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EPS Concrete cladding panel fire performance

Technical advice report

Author: N. White
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Inquiries

Inquiries should be addressed in the first instance through the State Building Surveyor Victorian Building Authority, 733 Bourke Street Docklands 3008.

Author

Infrastructure Technologies:
Private bag 10, Clayton South,
VIC, 3169, Australia

T (03) 9545 2222•

Client

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AUTHOR	REVIEWED BY	AUTHORISED BY
N.White	A. Webb	N. White
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Copyright and disclaimer

Important disclaimer

Contents

Executive summary

The Victorian Building Authority has engaged CSIRO to provide technical advice on the risk of external wall fire spread posed for existing buildings (particularly focused on Class 2 and 3 buildings requiring Type A or B construction) currently constructed with wall systems including EPS Concrete[1]. EPS concrete is a generic label for a material that is a composite of EPS beads mixed in a cementitious matrix, formed into a block or board. In particular, QT Eco Series wall systems include a component/product called Conpolcrete® which has been identified as the most prevalent of this type of system in Australia.

CSIRO has based this advice on:

- Review of the composition and typical construction of EPS concrete products and specifically the QT Eco Series wall system.
- Review of publicly available fire test data and any information provided to CSIRO by the VBA.

This advice is subject to the limitations stated in Section 1.5. In particular, this advice only applies to QT Eco Series wall systems currently installed to existing buildings. This work does not make any conclusion or determination of suitability or compliance to be applied to use of products as replacement materials for building rectification or new construction.

It is recognised that QT wall systems have established a substantial level of testing for their product.

In developing this report CSIRO held brief discussions with QT wall systems to clarify aspects of the report including changes in product manufacturing processes and colour over time. However, at the time of this report revision, the report sponsor (VBA) has not provided QT wall systems the opportunity to review and comment on the report in full.

Summary of existing information:

1. QT Eco Series wall system specification is a system including render, 50 mm Conpolcrete, battens, sarking, framing and internal plasterboard lining. Inspection of existing buildings showed variation in the actual construction.
2. Conpolcrete is understood to consist roughly of cement matrix, adhesive, a small amount of fibres and ~ 70% by volume EPS bead aggregate sourced from clean recycled material.
3. The exact composition of Conpolcrete is not fully understood (outside the manufacturer) and materials test methods for this material have a low accuracy/suitability due to its complex composition and composite nature.
4. There appear to have been 3 major formulations of QT Conpolcrete over the years including:
    a. pink coloured cementitious matrix
    b. white coloured cementitious matrix
    c. grey coloured cementitious matrix (the current product).

    While visually identifiable the differences in these types are not well understood in regard to formal composition/identification. QT systems have provided some information on changes to manufacturing processes but have stated that the formulation has essentially not changed.
5. For all of the fire test reports for QT Conpolcrete, the reported bulk density of this product ranges from 345-420 kg/m^3.
6. QT Conpolcrete is combustible when tested to AS 1530.1.

[1] The term “EPS Concrete cladding panel” is used in this report to refer to cladding boards/panels manufactured from cementitious material mixed with EPS as a lightweight aggregate.

7. Bare Conpolcrete and rendered QT Eco Series wall systems have been tested to a range of other fire tests which indicate a low risk of external wall fire spread. However, several limitations and knowledge gaps in the tested systems have been identified.
8. There are no current fire test reports which show QT complies with the Deemed-to-Satisfy (DtS) BCA Clause C1.9 and related DtS clauses. The compliance therefore relies on either a performance approach or CV3, both of which may utilise AS 5113 testing.
9. The single AS 5113 EW/BS8414 full scale façade test report on a QT wall system demonstrated no significant fire spread. However, this test was conducted on a specimen with some significant differences from the system specified in the QT manual or most typically installed in practice on existing buildings. These differences included:
    a. 10 mm render of unknown detail was tested. 5 mm multilayer render with embedded full mesh is typical construction.
    b. 2 x 13 mm FR plasterboard installed in the cavity behind battens. FR plasterboard is not typically installed at this location within the wall system.
    c. No sarking was installed in the tested system. Sarking is required to be installed behind battens.
    d. Steel battens and frame was tested. Timber battens and frame appears most typical.
    e. Details of sealing at edges of tested wall system and around perimeter of combustion chamber (which can represent a window opening) are not well documented in test report and may not match the installation specification or typical construction.
10. The Single AS 5113 EW/BS8414 full scale façade test on a QT wall system was undertaken by a laboratory not holding NATA accreditation for this fire test method at the date of test.
11. No intermediate scale fire test data was available which investigated the propensity for ignition or fire spread of QT wall systems (with no render or thin or damaged render) when exposed to localised balcony fires of the order of 100-300 kW or cavity fire spread.

Recommendation for further testing

It is recommended that ideally, to provide further information on fire performance for existing buildings, a strategic set of further fire tests should be conducted. This should include:

1. Investigation of the range of the installations of the system on existing buildings.
2. Investigation of the difference between the 3 major formulations of the Conpolcrete. Test at small scale (cheaper and timely) and compare results to ACP FR materials to provide additional evidence for risk ranking similar (or better) than ACP FR for the State-wide cladding audit Risk Assessment Tool (RAT). Small scale test methods to consider for this include the cone calorimeter and the bomb calorimeter.
3. Conduct Intermediate scale (non-standard balcony fire scenario) tests exposing small wall sections to 100-300kW localised fires. Test specimens could have thin render or no render. This would provide data on QT's resistance to fire spread from non-flashover fires (localised balcony fire scenarios). Such tests could also provide information on cavity fire spread.
4. Conduct an AS 5113 EW full scale façade test on a QT wall system which may be more representative of some installations found in field (e.g. render ~5mm, QT without FR grade plasterboard directly behind, inclusion of sarking, inclusion of representative capping details around edges of wall system and perimeter of combustion chamber opening). This should be completed by a NATA accredited lab. It must be considered that such a test may not necessarily pass all AS 5113 EW criteria but would provide useful information on fire performance to inform a risk-based assessment of this system.

Conclusions based on currently available information

1. In the absence of the above recommended further testing, and on the basis of the limited available test evidence, it could be reasonably concluded that a QT system installed to the manufacturers specification has a low risk of façade fire spread and might reasonably be ranked as having a Risk Assessment Tool (RAT) material risk score input equivalent to ACP-30% PE in the statewide cladding RAT. This recommendation applies only to the state-wide cladding RAT. It does not apply to the ICA ACP risk categories which excludes EPS concrete products. Further testing (as recommended

above) would be needed to demonstrate a risk level comparable to ACP-A2 (for the purposes of the RAT).

2. CSIRO strongly recommended that the above decision to rank QT as having approximately equivalent risk to ACP-30% PE should be agreed upon by a panel of experts via a "Delphi" process to increase the robustness and reduce risk of this decision prior to being adopted. This has been completed. See the section below for the outcomes of the Delphi panel.
3. There have been a number of examples from the statewide cladding audit, where buildings have had QT specified, but upon closer inspection have been proven to have areas of walls installed with 100% EPS. This may either be due to substitution; design changes; or where QT may be specified close to boundaries and other fire source features, but EPS may be specified at other areas.
4. We do not recommend that QT should automatically be considered to be "Out of scope" for the statewide cladding audit for the following reasons.
    a. Although QT may reasonably be considered lower risk, it is still a combustible cladding material.
    b. Difficulty differentiating if cladding is actually QT or EPS without detailed site inspections including penetrations to verify core at multiple locations. For this reason, the State-wide cladding audit should consider that buildings nominated to have QT on design documents should still require verification via detailed penetrative site inspection.
5. If a building is verified via site inspection to be QT (without other higher risk combustible cladding) then it may be reasonable to acquit the building following the VBA low risk building acquittal guidelines.

<u>Conclusions regarding material characterisation testing of EPS Concrete panel cladding</u>

1. The Ash Content test alone underpredicts (by about 20-30 %) the mass ratio of cementitious to EPS material as the cementitious material loses mass in the form of H2O and CO at elevated temperatures. Typical Ash mass % for QT Conpolcrete specimens is in the range ~ 60-70% which is significantly less that the actual cementitious mass % of ~90-97%, however this test does provide one point of comparison between EPS concrete specimens.
2. CSIRO has developed a solvent dissolution method, which measures mass of sample, then dissolves the EPS component away with a solvent and carefully dries the remaining cementitious component at low temperatures and measures the remaining mass. This provides a more accurate mass ratio measurement of EPS to Cementous content.
3. CSIRO has previously also conducted XRD on the cementitious component and FTIR on the EPS component for all samples received to increase information gathered and build an understanding of the amount of variation between batches and three versions of QT Conpolcrete.
4. CSIRO material characterisation reports for EPS Concrete specimens include a cautious allowance for expanded accuracy and uncertainty. This typically expands the stated mass % cementitious content test result for QT Conpolcrete specimens to a range of ~85-97%. This is to account for possible variation in homogeneity in specimens, other possible minor components such as resins & fibres and accuracy of test methods and amorphous mineral. However, the actual mass % cementitious content of grey core QT Conpolcrete is most likely to be in the average range ~90-97%.
5. It may be reasonable for future samples to only be tested applying the Solvent Dissolution method to indicate EPS: Cement ratio. Further testing may only be needed if a significant visual or mass% difference is found between the specimen and typical QT Conpolcrete product.
6. Bulk density may also be used to compare EPS sampled from existing buildings to the range of bulk densities for QT Conpolcrete reported in fire test reports (345-420 kg/m^3). A density below this range may indicate an increased EPS content.
7. Appendix B of this report provides guidance on a method of bulk density measurement for EPS concrete specimens.
8. It may also be possible to base conclusions on EPS concrete installed to existing buildings based on a visual comparison and bulk density measurement of core samples. However, the following caution should be taken:

a. The person doing the inspection must be familiar with the visual appearance of all types of EPS concrete core.
b. There have been cases in the past where (non-CSIRO inspectors) have mistaken white core QT for 100% EPS.
c. CSIRO has at least one example of an existing building clad with an EPS concrete product that is not a QT product. The trade name of the product type cannot be identified and it has a significantly different composition of cement matrix. We do not have any reaction to fire test reports for this product and it could easily be mistakenly assumed to be a QT product based on visual identification only.
d. To ensure relatively repeatable bulk density measurements, CSIRO has provided a bulk density measurement procedure in Appendix B of this report.
e. It is noted that bulk density measurement does not directly measure the mass % of cementitious content or identify the major mineral component of the cementitious material. Laboratory testing can provide this further detail if needed.

Delphi Panel outcomes

The VBA arranged for Revision D of this report to be reviewed by a panel of experts (Delphi Panel). The Delphi panel provided written comments which CSIRO responded to and then The VBA held a final Delphi Panel meeting on 9/07/2021, which CSIRO attended as Co-Chair. The Delphi Panel voted (by majority vote) on the following outcomes:

1. It was confirmed that the Delphi Panel would vote on the Statewide cladding risk assessment tool (RAT) material risk score input to be applied for EPS concrete (i.e., the risk ranking of the material in isolation). It was discussed that other factors such as combination of EPS concrete with other combustible external wall materials, insulation type or poor fixings/installation should be addressed by the other RAT inputs already provided in the RAT for these items.
2. Majority Vote outcome was that the RAT material risk score input to be applied for EPS concrete shall be 0.5 (same ranking as applied to ACP with a core consisting of 30% or less polyethylene), provided that the EPS concrete visually matches QT Conpolcrete and has a bulk density of at least 345 kg/m^3 or greater.
3. EPS concrete which has a bulk density of less than 345 kg/m^3 or does not visually match QT Conpolcrete should be conservatively assigned a RAT material risk score input of 1.0 (same ranking as applied to 100% EPS), reflecting that the material may potentially have increased EPS content.

It was noted that a RAT material risk score input of 0.5 for QT Conpolcrete was conservatively assigned giving full consideration to the gaps in fire testing identified.

The above outcomes apply only to the state-wide cladding RAT. It does not apply to the ICA ACP risk categories which does not apply to EPS concrete products.

1 Introduction

1.1 Project

EPS Concrete cladding panel fire performance review and technical advice.

1.2 Client

Victorian Building Authority (VBA).

1.3 Scope of work

The scope of work is set out in VBA's statement of work Ref No SCA04062020. VBA has requested CSIRO to provide advice on the following matters:

1. "to make a recommendation as to whether QT poses enough of a risk for the SCA to continue auditing it. This could be phrased as - The SCA is auditing buildings for use of high-risk cladding materials, specifically being EPS and ACP. In carrying out our audit functions the VBA has audited products that can be commonly mistaken for EPS. One such product is Concrete Polystyrene Blend Panels (Conpolcrete, QT, Quick'n'Tuff etc.). We are seeking the CSIRO's opinion of the risks posed by these panels in the event of a fire. Specifically, the VBA seeks the CSIRO's opinion if the risks posed by these panels are comparable to EPS to justify continuing audit activities".
2. If Conpolcrete is considered within scope of the State-wide Cladding Audit, based on the known performance of Conpolcrete in a fire event and available literature and testing results, then what is the most appropriate value to assign to it in the RAT?

The above advice would be based on the following scope:

1. CSIRO to review all test/other documented evidence on composition of and the known performance of Conpolcrete in a fire event that is provided by the VBA (CSIRO cannot provide any client confidential test evidence).
2. Based on this, CSIRO can summarize the test evidence and provide a reasoned proposed recommendation for the most appropriate RAT ranking to be used for preliminary ARP risk assessments. This would be documented in a brief summary information document. This recommendation could not be applied to the RAT without further Delphi/consensus agreement being documented via reference to a suitable panel of experts.
3. To achieve Delphi/consensus agreement, the VBA shall hold an internal workshop including fire safety engineers and other VBA stakeholders/experts (such as a similar workshop previously arranged by Max Ginn for EPS Sandwich panel) to obtain consensus agreement or disagreement (which is effectively how ranking for other ACP materials was obtained)
4. The above process would be documented as an internal record for VBA.
5. The above would strictly only apply to preliminary risk ranking by the VBA of existing buildings.

This technical advice report addresses items 1 and 2 above.

1.4 Sources of information

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

- Product information and test reports provided to CSIRO by VBA or found to be publicly available on supplier's websites. CSIRO cannot provide any client confidential test evidence.
- The National Construction Code (NCC)[1], including Building Code of Australia (BCA) Volume 1 and Volume 2.
- The previous published CSIRO Report "*Fire Hazards of Exterior Wall Assemblies Containing Combustible Components*"[2].
- 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.
- University of Queensland (UQ) who have published a material library of cladding materials and a supporting protocol for sample preparation and testing methodologies[3-5].

From 2017-2020 CSIRO has acted as a fire safety engineering representative in various Advisory Reference Panels (ARP's) under the State-wide 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[6] and final[7] 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 Concrete and EPS bead composite cladding panels in Australia. However, due to confidentiality, CSIRO cannot include details of specific buildings.

It is recognised that QT wall systems have spent significant resources to establish a substantial level of testing for their product.

In developing this report CSIRO held brief discussions with QT wall systems to clarify aspects of the report including changes in product manufacturing processes and colour over time. However, at the time of this report revision, the report sponsor (VBA) has not provided QT wall systems the opportunity to review and comment on the report in full.

1.5 Limitations

This report is subject to the following strict limitations:

- This report is primarily focused to provide a review of EPS Concrete cladding where it is already present on existing Class 2 or 3 building which require Type A or B construction. The scope and conclusions of this report exclude Class 1 buildings or Buildings of Type C construction.
- This work does not form a peer review or endorsement of any test report or performance-based solution.
- This work does not make any conclusion or determination of suitability or compliance to be applied to use of products as replacement materials for building rectification or new construction.

- This work does not make any conclusion or determination of suitability or compliance for existing installations on existing buildings beyond a rough risk ranking to specifically be applied for VBA ARP RAT
- This report does not address any other types of materials, except so as to form a basis for comparison against concrete and EPS bead composite cladding panels.
- Conducting any new testing is not included in the scope (this would be additional scope that CSIRO could offer upon request).
- The report is limited to the scope identified in this report.
- This report by CSIRO does not constitute a test report. This report contains review, assessment and opinions provided by a CSIRO Fire Safety Engineer and does not represent a CSIRO NATA accredited test laboratory report.
- Reports marked 'Draft' are subject to change and CSIRO accepts no liability pending release of the final version of the report.
- The recommendations in this report are based on information provided by others. CSIRO has not verified the accuracy and/or completeness of this information and accepts no responsibility or liability for any errors or omissions which may be incorporated into this report as a result.
- The goal of 'absolute' or '100%' safety is not attainable and there will always be a finite risk of injury, death or property damage. Fire and its consequent effects on people and property are both complex and variable. Thus, a fire safety system may not effectively cope with all possible scenarios. The intent of regulations and this report related to health, safety and amenity in buildings is to mitigate risks to a level acceptable to the community.
- The provision of this report by CSIRO does not ensure [the Client's] compliance with Work, Health and Safety legislation or other legal or regulatory requirements.
- CSIRO reserves the right to revise this report at any time in response to any new information or knowledge.
- Other assumptions and limitations are stated throughout the body of the report.

