Heat flow rate (W/m2)
- Thermal Resistance (R-value) - is the temperature difference, at steady state, between two defined surfaces of a material that induces a unit heat flow rate through a unit area. R-value (K·m2/W) is dependent on material thickness. Thermal conductivity and thermal resistance are related via the following equation.

  $$R = \frac{\Delta T}{q} = \frac{L}{k}$$

- Specific heat capacity - is the amount of heat per unit mass of material required to raise the temperature of the material by one degree Celsius (J/kg.K).
- Glass Transition (softening) Temperature - is the temperature region where an amorphous polymer transitions from a hard, glassy material to a soft, rubbery material. Due to the blown air-filled structure of EPS this material shrinks/contracts away from heat source when it reaches its glass transition state.
- Melting Temperature - is the temperature at which a material changes state from solid to liquid.
- Thermal degradation/pyrolysis temperature – is the temperature at which a substance chemically decomposes, breaking bonds between molecules and polymer strands which typically results in char formation (for char forming materials) and production of combustible volatile gases. Thermal degradation occurs over a range of temperatures for a given material. This is typically measured using Thermal Gravimetric Analysis (TGA) as spike regions in a mass loss vs temperature graph. The onset temperature stated in the table above is selected to represent the lowest temperature where significant thermal decomposition begins to occur.
- Piloted (flash) ignition temperature – the lowest temperature at which vapours/pyrolysis product of a material will ignite in the presence of a pilot ignition source.
- Non-piloted self-ignition temperature - The lowest temperature at which vapours/pyrolysis product of a material ignite without the presence of a pilot ignition source. Also known as Auto-ignition temperature.
- CHF Piloted – is the Critical Heat Flux (CHF) or minimum radiant heat flux required to ignite a material in the presence of a pilot ignition source. Typically determined based on cone calorimeter testing or Fire Propagation Apparatus (FPA) ASTM E-2085 tests.
- Gross Heat of combustion - is the total energy released as heat when a unit mass of substance undergoes complete combustion with oxygen under standard conditions using an oxygen bomb

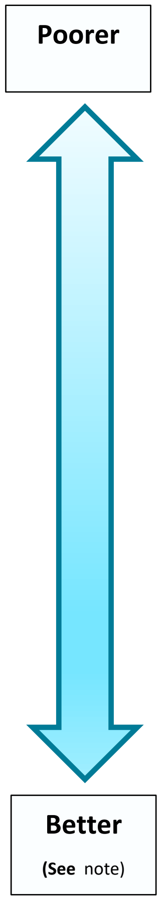
calorimeter. Because the bomb calorimeter cooling water temperature remains close to ambient during a test, all water vapour generated in the combustion process fully condenses. The measured gross heat of combustion therefore includes the heat released due to condensation of the water vapour back to a liquid state.

- Net Heat of combustion – is the heat released per unit mass of fuel burnt assuming that all water vapour remains in the gaseous state. It is equal to the gross heat of combustion measured in an oxygen bomb calorimeter minus the heat of vaporization of the water in the products of combustion which is a function of the moisture and hydrogen content of the fuel. Net heat of combustion is more relevant to real fire combustion, as in practice, combustion products are usually removed from the system at a temperature above the dew point. However, for real fires combustion is typically incomplete with unburnt material escaping complete combustion as solid residue, unburnt gasses or soot. Effective heat of combustion is a measure applied for such incomplete combustion and is determined via test methods such as the cone calorimeter.

Based on the above reaction to fire properties and behaviour this literature review has concluded that that the key foam polymer insulation materials can be ranked as follows in order of poorest to best fire performance. This ranking is based on the performance of the bare foam polymer materials and does not consider possible performance when paired with a specific EIFS or ISP encapsulation system.

Table 8. Foam polymer insulation types ranked from poorest to best based on reaction to fire behaviour

Foam polymer insulation type	Notable behaviour
EPS and XPS (non-fire retarded)	• Ease of ignition via small ignition sources • Melting behaviour • High heat of combustion
EPS-FR and XPS-FR	• Improved resistance to ignition via small ignition sources. • Ignites and burns with large ignition sources • Melting behaviour • High heat of combustion
PUR (fire retarded)	• Resistance to ignition via small ignition sources (due to fire retardants) • Ignites and burns with large ignition sources • Does not melt but does not form significant char layer • Medium heat of combustion
PIR	• Resistance to ignition via small ignition sources • Ignites and burns with large ignition sources but fire growth/spread can be limited by protective char • Does not melt, forms thick protective char layer (which can be brittle) • Lower heat of combustion
Phenolic foam	• Increased resistance to ignition via small ignition sources due to high ignition temperature and CHF intrinsic for phenolic material. • Ignites and burns with large ignition sources but fire growth/spread can be limited by protective char • Does not melt, forms protective char layer (which can be more brittle compared to PIR and prone to spalling) • Lowest heat of combustion



Note – "Better" in the context of the above table does not mean that the material is suitable for all applications or that it is the absolute best material available in terms of fire performance, it is simply a ranking of the materials considered based on the reaction to fire properties considered.

The scope of this literature review has not included any detailed review of toxic species production by the above materials during combustion. However the following is briefly identified[61, 62].

- The NCC does not regulate materials based on toxic species production.
- A good strategy to minimise the risk of toxic species production is to minimise the risk of:
  - Firstly – ignition of the material.
  - Secondly – burning rate and fire spread on material.
- In real fires, toxic species production will be strongly influenced by burning rate and ventilation conditions.
- Under poorly ventilated burning conditions, all the above insulation materials will be likely to produce CO in quantities as the most significant toxic species.
- PUR and PIR, due to containing nitrogen within their chemical structure, will produce HCN which is a significant toxic species.
- Bench scale toxicity tests which measure total amount of toxic species produced per mass of material burnt may not always be a reliable predictor of overall toxic hazard where products or systems show toxic fire hazard reduction due to reduced rates of burning.

4.1.8 OTHER INSULATION CORE MATERIALS

The following other types of insulation core materials exist.

Mineral wool insulation (MW)[63]

Mineral wool insulation (also referred to as stone wool) is made from stone or slag (industrial waste) that is spun into a fibre-like structure. Inorganic volcanic rock, typically basalt or dolomite, or slag (waste from metal refining) are the main components (typically 98%) of mineral wool. The remaining 2% organic content is generally a thermosetting urea-phenolic resin binder (an adhesive) and a little oil. Due to the low binder content mineral wool typically achieves a non-combustible result when tested to AS 1530.1.

Mineral wool has a higher density than rigid foam polymer insulation and is available in the range of 50-180 kg/m^3. With thermal conductivity in range of 0.033-0.045.

Mineral wool is used as a core for steel faced ISP and requires a thin adhesive layer to bond the skins.

Mineral wool has been used for EIFS cores (in entirety) or cavity fire barriers embedded within EIFS overseas, but this practice has not been common in Australia.

The fire performance of Mineral wool based EIFS and ISP is excellent in terms of fire resistance and fire spread due to it very low heat of combustion (non-combustible) and its resistance to thermal degradation and melting at elevated temperatures.

Mineral wool ISP's can be used to achieve required FRL's.

Mineral wool can be prone to moisture ingress. Manufacturers specify denser mineral wool for increased water repellence however inclusion of this material in external walls generally requires careful encapsulation or protective membranes.

Figure 23. Example of Mineral Wool Core ISP. Photo by CSIRO

Autoclaved Aerated Concrete (AAC)[64]

Autoclaved aerated concrete (AAC) is a lightweight, precast, foam concrete. It is manufactured using a mixture of cement, sand, lime and water and some materials which react to form hydrogen as a foaming agent when mixed. It is initially set into a mould and once the mixture is semi-solid, it is wire cut into required panel sizes before being cured further with high pressure steam in autoclaves. AAC was invented in the mid 1920's and has a long history of use in Australia as products such as Hebel. CSR Hebel is available in the following density, thickness and thermal conductivity ranges:

- Density range = 510-650 kg/m^3
- Thermal conductivity range = 0.12-0.16
- Thickness range = 75-300 mm

AAC is non-combustible and can be used to achieve required FRLs. Due to its higher thermal conductivity it needs to be applied at greater thicknesses compared to rigid foam polymer insulation to achieve the same thermal resistance.

AAC products such as Hebel can be installed and rendered like an EIFS system.

AAC is also used in some steel faced ISP systems. "Speedpanel" is an example of such a product in Australia. Speedpanel is mostly used for internal fire-resistant walls and shafts but can be used as an external wall system. 51 mm thick speed panel achieves an FRL of -/60/60 and 78 mm thick speed panel achieves an FRL of -/240/240.

Figure 24. typical AAC structure (left), Hebel block (centre), Typical AAC EIFS installation (right), all photos by CSIRO.

EPS in cement matrix composite[65]

EPS in a cement matrix composite is referred to as Conpolcrete. It is made from a blend of cement and EPS beads which in some cases may be sourced from recycled polystyrene. There are several manufacturers of this material around the world, but "QT EcoSeries" wall panels appear to be the most common version of this material in Australia at present.

The QT EcoSeries wall panel has the following physical properties:

- Density = 380 kg/m^2
- Thermal conductivity = 0.07 W/m.K

It is roughly estimated that QT panel may be approximately 1 part (15%) cement to 6 parts (85% EPS) by volume. This was estimated assuming the cement component has a density of 2,400 kg/m^3 and the EPS component has a density of 20 kg/m^3, the rough estimate appears to match visual appearance of QT.

QT panel appears to be mostly supplied at 50 mm thick panels 900 mm wide x 2250 mm long. It is installed as an EIFS system in a similar manner as EPS cavity EIFS systems, being mechanically nailed or screw fixed to cavity battens (steel or timber). The exterior surface is rendered with a proprietary polymer modified render and acrylic texture and paint.

QT panel has test reports for:

- FRLs of -/90/90 and -/120/90 (when installed as per tested systems, but not requiring fire rated plaster board etc.)
- AS 5113 Building to Building fire spread test at 80 kW/m^2
- AS 3837 prediction Material Group Number 1, average specific extinction area = 11.7 m^2/kg
- AS 1530.3 (Not a relevant test for External Walls).
    - Ignitability index (0-20) = 0.
    - Spread of flame index (0-10) = 0.
    - Heat evolved index (0-10) = 0.
    - Smoke developed index (0-10) = 0-1.

However, QT panel does not appear to have a publicly available AS 5113 External wall full scale façade fire spread test report (or similar international façade fire test).

During this literature review CSIRO obtained a sample of 50 mm Compolcrete panel having a density of ~380 kg/m^2 (not rendered, material generically identified, manufacturer not disclosed) and conducted a single AS 3837 cone calorimeter test with 50 kW/m^2 heat flux exposure as an indicative test to investigate fire behaviour. Note this test was not repeated on multiple replicates as required by the standard due to limited sample and therefore results are indicative only. The cone calorimeter test does not directly predict fire behaviour in real façade fire scenarios but does provide a point of comparison to standard EPS.

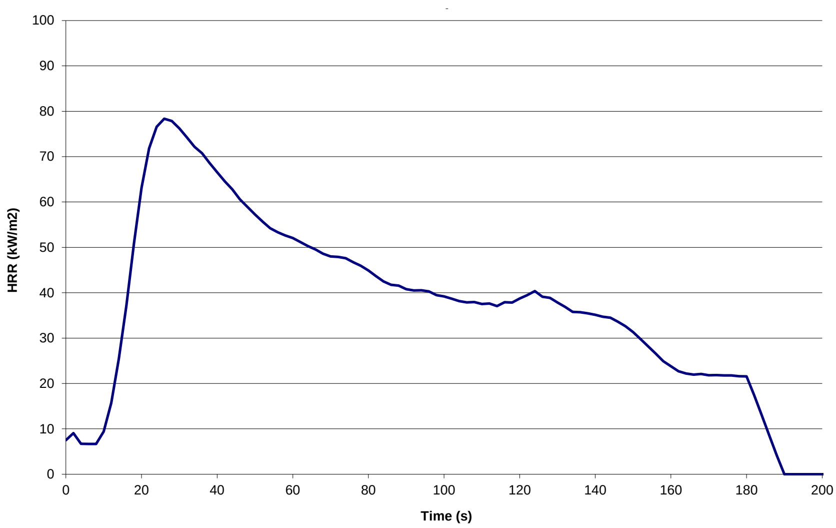


Figure 25. HRRPUA vs time for 50 mm Compolcrete tested to AS 3837 cone calorimeter at 50 kW/m^2

Figure 26. Compolcrete prior to cone calorimeter test (left) and after cone calorimeter test (right) – All photos by CSIRO

The exposed surface of the compolcrete ignited at 12 s and reached a peak HRRPUA of 78 kW/m^2 at 26 s. As the EPS within the top ~ 5-10 mm shrank or burnt away the cement matrix remained in place forming a protective insulating layer. This resulted in the HRRPUA steadily decreasing so that at 60 s there was only small surface flames and by 160 s all flaming had ceased. Inspection of the specimen after the test showed that only the EPS in the top ~ 5-10 mm layer had been consumed or melted and the EPS within the remainder of the specimen remained in its normal state. There was no melted EPS at the bottom of the specimen holder.

This indicates a significant improvement in reaction to fire behaviour compared to normal EPS (but does not directly predict full scale façade test behaviour).

AS 1530.1 test reports for Compolcrete materials have not been found publicly available. Based on the EPS content and ignition in the above cone calorimeter test is considered likely that typical Compolcrete products, if tested as a mixture of EPS and concrete components would be deemed combustible according to AS 1530.1 criteria.

EPS in Phenolic Resin Matrix (Syntactic)[66, 67]

This type of insulation foam is a composite of EPS beads within a phenolic resin matrix. When exposed to fire the EPS in the localised area of heating melts and burns and leaves behind a honeycomb matrix structure of phenolic resin which remains rigid (but brittle) and forms a protective char. The phenolic can degrade and burn at higher temperatures than EPS. This phenolic matrix acts as a protective insulating layer minimising melting or combustion of the EPS deeper within the panel and minimising fire spread and growth beyond the area of direct flame impingement. This type of insulation material is most commonly used as a core for steel faced ISP, but it could possibly also be used for EIFS.

Two examples of such products applied to ISP in Australia are:

- XFLAM
    - Density = 32 kg/m^2
    - Range of panel thickness = 50-250 mm
    - Thermal conductivity = 0.029-0.031 W/m·K
    - ISO 9705 – Group 1
    - 50 mm wall FRL = -/120/15
    - 100 mm wall FRL = -/120/30
    - 250 mm wall = -/120/90
    - FM 4881 external wall approval – unlimited height
- Polyphen
    - ISO 9705 – Group 1
    - Marketed as RMAX Thermaphen for application as EIFS

Figure 27. Example of EPS in phenolic resin matrix, Photo by CSIRO

EPS in graphite matrix

Insulation board applying EPS beads in a graphite matrix is available. The main purpose of this material appears to be increased thermal efficiency due to heat reflective properties of graphite. Based on the limited available information reviewed in this literature review this material does not appear to significantly change the reaction to fire properties from traditional EPS.

Exterior Board Materials as light weight substrate for rendered external wall.

As an alternative to EIFS, exterior board materials may be fixed to the exterior of light weight stud walls and rendered on the external surface. However, such board systems offer no significant insulation compared to rigid foam polymers and therefore would typically need to be combined with a stud wall cavity insulation and stud membrane/sarking (which may be combustible or non-combustible).

Examples of such external board materials are:

- Compressed Cement Sheet – Typically applied to external walls in thickness ranging from 6-12 mm. Complies with NCC Clause C1.9 for use where a non-combustible material is required. Compressed cement sheet will crack and spall when directly exposed to fire and therefore does not typically provide an FRL. Where an FRL is required systems typically include layers of fire-resistant plasterboard (or other materials) behind the external cement sheet.
- Magnesium Oxide Board – MgO board can achieve a non-combustible result when tested to AS 1530.1. Some suppliers such as “ResCom” state that FRL ranging from -/60/60 for 10 mm MgO board to -/120/120 for 18 mm MgO board can be achieved. However, it is noted this is dependent on other components within the tested system such as various types of mineral wool cavity insulation.

4.2 Render systems used in EIFS

The render system consists of a reinforced base coat, a system primer and finishing coat.

Cement based renders

Traditional cement render consists of plaster's sand, cement and lime and is typically mixed from raw materials onsite. Cement render consists of six parts clean sharp fine sand, one part cement, and one part lime. It is cheaper than acrylic polymer modified render but is only recommended for application to course solid surfaces such as brick, cement block or stone. It is not recommended for application to rigid foam polymer.

Cement based render applied to EIFS is prone to result in poor adhesion to and encapsulation of rigid foam polymer insulation. It is also prone to spalling and cracking during a fire exposure.

Polymer/Acrylic modified renders

Acrylic resins (or other polymer additives) are added to the traditional cement, lime and sand mix for enhanced water resistance, flexibility and adhesion.

Acrylic render is more expensive than traditional cement-based render and is only available in premixed bags or tubs. The acrylic polymer significantly increases the adhesion and elasticity of the render system making it suitable for application to smooth surfaces such as polymer foam and making it more resilient to cracking and delamination.

Most EIFS Systems require application of Acrylic/Polymer modified renders. There are a wide range of Acrylic/Polymer modified renders available and it was not possible for this literature review to determine the exact composition (% of combustible polymer additive) of commonly available acrylic renders. There was little literature found focusing on the reaction to fire performance of Acrylic/Polymer modified renders.

One study[68] indicated that:

- A polymer/cement mortar of less than 20 kg (polymer)/m^3 (total mortar mix) did not ignite or smoke when tested in the ISO 1182 combustibility test (an equivalent test method very similar to AS 1530.1). For the specimens tested, 20 kg/m^3 equates to a polymer : cement mass ratio of ~4%.
- However, ISO 1182 combustibility tests on (ethylenevinyl acetate copolymer (EVA) based render series with 100 kg/m3 polymer content showed a temperature change of more than 50°C when tested to ISO 1182. For the specimens tested, 100kg/m^3 corresponds to a polymer: cement mass ration of ~20%. A rise in temperature of more than 50°C indicates the material would be deemed combustible by AS 1530.1 criteria

Another study[69] indicated that polymer/cement mortars of less than 20 % polymer / cement ratio, when tested in the ISO 5660 cone calorimeter test, with a 50 kW/m^2 radiant heat exposure over 20 minutes, did not exceed a peak HRR of ~ 10 kW/m^2 or a total heat released of 8 MJ/m^2 (over 20 minutes) indicating that these materials did not undergo flaming ignition or significant combustion in response to this test exposure (which is less severe than an AS 1530.1 or ISO 1182 combustibility test).

This generalised testing and literature should not be used to deem specific render products as not combustible, instead AS 1530.1 testing should be undertaken to determine if a specific render product may be deemed not combustible.

Acrylic/Polymer modified render (correctly applied) will provide improved encapsulation of rigid foam polymers but may still be prone to spalling and cracking when exposed to fire.

Note, rendered EIFS can sometimes be stencilled or painted to give a brick work appearance.

Render paints

Render paints such as Dulux Texture Rock are water based, acrylic paint that creates a subtle sand grained finish. They can be applied on concrete, fibre cement and masonry construction walls and are not intended for rigid foamed polymer insulation. As the resulting coat is very thin it provides no thermal protection or encapsulation of polymer insulation in the event of a fire.

It is possible that render paints could possibly be substituted for specified render systems in cases of extremely poor installation.

4.3 Panel Skins used in ISP

The scope of this literature review focuses on steel faced ISP's which are the most prevalent form of ISP in Australia. Steel sheet of 0.4-0.7 mm thick with painted/colorbond type external coating is most typically used. It is noted that in the past some older ISP's may have used thicker steel facings up to ~ 1.2 mm thick.

However, there are several other types of materials that do get used for ISP's. Where the facing material has a thickness and strength that give the panel additional structural capability these are sometimes referred to as Structural Insulated Panels (SIP's). Other possible facing types (excluded from this literature review) include:

- Plywood.
- Oriented strand board.
- Concrete (filled with insulation).
- Gypsum/plaster board.
- Compressed cement sheet.
- Plastic sheeting.
- Aluminium.
- Cardboard.

5 Mechanics of fire spread on complete EIFS and ISP systems.

Based on review of reported fire incidents and existing research the following key types of initiating fire events and types of fire spread after the initiating event have been identified as applicable for a broad range of combustible external wall systems:

Key Initiating events

- Interior fire (pre flashover or post flashover) spreading to external wall system via external openings such as windows.
- Interior fire (pre flashover or post flashover) spreading to external wall system via internal openings including cavities and concealed spaces.
- Exterior fire directly adjacent the external wall system igniting the wall due to radiant heat and/or flame impingement (fire on balcony fuel load or fire at ground level such a garbage bin or vehicle fire).
- Exterior fire spatially separated from external wall system resulting in radiant heat and embers only (fire in adjacent building for example).
- Exterior Bushfire/Wildfire as source of radiant heat, flame impinged and/or ember attack.
- Cavity ignition source such as electrical penetration etc. These are typically smaller than the above events.

Key mechanisms of fire spread after initiating event

- Heat flux impacts cause degradation/separation of non-combustible external skin resulting on flame spread on internal core.
- Flame spread over the external surface of the wall.
- Flame spread within an internal vertical cavity /air gap.
- Fire spread to the interior of level above via openings such as windows causing secondary interior fires on levels above resulting in level to level fire spread.
- Fire spread to external balcony fuel loads on balcony levels above.
- Secondary external fires to lower (ground) levels arising from falling burning debris.

The key initiating fire may be simply summarised as one of three possible types of fires:

- Fires external to the building - Adjacent property fires, external ground fires, balcony fires or bushfires.
- Fires internal to the building - which either result in flames ejecting from openings (such as broken windows) and impinging directly on the external wall or fire spread from the building interior to external wall cavities.
- Smaller ignition sources within the wall cavity.

For buildings with non-combustible wall systems or combustible wall systems with acceptable fire performance (as determined by full-scale facade fire tests), external vertical fire spread can still possibly occur due to “leap frogging” (spread to interior level above via window openings or balcony to balcony spread if combustibles are stored on balconies). However, the risk of this occurrence is greatly reduced and if it does occur, the fire spread would be constrained and occur at a reduced rate.

In cases of poor performing combustible wall systems, the mechanisms listed above occur which act to enhance external fire spread resulting in rapid fire spread. Experimental research and approved systems tested overseas (BRE and FM global for example) reviewed in this literature review demonstrates that both

EIFS and ISP when designed and installed to include appropriate materials, construction, and fire protection measures (as indicated in Section 10) can perform suitably in terms of full-scale façade fire spread tests.

However, the experimental research and fire incidents reviewed also highlight that when these systems are not designed and installed to include appropriate materials, construction and fire protection measures, or they are damaged or poorly maintained, they can support rapid external fire spread.

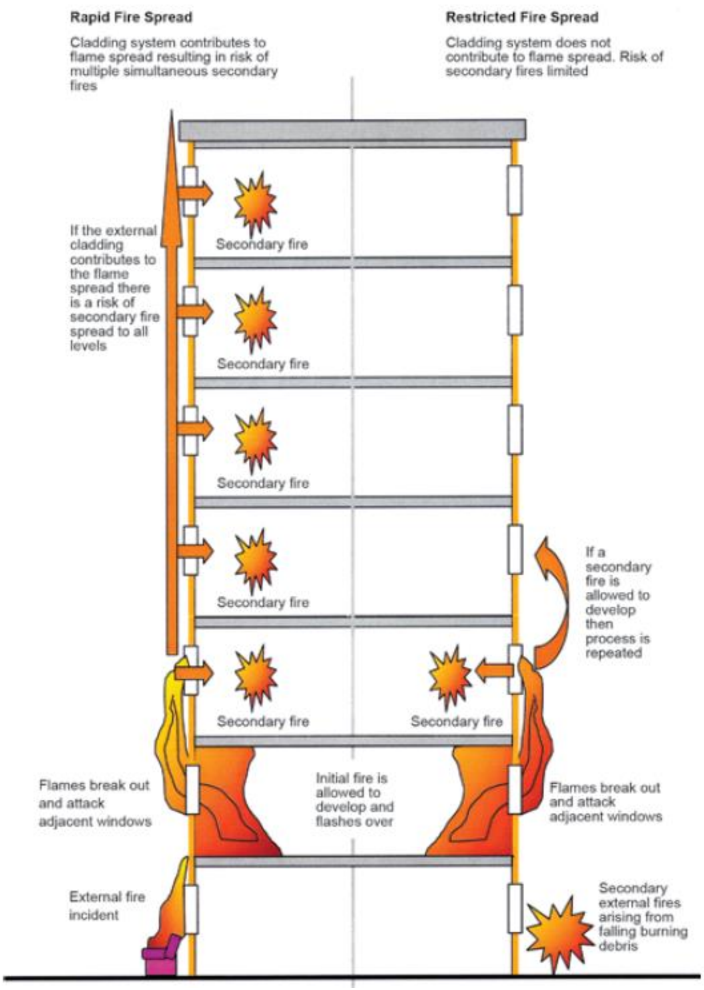


Figure 28. Mechanisms if combustible external wall fire spread [70]

5.1 EIFS Fire Spread Mechanisms

The following discussion of EIFS fire spread is focused on EPS as this is the main insulation material used in Australia.

If EIFS is poorly designed, not installed to include appropriate materials, construction and fire protection measures, or is poorly maintained it can exhibit the following mechanisms of fire spread (as demonstrated by fire incidents reviewed in Section 6 and experimental research reviewed in Section 10).

- EPS has a glass transition temperature of 100 °C. EPS located directly behind render which is exposed to radiant heat or flame impingement may reach this temperature easily. At this temperature the EPS will start to soften and shrink away from the heated render. This can weaken the supporting substrate of the render.

- When exposed to direct flame impingement the render can form cracks and openings. This failure mode can be enhanced if there is inadequate render thickness, the cement-based render does not incorporate polymer modified adhesive or there is poor reinforcement of the render.
- When exposed to direct flame impingement the render can explosively spall and fall away in chunks. This is particularly the case if poor sealing of the render has occurred or moisture ingress between the EPS and render has occurred resulting in moisture which expands to steam building up pressure within or behind the render layers.
- If the render has pre-existing holes/openings in it then the EPS will be directly exposed to flame and heat.
- EPS and EPS-FR will sustain ignition and surface burning when exposed to prolonged flame contact.
- EPS melts and will form molten pool fires on horizontal surfaces below EIFS. This can result in downward fire spread and can act to enhance the fire exposure to the EIFS above (in addition to the initiating fire source.
- Render can progressively fail vertically and horizontally resulting in vertical and horizontal fire spread.
- In the case of direct fixing or cavity fixing of EPS with a wall cavity directly behind the EPS it is possible that if fire penetrates into the cavity and there is sufficient ventilation available into the cavity then fire will spread rapidly within the cavity.

However as demonstrated by the list of BRE BS 8414 tested EIFS Systems (see Section 3.5.1) and experimental research reviewed in Section 10, EPS based EIFS can perform adequately in terms of vertical external fire spread but this is very dependent on correct design and installation typically including thick render layers, solid substrates and embedded cavity fire barriers. The feasibility of maintaining onsite quality control/inspection to ensure that these required measures are installed as required may be onerous.

5.2 ISP Fire Spread Mechanisms

Steel faced ISP's used as external walls utilise a broader range of core materials which will significantly influence mechanisms of fire spread.

- EPS will contract and then melt away and also undergo pyrolysis in areas of direct flame or high radiant heat exposure. This can result in flaming of gases released at seams, formation of molten EPS pool fires at horizontal surfaces and loss of panel rigidity if the area of melting is significant.
- Thermosetting cores will not melt and are less likely to lose panel rigidity but can still result in pyrolysis of the core material and flaming of gases released at seams (or where sufficient oxygen is available).

Steel faced ISP external wall mechanisms of fire spread will also be strongly influenced by fixing materials and details:

- If panels are not through bolted through both steel faces back to the supporting structure (e.g. only screwed to rear face) then there is a risk of delamination of the exposed face resulting in increased exposed area and burning rate of the combustible core, and a significant risk from falling debris.
- If panel edges and joints are flashed with aluminium channels or angles these may melt away under flame impingement exposing the combustible core. Melting temperature of aluminium is <600 °C
- Panel facing joints and seams not fixed with steel rivets at regular spacing's may open up resulting in partial facing delamination and exposure of the combustible core.
- Penetrations through ISP's must be appropriately sealed.

6 EIFS and ISP related fire incidents

This section reviews a selection of fire incidents involving either EIFS or ISP external wall assemblies. The identification of fire incidents presented is not exhaustive. It is likely that there are a number of fire incidents that have occurred that are not identified in this report. However, the selected incidents have been reviewed and presented here to establish common fire safety risk factors and behaviours related to these particular types of external wall systems.

Fire incident information has been extracted from:

- The book 'Fire Hazards of Exterior Wall Assemblies Containing Combustible Components' compiled by Nathan White (CSIRO) and Michael Delichatsios (University of Ulster)[3].
- News articles.
- Fire science/engineering journals and publications.
- Other reports from organisations found on the internet.

Most of the information available is in the form of news articles that typically do not include detailed information on materials present, fire behaviour or mechanisms of fire spread.

Both the MFB and CFA were requested to provide examples of any relevant local EIFS and ISP fire incidents. Both responded with references to a limited number of recent incidents and further information on these was gained from news articles. Both CFA and MFB indicated that their existing/previous systems for recording fire incident details does not capture the specifics of cladding so they were unable to easily extract and provide statistics or details on EIFS or ISP over past years.

It is noted that the majority of high-profile façade fire incidents found in news articles tend to be fires where ACP has been the main material involved. This may be due in part to the following:

- ACP tends to be applied to high rise buildings more than EIFS or ISP. This is likely to influence the total number of high-rise fire incidents for ACP being higher.
- 100 % PE ACP can result in fast and extensive vertical fire spread (which captures media attention).
- Fires in medium and low-rise buildings generally receive less media attention.
- EIFS is predominantly applied in low and medium rise buildings as EIFS involves relatively higher labour-intensive installation process compared to other forms of cladding.

For EIFS fire incidents within Australia, only EIFS fire incidents in Victoria have been identified and summarized. EIFS fire incidents in other states were not identified or focused upon, but it appears that major EIFS fire incidents resulting in extensive multistory fire spread or fatalities has not occurred in Australia. However, there are examples of such EIFS fire incidents internationally

Please Note - incidents marked in asterisks (*) are suspected to, but not confirmed to have EIFS Façade.

Refer to Appendix D for tables which summarise the fire incidents discussed below.

6.1 Fires involving exterior insulation and finish systems (EIFS)

6.1.1 LOCAL TO MELBOURNE, VICTORIA EIFS FIRE INCIDENTS

RENNISON ST BEAUMARIS[71], 2019

A fire appears to have started on the top storey of a double storey class 1 mansion around 9:15pm on 19th of February, 2019. Firefighters were battling the blaze against a strong sea breeze. Radiant heat and flying embers were threatening neighbouring properties however firefighters were able to contain the fire to the building of origin. The fire appears to have started due to an electrical fault near the interface of the roof structure and EPS walls. The roof structure was significantly consumed with some contribution for the EPS walls.

Figure 29. RENNISON ST BEAUMARIS during fire and post fire damage.[72]

161 PRINCES HWY DANDENONG, 2019

CFA informed that a fire incident had occurred started by cigarette on a balcony which spread to the EPS cladding on the building located at this address. No published media articles or other information was found.

Figure 30. Street elevations of 161 Princes Hwy Dandenong (google street view)

ANSTEY SQUARE APARTMENTS – 601 SYDNEY ROAD, BRUNSWICK[73], 2017

In March 2017, a fire developed on the cladding of a Class 2, apartment complex consisting of 105 apartments, retail tenancies and nine offices tenancies. The building is clad with a combination of EPS EIFS and aluminium composite cladding. The fire was believed to be started by a faulty air conditioned unit[74] on the balcony of one apartment and spread mainly via the EIFS to another apartment on the next level above . The Municipal Building Surveyor (City of Moreland) has ordered that additional sprinklers be installed on each balcony within 3 months and all flammable cladding to be removed around fire hydrants and hose reels within two months. The overall cost of repair is estimated to be $2 million.

Figure 31 - Photo of Anstey Square Complex after fire spread from one apartment to the next[74]

Figure 32. Anstey Square apartment street elevation (Google streetview)

16 HUGHENDEN ROAD, ST KILDA[72], 2017

On the 27th of September, 2017, fire fighters were called to a fire within the garage of a two-storey unit. The fire spread onto the cladding of the building consisting of expanded polystyrene. The fire was caused by a leaking gas bottle stored in the boot of the car. MFB spokesmen David Rankin stated that fire fighters did an aggressive internal attack on the fire wearing BA units, taking 30 minutes to control the blaze. The two storey unit fronts onto Hughenden Street and adjoins a block of three storey units, however the post incident damage was confined to the front of the two-storey unit only. One occupant suffered burns to face and hands. Based on news article descriptions and photos this appears to be a Class 1 townhouse (attached) building.

Figure 33 - Post fire damage to street frontage shown on two storey unit (Photos provided by MFB)

6.1.2 SERIES OF EIFS FIRES INCIDENTS IN GERMANY FROM 2001-2017[75]

Germany has had a significantly high use of EIFS over more than 50 years. Following a fire on 29/05/2012 in Frankfurt where fire rapidly spread over all six levels of an EIFS clad building (under construction at the time), German fire brigades began collection and publication of EIFS related fire incidents[76]. Ninety-six EIFS related fire incidents were collected in Germany from 2001 to 2017 with 12 fatalities and 173 injured persons. Especially remarkable is the fact that fatalities occurred not in the room or floor of fire origin but on floors above the fire origin. Fires in Berlin (2005) as in Cologne (2005) and in Duisburg (2016) spread over the façade to all other floors above. This is significant because fatalities occurred in compartments not related to the room of fire origin.

Table 9. Collected EIFS fire incidents in Germany 2012-2017

Location of Fire Origin	Quantity of Fires	Fatalities/ Injured	Loss of Property in € (Estimate)
Fire inside building	24	12/62	Several millions
Fire at building site	4	0/1	2.4 mio
Fire in front of building	68	0/65	2.2 mio
Fraction of fires in front of building where waste/waste containers were the first burning object	37	0/45	1.2 mio
Total	96	12/173	>10 mio

A selection of these fires with available information are listed below:

UNTERBIBERGER STRAßE, MUNICH, GERMANY, 2016 [75]

- On New Year's Eve night 2016, a fire initiated on a balcony and then quickly spread to the EIFS façade over two storeys and then into the roof truss.
- The insulation thickness was approximately 100mm thick.
- The fire caused four injuries however one person became a fatality a few days after the fire due to the injuries sustained during the incident. Estimated damage ~€200,000.

Figure 34. Unterbiberger Straße, Munich EIFS fire 31/12/2016. Note photo appears to be taken from opposite side of building from fire start area. [75]

DUISBURG, GERMANY, 2016 [75]

- On May 17, 2016, a fire was initiated by an overturned candle within a ground floor apartment. The fire spread to the EIFS via a ground floor window and then spread on the EIFS to the top of the building with fire spread into apartments on levels above via broken windows.
- The fire spread to the top of the building and the EIFS façade was completely burned.
- It was concluded that the EIFS façade system significantly enhanced fire spread.
- The building had no sprinkler protection.
- Three fatalities (one adult, three children) and 28 injuries were incurred.

Figure 35 – ETICS Façade fire at Apartment building in Duisburg[75]

DITZINGEN, GARTENSTR, GERMANY, 2012[75]

- Building of fire origin was building Class 3, special building less than 7 m height (as defined by MBO). Based on fire incident description it appeared to be a public assembly/hall type building.
- On the 31st of May, a fire started due to sparks or heat source from construction igniting the insulation material. Based on description it appears that the building may have been either under construction or renovation at time of fire.
- No details are provided on the EIFS except that no cavity fire barriers were installed. The degree to which the render was installed is not stated.
- The hall appears to have been destroyed and two adjacent houses damaged by heat.
- Significant smoke production resulted in evacuation of several nearby buildings and surrounding parts of the city/town centre being closed for several hours.
- No fatalities or injuries. Estimated damage ~ €600,000.

Figure 36. Ditzingen EIFS fire 31/05/2012[75]

FRANKFURT, GERMANY, 2012[77]

- On the 29th of the May, a fire started at the exterior ground level of a six storey apartment building which was under construction and clad in EPS EIFS. It is not clear to what degree the rendering of the EIFS had been completed (if at all) at the time of the incident.
- The building was Class 5 high rise (defined by HBO) which would require sprinkler protection, but it appears that sprinklers were not operational at time of fire.
- The EIFS included ~ 220 mm thick EPS and mineral wool cavity fire barriers.
- It is not clear from report and photo if fire started as a vehicle fire or if it started within insulation materials stored at base of construction (and subsequently spread to and destroyed adjacent parked vehicle).
- The fire rapidly spread to the top of the building and horizontally over a substantial area of building exterior with fire damage to interior of building at all levels prior to fire brigade suppression. A large amount of smoke production was noted in the incident report.
- Cavity fire barriers were destroyed over a large area.
- No fatalities or injuries but damage estimated to be ~€1.5 Million.

Figure 37. Frankfurt EIFS fire 29/05/2012[77]

FRANKFURT, GERMANY, 2010[77]

- On the 20th of March, a rubbish container/bin fire at the external base of the EIFS facade of a seven-storey residential building resulted in fire spread to the top of the building.
- Building class: G (defined by older version of HBO). EPS Insulation layer thickness ~ 60 mm.
- It is not clarified if sprinklers were installed and functioning within this building. It is not clarified if cavity fire barriers were installed within EIFS.
- The fire brigade had to rescue several people using rescue equipment.
- No Fatalities, 21 injuries and estimated damage of €500,000.

Figure 38. Frankfurt EIFS fire 20/03/2010[77]

AACHEN, CLEMONTSTRAßE, GERMANY, 2009[75]

- On the 22nd of May, a fire was reported to have started due to works being conducted on the roof.
- Four storey apartment building clad with EPS EIFS. Details of EIFS not reported.
- Details of sprinklers not reported but building height would not require sprinklers.
- Fire rapidly spread on EIFS with some fire spread into apartments.
- One resident was rescued from apartment by acquaintances before the arrival of firefighters, and before fire rendered apartment untenable. Based on photo there was significant smoke production.
- No fatalities, one injury, estimated damage ~ €250,000.

Figure 39. Aachen EIFS fire 22/05/2009[75]

COLOGNE-MÜLHEIM, 2005[75]

On the 24th of December, an apartment fire started on the second floor, this resulted exterior fire spread enhanced by the EPS EIFS system to at least the fourth floor. The building had no sprinkler protection. The total resulting fatalities and injuries were:

- Five fatalities (including two children),
- Three injured (reported), other injured occupants considered highly possible (due to extensive smoke spread) but not reported.

In the apartment of fire origin on the second floor there was one fatality and one injured person. However, there was a subsequent flashover in the apartment on the fourth floor resulting in four fatalities and two persons reported as injured with extensive smoke spread through the buildings and the fire stairwell. Several people were rescued by the fire department.

Figure 40. Cologne-Mülheim, Germany 24/12/2005[75]

BERLIN, GERMANY, 2005[77]

- On 21 April 2005 at 1:50pm, a fire started on the second floor of a seven-storey apartment building constructed between 1995 and 1996. The building had no sprinkler protection.
- The building was constructed with a poured concrete exterior using lost formwork 25 mm chipboard. An 80mm thick fire-retarded EPS foam insulation was fixed directly to chipboard and encapsulated with reinforced mesh and render.
- The room of origin reached flashover and resulted in flames extending from burst window. Flames spread to the top of the building. The fire took an estimated 20 minutes to reach top of building from the time of ignition.
- The fire spread to some rooms above and caused significant smoke to spread to entire building.
- The fire resulted in two fatalities and three injured individuals.

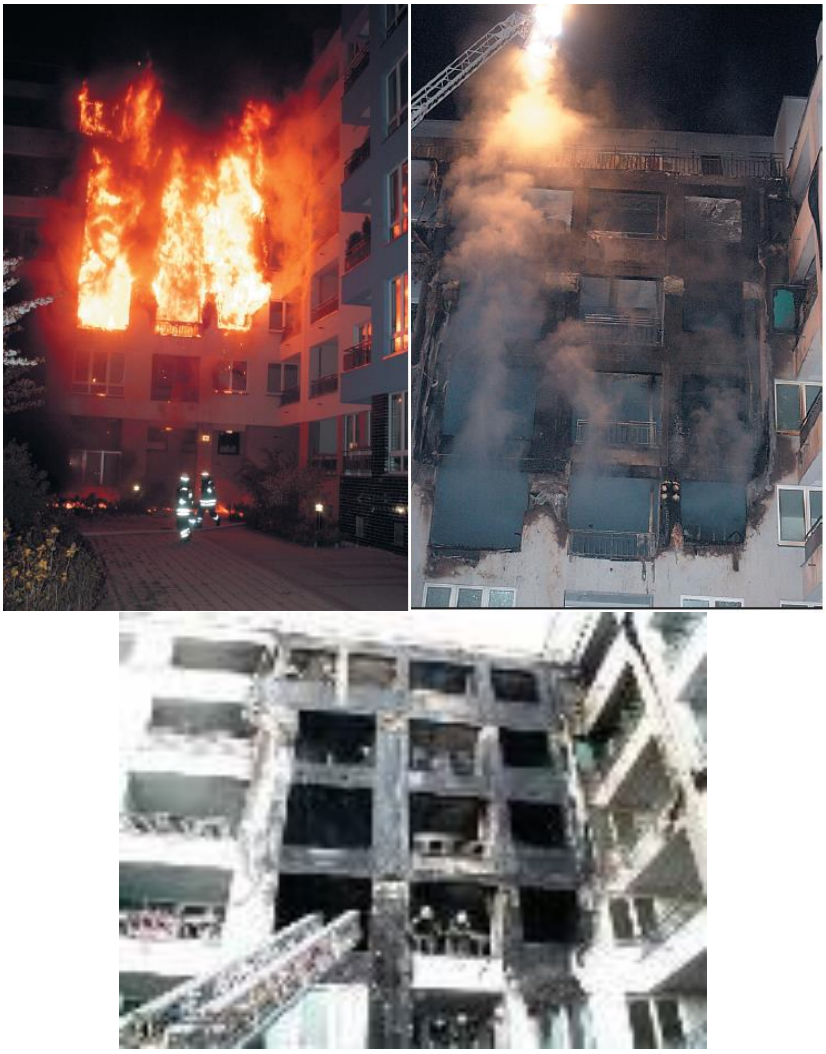


Figure 41 – The stage of the fire upon the arrival of the fire brigade (LHS) and Post fire damage (RHS and bottom)[77]

6.1.3 OTHER INTERNATIONAL EIFS FIRE INCIDENTS

*BAKU, AZERBAIJAN, 2015

- Fire occurred at 10:00am on 19 May 2015 in a soviet style residential building consisting of 16 floors housing 200 apartments.
- According to tenants – fire began in first floor and swept through entire building within seconds.
- 15-17 fatalities with 63 injured.
- A refurbishment of the facade had occurred. The choice of cladding for this building is unknown, however there are claims in the media suggesting that either ACP or 'Styrofoam' facing (EIFS) was used on the façade.
- Those that stayed in place within non affected apartments did not suffer any injuries however those that attempted to escape the building were affected by the toxic smoke.

Figure 42 - Baku High Rise residence fire, Baku, Azerbaijan (2015)

VAN NEST AVE, BRONX, NEW YORK, USA, 2012[78]

- An exterior fire started in an alley between two separate three storey timber framed buildings (Type V – as defined in the International Building Code) which were not clad in EIFS. The fire spread to the two buildings within the alley and then spread to an adjacent two storey (Type III as defined in IBC) building cladded with EIFS.
- The EIFS had been installed directly over a pre-existing asphalt material (never removed). This combination of materials contributed to rapid fire spread.
- The fire spread quickly on the building clad with EIFS with fire and smoke entering the second floor, creating untenable conditions.
- Two hundred fire fighters were required on multiple buildings to extinguish the fire.

Figure 43 -Flames burn vigorously above the roof line of the EIFS-clad structure (left), View of opposite side of building (away from area of fire spread) [78]

*RESIDENTIAL BUILDING, SHANGHAI, 2010[79]

- On 15 November 2010, a 28-storey high-rise residential building was undergoing renovation to install external wall insulation when welding operations ignited the polyurethane foam.
- Burning polyurethane foam fell and ignited wood and bamboo decking located on the ninth floor as well as the nylon safeguard netting and the external wall insulation.
- It was observed that fire spread to the 20th and 21st floor within three minutes and only took a total of four minutes to spread to the top of the roof.
- Fourteen minutes from ignition, the fire had burnt out on the northern façade but had spread to the west and east faces of the building along the building envelope. On the northern face of the building, fire spread had into internal rooms occurred between the 6th and 27th floors.
- Vertical propagation of the fire occurred very fast due to the flammability of the insulation and the stack effect caused by the vertical re-entrant corner and "U" shaped channel geometries on the exterior.
- Internal Sprinklers were only available between the first and fourthfloor. These activated and stopped further internal spread.
- A total of 58 fatalities and 71 injuries were reported.

Figure 44 –Plan view of the building showing the outline of the external face of the building and location of fire.[79]

DIJON, FRANCE, 2010[80]

- On 14th of November 2010 a fire within an immigrant hostel resulted in seven fatalities and eleven injuries.
- Ignition source was an external garbage container at base of building that resulted in rapid fire spread.
- The building is believed to have been EIFS with EPS insulation and mineral wool barriers however no detailed fire brigade reports have been found.
- 130 occupants were evacuated. Some occupants jumped from windows.
- The significant smoke spread within the building prevented many occupants from escaping.
- It was reported that the wind was blowing flames against wall.
- From the image below, it seems that the fire spread is concentrated along the vertical 'U-shape' channel created for balconies.

Figure 45 – Dijon France Immigrant hostel post fire damage[80]

MISKOLC, HUNGRY, 2009[81]

- On the 15th of August 2009, a kitchen fire started on the sixth floor resulting in vertical fire spread along the exterior of the 11-storey building.
- There were three fatalities.
- The building was built in 1986 but refurbished in 2007. The refurbishment included polystyrene based EIFS.
- Smoke spread internally through stair and mechanical shafts.
- An Investigation into the incident outlined the following issues:
    - The building was not constructed in accordance to industry requirements.
    - Use of polystyrene insulation.
    - Inadequate sticking or fixing of lamina to polystyrene sheets.
    - Absence of mineral wool insulation as fire propagation barriers (especially around window reveals).

Figure 46 – EIFS fire in Miskolc showing damage to cladding (LHS) and extent of damage to façade (RHS)[81]

MINI MALL, QUEENS, NEW YORK, USA, 2008[78]

On November 2, 2008, at 1:10 am, FDNY units were dispatched to a structure fire in a strip mall which contained eight businesses including a diner, a Chinese restaurant, two banks, a health store, a liquor store and two vacant store fronts.

- The building was approximately 250 feet long and 100 feet deep.
- The cause of fire was arson. The arsonist broke the front window which exposed the fire to the EPS on walls and overhang.
- Flaming molten EPS showered on the front of the building. Firefighting operations (forcible entry, search and rescue, hose line interior attack, roof ventilation and ladder placement) were suspended until outside water streams were started.
- No injuries were reported however there was significant damage to all occupancies.

Figure 47 -Flames burn vigorously on walls and overhang

MGM MONTE CARLO HOTEL, LAS VEGAS, USA, 2008[78]

- Before 11am on 25 of January 2008, welding operations to construct a catwalk on the roof ignited the parapet wall.
- EIFS was installed on the flat sections of the building's exterior and along decorative column extrusions located from floor 29 to 32. Non EIFS polystyrene foam (encapsulated in a polyurethane resin) was installed as a horizontal band on the 29th floor, at the top of the 32nd floor, the railing at the top of the parapet wall and may have included the medallions between the windows and the 32nd floor.
- Post incident analysis revealed that the EIFS did not have appropriate render installed.
- The fire started at the top of the 32-storey building from the left-hand side of the central core area and spread laterally in both directions. The fire spread approximately 24 meters to the left (along the upper portions of the west tower).
- The fire did spread downwards however did not pass the 29th floor.
- Flaming droplets or pieces of decorative EPS ignited the façade materials on the horizontal cornice between the 28th and the 29th floors
- Heat from the fire managed to break windows however activation of internal sprinklers managed to halt further spread into the interior of the building. A total of 17 sprinklers were activated.
- The fire on the exterior façade was extinguished by 12:15pm.
- The estimated Loss was approximated to be $100 Million.
- No fatalities or injuries.

The investigation of the fire resulted in the following conclusions:

1. The main contributing material to the fire was the combination of materials in the decorative band at the top of the wall, the decorative band at the top of the 32nd floor (EPS with a polyurethane resin coating) and the undetermined materials in the medallions.
2. Flaming droplets and burning pieces of EPS and/or polyurethane caused ignition of the large decorative band at the 29th floor. This decorative band was composed of EPS and had a non-EIFS coating.
3. EIFS in the flat portion of the parapet wall was involved in the fire however was not the main contributor even though it appeared to have a non-complying thickness of lamina. As the fire progressed along façade made of the non-EIFS polystyrene (encapsulated in a polyurethane resin), it continued to involve the EIFS, but did not contribute significantly to the spread of fire.

Figure 48 – Monte Carlo Casino Façade Fire (2008)

APARTMENT BUILDING, MUNICH, GERMANY, 1996[82]

- The façade of a five-storey apartment made of 100mm EPS EIFS ignited from an external rubbish container fire.
- Fire spread vertically to the top of the façade and the heat generated from the fire caused windows to break causing fire spread into apartment rooms at upper levels.