1.6 List of abbreviations

Table 1. List of abbreviations

ABCB	Australian Building Code of Australia
ACP	Aluminium Composite Panel
ARP	Advisory Reference Panels conducted in Victoria on behalf of either VBA, DELWP or the Victorian Cladding Taskforce . A 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
ATR-FTIR	Attenuated total reflection Fourier-transform infrared spectroscopy
BAB	Building Appeals Board (Victoria, Australia)
BAL	Bushfire Attack Level (as defined by AS 3959).
BB	Building to Building
BRAC	Building Regulations Advisory Committee
BRANZ	Building Research Association of New Zealand
BRE	Building Research Establishment Limited
BS	British Standard
CCP	Concrete Composite Panel. An alternative naming convention which Cladding Safety Victoria uses to refer to EPS Concrete panel products.
CHF	Critical Heat Flux
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning, Victoria
DIN	Deutsches Institut für Normung (German Testing Standard)
EPS	Expanded Polystyrene
EW	External Wall
EWFA	Exova Warringtonfire Assessment
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.
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 an FRL.
FZ	Flame zone (Bushfire Attack Level), as defined in AS 3959
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.
IBC	International Building Code (North American Model Building code)
ICA	Insurance Council of Australia
ISO	International Standards Organisation
JAS-ANZ	Joint accreditation system of Australia and New Zealand
NCC	National Construction Code (NCC) Australia
NFPA	National Fire Protection Association

SBI	Single Burning Item (test)
TGA	Thermal Gravimetric Analysis
VBA	Victorian Building Authority
RAT	Victorian Statewide Cladding Audit Risk Assessment Tool
QT	Common term used to refer to QT wall systems which is a complete wall system comprising render, 50 mm Conpolcrete, battens, sarking, framing and internal wall lining installed to manufacturers specifications. Sometimes referred to as "Quick'n'Tuff"
XRD	X-ray diffraction crystallography

2 EPS Concrete cladding panel overview.

2.1 What is EPS Concrete cladding panel?

The term "EPS Concrete cladding panel" is used in this report to refer to cladding boards/panels manufactured from cementitious material mixed with EPS as a lightweight aggregate. Cladding Safety Victoria currently refers to this type of product as "concrete composite panel" (CCP). Other materials such as adhesives/resins and fibres may sometimes be mixed with the composite at typically lower quantities than the cement and EPS. Such materials have been developed as an alternative method of producing light weight concrete panels to the traditional autoclaved aerated concrete (AAC).

There have been numerous scientific journal articles published around the world on methods of production of light weight concrete using EPS beads as aggregate and the effects of different compositions on mechanical, acoustic and fire properties[8, 9]. It appears to have been first developed by John Cook at University of New South Wales in 1972[10]. Light weight concrete with EPS aggregate is typically composed of a cementitious slurry/mortar mixed with EPS beads which are typically sourced from recycled EPS materials. The cementitious component typically is composed of Portland cement with fine aggregate/sand.

The very low density and hydrophobic nature of EPS beads is a challenge as the EPS beads tend to float when mixed with the cement slurry and this can result in poor mixture of the EPS beads in the cement matrix which result in poor product properties. To address this, additives are typically used to increase bonding dispersion between the EPS beads and the matrix. Additives can include mineral admixtures such as fly ash, epoxy resins, or EPS beads chemically treated prior to mixing. Foaming agents can typically be added to concrete slurries whilst mixing with the EPS beads to aerate the cement as it sets around the EPS beads. Fibres including glass fibres and metal fibres can be added to the mix to change mechanical properties

The range of EPS to cement ratio and various additives and production methods stated in scientific journal articles vary greatly.

The most common cement and EPS bead composite panel product in Australia is a product known as Conpolcrete which is used in QT Eco Series wall systems. The exact composition of this product is not clearly stated in the supplier's patent or literature (as this is a typical method of maintaining intellectual property).

As a point of comparison, Autoclaved aerated concrete (AAC)[11] 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 (a registered trademark product by CSR). 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.

Figure 1. typical AAC structure (left), Hebel block (centre), Typical AAC EIFS installation (right), all photos by CSIRO.

2.2 How is it used?

EPS Concrete is typically produced in panels to be used as non-load bearing external wall cladding. It is installed in a similar manner to exterior insulated finish systems (EIFS) such as rendered EPS board. It typically has a lower density and increased thermal insulation compared to AAC. It is typically higher density and lower thermal insulation compared to 100% EPS but has significantly improved fire performance.

EPS Concrete does not typically have the mechanical strength required to be used as structural load bearing elements.

2.3 Products available in Australia

This section of the report includes examples of some products (other than QT Eco Series wall systems) where fire test results are stated on product websites without corresponding fire test reports available from the website. <u>Any fire test results stated on product websites without a credible fire test report being provided should be treated with caution regarding validity.</u>

2.3.1 QT ECOSERIES WALL PANEL SYSTEM[12-15]

QT Eco Series wall system appears to be, by far, the most commonly used wall system in Australia using a composite and EPS bead composite cladding panel. The QT Eco Series wall system is technically a complete external wall system including external render, cement/EPS bead composite panel, battens, cavities, sarking/insulation, Framing and internal wall linings. The QT Eco Series wall panels are manufactured from a trademark registered material called “Conpolcrete®”. However, the building industry often confuses this naming of materials/products and complete wall systems (the QT website also appears to do this) and typically refers to the EPS Concrete panel used as any of the following:

- QT,
- Quick n’ Tuff and
- Conpolcrete.

Conpolcrete is currently manufactured by a Queensland based company named “Eco Cladding Pty Ltd”, with the trading name “QT systems”. This current company name appears to be a name change from the original company name of the developer/manufacturer of Conpolcrete, “E.I.F.S (Australasia) Pty Ltd”.

E.I.F.S (Australasia) Pty Ltd registered the following trademarks and patents for Conpolcrete:

- Registered the trademark “Conpolcrete” (TM no: 884645) on 2, August 2001.
- International patent titled “Composite light weight building panel and core material therefor”, WIPO number: W002/12143, dated 2001.08.02
- International patent titled “Improved cementitious mixtures”, WIPO number: W006/037187, dated 2005.10.07

However, the details in the patents are very broad and do not directly state the exact formulation and manufacturing details of Conpolcrete or how this may have changed over time. The QT Eco Series wall panel Safety Data Sheet states the following composition/information on ingredients:

“*N/A- Due to the copyright of the unique product “Conpolcrete®”. QT Eco-Series Wall Panels are manufactured from a cementitious admixture material called “Conpolcrete®” which consists of a blend of Cement, Fibre and Polystyrene creating a lightweight masonry product*”.

Figure 2. Conpolcrete® product obtained by CSIRO in 2019 – Photo by CSIRO

As Conpolcrete® and QT Eco Series wall system appears to be, by far, the most commonly used wall system in Australia using a composite and EPS bead composite cladding panel, it is the focus of the majority of the rest of this report. Other sections of this report review detail of material composition, physical properties, construction and available fire test results for this product/system.

Other products identified as either currently, or previously being available in Australia are listed below. However, these appear to have had significantly less use as building exterior cladding compared to QT Eco Series wall system.

2.3.2 AEROCRETE[16, 17]

Aero Crete panels have an inner core of EPS Concrete and 5 mm thick fibre cement sheets are laminated to both external faces of the panel. It is manufactured in 2400 mm long x 450 mm high x 75 mm thick panels with a tongue and groove along the long edges of the panel.

Figure 3. Aero Crete panels (image from Aero Crete website)

The product is sold as a modular external fencing system. It may be possible that this product could be used as an external building cladding, but no evidence has been found indicating this. No details of the core composition or colour have been found.

Note – The term aero Crete can also be generically used by building industry to refer to a range of other types of light weight aerated/foamed concrete products.

2.3.3 BENEX[18]

Benex blocks are light weight masonry blocks which contain some EPS beads. The product is manufactured in Bathurst NSW. The Benex website states the following composition.

Component	% by weight
Off-white cement	34.2%
Fine sand	46.1%
EPS Beads (2-3 mm)	1.3%
Water	18.3%

The EPS loading appears to be less compared with products such as QT Conpolcrete.

Benex blocks can be used to construct either hollow or concrete core filled loadbearing walls. Benex blocks H600 blocks are 600 mm x 200 mm x 200mm (making a 200 mm thick wall). Each block is 13 kg.

Test reports and assessments provided on product website state the product can achieve AS 1530.4 structural adequacy and integrity of up to 240 minutes (dependant on wall height and loading). An AS 1530.4 test on a hollow core wall failed insulation after 198 minutes.

Benex also produce wall cladding and floor panels at 1200 mm x 200 mm x 35 mm thick. The website refers to the same MSDS as for Benex blocks indicating that the wall panels have the same composition as the blocks. The wall panels can be used as external rendered wall construction. The product website provides the following test reports:

- CSIRO report No FNC12153, Dated 18 April 2018. Combustibility test in accordance with AS 1530.1. Result = Not Combustible. Note the report states product colour as grey and nominal density as 1000 kg/m^3.
- Exova Warringtonfire Test report no:26704300, Dated:28 October 2013. Fire resistance test of a partially loaded double stud wall system clad each side 35 mm Benex panels tested in accordance

with AS 1530.4. Result = Structural adequacy no failure at 64 min, integrity failure at 63 min, insulation failure at 63 min.

It is noted that a reason this product has achieved an AS 1530.1 not combustible test result may be due to it relatively low EPS loading compared to other products which are deemed combustible when tested to AS 1530.1 and which typically have a higher EPS loading. The Benex wall panel is stated to have a mass per unit area of panel of 35 kg/m^2 (for 35 mm thick panel) or a density of 1000 kg/m^3. Based on this the EPS content must be considerably less than for QT Systems Conpolcrete®. Photos of the product on the website indicate that the EPS aggregate is not easily visible.

Figure 4 Benex wall panel (image from Benex web site)

2.3.4 PRONTO PANEL[19]

Pronto panel has core consisting of EPS Concrete. Both external faces are laminated with 4-5 mm thick calcium silicate board. The panels are a total of 60 mm wide and have a tongue and groove edge profile and are marketed for application as external wall systems. Pronto Panel is Brickworks Building product. They are stated to have a mass per unit area of 52 kg/m^2. For a panel thickness of 60 mm this equates to a total density of 867 kg/m^3, however this includes both the calcium silicate board and the core. Test certificates provided on the product website state the following information relevant to core composition:

- Light weight aggregate of polystyrene and saw dust in a cementitious mixture of Portland cement, fly ash and polymers
- Density = 840-865 kg/m^3
- Colour = grey

The product website provides numerous technical manuals, certificates and test reports including:

- AS 1530.1 Not combustible test result – CSIRO Report no FNC11425, dated 2 July 2015.
- AS1530.4 wall test on Pronto Panel wall system incorporating offset plasterboard lined framed wall, Test result: FRL = -/120/120 – CSIRO Certificate of test COT2639, dated 9 January 2015.

- AS1530.4 wall test on Pronto Panel wall system (on its own, not combined with plasterboard wall system) Test result: FRL = -/60/60 – CSIRO Certificate of test COT2668, dated 27 July 2015
- Codemark Certificate of conformity - CM30077 Rev 4 . Date of issue = 01/08/2019, Date of expiry = 18/07/2021. States "Pronto Panels may be used where non-combustible materials are required applicable to Class 2, 3, 4, 5, 6, 7, 8 & 9". No specific conditions except that system to be installed in accordance with Pronto Panel Technical manual.

The density and non-combustible test result suggest that the ratio of Cement:EPS may be greater for Pronto Panel compared to QT wall systems Conpolcrete. However, photos of the product on the website show that the EPS aggregate is easily visible at cut exposed edges. Products where EPS beads are exposed at outer surface to the extent shown in the image below would not typically be expected to achieve a non-combustible result in AS 1530.1.

Figure 5. Pronto panel wall system (image from pronto panel web site)

It is noted that the website for this products was accessed by CSIRO when first drafting this report . At the time of Revision D of this report, the website for this particular product appears to be no longer accessible.

2.3.5 QPANEL[20]

QPanel is a lightweight interlocking sandwich panel with 4 mm thick fibre cement sheet facing laminated to both sides and a low-density concrete core consisting of "*a mix of Portland cement, Silicaceous & Micaceous aggregate".* Based on website images, it also appears to have an EPS bead aggregate.

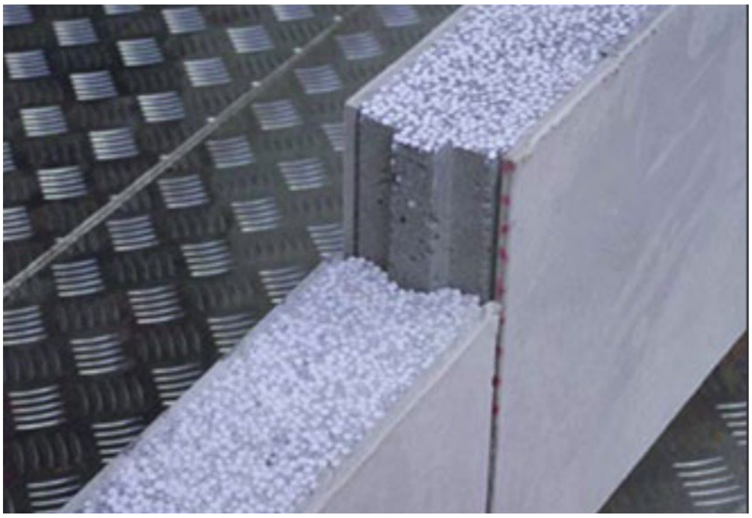

Figure 6. Qpanel (image from Qpanel website)

It is produced in Panel thicknesses of 50 mm and 75 mm. The product website states a total density (including external fibre cement sheet facing) of 835 kg/m^3 (50 mm thickness) and 807 kg/m^3 (75 mm thickness). The website also states the following fire test results but does not provide reference test reports:

- AS 1530.1 – Non-combustible
- AS 1530.4 – 50 mm thickness = "60 minutes", 75 mm thickness = "120 minutes"

Products where EPS beads are exposed at outer surface to the extent shown in the image above would not typically be expected to achieve a non-combustible result in AS 1530.1.

The product appears to be manufactured in Indonesia but appears to have some level of marketing presence in Australia. It is noted that the website for this products was accessed by CSIRO when first drafting this report . At the time of Revision D of this report, the website for this particular product appears to be no longer accessible.

2.3.6 MAK-STYROCON[21]

This product is similar to Qpanel and the two products may possibly be related. It is an interlocking sandwich panel with lightweight core of Portland cement and expanded polystyrene bead aggregate, laminated on both sides with 4.5 mm fibre cement facings.

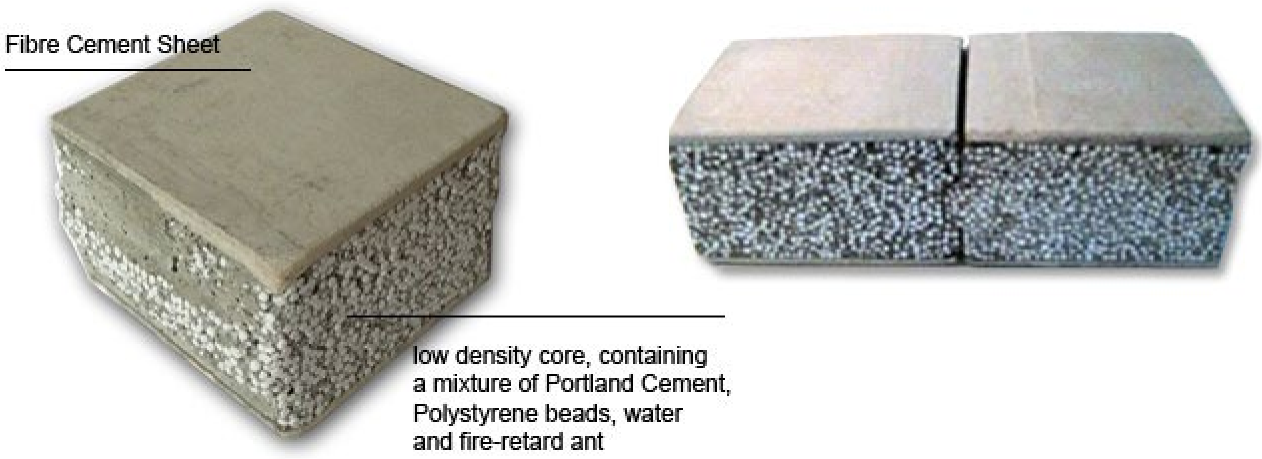

Figure 7. MAK-Styrocon (Image from MAK-Styrocon website)

The product website states the following panel weights

- 50mm x 600mm x 3.0 metre = 23kg [approx.] (Density ~ 255 kg/m^3)
- 75mm x 600mm x 3.0 metre = 24.5kg [approx.] (Density ~ 181 kg/m^3)
- 100mm x 600mm x 3.0 metre = 26.5kg [approx.] (Density ~ 147 kg/m^3)

The website also states the following fire test results but does not provide reference test reports:

- AS 1530.1 – Non-combustible
- AS 1530.4
  - 50 mm thickness = "1 hour
  - 75 mm thickness = "2 hours"
  - 100 mm thickness = "3 hours"

Products where EPS beads are exposed at outer surface to the extent shown in the image above and with the stated low density (indicating high EPS to cement ratio) would not typically be expected to achieve a non-combustible result in AS 1530.1.

The product appears to be manufactured in Indonesia but appears to have some level of marketing presence in Australia.

2.4 Other types of systems combining concrete and EPS

There are other types of wall systems which combine concrete and EPS which are excluded from the scope of this report. The main other type of system uses EPS as an external formwork which has a core filled with concrete. The EPS provides thermal insulation whilst the concrete core provides structural capability. The exterior of the EPS is typically either rendered or laminated with a cement sheet of similar board product and the internal face is typically lined with plasterboard. One example of such a product is Eco Block[22].

3 Conpolcrete® composition

3.1 Composition

The exact composition and manufacturing process for Conpolcrete® is not published by QT systems as it is protected intellectual property of the manufacturer. The product colour and manufacturing process has changed since the commencement of manufacture.

3.1.1 CURRENT VERSION

Information on the product as it is sold at the time of writing the report is:

- The Safety Data Sheet for the product states "*QT Eco-Series Wall Panels are manufactured from a cementitious admixture material called "Conpolcrete®" which consists of a blend of Cement, Fibre and Polystyrene".*
- The QT Systems website states:
  - *"The Eco Series Wall Panels are constructed of Conpolcrete™, a Cementitious mixture containing recycled polystyrene"*
  - *"Conpolcrete® is 70% (by volume) recycled material".*
  - *"Conpolcrete® has a material density of 380 kg/m³"*

The patent titled "Improved cementitious mixtures", WIPO number: W006/037187, dated 2005.10.07, provides very broad composition details which permits a range of different light weight aggregate materials, resins and fibres to be used at varying composition ratios. It provides one detailed formulation example, but states this resulted in a finished set block material density of 180 kg/m³, which is significantly less than the commercially produced Conpolcrete® product. The patent detailed example had the following composition and was mixed with a hand mixer and hand poured into a mould (without pressure/temperature) and allowed to dry/set at ambient conditions.

Table 2. Patent detailed example composition.

Component	Quantity
Cement	6 kg
Sand	1 kg
Water	3 litres
Resin - carboxylated butadiene styrene latex	1 litre
EPS beads	54 litres
Fibre - 10 mm polypropylene fibre.	50 ml

The following was observed by CSIRO from a 200 mm x 100 mm x 50 mm sample block of grey Conpolcrete® obtained by CSIRO in 2019.

- The block had a measured density of 398.8 kg/m³
- The cement component was light grey in colour

- Small fibres ~5 mm long could be observed (by eye) to be sparsely distributed over the exposed surface.
- The block contained well distributed air pockets, indicating that the material was aerated during manufacture, either via a mixing process or possibly via inclusion of a foaming agent.
- The exposed edges of the block had a large proportion of cut EPS beads. This indicates that during manufacture, the Conpolcrete is moulded into thicker blocks/slabs and then cut into 50 mm thick panels.
- Based on visual (by eye) inspection, the following proportions by volume have been very roughly estimated
    - The QT website statement that Conpolcrete is ~70% by volume EPS appears reasonable
    - With EPS component removed, the remainder of the material appears to be ~ 70% (by volume) cement/sand/resin/fibre mix and ~30% (by volume) air pockets.
    - The fibre makes up a very minor portion of the cement/sand/resin/fibre mix.

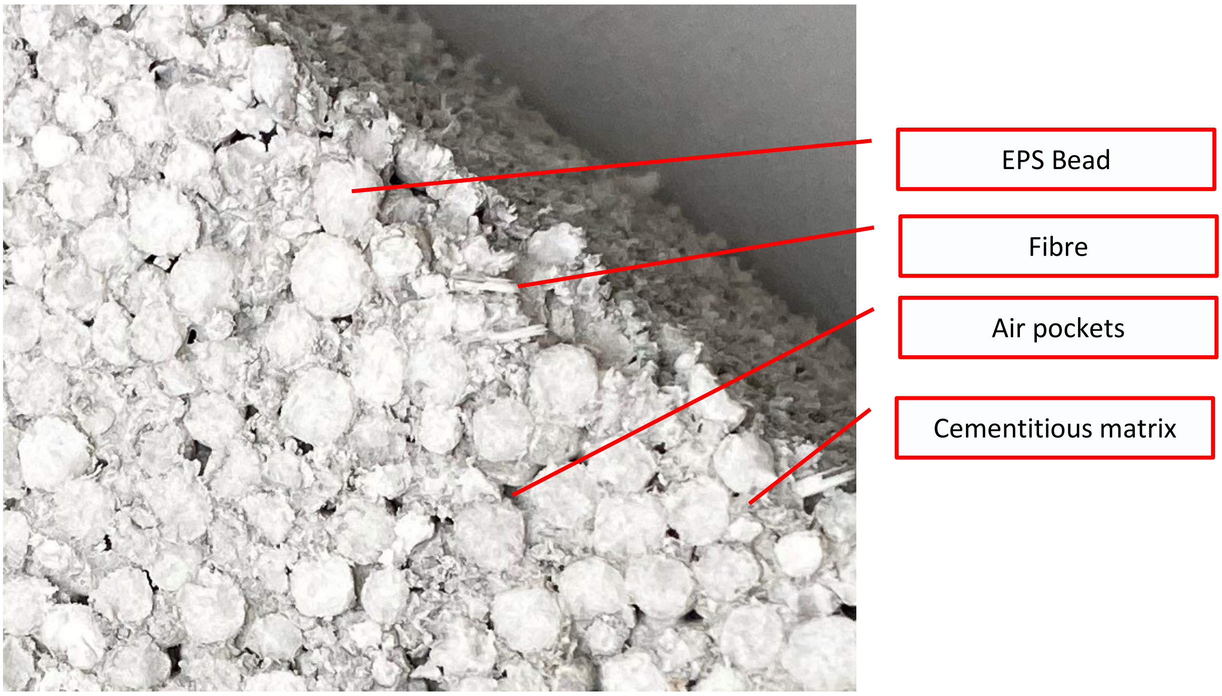

Table 3. Sample block of grey Conpolcrete® obtained by CSIRO in 2019 (close up photo – Bottom)

Based on the above visual observations a very rough estimate of % volume and % mass component ratios for Conpolcrete® can be derived. The following typical densities for materials are considered:

- EPS – dependant on grade, EPS can have density ranging from 11-28 kg/m^3. M grade EPS is commonly used for rendered 100% EPS wall panel systems. M Grade EPS has a density of 19 kg/m^3 and this density is assumed for EPS in the following calculation
- Concrete - density varies dependant on the type and ratio of sand and aggregate used but has a typical density of ~ 2400 kg/m^3
- AAC – density is typically in range of 510-650 kg/m^3
- Mortar (dry) – density varies dependant on the type and ratio of sand and cement but is typically in range of 1700-2020 kg/m^3. For this calculation an average density of 1800 kg/m^3 has been assumed.
- AAC is considered to be less dense (have more air pockets) than the Conpolcrete® cement/sand/resin/fibre/air pocket(EPS omitted) component.
- The Conpolcrete® cement/sand/resin/fibre/air pocket(EPS omitted) component density is estimated to be equal to the density of mortar with additional 30% air pockets (~ 0.7*1800 = 1260 kg/m^3).

Table 4. Rough estimate of % volume and % mass component ratios for Conpolcrete® based on visual inspection

Conpolcrete component	Density (kg/m3)	volume % (estimated)	mass % (calculated)
EPS	19 (estimated)	70%	3.4%
Cement/sand/resin/fibre/air pocket component density	1260 (estimated)	30%	96.6%
Total Conpolcrete density (calculated)	391.3	-	-

The above estimate is very rough and should not be considered accurate or relied upon. However, the resulting calculated total density does match the measured density of the sample Conpolcrete® block relatively well. The above estimate calculation demonstrates the following:

- The volume% of EPS in Conpolcrete is relatively high (~70% by volume)
- However, the mass% of EPS is relatively low(~3% by mass) and this is due to the very low density of EPS (mostly being air).
- If the density of the Cement/sand/resin/fibre/air pocket component is assumed to be 500 kg/m3 (representing a lower limit for typical aerated concrete), rather than 1260 kg/m3 then the above estimate changes to 8.1 mass% EPS and 91.9 mass% Cement/sand/resin/fibre/air pocket component. However, this also reduces the total density of the material to 163 kg/m3 (which does not match the measure density of the product).
- Considering the assumptions involved in the above estimate it is possible that the EPS component is likely to be somewhere in the range of 3-9% by mass.

3.1.2 PREVIOUS PRODUCT VERSIONS

The Conpolcrete® product is known to have changed colour/visual appearance over the years that it has been commercially available, with the following three product colourings having been noted for samples taken from existing buildings which state “QT” as the cladding material on the architectural drawings. In discussions between CSIRO and QT Systems dated 13/01/2021, QT systems stated the following details to CSIRO:

- Conpolcrete with Pink cementitious matrix with white EPS beads - This is the colour of an older, first version of the product. QT wall systems have confirmed that this was produced by a casting process (which produced single cast panels) and incorporated an alkali resistant glass fibre mesh reinforcing cast into the centre of the panel. Some loose glass fibres were also mixed through the product the quantity of loose glass fibres is less than the current Grey cementitious matrix product. The pink colour was due to a pigment additive.

- Conpolcrete with White cementitious matrix with white EPS beads - This is the colour of a second version of the product. The main change from the pink to the white coloured product were:
    - Pigment change
    - Manufacturing process changed from single cast panels to moulded and cut panels
    - As part of the manufacturing process change the glass fibre mesh reinforcing cast into the centre of the panel was removed and replaced with an increased amount of evenly dispersed loose glass fibres.
- Conpolcrete with Grey cementitious matrix with white EPS beads – This is the colour of the currently supplied product. The manufacturing process is the same as for the white Conpolcrete. The only changes were:
    - pigmentation has been removed from the matrix to give a natural Grey concrete colour

In discussions dated 13/01/2021, QT wall systems confirmed the following further details to CSIRO:

- QT stated that the above colour changes to the product do not reflect changes to the matrix formulation, yet simply identifies the different manufacturing process from pink single cast panel to moulded and cut panels which was white, then changed to natural grey. There is a change in the use of reinforcing mesh and loose fibre content.
- The EPS to Cementitious matrix ratio is controlled on a volume basis, rather than a mass basis during production.
- EPS feedstock is a range of recycled EPS (packaging, sandwich panels, waffle pods etc). Only clean EPS material is used. However, there is no specific control on the range of EPS density feedstock used. It is ground to beads and all placed in the same Hopper which typically results in a mix of EPS bead density and grade.
- The manufacturing process has been developed to prevent clumping and achieve a homogenous mix of EPS and Cementitious matrix.

3.2 Materials Characterisation Testing

In 2019, CSIRO conducted ATR-FTIR and Ash material characterisation testing on the grey Conpolcrete® sample block (same sample discussed above). This is named "Reference Conpolcrete®" in results. In 2019, VBA also provided a limited number of grey, pink and white Conpolcrete® core samples taken from existing buildings for FTIR and ASH testing as part of the State-wide Cladding Audit.

FTIR Spectrometry is applied to identify chemical components, both polymer and mineral types, in a sample. It does not quantify the amounts of each component. The basic principle relies on the fact that unique molecular vibrations for different molecules will absorb infrared light energy at different (often unique) parts of the infrared wavelength spectrum. By passing infrared light though a material and measuring the intensity of received infrared light at specific wavelengths over a wide spectral range, an infrared spectrum of absorption is measured, with peaks at specific wavelengths acting like a fingerprint to identify the molecules contained in a material. In the case of Conpolcrete® ATR-FTIR simply confirms the presence of EPS.

Ash content testing (ASTM D5630-13) is applied to conservatively indicate the mass content of mineral fillers in ACP cores. It has also been used to indicate the amount of inert cementitious material in Conpolcrete® and other cladding samples. The basic principle is to burn/decompose the material at high temperature in a furnace and measure the ratio of the residual ash mass to the original sample mass. However as common cementitious materials and mineral fillers used in ACP and Conpolcrete® also partially decompose to produce water or CO_2 when heated this method typically significantly underpredicts the filler mass content.

Small samples of material (typically 2 g) and inert crucibles are pre dried, with samples being dried in an oven at 40-50 °C for a period of at least 2 hours. The dried sample and crucible are weighed prior to ashing. The sample is placed on a crucible and ignited and ashed by placing within a muffle furnace at 800 °C for a pre-defined standard period of 20 minutes (which is increased to 2 -4 hours to ensure complete ashing for Conpolcrete®). The crucible and ash sample are cooled to room temperature in a desiccator and the resulting ash and crucible mass is weighed. The ash mass % is calculated by the following equation.

$$Ash\ mass\% = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

Where:

W_1 = mass of sample crucible (g)

W_2= mass of sample crucible plus mass of sample prior to ashing (g)

W_3= mass of sample crucible plus ashed mass of sample (g)

The results of the above testing were reported in CSIRO report project numbers XC3607C and XC3607D issued to the VBA in 2019 and are summarised below.

Figure 8. Examples of State-wide Cladding Audit Conpolcrete® samples provided by VBA from existing buildings. Grey Conpolcrete® (top), Pink Conpolcrete® (middle), White Conpolcrete® (bottom)

Table 5. Summary results of ash testing on Conpolcrete® samples.

Conpolcrete® colour	CSIRO Sample ID	Ash mass%
Grey	Reference	68.3
	XC3607D-01	67.2
Pink	XC3607C-01	64.8
	XC3607C-02	62.9
	XC3607C-03	65.4
	XC3607C-04	66.0
White	XC3607D-02	63.8

The following can be concluded from the above testing:

- Ash testing significantly under predicts the inert/cementitious mass content of Conpolcrete® and this is likely to be due to partial decomposition of the cementitious component to produce water or CO_2 when heated. This method should not be relied upon alone to accurately measure mass% composition
- Based on ash mass% results alone, it appears that the grey Conpolcrete® may have a marginally lower mass% of EPS compared to the pink and white Conpolcrete. Due to the low density of EPS, marginal changes in mass% EPS content can represent larger changes in volume% EPS content.
- ATR-FTIR is not suitable to detect any possible differences on the composition of the cementitious component of the above samples.

VBA has provided CSIRO with Ignis Advisory Note "QT Systems Combustible Composition", Dated 20 July 2018. This summarises ATR-FTIR, Ash content and XRD testing conducted by CSIRO on Grey Conpolcrete® (CSIRO report OSA-000018 dated 16 July 2018 on behalf of Ignis Labs).

- Ash content test result was 71.0 ash mass%
- XRD testing concluded the sample to have a mineral loading of 91% by mass with the major matrix minerals including Quartz, Portlandite and Calcite. The remainder of the material mass (~9%) was assumed to be EPS

The above XRD result more reasonably matches the mass % content estimated from visual inspection and Manufactures stated EPS content of 70% by volume.

CSIRO has developed a solvent dissolution method, which measures mass of sample, then dissolves the EPS component away with a solvent and carefully dries the remaining cementitious component at low temperatures and measures the remaining mass. This provides a more accurate mass ratio measurement of EPS to Cementous content.

CSIRO currently(at time of issue of this report) provide the following tests on all cement/EPS bead composite cladding materials sent to CSIRO for materials characterisation testing.

- FTIR,
- Ash content test
- solvent dissolution method
- XRD

CSIRO material characterisation reports for EPS Concrete specimens include a cautious allowance for expanded accuracy and uncertainty. This typically expands the stated mass % cementitious content test result for QT Conpolcrete specimens to a range of ~85-97%. This is to account for possible variation in homogeneity in specimens, other possible minor components such as resins & fibres and accuracy of test methods. However, the actual mass % cementitious content of grey core QT Conpolcrete is most likely to be in the average range ~90-97%.

Bulk density may also be used to compare EPS sampled from existing buildings to the range of bulk densities for QT Conpolcrete reported in fire test reports (345-420 kg/m^3). A density below this range may indicate an increased EPS content.

3.3 Application of ICA ACP risk categories

The Insurance Council of Australia, Engineers Australia and Fire Protection Association (Australia) have published a protocol for the identification, categorisation and risk ranking of ACP and other combustible façade materials installed to existing buildings:

https://www.insurancecouncil.com.au/assets/aluminium%20protocol/ACPRHP_ICA_16092020.pdf

Note that this classification was first published in November 2017 and has had several updates. The protocol sets out a process for identifying residual hazard for aluminium composite panel and other combustible façade materials. This protocol also provides risk categories for ACP as summarised in Table 6. This category system was established by comparison of typical ranking results for ACP with different %mass mineral filler in similar category systems used by BRE (based on gross heat of combustion) and EN 13501 (based on a range of small-scale fire tests).

Table 6. ICA ACP Risk Categories

Category	Polymer Percentage	Polymer %	Inert Filler %
A	30-100% Polymer and 0-70% inert materials	30-100%	0-70%
B	8-29% Polymer and 71-92% inert materials	8-29%	71-92%
C	1-7% Polymer and 93-99% inert materials	1-7%	93-99%
D	0% Polymer and 100% inert materials or deemed non-combustible by the National Construction Code	0%	100%

Note – all percentages represent % by mass

The ICA ACP risk categories should not be directly applied to EPS Concrete products for the following reasons:

1. The ICA ACP risk categories were developed specifically for ACP and have not considered significantly different types of combustible cladding materials.
2. The materials of composition and fire behaviour of EPS Concrete products differ significantly to ACP.

This report has reviewed all available Conpolcrete fire test evidence to make recommendation that QT wall systems (complete wall system including Conpolcrete and render installed to manufacturers specifications) might reasonably be ranked at least equivalent to ACP-30% PE in the statewide cladding risk assessment tool. This recommendation should not be confused as "application of the ICA ACP risk categories to Conpolcrete".

4 QT Eco Series wall system construction

4.1 Wall system construction specified in QT wall system manual

The QT Eco Series wall system is an external wall system comprising of a number of material components as summarised in the table below. The QT wall system is similar to a rendered EPS EIFS construction except that the 100% EPS board is replaced with Conpolcrete®. The walls are light weight framed wall construction which may either be loadbearing or non-loadbearing.

Table 7. Summary of QT wall system components

Component	Description
Coating system	Suppliers' manual states "proprietary coating systems" but does not state specific product/composition. • 1st coat – Base coat polymer modified cement render embedded with full mesh (fibreglass mesh). 3-5 mm thick • 2nd coat – levelling render. 2-3 mm thick. • 3rd coat – texture coat • 4th coat – 100% Acrylic Paint Suppliers' manual does not specify total coating system thickness. Based on the above it is considered that total thickness would be minimum 5 mm and maximum ~ 8-10 mm dependant on thickness of 3rd and 4th coat (not specified).
Fibreglass mesh	A full fibreglass mesh is embedded in render base coat. However, strip fibre glass mesh is also used to reinforce render at corners, joints and corners of door and window openings.
Conpolcrete®	Cement/EPS bead composite as per Section 3 of this report. Standard panel dimensions are 900 mm wide x 2250 mm long x 50 mm thick (non). Mass per panel = 40 kg (nom). Note: it appears a 40 mm thick panel may previously have been available but is no longer available.
Battens	Conpolcrete is fixed to vertical battens to create a ventilated drainage cavity. Battens may be either: • Timber (~45mm wide x 20 mm deep), or • Steel 40 mm top hat battens, or • Steel clip and channel system (~ 45 mm wide x 16 mm or 28 mm deep)
Screw fixings with plastic washers	100 mm x 3.75 mm galvanised nails or 10 g 100 mm screws with plastic washers (QT buttons) are used to mechanically fix Conpolcrete to battens prior to coating system. Nominal fixing centres are 225mm centres and no less than 50 mm from edges (at 600 mm max stud spacings).
Polyurethane foam adhesive	Polyurethane foam adhesive is specified for all Conpolcrete panel butt joints and is also recommended to be applied to face of battens prior to placing and fixing panels.
Sarking	Vapour permeable Sarking must be installed to external face of framing between framing and battens. Suppliers' manual does not state specific sarking requirements. Assumed BCA DtS compliant sarking must be used.
Framing	Timber framing in accordance with AS 1684 or Steel framing in accordance with AS 3623. Maximum stud spacings of 600 mm centres.