Figure 49 - Munich EIFS fire 1996[78]

393 KENNEDY ST, WINNIPEG, CANADA, 1990[82-84]

- Constructed in 1987, the building housed 75 units within eight storeys. The ground floor was a covered open sided carpark than can accommodate up to 54 cars. Extra car spaces are located outside; adjacent to the east wall of the building.
- The façade was made up of EIFS of different thicknesses applied to a gypsum board on either a masonry wall or steel frame. The foam insulation was 75mm thick except in limited areas including the north façade where it was 140mm thick. Glass fibre batts insulation was placed between the steel studs and no horizontal fire stops were installed.   The carpark ceiling was covered by 65mm thick rigid foam insulated protected with an aluminium soffit.
- The fire safety provisions of the building included a single stage, central fire alarm, two-hour fire resistant reinforced concrete for the garage ceiling slab and supporting columns. No fire detectors were installed in the garage. There was no sprinkler protection to building except for the garbage chute and garbage room.
- At 5am on the 10 January 1990 a fire started on the Ground Floor carpark and quickly involved 25 cars. The relatively quick fire spread was attributed in part of foamed ceiling.
- Flames issuing from open sides reached third storey (neglecting contribution from EIFS).
- Fire spread to fourth floor except for narrow strip on eastern façade which had fire spread to the top of seventh floor. The North façade had fire spread to top of building.
- The North façade fire spread was attributed to south wind driving flames across the carpark opening onto the north wall, its close proximity to adjacent buildings (resulting in re-radiation and causing the chimney effect) and its thicker foam insulation.

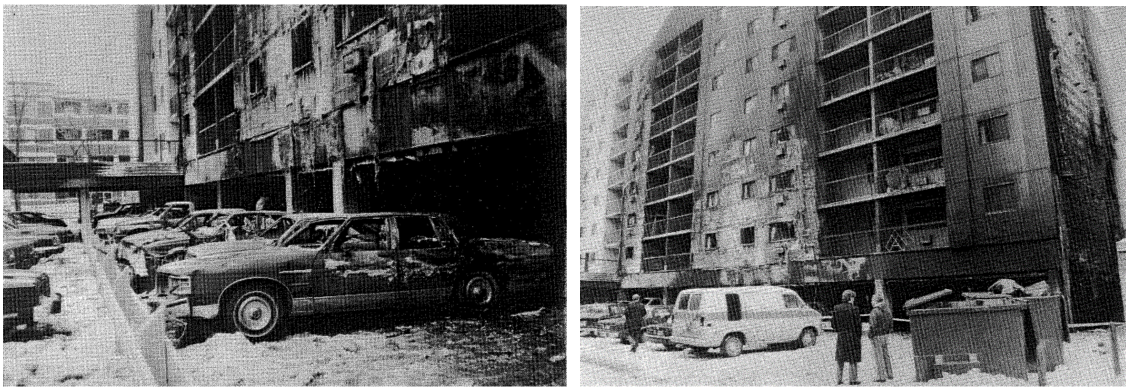


Figure 50 - Damaged cars outside east wall (LHS) and extent of damage to east and north walls (RHS) [82-84]

6.2 Fires involving insulated sandwich panels

It is noted that all ISP fire incidents reviewed for Australia and New Zealand (and most ISP fire incidents internationally involved Class 7 or 8 storage or manufacturing facilities that were mostly single storey.

6.2.1 AUSTRALIAN AND NEW ZEALAND ISP FIRE INCIDENTS

ERNEST ADAMS LTD, CHRISTCHURCH, NZ, 2000[85, 86]

On the 4th of February, a fire began ~ 8.30 am, was attended by 60 fire fighters and took one hour to bring under control. All 75 occupants of building evacuated successfully. The building was a baked goods factory, predominantly constructed from EPS ISP. The building was virtually destroyed by the fire.

Four fire fighters were injured in the incident. Two Fire Service personnel were injured as they exited a large roof/ceiling void where the fire initially took hold, while a further two received injuries when a section of ceiling collapsed. Following the Ernest Adams fire in Christchurch, the New Zealand Fire Service produced a publication (NZFS, 2000a) dealing with the hazards of fires in buildings constructed from ISP. In relation to firefighting tactics, the document recommends that personnel should not attempt firefighting within burning ISP buildings.

TIPTOP BAKERY, NSW, AUSTRALIA, 2002[87]

- Single storey large factory of 10,000m2 with walls and some areas of roof constructed of EPS ISP.
- The building had no sprinkler protection, but it had a thermal fire detection system connected to fire brigade monitoring.
- On 2 June 2002, the failure of the gas fired heating system resulted in the ignition of polenta flour. The fire then spread to EPS ISP structure.
- The Fire Brigade had to conduct defensive firefighting due to poor water supply and rapid fire spread to EPS sandwich panels.
- The fire incident report highlights the structural collapse of the EPS sandwich panels as a governing factor from the switch from offensive to defensive.
- Fire caused destruction to most of the building with a total loss estimated to be $100 million.

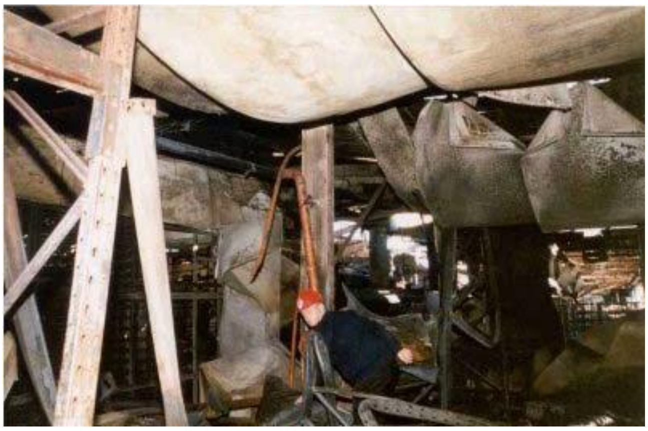



Figure 51 Tip Top Bakery fire 2002[87]

INGHAM CHICKEN FACTORY, SOMMERVILLE, VICTORIA, AUSTRALIA, 2010[88, 89]

The building was mostly an EPS ISP cold store/factory building. On the 12th of January, a fire started in a staging area for plastic packaging trays. The cause of the fire could not be definitively determined. The fire developed rapidly. The fire was detected at an early stage by an operator who unsuccessfully discharged an extinguisher.

An evacuation was initiated (~ 400 staff safely evacuated) and the fire brigade called. By the time the CFA fire brigade arrived with their first unit, some 10-15 minutes into the fire, flames were erupting through the steel deck roof over half the length of the building. Before the fire fighters could mount any first attack, the fire had spread the full length of the main production building, associated loading dock and cold store, overall a length of around 100 metres. Nearby residents were warned to stay indoors because of “thick acrid smoke”.

Over 100 fire fighters eventually attended and were able to contain the fire to the main building and protect the large ammonia receivers adjacent to the building. A total loss of the production building resulted in major business interruption and some loss of business.

A new extension to the existing EPS cold store had been constructed from PIR. The fire burnt up to the PIR wall but did not penetrate, the PIR section was left largely intact.

Figure 52. Ingham Chicken factory fire, 2010[88]

TEGEL POULTRY PROCESSING PLANT, CHRISTCHURCH, NZ, 2007[89]

The Tegel Poultry Processing Plant in the Christchurch suburb of Hornby was destroyed by fire on 5 January, 2007. The total losses are estimated to be between NZ$50m and NZ$100m. The building was constructed of EPS ISP.

Figure 53. Tegel factory fire 2007 [90]

PRIMO SMALLGOODS FACTORY, GREENACRE, NSW, 2007[91].

Approximately $200 Million of loss occurred due to a fire which spread through a series of factory buildings at the Primo Smallgoods factory in Greenacre, NSW. The fire started on the 8th of October 2007, in packaging machinery in the front section of one of the two large buildings in the complex. The fire quickly took hold and spread through sandwich panelling which lined an interconnected conveyor belt shaft to the neighbouring building. Firefighters on the scene faced various challenges. Sandwich panelling had been used as insulation throughout the two buildings onsite. It lined the outer perimeter walls and partitioning walls, and was also used as a suspended ceiling. The panelling was reported to be made of two layers of aluminium sheeting with a thick layer of polystyrene foam in the centre which intensified the fire and caused it to spread rapidly. The NSWFB provided a large resource commitment which at its peak involved 24 pumpers and 130 fire fighters. There were three aerials, Hazmat, Heavy Hazmat, Incident Command, Rescue and USAR (Urban Search and Rescue) appliances.

6.2.2 INTERNATIONAL ISP FIRE INCIDENTS

UK SANDWICH PANEL FIRE INCIDENTS, PRIOR TO 1997

In 1997 Harwood and Hume[92], and Shipp et al[93] undertook a review and investigation of 21 fire incidents involving sandwich panels.

- A total of 21 fire incident investigations were done by Fire Research Station that include two cold store buildings, twelve food processing plants and five factory buildings.
- All fires reviewed included ISP's with EPS cores.
- Small fires are not uncommon within these types of buildings and are often extinguished by staff. However, if staff are not present, the fire remains hidden or the cause is not routine, then fire is likely to spread to ISP cladding, resulting in the loss of the entire building.
- ISP fires are characterised by a large volume of black smoke. Many incidents require the Fire Brigade to wear breathing apparatus while working around the perimeter of building.
- Out of the 21 incidents, eight incidents prevented firefighting activities to proceed to the inside of the building and three incidents required forced retreat from the building.
- Two fire fighters died in the Sun Valley Poultry fire – trapped by collapsed of panels. Fire brigade reported collapsing panels as they retreated out of the building or fought fire at the entrance.
- In all cases, staff had escaped the buildings before untenable conditions were reached.

WHARFEDALE HOSPITAL, OTLEY, WEST YORKSHIRE, UK, 2003[94]

This three-storey hospital building was under construction at the time of the incident in July 2003. Fire occurred at the ground floor where building materials were stored. The fire occurred in stored materials (plastics and paints) and was ignited by arson by pouring adhesive over slabs of insulating materials.

- The building had steel frame and all floors were concrete. First and second floor were clad with 70mm thick PIR Insulated Panels approved by LPCB to LPS1181 Part 1 2003 as Grade EXT-B.
- Direct flame impingement occurred on the cladding up to 10 m high from the ground floor.
- Post fire inspection holes cut to inspect steel columns revealed that the PIR core was unaffected except for surface char in area of flame impingement to steel skins.
- Fire did not spread to the levels above. There was damage to the metal skin of the cladding, but no fire spread or deep charring on the insulation of the wall panels.

Figure 54 – PIR Insulated sandwich panel post fire on Wharfedale Hospital, UK

SPIDER TRANSPORT, WICKLOW, IRELAND, 2008[95]

- Fire occurred on 17th September 2008 outside Spider Transport located at Unit 12, Charvey Lane, Rathnew, Wicklow, Ireland.
- The external wall was constructed of a steel frame with blockwork on the lower part of the wall.
- The upper part of the wall was clad with ISP with PIR core. The sandwich panels complied with LPCB Grade EXT-B to LPS1181: 2003.
- Fire was started by arson by pouring flammable liquid into the cab area of a truck parked just outside the building ~1m away from external wall. The truck was destroyed in the fire
- Flames from the truck directly impinged the ISP.
- The PIR ISP did not support fire spread on the external wall beyond the area of direct fire impingement from the truck fire. The ISP did not delaminate, or loose integrity and the fire did not penetrate to the interior of the building via the ISP, although some internal fire damage resulted via the roller door and broken windows.

Figure 55. Spider Transport fire[95]

FURNITURE RETAIL WAREHOUSE, SLOVAKIA, YEAR UNKNOWN[96]

- Fire was initiated from a food cooking grill located 1.2m from the exterior of a building clad with PIR insulated panels.
- The building was roughly 100m x 40m and 8.5m high
- The flames from five propane gas cylinders and grill were 10m high and directly impinging on the façade for approximately 10 minutes.
- Flames melted an ACP sign on the building.
- Fire did not spread to building interior. The PIR ISP did not promote fire spread beyond the area of direct fire source impingement. The PIR ISP did not delaminate and maintained integrity.

Figure 56 – PIR Insulated Sandwich panel post fire damage on Furniture Retail Warehouse, Slovakia

7 Building code requirements relating to fire safety of EIFS and ISP external walls.

The following key aspects of regulation have been identified to have significant impact on performance and fire risk of external wall assemblies and therefore the review has focussed primarily on these aspects:

1. Reaction to fire requirements for external wall assemblies and materials.
2. Fire stopping/cavity barrier requirements both within and behind external walls.
3. Separation of buildings, in terms of minimum separation of unprotected openings from a relevant boundary (or fire source feature).
4. Separation of openings between storeys.
5. Requirements for sprinkler protection – which influences the risk of an initiating compartment fire and fire spread into compartments.

The above requirements (relating to EIFS and ISP application as external walls) have been reviewed for Australia, New Zealand, UK, Germany and USA. Requirements for single residential dwellings has been excluded from the scope of this literature review however the Australian NCC requirements for Class 1 are briefly summarised for comparison (they are not summarised for other countries).

The Australian National Construction Code (NCC) has been a performance-based code since its edition as the 1996 Building Code of Australia (BCA). The NCC states a range of performance requirements. The Performance Requirements can only be satisfied by a—

a) Performance Solution (typically demonstrated via fire engineering analysis); or
b) Deemed-to-Satisfy (DTS) Solution (Prescriptive provisions of the NCC deemed to comply with the performance requirements); or
c) Combination of (a) and (b).

The NCC has the following two main volumes:

- Volume 1 – which deals with Class 2 to Class 9 buildings.
- Volume 2 – which deals with Class 1 and 10 buildings.

The current edition of the NCC is NCC 2019, adopted since 1 May 2019.

The following flow diagram summarises the various NCC DTS and performance-based compliance pathways possible for an external wall system relating to external wall reaction to fire. Other pathways to demonstrate compliance include a CodeMark Certificate of Conformity or a Certificate of Accreditation issued by a State or Territory accreditation authority. However, such certificates should ideally be based upon a similar process of testing and assessment as that depicted in the following diagram.

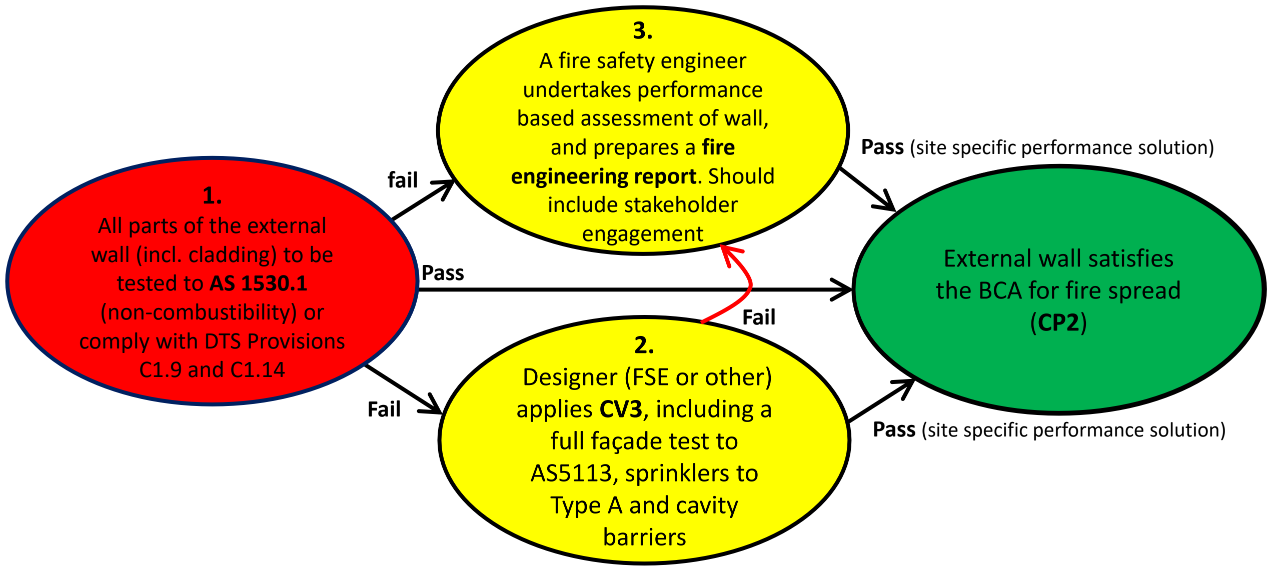


Figure 57. NCC compliance pathways possible for an external wall system relating to external wall reaction to fire (does not cover fire resistance requirements)

7.1 Australia - Current Class 2-9 requirements

7.1.1 PERFORMANCE REQUIREMENTS

The relevant performance requirements are:

CP2 – Spread of Fire

(a) A building must have elements which will, to the degree necessary, avoid the spread of fire—
- (i) to *exits*; and
- (ii) to *sole-occupancy units* and *public corridors*; and

  Application: CP2(a)(ii) only applies to a Class 2 or 3 building, or Class 4 part of a building.
- (iii) between buildings; and
- (iv) in a building.

(b) Avoidance of the spread of fire referred to in **(a)** must be appropriate to—
- (i) the function or use of the building; and
- (ii) the *fire load*; and
- (iii) the potential *fire intensity*; and
- (iv) the *fire hazard*; and
- (v) the number of *storeys* in the building; and
- (vi) its proximity to *other property*; and
- (vii) any active *fire safety systems* installed in the building; and
- (viii) the size of any *fire compartment*; and
- (ix) *fire brigade* intervention; and
- (x) other elements they support; and
- (xi) the *evacuation time*.

CP4 – Safe Conditions for Evacuation

To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to—

(a) the *evacuation time*; and
(b) the number, mobility and other characteristics of occupants; and
(c) the function or use of the building; and

(d) any active *fire safety systems* installed in the building.

Application:

CP4 applies to linings, materials and assemblies in a Class 2 to 9 building.

GP5.1 - Bushfire Resistance

A building that is constructed in a *designated bushfire prone area* must, to the degree necessary, be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—

(a) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and

(b) intensity of the bushfire attack on the building.

Application

GP5.1 only applies to—

(a) a Class 2 or 3 building; or

(b) a Class 10a building or deck associated with a Class 2 or 3 building, located in a *designated bushfire prone area*.

7.1.2 VERIFICATION METHOD

An NCC Verification Method is a test, inspection, calculation or other method that determines whether a Performance Solution complies with the relevant Performance Requirements. It is not intended to be a DTS provision. NCC Verification methods are non-mandatory.

Verification Method CV3 states that compliance with **CP2** to avoid the spread of fire via the *external wall* of a building is verified when the requirements summarised in the following flow diagram are satisfied.

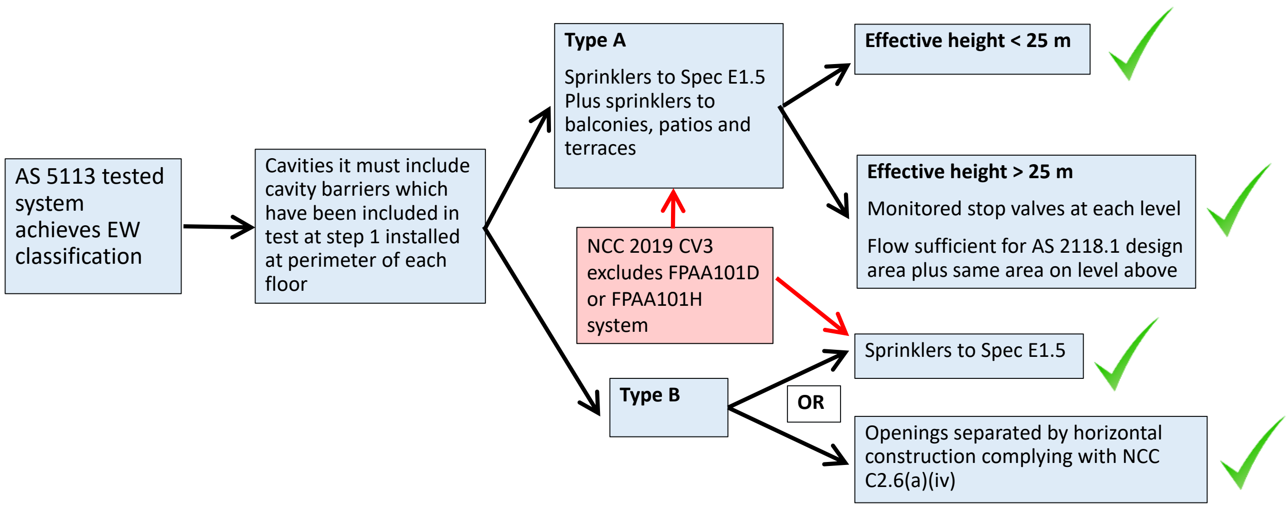


Figure 58. Summary of NCC CV3 Requirements.

Application of CV3 is not mandatory and is not a DTS provision of the NCC. Other forms of assessment method or evidence (as detailed in NCC clauses A0.5 and A2.2) may be used to demonstrate compliance of a performance solution.

7.1.3 DTS PROVISIONS

The minimum type of fire resisting construction required is grouped into 3 different Types dependant on building class and rise in storeys as summarised in the table below.

Table 10. Type of fire resisting construction (from NCC Vol 1 2019 Table C1.1)

Rise in storeys	Class of Building	
	2, 3, 9	**5, 6, 7, 8**
4 or more	A	A
3	A	B
2	B	C
1	C	C

NCC Volume 1, Clause C1.5 for two storey Class 2, 3, or 9c buildings permits a building having a rise in storeys of 2 may be of Type C construction if—

(a) it is a Class 2 or 3 building, or a mixture of these classes and each sole-occupancy unit has—

  (i) access to at least 2 exits; or

  (ii) its own direct access to a road or open space; or

(b) it is a Class 9c building protected throughout with a sprinkler system (other than a FPAA101D or FPAA101H system) complying with Specification E1.5 and complies with the maximum compartment size specified in Table C2.2 for Type C construction.

It is noted that if a two-story Class 2, 3, or 9c is determined to be Type C then there may be no requirements relating to external wall combustibility or reaction to fire.

External wall reaction to fire

NCC 2019 Volume 1, Clause C1.9 Non-combustible building elements:

A building required to be of Type A or B construction must have external walls which are non-combustible, including all components incorporated in them including the facade covering, framing and insulation.

NCC Clause C1.9(e) lists materials that may be used wherever a non-combustible material is required such as plasterboard, cement sheet, pre-finished metal sheeting and bonded laminated materials (with limitations). EIFS and ISP with foamed polymer cores would not comply with this DTS requirement for Type A or B Buildings.

NCC 2019 Volume 1 Clause C1.13 - provides a concession for fire protected timbers to be acceptable for Type A or B construction where non-combustible elements are required. This is does not apply to EIFS or ISP.

NCC Volume 1 Clause C1.14 Ancillary elements -

This clause lists ancillary elements which are permitted to be combustible and be attached to internal parts or external face of an external wall that is required to be non-combustible. EIFS or ISP are not ancillary elements.

NCC 2019 Volume 1 Specification C1.1 Clause 3.10 and Clause 4.3 - give concessions applicable to Class 2 or 3 buildings having a rise in storeys of not more than 3 (or 4 storeys if the lowest storey is car parking or ancillary use of masonry or concrete construction having the required FRL separation from the stories above) to permit external walls to be timber frame construction combined with other non-combustible materials, provided that any insulation installed in the cavity of a wall required to have an FRL is non-combustible; and the building is fitted with an automatic smoke alarm system complying with Specification

E2.2a. It is CSIRO's interpretation that this clause does not permit EIFS or ISP as DTS as such systems represent insulated material forming the external cladding of the wall system (not insulation installed in the cavity of the wall) which is required to be non-combustible regardless of FRL requirements for the wall.

NCC 2019 G5.2 Construction in bushfire prone areas:

In a *designated bushfire prone area*, the following construction must comply with AS 3959—
(a) A Class 2 or 3 building; or
(b) A Class 10a building or deck associated with a Class 2 or 3 building,
Note there are several state based NCC Appendices which vary the application of NCC G5.2.

In summary

- NCC does not specifically identify or define EIFS or ISP and does not state any requirements that are intended exclusively for these products, however the general DTS requirements of Clause C1.9 require external walls for Type A and B construction to be non-combustible.
- Therefore, NCC DTS does not permit EIFS or ISP with combustible foam polymer content in the core as DTS for Type A or B construction.
- NCC DTS is silent on combustibility and fire spread/reaction to fire requirements for external walls in Type C construction, except that FRL and construction in bushfire prone area DTS requirements may apply in specific circumstances. Therefore, EIFS and ISP external walls with combustible cores are permitted as DTS for Type C construction but may be impacted by FRL and bushfire requirements in circumstances where these additional requirements apply.

Fire stop barriers

NCC 2019 Vol 1 Clause C2.6 states that buildings of Type A construction which are not sprinkler protected require any gaps behind curtain or panel walls at each floor level to be packed with a non-combustible material which is resistant to thermal or structural movement to act as a seal against fire or smoke.

NCC 2019 Vol 1 Specification C1.13 details cavity barrier requirements applicable to fire protected timber.

Fire stop barriers to specific to EIFS or ISP are not prescribed by NCC DTS EIFS and ISP are not specifically identified by the NCC.

Separation between buildings

NCC 2019 Vol 1 Specification C1.1 states that non loadbearing external walls separated by 3 m or more from a fire source feature (far side of a road, a side or rear boundary of an allotment or an external wall of another building on the same allotment) do not require an FRL. Non-loadbearing external walls with less than 3 m separation distance from a fire source feature are required to have an FRL.

NCC 2019 Vol 1 Clause C3.2 states the requirements for separation or protection of openings in external walls where the external wall is required to have an FRL. Such openings are generally required to be separated from other buildings or fire source features by the following horizontal distances.

- 3 m from a side or rear boundary of an allotment.
- 6 m from the far boundary of road, river, lake or the like adjoining the allotment.
- 6 m from another building on the same allotment.

If openings in external walls are not separated by the above distances, then buildings must be separated by walls having prescribed FRLs and all openings are to be protected by either external sprinkler protection or self-closing barriers having prescribed FRL's.

NCC 2019 Vol 1 Clause C3.3 states required separation distances between external walls and associated openings in different fire compartments (within the same building). Required separation distance reduces with angle between the walls from 6 m separation required for 0° (opposite walls) to no separation distance required for walls with 180° angle or more. If required separation distances are not provided the external walls must have an FRL not less than 60/60/60 and all openings are to be protected by either external sprinkler protection or self-closing barriers having prescribed FRL's

Separation of vertical openings

NCC 2019 Vol 1 Clause C2.6 states for Buildings of Type A construction, openings (windows) in external walls that are above openings in the storey below must be separated by either:

- A spandrel having an FRL of 60/60/60 that is at least 900 mm in height and extends at least 600 mm above the intervening floor, or;
- A horizontal projection having an FRL of 60/60/60 which projects 1100 mm horizontally from the external face of the wall and extends along the wall at least 450 mm beyond the openings.

The above separation is not required if the building is internally sprinkler protected.

Sprinkler protection

NCC 2019 Vol 1 Clause E1.5 states that sprinkler protection is required for the following buildings:

- All classes with an effective height greater than 25 m.
- Class 2 or 3 building (excluding residential care) with a rise in storeys of 4 or more and an effective height not more than 25 m.
- Class 3 building used as residential care (regardless of height).
- Class 9a building used for residential aged care or class 9c buildings.
- Class 7a non-open deck carparks accommodating more than 40 vehicles (protection of car park fire compartment).
- Building containing Atrium where required by **NCC Vol 1 part G3** (sprinkler protection throughout).
- Theatre, public hall or the like where required by **NCC Vol 1Part H1** (sprinkler protection throughout).
- Or for buildings where maximum fire compartment size limits (which are dependent on the class of building) are exceeded.

NCC 2019 Vol 1 Clause D1.3 states that sprinkler protection is required for:

- Class 2 building where an open stair is connecting 4 consecutive storeys (sprinkler protection is required throughout).
- Class 3, 5, 6, 7, 8 or 9 (excluding 9c and 9a) building open stair connecting 3 consecutive storeys requires sprinkler protection throughout.

Required fire sprinkler systems must generally comply with NCC 2019 Vol 1 Specification E1.5 which references AS 2118.1, AS 2118.6 and AS2118.4.

AS 2118.1-2017 clause 5.9.10 has increased stringency on the dimensional criteria for the sprinkler protection of covered balconies (required for covered balconies > 6 m^2 OR >2 m deep).

An exception is provided for Class 2 or 3 building (excluding residential care) with a rise in storeys of 4 or more and an effective height not more than 25 m which may have a sprinkler system which complies with NCC 2019 Vol 1 Specification E1.5a. This references FPAA101D (sprinkler system with drinking water supply) and FPAA101H (sprinkler system with hydrant water supply). Note that FPAA101D and FPAA101H are excluded (regardless of height) from use in a number of cases for example where CV3 (for combustible external walls) or C1.13 fire protected timber concession is applied.

FPAA101D and FPAA101H both require sprinkler protection of covered balconies as defined by the dimensional criteria in AS 2118.1-2017.

NCC 2019 Vol 1 Specification E1.5a permits concessions related to fire compartmentation, exit travel distance and hydrant requirements where class 2 and 3 buildings with a rise in storeys of 4 or more and an effective height not more than 25 m are sprinkler protected.

NCC 2019 Vol 1 Schedule 1 Victoria Appendix Vic H103.1 permits concessions related to fire compartmentation, exit travel distance and hydrant requirements where class 2 and 3 buildings with a rise in storeys of not more than 3 and an effective height not more than 25 m are sprinkler protected (excluding FPAA101D and FPAA101H).

NCC 2019 Vol 1 Schedule 1 Victoria Appendix states that for class 2 and 3, AS 2118.1-2017 clause 5.9.10 does not apply and is replaced with "Covered balconies shall be sprinkler protected". This means that for sprinkler protected residential buildings in Victoria, Sprinkler protection must extend to all covered balconies regardless of dimensions.

7.2 Australia - Current Class 1 requirements

Class 1 buildings include:

- Class 1a is a single residential dwelling being a detached house, or one of a group of attached dwellings separated by a fire resisting wall.
- Class 1b is one or more buildings which together constitute a boarding house, guest house, hostel or the like that accommodate not more than 12 people; and have a total area of all floors not more than 300 m^2; or four or more single dwellings located on one allotment and used for short-term holiday accommodation

In all cases, a Class 1 building cannot be located above or below another dwelling or another Class of building, other than a private garage.

7.2.1 PERFORMANCE REQUIREMENTS

NCC Vol 2 P2.3.1 Spread of Fire

(a) A Class 1 building must be protected from the spread of fire from—

(i) another building other than an associated Class 10 (garages) building; and

(ii) the allotment boundary, other than a boundary adjoining a road or public space.

NCC Vol 2 P2.7.5 Buildings in Bushfire prone areas

A Class 1 building or a Class 10a building or deck associated with a Class 1 building that is constructed in a designated bushfire prone area must, to the degree necessary, be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the—

(a) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and

(b) intensity of the bushfire attack on the building.

7.2.2 DTS PROVISIONS

External wall reaction to fire

There are no reaction to fire requirements for external walls. External walls less than 900 mm from an allotment boundary or less than 1.8 m from another building on the same allotment other than a Class 10 building associated with the Class 1 building or a detached part of the same Class 1 building are required to comply with NCC Vol 2 Clause 3.7.2.4 which requires:

- External walls must either:
  - have an FRL of not less than 60/60/60 when tested from the outside; or
  - be of masonry-veneer construction in which the external masonry veneer is not less than 90 mm thick; or
  - be of masonry construction not less than 90 mm thick.

- And the external wall must commence at the footings, ground slab or separating wall and extend to the underside of either
    - a non-combustible roof covering, except that a wall may terminate not more than 200 mm from the underside of a non-combustible roof covering, where the area between the external wall and underside of the roof covering is sealed with a non-combustible fascia, gutter or flashing; or
    - non-combustible eaves lining.

NCC Vol 2 Clause 3.7.3.2 requires separating walls (a separating wall between Class 1 buildings, or a wall that separates a Class 1 building from a Class 10a building which is not associated with the Class 1 building) to either:

- have an FRL of not less than 60/60/60; or
- be of masonry construction not less than 90 mm thick.

It is noted that walls having an FRL of 60/60/60 can still be combustible. For example, it would be possible for combustible cladding material such as EIFS, if applied to a suitable light weight fire resistant wall substrate (e.g. layers of fire resistant plasterboard) to achieve the required external wall FRL of 60/60/60 when tested to AS 1530.4 but still be a combustible wall system that could ignite and burn vigorously on the external surface.

Fire stop barriers

There are no requirements for fire stop barriers within external or separating walls/cavities between floor levels etc. (with exception of sealing between the top of the external wall and underside of non-combustible roof covering as per Clause 3.7.3.2 (a) and (c), requirement for packing any gap of more than 50 mm between a separating wall and a masonry veneer external wall with mineral fibre or suitable fire resistant material as per Clause 3.7.3.2 (d) or separation within cavities of eaves/verandas or similar that areopen to roof space and common to more than one Class 1 dwelling as per Clause 3.7.3.2 (e).

Separation between buildings

NCC Vol 2 Clause 3.7.2.2- An external wall of a Class 1 building, and any openings in that wall, must comply with 3.7.2.4 if the wall is less than—

(a) 900 mm from an allotment boundary other than the boundary adjoining a road alignment or other public space; or
(b) 1.8 m from another building on the same allotment other than a Class 10 building associated with the Class 1 building or a detached part of the same Class 1 building .

The fire resistance construction requirements stated in Clause 3.7.2.4 are summarised in the "external wall reaction to fire" section on the previous page of this report.

Vertical separation of openings

No Requirements/Not applicable.

Sprinkler protection

No requirements. Class 1 is typically not sprinkler protected.

7.3 Australia – Building code requirements over previous decade

NCC 2016 volume 1 was amended in 2018 with specific amendments which clarified the intended DTS provisions relating to combustible external walls and introduced verification method CV3 for combustible external walls. Many of the NCC 2016 volume 1 requirements relating to combustible cladding had only minor changes for NCC 2019.

A major change to NCC 2019 was requirement for sprinkler protection of Class 2 and 3 buildings of 4 or more storeys less than 25 m effective building height and the inclusion of FPAA101D and FPAA101H sprinkler standards for this purpose.

NCC 2016 Volume 1 Amendment 1 in 2018 included specific amendments which clarified the intended DTS provisions relating to combustible external walls. Key changes included:

1. The introduction of a new Verification Method (CV3) for testing of external wall assemblies for fire propagation. CV3 references a new testing standard, AS 5113-2016 'Fire propagation testing and classification of external walls of buildings', and in most circumstances requires additional measures (e.g. enhanced sprinkler protection) to mitigate the hazard presented by a combustible façade. – Prior to this there was no Full-scale façade fire spread test referenced in the NCC.
2. Clarification of provisions relating to external wall claddings and attachments, provisions that provide exemption to the non-combustibility requirements, and provisions that control the fire hazard properties of building elements. In particular:
    a. Clause C1.9 was introduced to clarify the requirements for non-combustible external walls for Type A or B construction which were previously contained within NCC Spec C1.1
    b. Clause C1.10(a) was clarified to apply to internal linings
    c. Specification C1.1 clause 2.4 (a) was revised to delete reference to attachments regarding fire hazard properties and "undue risk of fire spread". This section previously referred to "attachments" to walls requiring an FRL being permitted to be combustible if:
        i. The material complies with fire hazard properties of Spec C1.10; and
        ii. It is not directly located near/above a required exit so as to make the exit unusable in a fire; and
        iii. It does not otherwise constitute an undue risk of fire spread via the façade of the building.
3. Increased stringency for the sprinkler protection of balconies of residential high-rise buildings through referencing an updated sprinkler standard, AS 2118.1-2017 'Automatic fire sprinkler systems – General systems'.
4. Clause C1.14 was introduced to provide a clear list of Ancillary elements to external walls which are permitted to be combustible.

Observation from Victorian ARP's and building audits has indicated that prior to the 2018 amendment of NCC 2016 there appeared to be varying interpretations (or an unawareness) by industry practitioners of the DTS requirements for non-combustibility and fire hazard properties of external walls for Class 2-9 Type A and B construction. This resulted in either combustible external wall materials being approved for use based on unsuitable test methods such as AS 1530.3 or in many cases combustible external wall materials being installed to buildings where they were not permitted by DTS with no documented assessment or approval. This is re-iterated by the following statement from the Shergold-Weir report[35], "*Many stakeholders report that building practitioners across the industry do not have a sufficient understanding of the NCC or its revisions. This has led to non-compliance or poor quality documentation of compliance. Misinterpretation or ignorance of the requirements of the NCC is not uncommon. Indeed, this failure has been offered as one explanation for the prevalence of non-compliant cladding on buildings across Australia".* The Victorian Cladding Taskforce interim[1] and final[2] reports re-iterate similar conclusions.

The absence of requirements (other than FRL for < 900 mm to boundary) for fire behaviour of external walls for Class 1 buildings (NCC Volume 2) that impact the use of EIFS or ISP has not changed over the previous decade.

7.4 New Zealand Building code requirements

The New Zealand Building Code is a performance-based building code which specifies prescriptive requirements called Acceptable Solutions (AS) but also permits performance based alternative solutions provided that these alternative solutions are demonstrated by fire engineering analysis to satisfy the codes performance requirements.

Acceptable solutions (prescriptive requirements) are detailed in the separate documents as listed in the following table for different types of buildings.

Table 11. New Zealand Acceptable solution documents for different building types

Acceptable solution document	Building type	Applies to	Comment
C/AS1	Single household units and small multi-unit dwellings	Houses, townhouses and small *multi-unit dwellings* Limited area outbuildings	Outside of scope of this report
C/AS2	Sleeping (non institutional)	Permanent accommodation e.g., apartments Transient accommodation e.g., hotels, motels, hostels, Backpackers, education accommodation	
C/AS3	Care or detention	Institutions, hospitals (excluding special care facilities), residential care, rest homes, medical day treatment (using sedation), detention facilities (excluding prisons)	
C/AS4	Public access and educational facilities	Crowds, halls, recreation centres, public libraries (<2.4 m storage height), cinemas, shops, personal services (e.g., dentists and doctors except as included above, beautician and hairdressing salons), schools, restaurants and cafes, *early childhood centres*	
C/AS5	Business, commercial and low level storage	Offices (including professional services such as law and accountancy practices), laboratories, workshops, manufacturing (excluding *foamed plastics*), factories, processing, cool stores (capable of <3.0 m storage height) and warehouses and other storage units capable of <5.0 m storage height, light aircraft hangars	
C/AS6	High level storage and other high risks	Warehouses (capable of 5.0 m storage height), cool stores (capable of 3.0 m storage height), trading and bulk retail (3.0 m storage height)	
C/AS7	Vehicle storage and parking	Vehicle parking – within a *building* or a separate *building*	Outside scope of this report

7.4.1 PRESCRIPTIVE REQUIRMENTS

External wall reaction to fire

The acceptable level of fire performance of external wall systems depends on the building height, presence of sprinklers and the distance from the relevant boundary of the allotment.

Table 12 NZ Building code requirements for external wall fire performance

Building type	Requirements	
	Distance to boundary and building height	Cone Calorimeter test requirements at irradiance of 50 kW/m² for duration of 15 minutes.
Sleeping/Residential (non institutional) AS2 Public access and educational facilities AS4 Business, commercial and low level storage AS5 High level storage and other high risks AS6	Distance to relevant boundary < 1.0 m	Peak HRR shall not exceed 100 kW/m² and total heat released shall not exceed 25 MJ/m².
	Distance to relevant boundary ≥ 1.0 m and building height > 7.0 m	Peak HRR shall not exceed 150 kW/m² and total heat released shall not exceed 50 MJ/m².
Care or detention (hospitals or prisonsAS3	Distance to relevant boundary < 1.0 m, or building height > 7.0 m	Peak HRR shall not exceed 100 kW/m² and total heat released shall not exceed 25 MJ/m².
	Distance to relevant boundary ≥ 1.0 m and building height ≤ 7.0 m	Peak HRR shall not exceed 150 kW/m² and total heat released shall not exceed 50 MJ/m².

Note- Materials with metal facing with a melting point of less than 750 °C covering a combustible core are to be tested without the metal facing present. However, rendered EIFS and steel faced ISP appear to be tested with the facing in place.

However, the requirements in the above table do not apply if:

a) *Surface finishes* are no more than 1 mm in thickness and applied directly to a *non-combustible* substrate, or
b) The entire wall assembly has been tested at full scale in accordance with NFPA 285 and has passed the test criteria.

Fire stop barriers

Fire stopping is required for all interior gaps at fire compartment (fire cell) boundaries. This includes gaps between slabs and external wall systems such as curtain walls. The fire stopping must have a fire resistance rating equivalent to that required for the fire compartment boundary.

Mineral wool fire stop barriers (at least 50 mm thick) are required for buildings of three or more storeys fitted with combustible external insulation. The fire stop barriers must be installed across the insulation at intervals of not more than two storeys. Where the insulation is fixed to a light weight framed wall the fire stopping must continue across the wall frame cavity of be aligned with a timber blocking cavity barrier.

Separation between buildings

The critical distance for separation of buildings from the boundary in terms of protection of openings and fire performance of external cladding is 1 m. At less than 1 m separation all openings (windows) must be protected by fire rated glass. At greater than 1 m the percentage of unprotected opening area permitted for external walls gradually increases with no requiring for protection at a separation distances ranging from 6 m for residential buildings (AS2) to 16 m for high risk storage (AS6)

Separation of vertical openings

Openings (windows) in external walls that are above openings in the fire compartment below must be separated by a combination of spandrels and/or horizontal projections having the same FRL as the floor separating the upper and lower fire compartments.

Table 13. Permitted combinations of horizontal projection and spandrel separation of openings

Horizontal Projection (m)	Spandrel height (m)
0.0	1.5
0.3	1.0
0.45	0.5
0.6	0.0

The above separation of vertical openings is not required where the building is internally sprinkler protected.

Sprinkler protection

Sprinkler protection is generally required for most building types where the height exceeds 25 m or where maximum compartment size limits are exceeded. Sprinkler protection is generally required for all care or detention type buildings.

7.5 UK Building code requirements

The Building Regulations 2010 for England and Wales state the performance requirements with regards to fire safety. Approved Document B states prescriptive requirements for fire safety which achieve compliance with the Building Regulations 2010. Alternative solutions supported by fire engineering analysis are permitted.

In response to the Grenfell Tower fires that occurred in June of 2107, an independent review of the current state of the Building Regulatory environment was undertaken and a final report was published on May 2018 (Hackitt report)[97]. The report identified issues and challenges facing both UK's and international regulatory frameworks and listed several recommendations for reform.

A 2018 amendment to Approved Document B volume 2 took effect on 21 December 2018, for use in England. The Amendment focuses on the requirements for external wall fire spread but appear to not significantly change the basic requirements but provide further clarification of the existing requirements.

A new clarified Approved Document B (Fire safety) 2019 edition, volume 2: Buildings other than dwellings appears to have been release in April 2019 and comes into Force on 30 August 2019

Key changes with the recent amendments of Approved Document B include:

- Introduction of Regulation 7, which applies to buildings with an effective height of 18 m or more which have a residential or institution (hospital, aged car or the like with sleeping accommodation), requires all external materials to be European Classification A2-s1, d0 or Class A1 and does not permit other materials including systems which 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.
- General clarification on external wall fire spread requirements and impacts such as building change of use.

7.5.1 PRESCRIPTIVE REQUIRMENTS

External wall reaction to fire

Approved Document B, Section 12 states external wall reaction to fire requirements.

Regulation 7

- Regulation 7 applies to "relevant buildings" which are buildings with a storey at least 18m above ground level and which contains one or more dwellings; an institution; or a room for residential purposes (excluding any room in a hostel, hotel or a boarding house). This includes student accommodation, care homes, sheltered housing, hospitals and dormitories in boarding schools.
- It requires that all materials (other than exempted materials) which become part of an external wall or specified attachment achieve class A2-s1, d0 or class A1.
- Exempted materials include membranes, seals, gaskets, fixings, backer rods, thermal break materials, window frames and glass, door frames and doors, electrical installations etc.
- Systems which fail to achieve class A2-s1, d0 but meet the performance criteria of BR 135 using full-scale test data from BS 8414-1 or BS 8414-2 are not permitted for 'relevant buildings'.

For buildings other than those prescribed as 'relevant buildings' in Regulation 7, external walls must either:

a. meet the following requirements for:
    i. external surfaces.
    ii. materials and products.
    iii. cavities and cavity barriers.
b. meet the performance criteria of BR 135 using full-scale test data from BS 8414-1 or BS 8414-2

External surfaces

The external surfaces (i.e. outermost external material) of external walls must comply with table below.

Table 14 Reaction to fire requirements for external surface of walls, taken from Approved Document B Volume 2 2009, Table 12.1

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		Class A2-s1, d0(1) or better	Class A2-s1, d0(1) or better
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

Numbered Table Notes:

1. The restrictions for these buildings apply to all the materials used in the external wall and specified attachments
2. Profiled or flat steel sheet at least 0.5 mm thick with an organic coating of no more than 0.2mm thickness is also acceptable.
3. Timber cladding at least 9mm thick is also acceptable.
4. 10m is measured from the top surface of the roof.

General Table notes

- Class refers to classification in accordance with EN 13501-1. See Section 9.1.4 for description of EN 13501-1 (Euro Class) testing and classification.

Materials and Products

In a building with a storey 18m or more in height any insulation product, filler material (such as the core materials of metal composite panels, sandwich panels and window spandrel panels but not including gaskets, sealants and similar) etc. used in the construction of an external wall should be class A2-s3, d2 or better (this restriction does not apply to masonry cavity walls compliant with other specific requirements).

Note the wording of this requirement does not make it clear if this restriction also applies to other insulation materials used externally (EIFS) or within cavities that are not "core materials", but it appears to be intended to extend to these other insulation materials.

Fire stop barriers

Cavity barriers are required in external walls at:

- the edges of cavities, including around openings (such as windows, doors and exit/entry points for services).
- the junction between an external cavity wall and every compartment floor and compartment wall.

Cavity barriers must provide 30 minutes fire resistance integrity and 15 minutes fire resistance insulation. However, cavity barriers formed around openings may be formed by either (and not achieve the above fire resistance):

- Steel, a minimum of 0.5mm thick.
- Timber, a minimum of 38mm thick.
- Polythene-sleeved mineral wool, or mineral wool slab, under compression when installed in the cavity.
- Calcium silicate, cement-based or gypsum-based boards, a minimum of 12mm thick.

- Cavity barriers provided around openings may be formed by the window or door frame if the frame is constructed of steel or timber of the above minimum thickness

Fire stop barriers within core of EIFS and ISP are not explicitly specified in approved document B but are recommended in BR135.

Separation between buildings

The critical distance for separation of buildings from the boundary in terms of protection of openings and fire performance of external cladding is 1 m. At less than 1 m separation all openings (windows) must be protected by fire rated glass. At greater than 1 m the percentage of unprotected opening area permitted for external walls gradually increases to 100 % at a separation distances of 6 meters for small residential buildings, 12.5 m for larger residential, office, assembly and recreation and 25 for retail/commercial, industrial, storage and other non-residential type buildings.

Separation of vertical openings

There is no requirement for vertical separation of openings in external walls between each level.

Sprinkler protection

Sprinkler protection is generally required for all building types where the height exceeds 30 m excluding institutional, other residential and car parks or where maximum compartment size limits are exceeded (as detailed in Table 8.1 of Approved Document B). Sprinklers are generally required to blocks of flats (apartments) where the height exceeds 30 m.

7.6 German Building codes.

Full copies of the German building codes were not obtained or reviewed as part of this literature review however the following requirements were confirmed from journal paper and correspondence with Anja Hofmann-Böllinghaus at BAM.

The two key model building codes for Germany are:

- **Model building code** (Musterbauordnung MBO, from 2002 with recent amendments from May 2016).
- **Building regulations for high rise buildings (Musterhochhausrichtlinie 2008 with amendments 2012, known as HBO)**

The Model building code is representative for regulations in different German states, however the mandatory building regulation for each state can differ from the model building regulation.

In Germany buildings are categorized according to the following classes

Table 15. German Building Classes

Building class	**1**	**2**	**3**	**4**	**5**	**High-rise**
Description	a) free standing buildings with heights up to 7 m and not more than two building units and not more than 400 m² and b) free standing buildings in agriculture	Not free-standing Buildings with heights up to 7 m and not more than two building units and not more than 400 m²	other buildings with heights up to 7 m	other buildings with heights up to 13 m and not more than 400 m²	Other buildings and underground buildings with heights from 13 m up to 22 m or more than 400 m²	Buildings with heights more than 22 m

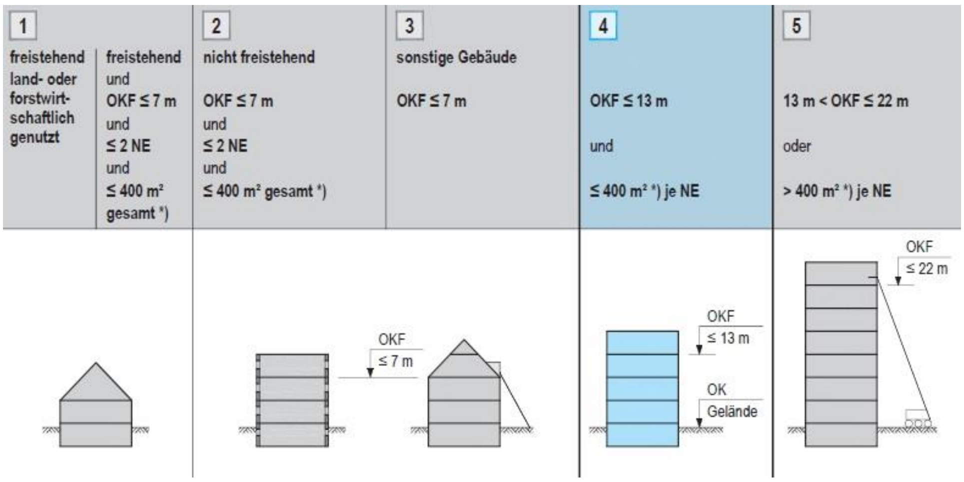


Figure 59. German Building classes

External wall reaction to fire

German external reaction to fire requirements are summarised in the following table.