Internal wall lining	Suppliers' manual specifies 10 mm (standard grade plasterboard). AS 1530.4 tests on QT systems have included 10 mm standard grade plasterboard on the internal face and have assessed FRL from external side only. Application of fire-resistant plasterboard as the internal wall lining does not appear to be a standard/tested part of the QT wall system. However, CSIRO has seen examples of existing buildings, as part of the state-wide cladding audit, where fire resistant plasterboard has been applied to internal face of the wall system to provide an FRL from both sides (in some cases an FER for the specific building has provided assessment for this based on published fire-resistant plasterboard systems). Note – 2 x 13 mm FR plasterboard was included in an AS 5113/BS8414 test on QT wall system by Ignis labs. However, in this case the FR plasterboard lined the internal wall cavity (between the steel battens and the external side of light weight wall frame) rather than the internal wall lining. This detail is not specified in the QT manual and does not appear to be used in practice on existing buildings installed with QT wall systems (inspected).
Relief joints	Required extending from edges of window or door openings if panel above or below opening is: • Less than 300 mm in depth, or • More than 2400 mm in length 45° Mesh to be installed at corners of all other openings to prevent 45° hairline cracks forming.
Control joints	• Vertical control joints required at no greater than 5 m centres for walls more than 8 m in length. Vertical control joints are 10 mm gap between panels filled with backing rod and sealant. • 15 mm Horizontal control joints required at each floor level where timber floor joists are used. • 10 mm control joints required where QT wall system meets other wall systems such as weatherboards or brickwork etc
Starter trim and base of wall details	Starter trim (PVC or Aluminium) which is perforated for cavity drainage is place at the bottom of the wall system installation. Base of QT wall panel system must be either 100 mm above paved level or 150 mm above ground level with minimum 15 mm clearance to rebated slab edge below to enable drainage of cavity.
Corner beads and mesh	Internal corners must have full fibreglass mesh or corner fibre glass mesh embedded in render base coat. External corners may either have corner fibreglass mesh or corner bead (aluminium angle) embedded into render base coat
Flashing	Suitable cap flashing must be installed at top of wall system parapets etc. Suitable PVC reveals or flashings must be installed around window and door openings. Suitable damp courses and flashing must be installed at wall to roof transitions or at base of wall to rebated slab.

It is noted that the QT Eco Series wall system comprises a number of components, other than the EPS Concrete panels, which are typically combustible including:

- Timber stud framing and battens (Note this may be permitted as DtS concession),
- PU adhesive,
- Caulking/sealants and backing rods (Note this may be permitted as DtS concession in accordance with BCA 2019 amdt 1 Clause C1.9(d) or C1.14.),
- PVC starter channels and flashings (Note flashings are permitted as DTS ancillary items by BCA 2019 amdt 1 C1.14, however starter channels are not directly addressed as an ancillary item),

- Sarking (This may be permitted as DtS concession in accordance with BCA 2019 amdt 1 Clause C1.9(e)) and
- Dampcourses (this may be permitted as DtS concession in accordance with BCA 2019 amdt 1 Clause C1.9(d)).

However, ss the EPS concrete cladding panels are combustible, the fire performance of the entire system including the above other components must be considered/assessed either when providing a performance based solution or (in the case of this report) considering the likely level of risk presented by the system.

4.2 Render/coating systems used in EIFS

QT Suppliers manual states "proprietary coating systems" but does not state specific product/composition. It is noted that various different proprietary render products have been used in the various QT wall system fire test reports reviewed. This possibly indicates that in reality, the building industry may apply a range of render products/systems to QT wall panel cladding dependent upon builder preference/experience with different render products applied to EIFS (both QT panels and 100% EPS).

Render systems applied to EIFS typically consists of a mesh reinforced base coat, a system levelling/texture finishing coat and sometimes paint over exterior finish.

4.2.1 TRADITIONAL 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 100% EPS is prone to result in poor adhesion and encapsulation of rigid foam polymer insulation. It is also prone to spalling and cracking during fire exposure.

It is noted that the QT wall system manual specifies base coat polymer modified cement render embedded with full mesh.

4.2.2 POLYMER/ACRYLIC MODIFIED CEMENT 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[23] 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[24] 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.

4.2.3 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 external surface of render, concrete, fibre cement and masonry construction walls and are not intended for application directly to rigid foamed polymer insulation.

It is possible that render paints could possibly be substituted for specified complete multi-coat render systems in cases of extremely poor installation. As the resulting coat is very thin, it provides no thermal protection or encapsulation of polymer insulation in the event of a fire.

4.3 End use application to buildings

Through the State-wide cladding Audit, CSIRO has had opportunity to either review (via VBA Advisory Reference Panels) or inspect a subset of buildings in Melbourne metropolitan area having EPS Concrete cladding panels. Based on inspection and materials specified in architectural details, all of these building inspected by CSIRO appear to have been QT wall systems. CSIRO has not identified any of the other products listed in Section 2.3 of this report during these inspections. The following is indicated from this:

- QT wall systems appear to have predominantly been used on low rise type A residential construction having a rise in stories of 3-4 stories. Note Class 1 buildings are excluded from state-wide cladding audit, so it is unclear the extent to which QT has been installed to class 1.
- QT wall systems in class 2 buildings appear to have been predominantly applied to light weight timber frames rather than steel frames.
- Where QT wall systems have been installed to Type A class 2 buildings this has typically not been documented (at the time of design/construction) as a performance solution against performance requirements CP2 and CP4. In some cases, it has been documented as a performance solution with regard to achieving FRL's and meeting CP1. However, in such cases the performance solution typically remains silent on CP2 and CP4 with regard to use of a combustible external wall system where non-combustible materials are required by DtS.
- Render systems installed to QT wall systems have typically been ~ 5 mm total thickness.
- All three colours of Conpolcrete core (Grey, Pink and white) have been observed to be installed on different buildings. In each case, it appears to be a single formulation/colour of Conpolcrete used on each separate building.

- In a small number of cases, QT wall systems have been installed with FR grade plasterboard replacing the standard grade plasterboard as an internal wall lining so as to achieve an FRL from both internal and external sides. This has been indicated both via architectural wall type drawings and wall system/cavity inspections for some existing QT clad buildings inspected by CSIRO . In some cases, this has been documented as a performance solution in the original FER (with regard to FRLs only and not addressing combustibility).
- In a small number of buildings, QT wall systems have been strategically installed at a limited number of locations where an external wall are required to achieve an FRL (for example within < 3 m to allotment boundary). However other areas of the building not required to have an FRL have been installed with rendered 100% EPS.
- In a small number of buildings, QT wall systems were specified on original architectural drawings and in FER with no rendered 100% EPS specified. However, inspection revealed that some areas of cladding had been substituted with 100% rendered EPS.
- In most cases it is not easy to visually ascertain if Conpolcrete or 100% EPS has been installed without at least drilling inspection pilot holes through the render surface. In some cases, core type can be visually inspected at bottom edges of walls if left un-unrendered.

4.4 Recommendations for site inspection of suspected QT wall systems on existing buildings.

Based on the above, when assessing the fire hazard of existing buildings suspected to be installed with QT wall systems, it is important to perform a detailed site inspection of the building to confirm that no areas have been installed with 100% Rendered EPS. Recommendations when performing site inspection and sampling are:

1. Review Architectural wall type detail drawings prior to inspection to ascertain what cladding was specified and where it was specified to be installed so that it can be checked that as installed cladding matches the original drawings.
2. Take 40 mm diameter core samples of Conpolcrete at least 40 mm thick and perform FTIR, Ash content and XRD laboratory tests to confirm ~ Cementitious % mass content. Hole saw samples should be taken from at least 2 different locations on the building. Hole saw samples also enable easier observation of the following which should be recorded:
    a. Render thickness
    b. Conpolcrete thickness and colour
    c. Sarking
    d. Timber or steel frame
    e. Presence and type of any additional insulation within wall cavity
    f. Note – it is typically difficult to confirm if internal plasterboard lining is standard grade or fire resistant without either cutting through the internal lining or inspecting via a pre-existing internal lining penetration – this is often difficult to achieve.
3. Pilot holes (6-12 mm drill bit) and visual inspection should be used at sufficient other locations on the building so as to provide a reasonable level of confidence that no 100% EPS has been used. Visually 100% EPS will typically swarf out of the hole as fluffy/loose EPS beads, where Conpolcrete will swarf out of hole as a ground mixture of cement and EPS. Typical inspection locations to consider should include
    a. Cladding on balconies or at ground level (representing higher risk of exposure to ignition sources),
    b. Cladding directly above or along exit paths (representing a possible risk to safe evacuation),
    c. Cladding on non-load bearing walls located > 3 m from boundary that are unlikely to be required to have an FRL,

   d. Cladding at locations that may be prone to damage and repair/replacement leading to substitution of materials (e.g. above low hanging driveway entrances, corners on narrow laneway entrances and
   e. Pilot hole inspections should be distributed on more than 1 level and more than one elevation to be reasonably representative.
4. As QT wall systems may be part of a required FRL wall system achieving an integrity of either 90 or 120 min, any penetrations made during sampling/inspection should be rectified so as to achieve the required FRL. Whilst the following may not have been specifically tested for FRL when combined with QT, they may form suitable options for FRL rectification of small sample or inspection holes:
   a. Holes of 40-50 mm diameter should be filled with either of the following and the external face covered with either a suitable render of a suitable flashing silicone in place to prevent moisture ingress:
      i. An expanding foam product having and FRL for penetration seals of at least -/120/120
      ii. A fire-resistant mortar product having and FRL for penetration seals of at least -/120/120.
   b. Holes of 6-12 mm diameter should be filled with a fire rated sealant having an FRL for penetration seals of at least -/120/120.

5 QT Eco Series fire test review

Please see descriptions of key referenced fire test methods provided in Appendix A for any readers unfamiliar with these test methods.

5.1 AS 1530.1 Combustibility

When tested to AS 1530.1, Conpolcrete® used in QT Eco Series wall systems is understood to be combustible due to the EPS content. CSIRO does not have knowledge of any AS 1530.1 test results which indicate that this product is not combustible.

Cladding Safety Victoria and VBA have provided the following for review:

- CSIRO Assessment Report FCO-2545, "Combustibility of Conpolcrete", dated 19 August 2011.

In summary:

- FCO-2545 expired on 31 August 2016 and has not been renewed.
- FCO-2545 originally reviewed the results of a range of fire test performed by CSIRO including AS 1530.1 combustibility, AS 3837 cone calorimeter, AS 1530.3 and AS 1530.4 fire resistance.
- FCO-2545 identified that the material failed to meet the AS 1530.1 test criteria for a material to be designated not combustible. The AS 1530.1 test report specimen was described as Conpolcrete, Nominal density 350 kg/m^3 and colour = Pink/orange with white beads.
- However, FCO-2545 provided an opinion that "*this material may be considered to be non-combustible in terms of the Building Code of Australia in order to satisfy the intent of this regulation*". This opinion was originally based on a consideration of comparable reaction to fire behaviour to other materials which are permitted by BCA DtS to be used wherever a non-combustible material is required.

The expiry and non-renewal of FCO-2545 means that the above opinion is no longer supported by CSIRO. FCO-2545 (expired) must not be applied as evidence of compliance to any current NCC DTS clauses or Performance Requirements.

No AS 1530.1 test report for the current Grey Conpolcrete product has been made available for this review.

5.2 Gross Heat of combustion

5.2.1 KNOWN TEST RESULTS

CSIRO has not been provided any gross heat of combustion (bomb calorimeter) test results for Conpolcrete. Given the small Bomb Calorimeter test sample size (1 g) and the mix of EPS beads in cementitious materials, obtaining a representative Conpolcrete test specimen sample which represents the bulk product properties may present a challenge.

Gross heat of combustion for Conpolcrete has been roughly estimated based on the following:

- Gross heat of combustion for EPS is typically 41.2-42.5[25], and for EPS-FR is typically 39.7[25]. Based on this, a gross heat of combustion of 40 MJ/kg has been assumed for the EPS used in Conpolcrete.
- The Cement/sand/resin/fibre components of the Conpolcrete have been assumed to be inert and not contribute to Gross Heat of combustion. It is noted that the resin and fibre may have some heat of combustion but the contribution of this has been assumed to be marginal compared to that of the EPS due to small quantities.
- The total gross heat of combustion for Conpolcrete is estimated simply as the products of the EPS mass% content and the EPS gross heat of combustion. Depending on the EPS mass % assumed this results in an estimated gross heat of combustion in the range 1.2-3.6 MJ/kg, corresponding to EPS mass% content in the range 3-9%. A mass% content of 4% EPS corresponds to a gross heat of combustion of 1.6 MJ/kg.

5.2.2 COMPARISON AGAINST OTHER CLADDING MATERIALS

The following table estimates and compares the gross heat of combustion per unit mass, gross heat of combustion per unit volume and gross heat of combustion per unit area of cladding.

Table 8. Comparison of gross heat of combustion for various cladding types

	Conpolcrete (4 % mass EPS)	**100% EPS (M Grade) [25]**	**ACP-PE**	**ACP-FR**	**ACP-A2**	**Timber (pine) [25]**
Gross Heat of combustion per unit mass (MJ/kg)	1.6	40	46.4	13.6	2.3	20
Density of product (kg/m^3)	380	19	920	1,960	2260	500
Gross heat of combustion per unit volume (MJ/m^3)	608	760	42,688	26,656	5,198	10,000
Typical thickness used in cladding (mm)	50	50	3	3	3	19
Gross heat of combustion per unit area of cladding (MJ/m^2)	30	38	128	80	16	190

The following is noted from the above comparison:

- The Gross heat of combustion per unit mass is significantly less for Conpolcrete compared to EPS due to the mass content of the cement matrix.
- However, as EPS forms the majority of the volume in Conpolcrete, the gross heat of combustion per unit volume and unit area is similar for Conpolcrete and EPS.
- Fire hazard should not be assessed based only on heat of combustion (on a mass, volume or unit area basis). Other factors such as ease of ignition, melting and surface char formation influence the amount of material that may become involved, the hazard of fire spread and the resulting heat release rate for a given fire scenario. For example:
  - the high heat of combustion per unit mass of PE and 100% EPS combined with it melting behaviour and no intrinsic fire-retardant mechanisms such as charring result in a high hazard of fire spread for these materials.
  - Although timber has a relatively high heat of combustion per unit area, the char formation behaviour of timber can produce a protective layer which reduces or slows the rate of burning of the material and reduces fire spread risk.
  - Similarly, for Conpolcrete, the EPS at the outer exposed layer can burn/melt away but the cement matrix tends to remain to form a protective char layer which limits or slows that rate of burning of the EPS deeper within the material.

The following is the basis of heat of combustion and density for ACP cores used in table above. The following table presents the range of Gross heat of combustion for

- BRE screening categories,
- ACP tested in BRE DCLG post Grenfell fire BS 8414 tests and
- ALPOLIC's range of ACP's as stated in ALPOLIC product literature and ICA "BRE_NOTES_ANEXURE"

Table 9. Range of gross heat of combustion for different types of ACP core

BRE Screening Category Ranges	ACP tested in BRE DCLG post Grenfell fire BS 8414 tests	ALPOLIC range of ACP
Category 1 ≤ 3 MJ/kg	Category 1 = 2.3 MJ/kg	ALPOLIC A2 < 3 MJ/kg
Category 2 > 3 MJ/kg and ≤ 35 MJ/kg	Category 2 = 13.6 MJ/kg	ALPOLIC-FR < 13 MJ/kg
Category 3 > 35 MJ/kg	Category 3 = 46.4 MJ/kg	ALPOLIC PE > 45 MJ/kg.

LDPE has a density of 917 to 930 kg/m^3. HDPE has a density of 930 to 970 kg/m^3.

Aluminium Hydroxide and Magnesium Hydroxide both have densities of ~ 2400 kg/m^3. The density of ACP cores increases with mineral filler content. The theoretical density of ACP with various mineral filler contents is graphed by CSIRO below.

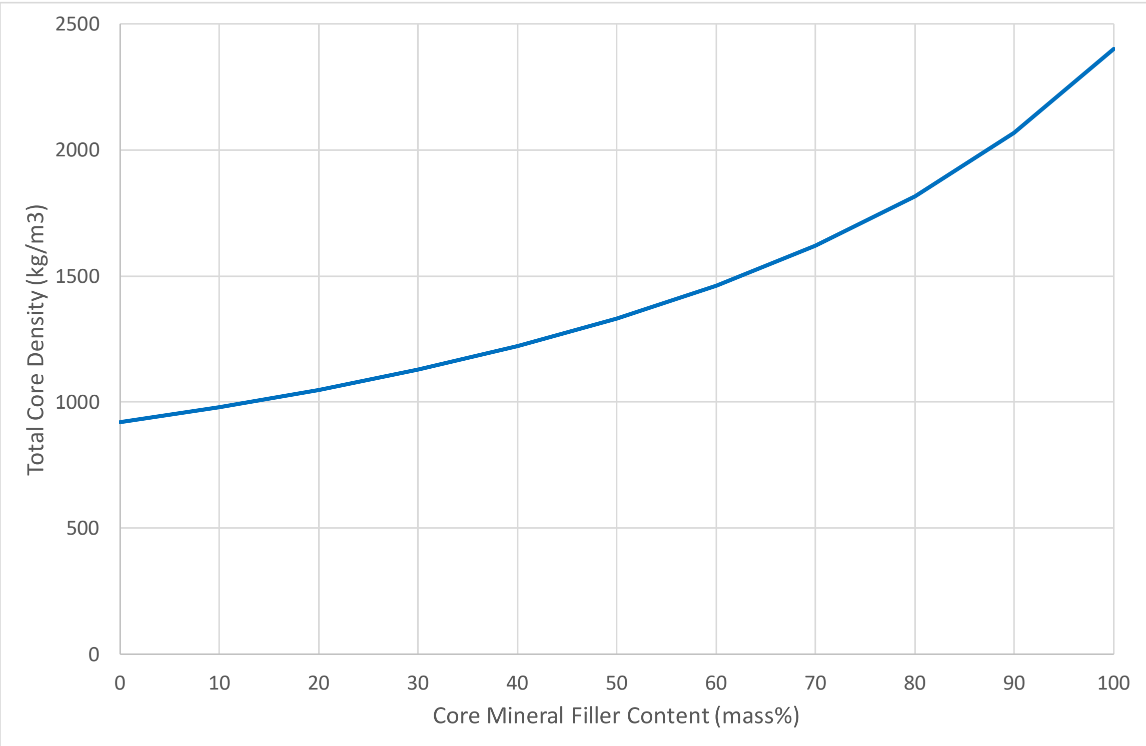

Figure 9. Increase in density of ACP core with increasing mineral content assuming ρ_{PE} = 920 kg/m^3 and ρ_{filler} = 2400 kg/m^3.