Table 16. German external wall reaction to fire requirements for according to German building code

Building height	Requirement
up to 7 m	Low flammability according to DIN EN 13501-1 and-2
7 m – 22 m	Additional requirements: systems must be tested according to DIN 4102-20 and for ETICS with EPS insulation additionally must be tested according to technical regulation A 2.2.1.5 (200 kg crib test - fire from outside the building).
>22m	Need to be non-combustible, according to DIN EN 13501-1 /-2

The German model building codes requires:

- All buildings of class 1-5 to have low flammability external walls; and
- High rise buildings to have non-combustible external walls.

Reaction to fire categories in terms of combustibility and flammability are summarized in the following table:

Table 17. German reaction to fire categories and their relationship to European classification

Requirement in building code	Additional requirements		European classes according to EN 13501-1	German classes according to DIN 4102-1
	Less smoke	No burning droplets, debris		
Non-combustible	X X	X X	A1 A2 -s1, d0	A1 / A2
Low flammable	X	X	B – s1, d0 C – s1, d0	B1
		X	A2 – s2, d0 / A2 – s3, d0 B – s2, d0 / B – s3, d0 C – s2, d0 / C – s3, d0	
	X		A2 – s1, d1 / A2 – s1, d2 B – s1, d2 / B – s1, d2 C – s1, d1 / C – s1, d2	
			A2 – s3, d2 B – s3, d2 C – s3, d2	
Normal flammable		X	D – s1, d0 / D – s2, d0 / D – s3, d0 E	B2
			D – s1, d1 / D – s2, d1 / D – s3, d1 D – s1, d2 / D – s2, d2 / D – s3, d2	
			E -d2	
highly flammable			F	B3

However additional requirements for buildings 7-22 m in height are set by DIBt (Deutsches Institut für Bautechnik – German Institute for Building technology) via Administrative regulations (Musterverwaltungsvorschrift MVV TB 2016) with Technical Building regulations (Technische Baubestimmungen). Which require in addition to Low flammability materials:

- Testing to the requirements of E DIN 4102-20 (façade fire test with 30 kg timber crib).
- For systems with EPS foam insulation testing according to Technical regulation A 2.2.1.5 (fire from outside the building – "Sockelbrandversuch – 200 kg wood crib test).

Fire stop barriers

DIBt (Deutsches Institut für Bautechnik – German Institute for Building technology) Administrative regulations (Musterverwaltungsvorschrift MVV TB 2016) require the following for EIFS with EPS core up to 300 mm thick

Mineral wool belts (additional to belts already mandatory for these systems prior to 2016):

1. Mineral wool belt at the bottom of the system, not more than 90 cm above ground.
2. Mineral wool belt at location of ceiling of first floor (not more than 3 m above the bottom one)
3. Mineral wool belt at location of ceiling of third floor but not more than 8 m above the next one below.
4. Mineral wool belts at edge to horizontal areas

Mineral wool belts must have height of at least 200 mm and be non-combustible, non-smoldering with melting point of at least 1000 °C and density between 60 and 100 kg/m³, the belts must be both glued with mineral glue and fixed with mechanical anchor pins.

Additional mineral wool belt must be applied at the top of the system to prevent fire spread into the roof.

Render thickness must be at least 4 mm. Internal corners must be enhanced with stabilization (glass fiber).

EPS insulation material with density not more than 25 kg/m³ is specified.

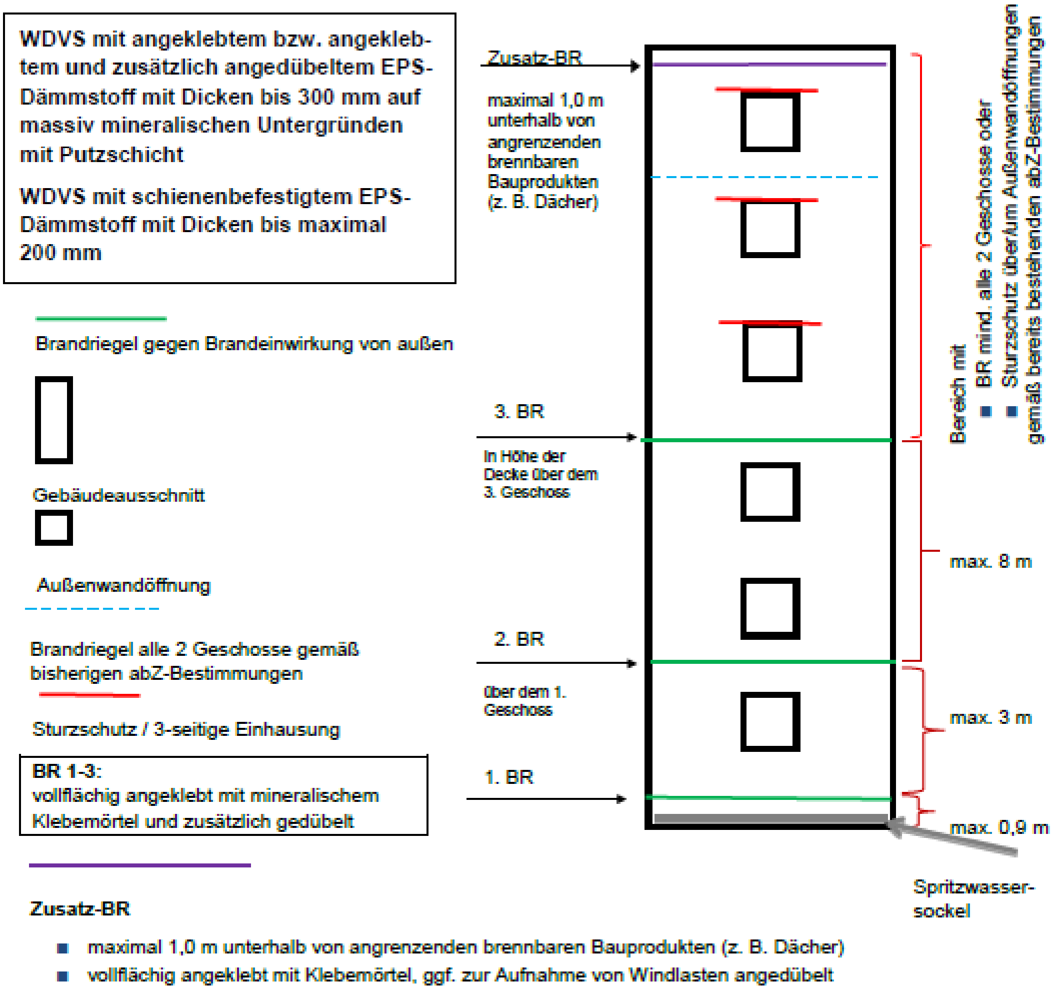


Figure 60. Additional mineral wool belts required from 2016: green and violet lines. Mineral wool belt as require prior to 2016: blue dotted line.

Separation between buildings

Requirements relating to this were not reviewed.

Separation of vertical openings

Requirements relating to this were not reviewed.

Sprinkler protection

Sprinkler protection is generally required for all building types where the height exceeds 22 m or where maximum compartment size limits are exceeded.

7.7 USA Building codes

The United States have two building codes:

1) The International Building Code (IBC) is both a prescriptive and performance-based building code that is adopted by most states.
2) National Fire Protection Association (NFPA) 5000 is an alternate building code that is adopted by some states.

Key differences in fire safety requirements for external wall assemblies exist between the two codes, however both request similar testing standards to be undertaken to seek compliance.

7.7.1 INTERNATIONAL BUILDING CODE (IBC), USA

The International Building Code (IBC) is a model building code developed by the International Code Council (ICC). It has been adopted throughout most of the United States. In many cases the IBC may only be adopted in part or with modifications in various States within America.

Buildings are classified into 5 different types of construction having a decreasing level of fire resistance in the following order; Type I, Type II, Type III, Type IV and Type V. Building classes having lower levels of fire resistance are limited to low building heights. Type V construction has the lowest fire resistance and is typically timber framed construction.

External wall reaction to fire

The general performance requirement for combustible external wall systems is that for buildings of Type I, II, III or IV construction that are greater than 12.192 m in height, combustible external walls must be tested and comply with NFPA 285 full scale façade test (IBC Section 1403.5).

However, the IBC also gives detailed reaction to fire requirements for specific types of materials such as MCM (ACP) etc. The following are the requirements relevant to EIFS and ISP. It is presumed that if these specific requirements are met then demonstration of compliance with the NFPA 285 test is not required.

<u>Combustible external wall coverings:</u>

Buildings of Type I, II, III or IV construction are permitted to have combustible external wall coverings if they meeting the following requirements

- Combustible coverings ≤ 10% of external wall surface area where fire separation distance is ≤ 1.524 m.
- Combustible coverings limited to 12.192 m in height.
- Fire retardant treaded wood is not limited in area at any separation distance and is permitted up to 18.233 m in height.
- Ignition resistance – combustible external wall coverings must be tested in accordance with NFPA 268 applying the following criteria (wood-based products and combustible materials covered with a listed acceptable material of low combustibility are excluded);

- Fire separation ≤ 1.524 m –combustible coverings shall not exhibit sustained flaming.
- Fire separation > 1.524 m - the acceptable fire separation distance is dependent on the maximum radiant heat flux that does not cause sustained flaming and ranges from 1.524 m separation at 12.5 kW/m^2 to 7.62 at 3.5 kW/m^2.

Foam Plastic Insulation (ICC Section 2603)

Foam plastic insulation in or on external walls without a thermal barrier separation from the interior is permitted for one storey buildings with the following requirements:

- Flame spread index of ≤ 25 and a smoke developed index of ≤450 (ASTM E 84 or UL 723).
- Foam plastic thickness ≤ 102 mm.
- Foam plastic covered by ≥ 0.81 mm aluminium or ≥ 0.41 mm steel.
- Building must be sprinkler protected.

Any Height

- Separated from building interior by approved thermal barrier of 12.7 mm Gypsum wall board or equivalent.
- Insulation, exterior facings and coatings shall be tested separately to ASTM E 84 or UL 723 and shall have a flame spread index of ≤ 25 and a smoke developed index of ≤450. (aluminium composite panels of ≤ 6.4 mm are permitted to be tested as an assembly).
- Potential heat of foam plastic shall be determined applying NFPA 259. The potential heat of the foamed plastic in the installed walls shall not exceed that of the material tested in the full-scale façade test.
- The complete wall assembly must be tested and comply with NFPA 285 full-scale façade test.

Special Approval – Special approval may be provided without compliance with the above requirements based on large scale room corner tests such as NFPA 286, FM 4880, UL 1040 or UL 1715 if these tests are determined to be representative of the end use configuration.

EIFS

EIFS must meet the requirements of ASTM E2568[98].

Fire Stop Barriers

Internal gaps (e.g. between compartment floors on the inside face of a wall such as a curtain wall) must be fire stopped with an approved material having a fire resistance at least equivalent to the compartment (ICC Section 715).

Fire Blocking, using non-combustible materials such as mineral wool is to be installed within concealed spaces of external wall coverings at maximum intervals of 6.096 m (both horizontally and vertically) so that the maximum concealed space does not exceed 9.3 m^2..

Use of fire stop barriers imbedded in EIFS may be specified in ASTM E2568.

Separation between buildings

For non-sprinkler protected buildings, no unprotected openings are permitted at a separation distance of less than 5 ft. The percentage of unprotected openings permitted increases to no limit at 30 ft.

For sprinkler protected buildings, no unprotected openings are permitted at a separation distance of less than 3 ft. The percentage of unprotected openings permitted increases to no limit at 20 ft.

Separation of vertical openings

For buildings more than 3 storeys in height which are not sprinkler protected openings must be separated from openings in the storey above by (IBC Section 705.8.5) either:

- the lower storey opening has a protection rating of at least ¾ hour, or
- A 915 mm spandrel with 1-hour fire resistance, or

- A 760 mm horizontally projecting barrier with 1 hr fire resistance.

Sprinkler protection

Typical thresholds above which sprinkler systems are required in the *International Building Code* (IBC) include:

- Mercantile: Over 12,000 ft^2 (1115 m^2) in one fire area, or over 24,000 ft^2 (2230 m^2) in combined fire area on all floors, or more than 3 storeys in height.
- High-Rise: All buildings over 75 ft. (22.86) m in height. However, sprinklers are also required for all buildings with a floor level having an occupant load of 30 or more that is located over 55 ft. (16.8 m) in height (IBC 903.2.11.3).
- Residential Apartments: All buildings except townhouses built as attached single-family dwellings.

7.7.2 NFPA 5000, USA

NFPA 5000 was developed as an alternative building code to the IBC. However, in practice NFPA 5000 is not adopted by most states of America. The IBC is the model building code currently most adopted within the USA.

Buildings are classified into 5 different types of construction, the same as for the IBC.

External wall reaction to fire

NFPA 5000 Section 7.2 states that the general flammability requirement for all external walls for building class Type I, Type II, Type III and Type IV are required to meet the requirements of the large-scale façade test NFPA 285.

However, the following specific requirements for different types of external wall materials are also stated.

Foam plastic Insulation requirements are stated in NFPA 5000 section 48.4.1. Foamed plastics used in external walls for Type I, Type II, Type III and Type IV buildings must comply all of the requirements in Table 18.

Table 18 Foamed plastic insulation requirements for Type I, Type II, Type III and Type IV buildings

Property	Requirement
Thermal barriers	Foam plastic insulation must be separated from the building by an acceptable thermal barrier such as 13 mm gypsum board or a material meeting temperature transmission and integrity requirements of NFPA 275.
Flame spread index and smoke developed index	Insulation, exterior facings and coatings shall be tested separately to ASTM E 84 or UL 723 and shall have a flame spread index of ≤ 25 and a smoke developed index of ≤450. (aluminium composite panels of ≤ 6.4 mm are permitted to be tested as an assembly)
Wall assembly flammability	The complete wall assembly must be tested and comply with NFPA 285 full-scale façade test
Potential heat content	Potential heat of foam plastic shall be determined applying NFPA 259. The potential heat of the foamed plastic in the installed walls shall not exceed that of the material tested in the full-scale façade test.
Ignition characteristics	External wall shall not produce sustained flaming when tested to NFPA 268 (ignitability of external walls using radiant heat). This requirement does not apply when the assembly is protected on the outside facing with complying facings such as 13 mm gypsum board, 9.5 mm glass reinforced concrete, 22mm Portland cement plaster, 0.48 mm metal faced panels or 25 mm concrete or masonry.

Insulation other than foamed plastic, including vapour barriers and reflective foil insulation, must comply with the following requirements when tested to ASTM E 84 or UL 723 (NFPA 5000 Section 8.16):

- Concealed insulation – flame spread index of ≤ 75 and a smoke developed index of ≤450.
- Exposed insulation - flame spread index of ≤ 25 and a smoke developed index of ≤450.

EIFS must be specified and installed in accordance with EIMA 99A (NFPA 5000 Section 37.5).

Fire stop barriers

Internal gaps (e.g. between compartment floors the inside face of a wall such as a curtain wall) must be fire stopped with an approved material having a fire resistance at least equivalent to the compartment

Use of fire stop barriers imbedded in EIFS or internal cavities of external wall systems are not specifically stated but would typically be required for compliance with the full-scale façade fire test and EIFS Standards/guidelines specified.

Separation between buildings

The critical distance for separation of buildings from the boundary in terms of protection of openings is 3 m. No unprotected openings are permitted at a separation distance of 3 m or less. At greater than 3 m the percentage of unprotected opening area permitted for external walls gradually increases to 100 % at a separation distances of >10 m for most building types and > 30 m for industrial and storage type buildings with ordinary and high hazard contents.

Separation of vertical openings

For buildings more than 4 storeys in height which are not sprinkler protected openings must be separated from openings in the storey above by (NFPA 5000 Section 37.1.4) either:

- Protection of openings sect 7.3; or
- A 915 mm spandrel with 1-hour fire resistance.
- A 760 mm horizontally projecting barrier with 1 hr fire resistance.

Sprinkler protection

Typical thresholds above which sprinkler systems are required in NFPA 5000, *Building Construction and Safety Code*, 2012 Edition include:

- Mercantile: Over 12,000 ft^2 (1115 m^2) in gross fire area or three or more storeys in height.
- High-Rise: All buildings over 75 ft. (22.9 m) in height.
- Residential Apartments: All buildings except those in which each unit has individual exit discharge to the street.

8 Industry bodies, guidelines, standards and codes of practice.

8.1 Australia

8.1.1 PLASTICS AND CHEMICALS INDUSTRIES ASSOCIATION (PACIA)[99]

PACIA is the peak body representing all sectors of the Australian plastics and chemicals industry, and includes industry members in chemical manufacturing, importers and distributers, logistics and supply chain partners, raw material suppliers, plastics fabricators, compounders, recyclers and service providers. Other Australian industry bodies such as IPCA and EPSA (see below) which have more direct relevance to the Australian building industry appear to either have formed as an offshoot of, or have close alliance with PACIA.

A certificate titled "*Industry Code of Practice, External Insulation Finishing Systems (EIFS), EIFS Manufacturing and installation responsibilities*"[25] dated 2010, which appears to be endorsed by PACIA, was found on the Insulcon Pty Ltd website (Insulcon Pty Ltd is a manufacture/supplier of EIFS using EPS insulation board and accessories). The certificate:

- Only lists 5 Australian EIFS suppliers as signatories:
    - EzyClad Pty Ltd,
    - Insulcon Pty Ltd,
    - Multitex Corporation Pty Ltd,
    - The Render Warehouse Pty Ltd and
    - Unitex Pty Ltd.
- Is only 1 page and not very detailed. It dot point lists responsibilities of the system supplier, installer and builder/developer/building surveyor.
- It does not state any direct fire safety requirements. It requires the systems to be installed in accordance with the supplier's manuals.

All five suppliers/manufacturers are still in operation however no further information on the 2010 Industry Code of Practice was found on the PACIA website or elsewhere. It is suspected that since 2010, this Industry Code of Practice for EIFS has dissolved.

8.1.2 EXPANDED POLYSTYRENE AUSTRALIA INCORPORATED (EPSA)[100]

EPSA is an industry body for manufacturers and distributors of EPS products within Australia. EPSA is formed around five sector groups representing the EPS industry in Australia being:

- Block – Block moulded EPS used for building and construction industry.
- Packaging.
- Pod – under slab void filler pods used in building slab construction.
- Raw materials.
- EPS recyclers.

EPSA Block sector group represent Australian manufacturers of moulded EPS that are used within EIFS and ISP systems. EPSA has supported IPCA (see below) to develop an Industry Code of Practice for the manufacture and installation of ISP.

The EPSA website states that it requires members to use flame retardant material in al EPS products manufactured for the building industry.

The EPSA website states that "*recently the Block Group has supported the establishment of an Exterior Insulation Finishing Systems (EIFS) industry group. The major activities of this group include developing standards and a code of practice for the employment of EPS as a barrier cladding system for domestic housing"*. However no further published information regarding this group or development of standards or a code of practice could be found by the authors of this literature review (except for the 2010 EIFS code of practice certificate by PACIA above). The scope of this literature review did not include contacting such industry groups to pursue further information, however this is included as a recommendation for further work at the end of this report.

8.1.3 INSULATED PANEL COUNCIL AUSTRALASIA (IPCA)[101]

IPCA was formerly known as the Panel Manufacturers Group and was formed in 2007 as a sector of the Plastics and Chemicals Industries Association (PACIA)'s EPS Australia (EPSA Inc.). IPCA was established to represent a wider interest of its members who produce, supply and install ISP systems, however still has a close alliance of EPSA Inc., PACIA and Plastics New Zealand.

In 2017, IPCA issued a *Code of Practice* document[26] that sets out minimum requirements for ISP installation however this is focused on large internal rooms/compartments (cool rooms) within Class 7 and 8 Buildings and rooms < 20m^2 internal to other building classes. The installation requirements appear to be based on minimum fixing requirements needed for EPS-FR core steel faced ISP to achieve Group 1 when tested to AS/ISO 9705. It does not provide installation requirements specifically for external wall façade applications. The IPCA code of practice includes the following minimum standards and principles:

a) Fire retardant treatment to the EPS core in accordance with AS1366.3 1992.
b) All Panels to achieve Group 1 classification (Spec C1.10 -Fire hazard properties) as per the National Construction Code (NCC) by meeting AS/ISO 9705 or FM Class 1, with the additions noted in this CODE including perimeter suspension.
c) A labelling system to allow fire fighters to identify buildings, compartments or rooms which have been constructed using ISP and EPS-FR Panel Systems. The Labelling system consists of a key diagram, numbered Compliance Plates and Insulated Panels to be labelled with the Compliance Plates. The Panel Labels will be located at doorways into Code Compliant Areas of the building. See Figure 61 for examples.
d) Location of strategic fire plans at entrance, Control room or other appropriate place such as within a FIP panel.
e) Establishment of a Certification body to send copies of Certificate of Compliance/Exception to the relevant Fire Brigade along with an annual list of Certified Buildings. This will aim to assist fire fighters to prepare Pre-Incident Plans and undertake site inspections.
f) Evidence to support the provisions of the appropriate panels in areas where elevated temperatures are prevalent such as near cooking equipment or similar heat generation equipment/processes.
g) Design of appropriate Insulated Sandwich Panel and Expanded Polystyrene Panel joint and fixings to assist in the prevention of delamination and skin separation.
h) Implementation of a Certification Scheme – to govern the design and installation of ISP and EPS-FR Panels Systems are in accordance with the principles and requirements of the CODE.
i) An audit system established that verifies that the improvements and benefits are actually implemented.
j) The provision of post construction occupancy recommendations for better 'housekeeping' and emergency procedures that include:
    i) Regular inspection and maintenance regime for each Code Compliant ISP and EPS-FR Panel System;
    ii) Risk Management planning for the sites with 'Safe Work' and 'Hot Work' permits;
    iii) Emergency procedures planning; and
    iv) Training to ensure experience, knowledge and standards remain relevant and applied.

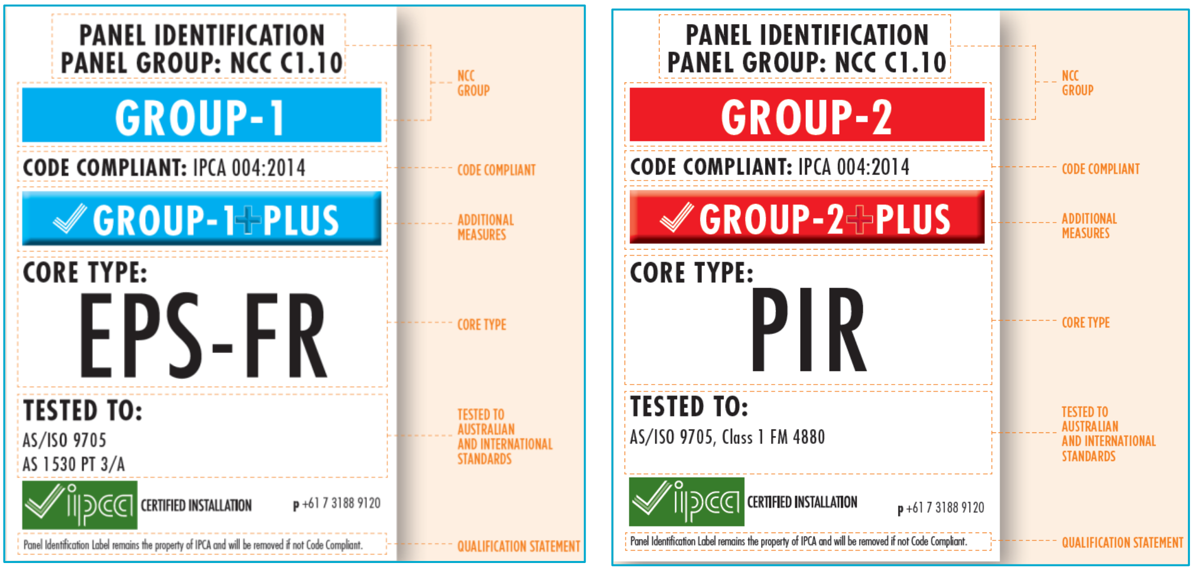


Figure 61 - Examples of Compliance Plates showing key information for identification of the type of insulation panel installed.

Whilst the IPCA code of practice for ISP is well written and is based upon documented research and testing, it does not appear to directly apply to ISP use as external walls for buildings requiring Type A and B construction.

8.1.4 OTHER RELEVANT GUIDELINES OR PRACTICE NOTES ISSUED RECENTLY IN VICTORIA.

Since the 2014 Lacrosse fire there have been a number of relevant guidelines or practice notes issued in Victoria. These include

- Ministers Guideline MG-14[102] states that for Type A or B construction building surveyors should not be satisfied that prescribed combustible products, being ACP with 30% or more ACP by weight, or rendered EPS, comply, unless a determination is made by the BAB.
- Building product safety alert for use of ACP and EPS as external wall cladding[103] – explains MG-14 and provides further detail on the potential fire hazards of these materials.
- ABCB Advisory Note 2016-3 Fire performance of external walls and cladding[104]. Provides clarifying advice regarding NCC requirements relating to fire performance of external walls. Has been updated to reflect 2018 Amendment to NCC 2016.
- VBA Industry alert External walls and BCA compliance[105] – Summarises NCC Requirements for fire performance of external wall materials. Not updated for NCC 2018 amendment.
- CSIRO fire safety guideline for external walls[106] – summarises NCC requirements, test methods and evidence of suitability. This guideline has not been updated for NCC 2018 amendment or NCC 2019.

Numerous other resources are provided at the VBA Resources for practitioner’s website. https://www.vba.vic.gov.au/cladding/practitioner-resources

8.2 New Zealand

8.2.1 NZ METAL AND WALL CLADDING CODE OF PRACTICE

The NZ Metal roof and wall cladding code of practice is published by NZ metal roofing manufacturers Inc. it provides a design & installation guide primarily for metal cladding and roofing in NZ, and is a recognised related document for Acceptable Solution E2/AS1 of the NZ Building Code. Most of it focuses on non-combustible metal cladding materials, however a small section (Section 15.5) addresses use of ISP for external wall and roof cladding:

- A brief fire safety section is provided which in summary states *"Aluminium-skinned composite panels, nylon bolts or polystyrene cores must not be used where the building is required to have a fire rating or is considered a likely fire risk".*
- A brief section on fixings states that ISP roof and external wall cladding must be through fixed (through both facings) to the supporting structure.

8.3 Europe

8.3.1 EUROPEAN ASSOCIATION FOR ETICS (EAE)[107]

EAE was founded in 2008. It is the main industry body in Europe for EIFS. The members of the EAE include 12 national ETICS associations, six major European supplying materials associations and nine supporting members, which include ETICS manufacturers as well as research institutes. The EAE represents about 80 per cent of Europe‘s revenue from ETICS.

EAE has published the "European Guideline for application of ETICS"[23]. It provides a guideline based upon:

- ETAG 004 Guideline for European technical approval for external thermal insulation composite systems with rendering.
- ETAG 014 Guideline for European technical approval for plastic anchors for thermal insulation composite systems.
- EN 13162 Thermal insulation materials for buildings – factory-made mineral wool (MW) products – specification.
- EN 13163 Thermal insulation materials for buildings – factory-made expanded polystyrene (EPS) products – specification.

The EAE guideline is extensive (~100 pgs.) and presents guidance on best practice for materials and installation. Due to the lack of harmonisation of requirements between European countries the EAE Guideline simply states that local Building codes and standards as well and supplier's manuals must be complied with. It does not provide any specific fire safety requirements, but drawings of example installation details include mineral wool fire barriers installed above window transoms and between building storeys.

8.3.2 EUROPEAN ORGANISATION FOR TECHNICAL APPROVALS (EOTA)[108]

EOTA was established in 1990 in Belgium. EOTA's primary purpose is the drafting of European Technical Assessment (ETA) documents which provide information and assessment of the performance construction products. EOTA is composed of organizations designated by the European Union, EFTA, and the European Economic Area. Typical members are the national Technical Assessment Bodies of each member state.

EOTA publish European Technical Approval Guidelines (ETAGs) which are to be used by European Technical Assessment Bodies for issuing European Technical Assessments (ETAs). They provide guidance on the performance requirements and testing and verification methods required for particular types of products.

ETAG 004 is the *"Guideline For European Technical Approval Of External Thermal Insulation Composite Systems (ETICS) With Rendering"*. It applies specifically for assessment of ETICS systems bonded or fixed to solid substrates and does not apply for direct fixing to light weight framing without a substrate. It sets requirements and clarifies tests required to verify performance related to:

- Mechanical resistance and stability.
- Fire safety.
- Hygiene health and environment (including weather proofing).
- Safety in use (including fixing strength and wind load resistance).
- Noise.
- Energy and thermal performance.
- Durability/ageing.

For fire safety it simply required ETICS components and systems to be classified for flammability in accordance with EN 13501-1[109] euro classification tests. Annex D of ETAG 004 sets requirements on how to test ETICS components or systems in accordance with the EN 13501-1 set of reaction to fire tests to ensure that the worst-case arrangements for ETICS components or systems are tested. ETAG 004 does clarify that additional building code, regulation or standard requirements will apply in each country.

8.3.3 EUROPEAN ASSOCIATION FOR PANELS AND PROFILES[110]

The European Association for Panels and Profiles is one of the main industry bodies for ISP in Europe. They operate a quality assurance and certification system for ISP called EPAQ. They publish a document called "quality regulations for sandwich panels"[111] which specifies requirements, auditing and tests for sandwich panel products to be issued with an EPAQ quality certificate. This deals with ISP products and not their application or installation on buildings. Regarding reaction to fire it only requires the core material to be tested to EN ISO 11925-2 (small flame test) and achieve class Cs3d0.

8.3.4 BR135 – FIRE PERFORMANC OF EXTERNAL THERMAL INSULATION FOR WALLS OF MULTI-STOREY BUILDINGS.

BRE published BR-135 as a guidance document which also specifies the pass-fail criteria to be applied for assessment of BS 8414 façade fire tests in the UK. It covers:

- The various types of combustible cladding and insulation used
- Guidance on fire performance design principles for external cladding systems
- Criteria and classification method for BS8414 facade tests.

In particular BR135 recommends the inclusion of fire barriers within EIFS and cavities and testing in accordance with BS 8414.

8.4 USA

The USA appears to have numerous industry bodies relevant to EIFS and ISP including

- Insulation Contractors Association of America.
- Polyisocyanurate insulation manufacturer association.
- Society of the Plastics Industry.
- Extruded Polystyrene Foam Association.
- Association of the Wall and Ceiling Industry.
- EPS Industry Alliance.
- Extruded Polystyrene Insulation Association.
- EPS Molders Association (EPSMA).
- Energy Efficient Foam Coalition.

- Centre for Polyurethane Industry.
- EIFS Industry Members Association.
- Metal Construction Association's Insulated Metal Panel Group.

It is not practical to summarise all of these industry bodies. However the two most relevant industry bodies appear to be:

- EIFS Industry Members Association.
- Metal Construction Association's Insulated Metal Panel Group.

8.4.1 EIFS INDUSTRY MEMBERS ASSOCIATION (EIMA)[112]

EIMA, founded in 1981, is the main industry body representing EIFS suppliers, manufacturers, distributors and contractors in the USA.

EIMA sponsored the publication of ANSI/EIMA 99 – A-2001: American National Standard for EIFS[24]. This standard sets requirements for:

- Product Delivery, Storage and Handling.
- Quality Assurance.
- Contractor Requirements.
- Submittals Prior to Commencement of Work.
- Environmental and Weather Conditions (during installation).
- Manufacturers.
- Materials (types of materials to be used).
- Performance Characteristics (durability, fire, impact and structural).
- Installation.

The standard requires self-certification of the materials and systems, contractor expertise, and installation by the manufacturers and contractors themselves. It does not refer to any independent national EIFS inspection and certification scheme.

The standard specifies the following fire performance tests for the complete EIFS system:

Figure 62. ANSI/EIMA 99 – A-2001 fire performance tests for the complete EIFS system.

Characteristic (as stated in ANSI/EIMA 99-A-2001)	Test Method	Type of test	Acceptance Criteria (as stated in ANSI/EIMA 99-A-2001)
Fire Endurance	ASTM E119	Fire resistance test	Maintain fire resistance of known, rated wall assembly
Full Scale Diversified Fire Test	Modified ASTM E108		No significant contribution to vertical or horizontal flame spread
Full Scale Multi-Storey Fire Test	UBC Standard 26-4	Façade fire test (predecessor to NFPA285, slightly larger scale and applies timber crib ignition source)	1. Resistance to vertical spread of flame within the core of the panel from one storey to the next. 2. Resistance to flame propagation over the exterior surface. 3. Resistance to vertical spread of flame over the interior surface from one storey to the next. 4. Resistance to significant lateral spread of flame from the compartment of fire origin to adjacent spaces.
Intermediate Scale Multi-Storey Fire Test	ANSI/NFPA 285 (UBC Standard 26-9)	Façade fire test	1. Resistance to vertical spread of flame within the core of the panel from one storey to the next. 2. Resistance to flame propagation over the exterior surface. 3. Resistance to vertical spread of flame over the interior surface from one storey to the next. 4. Resistance to significant lateral spread of flame from the compartment of fire origin to adjacent spaces.
Radiant Heat Exposure	ANSI/NFPA 268	External wall radiant heat exposure test	No surface ignition when exposed to 12.5 kW/m2.

The standard specifies the following fire performance tests to be done individually on the insulation board and render:

Figure 63. ANSI/EIMA 99 – A-2001 fire performance tests for individual EIFS components

Characteristic (as stated in ANSI/EIMA 99-A-2001)	Test Method	Type of test	Acceptance Criteria (as stated in ANSI/EIMA 99-A-2001)
Surface Burning	ASTM E84	Steiner tunnel flame spread test	Insulation board and reinforced coating system shall each separately have a flame spread of 25 or less, and smoke developed of 450 or less.

8.4.2 METAL CONSTRUCTION ASSOCIATION'S (MCA) INSULATED METAL PANEL GROUP[113]

The MCA is a key industry body representing a range of metal construction product types in the USA. They represent the ISP industry in the USA via a sub-group called the Insulated Metal Panel Council.

They publish a range of information relevant to application of ISP as external walls including:

- Selection Guideline for Insulated Metal Panels - Published 10/2017 – This provides a guideline for product testing and certification (including fire), and installation including external walls. Regarding fire safety requirements it simply refers to the IBC IMP requirements and states that additional requirements from insurance industry may apply.
- Best Practices for Installing IMPs-5-Part Video Series – short videos including external wall installation.
- Fire Safety of Insulated Metal Panels - Published 07/2018 – Research paper reviewing the typical fire performance and test requirements for ISP applied as external walls.
- Insulated Metal Panels and NFPA 285 - Published 11/2013 – Paper clarifying how NFPA 285 is applied to ISP's and where variations to tested systems may be accepted via assessment.

8.4.3 ASTM E2568 STANDARD SPECIFICATION FOR EXTERIOR INSULATION AND FINISH SYSTEMS[98]

ASTM E2568 is the standard referenced as the requirement for EIFS by the IBC. It states requirements for waterproofing, physical properties of component materials, fire performance, structural performance and impact performance. It does not state any requirements for installation methods, inclusion of fire barriers, or certification/qualifications of suppliers/installers or post construction inspection and certification.

Figure 64. ASTM E2568 fire performance tests for the complete EIFS system.

Characteristic (as stated in ASTM E2568)	Test Method	Type of test	Acceptance Criteria (as stated in ASTM E2568)
Fire Endurance	ASTM E119	Fire resistance test	Maintain fire resistance of known, rated wall assembly
Intermediate Scale Multi-Storey Fire Test	ANSI/NFPA 285 (UBC Standard 26-9)	Façade fire test	1. Resistance to vertical spread of flame within the core of the panel from one storey to the next. 2. Resistance to flame propagation over the exterior surface. 3. Resistance to vertical spread of flame over the interior surface from one storey to the next. 4. Resistance to significant lateral spread of flame from the compartment of fire origin to adjacent spaces.
Radiant Heat Exposure	ANSI/NFPA 268	External wall radiant heat exposure test	No surface ignition when exposed to 12.5 kW/m2.

The standard specifies the following fire performance tests to be done individually on the insulation board and render:

Figure 65. ASTM E2568 fire performance tests for individual EIFS components

Characteristic (as stated in ASTM E2568)	Test Method	Type of test	Acceptance Criteria (ASTM E2568)
Surface Burning	ASTM E84	Steiner tunnel flame spread test	Insulation board and reinforced coating system shall each separately have a flame spread of 25 or less, and smoke developed of 450 or less.

8.5 Insurance companies

8.5.1 FM GLOBAL

FM Global is an American mutual insurance company with offices worldwide, that specializes in loss prevention services primarily to large corporations in the Highly Protected Risk property insurance market sector. A strategy for FM Global is providing building product testing and approvals schemes through a section of the company called FM Approvals. FM Approvals approves ISP and EIFS for use on external walls up to various height restrictions or to unlimited height by applying product testing, inspection and surveillance requirements defined in FM Approvals Standard 4881 for Class 1 External wall systems[114]. All fire test requirements are stated in FM Approvals standard 4880 [115]. Fire tests, including room corner tests, parallel panel tests, and 25 ft. and 50 ft. corner tests are required to determine Class 1 rating. In practice these are mainly applied to Insulated Sandwich Panels for industrial and storage type buildings. These requirements are applied within countries beyond the USA where FM Global is an Insurer.
The requirements are additional to any regional regulatory compliance requirements. FM Approvals does approve ISP systems that are used in Australia for their insurance purposes. However, FM approvals test requirements are not applied by the Australian building code and do not directly correlate to NCC requirements for Type A and B construction.

8.5.2 LPCB LOSS PREVENTION STANDARDS

The Loss Prevention Certification Board (LPCB) is a UK based certification body recognised by insurers internationally. LPCB publishes loss prevention standards which are used to certify materials. LPS 1181 part 1 is the relevant standard for external wall ISP and EIFS. Those products that pass the test are graded into 2 classes: -

- EXT A** - A product that satisfies the requirements of LPS 1181 part 1 and demonstrates fire resistance in accordance with LPS 1208 when tested to BS 476 part 21 or 22 (** is the insulation grade in minutes i.e. the resistance to the transfer of excessive heat).
- EXT B – A product that satisfies the requirements of LPS 1181 part 1 only.

This standard applies a large free-standing room fire test (10 m L x4.5 m W x 3 m H). In practice these are mainly applied to Insulated Sandwich Panels for industrial and storage type buildings.

8.5.3 UL (UNDERWRITERS LABORATORIES)

UL (formerly known as underwriters laboratories) is a global safety certification and testing company headquartered in Northbrook, Illinois. UL product category FWFO is [Exterior Wall Systems and Components] Exterior Wall Systems. This certification requires testing to ANSI/NFPA 285 and/or UL 2079 (Standard for Tests for Fire Resistance of Building Joint Systems), UL263 (fire resistance) and UL723 (flammability).

9 EIFS and ISP fire test methods

This section reviews the small-scale, intermediate-scale and full scale fire test methods that can be applied to the EIFS and ISP.

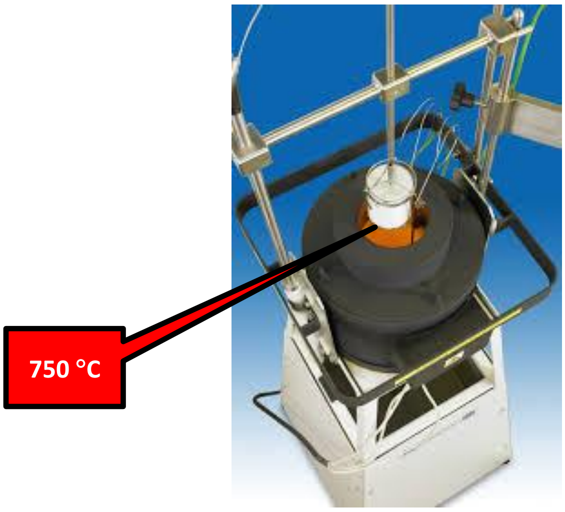
9.1 Small scale fire tests

9.1.1 COMBUSTABILITY TESTS

Combustibility tests are essentially used to determine if materials are combustible or non-combustible (will not contribute significantly to fuel load). The relevant Australian standard is AS 1530.1. Various standard test methods exist around the world including (ISO 1182, BS 476 part 4, ASTM E136, ASTM E2652, AS 1530.1)[116-120] however they are all fairly similar with some differences in furnace temperature and failure criteria.

In AS 1530.1 small specimens are exposed to a temperature of 750 °C within a small conical tube furnace. Criteria for non-combustibility are typically.

- The mean duration of sustained flaming (flaming longer than 5 s), is other than zero.
- The mean furnace thermocouple temperature rise exceeds 50°C.
- The mean specimen surface thermocouple temperature rise exceeds 50°C.



Many building codes around the world deem materials such as gypsum plaster suitable for use where non-combustible materials are required as they don’t necessarily meet the above test criteria for items such as flaming or mass loss.

External wall assemblies constructed entirely of non-combustible materials do not generally pose any hazard relating to enhanced fire spread.

9.1.2 CONE CALORIMETER

The cone calorimeter[121] is a small-scale oxygen consumption calorimeter. Specimens, 100 mm square are supported horizontally on a load cell and exposed to a set external radiant heat flux in ambient air conditions. The radiant heat source is a conically shaped radiator that can be set to impose any heat flux in the range 0-100 kW/m2 on the specimen surface. Ignition is promoted using a spark igniter. Combustion gases are extracted in an exhaust duct where instrumentation measures exhaust gas flow, temperature, O2, CO and CO2 concentrations and smoke optical density. From these measurements the following key quantities are calculated:

- heat release rate per unit area.
- mass loss rate.
- effective heat of combustion.
- smoke production can be calculated.
- Time to ignition at set heat flux exposures is determined by observation.

The cone calorimeter apparatus and procedure are described in ISO 5660, AS/NZS 3837 and ASTM E 1354[122-124].

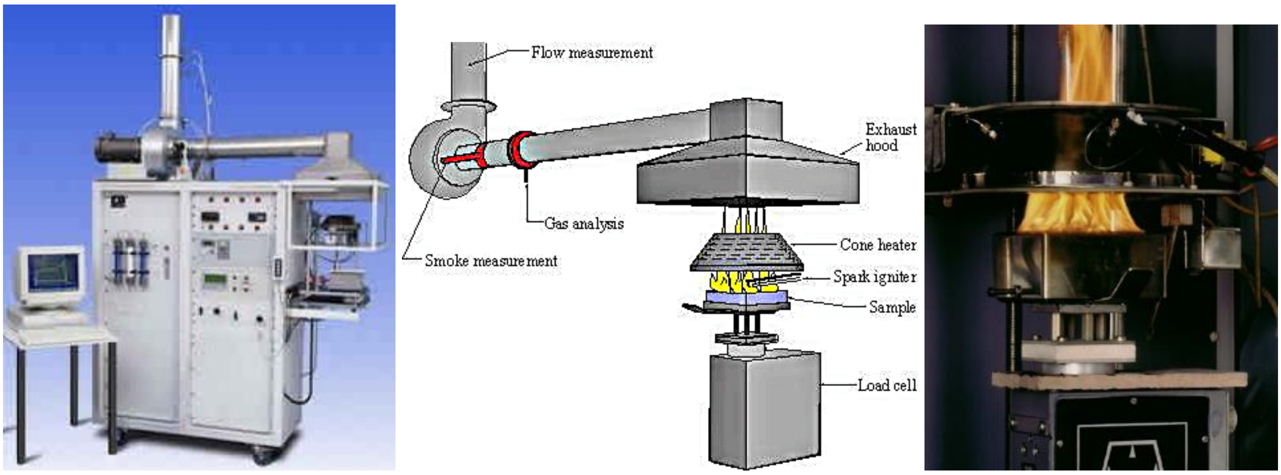


Figure 66. Cone Calorimeter (CSIRO)

The cone calorimeter attempts to measure fundamental flammability properties of materials that are required to predict material behaviour in real fires. Much research has been focused on predicting real fire behaviour based on cone calorimeter results, however the ability to make such predictions remains very limited. Some reasons for this are:

- The cone calorimeter method measures properties under set conditions which affect the properties attempting to be measured.
- The cone calorimeter does not directly measure all fundamental properties that may be required such as heat of volatilisation, heat capacity and thermal conductivity.
- The theoretical link between fundamental properties and real fire behaviour is complex and not well developed.

For materials which are complex composites with protective external layers that have a low combustibility the cone calorimeter often fails to predict the true hazard of the combustible core material which may become exposed in a full-scale fire due to fail of joints etc. This limitation is applicable to testing of EIFS or ISP with protective facings. The cone calorimeter also has similar limitation when testing materials with reflective surfaces due to the large amount of heat reflection. The cone calorimeter has similar limitations when testing materials which significantly melt or shrink away from the heat source (especially prior to ignition) as this can significantly reduce the heat flux received at the surface of the specimen. This limitation is applicable to EPS particularly when tested at lower heat fluxes.

The Cone calorimeter is applied by the NCC and AS5637.1 to predict time to flashover, expressed as “material group number” in the AS/ISO 9705 room corner test for wall and ceiling linings. However, there are significant limitations to this prediction correlation.

The cone calorimeter is a very complex apparatus requiring more maintenance and calibration than other small-scale fire apparatus. Erroneous data can easily be generated if the operator does not have a high level of competency.

Despite these limitations the cone calorimeter is still one of the most useful tools for determining flammability properties for materials.

9.1.3 AS 1530.3 (EARLY FIRE HAZARD TEST)

AS 1530.3, known as the early fire hazard test was originally intended for testing flammability of internal wall linings. A specimen 450 × 600 mm is mounted vertically opposite a vertical gas fired radiant panel (set to produce a heat flux of 2.4 kW/m2 measured 850 mm in front of panel. The specimen is incrementally advanced towards the radiant panel at a prescribed rate. A pilot flame is applied to the specimen surface to ignite pyrolysis gases. Movement of the specimen stops upon ignition. A radiometer measures radiant heat produced by ignition of the specimen. Smoke is collected in a hood and rises through a vertical duct where optical density is recorded. These measurements are used to express performance in terms the following Index’s (the lower the index the better the result):

- Ignitability Index (0-20)
- Spread of Flame Index (0-10)
- Heat Evolved Index (0-10)
- Smoke Developed Index (0-10).

These index results are not directly related to fundamental flammability properties or real fire performance. In the past this test has been applied to floor and ceiling linings and internal wall linings but has been demonstrated as inappropriate for these materials and to provide a poor assessment of hazard for materials that melt, materials with reflective facings or non-combustible skins. Similarly, this test does not provide suitable assessment or prediction of façade fire spread performance.

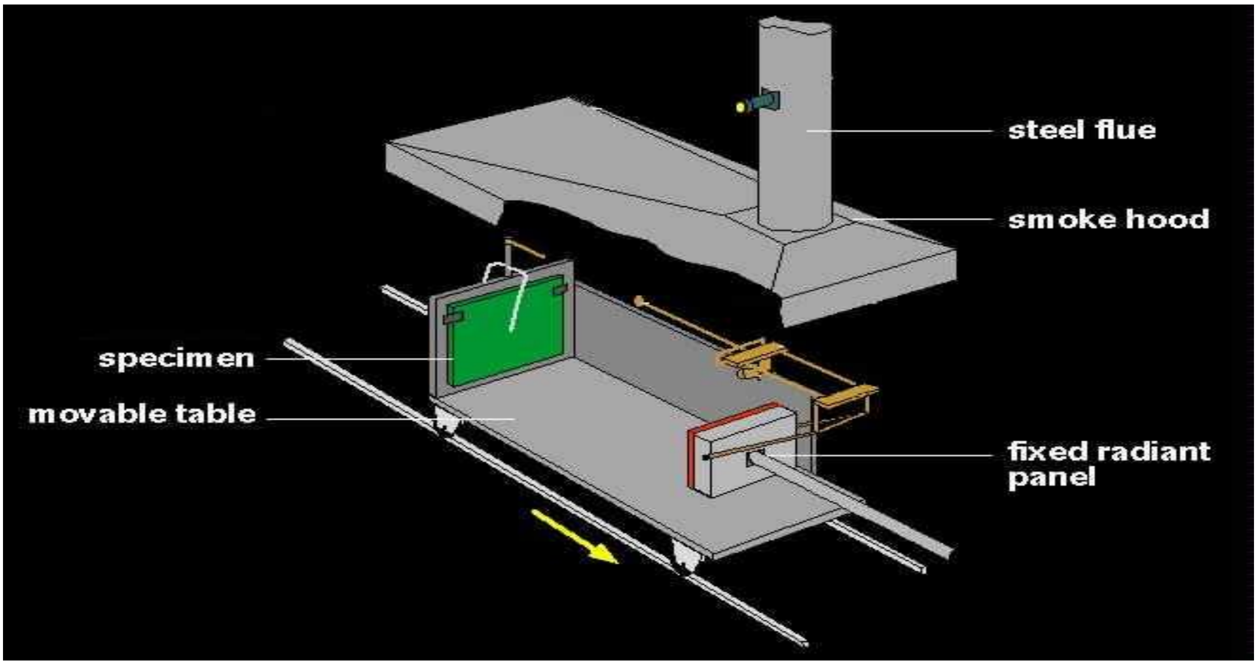


Figure 67 AS 1530.3 test.

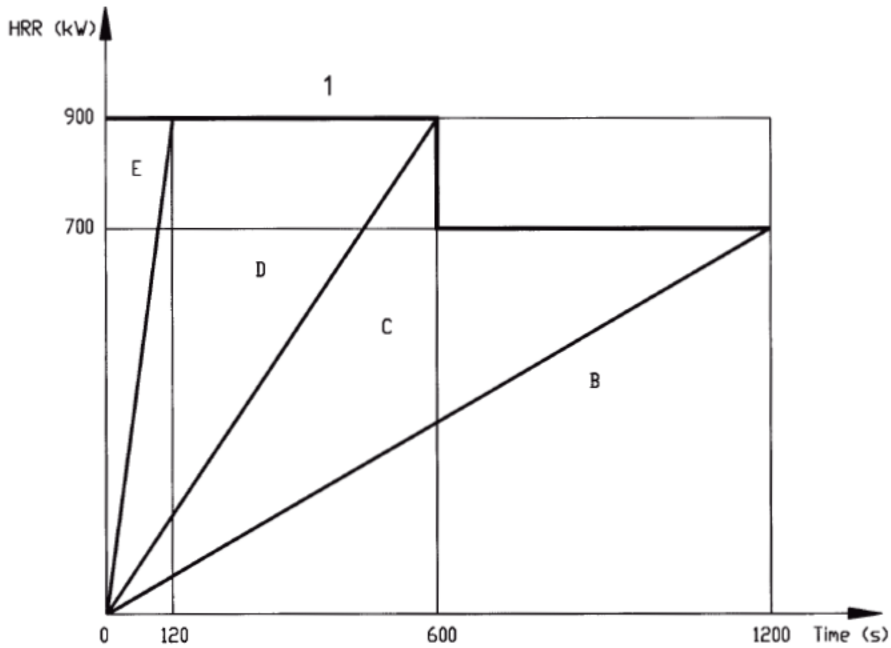
9.1.4 EUROCLASS TESTS

The Euroclass system for characterising reaction to fire behaviour of construction products is applied throughout most of Europe and is specified in EN 13501-1[109]. The Euroclass system was designed for controlling flammability of internal materials and does not specifically address external wall systems. However due to a lack of any uniform approach throughout Europe to control external wall systems via harmonised requirements for either small or large scale testing, individual European countries have resorted to either relying on Euroclasses or national large scale façade tests for control of external wall systems.

It is often applied to external wall systems.

For non-flooring materials the Euroclass system applies a range of small-scale tests and is intended to classify materials in terms of contribution to fire development for a scenario of a fire starting in a small room by a single burning object. As follows:

- Class A1 products are essentially non-combustible and will not contribute to fire growth nor to the fully developed fire
- Class A2 products have a very low combustibility and will not significantly contribute to the fire growth and fuel load in a fully developed fire
- Class B products are combustible, will not lead to a flashover situation but will contribute to a fully developed fire
- Class C-E products may lead to flashover at the reference scenario test times shown in Figure 68



Key
1 - Flashover
B - Class B/A2
C - No flashover for 100kW but flashover
D - Flashover after more than 2 min for 100 kW ignition source
E - Flashover before 2 min for 100 kW ignition source

NOTE HRR from the specimen exludes the burner

Figure 68. Relationship between Euroclasses and ISO 9705 room corner test time to flashover[109]

For non-flooring materials the four following tests are applied to determine the classification

EN ISO 1182 Non Combustibility[116] – See Section 9.1.1

EN ISO 1716, Gross calorific value[125]

This is an Oxygen Bomb Calorimeter test where a specified mass of material is burnt under standardised conditions within a confined volume combustion chamber with high oxygen concentration. The Gross calorific potential (heat of combustion) is calculated based on the measured temperature rise of the combustion chamber taking into account heat loss.

EN 13823 Single Burning Item (SBI) test[126]

The SBI test is an intermediate scale corner test conducted under an exhaust hood fitted with oxygen consumption calorimetry equipment and smoke meters (typically inside a test room with controlled makeup ventilation). Heat release rate (kW), total heat release (MJ) and smoke production rate (m^2/s) are measured. Flame spread and burning droplets are observed visually. The specimen is installed in a corner with a 1m wide x 1.5 m high long wing and a 0.49 m x 1.5 m high short wing. A 30 kW gas burner is located in the corner and the total test time is 21 minutes.

Figure 69. SBI test[127]

EN ISO 11925-2 small flame test[128]

- The specimens are ignited with a 20 mm high propane gas flame. The flame is impinged on the bottom edge of the specimen (edge exposure) or 40 mm above the bottom edge (surface exposure) or both. The specimen is exposed to flame for 15 seconds or 30 seconds.
- For each test specimen it is recorded whether an ignition occurs (flaming longer than 3 s), whether the flame tip reaches 150 mm above the flame application point and the time at which this occurs. The occurrence of burning droplets/particles is also observed.
- For each exposure condition a minimum of six specimens (250 mm x 90 mm) of the product shall be tested, three cut lengthwise and three crosswise

Materials are classified based on the above tests as shown in the following table.

Figure 70. EN 13501-1 Classes of reaction to fire performance for construction products excluding flooring and linear pipe thermal insulation products.

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

[a] For homogeneous products and substantial components of non-homogeneous products.
[b] For any external non-substantial component of non-homogeneous products.
[c] Alternatively, any external non-substantial component having a $PCS \leq 2{,}0$ MJ/m^2, provided that the product satisfies the following criteria of EN 13823: *FIGRA* ≤ 20 W/s, and *LFS* < edge of specimen, and $THR_{600s} \leq 4{,}0$ MJ, and s1, and d0.
[d] For any internal non-substantial component of non-homogeneous products.
[e] For the product as a whole.
[f] In the last phase of the development of the test procedure, modifications of the smoke measurement system have been introduced, the effect of which needs further investigation. This may result in a modification of the limit values and/or parameters for the evaluation of the smoke production.
s1 = $SMOGRA \leq 30$m^2/s^2 and $TSP_{600s} \leq 50$m^2; **s2** = $SMOGRA \leq 180$m^2/s^2 and $TSP_{600s} \leq 200$m^2; **s3** = not s1 or s2
[g] **d0** = No flaming droplets/ particles in EN 13823 within 600 s;
d1 = no flaming droplets/ particles persisting longer than 10 s in EN 13823 within 600 s;
d2 = not d0 or d1.
Ignition of the paper in EN ISO 11925-2 results in a d2 classification.
[h] Pass = no ignition of the paper (no classification);
Fail = ignition of the paper (**d2** classification).
[i] Under conditions of surface flame attack and, if appropriate to the end–use application of the product, edge flame attack.

9.1.5 BRITISH CLASSIFICATION TESTS

In addition to the non-combustibility test the UK Approved Document B previously applied the following British small-scale tests to external walls. However recent revisions to UK Approved Document B now only apply Euroclass tests to regulate external wall fire spread (in addition to BR135/BS8414 full scale façade fire test where applicable).

BS 476 part 6[129]

This fire propagation test was developed primarily for interior wall linings. The result is given as a fire propagation index. The test specimens measure 225 mm square and can be up to 50 mm thick. The apparatus comprises a combustion chamber attached to a chimney and cowl (with thermocouples). The chamber is heated using electrical elements and a gas burner tube is applied to the bottom of the test specimen. The test specimens are subjected to a prescribed heating regime for a duration of 20 minutes and the index obtained is derived from the flue gas temperature compared to that obtained for a non-combustible material.

BS 476 part 7[130]

This surface spread of flame test is used to determine the tendency of materials to support lateral spread of flame. The test specimen is rectangular, 925 mm long x 280 mm wide with thickness up to 50 mm. The vertical specimen is mounted perpendicular to a large 900 mm square gas-fired radiant panel. The radiant heat flux along the specimen decreases from 30 kW/m^2 at the near end to 5 kW/m^2 at the far end. Depending on the extent of lateral flame spread along the specimen, the product is classified as Class 1, 2, 3 or 4 with Class 1 representing the best performance.

BS 476 Part 11[131]

This test is very similar to the BS 476-part 4 non-combustibility test. Small samples are exposed to 750 °C in a small tube furnace and the occurrence of any flaming, specimen surface temperature, furnace temperature and specimen mass loss at end of test are measured. UK Approved document B uses this test to classify materials as having limited combustibility.

9.1.6 US BUILDING CODE TESTS

NFPA 268 – Determining ignitability of exterior wall assemblies using a radiant heat energy source[132]

This test evaluates the propensity for ignition of an exterior wall assembly when exposed to a radiant heat flux of 12.5 kW/m^2 and a pilot ignition source over a 20-minute test period. The test specimen must be 1.22 m wide x 2.44 m high. The gas fired radiant panel is 0.91 m x 0.91 m. The radiant panel is stationary, and the specimen is mounted on a trolley. The radiant heat flux exposure is controlled by the separation distance. This test only assesses risk of ignition from an external radiant heat source. It does not assess risk of ignition or flame spread from direct flame exposure.

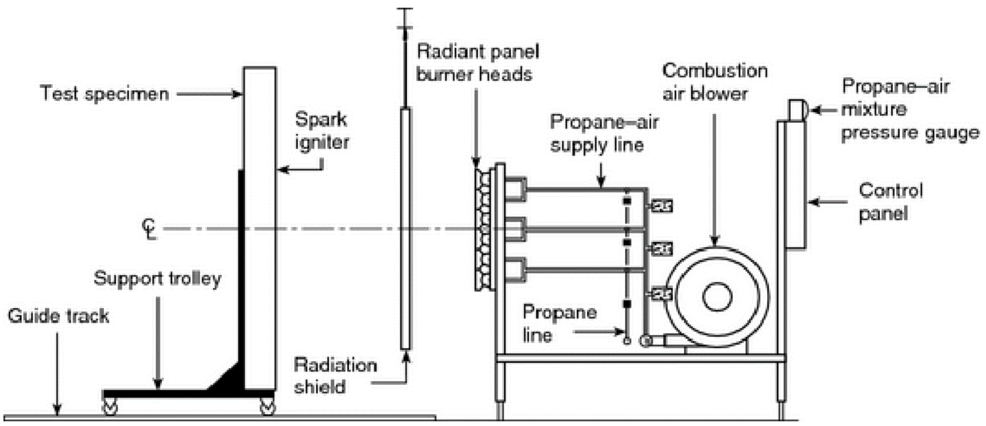


Figure 71. NFPA 268 test side view (from NFPA 268[132])

ASTM E 84, UL 723, NFPA 255 – Steiner tunnel test[133-135]

This test was originally developed for interior wall and ceiling linings and measures both flame spread and smoke production. The test is conducted inside a non-combustible horizontal tunnel/box that is 7.3 m long x 0.056 m wide x 0.305 m high. The specimen is mounted to the ceiling of the tunnel. Gas burners at one end of the tunnel provide a heat output of 89 kW and air and combustion products are drawn through the tunnel in the direction of fire spread at a controlled velocity of 73 m/min. The test duration is 10 minutes. Flame spread is measured by observation and smoke optical density is measured by an obscuration meter located in the exhaust duct. Results are expressed in terms of a flame spread index and a smoke developed index. Both indices are based on arbitrary scales where cement board has a value of 0 and red oak has a value of 100.

These indices cannot be easily used as basic fire engineering properties or correlated to performance in an exterior wall end use. This test does not properly assess thermoplastic materials which may tend to melt away from the assembly rather than spread flame in the horizontally prone test orientation.

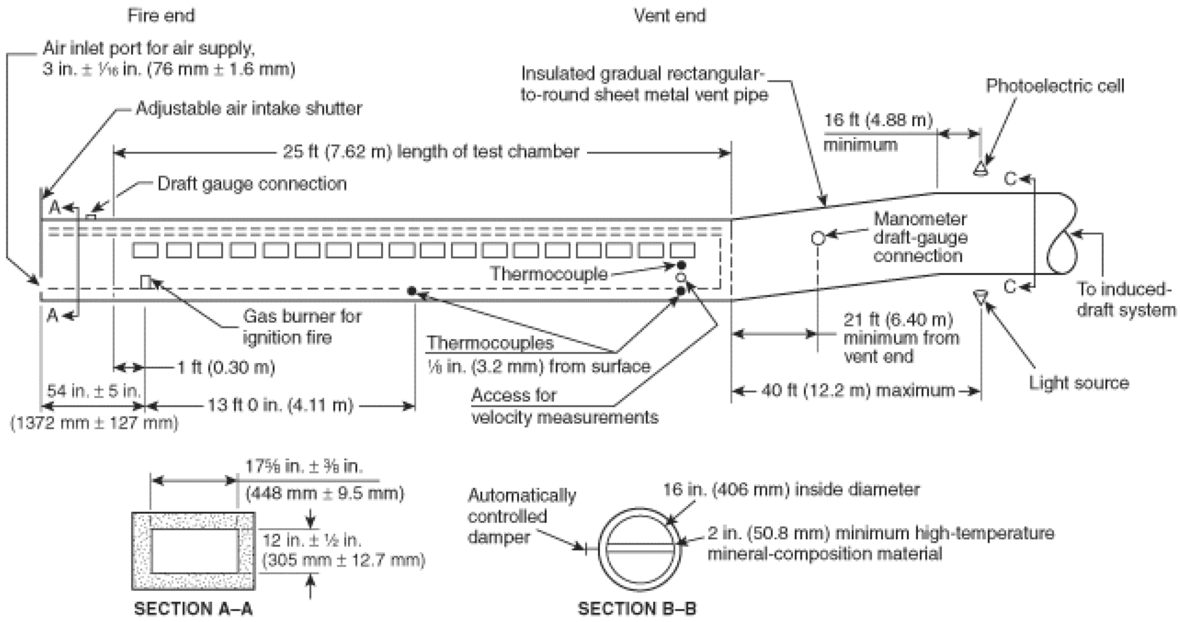


Figure 72. Steiner Tunnel Test (from NFPA255[134])

NFPA 259 – Potential heat of building products[136]

This test uses an oxygen bomb calorimeter to determine the heat of combustion for a material. It also specifies placing the same material in a muffle furnace at 750 °C for two hours and then testing the residue in a bomb calorimeter to determine the potential heat of the residue.

ASTM D 1929 standard test method for determining ignition temperature of plastics[137]

This test exposes small pellets of plastic materials to a controlled flow rate of heated air inside a tube furnace. This test measures the two following properties;

- Flash-Ignition Temperature – the lowest initial exposure air temperature at which the combustible gas evolved from the specimen can be ignited by a small external pilot flame.
- Spontaneous-ignition (Self-ignition) temperature -The lowest initial exposure air temperature at which unpiloted ignition of the specimen occurs indicated by an explosion, flame or sustained glow.

ASTM E108: Standard Test Methods for Fire Tests of Roof Coverings

Although this test method is designed primarily for combustible roof coverings it is applied by ANSI/EIMA 99 – A-2001 for EIFS (appears to be applied to EIFS in a modified form).

Roof systems can be tested to three classifications of different severity of testing parameters and criteria:

- Class A roof coverings are effective against severe fire test exposures.
- Class B roof coverings are effective against moderate fire test exposures.
- Class C roof coverings are effective against light fire test exposures.

There are six different test sections that the roof covering can be tested to depending on the type of roof covering and associated characteristics. The sections are: Spread of Flame test, Intermittent Flame test, Burning Brand test, Flying Brand test, Rain test, and Weathering test.

This test procedure utilizes a test apparatus which exposes a roof system to simulated wind conditions and fire sources (test specimen exposure simulates a fire originating from outside environment) by means of an inline blower and either a gas burner or burning brands. The test apparatus framework incline can be adjusted to different slopes as per the test sponsor's instructions, with the default test slope being 5 inches per horizontal foot. The blower is adjusted to simulate a 12 mile per hour wind condition over top of the roof covering. The gas burner (for intermittent-flame, spread of flame, and flying brand tests) is adjusted to 1400°F ± 50°F for Class A and B test exposures or 1300°F ± 50°F for Class C test exposure. The brands for Class A and Class B are constructed from 1-inch-by-1-inch wood strips spaced 1/4 in. The Class A brands are 12 inch by 12 inch by 2¼ inch, and Class B brands are 6 inch by 6 inch by 2¼ inch. Class C brands are 1½-inch-by-1½-inch-by-25/32-inch wood pieces with two 1/8-inch saw kerfs. Class A tests use a single brand, Class B tests use two brands, and Class C tests use 20 brands.

Figure 73. ASTM E-108 Spread of flame test

9.1.7 SMALL FLAME SCREENING TESTS

Small flame tests have been used and misused to test the flammability of materials since the 1930s. During the 1950s and 1960s there was an increased reliance on small flame tests but in recent years this reliance has decreased as new test methods that produce more useful measurements have been introduced[138]. Small flame tests have originated from a need to perform quick and cheap screening tests (such as holding a match to a material to see if it burns) Some methods have become overly complex given these origins. These methods assess the ease of ignition and the ability to sustain flaming under set laboratory conditions but do not provide useful data that can be used to predict fire behaviour for real fire scenarios. They can only be used for screening. Dripping of materials can unseat and extinguish flaming in these tests producing a good test result however in real fire scenarios the material may be orientated or restrained so that it either forms a molten pool or drips onto other combustible materials which may increase hazard of flame spread.

AS 1530.2 is an example of a small flame test which is applied by the NCC to regulate sarking material.

ASTM D 635[139] is an example of one small flame test which is used in the US IBC relating to external wall assembly including plastic panels and metal composite materials. This tests specimens 125 mm long x 13 mm wide in the horizontal position. A Bunsen burner flame is applied for a specified time and time to flame extinguishment, burn distance, linear burning distance and occurrence of flaming droplets are recorded. Other similar small flaming tests that may test in either the horizontal or the vertical position include UL94, IEC 60707, IEC 60695-11-10, IEC 60695-11-20, ISO 9772 and ISO 9773, and EN ISO 11925-2.

9.2 Room corner fire tests

A range of standard room corner test methods exist around the world. These tests simulate the scenario of an interior localised fire occurring in one corner of a room with a ventilation opening (typically a door) and they evaluate the propensity for fire spread on interior wall and ceiling linings resulting in flashover. In some tests the wall and ceiling linings are fixed to a non-combustible lined test room substrate and in others, materials such as insulated sandwich panels are constructed as a self-supporting, free standing test room so that structural integrity and collapse can also be evaluated under fire conditions. (Opening up of joints in such systems can significantly influence fire growth).

AS ISO 9705[140] is applied in Australia by the NCC regulate interior wall and ceiling linings based on material group number.

Room corner tests would not usually be applied to EIFS but they are often applied to ISP’s for the purposes of cool room type applications.

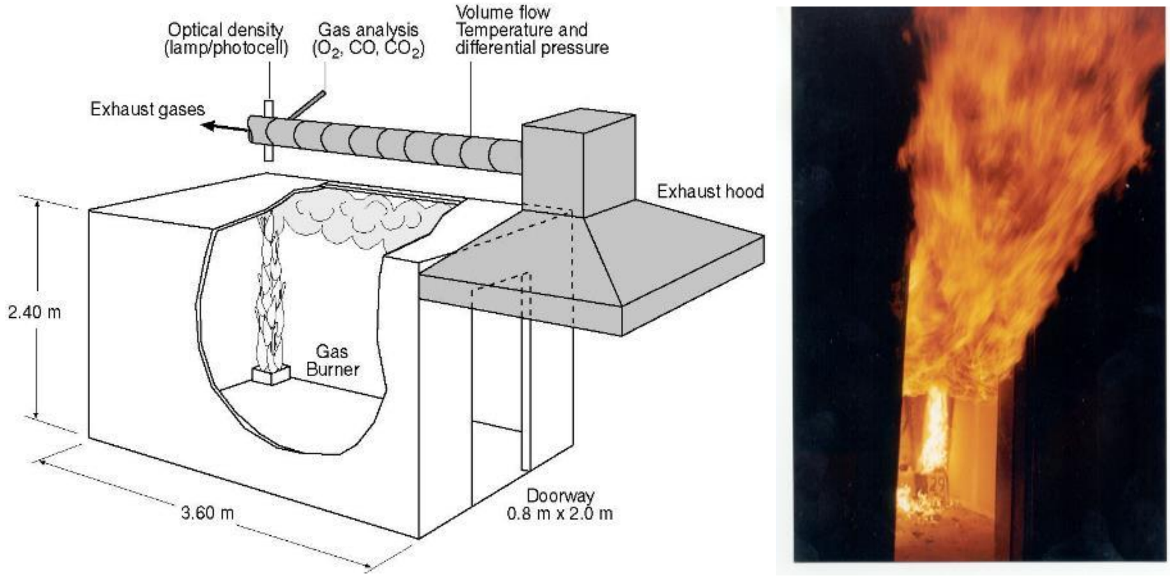


Figure 74. ISO 9705 room corner test layout and resulting flashover (CSIRO)

Room corner tests certainly are not intended to assess fire performance of external walls and facades. However, test results showing good performance of a material in a room corner test are sometimes used (particularly by fire engineers justifying an alternative solution) to indicate a level of fire performance. Whilst this may give some degree of confidence in performance the following issues must be considered:

- The ignition source HRR for a room corner test simulates a localised pre-flashover fire and is significantly lower than the worst-case scenario identified for external wall assemblies, being a post flashover fire with flames ejecting from an opening.
- The orientation and exposure of materials in the room fire test can be significantly different to an external wall system.

- Room corner tests do not expose or test the edge treatment/design of the window opening and therefore the propensity for fires to spread into the internal cavity of the wall system via this opening is not tested.

The following table provides a brief summary of the various room corner test methods.

Table 19 Summary of room corner test methods

Test Method	Fixed linings inside non-combustible test room or free standing room test	Room dimensions	Ventilation opening	Ignition source	Measurements
ISO 9705[140]	Fixed	2.4m wide x 2.4 m high x 3.6 m long	0.8 m x 2.0 m doorway	Gas burner with output of 100 kW for 0-10 min and 300 kW for 10-20 min	HRR Smoke optical density Temperatures at ceiling level and opening Heat flux at floor level
NFPA 286[141]	Fixed	2.44m wide x 2.44 m high x 3.66 m long)	0.78 m x 2.02 m doorway	Gas burner with output of 40 kW for 0-5 min and 160 kW for 5-15 min	HRR Smoke optical density Temperatures at ceiling level and opening Heat flux at floor level
UBC 26-3[142]	Fixed	Interior dimensions 2.44m wide x 2.44 m high x 3.66 m long)	0.78 m x 2.13 m doorway	Douglas Fir timber crib 13.6 kg, 381 mm square base area, each stick 38 mm square. 5 sticks per tier.	Temperatures at ceiling level and opening Internal panel temperatures Visual observation of fire spread, flashover damage and smoke.
ISO 13784 Part 1[143]	Free standing	2.4m wide x 2.4 m high x 3.6 m long	0.8 m x 2.0 m doorway	Gas burner with output of 100 kW for 0-10 min and 300 kW for 10-20 min	HRR Smoke optical density Temperatures at ceiling level and opening Heat flux at floor level Internal panel temperatures
ISO 13784 Part 2[144]	Free standing	4.8m wide x 4.0 m high x 4.8 m long	4.8 m x 2.8 m doorway	Gas burner with output of 100 kW for 0-5 min and 300 kW for 5-10 min and 600 kW for 10-15 min	Internal and surface panel temperatures Visual observation of fire spread, flashover and damage
LPS 1181 Part 1 and Part 2[145, 146]	Free standing	Large free standing room fire test (10 m L x4.5 m W x 3 m H). Applies timber crib	2.25 x 4.5 m W opening.	Redwood/Scots Pine timber crib. 70 Sticks of 50 mm x 25mm x 750 mm	Temperatures at ceiling level and opening Internal panel temperatures Visual observation of fire spread, flashover and damage

9.3 AS 1530.8.1 and AS 1530.8.2 Bushfire test method

The NCC and AS 3959 regulates building construction in bushfire prone areas based on an assessed Bushfire Attack Level (BAL) for the building site. The following BAL categories exist:

BAL category	Description
BAL—LOW	There is insufficient risk to warrant any specific construction requirements but there is still some risk.
BAL—12.5	The construction elements are expected to be exposed to a heat flux not greater than 12.5 kW/m^2.
BAL—19	The construction elements are expected to be exposed to a heat flux not greater than 19 kW/m^2.
BAL—29	The construction elements are expected to be exposed to a heat flux not greater than 29 kW/m^2.
BAL—40	The construction elements are expected to be exposed to a heat flux not greater than 40 kW/m^2.
BAL—FZ	There is an extremely high risk of ember attack and burning debris ignited by windborne embers, and a likelihood of exposure to an extreme level of radiant heat and direct exposure to flames from the fire front exceeding 40 kW/m^2

AS 3959 specifies DTS requirements for construction for the above BAL categories. For construction outside of the prescribed DTS solutions AS 1530.8.1 or AS 1530.8.2 is required as a performance-based test.

AS 1530.8.1 is required for BAL 12.5 to BAL 40 and exposes test specimens to a radiant heat exposure which peaks at the prescribed BAL radiant heat level. This is combined with application of a pilot flame and timber cribs at specified location on the exposed face of the specimen. Specimens such as walls must be tested as complete 3 m x 3 m wall system specimens exposed to a 3 m x 3 m radiant panel (formed by a steel sheet panel over an AS 1530.3 furnace. Smaller elements such as penetrations or small windows are permitted to be tested using smaller pilot scale radiant panels.

Failure criteria include:

- Formation of an opening through which a 3 mm probe can penetrate.
- Sustained flaming on the non-fire side.
- Flaming on the fire-exposed side at the end of the 60 min test period.
- Radiant heat flux 365 mm from the non-fire side of the specimen in excess of 15 kW/m2 from glazed and uninsulated areas during the 60 min test.
- Mean and maximum temperature rises greater than 140 K and 180 K, respectively, on the non-fire side during the 60 min test, except for glazed/uninsulated areas for which the radiant heat flux limits are applicable.
- Radiant heat flux 250 mm from the fire-exposed face of the specimen, greater than 3 kW/m2 between 20 min and 60 min after the commencement of the test.
- Mean and maximum temperatures of the internal faces of construction including cavities, exceeding 250°C and 300°C respectively between 20 min and 60 min after the commencement of test.

BAL –FZ requires AS 1530.8.2 which is essentially an AS 1530.4 fire resistance test to an FRL of -/30/30 with some additional requirements.

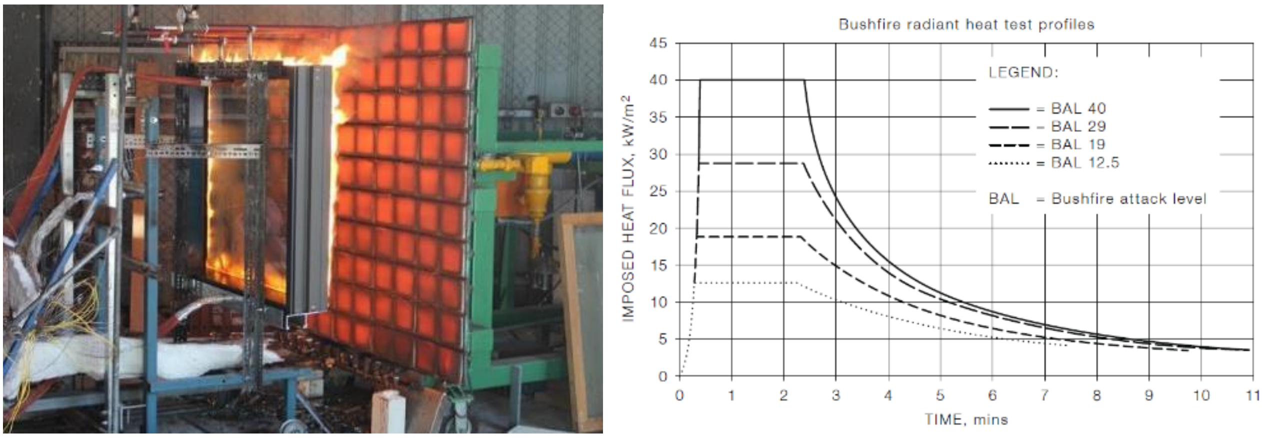


Figure 75. CSIRO pilot scale AS 1530.8.1 test (left), BAL radiant heat test profiles (right)

AS 1530.8.1 and AS 1530.8.2 are sometimes applied to EIFS for application in bushfire prone areas. However, these tests should not be used to directly assess façade external fire spread performance for the following reasons:

- AS 1530.8.1 is predominantly a radiant heat exposure only combined with cribs representing relatively small quantities of burning debris. It does not represent direct flame impingement from larger fuel loads. It does not examine upwards external flame spread. A tested system can undergo significant flaming of the external surface and still be acceptable so long as the fire does not spread to the cavity or the non-exposed side.
- AS 1530.8.2 is predominantly a fire-resistant barrier test. A tested system can completely burn away on the exposed face and still be acceptable so long as the fire does not burn through to the non-exposed side. EIFS systems may typically incorporate a fire-resistant plasterboard layer behind the foamed insulation to achieve this result.

Based on AS 1530.8.1 bushfire tests referenced by some Australian EIFS products and CodeMark Certificates of Conformity, EPS based EIFS systems (as tested) can potentially perform well when exposed to this test. This test is not a vertical fire spread test but represents an external heat flux exposure of up to 40 kW/m^2 combined with small timber cribs representing burning debris of ~ 20 kW or less. Provided the render system is sufficiently thick and mesh re-enforced, the EPS can soften, contract and melt (in regions) behind the render without igniting so long as the render remains intact.

However, review of test reports and certificates found on Australian supplier websites raises the following concerns:

- EIFS Systems tested to AS 1530.8.1 appear to have been tested without any render expansion joints or a bottom wall edge detail which has a ground clearance and is either an unfinished EPS edge or fitted with a starter channel (typically aluminium or PVC with weep holes). However, these items are typical of end use EIFS construction and are in many cases specified by supplier manuals.
- It's understood that due to this practice, AS1530.8.1:2018 included the following new requirements for external wall test specimens:
    - The wall system must be installed and tested in a manner representative of the intended application.
    - It shall include representative base of wall details and any openings to wall cavities
    - It shall also be tested with horizontal or vertical joints (expansion joints) where these form part of the wall in practice.
- This review has not identified any publicly available test reports or certificates which indicate that EIFS systems have been tested (or re-tested) including the above details as specified in AS 1530.8.1:2018
- It is considered possible that such details may reduce the performance of EIFS Systems in this test.

The above tests do not reflect the bushfire performance of poor/defective construction or maintenance.

9.4 Intermediate scale façade fire spread tests

There are a limited number of intermediate scale façade fire spread test methods around the world. Tests such as ISO 13785:2002 Part 1 – Intermediate scale facade test[147] and vertical channel tests [148, 149] have been previously reviewed by White et al[3] and are not presented in this report as they are not actively being used to regulate/test EIFS or ISP. Whilst DIN 4102-20 may possibly be considered as intermediate scale due to its ignition source size of ~ 320 kW it is summarised in the large-scale test method section due to the size and arrangement of the specimen.

9.4.1 FM TEST METHOD FOR FIRE SPREAD WITHIN CAVITY WALL SYSTEMS.[150, 151]

FM 4411[150] specifies approval requirements for cavity wall systems such as rain screen cladding with a wall cavity air gap behind, particularly where the cavity may be lined with combustible insulation such as EPS or other foamed polymer materials. FM4411 specifies an intermediate test for fire spread within a wall cavity system. This test method is specified in more detail in a paper by FM global[151]. The test apparatus consists of two parallel panels, each 1.2 m wide x 2.4 m high consisting of 13 mm glass faced gypsum board or other suitable non-combustible board. The cavity insulation material is placed within the cavity representative of the system being tested.

- If approval is desired with a 24-51 mm air gap, then the construction is tested as a 51 mm air gap. A 51 mm x 305 mm propane sand burner with a heat output of 5.8 kW is located at the centre bottom of the cavity.
- If approval is desired with a >51 - 102 mm air gap, then the construction is tested as a 102 mm air gap. A 102 mm x 305 mm propane sand burner with a heat output of 9.5 kW is located at the centre bottom of the cavity.

The test is conducted under a fire calorimetry hood with oxygen consumption calorimetry. The gas burner is applied for a 15-minute exposure. During this time the specimen must not exceed a HRR of 100 kW and must not exceed a visible flame height of 1.8 m.

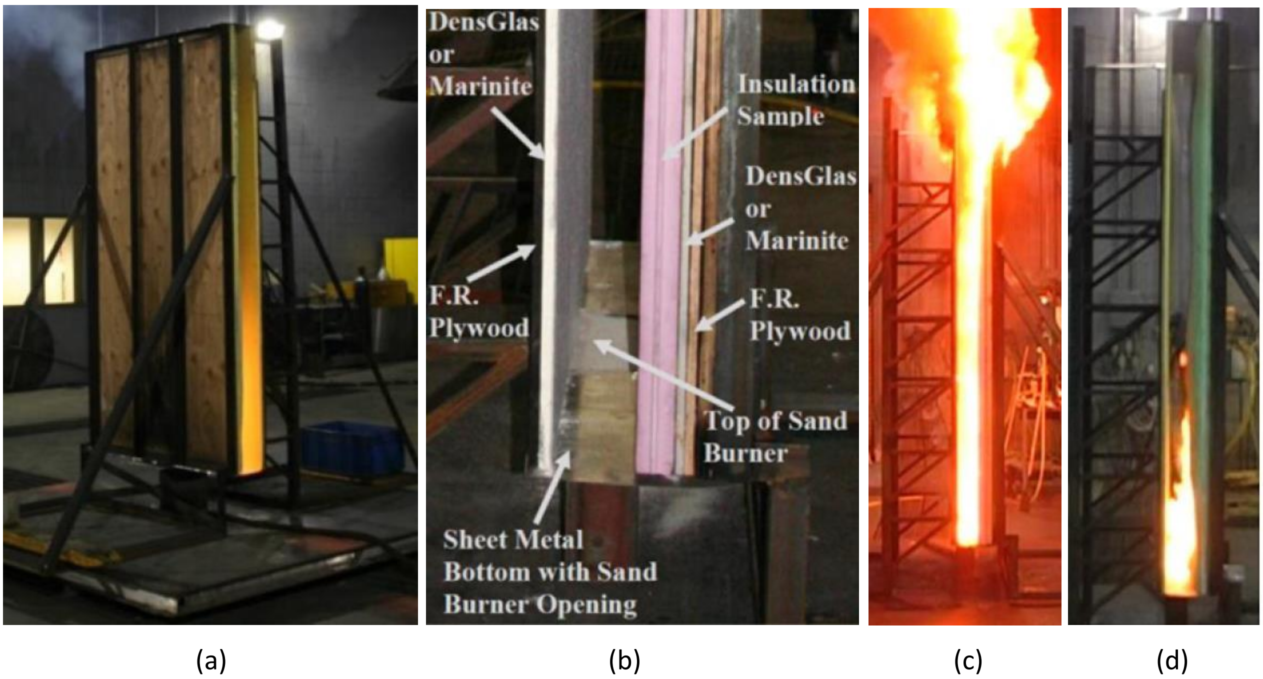


Figure 76. FM 4411 Cavity fire spread test. (a) and (b), apparatus. (c) poor performing insulation. (d) good performing insulation

FM 4411 states that “this standard shall not qualify EIFS”. However, CSIRO review identifies this as a test which simulates an insulated wall cavity similar to that occurring in cavity EIFS systems and therefore could have application in assessing/understanding EIFS cavity fire spread performance.

9.4.2 FM 16 ft (4.9 m) PARALLEL PANEL TEST[115, 152, 153]

FM Global has developed a parallel panel test as an intermediate scale test to predict results for the 25 ft. and 50 ft. corner tests. The parallel panel test apparatus consists of two parallel panels, each 4.9 m high by 1.1 m wide, separated by 0.5 m. A sand burner, 1.1 m by 0.5 m by 0.3 m high, is located at the bottom of the panels. The total heat release rate from the burning panels during the test is measured by a 5 MW capacity oxygen consumption calorimetry exhaust hood. The burner exposure is controlled to 360 kW to provide a maximum heat flux to the panels of 100 kW/m^2. This corresponds to the maximum heat flux measured at the panels at the top of the crib in the 25 ft. corner test.

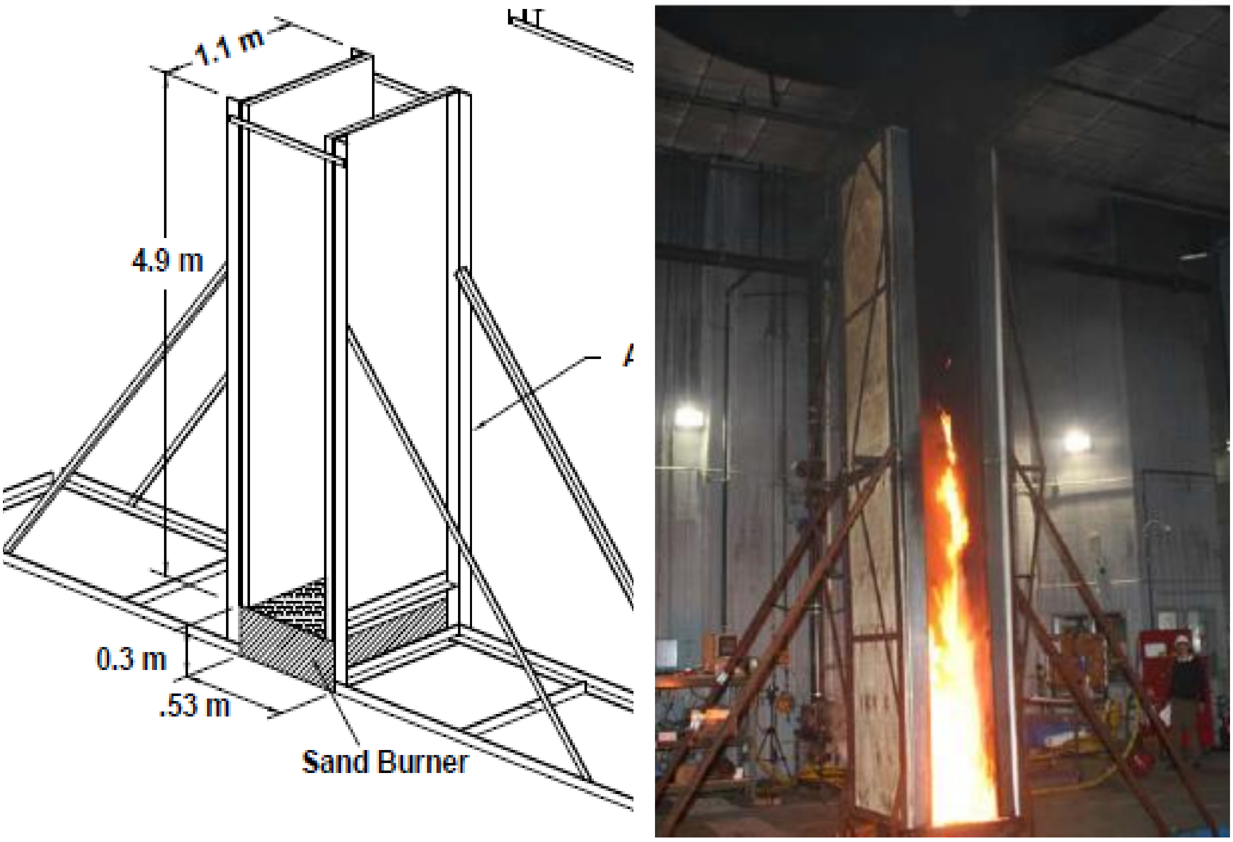


Figure 77. FM Global Parallel Panel Test[153]

A measured HRR of 1100 kW in the parallel panel test was found to represent fire spread to the top of the panels and this criterion is used in additional to visual observation of fire spread which is often difficult due to smoke production.

It was concluded that fire will not propagate to the end of the test array in the 25-ft corner test with combustible wall panels and a non-combustible ceiling if the HRR in the parallel panel test is <1100 kW; fire will not reach the top of the test array in the 50-ft corner test if the HRR in the parallel panel test is less than 830 kW; fire propagation will not reach the ends of the horizontal ceiling in the 25-ft corner test with both combustible wall and ceiling panels if the HRR in the parallel panel test is <830 kW.

9.5 Full scale façade fire spread tests

There are a significant number of large-scale façade fire spread test methods around the world. These have been previously reviewed by White et al[3]. Please refer to Appendix B for a table which summarises the main international full-scale façade fire test methods. This section provides details of the following key test methods as they are applied for combustible external walls in the relevant countries:

- AS 5113.1 – Australia.
- BS 8414 – UK.
- NFPA 285 – USA.
- DIN 4102-20 – Germany.

9.5.1 AS 5113[154]

AS 5113 provides a test methodology for classifying fire performance of external walls in terms of two distinctly different parameters:

- External Wall (EW) – Fire spread performance in response to an ignition fire directly impinging on the wall.
- Building-to-building (BB) – ignition and fire spread performance in response to radiant heat exposure from an adjacent building fire.

External wall classification

External wall tests may be performed according to either ISO 13785-2 or BS 8414. AS 5113 specifies additional test requirements and acceptance criteria. In practice, all Australian test labs are currently only testing according to BS 8414 as this is more commonly adopted internationally. Only the application of BS8414 is discussed below.

The timber crib is the same crib as specified in Annex A of BS8414 and the timber is permitted to be pinus silvestris or pinus radiata. AS 5113 specifies that all of the following classification criteria for BS 8414 tests must be satisfied:

5.4.5 Classification criteria for BS 8414 tests

All of the following performance criteria shall be satisfied:

a. Temperatures 5 m above the opening measured 50 mm from the exposed specimen face shall not exceed 600°C for a continuous period greater than 30 s.
b. Temperatures at the mid-depth of each combustible layer or any cavity 5 m above the opening shall not exceed 250°C for a continuous period of greater than 30 s.
c. Where the system is attached to a wall that is not required to have an FRL of –/30/30 or 30/30/30 or more, the temperature on the unexposed face of the specimen 900 mm above the opening shall not exceed a 180 K rise. Five thermocouples equally spaced at 500 mm centres with insulating pads, fitted in accordance with the requirements of AS 1530.4 for the measurement of surface temperatures shall be used.
d. Where the system is attached to a wall not required to have a fire resistance of –/30/30, 30/30/30 or more, flaming or the occurrence of openings in the unexposed face of the specimen above the opening shall not occur.
e. Flame spread beyond the confines of the specimen in any direction, as determined during the post-test examination, shall not occur. The examination shall include flame damage such as melting, charring but not smoke discolouration or staining of the surface, any intermediate layers and the cavity.
   NOTE: The confines of the specimen is the minimum specimen size specified in the 'Dimensions of test specimen' clause in BS 8414, Parts 1 and 2. The specimen may be constructed larger than the minimum size in which case spread is determined at the positions associated with the minimum specimen size.

f. Continuous flaming on the ground for more than 20 s from any debris or molten material from the specimen shall not occur.

g. The total mass of debris falling in front of the specimen shall not exceed 2 kg. The mass shall be measured after the end of the test.

The above criteria are different and more stringent than the BR 135 criteria applied to BS8414 tests in the UK.

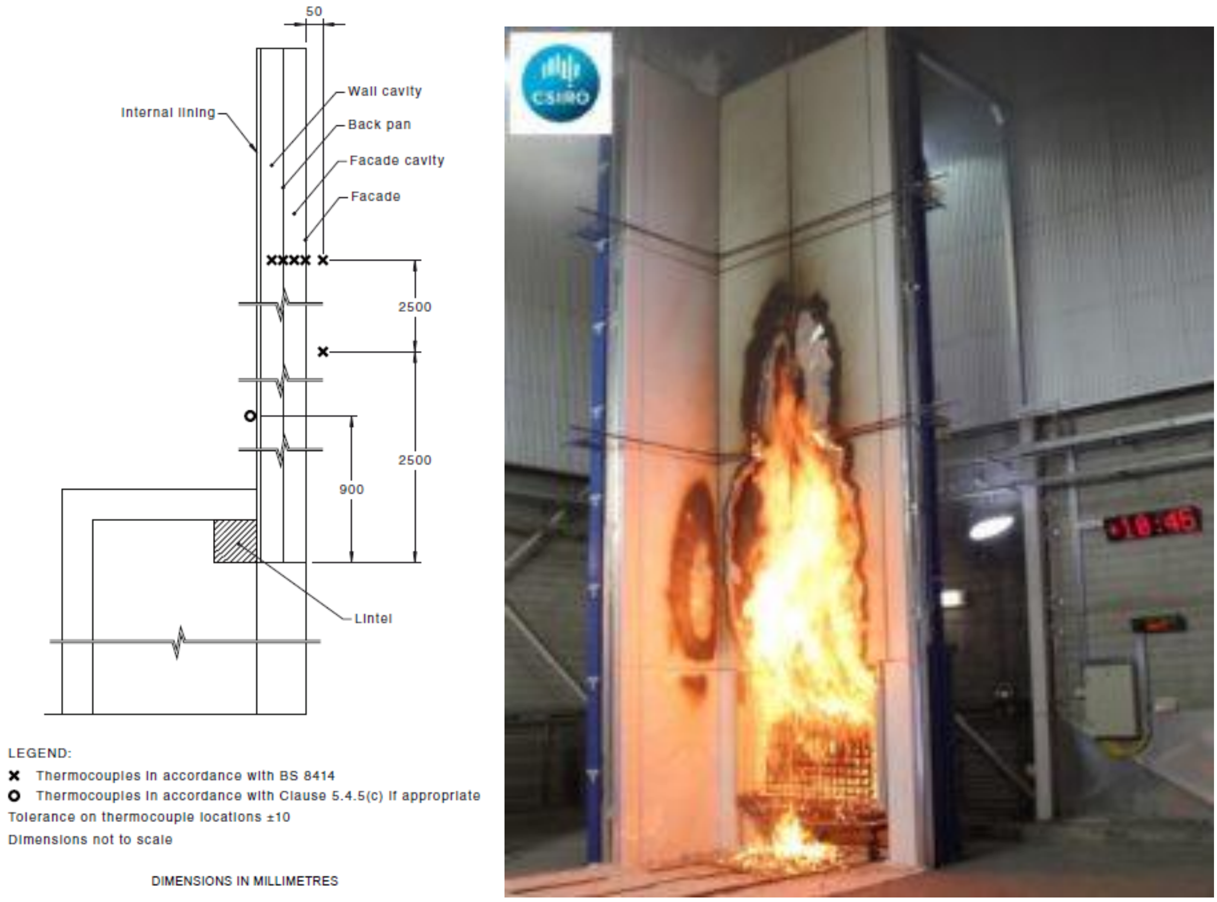


Figure 78 AS5113 thermocouple locations (left), CSIRO AS5113/BS8414 test rig (right)

Building-to-building classification

A representative external wall system specimen at least 3 m x 3 m is exposed to the prescribed radiant heat exposure level which is achieved via an AS 1530.4 fire resistance furnace with a sheet steel closure forming a radiant heat source at least 3 m x 3 m. The heat flux exposure level is subject to the BB classification being tested.

Table 20. BB classification radiant heat flux levels.

BB classification	Heat flux, kW/m²
BB80	80
BB40	40
BB20	20
BB10	10

The specimen shall be exposed to the required heat flux for a minimum of 30 min plus 10 minutes heat up phase (i.e. total test duration at least 40 min allowing for the heat up phase). A small 25 mm long pilot ignition flame is applied to the exposure face of the specimen during the test

All the following performance criteria shall be satisfied:

a. Temperatures at the mid-depth of each combustible layer or any cavity shall not exceed 250°C for a continuous period of greater than at least 30 s.
b. Where the system is attached to a wall not required to have a fire resistance of –/30/30, 30/30/30 or more, temperatures on the unexposed face of the wall specimen shall not exceed a 180 K rise.
c. Where the system is attached to a wall not required to have a fire resistance of –/30/30, 30/30/30 or more, flaming or the occurrence of openings in the unexposed face of the specimen shall not occur.
d. Continuous flaming on the side of the specimen exposed to radiant heat exceeding 30 s shall not occur.
e. Continuous flaming on the ground for more than 20 s from any debris or molten material from the specimen shall not occur.
f. The total mass of debris falling in front of the specimen shall not exceed 2 kg. The mass shall be measured after the end of the test.

9.5.2 BS 8414 PART 1 AND PART 2[155, 156]

BS 8414 part 1 and part 2 were developed by BRE. BS 8414-1 is a full-scale fire test for non-load bearing external cladding systems applied to the face of a solid external building wall. The test simulates the scenario of flames emerging from a compartment fire via a window at the base of the wall. The test façade is installed as a re-entrant corner “L” arrangement. The test rig has a masonry block wall construction as the substrate for mounting test specimens to. The test wall extends at least 6 m above the window soffit. The main wall is at least 2.6 m wide and the wing wall is at least 1.5 m wide. The window opening is at the base of the main wall and is 2 m wide x 2 m high. The façade is installed around the window down to the bottom of the window. The façade is installed representative of the end use including all insulation, cavity air gaps, fixings and window details. The tested façade must be at least 2.4 m wide on the main wall and 1.2 m wide on the wing wall.