5.3 AS 1530.3

5.3.1 KNOWN TEST RESULTS

The QT Systems website provides the following AS 1530.3 test certificate for Conpolcrete:

- CSIRO Report No: FNE7959, Dated 7 August 2001
- Specimen description: Conpolcrete, Nominal thickness 55 mm and 38 mm, nominal density = 420 kg/m^3, Colour = white
- Results:
    - 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

The specimens in the above test did not ignite – the specimens appeared to have been the bare Conpolcrete with no render on exposed surface.

No AS 1530.3 test results have been provided for the current Grey Conpolcrete product for this review.

Whilst this test does demonstrate some level of resistance of Conpolcrete to ignition and fire spread for radiant heat exposure up to ~ 25 kW/m^2 radiant heat flux (with only a pilot flame applied), it is not considered a suitable test method for predicting façade fire spread behaviour for the following reasons:

- The test exposure maximum heat flux is significantly less than typical façade fire scenarios,
- The test does not include significant flame immersion and
- The progressively increasing heat flux exposure can result in exposed EPS (in this case on the outer surface) melting away without ignition, prior to significantly high heat flux exposures occurring in the test.

5.3.2 COMPARISON AGAINST OTHER CLADDING MATERIALS

The following comparison is based on CSIRO generalised testing experience with a range of products over several years. The following results are indicative only and a subject to variability depending on details of each product.

Table 10. AS 1530.3 comparison of typical results

Conpolcrete (no render to exposed surface)	**EPS (no render to exposed surface) Lower limit**	**EPS (no render to exposed surface) Upper limit**	**EPS (render to exposed surface)**	**EPS with metal facing**	**ACP-PE**
Ignitability index (0-20)	0	12	0	0	0
Spread of Flame Index (0-10)	0	0	0	0	0
Heat Evolved Index (0-10)	0	3	0	0	0
Smoke Developed Index (0-10)	1-4	5	1-4	0-4	1-2

Did not ignite EPS close to exposed surface may have melted away rather than ignited	Some raw exposed EPS melts away rather than igniting at early (lower heat flux) stage of test	Some raw exposed EPS ignites before all of specimen has melted away – results can be highly variable	Render protects EPS from radiant heat and ignition	Metal facing reflects radiant heat and prevents ignition	Aluminium facing reflects radiant heat and prevents ignition

5.4 AS 3837 Cone Calorimeter

5.4.1 KNOWN TEST RESULTS

The QT Systems website provides the following Certificate of assessment for group number assessment based on AS 3837 cone calorimeter testing for Conpolcrete:

- CSIRO Certificate of assessment No: 435, Dated 11 August 2004
- Specimen description: Conpolcrete, Nominal thickness 51 mm, nominal density = 420 kg/m^3, Colour = light orange/pink
- Result:
    - Group number = Group 1
    - Average specific extinction area = 11.7m^2/kg

It is noted that this test certificate appears to be for the Pink Conpolcrete, not the Grey Conpolcrete.

It is noted that since this test certificate was issued, AS 5637.1:2015 “Determination of fire hazard properties Wall and ceiling linings” has been published. This standard states conditions where use of cone calorimeter tests is suitable for predicting group number and for conditions for where it is not appropriate, an ISO 9705 test is required. This standard states that prediction of group number based on cone calorimeter tests is unsuitable for materials “*that contain materials that melt or shrink away from a flame*”.

CSIRO conducted a single AS 3837 cone calorimeter test with 50 kW/m^2 heat flux exposure as an indicative test to investigate fire behaviour of a Grey Conpolcrete sample obtained in 2019. Note that this test was not repeated on multiple replicates, as required by the standard, due to limited samples, and therefore results are indicative only.

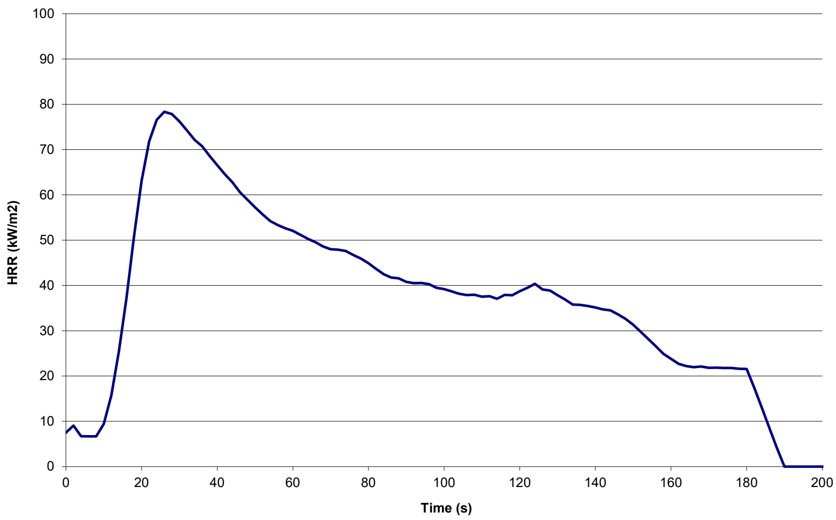

Figure 10. HRRPUA vs time for 50 mm Conpolcrete tested to AS 3837 cone calorimeter at 50 kW/m^2

Figure 11. Conpolcrete prior to cone calorimeter test (left) and after cone calorimeter test (right) – All photos by CSIRO

The exposed surface of the Conpolcrete 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.

5.4.2 COMPARISON AGAINST OTHER CLADDING MATERIALS

The following compares CSIRO Cone calorimeter test result on Grey Conpolcrete with other cladding materials from UQ cladding materials library.

Table 11. Comparison of AS 3837 cone calorimeter test results (all tests except Conpolcrete from UQ[4])

Material	Time to Ignition (s)	Peak HRRPUA (kW/m^2)	Total energy released (MJ/m^2)
Grey Conpolcrete (no render) 50 mm thick	12	78	7.6
EPS - no render or metal facing (UQ INS04) assumed 50 mm thick	32	291	28.2
ACP. 7% polymer core aluminium skin removed(UQ ACP01) 2.8 mm thick	135	99	10.8
ACP 28% polymer core aluminium skin removed (UQ ACP02) 2.9 mm thick	75	145	56.9
ACP 99 % Polymer core aluminium skin removed (UQ ACP03) 2.9 mm thick	31	725	93.3

Based on the above, it is concluded that when exposed to 50 kW/m^2 radiant heat flux in cone calorimeter test:

- The time to ignition for Conpolcrete is less than for EPS. This is because 100% EPS melts and shrinks away from the heat source in this test prior to ignition. This also reduces the actual radiant heat flux received at the surface of the Molten EPS while it burns in this test.
- However once ignited the peak HRR and total energy released (and therefore total amount of EPS burnt) is significantly reduced for Conpolcrete compared to 100% EPS.

- The Peak HRR and Total energy released for Conpolcrete is less than for a typical ACP with only 7% polymer. However, the Conpolcrete is more easily ignited.
- The early ignition time of the Conpolcrete suggests that under some conditions of large background radiant heat the material may support ignition and some degree of surface flame spread. This would be reduced once the exposed surface EPS burnt away and protective cement char layer formed. The presence of a suitably thick render layer would also inhibit ignition and fire spread on the surface.

5.5 AS 1530.4 Fire resistance

5.5.1 KNOWN TEST RESULTS

The QT wall systems website provides the following AS 1530.4 fire resistance test reports and assessments.

CSIRO Test report FSV 1082, Dated 20 September 2004

Table 12 Summary of CSIRO FSV 1082 AS 1530.4 tested system

External coating	5-8 mm thick polymer modified render “supaCoat PM660” with 160 g/m^2 alkali resistant fibreglass mesh embedded in render
Conpolcrete	50 mm thick “QT Insulation wall panels”, Nailed to timber battens. Note – Colour and density of Conpolcrete is not stated in report or shown in photos
Battens	25 mm x 45 mm H3 treated timber battens nailed to timber studs
Sarking	Insulco 599 breathable sarking
Stud frame	Timber stud frame, 90 x 35 mm MGP12 timber studs, nominally 500 mm centres
Internal face lining	10 mm standard grade plasterboard
Wall loading	No Loading – tested as non-loadbearing wall system

Test results:

- Structural adequacy = Not applicable
- Integrity = Failure at 113 minutes
- Insulation = Failure at 115 minutes
- FRL = -/90/90 (from external side only)

CSIRO Assessment FCO-2425, Originally dated 9 December 2011, Review dated 24 May 2017

The original assessment concluded that the wall system fire resistance test reported in FSV 1082 would be capable of achieving an FRL of 90/90/90 for load bearing walls, for load calculated from relevant design standard. This was concluded due to timber studs not exceeding a measured surface temperature of 100 °C during the 90-minute period of the test.

The assessment was reviewed by CSIRO in 2017 and was concluded to remain valid. This review remains valid without further review until 31 May 2022.

Warringtonfire WFRA test report No. 2172500, Dated 1 May 2007

Table 13 Summary of WFRA test report No. 2172500 AS 1530.4 tested system

External coating	6-8 mm thick cementitious masonry render "Dulux 193-85835 Renderwall 2001", with "Dulux 194-51610 Acratex Acrabond" used as additive in render mix. "QT wallMesh" fibreglass mesh (0.1 kg/m^2) embedded in 1st render layer.
Conpolcrete	QT Eco Series exterior wall panel Conpolcrete®. Nominal density = 345 kg/m^3 (measured). 50 mm thick. Fixed to battens with 100 mm 3.2 g screws and 29 mm QT buttons at 300 mm vertical centres and 460 mm horizontal centres. Note – Colour of Conpolcrete is not stated in report or shown in photos.
Battens	25 mm deep x 35 mm wide pine timber battens nailed to timber studs
Sarking	Sisalation 499 – light duty breather foil
Stud frame	Pine Timber stud frame, 70 x 35 mm MGP12 timber studs, nominally 460 mm centres
Internal face lining	10 mm standard grade plasterboard
Wall loading	No Loading – tested as non-loadbearing wall system

Test results:

- Structural adequacy = Not applicable
- Integrity = No Failure at 137 minutes
- Insulation = Failure at 118 minutes
- FRL = -/120/90 (from external side only)

It is not clear if the colour/formulation of Conpolcrete tested in the above two Fire resistance tests was different. It is not clear if a fire resistance test has been done on the current Grey coloured Conpolcrete.

It is important to understand that fire resistance testing determines the ability of a wall system to act as a barrier to fire spread through the wall system. It does not provide any indication of a system's ability to prevent external vertical façade fire spread (except perhaps via penetration of cladding and spread via wall cavities, however window reveals and other penetrations are more typically the weak point for fire spread into cavities).

5.5.2 COMPARISON AGAINST OTHER CLADDING SYSTEMS

The following compare typical thicknesses and mass per unit area of comparable fire rated external cladding systems.

Table 14. Comparison of wall systems with similar FRL (from external side only)

System	QT Eco Series wall system	Hebel Power Panel external wall system[11]	CSR 5170 wall system[26, 27] FC Sheet (Cementil FC sheet 9 mm, 20 mm cavity battens, 2 x 13 mm WR FR plaster)	Clay Masonry brick veneer wall[28]
FRL	90/90/90	180/180/180	90/90/90	90/90/90
Cladding panel thickness	50 mm plus battens	75 mm plus battens	55 mm	110 mm
Cladding mass per unit area	19.75	40.3 kg/m^2	39.4 kg/m^2	170 kg/m2

5.6 Intermediate scale façade fire spread tests

No Intermediate scale façade fire spread tests have been identified to have previously been carried out on QT wall systems.

Intermediate scale façade spread tests can be of benefit to investigate system performance when exposed to the following types of fire scenarios:

- Medium sized (100-300 kW) localised balcony fires – whilst it is likely that good/thick render systems would prevent significant involvement of Conpolcrete, such experiments could be used investigate and understand the propensity for fire spread of bare Conpolcrete or Conpolcrete with a poor/damaged or thin render.
- Small cavity fires (within cavity with bare Conpolcrete exposed, possibly combined with other sarking or insulation).

The following intermediate scale test methods could provide a basis for better understanding the fire performance of Conpolcrete and comparing it to other cladding materials.

AS ISO 9705 room corner test

AS ISO 9705 tests are not directly relevant for product end use as an external cladding and further AS ISO 9705 tests would only be recommended if the system was to be used as an internal wall or ceiling lining.

The following summary is only provided as the QT website provides a group number assessment applicable to internal wall and ceiling linings.

This AS ISO 9705 test is intended to test propensity for fire spread leading to flashover on internal wall and ceiling linings. It applies a fire source of 100-300 kW which may reasonably represent a balcony fire, however the hot layer retention and resulting radiant heat feedback that can develop in this test would be more severe than a typical balcony fire.

It is noted that the QT website provides a group number assessment from 2004 based on AS3837 cone calorimeter testing of non-rendered pink Conpolcrete which states a group number 1 result. As stated in subsequently issued standard AS 5637.1, prediction of group number based on cone calorimeter tests is unsuitable for materials "*that contain materials that melt or shrink away from a flame*". Prediction of group number based on cone calorimeter tests is unsuitable for 100% EPS as the material shrinks and melts away from the radiant heat source in the test. Suitability of the correlation used for prediction of group number for Conpolcrete materials based on cone calorimeter tests is unknown and should, ideally, be verified by actual ISO 9705 room corner testing. The fire behaviour of the EPS bead aggregate at or near the exposed surface could possibly vary for 100-300 kW burner flame immersion compared to the 50 kW/m^2 radiant heat exposure (without flame immersion) in cone calorimeter testing.

Ideally conducting 2 sets of ISO9705 tests , one with bare Conpolcrete and one with a representative render coating system, would enable increased understanding of the behaviour of this material in fire scenarios similar to the ISO 9705 test.

ISO 13785 Part 1 tests on ACP

Guillaume et al have published a detailed series of intermediate scale façade fire tests on a range of ACP and cavity insulation material types, applying the ISO 13785-1[29]. This applied a 100 kW gas burner to the base of different test specimens of ACP-A2, ACP-FR and ACP-PE combined with different types of cavity insulation. All tests included a cavity fire barrier.

Key conclusions from this are:

- The ACP PE was by far the most significant contributor to fire growth and was the only material to support flame spread to the top of the specimen, reaching a peak HRR of ~ 5MW, more than 16 times higher than for all other tests. Significant fire growth occurred early at 4 minutes and by 8 minutes the majority of the ACP had burnt away.
- The test did discriminate between ACP FR and ACP A2 based on HRR (300 KW Peak HRR for ACP-FR with MW compared to 200 kW Peak HRR for ACP A2 with MW) however the difference between these two ACP materials was marginal compared to the ACP PE. Based on photo's only, it is difficult to discern a difference in terms of extend of flame spread for the ACP FR and ACP A2 tests.
- For ACP-FR and ACP-A2 the tests showed some limited contribution from PIR and K15 insulation with PIR contributing more to peak HRR and THR than K15 (PIR contributed an additional 100 kW Peak HRR compared to MW)
- For ACP-FR and ACP A2 tests the cavity barrier was effective and prevented involvement of insulation in cavity (and flame spread on cladding) above cavity barrier location.
- For ACP PE tests the cavity barrier was not effective as fire spread to cladding and cavity insulation above.
- For all tests the PIR and K15 was only burnt/charred to a depth of ~ 10 mm in areas of fire spread. Therefore, the majority of the combustible insulation material was not consumed.

FM 4411 wall cavity fire spread test

FM 4411[30] specifies an intermediate test for fire spread within a wall cavity system. The test apparatus consists of two parallel panels, each 1.2 m wide x 2.4 m simulating a cavity within/behind and external wall cladding. Insulation material is installed within the cavity and a small gas burner flame 5.8-9.5 kW is applied at the base of the cavity to test propensity for fire spread within the cavity.

Such a test may be useful to investigate propensity for fire spread on exposed Conpolcrete within wall cavities. However, this is not a standard BCA reference fire test.

5.7 AS 1530.8.1 and AS 1530.8.2 building in bushfire prone area testing or assessment.

No explicit testing to AS 1530.8.1 or AS 1530.8.2, or assessment of suitability for use in bushfire prone areas for QT wall systems was found on the QT website or provided to CSIRO for review.

Conpolcrete is not a type of material generally permitted via AS 3959 DTS requirements for construction in bushfire prone areas for elevated bushfire attack level (BAL) ratings.

Whilst AS 1530.4 tests and AS 5113 BB tests suggest QT wall systems may possibly pass AS 1530.8.1 BAL40 and AS 1530.8.2 (Flame Zone) if tested, no specific assessment of this appears to be documented.

5.8 AS 5113 BB Building-to-building fire spread test

The QT wall systems website provides the following AS 5113 BB Building-to-building fire spread test report:

Exova Warringtonfire EWFA Report No: 44388000.1, "Fire resistance test of an external wall when exposed to 80 kW/m^2 of radiant heat in accordance with AS 5113:2016, Dated 26 September 2016.

A 3 m x 3 m x 160 mm thick non-load bearing wall was tested exposed to 80 kW/m^2 in accordance with the AS 5113 BB test method.

Table 15 Summary of EWFA Report No: 44388000.1 AS 5113 BB tested system

External coating	5 mm thick "Acroloc Wallcote Pro" Render applied followed by "Dulux AcraTex-AcraShield" roller applied over render. Note – Test report does not clearly state if alkali resistant fiberglass mesh was embedded in render.
Conpolcrete	50 mm thick "QT Eco Series Wall Panels, Conpolcrete", Nominal Density = 374 kg/m^3(measured). Screw fixed to timber battens using 10g x 75 mm screws with QT buttons at 200 mm centres. Note – Colour of Conpolcrete is not stated in report or shown in photos.
Battens	25 mm deep x 40 mm wide treated timber battens nailed to timber studs.
Sarking	Bradford Thermoseal wall wrap.
Stud frame	Timber stud frame, 70 x 35 mm MGP10 radiata pine, studs nominally 500 mm centres.
Internal face lining	10 mm standard grade plasterboard.
Wall loading	No Loading – tested as non-loadbearing wall system.