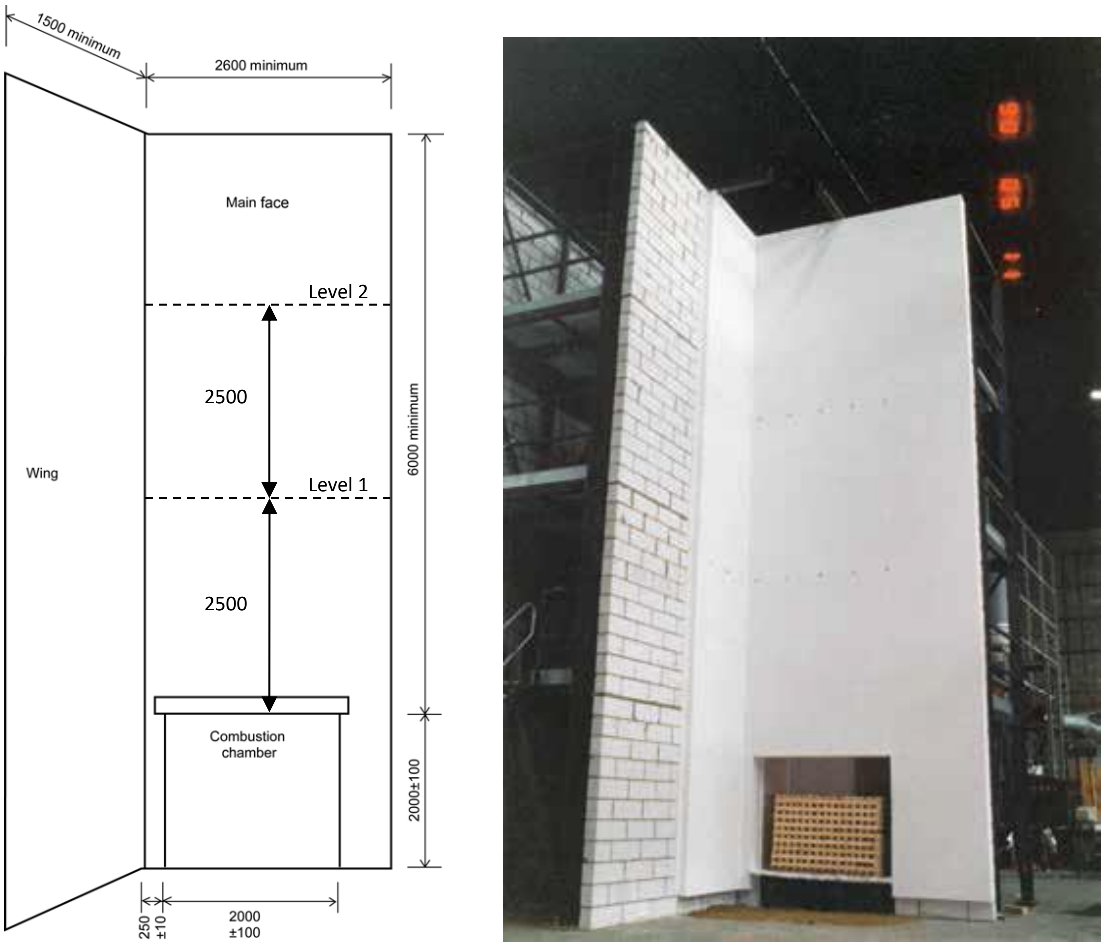


Figure 79. BS8414-1 test rig (from BRE report BR135[157])

The fire enclosure is 2 m wide x 1 m deep x 2.23 m high with a lintel at the front opening reducing the soffit height of the opening to 2 m. The standard fire source is a timber crib constructed of softwood sticks having a cross sectional area of 50 mm x 50 mm. The constructed timber crib is nominally 1.5 m wide x 1 m deep x 1 m high. The crib sits on a platform 400 mm above the base of the test frame and the front of the crib sits 100 mm in front of the outside surface of the masonry support wall. Therefore, the front of the crib is directly 600 mm under the soffit of the tested façade. The crib has a nominal heat output of 4500 MJ over 30 minutes and a peak HRR of 3±0.5 MW. A previous 2002 edition of the standard included an Annex which stated the ignition source should achieve the following calibrated exposure:

- The mean temperature across the top of the combustion chamber opening measured at 3 thermocouple locations exceeds 600 °C above ambient over a continuous 20 minute period. The variation between mean temperature and any individual thermocouple temperature shall not exceed ±20 °C
- The mean temperature at level 1 height on the main wall face exceeds 500 °C above ambient over a continuous 20 minute period.
- Mean heat flux measured at 1 m above the window soffit on the main wall shall remain within the range of 45-95 kW/m^2 over a continuous 20 minute period and typically achieves a steady state peak mean heat flux of approximately 75 kW/m^2 within this period.

However, the above details were removed from the current 2015 edition of the standard.

During the test temperatures are measured at the external surface at the test façade on the main and wing walls at level 1 (2.5 m above the window soffit) and level 2 (5 m above the window soffit). Internal thermocouples are only located at level 2 on the main and wing wall and are positioned at the centre of each combustible layer >10 mm thick or cavity. No heat flux is measured during the test.

The fire source is extinguished 30 minutes after ignition and observations and measurements are continued for a total test period of 60 minutes or until all flaming ceases. Key observations are extent of flame spread on all surfaces, intermediate layers and cavities, the extent of burn away or detachment for the cladding system and any collapse or partial collapse of the cladding system. The performance criteria for BS8414-1 is given in BRE Report BR135[157] and is:

- The fire spread start time is defined as the time when the temperature measured by any external thermocouple at level 1 exceeds 200 °C above ambient.
- Failure due to external fire spread is determined when any external thermocouple at level 2 exceeds 600°C above ambient for a period of at least 30 s, within 15 minutes of the fire spread start time.
- Failure due to internal fire spread is determined when any internal thermocouple at level 2 exceeds 600°C above ambient for a period of at least 30 s, within 15 minutes of the fire spread start time.

BS8414-2 is a full-scale fire test for non-load bearing external cladding systems fixed to and supported by a structural steel frame. This test is essentially the same as BS8414-1 except that the test façade is mounted directly to a steel support frame without the masonry substrate. This tests curtain wall type construction where a solid concrete or masonry wall is not present. The dimensions of the test rig, the fire source and the test procedure are the same as for BS8414-1. The performance criteria for BS8414-2 is given in BRE Report BR135[157] and is the same as for BS8414-1 except for the following additional criteria for internal fire spread.

- Failure due to internal fire spread is also determined when burn through of the façade system with continuous flaming with a duration of at least 60 s is observed on the non-exposed side of the facade at a height of 0.5 m or greater above the window soffit within 15 minutes of the fire spread start time.

Figure 80. BS8414-2 test rig (from BRE report BR135[157])

There are no failure criteria set for mechanical performance by the BS8414 standards or the BRE report BR135. However, observation of mechanical behaviour including system collapse, spalling, flaming debris etc. should be recorded.

9.5.3 DIN 4102-20[158]

Please note that Authors have not had access to DIN 4102-20. The following description has been determined from descriptions provided in other reports[159, 160].

This test simulates the scenario of flames emerging from a compartment fire via a window at the base of the wall. The test façade is installed as a re-entrant corner “L” arrangement. The test rig has a light weight concrete wall construction as the substrate for mounting test specimens to. The test wall extends at least 5.5 m high. The main wall is at least 2 m wide (using the burner) or 1.8 m wide (using the crib) and the wing wall is at least 1.2 m wide using the crib. The fire enclosure and opening is nominally 1 m wide x 1 m high and is located at the base of the main wall at the intersection of the wing wall. The façade is typically installed around the opening down to floor level. The façade is installed representative of the end use including all insulation, cavity air gaps, fixings and window details.

The fire source is has a peak HRR of ~ 360 kW and is achieved by either a gas burner or a 30 kg timber crib. The timber crib appears to be most commonly used in practice.

- Wood crib: 30 ± 1.5 kg with density after conditioning 475 ± 25 kg/m³, sawn softwood (e.g. spruce) in rods of 40 ± 2 mm x 40 ± 2 mm x 500 -10 mm, wood air ratio of 1:1, base area of the crib: 500 mm x 500 mm, air supply to chamber: 400 ± 40 m³/h from the back side.
- Gas burner: burner housing is made of 2 mm steel plates, dimensions: 800 mm x 312 mm x 200 mm (length x width x depth), the fuel is propane, supply rate is 7.4 ± 5 % g/s propane and 24 ± 5 % m³/h air with 4 bar.

The fire source was selected to be a medium sized source which would not result in flame immersion more than one level above the fire opening. This is ~ 10 times smaller in terms of peak HRR and mass compared to the BS8414 and AS 5113 crib.

The fire source achieves a maximum temperature of approximately 780-800 °C measured 1 m above the opening soffit on a non-combustible wall. Flames from the fire source are understood to extend a maximum height of 2.5 m above the opening soffit on non-combustible wall.

The gas burner is turned off or wood crib is supressed after 20 minutes for combustible facades. Measurements and observations continue until all burning and smoke production ceases, or until 60 minutes.

The test performance criteria are:

- No burned damaged (excluding melting or sintering) above a height of 3.5 m or more above the opening soffit.
- Temperatures on the wall surface or within the wall layers/cavities must not exceed 500 °C at a height of 3.5 m or more above the opening soffit.
- No observed continuous flaming for more than 30s at a height of 3.5 m or more above the opening soffit.
- No flames to the top of the specimen at any time.
- Falling of burning droplets and burning and non-burning debris and lateral flame spread must cease with 90 s after burners are turned off.

Figure 81. DIN 4102-20 (Draft) test rig (From BRE Global[159])

Note – Germany also developed a larger 200kg crib façade test which is now being used to specifically regulate EIFS (see Section 10- Experimental Research).

9.5.4 NFPA 285[161]

This method tests façade claddings or complete external wall systems. The test wall is installed as a single wall surface. No re-entrant corner is installed. The test rig is a two-storey steel framed structure with an open fronted test room on each storey constructed of concrete slabs and walls. Each test room has internal dimensions of approximately 3 m wide x 3 m deep x 2 m high. The bottom test room serves as the fire enclosure and the top test room simulates an enclosure on the level above with no window.

The installed test wall is at least 5.3 m high x 4.1 m wide. The wall tested is a complete system including any external cladding, insulation, external substrate framing and internal wall membrane. The test wall construction and fastening to the test rig must be representative of the end use. The test wall is typically installed on a movable steel frame which is then attached to the front of the test rig concrete slabs. The test wall includes a single opening 1.98 m wide x 0.76 m high. The opening soffit is located 1.52 m above the fire enclosure floor.

The fire source consists of two separate pipe type gas burners. One burner is placed in the centre of the fire enclosure and the other burner in a 1.52 m long linear burner located near the soffit of the opening. The room burner output is gradually increased from approximately 690 kW to 900 kW over the 30 minute test duration. The window burner is ignited 5 minutes after the room burner and is gradually increased from 160 kW to 400 kW over the remaining 25 minute test period. The burners are calibrated to achieve average heat fluxes at the surface of a non-combustible test wall of approximately 40 kW/m^2 at 0.6 m and 0.9 m above the opening and 34 kW/m^2 at 1.2 m above the opening during the peak fire source period of 25-30 minutes.

During the test temperatures are measured at the front of the test wall and also in air cavity and insulation spaces within the wall at 305 mm intervals vertically from the opening soffit. Temperatures within the fire enclosure, at the rear of the test wall in the second storey test room are also measured. No Heat flux measurement is made during the test.

The NFPA 285 standard provides a very detailed set of performance criteria which are briefly summarised as follows.

- Temperatures at exterior of wall must not exceed 538 °C at a height of 3.05 m above the opening soffit.
- Exterior flames must not extend vertically more than 3.05 m above the opening soffit.
- Exterior flames must not extend horizontally more than 1.52 m from the opening centreline.
- Fire spread horizontally and vertically within the wall must not result in designated internal wall cavity and insulation temperatures exceeding stated temperature limits. The position of the designated thermocouples and temperature limits depends on the type and thickness of insulation materials and whether or not an air gap cavity exists.
- Temperatures at the rear of the test wall in the second storey test room must not exceed 278 °C above ambient.
- Flames shall not occur in the second storey test room
- Flames must not occur horizontally beyond the intersection of the test wall and the side walls of the test rig.

As the test does not include a wing wall geometry care should be taken when applying NFPA 285 test results to assess facades to be installed with vertical re-entrant corner geometries.

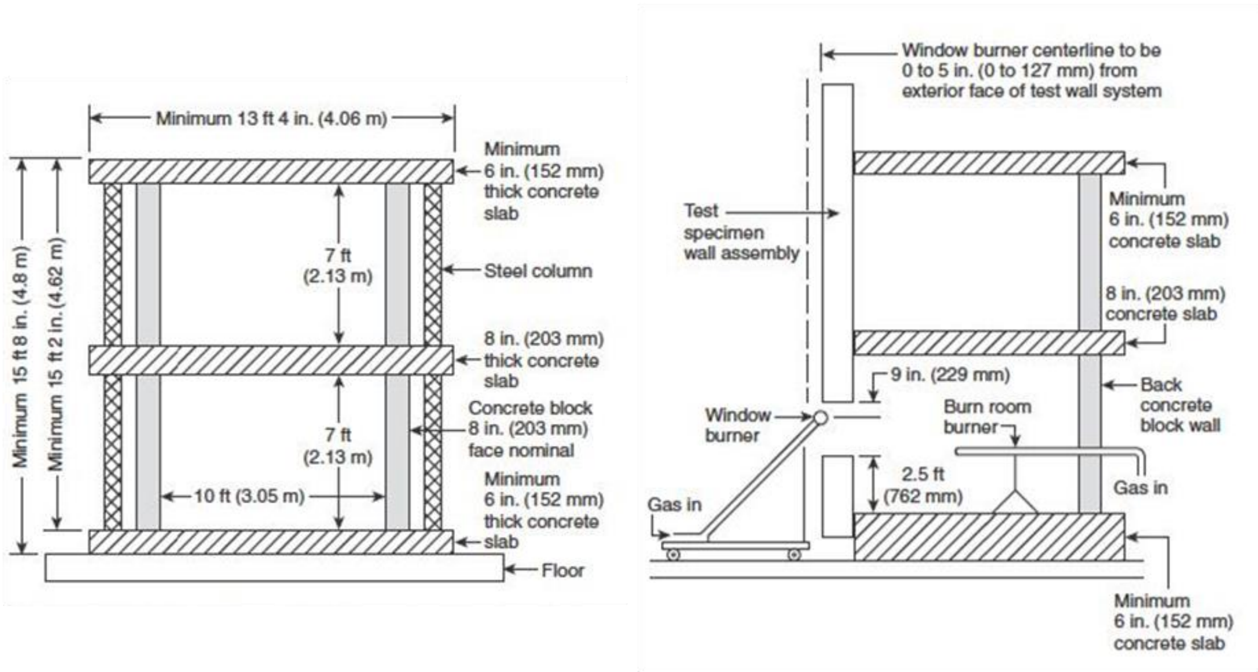


Figure 82. NFPA 285 test apparatus front view without test wall (left) and side view (right) (from NFPA 285-2012)[161]

Figure 83. Front view of typical NFPA 285 test (from Hansbro[162])

The NFPA 285 test method is related to a larger façade test developed in 1980 which used a 26 ft. (8m) two storey outdoors building. A 1285 lb timber crib was used as the fire source in the lower floor which resulted in flames exiting the window and exposing the exterior face of the wall assembly at approximately 5 minutes. This test method was published in the 1988 UBC as test standard 17-6 and in the 1994 UBC as UBC test standard 26-4. In the early 1990s a reduced scale, indoors version of the UBC 26-4 test was developed which replaced the wood crib with two gas burners to produce the same exposure. Testing was done to confirm that similar results were achieved for the same materials on the original large and new reduced scale tests. The reduced scale test became UBC 26-9 which eventually replaced UBC 26-4. NFPA 285 is technically equivalent to UBC 26-9.

9.5.5 FM 4880 25FT AND 50 FT CORNER TESTS[115]

FM 4880 details the FM Approvals process for testing of insulated wall or wall and roof/ceiling assemblies, plastic interior finish materials, plastic exterior building panels, wall ceiling and coating systems and interior or exterior finish systems. Part of this evaluation process details (dependant on end use application and height):

- 16 ft. (4.9 m) High Parallel Panel Test.
- A 25 ft high corner test to be applied for acceptance of assemblies for an end-use maximum height of 30 ft (9.1 m).
- A 50 ft high corner test to be applied for acceptance of assemblies for an end-use maximum height of 50 ft (15.2 m) or unlimited height.

Although FM 4880 states that it is applicable for exterior finish systems, the use of the above tests is mostly applied to assessing insulated sandwich panels, however FM-Global has done some work assessing other façade materials including EIFS . These tests and are not specifically external façade tests and are not referred to by building codes for regulation of external facades. However, these test methods are summarised here as they do provide a possible method for assessing performance in response to severe external fire sources (such as back of house fires for commercial/industrial buildings).

Both tests simulate an external (or internal) fire source located directly against the base of a re-entrant wall corner

25 ft (7.6 m) High Corner Test

The test apparatus structure consists of a two column and girt wall frames and a ceiling frame of joists and metal furring strips to which test wall and ceiling assemblies can be mounted. There is no non-combustible substrate such as concrete or masonry. The height to the underside of the ceiling frame is 7.54 m. One wall is 15.7 m wide and the other wall is 11.96 m wide. For tests on wall assemblies only, corrugated steel decking is installed to the underside of the ceiling frame. The test wall is installed representative of the end use, which typically involves through bolting of insulated sandwich panels directly to the frame. Test walls are installed to top half (above 3.8 m) extending over the entire width of each wall. Test walls are installed to the bottom half (below 3.8 m) extending only 6 m from the corner on each wall. The remaining sections of the wall are clad with gypsum board.

The fire source is 340 ± 4.5 kg crib constructed of 1.065 m 1.065 m oak pallets stacked to a maximum height of 1.5 m and located in the corner 305 mm from each wall. The crib is ignited using 0.24 L of gasoline at the base of the crib. The standard does not state any calibrated heat flux or temperature requirements for the fire source. However, it is understood that the maximum heat flux is 100 kW/m^2 or greater.

Thermocouples are located on the test walls on 2.5 m grid spacing. The test duration is 15 minutes.

The performance requirement for this test is that the tested assembly shall not result in fire spread to the limits of the test structure as evidenced by flaming or material damage.

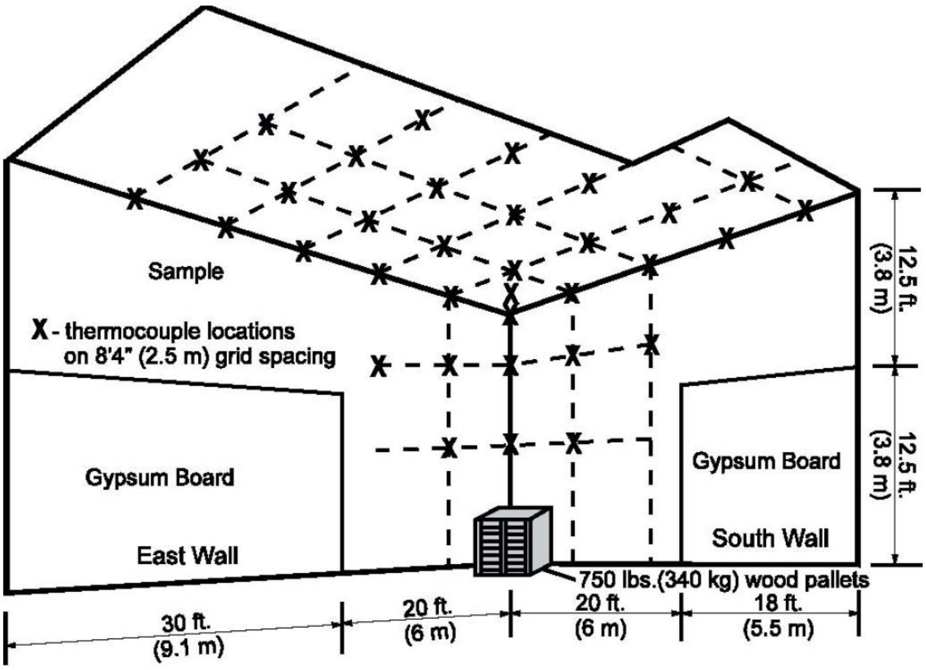


Figure 84. 25 ft (7.6 m) test apparatus (from FM 4880[115])

50 ft (15.2 m) High Corner Test

The test apparatus structure consists of two wall frames and a ceiling frame to which test wall and ceiling assemblies can be mounted. There is no non-combustible substrate such as concrete or masonry. The height to the underside of the ceiling frame is 15.2 m. Both walls are 6.2 m wide. For tests on wall assemblies only, corrugated steel decking is installed to the underside of the ceiling frame. The test wall is installed representative of the end use, which typically involves through bolting of insulated sandwich panels directly to the frame. Test walls over the entire height and width of the test frame

The same fire source as for the 25 ft high corner test is used.

Thermocouples are located near the intersection of the top of the walls and the ceiling both at the corner and 4.6 m out from the corner. The test duration is 15 minutes.

The performance requirements for this test are:

- The tested assembly shall also meet the requirements of the 25 ft corner test.
- For acceptance to a maximum height of 50 ft (15.2 m) the tested assembly shall not result in fire spread to the limits of the test structure as evidenced by flaming or material damage.
- For acceptance to an unlimited height the tested assembly shall not result in fire spread to the limits of the test structure or to the intersection of the top of the wall and the ceiling as evidenced by flaming or material damage.

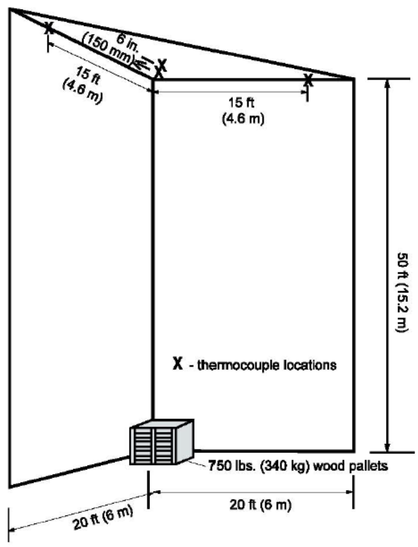


Figure 85. 50 ft (15.2 m) test apparatus (from FM 4880[115])

10 Experimental Research

Over more than two decades there have been several research reports which have focused on the fire behaviour of combustible external walls, covering a broad range of wall systems including EIFS and ISP. These reports have consistently identified hazards related to combustible external walls and identified areas where change is needed regarding industry use and regulation of combustible external walls. Some key reports which provide good background reading include:

- 1984 – The book "Fire and Cellular Polymers"[163] was published as conference proceedings. Chapters include contributions from fire safety luminaries including Dougal Drysdale and demonstrates a high level of understanding of the fire behaviour and hazards of building products including rigid foam polymer materials existed in the early 1980's.
- 1988 - In the UK BRE published the first edition of "*Fire performance of external thermal insulation for walls of multistorey buildings"*. It was published in response to the identified increasing use of thermal insulation in the refurbishment of multistorey buildings in the 1980's. The 2013 BR 135 3rd edition of this report is the latest[157].
- 2000 - The Australian Fire Code Reform Centre project report "*Fire Performance of exterior claddings"* was undertaken identifying the increasing use of combustible external wall systems in Australia and Internationally. It made recommendations including changes to BCA requirements including development and adoption of a suitable facade fire test and collection of fire incident data to be modified to collect data specifically on incidents of external fire spread[82].
- 2014 – NFPA Fire protection Research Foundation funded research report "*Fire Hazards of Exterior Wall Assemblies Containing Combustible Components" [3]*.

There have been numerous experimental research papers exploring the basic fire properties and thermal degradation behaviour of rigid foam polymer insulation including EPS, PUR, PIR and Phenolic foam. A good example is the 2016 paper "*Experimental Characterisation of the Fire Behaviour of Thermal Insulation Materials for a Performance-Based Design Methodology"[55]* by Hidaglo et al.

10.1 EIFS

10.1.1 GERMAN RESEARCH AND TESTING[164, 165]

Germany has had significant use of EIFS over more than 50 years. More than 500 million m² of EIFS have been installed in Germany from the early 1960's to 2006 and currently more than 30 million m² of EIFS are installed in Germany every year[166]. In 2015, in Germany almost 37 million m² of EIFS were installed[164, 165]. The predominant installation of EIFS in Germany appears to be over a masonry or concrete substrate.

Following Fire Brigade investigations into EIFS fires, the Conference of the Ministers responsible for building (Bauministerkonferenz, abbreviated as BMK) and the DIBt (German Centre of Competence for Construction) set up research groups to evaluate fire performance of EIFS, investigate the suitability of existing fire safety requirements and determine any further fire safety requirements needed.

Based on review of the reported fire incidents it was concluded [164, 165, 167, 168]:

- A large portion of the fires start from large external garbage bin fires rather than internal apartment fires.
- For a long time, the German institute for building technology DIBt approved ETIC systems according to a large-scale test with a medium size fire load which is now a standardised method: DIN 4102-20. The DIN 4102-20 test method applies a medium sized ignition source of 30 kg timber crib (or equivalent gas burner) which has a peak HRR of ~ 320kW. This ignition source had been established based on the assumption of a fire scenario of an internal apartment fire resulting in limited flame impingement to the exterior of a single level directly above the fire level. It was identified that some of the EIFS facades involved in fires, including fatality fires, were systems that had been tested and passed to this standard.
- A façade test with a larger ignition source was needed to investigate the performance of EIFS when exposed to larger external fire sources.

An experimental investigation of EIFS was undertaken by a number or German testing organisations including BAM (Federal Institute for Materials Research and Testing) and MFPA Leipzig GmbH[164, 165, 167] .

- Fire tests on large HDPE garbage bins with different rubbish contents resulted in:
    - For single bin – Maximum HRR in range 2.0-5.0 MW. Maximum flame heights in range of 2.5-3.0 m (short peaks up to 4 m).
    - For two bins – Maximum HRR of ~6.7 MW. Maximum flame heights in range of 4.0-4.5 m.
- Based on this a 200 kg wood crib was selected as a suitable larger ignition source. It had a maximum HRR in range of 2.8-3.4 MW and maximum flame height of 4-5 m (short peaks up to 7 m).

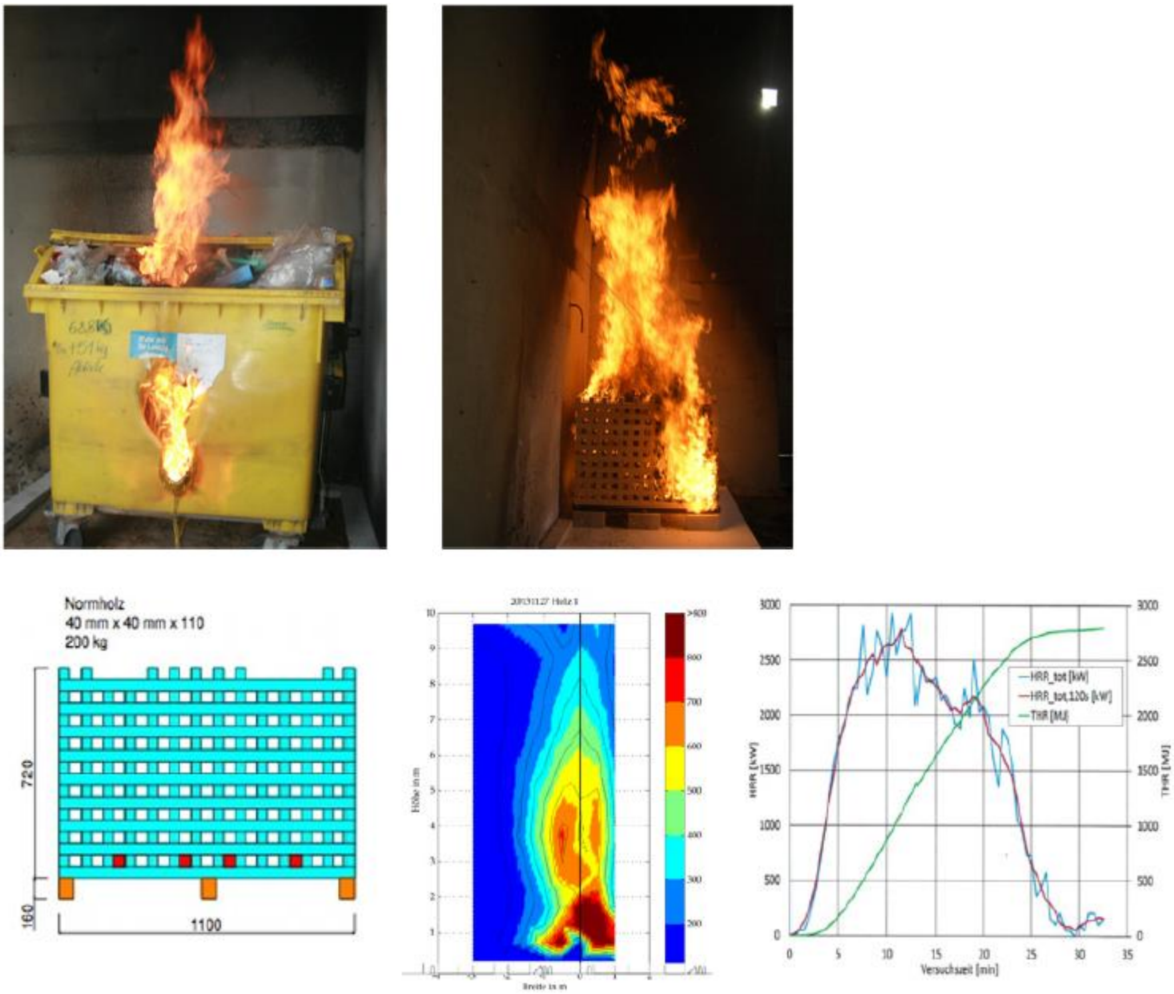


Figure 86. 200 kg crib dimensions, temperature profile and HRR against non-combustible facade[167]

- The 200kg crib was applied to a 9.7 m test wall with a main/wing wall façade arrangement made of an aerated concrete substrate.

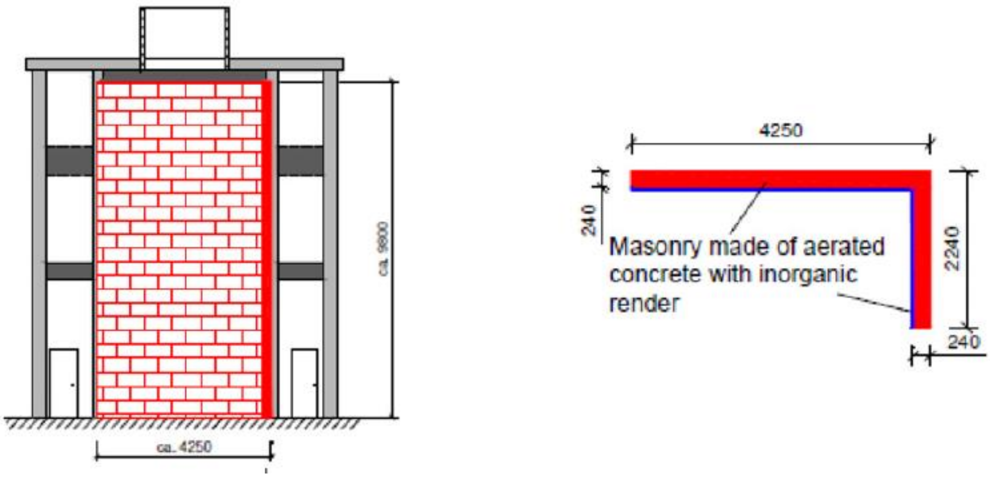


Figure 87. Front view and plan view of 200 kg crib EIFS façade test substrate[167].

- A series of 3 tests were conducted applying the 200 kg crib to EIFS. All EIFS systems tested had the following materials:
  - EPS fixed to aerated concrete substrate with PU foam adhesive.
  - EPS 300 mm thick with density ~25 kg/m^3.

- Base render coat with organic binders (e.g. acrylic render), 2mm thick, about 10% organic compounds in dried condition.
- Glass fibre mesh as reinforcement with a weight per unit area of about 150 g/m2,
- Finishing render coat with organic binders, 2mm thick, about 10% organic compounds in dried condition (e.g. acrylic render).
- 60 cm high splash water zone made up with polystyrene, 240mm thick, organic rendering and a profile made of PVC at the lower edge of the ETICS.
- The following summarises differences in tested system and test results.

Table 21. MFPA Leipzig 200 kg crib EIFS test results summary

Test No	Test 1	Test 2	Test 3
Tested EIFS Key Installation Differences	Single fire barrier of non-combustible mineral wool strip 200 mm thick located at 5 m height and fixed with adhesive mortar (no mechanical anchors), embedded within the EPS and covered with render	3 fire barriers, 200 mm mineral wool, installed at heights of 0.9 m, 3 m and 9.5 m (top of EIFS). Fire barrier fixing to include adhesive mortar plus mechanical anchors. Reinforcement of the base render coat was strengthened with a special mesh corner bracket at the inner corner of the ETICS test rig	Repeat of Test 2
Test results	7 min - fire spread on surface leaping over the fire barrier 9 min – Molten polystyrene pool fire at base of crib 11 min – Flames reach top of test rig 13 min – cracking of render and lateral fire spread 15 min – large parts of render and fire barrier fall away. Fully developed fire over most surfaces. 19 min onwards – pool fire then rest or test suppressed Post-test – EIFS completely consumed.	4-5 min - Combustion of material below first 0.6 m barrier only. Rendering above first fire barrier up to the top edge of the test assembly does not crack during entire test duration. Peak flame height of ~ 6–7m due primarily to wood crib with some contribution from pyrolysis gases from render and EPS Diffusing through non-cracked render above first fire barrier. > 20 min –EPS pool fire develops at base Fire barriers remain attached to the substrate Crib is only extinguished after 35 test minutes – at that time, the fire intensity is clearly decreasing.	Same as for test 2

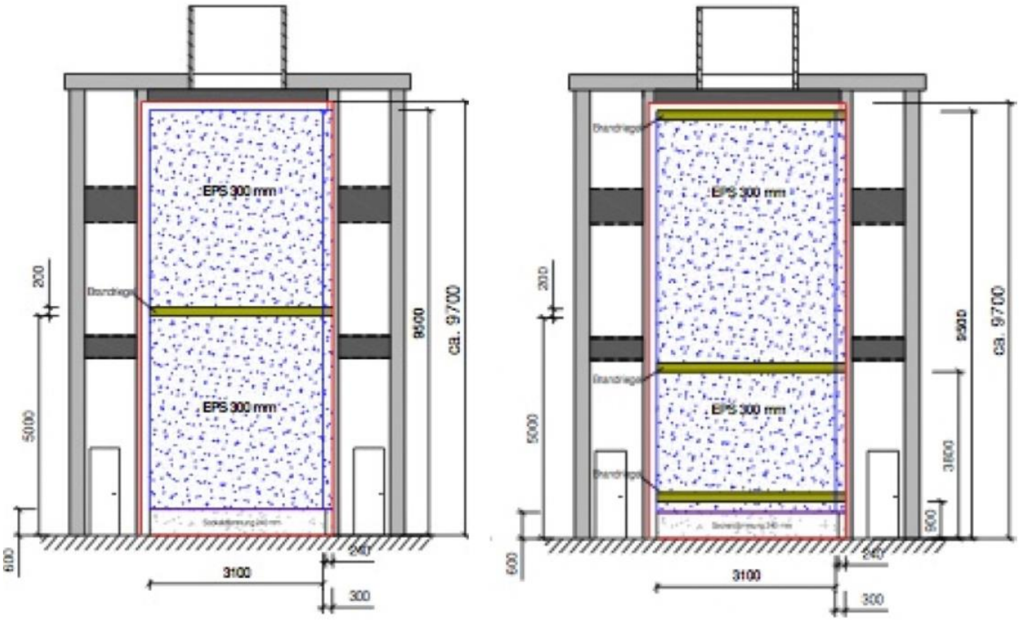


Figure 88. MFPA Leipzig 200 kg crib EIFS test position of fire barriers test 1 (left) and tests 2 &3 (right) [167]

Figure 89. Test 1 at 15 min and post-test (left); Test 2 and 3 at 18 min and post-test (middle and right) [167]

The Division of Fire Safety, Institute of Building Materials, Concrete Construction and Fire Safety (iBMB), Germany has also conducted a series of five full scale fire tests on EIFS applying large external ignition sources[168]. The ignition sources used included a 200 g timber crib with peak HRR of ~ 2 MW and a 200 L isopropanol pool fire. The tests were not carried out to any standard façade test method and were carried out on a flat façade (no wing wall) 6 m wide x 8 m high for Tests 1-2 and 9m high for Tests 3-5. The façade substrate was aerated concrete.

The EIFS system tested in all tests included 300 mm thick XPS at the base (below 0.9 m) and 300 mm thick EPS for the remaining façade. All tests appeared to include the same render system. However exact details of the XPS, EPS and render system are not given in the paper reviewed. Key variables between the 5 tests included:

- Number and location of 200 mm thick mechanically fixed mineral wool fire barriers.
- Type of ignition source.
- Presence of no window openings or three vertically stacked window openings 1.35 m x 1.01 m.

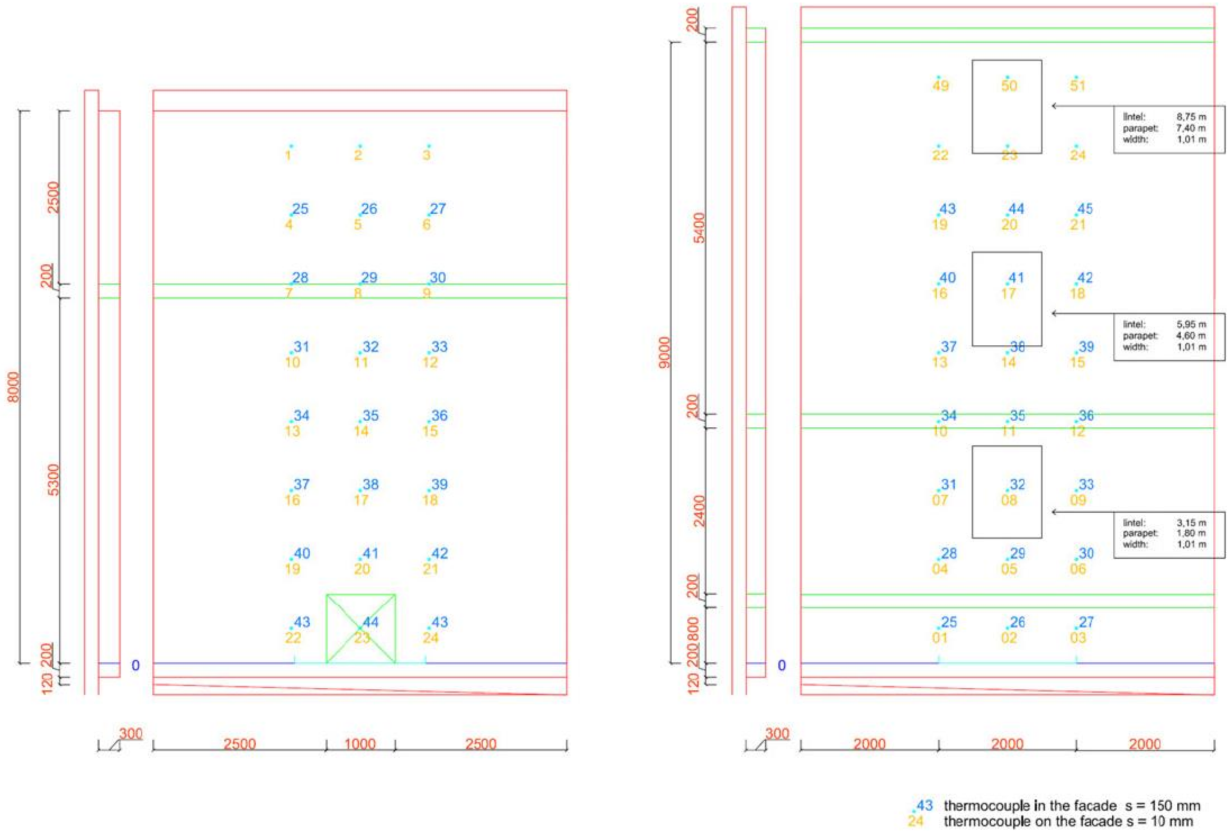


Figure 90. iBMB EIFS test arrangements. No windows (left) . Three windows (right)

Table 22: The five full-scale EIF system tests held at iBMB.

	Test 1	Test 2	Test 3	Test 4	Test 5
Ignition source	200 kg wood crib	200 L iso-propanol	200 L iso-propanol	200 L iso-propanol	200 kg wood crib
Ignition source peak HRR (MW)	2 ± 0.2	3.5 ± 0.35	3.5 ± 0.35	3.5 ± 0.35	2 ± 0.2
Ignition source peak Heat flux at 1.25 m height (kW/m^2)	32	125	125	125	32
Number of fire barriers & height	One 5.3 m	One 5.3 m	Three 0.9 m, 3.4 m, 9.0 m	Three 0.9 m, 3.4 m, 9.0 m	Three 0.9 m, 3.4 m, 9.0 m
Window Openings	none	none	none	Three	Three
Result	No fire propagation	Fire propagation to the top of the façade by 15 min	No fire propagation above middle fire barrier after 30 min	Fire propagation to top of façade and laterally over entire face of façade by 12 min	No fire propagation
Image at 15 minutes					
Image at 35 minutes				Test suppressed shortly after 12 min	

This research reinforced the importance of fire barriers for EIFS but demonstrated that for a very large ignition source, fire barriers can be insufficient to prevent fire spread.

In 2006 the Fraunhofer Institute for Building Physics published findings on long term susceptibility of EIFS to damage based on periodic inspections of EIFS buildings in Germany, Austria and Switzerland[166]. In 1975 the first investigation of 93 buildings took place. In 1983 the investigation was repeated on 87 buildings. Further investigations were carried out on a smaller number of buildings in 1995 and 2004. Key conclusions of this study were:

- Mechanical damage or degradation of ETICS façades are no more frequent than with conventional rendered masonry walls as a result of the de-coupling effect of the soft insulation layer from the brick-work / blockwork.
- Slightly greater susceptibility of ETICS to microbial growth due to rain or condensation water can be detected.
- Costs and frequency of maintenance for External Wall Insulation Systems (ETICS) are equivalent to those of conventional wall structures consisting of rendered masonry.

However the above findings of susceptibility of EIFS render surface to mechanical surface damage is contradicted by several other publications including an investigation by BAM[164, 165] which concluded that EIFS render is prone to damage , particularly at ground floor where it may be impacted by waste containers or vehicles and in other areas where penetrations or fixings (such as satellite dishes) are added. BAM conducted a series of SBI tests with standard 30 kW burner and increased 125 kW burner on EIFS with render damage f varying sizes and depths and demonstrated that damage of render can significantly increase the fire growth rate of EIFS.

Based on all of the above research German regulations now require:

- DIN 4102-20 30 kg crib façade test for all other combustible façade types for buildings 7-22 m in height.
- For EIFS with EPS insulation additionally must be tested according to technical regulation A 2.2.1.5 (200 kg crib fire from outside the building test).
- For buildings greater than 22 m in height external walls must be non-combustible.
- In 2015-2016 DIBt published documents for national approval of EPS based EIFS which required 200 mm horizontal perimeter mineral wool fire barriers to be installed at heights above ground of 0.9 m, 3.0 m (or L1 slab level) and then a maximum of 8 m spacing above (every second slab level above L1). It also requires minimum 4 mm polymer modified render thickness to be applied.

10.1.2 EUROPEAN HARMONISATION OF FAÇADE FIRE TEST STANDARDS

Since 2010 and earlier EU member countries have recognised that façade fire test standards and requirements have varied significantly between countries and a need to harmonise these requirements. Around 2016 the Standing Committee of Construction (SCC) has run a project to develop a harmonised European approach to testing and assessment of fire performance of facades. This project has had input from major fire research and testing authorities around Europe and the project outcomes to date have been published in a June 2018 project report[160]. The project has currently arrived at a proposed harmonised set of test requirements and classification/acceptance criteria. As future work the project proposes to undertake round robin tests to fully characterised the proposed test methods and compare them against existing tests in each country. Key outcomes of the project to date include:

- Adoption of both the DIN 4102-20 as medium fire exposure and BS 8414 as a large fire exposure are proposed. Each would be applied to achieve a different façade fire classification level.
- An alternative test method for medium and large fire exposure was proposed with differing size/geometry and ignition sources and measurements which tries to integrate as many of the variables from all the different European test methods. However, this alternative test method does not appear to be favoured and is not summarised further here.
- Geometry/size of test rigs are to remain as they are but if falling/burning debris is to be assesses they are to be up lifted 0.5 m so that radiation from the combustion chamber does not impact observation of debris.
- Ignition source and combustion chamber of test rigs are to remain as they are.
- A secondary opening may be included in the test set-up, to assess the mounting and behaviour of the façade system around openings. The secondary opening is optional in the proposed test method.
- Junction between façade and floors – Where a façade system is installed directly connected to floor slab edges a specific adaptation of the combustion chamber ceiling is done in the test. This measurement and classification are optional.
- Measurement of fire spread - Both BS 8414 and DIN 4102-20 are kept as they are.
- Acceptance criteria – pass/fail criteria including vertical fire spread, horizontal fire spread, falling parts and burning debris are defined.
- Classification system – A classification system is proposed which clearly states the conditions under which the Façade was tested and is summarised in Figure 91.

Figure 91. European Harmonisation of façade fire test project classification system proposed

Feature	Classification	Comment
Heat exposure	LF, MF	LF when a large size fire has been used MF when a medium size fire has been used
Junction	J	Junction between façade and floor
Secondary opening	W	If secondary opening was present and the test successful
Smouldering	S	If smouldering has been considered and the test is successful
Falling parts	F1, F2	If falling parts have been considered and the test has been successful • F1: No part larger than 1 kg and 0.1 m² • F2: No part larger than 5 kg and 0.4 m²
Burning debris	D0, D1	If burning debris have been considered and the test has been successful • D0: No burning debris at all • D1: Limited duration burning debris < 20 s

As the Harmonisation project is still progressing it is yet to be seen:

- If the member countries will accept and adopt a single harmonised testing approach.
- How the different classifications, specifically LF and MF would be integrated into building regulations for different building types and heights.

10.1.3 OTHER INTERNATIONAL EIFS EXPERIMENTAL RESEARCH

BRE Global Comparison of BS8414 and DIN 4102-20[159]

BRE published a report which compares experimental test results of a range of similar EPS core EIFS Systems applying BS 8414 and DIN 4102-20. In summary this shows that:

- The type and thickness of render can have a significant impact on performance. Inorganic render systems passed façade fire tested where similar EIFS with organic failed. Organic generally means carbon based, however the report does not clarify the difference between organic render (which may mean acrylic polymer modified) and in-organic render (which may be cement based render modified with some other non-carbon based polymer).
- The inclusion of mineral wool fire barriers was required to achieve a pass result in BS 8414.
- BS 8414 (Applying BR 135 criteria) was a more onerous test than DIN 4102-20 based on similar EIFS failing BS8414 but passing DIN 4102-20.
- Even EPS EIFS which passed BS 8414 (Applying BR 135 criteria) did produce molten EPS pool fires at test floor level.

Figure 92. BRE BS 8414 test on 200 mm EPS with organic render resulting in BR 135 criteria fail before and after test suppression[159]

University of Zagreb, Croatia EIFS tests[169-171].

Tests based on BS 8414 were conducted on the following three types of EIFS:

Table 23. Summary of University of Zagreb, Croatia EIFS tests

TEST SPECIMEN	Thermal insulation material and thickness	Render	Fixing method
E_1	Expanded polystyrene (EPS) – 150 mm	Basic render reinforced with glass fibre mesh and final organic (acrylic) render – 5 mm	Bonded and mechanically fixed
EM_2	Expanded polystyrene (EPS) – 150 mm + fire barrier 150 mm thick and 200 mm high; directly above combustion chamber		
M_3	Mineral stone wool (MW) – 150 mm		

All three tests were conducted simultaneously, side by side on an outdoor test pad. The maximum external face temperatures at levels 1 and 2 appeared to be very low (~ 200 °C max at level 2 for mineral wool EIFS) compared to other test laboratory experience. This result is considered questionable by the reviewer. None of the EIFS failed on external face temperatures, but interestingly E-1 displayed breaking of render at base of façade with flame spread on EPS in cavity behind render and flames emerging from broken render at top of façade coinciding with high cavity/insulation temperatures of 700 °C. The mineral wool barrier in EM-2 prevented this type of fire spread to a large degree but did result in some breaking of the render above the fire barrier resulting in molten burning droplets. The non-combustible stone wool M-3 did not support any fire spread as expected.

Figure 93. EIFS BS 8414 tests at 21 minutes and after suppression[169]

VTT study on fire safety of EPS EIFS

A 2013 report by VTT[172] investigates the effect of the use of EPS based EIFS on the fire safety of multistorey residential buildings. This investigation reviews statistical data from Finland and Sweden and uses probabilistic event tree based risk analysis to assess the risk of fire spread between floors. It also uses small scale cone calorimeter testing and FDS CFD modelling as inputs to the risk assessment.

The probability of vertical fire spread between compartments via windows was calculated to be 2.3 % for EPS ETICS and 1.9% for low combustibility facades.

It is noted that limitations relating to the use of small scale testing and reliance on FDS[173-175] fire modelling by this study may have resulted in errors in the prediction of the relative risk of fire spread on EPS ETICS vs. low combustibility facades.

It is also noted that the risk assessment was based on EPS ETICS installed with suitable rendering and mineral fibre fire barriers. The risk of non-compliant construction techniques was not evaluated.

FM study on the comparison of NFPA 285, BS 8414 and parallel panel test[176]

FM global carried out an experiment comparison of three test methods to enable a comparison of the methods. This showed a reasonable equivalence between the BS 8414 and the parallel panel test and concluded that the NFPA 285 was a less onerous fire test and a wall system complying with NFPA 285 may not comply with the BR 135 (BS8414) or FM requirements. This report and testing were focused on ACP cladding and not EIFS or ISP but is of relevance in understanding the differences between the different external wall fire spread test methods.

10.2 ISP

It is acknowledged that work by FM Global on development of test methods and requirements for insurance company approvals for ISP used as both as internal wall and ceiling linings and also external wall systems for external walls with height restrictions of 30 ft. (9.1 m), 50 ft. (15.2 m) and unlimited height represents considerable experimental research in this area. The ongoing testing that FM provides in approving ISP's also provides test based evidence of behaviour of different types of ISP's. It is noted that most FM approved ISPs for external wall use have Mineral wool, PIR or EPS in Phenolic matrix core. It does not appear that any EPS or EPS FR core ISPs are currently approved by FM for external wall use.

The BRE register of BS 8414 / BR-135 tested and approved wall systems predominantly lists EIFS and rain screen cladding type wall systems. Only one ISP is listed which is a PIR core.

Most experimental research found relating to ISP was mainly focused on its fire performance when used as wall and ceiling linings for single storey storage or factory type buildings rather than multi-storey external wall systems. It is noted that experimental research based on single storey room corner tests does assist to understand general fire behaviour of ISP systems but does not directly indicate performance for multistorey façade applications.

It is also noted that there are numerous published experimental research papers which appear to be biased in support of a particular core material type (EPS, PIR or mineral wool) in preference to all other types.

In the UK in 1997 Harwood and Hume[92], and Shipp et al[93] undertook a review and investigation of 21 fire incidents involving sandwich panels. This work included some limited fire testing of ISP materials. This work concluded that fire risks for ISP's were impacted by core material type, ISP installation and fixings, building usage and internal building fire risk management. It recommended labelling of panel types should be required, use of improved ISP types and construction methods was required, education of building owners to manage risks, recommendations for Fire brigade operation procedures and recommendations for government and industry to work together to further develop fire safety requirements for ISP's. It is noted that this work was over 2 decades ago and to a large degree appears to have been acted on (for new buildings) in the UK and USA and Australia.

In 2006, CSIRO published a paper summarising a series of eight room fire tests conducted on EPS ISP systems according to ISO 9705 or ISO 13784-1[177]. The thickness of the panel cores, grade of EPS, and construction methods of fixing the panels were varied. EPS core materials were also characterised by cone calorimeter and TGA. The time to flashover results varied significantly from 400 s (NCC Group 3) to no Flashover (NCC Group 1) and that this variation of results was mostly due to the type and amount of fixings affecting the degree to which skins delaminated or joints opened. To achieve a no flashover result, through bolting of both internal and external panel faces was required combined with steel flashing/capping and steel rivet fixing of all internal panel seams at regular close spacing. The use of aluminium flashings or fixings and the omission of flashings or fixings generally achieved a poorer result. The EPS group of the Plastics and Chemical Institute of Australia (PACIA) was a financial supporter of this research.

In 2018, University of Lancashire and University of Edinburgh conducted a series of four free standing room fire tests on PIR ISP and Mineral Wool ISP[178]. The experiments were based on ISO 13784-1 however this was modified in two key aspects:

- Panels were subjected to damage including unsealed penetrations etc.
- The internal fire load was increased by stepping up the propane burner output from the usual maximum of 300 to 600 kW (for all tests), and by placing a substantial wooden crib in two of the rooms.

It was found that the PIR panels had a higher contribution to HRR and fire spread than the Mineral wool panels. For the PIR panels the wood crib ignited by radiation from hot layer at 11 minutes (1 min after burner increase to 300 kW). For the mineral wool panels the crib ignited at 22 min (2 min after burner increased to 600 kW). The PIR panels distorted exposing some areas of PIR and resulting in large flames and smoke production both internal and external to the test enclosure. The mineral wool panels did not spread fire to the exterior of the panel (except internal fuel load flames emerging from door opening) and significantly lower quantity of smoke was produced. The authors conclude that current insurance industry classification tests do not test the interaction between panels and stored fuel load or the presence of damage on panel facings and therefore fail to distinguish appropriately between PIR and mineral wool ISP fire performance. The journal paper lists Rockwool International in Acknowledgements. Although this study appears to represent an enhanced worst credible case combination of damaged panels, internal fuel loads and small enclosure volume/ventilation conditions, it does highlight a difference in the performance of the two core types under these worst credible case conditions.

The IPCA *Code of Practice* document[26] includes an "engineering support study" as Appendix E. The study appears to have a bias to support use of EPS_FR core ISP but does also support use of other core types such as PIR and mineral wool. It supports the use of EPS_FR core based on requirements for steel fixings, flashings and installation that would achieve an NCC Group 1 material group number. It supports this position based upon:

- Literature review of core material fire properties.
- Reference to ISP testing by BRANZ, NSW Fire Brigade and CSIRO.
- Insurance Interests. It notes that some insurers will not insure EPS ISP. It notes that FM Global will insure EPS ISP if the requirements of FM 4880 are met but does not clarify if this is possible. It notes that EPS ISP could at best only achieve an INT-3 classification under LPS requirements but may fail to achieve this due to extent of melting in LPS 1181 test.
- IPCA Code of practice requirements to control risks via appropriate installation, fixings, and structural support, and appropriate house-keeping, maintenance and management of internal building fire risks.

It is noted that the above is reasonably documented and supported but places a heavy reliance on adherence to the code of practice. EPS ISP is likely to perform poorly if the code of practice requirements are not strictly complied with. The IPCA research does not directly address multi-storey external wall use of ISP.

CSIRO has knowledge of a confidential AS 5113 EW façade fire test previously conducted on an EPS sandwich panel system. The test report EWFA report No 52999100.1 remains confidential. But the test sponsor has granted permission for the following generalised summary to be included in this literature review. It was expected prior to undertaking this test that the product would fail the EW classification criteria, however the purpose of this test to better understand the systems external wall fire spread behaviour. The tested system was 50 mm thick sandwich panel with EPS core and 1.2 mm thick steel skins. The ISP were installed as horizontal panel runs secured at tongue of panels with screws at 500 mm centres. ISP had a horizontal tongue in groove system whereby the groove of the top panel friction fitted to the tongue in the bottom panel. The tested system also had 1.5 mm thick steel capping installed to cover exposed edges of the sandwich panels and steel capping/flashing was installed vertically along the intersecting corner of the main and wing walls. All capping/flashing was riveted at nominally 300 mm centres. In summary the results were:

- External flames did not exceed level 2 and external level 2 temperature limit of 600 deg C was not exceeded.
- All other criteria failed. This included:
    - Failure of cavity (EPS) temperatures
    - Failure of rear face temperatures
    - Formation of openings and flaming on rear face
    - Panel core melted to vertical and horizontal extents
    - Flaming debris
    - Falling debris mass exceeded

General observations were that although flames did not extend vertically to level 2, the horizontal joints between panels opened up with flaming along the joints to edge of specimen and back face of specimen with significant melting of EPS core and some flaming and falling debris. The external steel skins did not completely delaminate and fall away but appeared to be retained in place which may have been due to them being riveted at 300 mm centres to steel edge capping and steel angle between external facing of main and wing wall. This could be considered to represent a well installed system where the external skin is mechanically fastened to resist complete delamination.

11 Fire safety rectification of existing EIFS or ISP external walls.

The following summarises the general process for fire safety rectification of existing EIFS or ISP external walls based on CSIRO experience with the current Cladding audit, inspection, review and rectification approval process in Victoria and findings of the Victorian Cladding Taskforce final report[2].

This literature review did not identify any published research or testing specifically focused on demonstrating suitability or cost effectiveness of specific rectification measures (such as removal to form external fire breaks or over cladding) applied to existing EIFS or ISP walls. The following is not an exhaustive list of all possible action and remediation.

11.1 Identification and inspection.

The first critical step is to identify the presence, type and extent of EIFS, ISP or any other combustible external wall materials installed to a building. An inspection should be carried out by a suitably skilled professional and may include"

- Review of any relevant and available construction, fire engineering and buildings approval documentation.
- Complete inspection of building external walls. This may require some destructive inspection such as cutting holes or removal of capping to confirm EIFS or ISP encapsulation material type and thickness, core material type and thickness and any other combustible cavity materials, presence of cavity barriers.
- Where the core material type cannot be visibly confirmed as EPS or reasonably confirmed by available documentation then sampling and materials characterisation lab testing may be recommended.
- The extent, location and vertical and horizontal connectivity of the materials and proximity to exits. This should be clearly recorded photographically or by marked up building elevation drawings (or both).
- Identification if the building in a bushfire prone area.
- Ignition hazards specific to the building such as combustible cladding adjacent to car parking or other street level risks, garbage storage, balconies and other electrical or heating appliances.
- The building interior should be inspected to determine the building fire safety measures installed, the egress provisions and any impacts the combustible cladding may have on these. Ideally the inspection should include access to at least one or more SOUs and balconies if present. The inspection should also determine if all fire safety systems and cladding systems have been suitably maintained and if not provide details on deficiencies.
- The inspection should be recorded in a detailed inspection report.

11.2 Risk assessment

A risk assessment should be conducted for the existing building to determine:

- if the building is currently unsafe to occupy – note in most cases whilst the building may have some level of risk it may still be reasonably considered as safe to occupy.
- Overall risk ranking for the building which considers a broad range of risk factors that may contribute to both the overall risk of fire spread and the overall risk to safe evacuation of occupants

It is noted that in Victoria, the VBA and DELWP operate Advisory Reference Panels (ARPs which apply to a limited range of building types) which undertake preliminary risk assessments using a semi quantitative matrix-based Risk Assessment Tool (RAT) under the Statewide Cladding Audit. However further detailed fire engineering analysis and risk assessment is typically required if a performance-based solution involving retention of combustible cladding on the building is to be pursued.

11.3 Interim rectification measures

Based on a preliminary risk assessment, any interim rectification measures required to immediately lower the risk of the building or make it safe to occupy should be identified. Such interim measures might possibly include:

- Rectification of any poorly maintained fire safety systems
- Installation of improved fire detection and automatic monitoring and notification of fire brigades.
- Removal of ignition hazards adjacent to EIFS or ISP. For example, removal of heating appliances or electrical appliances from close proximity to cladding, removal of stored fuel loads from balconies or other areas adjacent to cladding.
- Removal of EIFS or ISP from localised high-risk areas such as directly above or near exit paths, adjacent to car parking or rubbish storage, from occupiable balconies etc.

Interim rectification measures are intended to immediately mitigate any identified high-level risks, but do not achieve long term compliance of the building.

11.4 Long term rectification measures

Long term rectification measures to achieve compliance with NCC performance requirements (or an acceptable level of risk) must be determined.

In many cases the simplest option will be to achieve DTS compliance via complete removal of combustible all cladding (including EIFS or ISP) and replacement with DTS compliant external wall systems.

In some cases, a performance solution may be proposed and assessed by a fire engineer which involved retaining either all or a portion of the combustible cladding (including EIFS or ISP) if it is likely to produce a more cost-effective outcome. Such performance solutions would be building specific but might possible include consideration of the following options:

1. Retention of combustible cladding where it is only in limited areas without significant continuity vertically or horizontally and it can be demonstrated that it would not adversely impact on external fire spread or occupant evacuation.
2. Installation of or improvements to building sprinkler protection. The reliability of sprinklers must be considered. They may be effective in reducing the risk of a cladding ignition event but may have limited efficacy in halting external fire spread once it is initiated.
3. Partial removal of combustible cladding to produce vertical and/or horizontal non-combustible fire breaks on the external walls. However, evidence verifying the required fire break dimensions to prevent “leap frogging” would be required.
4. Over cladding with non-combustible fire-resistant material, improved render and/or inclusion of cavity fire barriers. However, evidence verifying the efficacy of a proposed system and the long-term durability/reliability as well as consideration on any negative impacts on the wall system such as moisture problems etc would be required.

Complete removal and replacement or Option 1 (where applicable) are likely to be simplest and most common solutions. Options 2-4 are more complex and require further research or testing to demonstrate viability.

Currently in Victoria, performance solutions for rectification of combustible cladding on existing buildings (which may be documented in fire engineering reports) are recommended for referral to the Building Appeals Board for determination under section 160A of the *Building Act 1993*.

The Victorian Cladding Taskforce final report recommends that rectification of buildings with combustible cladding be prioritised based on risk, ensuring the highest risk buildings are rectified first, reducing risk to residents and the broader community.

12 Conclusions

CSIRO has undertaken a literature review on behalf of the Victorian Building Authority (VBA) to identify the fire safety issues regarding exterior insulation finish systems (EIFS) and insulated sandwich panel (ISP) systems applied to external walls for Class 2-9 buildings.

The general conclusions of this report are:

- EIFS and ISP are not permitted by the National Construction Code (NCC 2019) Deemed-to-Satisfy (DTS) provisions for use on external walls of buildings of Type A and B construction. DTS provisions generally require external walls for type A and B construction to be non-combustible and this has been the case for more than 20 years of previous National Construction Code / Building Code of Australia versions.
- EIFS and ISP, particularly having expanded polystyrene (EPS) insulation, appear to have been installed on external walls of buildings of Type A and B construction in numerous cases without adequate certification or approval via a Performance Solution assessment process.
- There is currently insufficient test (or other) evidence available regarding façade fire spread performance of EPS cored EIFS and ISP systems as typically installed in Australia for Type A and B construction buildings to conclude that these products can perform suitably. The limited evidence that is available indicates that they are very unlikely to perform suitably in terms of façade fire spread performance if impacted by a large ignition source.
- Based on this it is recommend that EIFS and ISPs should not be not be applied to any new Type A and B construction buildings from this point forward without suitable demonstration of NCC compliance via full scale façade testing and performance-based assessment.

This review is based on publicly accessible publications, research and test reports. Confidential test reports for specific products or systems have not been reviewed and cannot be included for reasons of confidentiality.

This review has also drawn upon generalised information from Victorian combustible cladding inspection and Audits (by Victorian Cladding Taskforce, VBA and DELWP) as published in Victorian Cladding Taskforce reports and via CSIRO involvement in related Advisory Reference Panels (ARP's). VBA, DELWP and the Victorian Cladding Task Force has not provided CSIRO with detailed statistical or summary data from this ARP process and due to confidentiality, CSIRO cannot include details of specific buildings reviewed via ARP's. Instead this knowledge is drawn upon as a generalised knowledge base.

This review is limited in extent by the time and resources available to CSIRO. It is not exhaustive, and some relevant literature may not have been identified and included.

The findings from the literature review are summarised below.

12.1 What are EIFS and ISP?

1. Systems including foamed polymer materials are used as external wall cladding and come in several different forms. The main two types are External Insulating Finishing System (EIFS) and Insulating Sandwich Panel (ISP) and these are two distinctly different types of wall systems. Although they can both use the same rigid foam polymer core materials, the difference in facing materials, construction and fixing is substantial.
    a. EIFS consists of an exterior insulation board layer, most commonly expanded polystyrene (EPS), attached to an external wall support structure and finished with an external render system which encapsulates the insulation. EIFS Systems are typically constructed and rendered on site.
    b. ISP consists of a low-density insulating core material with a facing /skin material of increased density and strength bonded to both sides of the core material. The core may be EPS, or a range if other insulation types including PIR (Polyisocyanurate) or mineral wool. This report focuses on steel skinned ISP which are the most common type. ISP is premanufactured. They typically have an interlocking tongue and groove style joint at the edges of the panels and are mechanically fixed to a supporting structure.

12.2 How are EIFS and ISP used in Australian buildings?

2. EIFS used in Australia has predominantly been EPS or EPS-FR (EPS with brominated fire-retardant additive). ISP used in Australia usually includes EPS-FR but has also used a range of other core materials including PIR, EPS in phenolic matrix and Mineral wool.

3. The EIFS construction applied in Australia typically differs from European EIFS systems which have been tested in overseas full-scale façade tests as summarised in the table below.

Table 24. Key differences between typical Australian EIFS construction and European full-scale façade fire tested EIFS.

EIFS construction detail	Australian Typical Construction	European full-scale façade fire tested construction
Predominant External insulation polymer type	EPS	EPS
EPS thickness	50-100 mm	100-300mm thick
Cavity/substrate behind EPS	Combustible surfaces directly exposed to wall cavity. Direct fix – EPS directly fixed to Light weight wall frame with sarking and wall cavity with timber or steel framings directly behind Cavity – same as direct fix but EPS, timber or steel battens forming ~ 25 mm air gap/drainage cavity directly behind EPS	Solid substrate (typically masonry/concrete) or thick substrate board between insulation and stud walls.
Render thickness	~ 5mm typically specified but in practice may typically be installed as less than 5 mm thick	~ 5mm (installed for tested systems)
Cavity barriers/ fire stop barriers installed within EPS	None	~200 mm thick mineral wool fire barriers at regular horizontal intervals (e.g. 900 mm, first floor level, then every second floor level) and sometimes around openings

4. In Australia it appears that EIFS was initially predominantly installed to Class 1 buildings. This application has extended into multi storey buildings of other classes (predominantly Class 2) and

Type A and B building construction types applying the same systems and installation methods as originally intended/approved for Class 1, most likely without suitable testing, certification or performance-based assessment applied for this end use. Measures such as full-scale façade fire testing and inclusion of fire barriers to address EIFS fire spread hazards for multi storey application in Australia have not typically been applied/installed.. The above is indicated by Victorian combustible cladding inspection and audits (by Victorian Cladding Taskforce, VBA and DELWP), review of EIFS systems marketed in Australia and review of existing CodeMark certificates (see Section 3.5.1).

5. ISP is predominantly used in Australia for Class 7 and Class 8 Low rise Type C buildings. However, there are examples of ISP products marketed for application to other building classes of Type A and B construction. Victorian cladding inspection and audits have identified several examples of ISP with EPS and other core types applied to Type A construction buildings such as hospitals and sports stadia.

6. Internationally and within Australia, insurance company requirements and approvals testing such as FM approvals have resulted in testing and control (to some degree) of ISP used for external wall applications on multi storey buildings. In some cases, this has driven specifiers to require suppliers to provide panels with core materials with improved fire performance compared to that of EPS.

12.3 Construction quality and maintenance

7. The fire performance and moisture ingress performance of EIFS systems can be significantly influenced by defects such as insufficient render thickness, render cracking or impact damage, poor capping and sealing of EIFS and poor installation for moisture drainage. Such defects can result from poor construction quality or poor maintenance.

8. Some Australian EIFS suppliers publish detailed installation manuals which address issues such as required fixings, type of render and minimum thickness, limitations of use of product and requirement for installation by trained contractors approved by the manufacturer. Verification of the degree to which these requirements are met in practice via a systematic and broad inspection process is outside the scope of this literature review. Indications from Victorian cladding audits is that there are numerous examples of poor quality and non-compliant EIFS installation.

9. Measures such as inspection and surveillance to ensure suitable onsite installation of an EIFS system in accordance with type tested product systems or fire engineering assessment requirements would be challenging as the system encapsulation is installed onsite and construction quality may vary with location across the building exterior and cannot be visually confirmed from the exterior of the system once finished without destructive penetration of the render. Ensuring that the wall system is suitably protected from render damage caused by impacts or cracking and report may also present a challenge. It should be carefully considered if the Australian building construction and maintenance industry can be reasonably relied upon to meet these challenges if EIFS is to be applied to Type A and B construction.

10. As ISP is premanufactured with facing skins this reduces the issue of installation variability onsite compared to EIFS. However, fire performance is likely to be significantly dependant on installation and fixings. Fixings can easily be visually checked during installation (where front and rear of panels in supporting frame is visible) but may not be easily visually confirmed once the other internal wall linings are installed. In conclusion, the fire performance of ISP can be impacted by on site construction quality control, but due to the above, ISP may be less prone to be impacted by this compared to EIFS. ISP steel skin encapsulation is generally less prone to damage and cracking compared to EIFS.

12.4 Component material fire properties

11. External walls, including EIFS and ISP, are systems of materials, fixings and construction. The fire risk of a wall system is not solely dependent on the materials of construction, but is also influenced by the fixings, construction and extent of encapsulation of combustible materials by materials that are either non-combustible or have good material fire properties.

12. However, the fire properties of the insulation core material does have a significant impact on the fire performance of the complete EIFS or ISP system.

13. Fire properties of various types of rigid foam polymer insulation have been reviewed. EPS has been ranked as one of the poorest material options in terms of fire performance due to its thermoplastic/melting behaviour, its ignitability and its high heat of combustion. Inclusion of brominated fire retardant to EPS will significantly reduce its susceptibility to small incidental ignition sources only but does not significantly change its fire spread and burning behaviour when exposed to large flame immersion or high radiant heat levels.

14. EIFS render systems are typically specified to consist of a base render coat with fibre glass mesh, subsequent render coats and finishing coat/sealer. Render comes in two main types:
    a. Cement based render - consists of plaster's sand, cement and lime typically mixed from raw materials onsite. Cement based render is prone to poor adhesion and encapsulation of EPS and spalling and cracking during a fire exposure. It is not recommended for application to EIFS.
    b. Polymer/acrylic modified render - Acrylic resins (or other polymer additives) are added to the traditional cement, lime and sand mix for enhanced water resistance, flexibility and adhesion. Acrylic render is more expensive than traditional cement-based render and is typically only available in premixed bags or tubs. Most EIFS Systems specifically require application of Acrylic/Polymer modified renders.

    Both types of renders may be prone to cracking or spalling if exposed to a large fire with direct flame impingement over a significant surface area. This behaviour can be enhanced by any existing defects in the render system such as insufficient render thickness, reinforcement or pre-existing cracks or damage.

15. Steel faced ISP are faced with Steel sheet, typically 0.4-0.7 mm thick with a painted/coated external surface. The steel sheet is typically more resilient to mechanical damage and cracking compared to EIFS render. However, during fire exposure steel facings can open or delaminate at panel joints if insufficient fixings are installed and they will not retain any structural stability if the structural stability of the core material is lost due to melting.

12.5 Mechanisms of fire spread on complete EIFS and ISP systems

16. The façade fire performance of an EIFS system can be affected by any of the following factors:
    a. Core material type and thickness.
    b. Render type, thickness, adhesion, mesh, expansion joints, bottom edge treatment and completeness of encapsulation.
    c. Internal wall cavity and type of framing within cavity vs solid substrate.
    d. Presence, Type and distribution of internal fire stops/cavity barriers.
    e. Fixings.
    f. Penetration protection.
    g. Quality of installation.
    h. Durability, weather and mechanical impact/stress exposure, moisture migration which may affect the encapsulation of the insulation during the life of the product.
    i. Ongoing maintenance.

17. The façade fire performance of an ISP system can be affected by any of the following factors:
    a. Core material type and thickness.
    b. Outer skin material and thickness.
    c. Fixing of panels to supporting structure (to collapse of panels or delamination of skins).
    d. Fixing or other retention at panel joints (to collapse of panels or delamination of skins).
    e. Edge capping/encapsulation of panels.
    f. Penetration protection.
    g. Quality of installation.
    h. Ongoing maintenance.

18. EIFS with EPS core can exhibit the following fire spread mechanisms:
    a. Melting and shrinking away of EPS from behind heat effected render which can weaken the render.
    b. EPS exposed to fire via pre-existing holes or un finished edges to render.
    c. Cracking, spalling or formation of holes in render exposing EPS to fire.
    d. EPS and EPS-FR will sustain ignition and surface burning when exposed to prolonged/sufficient flame contact.
    e. EPS melts and will form molten pool fires on horizontal surfaces below EIFS. This can result in downward fire spread and can act to enhance the fire exposure to the EIFS above.
    f. Render can progressively fail vertically and horizontally resulting in vertical and horizontal fire spread.
    g. In the case of direct fixing or cavity fixing of EPS with a wall cavity directly behind the EPS it is possible that if fire penetrates into the cavity and there is sufficient ventilation available into the cavity then fire will spread rapidly within the cavity.

19. Steel faced ISP's used as external walls utilise a broader range of core materials which will significantly influence mechanisms of fire spread as follows:
    a. EPS will contract and then melt away and also undergo pyrolysis in areas of direct flame or high radiant heat exposure. This can result in flaming of gases released at seams, formation of molten EPS pool fires at horizontal surfaces and loss of panel rigidity if the area of melting is significant.
    b. Thermosetting cores will not melt and are less likely to lose panel rigidity but can still result in pyrolysis of the core material and flaming of gases released at seams (or where sufficient oxygen is available).

20. Mechanisms of fire spread for steel faced ISP external walls will also be strongly influenced by the following fixing materials and details:
    a. If panels are not through bolted through both steel faces back to the supporting structure (e.g. only screwed to rear face) or have sufficient steel rivets or other fixings to outer facing then there is a risk of delamination of the exposed face resulting in increased exposed area and burning rate of the combustible core, and a significant risk from falling debris.
    b. If panel edges and joints are flashed with aluminium channels or angles and aluminium rivets these may melt away under flame impingement exposing the combustible core.
    c. Panel facing joints and seams not fixed with steel rivets at regular spacing's may open up resulting in partial facing delamination and exposure of the combustible core.
    d. Suitable sealing of any penetrations and maintenance of damaged panel skins.

12.6 EIFS and ISP related fire incidents

21. Fire incidents involving EIFS overseas have demonstrated that rapid external fire spread with fatalities beyond the level of fire origin can result. German EIFS fire incidents from 2001 to 2017 recorded 96 incidents with 12 fatalities and 173 injured persons. Many of these fatalities occurred not in the room or floor of fire origin but on floors above the fire origin. The high number of fire incidents in Germany may be in part due to climatic conditions promoting more extensive use of EIFS in low to mid rise (~ 22 m) buildings compared to Australia.

22. Less EIFS fire incidents have been identified locally in Australia (specifically Victoria) and none have been identified to have resulted in fatalities. This may be due to a combination of:
    a. The total number of multi-storey, Multi-occupancy buildings clad in EIFS is less compared to Europe.
    b. Past fire brigade incident records in Victoria do not specifically capture details such as involvement of EIFS.

23. A number of fire incidents involving ISP have been identified both internationally and within Australia and New Zealand. These have mainly involved single storey or low-rise factory/storage buildings. Other than the Wharfedale Hospital fire, no fire incidents involving other building classes or mid-high rise buildings have been identified. This is likely due to ISP usage being far more common for low rise factory/storage buildings.

12.7 Building code requirements for EIFS and ISP external walls

24. In Australia the NCC does not specifically identify or define EIFS or ISP. It therefore does not specify any requirements that are solely intended for these systems, although other general requirements for external wall systems do apply.

25. NCC 2019 Vol 1 DTS requires external wall systems for buildings of Type A or Type B construction to be non-combustible excluding a limited set of materials which are permitted to be combustible listed in NCC Vol1 DTS clauses C1.9 and C1.14 (ancillary elements). EIFS and ISP systems do not constitute one of the limited set of materials permitted to be combustible for Type A or Type B construction and therefore EIFS and ISP external wall systems are not permitted as DtS.

26. NCC DTS Concessions do not apply to, or provide a pathway for, DTS compliance of EIFS or ISP as external walls for buildings of Type A or Type B construction. For example, NCC 2019 Volume 1 Specification C1.1 Clause 3.10 and Clause 4.3 permits timber framed construction for Class 2 and 3 buildings having a rise in stories of up to 3 or 4 storeys but this does not include EIFS or ISP. Specification C1.10 requirements for fire hazard properties of internal building linings and other materials including insulation is not applicable to EIFS and ISP materials when applied as external walls.

27. Assessment as a Performance Solution supported by a documented fire engineering assessment is a key pathway for evidence of compliance of these systems with NCC Performance Requirements for Type A and Type B construction. However, based on results of audits undertaken as part of the Statewide Cladding Audit, it appears that previous/existing buildings which have adopted these materials often have not appropriately addressed them as a Performance Solution, or applied any other relevant method of demonstrating compliance.

28. NCC 2019 CV3 is a non-mandatory verification method which provides one method of verifying that a Performance Solution for a combustible external wall for Type A or B construction is compliant. CV3 is non-mandatory and other performance solution assessment methods can be applied. In summary, for Type A construction CV3 requires an AS 5113 EW classified tested wall system, plus

cavity fire barriers installed at each floor level, plus sprinkler protection internally and on balconies, patios and terraces regardless of effective height, plus monitored sprinkler stop valves at each level and sufficient water supply to support extended sprinkler activation area over two levels for buildings with effective height greater than 25 m. Note CV3 does not address site construction quality control or long term maintenance of EIFS which may impact performance.

29. Building codes and standards in USA and Europe do specifically identify and define EIFS or ISP (in some cases alternative acronyms are used) and set requirements specifically and solely intended for these systems. Requirements typically include full scale façade fire testing, inclusion of mineral wool fire barriers and minimum requirements for render types and thickness.

30. NZ Building code does not specifically define EPS, EIFS or ISP but does set the following relevant requirements:
    a. Fire stop barriers at 2 storey intervals for buildings of three or more storeys fitted with combustible external insulation.
    b. Application of cone calorimeter testing. However, only requires metal facing with a melting point of less than 750 °C to be removed for testing. Rendered EIFS and steel faced ISP appear to be tested with the facing in place which can significantly influence results.

12.8 Certification

31. CodeMark certificates for EIFS and ISP products have been reviewed. The following issues with these certificates have generally been observed:
    a. Most CodeMark certificates do not address all relevant NCC performance requirements that apply to a given product. In many cases only performance requirements related to energy efficiency and weatherproofing are addressed.
    b. Most CodeMark certificates do not directly address vertical façade fire spread performance or the use of combustible materials for Type A and B construction
    c. Some CodeMark certificates do address fire performance but typically this is limited to internal wall and ceiling lining fire hazard properties and building in bushfire prone areas requirements.
    d. Some CodeMark certificates are clearly limited to Type C construction or Class 1 buildings. Other CodeMark certificates do not clearly state any such limitations
    e. It is evident that in the past, industry may have assumed or mis-used CodeMark certificates to represent full and complete product compliance with NCC requirements for end use applications (such as fire performance for Type A and B external walls) not actually addressed by the CodeMark certificates. Proper regard has not been given to the limitations of such certificates (whether they are clearly stated or not).
    f. The Shergold-Weir report[35] states *"There have been criticisms of the CodeMark system. The BMF (Building Ministers Forum) has been aware of these issues for some time. Indeed it has already tasked the ABCB with making recommendations to address shortcomings with the CodeMark system*."

32. Other state-based accreditation authorities exist such as the Building Regulations Advisory Committee (BRAC) in Victoria. BRAC has issued several certificates of building product accreditation for EIFS. Based on CSIRO review of a limited selection of BRAC certificates for EIFS, these generally appear to be limited to class 1 and 10 building use and may only address specific NCC performance requirements (e.g. relating to weatherproofing, thermal or structural performance) but may not fully address all performance requirement that may be relevant to the products potential end uses (such as reaction to fire and fire resistance performance). It is noted that the BRAC certificates of building product accreditation are not available for download from the "BRAC Building Product

Accreditation” web page (which is part of the VBA website) and CSIRO only reviewed a limited set number of BRAC certificates obtained directly from supplier websites.

33. Insurance industry approvals testing and certification systems exist, such as FM approvals, which provides certification applicable to a section of the building insurance industry, and may indicate a level of fire performance acceptable to sections insurance stakeholders. But these approvals (on their own) do not form evidence of compliance with the NCC but could be considered as part of the evidence applied to a Performance Solution. FM Approvals have focused predominantly on ISP for non-residential use and not EIFS.

12.9 EIFS and ISP Industry bodies, guidelines and standards in Australia.

34. In Australia, industry bodies such as PACIA (Plastics and Chemicals Industries Association) and EPSA (Expanded Polystyrene Australia Incorporated) which broadly represent a range of rigid foam polymer applications also represent the EIFS industry. There is no specific Australian industry body solely representing the EIFS industry and no Australian code of practise or industry standards. This indicates a possible lack of effective self-regulation by industry on the application of EIFS in Australia. In the USA and Europe there are industry bodies such as EAE and EIMA which solely represent the EIFS industry and proactively lead via self-regulation, or published standards, guidelines etc.

35. IPCA has specifically represented the ISP industry in Australia and developed a code of practice for ISP application. However, this code of practice focuses on internal wall and ceiling applications for Class 7 and 8 buildings and does not specifically address use of ISP as external walls in multi-storey buildings of other classifications, including residential.

12.10 Fire tests and experimental research applicable to EIFS and ISP external walls

36. A range of fire test methods that can be applied to EIFS and ISP intended for use as external wall systems has been reviewed. It is concluded that:
    a. Small scale tests provide useful measures of fire behaviour of individual component materials under specific limited fire conditions but do not directly predict full scale wall system fire behaviour.
    b. Intermediate scale tests on wall systems, such as ISO 13785 Part 1), can provide useful information on system fire behaviour limited to specific small, localised ignition source scenarios such as small balcony fires of ~ 100 kW. But do not directly predict full scale wall system fire behaviour when exposed to a larger ignition source.
    c. Full scale external wall fire spread tests such as AS 5113 and BS 8414 (and FM 4881 approval tests in the case of ISP) are the most reliable method of verifying system fire behaviour when exposed to a larger ignition source.

37. Full scale external wall fire spread tests such as AS 5113 and BS 8414 (and FM 4881 approval tests in the case of ISP) represent large fire exposure scenarios and can provide suitable evidence as input to a performance-based solution. However, this is reliant upon ensuring the end use installation is consistent with that of the tested system.

38. The differences in construction between typical Australian EIFS and European tested EIFS systems are expected to significantly influence façade fire spread performance. It is noted that European EIFS fire tests and fire incidents without suitable cavity fire barriers installed have resulted in unacceptable vertical fire spread and this indicates that typical Australian EIFS which has no cavity

fire barriers (for type A and B construction) would support similar unacceptable vertical fire spread. Beyond this, European EIFS full scale façade fire tests cannot be directly applied to typical Australian EIFS fire spread behaviour. This literature review has not identified a publicly available test report or test summary for an AS 5113 (or other standard) full scale façade fire spread test conducted on a typical Australian EIFS construction.

39. The majority of EIFS system full scale façade fire tests published from other countries include cavity barriers, solid substrates directly behind EIFS, render thickness of > 6mm, fixing methods and other elements that differ to the construction methods of existing Australian building stock. Such tests cannot be directly applied to represent typical Australian construction.

40. Numerous EPS EIFS systems have achieved BRE BR135/BS8414 full scale test compliance. However, all these systems have been significantly different to typical Australian EIFS construction as they include:
    a. Thick, well installed reinforced render free of any cracks or other defects.
    b. Mineral wool fire stop cavity barriers.
    c. A solid continuous substrate behind the EPS (Not a light weight framed wall cavity).

41. AS 5113 EW applies the BS 8414 test method with more stringent acceptance criteria compared to BR 135. It is unlikely that an EPS EIFS system that has achieved BRE BR135/BS8414 full scale test compliance would achieve AS 5113 EW compliance due to the more stringent AS 5113 EW criteria related to falling debris, burning debris and inclusion of melting as a criterion for flame spread beyond the confines of the specimen. The NCC does not preclude a performance-based assessment from being based on either:
    a. A BS 8414 test which passes BR 135 criteria, or
    b. An AS 5113 test which fails criteria related to burning debris and/or melting but demonstrates that vertical fire spread is limited to an "acceptable" extent

    However, such a performance assessment should ideally address issues including

    a. What performance-based definition/measurement is used to verify that vertical fire spread is limited to an acceptable extent.
    b. Hazards relating to molten burning debris and downward fire spread.
    c. Hazards relating to reduction in fire performance that could result from poor onsite construction or poor maintenance during the life of the system.

42. EIFS applying combustible insulation with improved fire performance (PIR, EPS in Phenolic matrix, Phenolic foam or EPS in cement matrix) is likely to perform better than EPS EIFS if tested in a full-scale façade fire test. However no published test results for such EIFS Systems have been identified. EIFS with mineral wool insulation performs significantly better than EPS EIFS in published full scale façade fire tests.

43. FM Approvals does not list any approved EPS ISP and it is unlikely that EPS ISP would meet FM 4881 acceptance criteria. ISP's with cores of PIR, PUR, EPS in phenolic matrix and miner wool have met FM 4881 acceptance criteria.

44. It is unlikely that EPS ISP would achieve AS 5113 EW compliance due to criteria related to falling debris, burning debris and inclusion of melting as a criteria for flame spread beyond the confines of the specimen. No publicly available AS 5113 EW tests on ISP with ESP or other combustible core types have been identified in this literature review.

45. Bushfire AS 1530.8.1 test reports referenced by CodeMark Certificates of Conformity provided for some products which hold BRAC certification indicate that some EPS based EIFS systems (as tested) comply with AS 1530.8.1 test requirements when tested at BAL of up to 40 kW/m2. However,

review of these reports indicates that some of these systems have been tested as specimens without render expansion joints or exposed base of wall details (a ground clearance having either an unfinished EPS edge or fitted with an aluminium/PVC starter channel with weepholes). Due to this practice, AS1530.8.1:2018 included the following new requirements for external wall test specimens:

- The wall system must be installed and tested in a manner representative of the intended application.
- It shall include representative base of wall details and any openings to wall cavities
- It shall also be tested with horizontal or vertical joints (control joints) where these form part of the wall in practice.

It is considered possible that such details may reduce the performance of EIFS Systems in this test.

12.11 Fire safety rectification of existing EIFS or ISP external walls.

46. Based on experience with the Statewide Cladding Audit, inspection, review and rectification approval process in Victoria, fire safety rectification of existing EIFS or ISP should include the following steps:
    a. Identification and inspection - Identify the presence, type and extent of EIFS, ISP or any other combustible external wall materials installed to a building. Also inspect the ignition hazards, fire safety systems, maintenance and exit provisions for the building.
    b. Risk assessment – Undertake a preliminary risk assessment to determine if the building is currently unsafe to occupy and determine a preliminary risk ranking for the building which considers a broad range of risk factors that may contribute to both the overall risk of fire spread and the overall risk to safe evacuation of occupants
    c. Interim rectification measures - Measures that may be required to immediately reduce the risk of the building or make it safe to occupy should be identified. This may include:
        i. Rectification of poorly maintained fire safety systems.
        ii. Installation of improved fire detection and automatic monitoring and notification of fire brigades.
        iii. Removal of ignition hazards.
        iv. Removal of combustible cladding from localised high-risk areas.
    d. Long term rectification measures – Measures required to achieve an acceptable level of risk or compliance with NCC performance requirements must be determined.

47. In many cases the simplest option for long term rectification may be DTS compliance via complete removal of all combustible cladding and replacement with DTS compliant external wall systems.

48. In some cases, a Performance Solution may be proposed and assessed by a fire engineer which involves retaining either all or a portion of the combustible cladding if it is likely to produce a more cost-effective outcome. Currently in Victoria, the typical process is for Performance Solutions for rectification of combustible cladding on existing buildings documented in fire engineering reports to be referred to the Building Appeals Board for determination under section 160A of the *Building Act 1993* that the Performance Solution complies with the relevant Performance Requirements. This process is being applied in part due to building surveyor insurance which often excludes coverage for matters relating to combustible cladding. This process is also currently recommended by the Cladding Safety Victoria website.

13 Knowledge Gaps and Suggestions to close these gaps.

13.1 Knowledge gaps

The following Knowledge gaps have been identified in this literature review:

- The scope of this literature review did not include communication and engagement directly with EIFS and ISP product suppliers or industry bodies to gain further information. This is recommended as possible further work.

- No published full-scale external wall fire spread tests were found representing installation of EIFS typical within Australia, characterised by direct fix or cavity systems with light weight wall cavity behind and no inclusion of mineral wool cavity fire barriers. In the absence of full-scale test data the fire performance of this system can reasonably be assumed to be poor.

- No published test data or research on the suitability and cost effectiveness of potential rectification options for existing buildings with poor performing EIFS or ISP was identified. Potential mitigation alternatives to complete removal/replacement might include over-cladding and/or partial removal to create external fire breaks, or enhancement of sprinkler protection. However, such measures are complex and require further testing or research to demonstrate viability.

- No Published full-scale façade fire tests were found for EIFS with PIR, PUR, phenolic foam, EPS in Phenolic matrix or EPS in cement matrix.

- Details on the extent of use of EIFS and ISP for external wall systems in different building classes and Type A, B or C construction for Victoria and Australia has not been obtained but has been indicated anecdotally from a limited subset of Victorian cladding audit reports conducted under the Statewide Cladding Audit.

- Details on the extent of poor or defective construction for EIFS and ISP in Victoria and Australia has not been obtained.

- MFB and CFA Fire brigade data previously collected does not identify or capture the details of EIFS and ISP related fires.

- This Literature review has not included any site inspections of EIFS and ISP. Some prior experience from limited inspection and testing of these systems by CSIRO has been drawn upon.

- No publicly available test reports, CodeMark certificates or similar have been identified that explicitly state that an EIFS system meets the NCC performance requirements applied to external wall fire spread for Type A or B construction.

- No publicly available test reports, CodeMark certificates or similar have been identified that explicitly state that an ISP system meets the NCC performance requirements applied to external wall fire spread for Type A or B construction. BRE BR-135 and FM 4881 approvals have been found for ISP core types other than EPS. Based on an absence of test approvals it is considered that EPS ISP performance for external walls of multistorey buildings can be assumed as poor.

- Bushfire AS 1530.8.1 tests on various EPS EIFS systems which indicate compliance ranging from BAL19-BAL40 may not have included representative base of wall details and control joints as required by the most recent 2018 version of this standard. It is considered possible that such details may reduce the performance of EIFS Systems in this test, but this needs to be verified by testing.

13.2 Suggestions

The following suggestions are made as opportunities to address the identified knowledge gaps:

13.2.1 EDUCATION

- Further education of the building industry including building surveyors, fire safety engineers and builders may be required ensure full understanding of the building code DTS and performance requirements and what constitutes suitable evidence of compliance relating to fire performance of EIFS and ISP. Many of the following recommendations may assist with such education.

- The VBA should produce a brief advisory document to communicate key conclusions from this literature review to industry.

- Regulatory Authorities should collaborate with industry bodies to develop or extend codes of practice addressing EIFS and ISP application for external walls for all building classes and Types of construction. These should be used to educate and improve building practice.

13.2.2 REGULATION

- EIFS and ISP should not be applied to any new Type A and B construction buildings from this point forward without suitable demonstration of NCC compliance via full scale façade testing and performance-based assessment.
- Any future application of EIFS or ISP external walls with combustible insulation components for Type A or B construction (performance based) must include strict independent site inspection and verification of compliance with installation requirements as part of the acceptance process. A regulatory process for this should clearly state who is responsible for this (the Relevent Building Surveyor or another authority) and what level of inspection and reporting is required.

13.2.3 CERTIFICATION

- The CodeMark and BRAC certification system regarding EIFS and ISP could be improved by the following recommendations:
    - All Certificates should be reviewed and revised to clearly state limitations including where the product is not assessed for compliance applicable to external wall fire spread.
    - Industry should be further reminded that CodeMark and BRAC Certificates typically only address compliance of a subset of NCC requirements applicable to a product and does not represent full compliance with all NCC requirements applicable to a product. As such these certificates should not be used or assumed to demonstrate full compliance with all aspects of the NCC.

13.2.4 AUDIT AND INSPECTION OF EXISTING BUILDINGS AND RECORDING OF FIRE INCIDENTS

- In the absence of further test data, the following course risk ranking for EIFS and ISP external walls for existing Type A and B buildings in Victoria/Australia is suggested:
  - EPS core/insulation – High risk of fire spread (roughly similar to that of 100% PE).
  - PIR, EPS phenolic Matrix, Phenolic foam – medium or lower risk of fire spread. Performance is dependent on encapsulation and fixings and this should be taken into consideration when assessing risk.
  - Mineral wool – No significant risk of fire spread.

- VBA and DELWP ARP cladding audits and Victorian cladding task force Audit (and other state-based audits) collect detailed reports on individual buildings but do not appear to combine all this collected data in a central searchable database. It is recommended that developing such a database and mining the data collected would provide valuable understanding of the extent and implications of EIFS and ISP (and other cladding type) use across a variety of build types etc.

- There would be benefit if Audit/site inspections conducted to support ARP's included some measurement of render depth for EIFS, even if restricted to limited locations on each building. This may inform not only the details of each specific building but the extent of quality of EIFS installation more broadly. This must be balanced against the impacts of destructive measurements on the buildings and the time/resources available for building inspections. Information on render thickness may not significantly change the risk ranking of the EIFS system if other aspects such as absence of cavity fire barriers or EPS open to rear wall cavity are confirmed or must be assumed as a worst case.

- Undertaking a series of detailed inspections, focused on destructive measurement of items such as render thickness, cavity barriers, EPS open to internal wall cavity and other installation factors for EIFS (and ISP), would enable the extent of quality of installation of these systems to be quantified. This could be focused on a specific/limited set of buildings already identified via the ARP process. If buildings are identified which are having EIFS removed/replaced anyway, this may provide a good opportunity for such inspection.

- Fire Brigade data incident data collection should be improved to capture specific details related to EIFS, ISP (and other cladding type) fires.

13.2.5 TESTING AND EXPERIMENTAL RESEARCH

- A series of Intermediate scale experiments simulating localised balcony fires impinging on EIFS or small fires within EPS lined wall cavities with installation typical for Australia would inform the expected performance and risk assessment applicable to small localised fire scenarios. Comparative tests against 100% PE ACP and EIFS with varying render thickness/quality and other possible factors varied may provide a cost-effective method to gain further resolution on the relative risk of EIFS vs ACP. It would not indicate performance in response to larger ignition sources.

- Bushfire tests to AS 1530.8.1:2018 should be conducted at BAL 40, BAL 29 and BAL 19 (the range that certification is typically given for) on representative EPS EIFS wall systems which include representative base of wall details and horizontal or vertical control joints to verify if these details have a significant effect on reducing fire performance in this test. Test cribs should be placed adjacent to these details on the tested specimen. If a significant reduction in test performance results, then the certification of existing EIFS products for use in bushfire prone areas based on tests not incorporating such details should be carefully considered. Tests could also be undertaken to investigate the impact of poor or defective installation or maintenance on performance against this test method.

- A series of carefully selected full-scale experiments should be undertaken to further understand the fire performance of EIFS and ISP as external walls where knowledge gaps have been identified. In particular, investigating cost effective rectification measures (potentially including over cladding or horizontal banding). Undertaking a series of carefully selected experiments may require either regulatory authority funding or collaboration between regulatory authority and private industry. Private industry is only ever likely to fund one-off tests on their specific products. Any project should be carefully planned (ideally by collaboration of a number of testing authorities and researchers) to achieve the most useful result prior to undertaking testing.

- Based on available material information EPS in cement matrix is expected to have a low risk of external wall fire spread (but may be expected to fail on some of the technical AS 5113 criteria such as falling debris and extent of melting/charring) however this does not appear to have been verified in a full-scale façade fire test. It is recommended that a full-scale façade fire spread test should be conducted to validate this to enable risk assessment for its use on existing buildings. It is noted that performance may vary with composition of the particular product.

- Any further research or testing should preferably be cognisant and harmonised with international developments in the same field to ensure value for money spent.

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Appendix A Summary of EIFS and ISP systems available in Australia.