Test results-

- Test terminated at 31 minutes.
- Integrity – no failure at 31 minutes
- Insulation – no failure at 31 minutes
- All of the AS 5113 BB acceptance criteria were met, including no sustained ignition of the exposed face and flaming/molten debris or total mass of falling debris not exceeding 2 kg.
- Some cracking of the render along QT panel joint lines did occur but the render did not delaminate and remained in place.

This demonstrates that the tested system is unlikely to support ignition and fire spread when exposed to predominantly radiant heat of 80 kW/m^2 from an adjacent fire source feature.

Reviewing cone calorimeter test results at 50 kW/m^2 on Grey Conpolcrete without render which resulted in ignition and burning of the EPS within an ~ 5-10 mm layer of the exposed surface, this indicates that the render plays an important role in preventing surface ignition at high radiant heat flux exposures.

Review of the test report has identified the following issues:

1. Test report does not clearly state if alkali resistant fiberglass mesh was embedded in render.
2. Colour and therefore the “version” of the Conpolcrete is not identified. Based on the 2016 test date it may be assumed that the Conpolcrete is the “current version” of the material.
3. The QT manual specifies a four-coat system including base coat with embedded full mesh, 2nd coat levelling render, 3rd coat texture coat and 4th coat 100% acrylic paint. The report did provide sufficient details on the two coat render system. It is not clear if this was a multi coat system complying with the QT manual specifications. A web search does not identify Acroloc Wallcote Pro as render brand/trade name. *Acryloc* Wallcote Pro is an identified product and this may be a typographical error.
4. The tested system did not include any bulk thermal or acoustic insulation batts within the wall cavity. Additional insulation is not part of the standard basic QT wall system specified in the QT Manual. However, the QT manual does state inclusion of insulation batts as an option to achieve increased thermal or acoustic performance.

5.9 AS 5113 EW Full-scale façade fire spread tests

5.9.1 KNOWN TEST RESULTS

The QT wall systems website provides the following AS 5113 EW External Wall fire spread test report and related render assessment

Ignis Labs Report no: IGNL-3282-08 I01 R01, “AS 5113 Fire Propagation testing and classification of external walls of buildings – QT Panel with 10 mm Cement Render”, Dated 18/01/2020.

Report details a test in accordance with BS 8414.2:2015 as modified by AS 5113:2016 Amdt 1:2018.

Table 16 Summary of Ignis Labs Report No: IGNL -3282-08 I01 R01 AS 5113 EW fire spread test

External coating	Test report states “10 mm concrete render” but does not give details of product trade name used or if fibreglass mesh was embedded in render. A subsequent Ignis assessment report identifies the tested render to be “10 mm Cement TCS render”. No details on beading or re-enforcement within render at corners, starter channel at base of wall or capping/flashing at top or edges of the wall system is given.
Conpolcrete	50 mm thick “QT Panel” horizontally installed with QT buttons and 12-14x 50 mm screws. Note • Test report does not state Conpolcrete density or colour, but photos show grey Conpolcrete.

	• 50 mm screws are shorter than specified by QT manual and would typically require over driving/indenting into 50mm thick QT surface to achieve fixing. • Fixing centres not stated • Use of polyurethane foam adhesive at panel butt joints, as required by QT manual, is not stated and it is not clear if this was included.
Control/expansion joints	One 10 mm vertical control joint (located centrally above combustion chamber) and one 10 mm horizontal control joint located at 2.4 m above the combustion chamber. Both control joints filled with polyurethane backing rod and gap sealed with Bostic FireBan One to a depth of 10 mm.
Combustion chamber/window reveal	No details on how cavity reveal/edge of system was sealed around combustion chamber opening are stated. Photos simply show a render coating. It is not clear what material was used to cap the cavity beneath the render around the perimeter of the combustion chamber opening (e.g. was a section of QT, timber, metal flashing, mineral wool or some other material used).
Wall system edge details	No details on starter channel at base of wall, or capping/flashing at top or edges of the wall system are stated. Details cannot be discerned from photos.
Battens	Steel top hats 20x25x50x25x20 1.15BMT were located between the rear side of the Conpolcrete panel and the fire-resistant plasterboard. The battens were fixed to the stud frame through the fire-resistant plasterboard at 450 mm spacings (details of fixings not stated).
Sarking	No details of sarking stated – photos indicate no sarking installed.
Fire resistant plaster board	2 x 13 mm fire resistant plaster board “CSR Fyrecheck (fixed to test wall sub-frame)”.
Stud frame	No details stated except “CSR Fyrecheck (fixed to test wall sub frame)” and “at 450 mm spacings” Details not clearly stated but it is possible this may have been a lightweight steel stud frame construction fixed directly to the heavy steel support frame (specified in BS 8414).
Insulation	No cavity Insulation stated – assumed not included.
Internal face lining	No details stated. No photos or rear face of wall system provided.
Cavity Barriers	No fire-resistant cavity barriers appear to have been installed (not stated in report).

The report states the following results and concludes an EW classification for the tested specimen:

Table 17. Ignis Labs Report no: IGNL-3282-08 I01 R01 stated test results.

Classification Criteria	**Related classification measure**	**Result in test**	**Pass/Fail**
5.4.5(a) T_{w5m}	≤600°C	Max 717°C spike @ 15 min < 10 s	Pass
5.4.5(b) $T_{layer5m\text{ - Cavity}}$	≤250°C	Max 55°C	Pass
5.4.5(b) $T_{layer5m\text{ – insulation}}$	≤250°C	Exceeded 250°C >30 seconds at 10:20 (min:s) after crib ignition	Pass
5.4.5(c) $T_{unexposedside0.9m}$	≤180 K rise	Max 101°C	Pass
5.4.5(d) flaming	No flaming	No flaming (on unexposed side of specimen)	Pass
5.4.5(d) openings	No opening	No opening occurred (on unexposed side of specimen)	Pass

5.4.5(e) spread	Spread beyond specimen	No Spread occurred (beyond minimum confines of specimen)	Pass
5.4.5(f) debris flaming	≤20 s	No Flaming debris	Pass
5.4.5(g) debris mass	≤2 kg	No Debris	Pass
Classification			EW

Review of the test report (and related render assessment below) has identified the following issues:

1. The referenced test was not conducted by a laboratory holding NATA accreditation for the test method. Instead, the report includes a statement that it satisfies the BCA A5.2 evidence of suitability criteria as it is a report from a professional engineer.
2. The tested system has some significant differences, in components and installation, which would differ in fire performance from that specified in both the QT manual (see summary in Section 4 of this report) and installation on existing buildings commonly observed during the statewide cladding audit. In summary these are:
    a. The tested system had a 10 mm thick render. The QT manual specifies a 5-8 mm render system. Inspection of actual buildings indicates a render thickness of ~ 5 mm is most typical. Render is expected to have a possible critical effect on encapsulation and protection of EPS near the exposed surface within the QT from ignition or flame spread prior to melting and creating a protective cementitious char layer.
    b. The QT manual specifies a four-coat system including base coat with embedded full mesh, 2nd coat levelling render, 3rd coat texture coat and 4th coat 100% acrylic paint. The report (and subsequent render assessment) did not provide sufficient details on the render system included in tested system and simply stated “10 mm Cement TCS render”. It is not clear if this was a multi coat system complying with the QT manual specifications. A web search does not identify TCS as render brand/trade name or related acronym.
    c. The tested system had 2x13 mm FR Plasterboard installed within the cavity, directly behind the steel battens (on external side of stud wall where sarking is typically located). The QT manual does not specify this detail. AS1530.4 tested QT wall systems also do not include this detail as the Conpolcrete panel itself appears to provide sufficient integrity and insulation for AS 1530.4 tests. This detail has also not been observed on existing buildings via the state-wide cladding audit. The test reports states that this is in compliance with AS 5113 Clause 5.4.4. This therefore limits the direct application of the report to installation over non-combustible walls such as fire-resistant plasterboard as tested, or a similar specimen arrangement where fire resistant plasterboard is replaced by masonry or concrete (as per the BS 8414.1 Test method for non-load bearing systems applied to the **masonry** face of a building).
    d. The tested system did not clearly state the details of the lightweight stud frame. Given steel battens were used it is likely that a lightweight steel stud frame may also have been used. The QT manual permits either steel or timber frame to be used. However, based on state-wide cladding audit observations, QT appears to predominantly installed over timber frames and timber battens. The AS1530.4 tested QT wall systems have all been constructed with timber frames and timber studs.
    e. The tested system did not include sarking. The QT manual requires Sarking to be installed within the cavity.
    f. The tested system did not include any bulk thermal or acoustic insulation batts within the wall cavity. Additional insulation is not part of the standard basic QT wall system specified in the QT Manual. However, the QT manual does state inclusion of insulation batts as an option to achieve increased thermal or acoustic performance.
3. The description of the tested system and components lacked considerable detail and did not include any system drawings. More detail and system drawings would typically be provided for

compliance with NATA requirements as demonstrated by the substantially more detailed specimen description and drawings provided in the existing AS 1530.4 test reports for QT wall systems.

4. The test report statements and photos indicate no significant burning occurred on the rear/cavity face of the Conpolcrete (which is not render coated) and only scorching/heat damage at edges of panel butt joints and particularly along vertical control joint. Fire penetrating through the edge/reveal finish detail around the top edge of the combustion chamber can be a typical weak point for fire to expose and spread within the cavity, however this type of failure appeared not to occur for the tested system, but no details are reported on how this aspect of the tested system was constructed and sealed. Where fire does penetrate into the wall cavity, further fire growth and spread can sometimes be limited by lack of available oxygen in cases where the perimeter and top edges of the wall specimen are capped and well-sealed. However, the test report does not state any details on how perimeter of the test specimen was capped/sealed.
5. The report states: "*Spikes in temperature for thermocouple 11 and 12 (level 2 external face) increased over 600°C for an average of approximately 10 s intervals with a maximum time of 30 s in one instance*" and the test results table states "*Max 717°C spike @ 15 min*" for level 2 external face temperatures. The relevant AS5113 classification criteria states "*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.*" However, review of the Temperature vs Time graph from the test report (see Figure 12 and Figure 13 below) indicates that the 600°C criteria may have actually been exceeded for a continuous period greater than 30 s. However due to the resolution of the graph not clearly showing individual temperature spikes, review of the raw test data would be needed to confirm this.

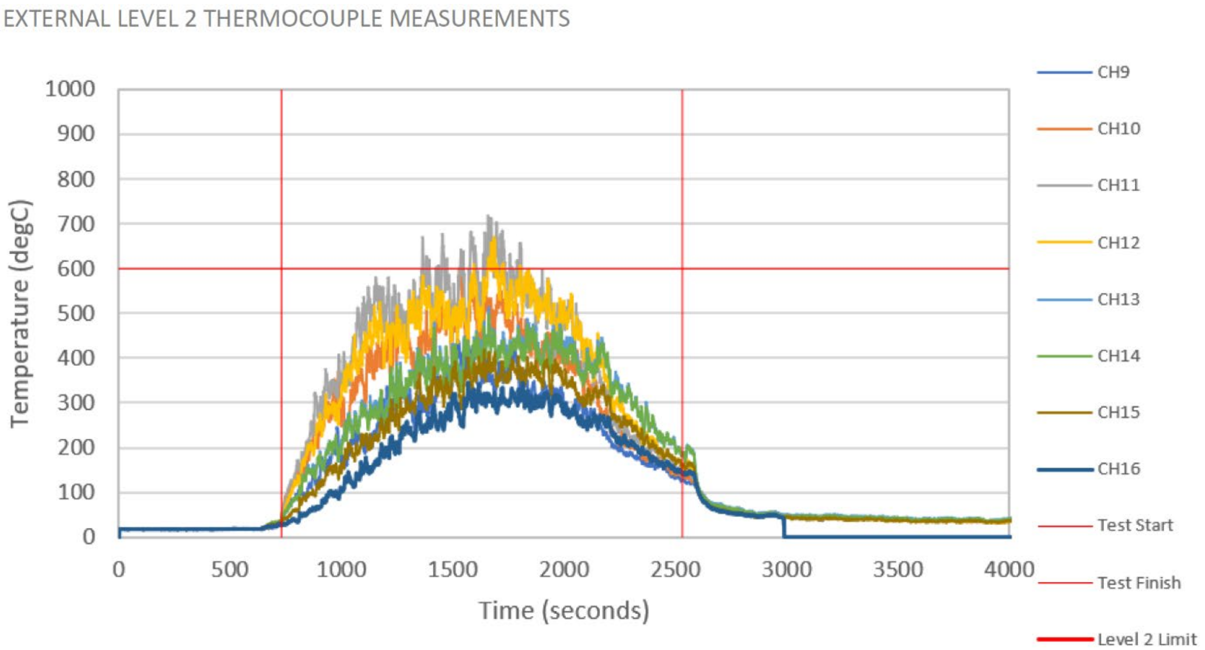

Figure 12. Extract of Level 2 external face temperature graph from Ignis Labs Report no: IGNL-3282-08 I01 R01

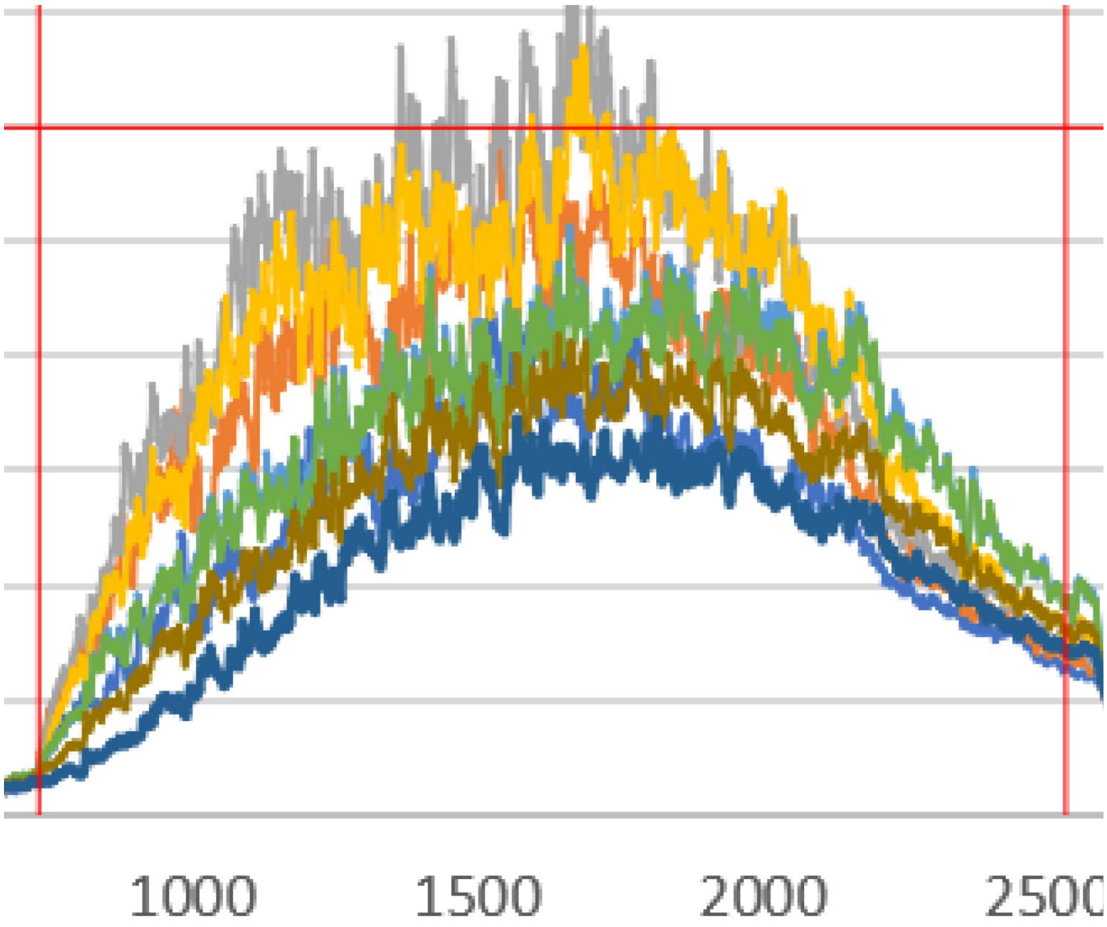

Figure 13. Close-up extract of Level 2 external face temperature graph from Ignis Labs Report no: IGNL-3282-08 I01 R01

5.10 Assessment reports related to the AS 5113 test

Ignis Solutions Report no: IGNC-8030 I01 R00, "QT Panel Render Assessment", Dated 30/01/2020.

This is a report issued by a professional engineer, not NATA accredited lab assessment. It provides assessment that the tested system render component "10 mm Cement TCS render" can be substituted with an alternative render system "Rockcote Quickntuff Armoured Flexi Tex Medium" and that this will not affect the external wall fire spread performance of the tested QT wall system.

This assessment is based on comparison to a different wall system (reported in Ignis Labs report IGNL-2067-08-02I01 R00 dated 4 July 2019) tested to BS 8414:2015 as modified by AS 5113:2016 Amt 1:2018. The comparison wall system, in summary consisted of the following (from external side to internal side):

- Coating system – Rockcote ArmourFlex Flexi Tex
    - Layer 1- Keycote, 1.4-2 mm thick
    - Layer 2 – Flexitex, 1.2 mm thick
    - Layer 3 – Masonry Primer Hi Op
    - Layer 4 – Armour Flex, 160 microns
    - Layer 5 – Armour Flex, 160 microns
- Rescom 10 mm thick magnesium oxide board
- PIRMAX 75 mm PIR insulation board
- 90 mm lightweight steel stud frame
- 10 mm standard grade plasterboard

Note – based on the description provided the total thickness of the alternative render system as tested appears to be ~3-4 mm total thickness and was applied directly to magnesium oxide board.