EIFS Codemark Product summary

Item	Product Name	Manufacturer Name	Substrate	Batten/Direct Fix	Type of Core	Available insulation Thicknesses (mm)	Fixing Details	Panel Jointing	Render System	Minimum Render thickness	Specific fire safety requirements stated in product data	Certification Number	Certification date of issue	Certification expiry date	NCC Volume 1 Performance requirement compliance stated by certificate	NCC Volume 2 Performance requirement compliance stated by certificate	Does certification cover fire safety matters	Building Class Limitation stated on Certification	Type of construction Limitation stated on Certification	Building height limitation stated on certification	Any other limitations relevent to fire safety stated on certification	Fire Performance/Testing stated in certification				Product documentation reviewed other than certification	Has an installer training and registration system	Comments
																						Bushfire	Fire Resistance Level	Internal Reaction to Fire	External Façade Fire test			
1	Cova-Wall®	JPS Coatings Pty Ltd	Timber frame (other substrates not mentioned)	Battened cavity - 25mm using EPS battens or Direct Fix	EPS- M grade (not clarified if EPS-FR)	50 75 100	10 gauge screws with polypropylene 40mm washers	foam adhesive	First Coat: Patch `Em-Up® - 2mm. Second Coat - Fastwall® Render - 2-4mm Finish Coat - Decorative top coat sealer.	5	None	CodeMark (CMA –CM40180-I01-R00)	30/07/2016	3/07/2019	**Performance requirements:** BP1.1 Part (b)(iii) - Wind action FP1.4 - Water penetration JP1 - Energy efficiency	**Performance requirements:** P2.1.1 (a), (b) and (c) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.6.1 - Energy efficiency	No	None stated	None stated	8.5 m height	None stated	None	None	None	None	https://www.covawall.com.au/ Product manuals requested but not received	yes	
2	Exsulite® Thermal Façade Cavity System	Dulux AcraTex	Metal or timber frame with breathable sarking membrane	Direct Fix or Cavity system with cavity spacer of 15 mm or 25 mm EPS battens.	EPS (not clarified if EPS-FR)	60 75 100	10 gauge screws with plastic 40mm washers	PU expanding foam adhesive	Exsulite Matrix Basecoat™ with Exsulite alkali resistant mesh – 4-5mm coat AcraTex Green Render Sealer ™(Optional) Exsulite Texture Coating Exsulite Membrane topcoat	5	Product only suitable for Class 1 and Type C construction Class 2 to 9. Not to be applied where an FRL is required. Suitable for BAL 29 application when installed in accordance with tested system	CMA-40006	13/01/2018	13/01/2021	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii) - Structural Provisions FP1.4 - Weather Proofing FP1.5 - Damp-proofing GP5.1 - Bushfire aeas (BAL-29) **Deemed-to-Satisfy Provisions:** J1.5 - Energy efficiency - Walls	**Performance requirements:** P2.1.1 (a), (b)(i)(ii)&(iii) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.2.3 - Dampness P2.3.4 -Bushfire areas - (BAL29) **Deemed-to-Satisfy Provisions:** Part 3.12.1.4 - Energy efficiency external walls	Yes	Class 1,2,3,4,5,6,7,8,9 & 10	Type C for building classes 2-9	8.5 m height	None stated	AS 1530.8.1 - BAL A-29 result on system including: - 10 mm Gyprock plasterboard on unexposed face. - 75mm thick panel with 25mm spacer, 60mm panel with 15mm spacer and 100mm panel with 40mm spacer. - Exposed face with 4.0 mm Dulux Exsulite Matrix as a basecoat with a further 1.5 mm coat of Dulux Exsulite Acrylic Texture Coat and Dulux Exsulite Membrane topcoat.	None	None stated (however stated in literature)	None	EWFA Certificate of assessment No : SFC 27615-02A (AS 1530.8.1) constructionDrawings_20180101-V3 exsulitebrochure20141008 installationManual_20180813-V4 http://www.exsulite.com.au/technical-data/	Yes	Instalation manual states: - should not be exposed to continuous temperatures > 80 degC. -BBQ's, Patio heaters etc should not be opperated closer than 1.5 m
3	Exsulite® Thermal Façade Non Cavity System	Dulux AcraTex	Metal or timber frame with breathable sarking membrane	Direct Fix or Cavity system with cavity spacer of 15 mm or 25 mm EPS battens.	EPS (not clarified if EPS-FR)	60 75 100	11 gauge screws with plastic 40mm washers	PU expanding foam adhesive	Exsulite Matrix Basecoat™ with Exsulite alkali resistant mesh – 4-5mm coat AcraTex Green Render Sealer ™(Optional) Exsulite Texture Coating Exsulite Membrane topcoat	5		CMA-CM40138-I01-R01	6/02/2015	6/02/2018	**Performance Requirements:** a. Clause A0.5 (c) being a combination of compliance with the Deemed-to-Satisfy Provisions and formulating an Alternative Solution which complies with the Performance Requirements. b. BP1.1 (a) and (b) (iii), (viii), (xi), (xii) and (xiv). c. FP1.4 d. JP1 (including NSW J(A)P1), in NT and QLD Section J is replaced by BCA 2009 Section J i. J1.2 (a) ii. J1.5 (a) & (b)	**Performance Requirements:** a. Clause 1.0.5(c) being a combination of compliance with the Deemed-to-Satisfy Provisions and formulating an Alternative Solution which complies with the Performance Requirements. b. P2.1.1 (a), (b) and (c) c. P2.2.2 a. Part 3.3.4 Weatherproofing of Masonry (including all sub provisions state variations) d. P2.3.4 Bushfire areas (including Tas P2.3.4). i. Part 3.7.4 Bushfire areas (including all sub provisions state variations) e. P2.6.1 Energy Efficiency Building (in NSW Part 2.6 does not apply, in NT Part 2.6 is replaced by BCA 2009 Part 2.6, Vic P2.6.1) i. Part 3.12.1.1 (a) Building fabric	Yes	None stated	None stated	8.5 m height	None stated	Approved for use in bushfire prone areas requiring BAL29 performance rating to AS 3959:2009 - Construction of buildings in bushfire-prone areas. **AS 1530.8.1 - BAL A-29 result on system including:** - 10 mm Gyprock plasterboard on unexposed face. - 75mm thick panel with 25mm spacer, 60mm panel with 15mm spacer and 100mm panel with 40mm spacer. - Exposed face with 4.0 mm Dulux Exsulite Matrix as a basecoat with a further 1.5 mm coat of Dulux Exsulite Acrylic Texture Coat and Dulux Exsulite Membrane topcoat.	none	Not stated (however stated in literature)	none	EWFA Certificate of assessment No : SFC 27615-02A (AS 1530.8.1) constructionDrawings_20180101-V3 exsulitebrochure20141008 installationManual_20180813-V4 http://www.exsulite.com.au/technical-data/	yes	Instalation manual states: - should not be exposed to continuous temperatures > 80 degC. -BBQ's, Patio heaters etc should not be opperated closer than 1.5 m
4	Exsulite® Composite Thermal Façade System	Dulux AcraTex	Metal or timber frame with breathable sarking membrane	Direct Fix or Cavity system with cavity spacer of 15 mm or 25 mm EPS battens.	Pre- Rendered EPS (not clarified if EPS-FR)	60 75 100	10 gauge screws with plastic 40mm washers	PU expanding foam adhesive	Exsulite Matrix Basecoat™ with Exsulite alkali resistant mesh – 4-5mm coat AcraTex Green Render Sealer ™(Optional) Exsulite Texture Coating Exsulite Membrane topcoat	5	Not to be applied where an FRL is required. Suitable for BAL 29 application when installed in accordance with tested system	CodeMark (CMA-CM40057-I02-R00)	22/07/2016	2/08/2019	**Performance requirements:** a. Clause A0.2 (c) being a combination of compliance with the Deemed-to-Satisfy Provisions and formulating a Performance Solution which complies with the Performance Requirements. b. BP1.1 (a) and (b) (iii), (viii), (xi), (xii) and (xiv). c. FP1.4 d. JP1 (including NSW J(A)P1), in NT and QLD Section J is replaced by BCA 2009 Section J i. J1.2 (a) ii. J1.5 (a) & (b) **Deemed-to-Satisfy Provisions:** Non stated	**Performance requirements:** a. Clause 1.0.2 (c) being a combination of compliance with the Deemed-to-Satisfy Provisions and formulating a Performance Solution which complies with the Performance Requirements. b. P2.1.1 (a), (b) and (c) c. P2.2.2 i. Part 3.3.4 Weatherproofing of Masonry (including all sub provisions state variations) d. P2.3.4 Bushfire areas (including Tas P2.3.4). i. Part 3.7.4 Bushfire areas (including all sub provisions state variations) e. P2.6.1 Energy Efficiency Building (in NSW Part 2.6 does not apply, in NT Part 2.6 is replaced by BCA 2009 Part 2.6, Vic P2.6.1) i. Part 3.12.1.1 (a) Building fabric thermal insulation ii. Part 3.12.1.4 External walls **Deemed-to-Satisfy Provisions:** None stated	Yes	None stated	None stated	8.5 m height	Approved in bushfire areas requiring BAL29 AS 3959:2009 - Construction of buildings in bushfire prone areas	AS 1530.8.1 - BAL A-29 result on system including: - 10 mm Gyprock plasterboard on unexposed face. - Exposed face with 4.0 mm Dulux Exsulite Matrix as a basecoat with a further 1.5 mm coat of Dulux Exsulite Acrylic Texture Coat and Dulux Exsulite Membrane topcoat.	None	None stated	None	EWFA Certificate of assessment No : SFC 27615-02A (AS 1530.8.1) constructionDrawings_20180101-V3 exsulitebrochure20141008 installationManual_20180813-V4 http://www.exsulite.com.au/technical-data/	yes	Instalation manual states: - should not be exposed to continuous temperatures > 80 degC. -BBQ's, Patio heaters etc should not be opperated closer than 1.5 m
5	Exsulite® - Kooltherm Thermal Façade System	Dulux AcraTex	Metal or timber frame with breathable sarking membrane. Concrete or masonry	Cavity system only. Timber batten cavity spaceres 20-25 mm	Kingspan Kooltherm K5 Phenolic foam	50 80	10 gauge screws with plastic 40mm washers.	PU expanding foam adhesive	Dulux AcraTex AcraPrime XPS (Prime coat) Exsulite Matrix Basecoat™ with Exsulite alkali resistant mesh –5mm coat (with addition of Dulux AcraTex Acra-Bond™ for extra adhesion) AcraTex Green Render Sealer ™(Optional) Exsulite Texture Coating Exsulite Membrane topcoat	5	Suitable for FRL up to 90/90/90 when installed in accordance with requirements. Suitable for BAL-FZ when installed in accordance with requirements. Building heights of > 5 storeys need pre-approval of design and fixing specification by Dulux AcraTex depending on building type and use.	CodeMark (CM40082-I02-R00) WITHDRAWN on 20/02/2019	23/02/2018	16/11/2019	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii) - Structural Provisions CP2 - Spread of fire FP1.4 - Weather Proofing GP5.1 - Bushfire aeas (BAL-29) **Deemed-to-Satisfy Provisions:** Spec C1.1 - FRL up to 90/90/90 depending on configuration F5.5 - Sound insulation J1.5 - Energy efficiency - Walls	**Performance requirements:** P2.1.1 (a), (b)(i)(ii)&(iii) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.3.1 - Spread of fire P2.3.4 -Bushfire areas - (BAL-FZ) **Deemed-to-Satisfy Provisions:** **3.7.1.5 - FRL up to 90/90/90 depending on configuration.** **3.8.6.2 - sound insulation** 3.12.1.4 - Energy efficiency external walls	yes	Class 1,2,3,4,5,6,7,8,9 & 10	Type A, B and C	Building heights of > 5 storeys need pre-approval of design and fixing specification by Dulux AcraTex depending on building type and use.	Building heights of > 5 storeys need pre-approval of design and fixing specification by Dulux AcraTex depending on building type and use. AS/NZS 3837 = Group 1	AS 1530.8.2 BAL-FZ	**FRL 30/30/30 EWFA Certificate No: SFC31431900.2A tested system:** Wall System consisting of timber framing at least 90mm deep. Unexposed side of timber framing faced with 10mm non-fire-rated plasterboard. Exposed side of timber framing faced with the following: • 9mm thick Plywood Sheets. • Exsulite™ Breathable Wall Wrap • Rondo Top Hat M525 • 50mm thick Kooltherm K5 External Wall Boards • Dulux Exsulite XPS Primer • 5mm thick Dulux Exsulite Matrix Basecoat with Alkali Resistant Fibre Glass Mesh • 1mm thick Dulux Exsulite Acrylic Texture Coating and Exsulite Membrane Topcoat. The Knauf Earthwool insulation batts are installed inside the timber frame cavity. **FRL 60/60/60 EWFA CERTIFICATE No : SFC 31431900.1B Tested system:**	For Kooltherm K5 insulation without render Report referenced however no results shown. Report Reference: Exova Warringtonfire; NATA Accreditation No. 3277; Report No. 25128-00b.1; Testing to AS 1530.3:1999 Testing to establish the Ignitability, Flame Propagation, Heat Release and Smoke Release properties of the Panel; Dated 17/02/2011.	None	exsuKoolInstallationManual20150224 68369_Kooltherm-K5-External-Wall-Board FRL 30/30/30 EWFA Certificate No: SFC31431900.2A FRL 60/60/60 EWFA CERTIFICATE No : SFC 31431900.1B FRL 90/90/90 EWFA CERTIFICATE No : SFC 31431900.1C	yes	
6	Kool-Wall Panel System	Active Building Systems	Metal or timber frame with breathable sarking membrane.	Direct Fix or Cavity system. Cavity with steel furring chanels or treated timber -25 mm thick .	EPS (not clarified if EPS-FR)	40, 60, 75 & 100	10 gauge screws with plastic 40mm washers.	Kool-wallEzy Seal	Mixture of of'Ezycoat Skim Render &Ezycoat Bond' and water (to be prepared on site) or pre-prepared Ezycoat ECA Render to 4mm finish. Ezycoat Acrylic Texture Finish.	5	None	CM40055 rev 1	11/08/2017	6/08/2019	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii) - Structural Provisions FP1.4 - Weather Proofing **Deemed-to-Satisfy Provisions:** J1.2 (a) - Thermal Construction J1.5(a)(b) - Energy Efficiency - Walls	**Performance requirements:** P2.1.1 (a), (b)(i)(ii)&(iii) - Structural stability and resistance to actions P2.2.2 - Weather proofing **Deemed-to-Satisfy Provisions:** **3.12.1.1 (a) - Building Fabric Thermal Insulation** 3.12.1.4 (a) - Energy efficiency external walls	No	Class 1,2,3,4,5,6,7,8,9 & 10	None stated	None stated	None stated	None stated	None	None	None	Kool-Wall Energy Smart Building Panel - for Kool-Wall Panel System & Kool-Wall Raw Panel System - Installation Manual V1.0 Sept 2016	Yes. Certificate claims to be 'installed by KOOL-WALL registered installers only'.	Maintenance Guide and schedule - recommended for owners in order to keep product warranty.
7	MasterWall®	New Era Nominees	Timber and steel-framed residential and commercial buildings. It may also be applied to concrete and masonry.	Direct Fix only.	EPS – M Grade with FR (stated in Installation Manual)	50, 75, 100,125	10 gauge screws with plastic 40mm washers.	PU expanding foam adhesive	Follow render system's manufacturer specifications . First coat: Fibreglass mesh tape is to be embedded into the first 3mm layer of acrylic render Second coat: 2mm leveling coat of acrylic render. Final: Coloured acrylic texture system and/or paint finish.	5	Suitable for BAL 29 application when installed in accordance with tested system	CM40209 Rev1	23/10/2018	23/10/2021	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii) - Structural Provisions FP1.4 - Weather Proofing GP5.1 - Construction in Bushfire areas – BAL A-29 **Deemed-to-Satisfy Provisions:** J1.5 - Energy Efficiency - Walls	**Performance requirements:** P2.1.1 (b)(iii) - Wind action – Minimum panel thickness 75mm P2.2.2 - Weather proofing P2.3.4 -Bushfire areas – BAL A-29 **Deemed-to-Satisfy Provisions:** 3.12.1.4 - Energy efficiency external walls	yes	Class 1,2,3,4,5,6,7,8,9 & 11	This certification is applicable to Type C only.	Excludes Type A or Type B Construction including Class 2, 3, and 9 buildings of 2 storeys or more and Class 4, 5, 6, 7, and 8 buildings of 3 storeys or more.	Not suitable for use as an FRL rated compliant system in accordance with AS 1530.4 for boundary walls and/or party walls as a standalone walling system. In the absence of a site-specific performance solution, this system is not suitable for use in or on Class 2 to 9 of Type A & B construction, where the NCC requires buildings and/or Ancillary Elements to be non-combustible	MasterWall® Direct-To-Frame System is considered to achieve a bushfire resistance performance of BAL - A-29 when incorporating: • render system with minimum thickness 6.5mm, and • EPS thicknesses of 75mm or 100mm, and • 160gsm fiberglass mesh, and • other components identified in Report Exova Warringtonfire Report FAS 180357.3 Section 2, dated 01/10/2018	None	AS1530.3 : ignitability index (0-20) =12 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 3 Smoke Produced Index (0-10) = 5 AS/NZS 1530: ignitability index (0-20) =0* Spread of flame index (0-10) = 0* Heat Evolved Index (0-10) = 0* Smoke Produced Index (0-10) = 4* *Results as 'Panel Fire Performance'	None	MasterWall - Direct to Frame System - System Installation and Construction Details - Manual dated 20.08.2018 & MasterWall Brochure. Both documents are available at https://www.masterwall.com.au/downloads/	None stated	None.
8	NGR Greenboard	NRG Building Systems (Aust) Pty Ltd	Timber or steel frame.	Direct Fix only.	EPS (not clarified if EPS-FR)	40,50,60,75,100	NRG Washers and screws (details not mentioned)	Non mentioned	Base coat: NRG Polymer Modified Render - 5mm Second Coat: NRG Textures - 1mm Final coat: NRG Shieldcoat (optional)	5	Suitable for BAL 29 application when installed in accordance with tested system	CM30005 Rev11 (Global Mark Pty Ltd)	13/05/2010	13/05/2019	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii)(iv)(v)(vi)(vii)(viii)(ix)(x)(xi) - Structural Provisions BP1.2 - Structural resistance FP1.4-Weatherproofing FP1.5-Rising damp **Deemed-to-Satisfy Provisions:** Spec A2.4 - Fire Hazard Properties G5.2 - Construction in Bushfire Prone Areas – Protection to BAL-29 J1.2 - Thermal construction – general J1.5 - Walls	**Performance requirements:** P2.1.1 (a), (b)(i)(ii)&(iii)(iv)(v)(vi)(vii)(viii)(ix)(x)(xi)(c) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.2.3 - Rising damp **Deemed-to-Satisfy Provisions:** 3.7.4 - Bushfire Areas to BAL-29 3.12.1.1 - Building fabric thermal insulation 3.12.1.4 - External walls	Yes	Class 1,2,3,4,5,6,7,8,9 & 10	None stated	None stated	1) Non compliance with NCC 2016 Volume One Section C: non-combustibility, fire hazard properties when used as a wall lining, fire hazard properties when used as a composite member (eg. insulation within a wall), fire hazard properties generally, and regarding fire resistance or fire resistance levels. 2) Non compliance NCC 2016 Volume Two Part 3.7: for non-combustibility and regarding fire resistance or fire resistance levels (FRL).	BAL 29	None	**AS1530.3 -1999:** Ignitability Index - 6 Spread of Flame Index - 0 Heat Evolved Index - 1 Smoke Developed Index - 4 (Fire Hazard properties as an insulation material)	None	1) NRG 75 DFF -Specified Components for BAL Areas 2)EWFA Bushfire Report, No.26733-04 3)EWFA Test Certificate, No. SFC 26733-04 4)1530.3 - Fire Hazard Test Report (Test No.7-566170-CQ)	Product installation shall be carried out by an NRG trained and competent person having received the NRG Greenboard™ Certificate of Competence under the direction of a Builder	None.
9	Renda Panel	Focal Point Architectural	timber of steel framing	Direct and cavity system. EPS H grade battens	EPS (not clarified if EPS-FR)	60,75, 100	Self drilling screws with blue Focal point washer	PU expanding foam adhesive	Base coat: 3-5mm Second Coat: Textures coating To be applied using manufacturer's specifications.	5	AS1530.3 Early Fire Hazard test comparison with Renda Panel and other timber products.	CM40139	20/04/2018	20/04/2021	**Performance Requirement(s):** BP1.1 (a)&(b) (i),(ii)&(iii) -Structural provisions FP1.4 - Weatherproofing FP1.5 - Damp-proofing GP5.1 - Bushfire areas – (BAL-29) **Deemed-to-Satisfy Provision(s):** J1.5 - Energy Efficiency - Walls	**Performance Requirement(s):** P2.1.1 (a)&(b) (i),(ii)&(iii) - Structural stability and resistance to actions P2.2.2 - Weatherproofing P2.2.3 -Dampness P2.3.4 - Bushfire areas – (BAL 29) **Deemed-to-Satisfy Provision(s):** Part 3.12.1.4 - Energy Efficiency - External walls	yes	Class 1,2,3,4,5,6,7,8,9 & 10	Limited to Type C construction for Class 2 to 9 buildings. For use in type A & B construction separate state or territory building approval must be sought independent of this Certificate of Conformity.	Up to 3 stories (8.5 m height due to wind conditions)	All penetrations are a potential source of water ingress and spread of fire and are required to be sealed with an approved flexible sealant.	Can be used in Bushfire prone areas up to BAL 29 in accordance with AS 3959:2009 - Construction of buildings in bushfire-prone areas. To achieve the BAL 29 bushfire rating, the render coat system must be installed with a minimum of 4.0mm cover of Dulux Acra-Tex Renderwall® P400 and or Exsulite® Matrix Basecoat render, followed by the application of 0.8mm minimum texture coating of either Dulux 951 Coventry Coarse Coat, 951 Accent, Exsulite® Acrylic Texture Coating and top coated with an Exsulite® Membrane and/or AcraShield®.	None	None stated (however stated in literature)	None	1)Focal Point RendaPanel Cladding System - System information and Technical Specification (V4 2002) 2)Focal Point Architectural Mouldings RendaPanel - System information	None	None.

10	Rendex External Cladding System	Prestige Wall Systems	timber of steel framing	Direct and cavity system. Horizontal steel battens 24mm depth or Vertical timber battens of 25mm	EPS – M grade and fire retarded in accordance with AS 1366.3:1992.	40, 50, 75 & 100	48mm flexible PVC waster with screws (4.8mm dia./10+gauge).	PU expanding foam adhesive	Basecoat: Rendex® Basecoat acrylic render to manuf. specs Second coat: RendeX™Texture Finish coat: Acrylic membrane	Not specified.	Suitable for use in Bushfire areas, with requirements up to BAL-29: EWFA Test Certificate to 1530.8.1 (26/03/16) is provided in product material. It is noted that the RendeX® External Cladding System has NOT been tested for fire rated construction, therefore the FRL performance is not stated and cannot be assumed.	CM40090 Rev2	14/03/2017	14/03/2020	**Performance Requirement(s):** BP1.1 (a) - Structural Reliability1 BP1.2 - Structural Resistance1 FP1.4 - Damp and Waterproofing FP1.5 - Rising Damp2 GP5.1 - Buildings in Bushfire Areas3 **Deemed-to-Satisfy Provision(s):** J1.2 (a) -Thermal Constructions	**Performance Requirement(s):** P2.1.1 (a)(b)(&c) Structural Stability and Resistance1 P2.2.2 -Weatherproofing P2.2.3 -Rising Damp2 P2.3.4 - Buildings in Bushfire Areas 3 Part 3.12.1.1 -Building fabric thermal insulation	yes	Class 1,2,3,4,5,6,7,8,9 & 10	1) Suitable for bushfire areas up to BAL 29 (CodeMark Certificate) 2) Rendex External Cladding System complyig with Performance requirements P2.1 (a), (b) and ©, P2.2.2 and P2.2.3 of Vol. 2 of the NCC, BCA Class 1 and 10 buildings (25 Nov 2013), Cert No. V13/01	None stated	None stated	BAL 29: The wall system consisted of two 90×45 timber stud frames, the central frame offset 310mm back incorporating an 800mm × 800mm aluminium framed window and eaves detail. The unexposed side was faced with 10mm Gyprock plasterboard while the exposed side had a nominally 16.4mm iClad Render system applied over 75mm thick RendeX® Panel System. **Report Reference:** Exova Warringtonfire (NATA 3277) Test report 27983000.1. Testing to AS1530.8.1-2007. Test reports conforms compliance for Bushfire prone areas up to BAL: A-29.	None	None	None	1) Rendex External Cladding System - Technical Manual v1.2019 2)Rendex External Cladding System - Installation Checklist 2011 4)BRAC Certificate of Accreditation, No. V13/01, (25/11/13)	None specific. Installation Manual only states that panels are to be installed by qualified and experienced carpenters or other tradesmen, who are conversant with the installation techniques set out in Manual.	
11	Rhinoboard™ EPS Wall Panel System	Pro-Lite Architectural Systems Pty Ltd	timber of steel framing	Direct and cavity system. Battens are 25mm H grade EPS.	EPS – M grade with a flame retardant additive with 0 ignitability properties. EPS panels are grooved.	40, 60, 75 and 100	Concrete or Masonry wall - Power foam adhesive and mechanical fixings (Hilti IDP polypropylene anchors) Frame (timber or steel) plated screws with PVC washers.	Silka Pro sealant to fill joints	Use approved render First Coat - Minimum of 3.5mm with mesh Second Coat - minimum 1.5 approved acrylic trowel texture coating Final - Seal and painted with protective paint	5	None stated	CM40219	17/11/2017	17/11/2020	**Performance Requirement(s):** BP1.1(a) & (b)(i),(ii),(iii),(iv),(viii), (x),(xi),(xii) & (xiv) - Structural reliability **Deemed-to-Satisfy Provision(s):** J1.2(a) Energy efficiency	**Performance Requirement(s):** P2.1.1(a) & (b) (i),(ii),(iii),(iv),(viii),(x),(xi),(xii) & (xiv)- Structural for External Wall Cladding(a) **Deemed-to-Satisfy Provision(s):** 3.12.1.1(a) Energy efficiency	yes	Class 1,2,3,4,5,6,7,8,9 & 10	None stated	None stated	Certificate states "No evaluation has been undertaken by CMI on the fire properties of this system." Certificate states "The Rhinoboard™ EPS Wall Panel System is manufactured from fire retardant polystyrene and will not support combustion. The EPS panels used in the system do not contribute to fire."	None	None	AS/NZS 1530.3:1999 Fire Indices for EPS only. Ignitability Index (0-20) = 0 Spread of Flame Index ((0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Developed Index (0-10) = 0 - 1	none	1) Rhinoboard - Issue C, 2017 (Installation Manual)		
12	RMAX Orange Board™ Direct Fix or Batten Cavity Fix (EIFS)	RMAX	Timber or steel framing only	Batten or Direct Fix	EPS - M grade (FR is not clarified)	75 & 100	10 gauge screws with plastic 40mm washers	PU expanding foam adhesive	First Coat - Apply 2-3 mm base coat RMAX Orange Board (Trademark) Plus Render and then embed reinforcement mesh Second Coat - Apply 2-3 mm ontop of mesh Third Coat - RMAX Orange BoardTM Plus render system is compatible with most acrylic and some cementbased finish coating systems. Apply selected coating system in strict	5	Stated in Batten Cavity Manual " BAL 29 only conformance applies to 75mm and 100mm RMAX Batten Cavity EIFS Cladding products only." Stated in Direct fix Manual "The BAL 29 conformance applies to 75mm and 100mm RMAX Direct Fix EIFS Cladding products only." Both Manuals note: " The use of any render system other than the RMAX Orange BoardTM Plus render, applied at minimum thickness of 5mm, is not covered by the scope of the RMAX BAL 29 certification." EWFA AS1530.8.1 BAL A-29 Test report is available in Installation manual(direct and cavity fix)	CM40039 Rev2	11/08/2017	17/07/2020	N/A	**Performance Requirements:** P2.1.1(a)&(b) (i),(ii),(iii) Structural for External Wall Cladding P2.2.2 Weatherproofing for External Wall Cladding P2.3.4 Bushfire Areas for External Wall Cladding P2.6.1 Energy Efficiency for External Walls **Deemed to Satisfy Provisions:** N/A	yes	Class 1 & 10 only	None stated	None stated	None stated	Assessed System achieved a BAL 29 or less. The assessed external wall system consisting of; - Timber framing or light gauge steel framing at least 70mm deep. Unexposed side faced with 10mm Gyprock plasterboard. - Exposed side faced with 4.8mm minimum thickness RMAX OB Render Plus render system coated over optionally M or X28 density grade 75mm or 100mm thick RMAX Orange Board, RMAX with Performguard, RMAX ThermaWall Board, RMAX ThermaWall Plus Board, RMAX ThermaSilver Board, RMAX ThermaWall Silver Board or RMAX ThermaWall Plus Silver Board. - Render mesh shall optionally be Vertex R451 A101 high impact resistant fibre glass or RMAX OB fibre glass Render Mesh - Starting channel and meshed external angle shall optionally be made of PVC or aluminium alloy. - Optional inclusion of EPS Battens 40mm wide with thicknesses optionally from 10 to 25mm attached to framing for all systems, the EPS panels are then	None	AS 1530.3:1999 Fire Indices: Fire resistance as tested on rendered Orange Board™ Panel Ignitability Index (0-20) = 0 Spread of Flame Index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Developed Index (0-10)= 4 No report reference provided on certificate	None	1) RMAX Direct Fix EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4) 2) RMAX Batten Cavity EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4)	None	
13	RMAX ThermaSilver™ Board Direct Fix or Batten Cavity Fix (EIFS)	RMAX	Timber or steel framing only	Batten or Direct Fix	BASF Neopor® EPS - M grade (FR is not clarified)	60, 75, 100	11 gauge screws with plastic 40mm washers	PU expanding foam adhesive	First Coat - Apply 2-3 mm base coat RMAX Orange Board (Trademark) Plus Render and then embed reinforcement mesh Second Coat - Apply 2-3 mm ontop of mesh Third Coat - RMAX Orange BoardTM Plus render system is compatible with most acrylic and some cementbased finish coating systems. Apply selected coating system in strict	5	Stated in Batten Cavity Manual " BAL 29 only conformance applies to 75mm and 100mm RMAX Batten Cavity EIFS Cladding products only." Stated in Direct fix Manual "The BAL 29 conformance applies to 75mm and 100mm RMAX Direct Fix EIFS Cladding products only." Both Manuals note: " The use of any render system other than the RMAX Orange BoardTM Plus render, applied at minimum thickness of 5mm, is not covered by the scope of the RMAX BAL 29 certification." EWFA AS1530.8.1 BAL A-29 Test report is available in Installation manual(direct and cavity fix)	CM40118 Rev1	21/12/2018	17/07/2020	N/A	**Performance Requirements:** P2.1.1(a)& (b)(i)(ii)(iii) - Structural for External Wall Cladding P2.2.2 Weatherproofing for External Wall Cladding P2.3.4 - Bushfire Areas for External Wall Cladding - Contributes to satisfying the NCC Performance Requirements for the construction of buildings in bushfire prone areas up to BAL – 29 P2.6.1 - Energy Efficiency for External Walls - Can be used in conjunction with other building elements to achieve a Total R-Value **Deemed to Satisfy Provisions:** N/A	yes	Class 1 & 10 only	None stated	None stated	None stated	Assessed System achieved a BAL 29 or less. The assessed external wall system consisting of; - Timber framing or light gauge steel framing at least 70mm deep. Unexposed side faced with 10mm Gyprock plasterboard. - Exposed side faced with 4.8mm minimum thickness RMAX OB Render Plus render system coated over optionally M or X28 density grade 75mm or 100mm thick RMAX Orange Board, RMAX with Performguard, RMAX ThermaWall Board, RMAX ThermaWall Plus Board, RMAX ThermaSilver Board, RMAX ThermaWall Silver Board or RMAX ThermaWall Plus Silver Board. - Render mesh shall optionally be Vertex R451 A101 high impact resistant fibre glass or RMAX OB fibre glass Render Mesh - Starting channel and meshed external angle shall optionally be made of PVC or aluminium alloy. - Optional inclusion of EPS Battens 40mm wide with thicknesses optionally from 10 to 25mm attached to framing for all systems, the EPS panels are then	None	AS 1530.3:1999 Fire Indices: Fire resistance as tested on rendered ThermaSilver™ Board Panel Ignitability Index = 0 Spread of Flame Index = 0 Heat Evolved Index = 0 Smoke Developed Index = 3	none	1) RMAX Direct Fix EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4) 2) RMAX Batten Cavity EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4)	None	
14	RMAX ThermaWall™ Direct Fix or Batten Cavity Fix (EIFS)	RMAX	Timber or steel framing only	Batten or Direct Fix	Isolite® EPS - grade M (not clarified if EPS-FR)	60, 75, 100	14 gauge screws with plastic 40mm washers	PU expanding foam adhesive	First Coat - Apply 2-3 mm base coat RMAX Orange Board (Trademark) Plus Render and then embed reinforcement mesh Second Coat - Apply 2-3 mm ontop of mesh Third Coat - RMAX Orange BoardTM Plus render system is compatible with most acrylic and some cementbased finish coating systems. Apply selected coating system in strict	5	Stated in Batten Cavity Manual " BAL 29 only conformance applies to 75mm and 100mm RMAX Batten Cavity EIFS Cladding products only." Stated in Direct fix Manual "The BAL 29 conformance applies to 75mm and 100mm RMAX Direct Fix EIFS Cladding products only." Both Manuals note: " The use of any render system other than the RMAX Orange BoardTM Plus render, applied at minimum thickness of 5mm, is not covered by the scope of the RMAX BAL 29 certification." EWFA AS1530.8.1 BAL A-29 Test report is available in Installation manual(direct and cavity fix)	CM40112 Rev2	11/08/2018	17/07/2020	N/A	**Performance Requirements:** P2.1.1(a)& (b)(i)(ii)(iii) - Structural for External Wall Cladding P2.2.2 Weatherproofing for External Wall Cladding P2.3.4 - Bushfire Areas for External Wall Cladding P2.6.1 - Energy Efficiency for External Walls - **Deemed to Satisfy Provisions:** N/A	yes	Class 1 & 10 only	None stated	None stated	None stated	Assessed System achieved a BAL 29 or less. The assessed external wall system consisting of; - Timber framing or light gauge steel framing at least 70mm deep. Unexposed side faced with 10mm Gyprock plasterboard. - Exposed side faced with 4.8mm minimum thickness RMAX OB Render Plus render system coated over optionally M or X28 density grade 75mm or 100mm thick RMAX Orange Board, RMAX with Performguard, RMAX ThermaWall Board, RMAX ThermaWall Plus Board, RMAX ThermaSilver Board, RMAX ThermaWall Silver Board or RMAX ThermaWall Plus Silver Board. - Render mesh shall optionally be Vertex R451 A101 high impact resistant fibre glass or RMAX OB fibre glass Render Mesh - Starting channel and meshed external angle shall optionally be made of PVC or aluminium alloy. - Optional inclusion of EPS Battens 40mm wide with thicknesses optionally from 10 to 25mm attached to framing for all systems, the EPS panels are then	None	AS 1530.3:1999 Fire Indices Fire resistance as tested on rendered Thermawall™ Panel Ignitability Index = 0 Spread of Flame Index = 0 Heat Evolved Index = 0 Smoke Developed Index = 4	none	1) RMAX Direct Fix EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4) 2) RMAX Batten Cavity EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4)	None	
15	RMAX ThermaWallPlus™ Direct Fix or Batten Cavity Fix (EIFS)	RMAX	Timber or steel framing only	Batten or Direct Fix	Isolite® EPS - grade M (not clarified if EPS-FR)	75 & 100	13 gauge screws with plastic 40mm washers	PU expanding foam adhesive	First Coat - Apply 2-3 mm base coat RMAX Orange Board (Trademark) Plus Render and then embed reinforcement mesh Second Coat - Apply 2-3 mm ontop of mesh Third Coat - RMAX Orange BoardTM Plus render system is compatible with most acrylic and some cementbased finish coating systems. Apply selected coating system in strict	5	Stated in Batten Cavity Manual " BAL 29 only conformance applies to 75mm and 100mm RMAX Batten Cavity EIFS Cladding products only." Stated in Direct fix Manual "The BAL 29 conformance applies to 75mm and 100mm RMAX Direct Fix EIFS Cladding products only." Both Manuals note: " The use of any render system other than the RMAX Orange BoardTM Plus render, applied at minimum thickness of 5mm, is not covered by the scope of the RMAX BAL 29 certification." EWFA AS1530.8.1 BAL A-29 Test report is available in Installation manual(direct and cavity fix)	CM40114 Rev2	11/08/2017	17/07/2020	N/A	**Performance Requirements:** P2.1.1(a)& (b)(i)(ii)(iii) - Structural for External Wall Cladding P2.2.2 Weatherproofing for External Wall Cladding P2.3.4 - Bushfire Areas for External Wall Cladding P2.6.1 - Energy Efficiency for External Walls - **Deemed to Satisfy Provisions:** N/A	yes	Class 1 & 10 only	None stated	None stated	None stated	Assessed System achieved a BAL 29 or less. The assessed external wall system consisting of; - Timber framing or light gauge steel framing at least 70mm deep. Unexposed side faced with 10mm Gyprock plasterboard. - Exposed side faced with 4.8mm minimum thickness RMAX OB Render Plus render system coated over optionally M or X28 density grade 75mm or 100mm thick RMAX Orange Board, RMAX with Performguard, RMAX ThermaWall Board, RMAX ThermaWall Plus Board, RMAX ThermaSilver Board, RMAX ThermaWall Silver Board or RMAX ThermaWall Plus Silver Board. - Render mesh shall optionally be Vertex R451 A101 high impact resistant fibre glass or RMAX OB fibre glass Render Mesh - Starting channel and meshed external angle shall optionally be made of PVC or aluminium alloy. - Optional inclusion of EPS Battens 40mm wide with thicknesses optionally from 10 to 25mm attached to framing for all systems, the EPS panels are then	None	AS 1530.3:1999 Fire Indices Fire resistance as tested on rendered Thermawall™ Plus Panel Ignitability Index (0-20) = 0 Spread of Flame Index (0-10)= 0 Heat Evolved Index (0-10)= 0 Smoke Developed Index (0-10) = 4	none	1) RMAX Direct Fix EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4) 2) RMAX Batten Cavity EIFS Cladding Product Range Technical Data and Installation Manual 08-17 (V4) 3) ThermaWall Plus - Technical Data Manual	None	
16	Unitex Base Board Lightweight External Cladding System - Non Cavity	Unitex Granular Marble Pty Ltd	Timber or steel framing only	Direct Fix.	EPS- SL grade (not clarified if EPS-FR)	50, 75, 100	Class 3 10 gauge screws with plastic Unitex washers.	Unitex® Adhesive Foam	Unitex Uni Cote® Dry Polymer Render - base coat for pre-embedded/coated mesh and render Unitex® Polymer Render - for site coated/ applied reinforcement mesh Dry Cote® Base Board Render - leveling coat for both factory coated and site coated panels. Unitex Applied Decorative Dry Powder - final coat for varies Textured finishes	5	Up to 3 stories in height.	CM70007	30/01/2019	30/01/2022	N/A	**Performance requirements:** P2.1.1 (Non cyclonic areas A and B) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.3.4 - Bushfire areas P2.6.1 - Building **Deemed-to-Satisfy Provisions:** 3.12.1.4 - Building fabric thermal insulation 3.12.1.4 - External walls	yes	Class 1 and 10 only.	None stated	None stated	Product cannot be used for Class 1 and Class 10a buildings located within 900mm of the building or within 1.8m of another detached building on the same property. The product cannot be used internally where a group rating less than Group 4 is required. Product cannot to be used as a wall requiring achieving a fire resistance level, or form part of a wall requiring achieving a fire resistance level.	**Report References:** Bushfire Resistance Assessment – A2.2(a)(i) (Volume 1) EWFA Report Number 2856500.1 dated 07 August 2013 issued by Exova Warringtonfire – testing to NCC BCA GP5.1 (Volume 1), P2.3.4 (Volume 2) – Construction of building in bushfire-prone areas (as per AS3959). Bushfire Resistance Assessment – A2.2(a)(i) (Volume 1) EWFA Certificate of Test (Certificate No. 2856500.1) dated 05 August 2013 issued by Exova Warringtonfire – testing to NCC BCA GP5.1 (Volume 1), P2.3.4 (Volume 2) – Construction of building in bushfire-prone areas (as per AS3959).	none	AS 1530.3:1999 Fire Indices Ignitability Index (0-20) = 0 Spread of Flame Index (0-10)= 0 Heat Evolved Index (0-10)= 0 Smoke Developed Index (0-10) = 3 **Report Reference:** CSIRO Materials Science and Engineering Division,Report No. FNE10077 of 28th March 2011	none	EWFA Certificate of assessment No : SFC 2856500.2 (AS 1530.8.1 - BAL A-29) EWFA Certificate of assessment No : SFC 2830900.2 (AS 1530.8.1 - BAL A-40) Branz Appraised - Appraisal No : 758 (2011) Uni-tex Non Cavity Baseboard System - Technical Manual June 2015 Uni-tex Cavity Baseboard System - Technical Manual June 2015 Unitex Base Board Lightweight External Cladding System Usage and installation Guide_March 2015 Unitex Base Board Lightweight Cladding Brochure https://www.unitex.com.au/product-category/baseboard/	Installation of system is to be completed by trained Unitex	

17	X -series	New Era Nominees	Timber or steel frame only	Batten or Direct Fix. Batten H grade EPS - 25mm thick	EPS - M grade with FR (grey in colour)	50, 75, 100 & 125	10G Class 3 screws with a 50mm diameter MasterWall® plastic button.	PU expanding foam adhesive	Follow render system's manufacturer specifications . First coat: Fibreglass mesh tape is to be embedded into the first 3mm layer of acrylic render Second coat: 2mm leveling coat of acrylic render. Final: Coloured acrylic texture system and/or paint finish.		Suitable for BAL-29 when installed with X-series ancilleries i.e. X-Series Breather Frame Wrap, window flashing tape, fixings, fixing buttons, MS sealants, foam sealants and selected Master A.R.T render system. Panel Performance to AS1530.3; ignitability, spread of flame and heat evolved = 0, Smoke developed =4 Applicable for Builing Classifcations 1 to 10	CM40242-I01-R00 (website), CM40242 (actual)	24/09/2018	24/09/2021	**Performance requirements:** BP1.1 (a)(b)(i)(ii)(iii) - Structural Provisions FP1.4-Weatherproofing FP1.5-Rising damp GP1.5-Bushfire areas (limited to BAL not exceeding BAL-29) **Deemed-to-Satisfy Provisions:** Spec A2.4 (b) - Fire Hazard Properties J1.5 - Walls	**Performance requirements:** P2.1.1 (a), (b)(i)(ii)&(iii) - Structural stability and resistance to actions P2.2.2 - Weather proofing P2.2.3 - Rising damp P2.3.4 - Bushfire areas - limited to BAL not exceeding BAL-29 - panel thickness to be 75mm or greater **Deemed-to-Satisfy Provisions:** 1.2.4 - Fire Hazard Properties 3.12.1.4 - Building fabric thermal insulation 3.12.1.4 - External walls	yes	Class 1,2,3,4,5,6,7,8,9 & 10 (Note: Limited to Class C buildings)	Class C construction only. For A and B - building approval must be sought independent of Certificate of conformity.	None stated	AS1530.3:1999 Panel Performance for 50mm thick panel	BAL-29 or less when installed in accodrances with X-series System installation manuals and exposed core is encapsulated in non-combustible covering.	None	AS1530.3 for EPS (without render): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 4 for 50 mm panel	none	1. X-series Direct to Frame System - Installation Manual 2. X-series Batten Fixed System - Installation Manual	None stated	

ISP Codemark Product Summary

Item	Product Name	Manufacturer Name	Sandwich face material	Type of Core	Product Description	Available Insulation Thicknesses (mm)	Panel Fixing Details	ExternalWall Finishing Details	Specific fire safety requirements stated in product data	Certification Number	Certification date of issue	Certification expiry date	NCC Volume 1 Performance requirement compliance stated by certificate	NCC Volume 2 Performance requirement compliance stated by certificate	Does certification cover fire safety matters	Building Class Limitation stated on Certification	Type of construction Limitation stated on Certification	Building height limitation stated on certification	Any other limitations or testing relevant to fire safety stated on certification	Fire Performance/Testing stated in certification				Product documentation reviewed other than certification	Has an installer training and registration system	Comments
																				Bushfire	Fire resistance level	Internal fire hazard properties	External façade fire spread			
1	InsulLiving®	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	External and Internal Face - 0.6mm G300 prime coated Bluescope® pre-painted steel	EPS-FR	Composite wall and roof panel system	90, 140	Bottom of panel to base channel Flat head screw (10 gauge - 16x16 flat head) 150mm max c/c Panel to Panel - Flat head screw (10 gauge - 16x16 flat head) 300mm max c/c or one flat screw midway with 7mm bead of sealant with one flat head screw fixed mid height	Skin allows for external render	None is specified.	CM40033-I02-R02 (CM40033 Rev 2)	7/11/2018	2/05/2015	N/A	**Performance Requirements:** P2.1.1(a),(b)(i), (ii),(iii) & © - Structural stability and resistance to actions P2.2.2 Weatherproofing – Limited to roof panels SolarSpan® and InsulRoof®. P2.3.4 Bushfire areas – External wall and roofs – BAL – 40. **Deemed to Satisfy Provisions:** 3.12.1.2 Energy Efficiency – Roofs.	yes	Class 1 & 10 only	none stated	none stated	none stated	BAL 40	None Stated	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2-3	none	1) InsulLiving Installation Guide v12 (13/04/2015)	No	
2	BondorPanel®	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	External and Internal Face - 0.6mm G300 prime coated Bluescope® pre-painted steel External finishes: Plain, Ribbed and Satinline	EPS-FR (SL grade)	Insulated wall and ceiling panel used in controlled environments such as cold storage, food preparation areas and clean rooms, transportable offices, wall partitions and other applications.	50, 75, 100, 125, 150, 200, 250	14g Tek screws or mushroom head bolts		BondorPanel® EPS-FR steel skinned insulated building panels conform to the requirements of the BCA Specification C1.10 as either Group 2 or Group 1 depending on the thickness and construction detail.	CM40189 Rev1	15/08/2018	16/05/2021	**Performance Requirements:** BP1.1(a) & (b)(i), (ii), (iii) - Structural Reliability FP1.4 - Weatherproofing **Deemed-to-Satisfy Provisions:** Spec C1.10(4)(b) - Fire Hazard Properties J1.5 - Wall	**Performance Requirements:** P2.1.1(a) & (b)(i), (ii), (iii) & © - Structural stability and resistance to actions P2.2.2 - Weatherproofing P2.3.4 - Bushfire Areas (BAL- 40) **Deemed-to-Satisfy Provisions:** 3.12.1.4 - External Walls - Refer to R Values in A3	yes	Class 1,2,3,4,5,6,7,8,9 & 10	none stated	none stated	**Material Group No:** Material Group 1 - Up to 250mm thick with steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at maximum 300mm centres Material Group 2 - Up to 150mm thick with aluminium 'wall-wall' and 'wall-ceiling' angles fixed with aluminium rivets or screws at 300mm centres. Panel thicker than 150mm requires steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at 300mm centres to be classified as Group 2.	BAL 40	None Stated	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2-3	none	1) Bondorpanel Technical Data sheet v46 (18/04/18) 2) Bondorpanel Technical Drawings v1 (09/04/18)	No	
3	EconoClad®	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	External Face – 0.42mm Zincalume® or Colourbond® Steel Steel G550 Internal Face – Lightweight Thermal Foil, fibreglass or PVC	PIR-FR	Industrial and commercial wall and roof high rib trapezodial cladding system,	25, 40, 60, 80, 100	Fixings to meet requirements of BlueScope TB-16 Fasteners for Roofing and Walling Product Selection Guide Panel laps to be sealed using continuous bead of approved sealant. Silicon, polyurethane, butyl mastic and acrylic based sealants may be appropriate if neutral cure and recommended by their manufacturer for use on Colorbond® steel	n/a	Material Group No. in accordance with AS/ISO 9705 - conform to the requirements of the BCA Specification C1.10 as Group 2. EconoClad® is suitable for use as roof covering for Class 1 and 10 buildings to be constructed in designated bushfire prone areas that have a BAL-40 or less. Fire Hazard Properties AS1530.3 - Ignitability Index - 0, Spread of Flame Index - 0, Heat Evolved Index - 0 and Smoke Index- 1 FM Approval FM 4880	CM40234	12/09/2018	12/09/2021	**Performance Requirements:** BP1.1(a)&(b)(i),(ii),(iii), (vi),(iv) & (xii) - Structural reliability **Deemed-to-Satisfy Provisions:** Spec C1.10(4)(b) - Fire Hazard Properties– Group Number 2 F1.5 - Damp and Weatherproofing - Roof coverings. J1.3 - Energy efficiency - Roofs & Ceiling Construction J1.5(a) - Energy efficiency - Wall Construction	**Performance Requirements:** P2.1.1(a)&(b)(i),(ii),(iii), (vi),(iv), (xii) & © - Structural stability and resistance to actions P2.2.2 - Damp and Weatherproofing. P2.3.4 - Bushfire Areas (BAL-40). **Deemed-to-Satisfy Provision(s):** 1.2.4 - Fire Hazard Properties–- Group Number 2. 3.12.1.2 - Energy Efficiency – Roofs. 3.12.1.4 - Energy Efficiency – External Walls. 3.12.1.6 - Energy Efficiency – Attached Class 10a buildings.	yes	Class 1,2,3,4,5,6,7,8,9 & 10	none stated	none stated	No Group # details shown on certificate. However certificate references following **Reports**: Exova Warringtonfire; NATA Accreditation No. 3277; Fire Test in accordance with AS ISO 9708-2003 and AS 5637.1:2015 to determine group number; Dated 29/11/2016. & Ignis Solutions; Evaluation No. IGNS-6180-02 I01R00; Product Evaluation – EconoClad Group Number evaluation; Dated 24/05/2018.	BAL - 40 **Report Reference:** Hendry Group Pty Ltd; Report No. BAL-AS-3959; Assessment of Bondor® wall panels in bushfire prone areas up to BAL-40; Dated 09/11/2017.	None Stated	AS1530.3 ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 1 AWTA Textile Testing; NATA Accreditation No. 1356; Report No. 7-599058-CQ; Fire Indices Testing in accordance with AS/NZS 1530.3-1999; Dated 22/07/2011.	none	1) EconoClad Technical Data sheet v6 (27/03/18) 2) EconoClad Technical Drawings v1 (18/04/18) 3) EconoClad Specification BON0532 v12 (31/10/18)	No	
4	Equitilt®	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	External and Internal Face - 0.6mm, 0.7mm G300 Colourbond® steel	EPS-FR (M grade)	Architectural façade with either ribbed, plain, satinline and shadowline profiles for vertical or horizontal orientations.	50,75,100,125,150, 200,250	Fixings to meet requirements of BlueScope TB-16 Fasteners for Roofing and Walling Product Selection Guide Panel laps to be sealed using continuous bead of approved sealant. Silicon, polyurethane, butyl mastic and acrylic based sealants may be appropriate if neutral cure and recommended by their manufacturer for use on Colorbond® steel	N/A	**AS/NZS 1530.3 -** ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2-3 **Material Group Numbers ion accordance with AS ISO 9705:** Group 1 - Panel up to 250mm thick with steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at maximum 300mm centres. Group 2 - Panel up to 150mm thick with aluminium 'wall-wall' and 'wall-ceiling' angles fixed with aluminium rivets or screws at 300mm centres is classified as Group 2. Panel thicker than 150mm requires steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at 300mm centres. **Bushfire Attack Level - AS3959** Equitilt® is suitable for use as external walls of Class 1 and 10 buildings to be constructed in designated bushfire prone areas that have a BAL-40 or less.	CM40104 Rev1	15/08/2018	26/03/2021	**Performance Requirement(s):** BP1.1(a)&(b)(i), (ii)&(iii) - Structural Reliability FP1.4 - Weatherproofing (can be used in conjunction with other building elements to a prevent the penetration of water) GP5.1 - Construction in bushfire prone areas - BAL-40 **Deemed-to-Satisfy Provision(s):** Spec C1.10(4)(b) - Fire Hazard Properties J1.5 - Walls (can be used in conjunction with other building elements to achieve a Total R-Value)	**Performance Requirement(s):** P2.1.1(a),(b)(i), (ii)&(iii)&© - Structural stability and resistance to actions P2.2.2 - Weatherproofing (can be used in conjunction with other building elements to a prevent the penetration of water) P2.3.4 - Bushfire areas - BAL-40 **Deemed-to-Satisfy Provision(s):** 3.12.1.4 External Walls (can be used in conjunction with other building elements to achieve a Total R-Value) 3.12.1.6 - Attached to Class 10a Building (can be used in conjunction with other building elements to achieve a Total R-Value)	yes	Class 1,2,3,4,5,6,7,8,9 & 10	The Equitilt® wall panels are limited to the use in Type C Construction in Class 2 to 9 buildings when being used as external walls. Note Equitilt® wall panels can be used as internal walls in class 2 to 9 buildings and as internal and external walls in class 1 & 10 buildings.	none stated	**Material Group No:** Group 1 - Panel up to 250mm thick with steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at maximum 300mm centres is classified as Group 1. Group 2 - Panel up to 150mm thick with aluminium 'wall-wall' and 'wall-ceiling' angles fixed with aluminium rivets or screws at 300mm centres is classified as Group 2. Panel thicker than 150mm requires steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at 300mm centres to be classified as Group 2. **Report References:** BRANZ; IANZ Accreditation No.37; Fire Test Certificate 374; Group 1 to AS ISO 9705:2013 Insulating panel with a thickness of 250mm or less; Dated 29/04/2005. BRANZ; IANZ Accreditation No. 37; Fire Test Certificate 373; Group 2 to AS ISO 9705:2013 Insulating panel with a thickness of 150mm or less; Dated 29/04/2005. BRANZ; IANZ Accreditation No. 37; Fire Test Certificate 372; Group 2 to AS ISO 9705:2013 Insulating panel with a thickness of 250mm or less; Dated 29/04/2005. Ignis Solutions; Evaluation No. IGNS-5396 Issue 01 Revision 01 [2017]; Bondor® Panels	BAL 40 **Report Reference(s):** Hendry Group Pty Ltd; Report No. BAL-AS-3959; Assessment of Bondor® wall panels in bushfire prone areas up to BAL-40; Dated 09/11/2017. Hendry Group Pty Ltd; Report on Deemed-to-Satisfy assessment of Bondor® Wall Panels under Volume Two of the NCC Construction in designated Bushfire Areas up to BAL-40 in accordance with AS 3959:2009 (compliance with NCC 3.7.1.2); Dated November 2017.	None Stated	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2-3 **Report Reference:** AWTA; NATA Accreditation No. 1356; Fire Test Report 7-563460-CQ; Testing to AS/NZS 1530.3:1999; Dated 25/11/2008	none	1) Equitilt Technical Data sheet v2 (20/08/18) 2) Equitilt Technical Drawings v2 (05/03/18) 3) Equitilt Product Specification BON0532 v12 (31/10/18)	No	
5	FlameGuard®	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	0.6mm or 0.7 mm Colorbond steel faces	Mineral wool fibre	Plain, Ribbed, Satinline, Shadowline profiles for all classes of buildings, residential and commercial external and internal walls and ceilings.	FlameGuard - 50mm & 75mm	Shadow joint extrusion and shadow joint clip between panels on either side with 14g tek screw to secure in place.	N/A	**Combustibility Test (AS 1530.1**) - Non-combustible **AS/NZS 1530.3 -** ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 3 **Bushfire Attack Level** - BAL-40 **AS/ISO 9705 - BCA Group Number (Spec C1.10)** Group 1 -Panel up to 150mm thick with steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at 300mm centres is classified as Group 1. Group 2 - Panel up to 150mm thick with aluminium 'wall-wall' and 'wall-ceiling' angles fixed with aluminium rivets or screws at 300mm centres is classified as Group 2.	CM40149	13/12/2018	13/12/2021	**Performance Requirement(s):** BP1.1(a)&(b)(i), (ii)&(iii) - Structural Reliability GP5.1 - Construction in bushfire prone areas - BAL-40 JP1.5 - Energy Efficiency – External walls. **Deemed-to-Satisfy Provision(s):** C1.1(b) - Fire-resistance of building elements C1.9(e)(v) - Non-Combustible material- tested to 1530.1:1994 C1.10(a)(ix) - Fire Hazard Properties. Refer A3	**Performance Requirement(s):** P2.1.1(a), (b)(i),(ii)&(iii) - Structural stability and resistance to actions P2.3.1 Fire-resistance of building elements P2.3.4 - Bushfire areas - Contributes to the Bushfire Attack Level of the Building P2.6.1 Energy Efficiency – External walls. Can be used in conjunction with other building elements to achieve a Total R Value. Refer to A3 **Deemed-to-Satisfy Provision(s):** N/A	yes	Class 1,2,3,4,5,6,7,8,9 & 10	none stated	none stated	**AS1530.1 Combustiblity test done for product** - Outcome of test or CSIRO report number not stated. **GP5.1** only applies to a Class 10a building or deck associated with a Class 2 or 3 building located in a designated bushfire prone area. **NSW GP5.1** only applies to (a) Class 2 or 3 buildings, (b) Class 4 part of Building, (c) Class 9 building that is a special fire protection purpose, (d) or a Class 10a building or deck associates with a building or part referred to in (a), (b) or (c).	FlameGuard = BAL 40 **Report References:** Hendry Group Pty Ltd; Deemed-to-Satisfy assessment for Bondor wall panels – BAL 40; Dated 09/11/2017. Hendry Group Pty Ltd; Deemed-to-Satisfy assessment for Bondor wall panels – BAL FZ (Equitilt Flameguard 100mm); Dated 09/11/2017.	No test completed Certificate states: 'Only panel thicknesses of 100mm and 150mm have been assessed for fire resistance performance by Exova Warrington Aus Pty Ltd NATA Accreditation Number: 3277'	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 3 Group No. = 1 **Report Reference:** AWTA; NATA Accreditation No. 1356; Fire Test Report 7-563460-CQ; Testing to AS/NZS 1530.3:1999; Dated 25/11/2008	None	1) Equitilt FlameGuard Technical Data sheet v47 (19/04/18) 2) FlameGuard and FlameGuard Plus Technical Drawings v1 (15/03/18) 3) Equitilt FlameGuard Product Specification BON0532 v12 (31/10/18)	No	
6	FlameGuard Plus	As above	As above	As above	As above	FlameGuard Plus - 100mm & 150mm	as above	as above	as above **Bushfire Attack Leve**l - BAL-FZ	as above	as above	as above	as above	as above	as above	as above	as above	as above	as above	FlameGuard Plus = BAL -FZ **Report Reference:** 'As above'	FRL for FlameGuard Plus - External Fire Only Depending on max revit spacings in panel joints, thickness of panel (100 or 150 mm), support distances and presence of intumescent on panel joints FRL for wall system can range from 60/60/60 to 180/180/180 **Report Reference**: Exova Warringtonfire Aus Pty Ltd; Nata	As above	as above	as above	as above	
7	LuxeWall	Metecno Pty Ltd (Trading as MetchnoPIR, Bondor®	0.6mm G300 Colorbond Steel	EPS-FR (SL or M grade)	Smooth or VJ profiles	50,75	M6 RoofZips 25mm with neoprene waster screws @ 300c/c to timber or steel stud frame via horizontally attached top hat battens	N/A	**Combustibility Test** - AS 1530.1 Non Combustible (MW) **Bushfire Attack Level** - BAL 40 **Fire Hazard Properties - AS1530.3:** ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 2-3 **AS ISO 9705 Material Group Number** - BCA Specification C1.10 as Group 1. Group 1 - Panel up to 250mm thick with steel 'wall-wall' and 'wall-ceiling' angles fixed with steel rivets or screws at 300mm centres is classified as Group 1. **Bushfire Attack Level to AS 3959** -LuxeWall® is suitable for use as external walls of Class 1 and 10 buildings to be constructed in designated bushfire prone areas that have a BAL 40 or less	CM40203	23/03/2017	23/03/2020	N/A	**Performance Requirement(s):** P2.1.1(a), (b) i, ii, iii, iv & xv, (c) -Structural Stability and Resistance – as applicable to external walls P2.2.1 Rainwater Management – as applicable to external walls. P2.2.2 - Weatherproofing- as applicable to external walls. P2.3.1 - Spread of fire P2.3.4 - Bushfire areas - Contributes to the Bushfire Attack Level of the Building P2.6.1 - Building Fabric **Deemed-to-Satisfy Provision(s):** N/A	yes	Class 1 and 10 only	none stated	none stated	none stated	BAL 40 or less **Report Reference:** CHG Group Report - Building Practitioner Board Registration No. BS-U 1012.	None Stated	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2.3 (Found in product documentation)	None	1)LuxeWall Guide Summary v7 02/03/2017 2)LuxeWall Brochure v19 04/10/2017 3)LuxeWall Product Specification Sheet v 12. 31/10/18 4) LuxeWall Technical Data Sheet v5 08/10/18	Nil	
8	LuxeWall FlameGuard	Metechno Pty Ltd (Trading as MetchnoPIR, Bondor®	External - 0.6mm G300 Colorbond Steel Internal - 0.6mm G300 Colorbond Steel with HygienePlus	Mineral Wool (MW)	Plain or VJ ^ profiles	50,75,100,150	Hex head screw @ 300c/c to timber or steel stud frame via horizontally attached top hat battens	N/A	**Combustibility Test** - AS 1530.1 Non Combustible **Bushfire Attack Level** - BAL FZ **Fire Hazard Properties** - AS1530.3: ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 2-3 **Material Group Number** - BCA Specification C1.10 as Group 1. **Fire Resistance** - AS 1530.4 - FRL 90/90/60 OR FRL 60/60/60 depending on construction details	CM40239	25/09/2018	25/09/2021	**Performance Requirement(s**) BP1.1(a),(b), (i),(ii),(iii) - Structural Reliability FP1.4 Weatherproofing P2.2.2 Weatherproofing GP5.1 Construction in bushfire prone areas – BAL FZ P2.3.4 Bushfire areas – BAL FZ **Deemed-to-Satisfy Provision(s)**: A2.3 Fire-resistance of building elements – Can be used where an FRL 60/60/60 or 90/90/90 is required. A2.4(b),(c) Fire hazard properties – Spread-of-Flame Index 0, Smoke-Developed Index 2-3, Group number: 1 C1.9(e)(vi) Non-combustible building elements J1.5(a) Energy Efficiency - Walls – Contributes to the overall performance of the wall. Refer A3	**Performance Requirement(s)** P2.1.1(a),(b)(i),(ii),(iii) &(c) - Structural Reliability P2.2.2 Weatherproofing P2.3.4 Bushfire areas – BAL FZ **Deemed-to-Satisfy Provision(s)**: Part 1.2.3 Fire-resistance of building elements – Can be used where an FRL 60/60/60 or 90/90/90 is required - Refer A3. Part 1.2.4 Fire hazard properties – Spread-of-Flame Index 0, SmokeDeveloped Index 2-3, Group number: 1 3.12.1.4(a) Energy Efficiency – External Walls – Contributes to the overall performance of the wall. 3.12.1.6(a) Energy Efficiency– Contributes to the overall performance of the wall.	yes	Class 1,2,3,4,5,6,7,8,9 & 10	none stated	none stated	none stated	BAL - FZ Bushfire - LuxeWall® FlameGuard® is suitable for use as an exterior wall when installed in accordance with the BON0535 Drawing Pack - LuxeWall - Flameguard 60 (v1, Dated 06/08/2018) and BON0535 Drawing Pack - LuxeWall - Flameguard 90 (v1, Dated 06/08/2018) and all exposed core material is encapsulated with a non-combustible covering **Report Reference:** None stated.	FRL 90/90/90 Option 1 construction: • From 50mm to 150mm thickness Bondor Flameguard® panels • with or without insulation in stud cavities; • Installation of weather wrap of Ametalin Silverwrap or other brands; the weather wrap may be optionally removed; • 90mm or deeper timber or equivalent steel stud frames • Bondor Flameguard® panel widths ranging from 900mm to 1200mm • With or without external acrylic coating on Bondor Flameguard® panels • Inclusion of weather resistant fire rated sealants in fire side of inter-locking joints and perimeter edges of the Bondor Flameguard® panels and metal capping over top of all panels FRL 60/60/60 Option 2 construction : As per option (1), but without fire rated joint sealants in the perimeter and inter-locking joints of Bondor Flameguard® panels. Capping at top of panel is not required except for top of parapet wall exposed to weather. Option 3 construction : As per option (2), except that the internal cladding be replaced with 13mm fire rated plasterboard. **Report Reference:** Exova Warringtonfire Report No. 41268000.4; Fire resistance test in	AS1530.3 (with skin): ignitability index (0-20) =0 Spread of flame index (0-10) = 0 Heat Evolved Index (0-10) = 0 Smoke Produced Index (0-10) = 2.3 **Report Reference:** AWTA Test Report – AS 1530.3-1999; Dated 12/03/2009.	None	1) LuxeWall FlameGuard Technical Data Sheet v1 11/09/18 2) LuxeWall FlameGuard Technical Drawings for 60/60/60 FRL wall v1 06/08/18 3) LuxeWall FlameGuard Technical Drawings for 90/90/90 FRL wall v1 06/08/18	Nil	LuxeWall FlameGuard Technical Data Sheet v1 11/09/18 has diagram stating fixings to be 'M6 Batten Screw Fixing' into Top Hat Batten..' however Technical Drawings indicate Hex head screws.
9	Metalcraft Insulated Panel Systems (ThermoPanel for walls)	Metecno NZ Ltd	0.59mm colorsteel flat or profile facing	EPS - S grade fire resistant core	Metal craft panels are used as roof ('ThermoSpan'), ceiling and wall (ThermoPanels')	50, 75, 100, 125, 150, 200, 250 and 300	4.8mm dia. X 14.3mm blind rivets at 150 c/c to aluminium base angles. Base angles hold panels in place and are secured to concrete or timber floor. Vertical panel to panel joint is sealed with silicon.	None	Product Properties (ThermoPanel EPS): Fire Rated: No Fire Resistant: No FM Approval: No However, under heading ' Use of Metalcraft Panels' - property description includes 'fire resistance.' This is in conflict with 'Product Properties' stated on p14 of the Installation Guide.	CM30078-Rev A (Certificate not made available)	28/06/2017	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	1) Metal Craft Insulated Panel System - Design and Installation Guide, v1 June 2017 2)Metal Craft Insulated Panel System - Care and Maintenance, v1 May 2017 3) Product Assurance Supplier Statement (PASS),No. 1808006, Expires: Aug 2019 4) 2)Metal Craft Insulated Panel System - Specification, v1 June 2017	Nil	
10	MetecnoPanel	Metechno Pty Ltd (Trading as MetchnoPIR, Bondor®	External & internal face – BlueScope® Steel 0.5mm, 0.6mm G300	PIR fire-retardant Polyisocyanurate	An insulated wall and ceiling panel.	50, 75, 100, 125, 150 &200	Panel to Panel fixing details not found in product information reviewed. Only Wall panel to beam, roof panel and concrete base connections described.	None	No height restriction with recommendation to be used where improved fire performance is required. **Bushfire Attack Level** - BAL 40 **Fire Hazard Properties** - AS1530.3: ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 1 **FM Approval** for 4880 and 4881 **AS/ISO 9705 Material Group No.** = C1.10 Group 2 - Panel up to 200mm thick with aluminium 'wall-wall' and 'wall-ceiling' angles (1.5mm) fixed with aluminium rivets or screws is classified as Group 2. Panel up to 200mm with steel 'wall-wall' and 'wall-ceiling' angles (0.5mm) fixed with steel rivets or screws is classified as Group 2.	CM40196	15/08/2018	15/08/2021	**Performance Requirement(s):** BP1.1 (a)&(b)(i), (ii),(iii) - Structural reliability CV3 (b)(i) & (ii) - Protection from the spread of fire – EW classification. **Deemed-to-Satisfy Provision(s):** Spec A2.3(2)(b) - Fire-resistance of building elements – FRL -/30/30 limited to 200mm or thicker panels. Spec C1.10(4)(b) - Fire Hazard Properties-– Group Number 2. J1.5 - Energy Efficiency – External Walls. Can be used in conjunction with other building elements to achieve a Total R Value. Refer to A3.	**Performance Requirement(s):** P2.1.1 (a)&(b)(i), (ii),(iii) & (c) -Structural stability and resistance to actions P2.3.4 - Bushfire Areas (BAL-40) **Deemed-to-Satisfy Provision(s):** 1.2.3 - Protection from the spread of fire – FRL -/30/30 limited to 200mm or thicker panels. 1.2.4 - Fire Hazard Properties-– Group Number 2. 3.12.1.4 Energy Efficiency – External Walls. Can be used in conjunction with other building elements to achieve Total R value.	yes	Class 1,2,3,4,5,6,7,8,9 & 10	none stated	none stated	**Construction in designated bushfire prone areas of** BAL-40 or less, require installation in accordance with the MetecnoPanel® Technical Drawings (v1 – Dated 09/04/2018) and all exposed core material is encapsulated with a non-combustible covering. **Material Group No**: Group 2 and SMOGRA$_{rc}$ 21.1-47m2s-2 x 1000	Bushfire Attack Level BAL- 40	Fire-resistance of building elements – FRL -/30/30 limited to 200mm or thicker panels. **Report Reference:** EXOVA Warringtonfire Australia Pty Ltd; NATA Accreditation No. 3277; Report No. 47868300.1; Testing to AS 1530.4-2014; Dated 05/04/2017.	Fire Hazard Properties - AS1530.3: ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 1 **Report References:** AWTA Textile Testing; NATA Accreditation No. 1356; Report No. 7-539731-CQ; Testing in accordance with AS/NZS 1530.3-1999; Dated 22/09/2005.	Testing in accodance with AS5113:2016, dated 21/11/2017 is completed. **Report Reference:** EXOVA Warringtonfire Australia Pty Ltd; NATA Accreditation No. 3277; Certificate No. SFC50791800.1; Testing to AS 5113:2016; Dated 21/11/2017. EXOVA Warringtonfire Australia Pty Ltd; NATA Accreditation No. 3277; Report No. 42649600.1; Testing to BS8414.2-2015; Dated 06/10/2016.	1) MechnoPanel Technical Data sheet v45 (22/03/18) 2) MechnoPaneTechnical Drawings v1 (09/04/18)	Nil	
11	MetecnoInspire®	Metechno Pty Ltd (Trading as MetchnoPIR, Bondor®	External & internal face – BlueScope® Steel G300	PIR - Fire-retardant Polyisocyanurate	Architectural façade wall system with Single V Rib, V Rib, Double V Rib, Micro V Rib, Satinline external finishesand available in a large range of colours.	50, 80, 100	Shadow joint extrusion and shadow joint clip between panels on either side with 14g tek screw to secure in place.	none	**Bushfire Attack Leve**l - BAL 40 **Fire Hazard Properties** - AS1530.3: ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 1 **FM Approval** for 4880 and 4881 **No Material Group #.**	CM40191 Rev1	15/08/2018	16/05/2021	**Performance Requirement(s):** BP1.1(a) & (b)(i),(ii), (iii) - Structural Reliability CP1 & CP2 - Fire Resistance – Restricted to non-loadbearing, non fire rated walls FP1.4 - Weatherproofing - Restricted to wall cladding **Deemed-to-Satisfy Provisions(s):** Spec C1.10(4)(b) - Fire Hazard Properties Group 2 J1.5 - Wall R values	**Performance Requirements:** P2.1.1(a) & (b)(i),(ii), (iii) & (c) - Structural stability and resistance to actions P2.2.2 - Weatherproofing - Restricted to wall cladding P2.3.4 - Bushfire Areas (BAL-40) **Deemed-to-Satisfy Provisions(s):** 3.12.1.4 External Walls – Refer to R Values in A3 3.12.1.6 - Attached Class 10a buildings	yes	Class 1,2,3,4,5,6,7,8,9 & 10	None specified	None specified	Report on verfication method for testing external wall assemblies for fire spread. Outcomes of report are not stated. **Report References:** Irwinconsult Pty Ltd; Report No. 18ME0160; Fire Engineering Report on CV3 Fire Compliance; Dated 26/03/2018.	Compliance with NCC Vol. 2 P2.3.4 - Bushfire Attack Level BAL- 40	Nil	Fire Hazard Properties - AS1530.3: ignitability Index (0-20) = 0, Spread of Flame Index (0-10) = 0, Heat Evolved (0-10) = 0 & Smoke Index (0-10) = 1 **Report References:** AWTA; NATA Accreditation No.983; Report No. 7-539731-CQ; PIR Panel Fire Indices Test; Dated 22/09/2005.	None	1)MetecnoInspire Technical Drawings v 1 27/03/18 2) MetecnoInspire Technical Data Sheet v6 27/03/18	No	

12	Unknown	Kingspan Insulated Panels Pty Ltd	Unknown	Unknown	Insulated panels are used for wall enveloping a structure to provide thermal performance on buildings, weather protection and protection from bushfire attack.	Unknown	Unknown	Unknown	Unknown	CM20113	suspended	suspended	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Appendix B Large scale façade fire test summary table

		Full-scale façade tests									
Test Standard		**AS 5113 : 2016 Amdt 1 (EW classification)**	**ISO 13785 Part 1:2002**	**BS 8414 part 1**	**BS 8414 part 2**	**DIN 4102-20**	**NFPA 285**	**SP FIRE 105**	**CAN/ULC S134**	**FM 25 ft high corner test**	**FM 50 ft high corner test**
Country used		Australia	International	UK	UK	Germany	USA	Sweden	Canada	US/International	US/International
Test Scenario		Same as for BS 8414	flames emerging from a flashover compartment fire via a window	flames emerging from a flashover compartment fire via a window	flames emerging from a flashover compartment fire via a window	flames emerging from a flashover compartment fire via a window	flames emerging from a flashover compartment fire via a window	flames emerging from a flashover compartment fire via a window		external (or internal) pellet fire located directly against the base of a re-entrant wall corner	external (or internal) pellet fire located directly against the base of a re-entrant wall corner
Summary geometry of test rig	Number of walls	Same as for BS 8414	two walls in re-entrant corner "L" arrangement	two walls in re-entrant corner "L" arrangement	two walls in re-entrant corner "L" arrangement	two walls in re-entrant corner "L" arrangement	one wall	one wall	one wall	two walls in re-entrant corner "L" arrangement. Ceiling over top of walls	two walls in re-entrant corner "L" arrangement. Ceiling over top of walls
	number of openings	Same as for BS 8414	1 (fire source opening)	1 (fire compartment opening)	1 (fire compartment opening)	1 (fire compartment opening)	1 (fire compartment opening)	2 (fire compartment opening and fictitious window above)	1 (fire compartment opening)	0	0
Fire source	Standard source	Same as for BS 8414 (construction from Pinus Radiata permitted)	Series of large perforated pipe propane burners. Total peak output 120 g/s (5.5 MW) within standard fire enclosure.	Timber crib 1.5 m wide x 1 m deep x 1 m high. Nominal heat output of 4500 MJ over 30 min. Peak HRR = 3±0.5 MW. Crib located on platform 400 mm above base of test rig.	Same as BS 8414 part 1	320 kW constant HRR linear gas burner located approx. 200 mm below soffit of opening.	Rectangular pipe gas burner in fire compartment (room burner). 1.52 m long pipe gas burner near opening soffit (window burner). Room burner increases from 690 kW to 900 kW over 30 min test period. Window burner ignited 5 min after room burner and increases from 160 kW to 400 kW over remaining 25 min test period	Heptane fuel tray, 0.5 m wide x 2.0 m long x 0.1 m high. Filled with 60 l Heptane.. Approx 2.5 MW peak	Four 3.8 m long linear propane burners. Total output 120 g/s propane (5.5 MW)	340 ± 4.5 kg crib constructed of 1.065 m 1.065 m oak pallets, max height 1.5 m. Located in corner 305 mm from each wall. Ignited using 0.24 L gasoline at crib base.	same as FM 25 ft test
	Alternative source	N/A	Liquid pool fires or 16 x 25 kg timber cribs distributed on floor of standard fire enclosure	permitted but must achieve calibration requirements	Same as BS 8414 part 1	25 kg timber crib, 0.5m x 0.5 m x 0.48 m, using 40 mm x 40 mm softwood sticks	Not specified or permitted by standard	permitted but must achieve calibration requirements	wood cribs of kiln dried pine with total mass of 675 kg	Not specified or permitted by standard	Not specified or permitted by standard
Fire exposure	Calibrated heat flux exposure (with non-combustible wall)	N/A	55 ± 5 kW/m^2 at a height of 0.6 m above opening 35 ± 5 kW/m2 at a height of 1.6 m above opening	Mean within range of 45-95 kW/m2 at height of 1 m above opening over continuous 20 min period. Typical steady state mean of 75 kW/m2 at height of 1 m above opening within this period.	Same as BS 8414 part 1	60 kW/m2 at 0.5 m above opening 35 kW/m2 at 1.0 m above opening 25 kW/m2 at 1.5 m above opening	38 ± 8 kW/m^2 at 0.6 m above opening during peak fire source period 25 -30 min 40 ± 8 kW/m2 at 0.9 m above opening during peak fire source period 25 -30 min 34 ± 7 kW/m^2 at 1.2 m above opening during peak fire source period 25 -30 min	15 kW/m^2 at 4.8 m above opening during at least 7 min of the test. 35 kW/m2 at 4.8 m above opening during at least 1.5 min of the test. < 75 kW/m2 at 4.8 m above opening at all times	45 ± 5 kW/m2 at 0.5 m above opening averaged over 15 min steady state period. 27 ± 3 kW/m2 at 1.5 m above opening averaged over 15 min steady state period.	Not specified	Not specified

		Full-scale façade tests									
Test Standard		**AS 5113 : 2016 Amdt 1 (EW classification)**	**ISO 13785 Part 1:2002**	**BS 8414 part 1**	**BS 8414 part 2**	**DIN 4102-20**	**NFPA 285**	**SP FIRE 105**	**CAN/ULC S134**	**FM 25 ft high corner test**	**FM 50 ft high corner test**
	Calibrated temperature exposure (with non-combustible wall)	N/A	> 800 Deg C at 50 mm above opening	> 600 Deg C above ambient within fire compartment. > 500 Deg C above ambient on exterior of non-combustible wall 2.5 m above opening.	Same as BS 8414 part 1	maximum temp. of 780-800 deg C on exterior of non-combustible wall 1 m above opening soffit	average 712 Deg C on exterior of non-combustible wall 0.91 m above opening. average 543 Deg C on exterior of non-combustible wall 1.83 m above opening.	Not specified	-	Not specified	Not specified
	Maximum height of flames extending above opening for non-combustible wall	Same as for BS 8414	-	Approx. 2.5 m	Same as BS 8414 part 1	Approx 2.5 m	Approx. 2.0 m	-	Approx 2.0 m	-	-
	Duration	Same as for BS 8414	23-27 minutes. 4-6 minute growth phase, approx 15 minute steady state phase, 4-6 minute decay phase	30 min (approx 7 min growth phase)	Same as BS 8414 part 1	20 min (gas burner) 30 min (crib)	30 min	Approx 15 minutes	25 minutes. 5 min growth phase, 15 min steady state phase, 5 min decay phase.	approx 15 minutes	same as FM 25 ft test
Detailed geometry of test rig	Total height of apparatus	Same as for BS 8414	≥ 5.7 m	≥ 8.0 m	Same as BS 8414 part 1	≥ 5.5 m	≥ 5.33 m	6.71 m	10.0 m	7.6 m	15.2 m
	Height of test wall above fire compartment opening	Same as for BS 8414	≥ 4.0 m	≥ 6.0 m	Same as BS 8414 part 1	≥ 4.5 m	≥ 4.52 m	6.0 m	7.25 m	N/A	N/A
	Width of main test wall	Same as for BS 8414	≥ 3.0 m	≥ 2.5 m	Same as BS 8414 part 1	≥ 2.0 m (using gas burner) ≥ 1.8 m (using crib)	≥ 4.1 m	4.0 m	5.0 m	15.7 m (specimen installed to full width over top 3.8 m and to 6 m out from corner for bottom 3.8 m)	6.2 m
	Width of wing test wall	Same as for BS 8414	≥ 1.2 m	≥ 1.5 m	Same as BS 8414 part 1	≥ 1.4 m (using gas burner) ≥ 1.2 m (using crib)	N/A	N/A	N/A	11.96 m (specimen installed to full width over top 3.8 m and to 6 m out from corner for bottom 3.8 m)	6.2 m
Detailed geometry of test rig *(continued)*	Height of fire compartment opening above bottom of test wall	Same as for BS 8414	0.5 m	0 m	Same as BS 8414 part 1	0 m	0.76 m	0 m	1.5 m	N/A	N/A
	Height of fire compartment opening	Same as for BS 8414	1.2 m	2 m	Same as BS 8414 part 1	1 m	0.76 m	0.71 m	1.37 m	N/A	N/A
	Width of fire compartment opening	Same as for BS 8414	2 m	2 m	Same as BS 8414 part 1	1 m	1.98 m	3.0 m	2.6 m	N/A	N/A
	Horizontal distance of opening from wing wall	Same as for BS 8414	50 mm	250 mm	Same as BS 8414 part 1	0 mm	N/A	N/A	N/A	N/A	N/A

		Full-scale façade tests									
Test Standard		**AS 5113 : 2016 Amdt 1 (EW classification)**	**ISO 13785 Part 1:2002**	**BS 8414 part 1**	**BS 8414 part 2**	**DIN 4102-20**	**NFPA 285**	**SP FIRE 105**	**CAN/ULC S134**	**FM 25 ft high corner test**	**FM 50 ft high corner test**
	fire compartment dimensions	Same as for BS 8414	4 m wide x 4 m deep x 2 m high with 0.3 m deep soffit across opening Alternative sizes permitted in range of 20 m3 – 30 m3	2 m wide x 2 m high (depth not specified)	Same as BS 8414 part 1	1 m wide x 1 m high	3 m wide x 3 m deep x 2 m high	3.0 m wide x 1.6 m deep x 1.3 m high.	5.95 m wide x 4.4 m deep x 2.75 m high	N/A	N/A
Test wall substrate		Typically same as for Same as for BS 8414 part 2	Details of substrate or supporting frame not specified by standard	Masonry	steel frame (open) to support complete test wall assembly	aerated concrete	steel frame and concrete floor slabs (open) to support complete test wall assembly	steel frame (open) to support complete test wall assemblies. Light weight concrete substrate to support claddings which require such a substrate.	Concrete	steel frame (open) to support complete test wall assembly	steel frame (open) to support complete test wall assembly
Test measurements	Heat flux at surface test wall	Not required	0.6 m, 1.6 m and 3.6 m above opening	not required	Same as BS 8414 part 1	-	not required	2.1 m above opening (centre of ficticiuos 1st storey window)	3.5 m above opening.	Not required	Not required
	Temperatures	Same as for BS 8414 Plus non exposed (rear face) surface temperatures 900 mm above combustion chamber opening	wall exterior and intermediate layers/Cavities immediately above window and at 4 m above window	wall exterior at 2.5 and 5.0 m above opening. Intermediate layers and cavities at 5.0 m above opening.	Same as BS 8414 part 1	wall exterior and intermediate layers/Cavities at 3.5 m above opening	Wall exterior and intermediate layers/cavities at 305 mm intervals vertically above opening. At rear of test wall within 2nd storey room enclosure	minimum 2 thermocouples measuring gas temperatures at top of wall on underside of 500 mm non combustible eave	Within fire enclosure and at opening 0.15 m below soffit. Wall exterior and intermediate layers/cavities at vertical intervals of 1 m starting from 1.5 m above opening. Gas temperatures 0.6 m in front of the top of the test wall.	exterior of exposed side of test walls on a 2.5 m grid spacing	near intersection of top of walls and ceiling, both at the wall corner and 4.6 m out from the wall corner.

		Full-scale façade tests									
Test Standard		**AS 5113 : 2016 Amdt 1 (EW classification)**	**ISO 13785 Part 1:2002**	**BS 8414 part 1**	**BS 8414 part 2**	**DIN 4102-20**	**NFPA 285**	**SP FIRE 105**	**CAN/ULC S134**	**FM 25 ft high corner test**	**FM 50 ft high corner test**
Performance criteria	External Fire spread	Temperatures 5 m above the opening measured 50 mm from the exposed specimen face shall not exceed 600°C for a continuous period greater than 30 s. Applies over entire test duration	Reported - Criteria not specified by standard	Fire spread start time = time external temp at level 1 (2.5 m above opening) exceeds 200 Deg C above ambient Level 2 external temp (5 m above opening) must not exceed 600 Deg C above ambient (over > 30 s), within 15 min of fire spread start time	Same as BS 8414 part 1	• No burned damaged (excluding melting or sintering) ≥ 3.5 m above opening. • Temperatures on wall surface or within the wall layers/cavities must not exceed 500 Deg C ≥ 3.5 m above opening. • No observed continuous flaming for more than 30s ≥ 3.5 m above opening. • No flames to the top of the specimen at any time.	• Wall exterior temp must not exceed 538 Deg C at 3.05 m above opening. • Exterior flames must not extend vertically more than 3.05 m above opening. • Exterior flames must not extend horizontally more than 1.52 m from opening centreline. • Flames must not occur horizontally beyond the intersection of the test wall and the side walls of the test rig.	No fire spread (flame and damage) > 4.2 m above opening (bottom of 2nd storey ficticious window) Temps at the eave must not exceed 500 DegC for more than 2 min or 450 Deg C for more than 10 min. Additionallay , for buildings >8 storeys high or hospitals of any height, Heat flux at 2.1 m above opening must not exceed 80 kW/m2.	Flame spread distance less than 5 m above the opening soffit Heat flux 3.5 m above opening must be less than 35 kW/m2.	the tested assembly shall not result in fire spread to the limits of the test structure as evidenced by flaming or material damage	Must meet requirements for 25 ft test • For acceptance to maximum height use of 50 ft (15.2 m), tested assembly shall not result in fire spread to limits of test structure as evidenced by flaming or material damage. • For acceptance to unlimited height use tested assembly shall not result in fire spread to the limits of the test structure or to the intersection of the top of the wall and the ceiling as evidenced by flaming or material damage.
	Internal fire spread	Temperatures at the mid-depth of each combustible layer or any cavity 5 m above the opening shall not exceed 250°C for a continuous period of greater than 30 s. Applies over entire test duration. Where the system is attached to a wall that is not required to have an FRL of –/30/30 or 30/30/30 or more, the temperature on the unexposed face of the specimen 900 mm above the opening shall not exceed a 180 K rise Where the system is attached to a wall not required to have a fire resistance of –/30/30, 30/30/30 or more, flaming or the occurrence of openings in the unexposed face of the specimen above the opening shall not occur Flame spread beyond the confines of the specimen in any		Level 2 internal temp (5 m above opening) must not exceed 600 Deg C above ambient (over > 30 s), within 15 min of fire spread start time	Same as BS 8414 part 1 Plus, Flaming (>60 s) must not occure on non-exposed side of the test wall at height of ≥ 0.5 m within 15 minutes of fire spread start time.	• No burned damaged (excluding melting or sintering) ≥ 3.5 m above opening. • Temperatures within the wall layers/cavities must not exceed 500 Deg C ≥ 3.5 m above opening	• Fire spread horizontally and vertically within wall must not exceed designated internal wall cavity and insulation temp limits. Position of designated thermocouples and temp limits depends on type/thickness of insulation and whether or not an air gap cavity exists. • Temp at the rear of test wall in 2nd storey test room must not exceed 278 Deg C above ambient. • Flames shall not occur in the second storey test room	No fire spread (flame and damage) > 4.2 m above opening (bottom of 2nd storey ficticious window)	Flame spread distance less than 5 m above the opening soffit	the tested assembly shall not result in fire spread to the limits of the test structure as evidenced by flaming or material damage	Must meet requirements for 25 ft test • For acceptance to maximum height use of 50 ft (15.2 m), tested assembly shall not result in fire spread to limits of test structure as evidenced by flaming or material damage. • For acceptance to unlimited height use tested assembly shall not result in fire spread to the limits of the test structure or to the intersection of the top of the wall and the ceiling as evidenced by flaming or material damage.

		Full-scale façade tests									
Test Standard		**AS 5113 : 2016 Amdt 1 (EW classification)**	**ISO 13785 Part 1:2002**	**BS 8414 part 1**	**BS 8414 part 2**	**DIN 4102-20**	**NFPA 285**	**SP FIRE 105**	**CAN/ULC S134**	**FM 25 ft high corner test**	**FM 50 ft high corner test**
		direction, as determined during the post-test examination, shall not occur. The examination shall include flame damage such as melting, charring but not smoke discolouration or staining of the surface, any intermediate layers and the cavity. Confines of specimen = 2.4 m horizontally on main test wall, 1.2 m horizontally on wing wall, 6 m vertically above top of combustion chamber opening									
	Burning debris and dropplets	Continuous flaming on the ground for more than 20 s from any debris or molten material from the specimen shall not occur	Reported - Criteria not specified by standard	Reported - Criteria not specified	Same as BS 8414 part 1	Falling burning droplets and burning and non-burning debris and lateral flame spread must cease with 90 s after burners off	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard
	Mechanical behaviour	The total mass of debris falling in front of the specimen shall not exceed 2 kg. The mass shall be measured after the end of the test.	Reported - Criteria not specified by standard	Reported - Criteria not specified	Same as BS 8414 part 1	Reported - Criteria not specified	Reported - Criteria not specified by standard	No large pieces may fall from the façade	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard	Reported - Criteria not specified by standard
Comments		Application of ISO 13785 Part 1 (with different criteria) is also permitted but not applied in practice in Australia.						Includes two fictitious window details in test wall and level 1 and level 2 blacked at rear with non combustible lining		Mostly only used for insulated sandwich panel	Mostly only used for insulated sandwich panel

Appendix C Supporting Documentation

Industry Code of Practice
External Insulation Finishing Systems (EIFS)

EIFS Manufacturing and installation responsibilities

2010 Code of Practice signatories (System Suppliers)

Ezyclad Pty Ltd
www.ezyclad.com.au

Insulcon Pty Ltd
www.insulcon.com.au

Multitex Corporation Pty Ltd
www.multitex.com.au

The Render Warehouse Pty Ltd
www.render.com.au

Unitex Pty Ltd
www.unitex.com.au

PACIA

The System Originator (S.O.) will:

- provide brochures detailing the complete system and installation details
- provide an installed defect free external walling system
- provide a 7 year warranty for the specified system
- state prior system limitations
- provide training and manuals for S.O. accredited installers
- ensure S.O. systems are compliant under the Alternative Solution assessment process outlined in the Building Code of Australia (BCA)
- deliver goods bag for clean up on-site

The EIFS Installer will:

- only install as per the S.O. manual with nil substitution
- be a trained S.O. Accredited EIFS installer
- provide signed joint works 7 year warranty with the S.O.
- provide proof of system accreditation currency
- inform the S.O. of all installations
- provide proof or registered business name
- arrange with S.O. for clean off-cut collection

The Builder/Developer/(Building Surveyor) will:

- only use S.O. accredited installer of the S.O.'s EIFS
- only use complete as specified S.O. systems
- provide a compatible substrate for the S.O. system
- inform the S.O. of the site to allow warranty Inspections prior and throughout the installation
- actively promote the use of systems of signatory firms to the EIFS Industry Code of Practice

For Further information on the EIFS group contact:
Manager, Industry Development –
EPSPlastics and Chemicals Industries Association

Level 1, Unit 7, Skipping Girl Place
651 Victoria Street, Abbotsford Vic 3067
PO Box 211 Richmond Vic 3121

Telephone (03) 9426 3804 **Facsimile** (03) 9429 0690

Figure 94 Industry Code of Practice Certificate for EIFS

Appendix D Fire Incident Summary Tables

Table 25 EIFS Fire incident summary

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Primary Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
LOCAL FIRES (IN VICTORIA) - EIFS												
Rennison St, Beaumauris	2019	Interface between roof structure and wall.	Electrical fault.	Night - 9:15pm	The roof structure was completely consumed with some EPS walls.	Cladding with EPS	1	2	Not reported - Assumed none	Not reported - Assumed none	Not reported - not required by NCC	Not reported
161 Princes Hwy, Dandenong	2019	Apartment balcony.	Disgarded cigerette.	Not reported.	Fire spread to EPS EIFS Cladding from the balcony.	EPS EIFS	2	3	Not reported - Assumed none	Not reported - Assumed none	Not reported - not required by NCC	Not reported.
Anstey Apartments, Brunswick	2017	Apartment balcony.	Faulty A/C unit.	Not reported.	Spread via EIFS to next level above	Combination of EPS EIFS and ACP	2	7 Some parts 4-5 stories	None	None	Yes - Building interior excluding balconies.	2 million AUD.
16 Hughenden Rd, St Kilda	2017	Garage interior	Leaking gas bottles.	Not reported.	2 levels at front of the 2 storey townhouse only	EPS EIFS	1	2 (adjoing 3 storey townhouses to the rear)	1 - burns to face and hands.	None	No - Not required by NCC	Not reported.
INTERNATIONAL FIRES - EIFS												
Baku, Azerbaijan	2015	1st floor.	Not reported.	Morning - 10:00am	Entire building.	Either ACP or 'styrofoam' - unconfirmed information from media reports	2	16	63	15-17	Not reported.	Not reported.

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Primary Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Miskolc, Hungry	2015	Internal 6th floor Kitchen	Kitchen fire	Not reported.	Spread vertically to top building. Limited external horizontal spread (confirmed from post fire photos)	EIFS with EPS (no horizontal fire barieres)	2	11	Not reported.	3	Not reported.	Not reported.
Van Nest Ave, Bronx , NY, USA	2012	External Alley (adjoining) fire - spread to building.	Exterior fire to building	Not reported.	The fire first spread to two buildings within alley (that were not clad with EIFS) before spreading to adjoining building with EIFS. The fire spread to the 2nd floor and entered building.	EIFS refurbishment onto pre-existing asphalt material	2 or 3 (residential on upper level). 9 (church on ground level)	2	Not reported.	Not reported.	Not reported - Not expected to be required	Not reported.
Dijon, France	2010	External Base of the building.	External Garbage container fire.	Not reported.	Entire building height over one face of building. Concentrated - within 'U' shaped vertical wall section.	EIFS with EPS with mineral wool barriers	3 - immigrant hostel	~10	11	7	Not reported.	Not reported.

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Primary Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Residential building, Shanghai	2010	External Burning Polyurethane (PU) foam fell and ignited wood/bamboo decking and nylon safeguard on 9th floor.	Welding operations for refurbishment works to install external wall insulation.	Not reported.	Full north face of building with further spread to east and west faces. Internal spread between floors 6 to 27 had occurred from the north face.	PU foam insulation.	2	28	71	58	Yes - Internal sprinklers between 1 to 4 floors only.	Not reported.
MGM Monte Carlo Hotel - Las Vegas	2008	External Top of the 32 storey building.	Welding operations.	Morning - 11am	Spread horizontally approximately 24 meters and downwards upto the 29th floor. Flaming droplets further ignited decorative EPS between 28th and 29th floor.	Non EIFS, EPS encapsulated in polyurethane resin.	Class 3 - hotel.	32	None	None	Yes - a total of 17 internally located sprinkers were activated.	$100 million USD
Mini Mall, Queens, NY, USA	2008	Internal fire spread to exterior façade system via broken windows	Arson.	Morning - 1:10am	Horizontal spread on external walls and awnings across multiple tenancies.	EPS EIFS	6 - outside strip mall	1-2	None	None	Not reported.	Not reported.

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Primary Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Munich, Germany	1996	External Base of the building.	External Garbage container fire.	Not reported.	Spread from the base to the top of the building. Horizontal spread across two adjacent faced of re-entrant corner walls	EPS EIFS (no horizontal fire barriers)	2	5	Not reported.	Not reported.	Not reported.	Not reported.
393 Kennedy St, Winnipeg, Canada	1990	Ground floor open carpark (beneath building)	Not reported.	Morning - 5 am	Main spread was to the 4th floor except for a narrow strip on the eastern façade where fire reached the top of the 7th floor. The north façade had fire spread to the top of the building.	EPS EIFS (no horizontal fire barieres)	2	8	Not reported.	Not reported.	No - Except for garbage chute and garbage room.	Not reported.
GERMANY - Examples from 96 EIFS FIRES BETWEEN 2001 to 2017												
Duisburg	2016	Internal Ground floor appartment	overturned candle	Not reported.	Spread to the top of the building. Internal spread occurred via window breakages to a few floors above.	EPS EIFS	2	Not reported. (>4 from photo)	28	3	No.	Not reported.
Unterbiberger Straße, Munich	2016	External Balcony	Not reported.	Night - New years eve	Spread over two storeys and into roof truss.	EPS EIFS	2	~4	4	1 (death occurred few days later from injuries sustained	Not reported. Not required by German Building code	200,000 Euros

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Primary Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
										during the incident)		
Ditzingen, Gartenstr	2012	External	Heat/sparks from construction works.	Not reported.	2 halls were destroyed and adjoining homes damaged by heat.	EPS EIFS (no horizontal fire barriers)	9b - Assembly building	Not reported - however building not higher than 7m.	none	none	not reported	600,000 Euros
Frankfurt	2012	External Base of the building	Either a vehicle fire or insulation material stored at base of building. Building under construction at time	Not reported.	Spread to the top of the building and horizontally for a substantial area.	EIFS with mineral wool cavity barriers. Not clear degree rendering had been completed (if at all)	2	6	none	none	No - Sprinklers were not operational at the time.	1.5 million Euros.
Frankfurt	2010	External Base of the building	External Garbage container fire.	Not reported.	Spread to the top of the building.	EIFS with EPS of ~60mm thickness.	2	7	21	None	Not reported.	500,000 Euros.
Aachen, Clemonstraße	2009	On the roof	Construction/refurbishment works.	Not reported.	Spread down one side of building.	EPS with EIFS	2	4	1	None	Not reported. Not required by German Building code	250,000 Euros
Apartment Building, Berlin, Germany	2005	Internal appartment fire 2nd floor.	Not reported.	Afternoon - 1:50pm	Flame spread to the top of the 7 storey building and into some rooms above.	Rendered 80mm EPS fixed directly to chipboard	2	7	3	2	No.	Not reported.
Cologne - Mülheim	2005	Internal appartment fire 2nd floor.	Not reported.	Not reported.	From the 2nd to 4th floor. Internal fire spread to 4th floor apprtment	EIFS with EPS	2	Not reported. At least 4	3	5	No.	Not reported.

Table 26. ISP fire incident summary

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Australian & New Zealand												
Ernest Adams Ltd, Christchurch NZ	2000	Internal	Not reported.	Morning - 8:30 am	Entire building destroyed.	EPS ISP	8 - Baked goods factory	1	4 - Fire brigade injuries	none	Not reported.	
Tiptop Bakery, NSW, Australia	2002	Internal	Failure of gas fired heating system - ignited flour	Not reported.	Most of the building destroyed.	EPS ISP	8	1	none	none	No	100 million AUD
Ingham Chicken Factory, Sommerville, Victoria, Australia	2010	Internal	fire in plastic packaging	Not reported.	Full length of main building and neighbouring loading dock and coldstore - overall length of 100m.	EPS ISP. PIR to extension part of coldstore building.	8	Not reported (likley 1)	none.	none.	Not reported.	Not reported.
Tegel Poultry Processing Plant, Christchurch, NZ	2007	Not reported.	Not reported.	Not reported.	Entire building destroyed.	EPS ISP	8	Not reported (likley 1)	Not reported.	Not reported.	Not reported.	50 - 100 Million NZD
Primo smallgoods factory, Greenacre, NSW, Australia	2007	Internal	Packaging machinery	Not reported.	Fire quickly spread to the both buildings via interbuilding conveyor belt shaft lined with EPS ISP. The external walls, ceilings and internal walls were all made of EPS ISP.	EPS ISP	8	Not reported (likley 1)	Not reported.	Not reported.	Not reported.	200 million AUD
International												

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Various locations in the UK (Total of 21 incidents)	Prior 1997	Generally internal	N/A	N/A	Generally loss of enitre buildings	All are EPS ISP	8	generally 1 storey	none	2 fire brigade deaths at Sun Valley Poultry fire - building/roof collapsed	Not reported.	Not reported.
Wharfdale Hospital, Otley, West Yorkshire, UK	2003	External Ground floor where building materials were stored.	Arson - adhesive poured over slabs of insulating materials and paints was ignited.	Not reported.	Flame imingment occurred up to 10m from ground floor - PIR core revealed showed to be unaffected except for surface char in area of flame impingement.	PIR ISP	9a	3	Not reported - however most likely none.	Not reported - however most likely none.	Not reported	Not reported.
Spider Transpot, Wicklow, Ireland	2008	External ~1m away from external wall	Arson - flammable liquid poured on cab area of truck parked close to building.	Not reported.	Cladding did not support flame spread beyond parts of flame impingment. ISP did not delaminate or loose integrity. Internal damage occurred via windows breakages and roller door.	PIR ISP	Possibly 8 or 7b	2	Not reported - however most likely none.	Not reported - however most likely none.	Not reported	Not reported.

Location	Year	Location of Fire Origin	Cause of Fire	Time of Incident	Extent of Spread	Details of Cladding	Building Classification (as per NCC)	Rise in Storeys	No. of reported Injuries	No. of reported deaths	Was Sprinkler Protection Available?	Cost of Damage
Furniture Retail Warehouse, Slovakia	unknown.	External ~ 1.2m away from external wall on ground floor.	cooking grill / gas cylinder fire	Not reported.	Direct flame impingment upto 10m high. PIR core did not promote fire spread. No delamination occurred and wall maintained integrity.	PIR ISP	6 or 7b	Not reported. Most likely 1 or 2 (ascertained from post-fire photo)	Not reported - however most likely none.	Not reported - however most likely none.	Not reported	Not reported.

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