Issues identified with the render assessment include:

a. The alternative render assessed appears to be significantly thinner (3-4 mm) than the 10 mm render described in QT wall system AS 5113 test report.
b. The alternative render tested was applied to Magnesium oxide board which does not have EPS bead aggregate within it and may possibly have different render adhesion behaviour when exposed to fire.
c. Given the above, the basis for the assessment does not have evidence that covers the range of parameters which may affect the behaviour of the material or involve systems that provide well founded comparisons. An AS 5113 test on a QT wall system with an alternative render system of equivalent thickness would provide more acceptable evidence.
d. However, based upon CSIRO test experience with render systems and knowledge of full-scale tests on rendered 100% EPS wall systems with a multi-layer polymer modified render system ~ 5 mm thick, it is considered possible that if the QT wall system was re-tested to BS8414 with such an alternative render system at ~ 5 m thickness, this may not adversely impact the outcome of the test.

<u>Ignis Solutions Report no: IGNS-8108 IO1 R02, "QT Panel Verification Assessment", Dated 27/11/2020.</u>

This report states it applies the NCC BCA Vol 1:2019 Amendment 1 Verification Method CV3 and applies the above AS 5113 EW test report as an input.

The report concludes that "*In the opinion of Ignis Solutions, the evaluation and associated testing has demonstrated that the proposed Performance Solution for the installation of the QT Conpolcrete rendered wall panel in an external wall does not increase the risk of fire spread and as such satisfies the BCA Performance Requirements CP2 through Verification Method CV3".*

Issues identified with this assessment include:

1. Verification method CV3 is applicable to a building, and not a product, due to the structure of the clause and requirements. The assessment report is very unclear as it states in section 1.1 "…a wall system complies with CV3 when…" however it is more accurate to state"…a wall system may form part of a solution for a building to comply with CV3 when…".
2. The Ignis Solutions CV3 assessment report is reliant upon the above, single AS 5113 EW test by a test laboratory not holding NATA accreditation for the test method. The tested system has significant variations to the typical end use installation as specified in the QT system manual, and the impact of these variations does not appear to be fully addressed in the Ignis Solutions CV3 assessment report.
3. Application of CV3 requires additional building sprinkler protection provisions (dependant on Construction Type A or B, and building height). However, the Ignis Solutions CV3 assessment report acknowledges these requirements.
4. Application of CV3 requires that the external wall system "*if containing a cavity, incorporates cavity barriers and these cavity barriers have been included in the test performed under (i) at the perimeter of each floor".* The Ignis Solutions CV3 assessment report acknowledges that cavity barriers were not included in the tested system but does not appear to:
    a. Provide a clear assessment as to why the test without cavity barriers is relevant for application to CV3, or
    b. Clearly state that, in accordance with CV3, Cavity barriers would be required to be installed in the wall system forming part of a CV3 building approval.

In summary:

- Regardless of the above identified issues, the Ignis Labs AS5113 test report clearly demonstrates that the tested system did not support any significant fire spread beyond the area of crib flame impingement.
- This test does provide some evidence, when combined with the other test evidence reviewed in this CSIRO report, to indicate that a QT wall system including Conpolcrete® presents a low risk of external wall fire spread.
- The inclusion of the 2 layers of 13 mm FR plaster board as described in AS 5113 clause 5.4.4 effectively limits the applicability to walls systems constructed similar to the tested system (installed over external fire-resistant plasterboard, masonry or concrete).
- However, it is unfortunate that the AS 5113 tested system did not more closely represent the wall system as specified in the QT manual, or typical QT wall system installation in existing buildings, as this would have provided more direct evidence of the performance of such systems. Parts of the system which in particular could have been more representative include:
    1. 5 mm multi layered render system with embedded mesh and finished with acrylic paint rather than the tested 10 mm render
    2. Inclusion of sarking
    3. Exclusion of FR plaster board within cavity behind battens
    4. Timber framing and battens rather than the steel
    5. Inclusion of 10 mm standard grade plaster at internal face of wall
    6. Representative details on reveals/capping/flashing around perimeter of combustion chamber opening and at base, side edges and top of wall system

5.11 Comparison against other cladding system results

Rendered 100% EPS cladding

CSIRO has reviewed several previous full-scale façade fire tests on European rendered EPS systems[2] which were typically installed directly to a solid concrete/masonry substrate and included thick EPS (typically 200 mm thick). The European tests reviewed included:

- German MFPA Leipzig 200 kg crib EIFS tests done on different wall systems with no internal fire barriers (Mineral wool breaks installed between levels of EPS) and with internal fire barriers[31-33]
- German iBMB tests including 200 kg crib tests and 200 L iso-propanol tray fire tests on different wall systems with no internal fire barriers and with internal fire barriers[34]
- BRE tests comparing EPS EIFS performance in BS 8414 tests and DIN 4102-20 tests[35] (which uses a significantly small crib source), and
- University of Zagreb, Croatia EIFS tests based on BS 8414[36-38].

All of the above tests demonstrated the following typical fire spread behaviour:

- In all tests the render (at least in the region of fire source exposure) cracked and exposed the EPS or remaining wall cavity. This failure appears to be, at least in part, due to the EPS substrate behind melting or receding away leaving the render relatively unsupported. Render failure can also be influenced by render type and thickness.
- In all tests a significant pool fire of molten EPS formed on the ground in front of the test wall.
- All tests without cavity fire barriers fitted resulted in rapid aggressive fire spread to the top of the test specimen.
- In some cases, the European rendered EPS systems when fitted with fire barriers (typically 200 mm non-combustible mineral wool inserted to break continuity of EPS) did prevent or slow fire spread to the top of the specimen, however they still produced significant pool fires.

In June 2020 the VBA sponsored an AS 5113 EW-BS8414 full scale façade fire test conducted on a rendered EPS wall system representing typical Australian construction.

- The tested system included a polymer modified mesh reinforced render system with total thickness of ~ 5 mm, 100 mm thick EPS direct fixed to timber stud frame.
- This resulted in a large pool fire at base of wall and rapid vertical fire spread to the top of the test specimen. Render remained in place during early stages of crib flame impingement and failed after EPS pool fire had developed at ground. Render failure appeared to be due, at least in part, due to melting away of EPS substrate behind resulting in large areas of unsupported render.

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[2] A literature review report on Fire performance of 100%EPS rendered cladding and also the test reports for an AS 5113 EW-BS8414 façade fire test conducted on 100% EPS rendered cladding can be found at the following VBA website: https://www.vba.vic.gov.au/about/research/fire-safety-of-rendered-expanded-polystyrene-eps-in-exterior-insulation-finishing-systems-eifs-on-class-2-to-9-buildings-of-type-a-or-type-b-construction

Aluminium Composite Cladding

In response to the Grenfell Tower fire, the UK Department for Communities and Local Government (DCLG) sponsored BRE Global to undertake a total of seven BS 8414 Façade Tests on three different categories of ACPs with three different Insulation types[39-45].

The range of ACP and Insulation materials tested are summarised in Table 18.

Table 18. Material types tested in BRE DGLC BS8414 tests

Material Type	Material Name	Description
ACP	ACP-PE	ACP with Gross heat of combustion of ~46.4 MJ/kg, total thickness = 4 mm, core thickness = 3 mm. (BRE CAT3 – No flame-retardant properties - > 35 MJ/kg)
	ACP-FR	ACP with Gross heat of combustion of ~ 13.6 MJ/kg, total thickness = 4 mm, core thickness = 3 mm. (BRE CAT2 – Limited flame retardant - > 3 MJ/kg and ≤ 35 MJ/kg)
	ACP A2	ACP with Gross heat of combustion of ~ 2.3 MJ/kg, total thickness = 4 mm, core thickness = 3 mm. (BRE CAT1 Limited combustibility - ≤ 3 MJ/kg)
Insulation	PIR	100 mm, foil faced, density 31.2 kg/m3, moisture content from 2.4% to 3.9%
	MW	180 mm, density 47.7 kg/m3, moisture content from 0.5% to 0.6%
	Phenolic	100 mm, foil faced, density 32 kg/m3, moisture content 8.5%

All test wall systems were fitted with vertical and horizontal cavity fire barriers.

Results are summarised as:

- ACP-PE supports aggressive vertical fire spread, with significant flaming debris and formation of pool fires, regardless of the type of insulation behind. Flames extended several meters above the test rig at the time of early test termination.
- ACP-FR supported significantly less aggressive fire spread compared to ACP-PE but did still support some flame spread beyond the crib impingement area and flaming debris, even with mineral wool insulation behind. It appears that ACP-FR / MW resulted in flames extending along main-wing wall junction to just reach the top of the test rig but not extend above the test rig. On this basis it narrowly met the BR135 classification criteria.
- ACP-FR combined with combustible PIR or Phenolic insulation showed some enhancement of fire spread and resulting fire size, compared to ACP-FR/MW, due to burning of the insulation within the cavity and this possibly enhancing the burning of the ACP-FR. Both tests failed BR135 classification criteria due to flames extending above the top of the test rig. Fire spread was significantly less aggressive and was delayed compared to ACP-PE tests.
- ACP-A2 did not support significant fire spread beyond the crib impingement area even when combined with PIR insulation. All ACP-A2 tests met the BR135 classification criteria.
- The test reports do not provide any photos during tests visually showing the area of flames and extent of flaming molten debris and pool fires. Based on written observations and measurements these appear to have been significantly reduced for ACP-FR compared to ACP-PE.

Comparison to QT wall system AS 5113 test

Comparing the Ignis Labs Report no: IGNL-3282-08 I01 R01 against the above tests the following can be concluded.

- The tested QT wall system did not support fire spread and performed significantly better than typical Rendered 100% EPS or ACP-PE wall systems.
- The tested QT wall system performed marginally better than the tested ACP-FR with mineral wool insulation system.

- The tested QT wall system performed approximately equivalent to the ACP-A2 system.
- The tested QT wall system differed from the QT wall system manual specified system and typical systems installed on existing buildings, particularly having a thicker 10 mm render. It is unclear if a test with a thinner render would result in some reduction of fire performance (possibly similar to ACP-FR with mineral wool insulation). However, considering performance of the Conpolcrete core in other types of fire tests and its ability to form a protective char layer, a reduction in render layer is considered unlikely to result in the extremely poor fire performance observed in ACP-PE and rendered 100% EPS full scale façade fire tests.

6 Conclusions

The detailed conclusions of this report are:

1. EPS Concrete has been used to manufacture a range of wall panel products. However, QT Eco Series wall system appears to be by far the most used system of this type in Melbourne.
2. QT eco series wall system, also known and Quick 'n Tuff, is a wall panel system. This incorporates a plasterboard internal wall, framing, EPS in concrete Matrix composite cladding panel with external render system. The cladding panel, referred to by QT both as "QT Eco Series panel" and "Conpolcrete®", is a cementitious matrix with EPS bead aggregate. The EPS bead is recycled material so may vary in grade and generally has poor fire performance (on its own). The cementitious matrix provides structural strength and improves the fire performance. The matrix remains in place when the EPS melts or burns and the remnant matrix forms an insulating non-combustible layer.
3. There is some confusion in the industry about the difference between Conpolcrete (foam core) and the complete QT wall system. QT wall system specifications can vary dependant on the end use and the required fire, thermal or acoustic requirements.
4. There appear to have been three major formulations of QT Conpolcrete over the years including:
    a. pink coloured cementitious matrix
    b. white coloured cementitious matrix
    c. grey coloured cementitious matrix (the current product).

   While visually identifiable, the differences in these types are not well understood in regard to formal composition/identification. QT systems have provided some information on changes to manufacturing processes but have stated that the formulation has essentially not changed.

5. For material characterisation testing of QT, CSIRO currently conducts Ash testing, Solvent dissolution method, FTIR and XRD. Some past tests have only provided Ash and FTIR but due to mass loss of the cement component during ashing the solvent dissolution method and/or XRD is needed to provide a better estimate of mass ratio of EPS to inert material. However, this method is still estimated to have an accuracy of ~± 5% or less due to the complexity of the Conpolcrete material.
6. Bulk density may also be used to compare EPS sampled from existing buildings to the range of bulk densities for QT Conpolcrete reported in fire test reports (345-420 kg/m^3). A density below this range may indicate an increased EPS content. For the purposes of material identification for the state-wide cladding audit, visual comparison and bulk density measurement of EPS concrete core samples compared to known QT Conpolcrete samples may be sufficient.
7. Appendix B of this report provides guidance on a method of bulk density measurement for EPS concrete specimens.
8. It is noted that bulk density measurement does not directly measure the mass % of cementitious content or identify the major mineral component of the cementitious material. Laboratory testing can provide this further detail if needed.
9. There has been a range of fire tests carried out. Some tests/approvals apply to the QT wall system, some only to the EPS Concrete core.
10. QT is a product developed in Australia and predominantly used in Australia and hence unlike ACP, there is no test reports or data from other countries. The IP of the system is protected by global patents. CSIRO have only found limited information/papers similar types of EPS in cement matrix products from overseas.
11. The tests/approvals technically apply to the QT wall system and the *version of Conpolcrete manufactured/installed* at the time. Test reports from the past in some cases do not clearly identify

exact details of which formulation was tested (beyond a broad generic product name description). This challenge applies to all the following points.

12. The fire performance of the systems is dependent on the fire performance of each element and how these interact when installed as a system in and around other features of a specific building.
13. QT wall system has been tested and demonstrated to achieve set FRL's when constructed in accordance with approved QT wall specification. The fire resistance tested systems are reasonably representative of the QT manual specified system and as-installed systems.
14. The single AS 5113 EW/BS8414 full scale façade test on a QT wall system was conducted on a specimen with some significant differences from the System as specified in the QT manual or most typically installed in practice. These differences included:
    a. 10 mm render of unknown detail tested. 5 mm multilayer render with embedded full mesh typical.
    b. 2 x 13 mm FR plasterboard in cavity behind battens with no sarking tested. No FR plasterboard is typical with sarking required to be installed behind battens. This limits the applicability of the test to installation over non-combustible walls such as fire-resistant plasterboard as tested, or a similar specimen arrangement where fire resistant plasterboard is replaced by masonry or concrete (analogous to BS8414.1).
    c. Steel battens and frame tested. Timber battens and frame appears most typical.
    d. Details of sealing at edges of tested wall system and around perimeter of combustion chamber (which can represent a window opening) not well documented in test report.
15. The Single AS 5113 EW/BS8414 full scale façade test on a QT wall system was not undertaken by a laboratory holding NATA accreditation for this test method at the time of testing. NATA accreditation cannot be retrospective or apply to tests outside the accredited scope.
16. There are no fire test reports which show QT complies with the BCA DtS Clause C1.9 and related DTS clauses. The compliance of this product applied to buildings therefore relies on either a performance approach or CV3, both of which may utilise AS 5113 testing.
17. The limited test data available indicates the risk of façade fire spread on QT on already installed on existing buildings is likely to be low. It may also be a promising material to install in new buildings and use for rectification, however, reliance on the existing information would expose an approval authority to risk.
18. It is not CSIRO's role to make a determination on the above. However, to improve certainty for Approvals Authorities, CSIRO recommends a structured approach to investigate any gaps in knowledge of fire performance for this system and reduce the risk for approval authorities.
19. It is not practical to conduct a single full scale AS 5113 test (or a series of such tests) to represent the multiple variants that may have been installed on existing buildings.
20. The issues could be separated as follows:
    i. The compliance of the system for new installations should be the responsibility of the manufacturer.
    ii. Further test-based evidence could be obtained to support the performance and potential retention of the multiple variants of the wall system in existing buildings for the following two purposes:
        a. Justification for a ranking parameter for the RAT including comparing 3 formulations. (Step 18 b below in particular may be suitable for this).
        b. evidence for supporting proposals to retain cladding.
21. The approach for existing buildings could be that strategic set of further fire tests should be conducted. This should include:
    a. Investigation of the range of the installations of the system on existing buildings.
    b. Investigation of the difference between the 3 major formulations of the Conpolcrete. Test at small scale (cheaper and timely) and compare results to ACP-FR materials to provide additional evidence for ranking similar (or better) than ACP-FR for the RAT. Small scale test methods to consider for this include the cone calorimeter and the bomb calorimeter.
    c. Consideration of the potential fire scenarios which may occur in existing buildings.
    d. Consideration of appropriate fire sizes for each scenario.

e. Conduct Intermediate scale (ad hock balcony fire scenario) tests exposing small wall sections to 100-300kW localised fires. Test specimens could have thin render or no render. This would provide data on QT's resistance to fire spread from non-flashover fires (localised balcony fire scenarios). Such tests could also provide information on cavity fire spread.
f. Conduct an AS 5113 EW full scale façade test on a QT wall system which may be more representative of some installations on existing buildings (e.g. thinner render, QT without FR grade plasterboard directly behind, inclusion of sarking, inclusion of representative capping details around edges of wall system and perimeter of combustion chamber opening). This should be completed by a NATA accredited lab. It must be considered that such a test may not necessarily pass all AS 5113 EW comparison but would provide useful information on fire performance to inform a risk-based assessment of this system.

22. In the absence of the above recommended further testing and on the basis of the limited available test evidence, it could be reasonably concluded that a QT system installed to the manufacturers specification has a low risk of façade fire spread and might reasonably be ranked as having a RAT material risk score input equivalent to ACP-30% PE in the statewide cladding RAT. This recommendation applies only to the state-wide cladding RAT. It does not apply to the ICA ACP risk categories which does not apply to EPS concrete products. Further testing (as recommended above) would be needed to demonstrate a risk level comparable to ACP-A2 (for the purposes of the RAT). CSIRO strongly recommend that the above decision should be agreed upon by a panel of experts via a "Delphi" process to increase the robustness and reduce risk of this decision. This has been completed, see section below for outcomes of the Delphi panel.
23. There have been a number of examples from the statewide cladding audit, where buildings have had QT specified, but upon closer inspection have been proven to have areas of walls installed with 100% EPS. This may either be due to substitution, or due to design, where QT may be specified close to boundaries and other fire source features, but EPS may be specified at other areas.
24. We do not recommend that QT should be considered to be "Out of scope" for the statewide cladding audit for the following reasons.
    a. Although QT may reasonably be considered lower risk, it is still a combustible cladding material.
    b. Difficulty ascertaining if cladding is actually QT or EPS without detailed multiple penetrative site inspections (meaning State-wide cladding audit should consider that buildings nominated to have QT on design documents should still require verification via detailed penetrative site inspection).
25. If a building is verified via site inspection to be QT (without other combustible cladding) then it may be reasonable to acquit the building following the VBA low risk building acquittal guidelines.

Delphi Panel outcomes

The VBA arranged for Revision D of this report to be reviewed by a panel of experts (Delphi Panel). The Delphi panel provided written comments which CSIRO responded to and then The VBA held a final Delphi Panel meeting on 9/07/2021, which CSIRO attended as Co-Chair. The Delphi Panel voted (by majority vote) on the following outcomes:

1. It was confirmed that the Delphi Panel would vote on the Statewide cladding risk assessment tool (RAT) material risk score input to be applied for EPS concrete (i.e. the risk ranking of the material in isolation). It was discussed that other factors such as combination of EPS concrete with other combustible external wall materials, insulation type or poor fixings/installation should be addressed by the other RAT inputs already provided in the RAT for these items.
2. Majority Vote outcome was that the RAT material risk score input to be applied for EPS concrete shall be 0.5 (same ranking as applied to ACP with a core consisting of 30% or less polyethylene), provided that the EPS concrete visually matches QT Conpolcrete and has a bulk density of at least 345 kg/m^3 or greater.

3. EPS concrete which has a bulk density of less than 345 kg/m^3 or does not visually match QT Conpolcrete should be conservatively assigned a RAT material risk score input of 1.0 (same ranking as applied to 100% EPS), reflecting that the material may potentially have increased EPS content.

It was noted that a RAT material risk score input of 0.5 for QT Conpolcrete was conservatively assigned giving full consideration to the gaps in fire testing identified.

The above outcomes apply only to the state-wide cladding RAT. It does not apply to the ICA ACP risk categories which does not apply to EPS concrete products.

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Appendix A Description of fire test methods

A.1 AS 1530.1 Combustibility

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)[46-50] however they are all fairly similar with some differences in specimen dimensions, configurations, furnace temperature and failure criteria.

In AS 1530.1 small specimens (45 mm diameter, 50 mm high cylindrical) are exposed to a temperature of 750 °C within a small conical tube furnace. Criteria for 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.

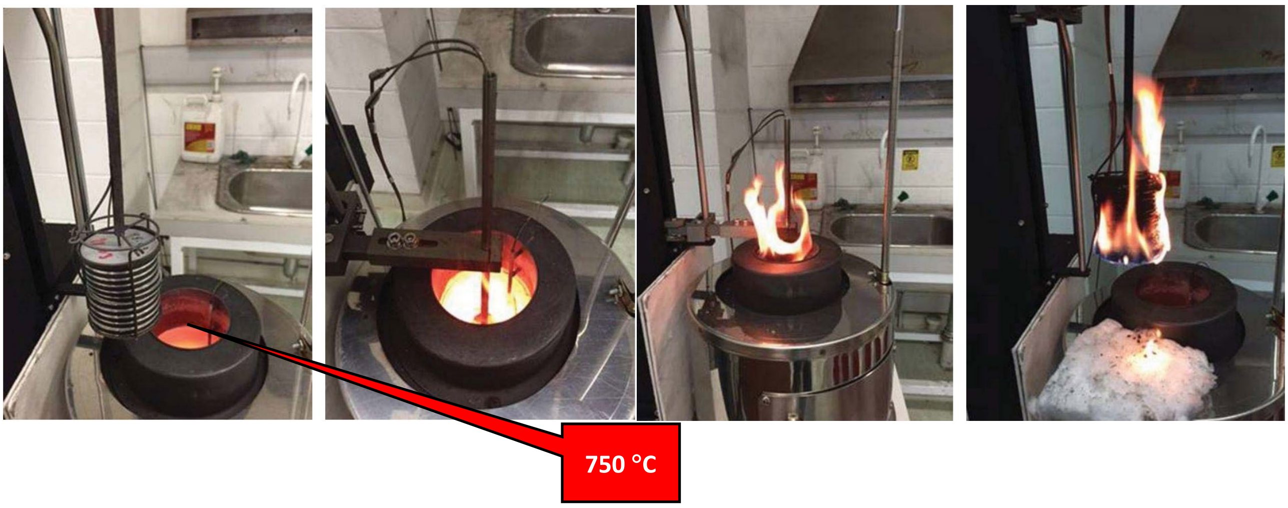


Figure 14. AS 1530.1 (note – indicative test applied to complete ACP-PE specimens. Standard test required testing of each component/layer separately). Photos by CSIRO

A.2 Bomb calorimeter (EN ISO 1716)

A bomb calorimeter (EN ISO 1716) measures the Gross Heat of combustion of a material. Whilst this could be considered a reaction to fire test, BRE have used Gross Heat of Combustion for ranking of ACP cores which has been loosely compared (by ICA's ACP core ranking protocol and others) to filler mass%.

The basic principle of a bomb calorimeter is that a specified small mass of material (typically ~ 1 g) is burnt under standardised conditions within a confined volume combustion chamber with high oxygen concentration to promote complete combustion. A fuse wire is used to ignite the specimen. The sealed combustion chamber is surrounded by an insulated water jacket. The temperature increase of the water jacket is accurately measured up until the time that the combustion chamber returns to 25 °C so that any water vapour within the combustion chamber has condensed. The water jacket temperature increases in conjunction with a bomb factor (calibration factor dependant on heat capacity of metal parts of calorimeter) determines the gross heat of combustion.

Samples are small (~1 g), must be free of contaminants, are typically dry and will typically be broken into several pieces to increase the surface area. For specimens which are difficult to ignite a compound of known gross heat of combustion (typically a benzoic acid pill) are added to promote ignition and combustion of the sample.

It is important to understand the difference between the following three measures of heat of combustion:

- 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. This includes the heat of vaporisation of any water produced as the vapour is condensed back to liquid.
- Net Heat of combustion – is the heat released per unit mass of fuel burnt assuming that all water vapour remains in the gaseous state (gross heat of combustion minus the heat of vaporisation of any water produced). 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 also measured using a bomb calorimeter however the water jacket temperature rise is measured at the time when the combustion chamber has cooled to 150 °C (prior to water vapour condensing back to liquid)
- Effective heat of combustion – is the heat released per mass of material consumed taking into account real fire combustion effects such as moisture contained in the materials (heat of vaporisation is not included as water vapour leaves the combustion system via the fire plume), and incomplete combustion of pyrolysis products (which leave the combustion system as unburnt mass via the fire plume as products such as soot and gaseous products of incomplete combustion). Effective combustion can be measured via test methods such as the cone calorimeter and results can be significantly variable dependent upon test fire exposure conditions.

A.3 AS 1530.3

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 + 0.1 kW/m^2 measured 850 mm in front of panel. The specimen is incrementally advanced towards the radiant panel at a prescribed rate. A small pilot flame is applied to the specimen surface to ignite pyrolysed 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.

Depending on the time to ignition (when movement of the specimen towards the radiant heat panel stops) specimens may be exposed to radiant heat flux ranging from a minimum of ~2.5 kW/m^2 up to a maximum of 25 kW/m^2 [51]. This is significantly less than the typical heat flux exposure to an external wall that can result for window fire plumes or large external fires with flame immersion of the external wall and does not reasonably predict degradation of aluminium facings on ACP to expose combustible core materials.

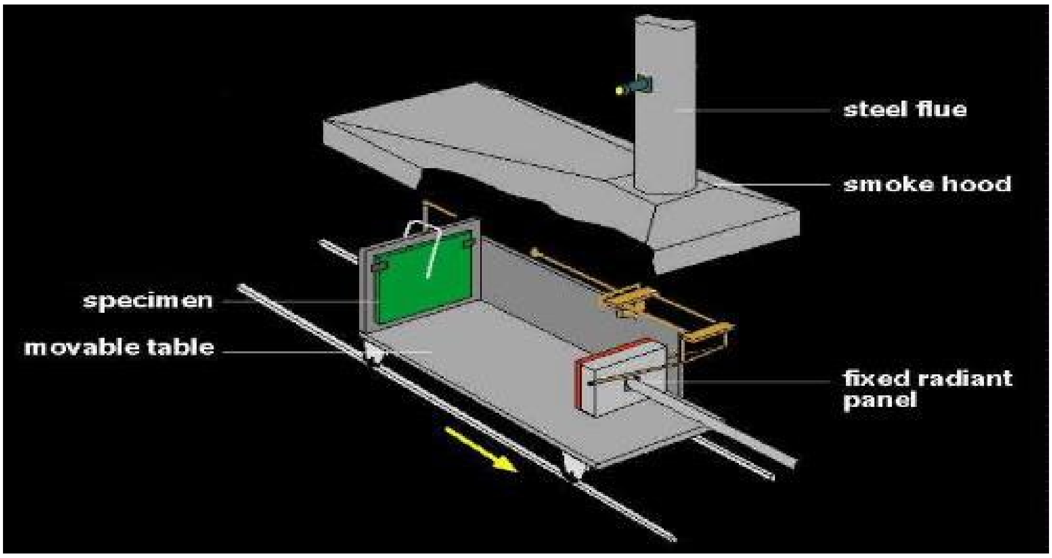


Figure 15. AS 1530.3 test.

A.4 Cone Calorimeter AS/NZS 3837, ISO 5660

The cone calorimeter[52] is a small-scale oxygen consumption calorimeter. 100 mm square specimens 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) and
- Time to ignition at set heat flux exposures (determined by observation).

The cone calorimeter apparatus and procedure are described in ISO 5660, AS/NZS 3837 and ASTM E 1354[53-55].

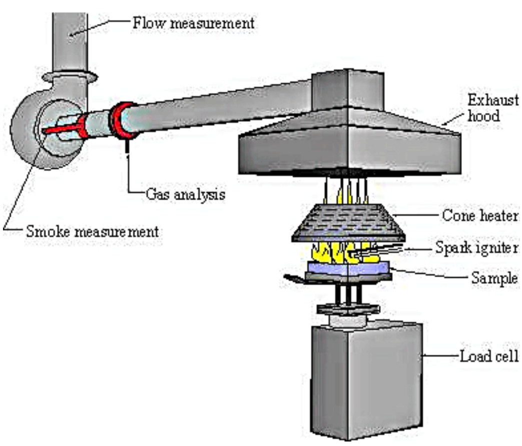


Figure 16. Cone Calorimeter (CSIRO)

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 or reflects radiant heat 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. The cone calorimeter also has similar limitation when testing materials with reflective surfaces due to the large amount of heat reflection. This limitation of a protective facing is applicable to testing of ACP. 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 applies to EPS.
The Cone calorimeter is applied by the NCC BCA 2019 Vol 1 DTS 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 resulting in the correlation not being valid for EPS or ACP. Therefore, Group Numbers for EPS or ACP should be determined by ISO 9705 tests.

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 reaction to fire properties for materials and can provide useful information on the reaction to fire properties of ACP cores with the facing material removed.

A.5 AS 1530.4 fire resistance test

Different types of structural and barrier systems are tested exposed to a standard time vs temperature exposure curve to determine ability to maintain structural adequacy, integrity as a barrier to fire spread, and insulation.

Time (t) min	Prescribed furnace temperature (T), °C
0	20
5	576
10	679
15	738
30	841
60	945
90	1006
120	1049
180	1110
240	1153
360	1213

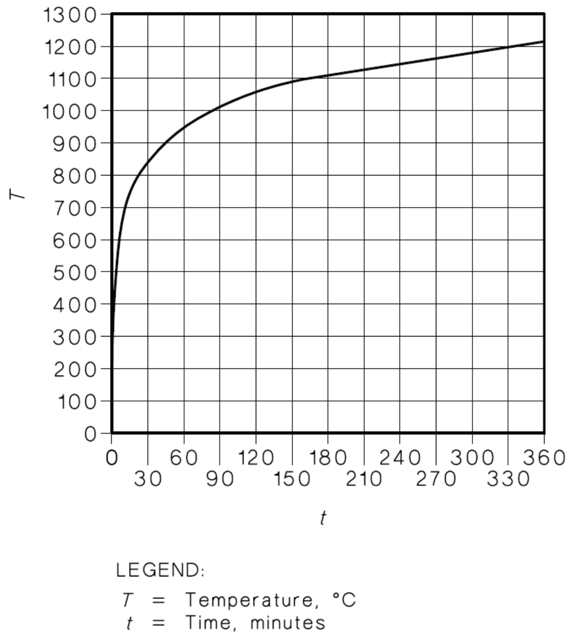


Figure 17. Standard time vs temperature furnace exposure curve (AS 1530.4)

Wall systems are tested in a 3 m x 3 m specimen arrangement with test furnace exposure to one side.

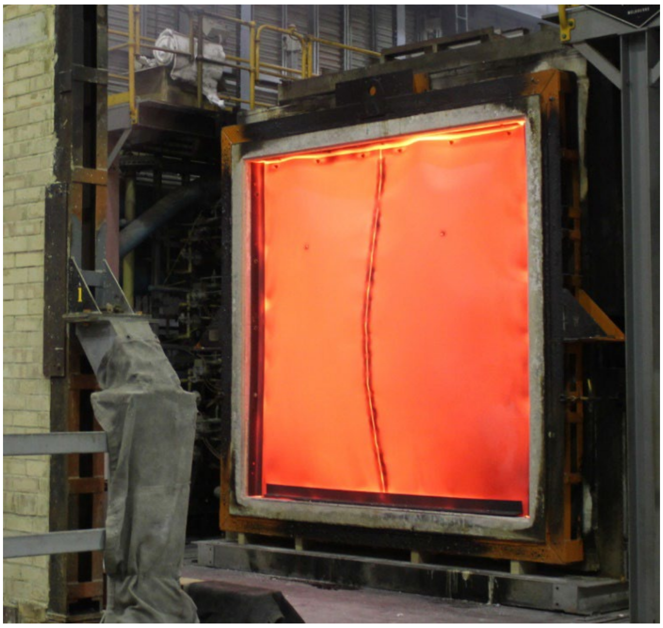


Figure 18. 3 m x 3 m AS 1530.4 test furnace (fitted with steel sheeting across opening) Photo by CSIRO.

Where walls are to be tested as load bearing a nominated load is applied for the duration of the test. Non-loadbearing walls are tested without any applied load.

The test is monitored for time to failure for the following criteria:

- Structural adequacy – the ability to maintain stability and adequate load bearing capacity as determined by AS 1530.4 criteria,
- Integrity – the ability to resist the passage of flames and hot gases as specified by AS 1530.4 criteria and
- Insulation – The ability to maintain a temperature over the whole of the unexposed surface below that specified by AS 1530.4 criteria.

The test results are expressed in terms of an FRL (fire resistance level) expressed as:

Structural adequacy/Integrity/Insulation

Where time to failure for each of the above criteria is expressed in whole minutes and rounded down to the nearest regulatory grading period in minutes (Typically 15, 30, 60, 90, 120, 180 or 240 minutes).

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 an FRL.

A.1 AS 1530.8.1 and AS 1530.8.2 Bushfire test method

The NCC BCA 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 1530.4 furnace.

Note that the same sized radiant heat panel source is adopted by AS 5113 to determine Building to Building (B2B) radiant heat classification however the range of levels of radiant heat exposure for AS 5113 (B2B) is higher, at a maximum of 80 kW/m^2 compared to AS 1530.8.1. 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 requirement. AS 1530.8.2 includes some failure criteria which are more onerous than AS 1530.4 relating to permitted gap formation size, flaming on fire exposed side between 60 and 90 minutes and temperature limits on internal faces of constructions including cavities.

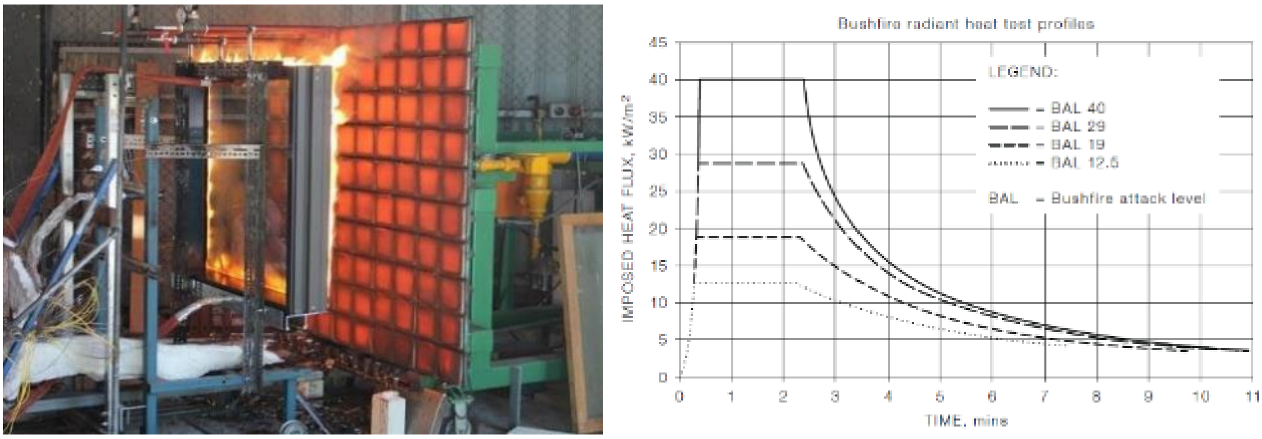


Figure 19. CSIRO pilot scale AS 1530.8.1 test (left), BAL radiant heat test profiles (right)

AS 1530.8.1 and AS 1530.8.2 are intended for determination of bushfire performance and 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 or exceed temperature failure criteria (not on exposed face).
- AS 1530.8.2 is predominantly a fire-resistant barrier integrity and insulation test with some more stringent criteria. This does not represent a typical façade exterior fire exposure or examine vertical 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 or exceed temperature failure criteria (not on exposed face).

A.6 AS ISO 9705 room corner test

This test simulates the scenario of an interior localised fire occurring in one corner of a room with a ventilation opening (typically a door). It evaluates the propensity for fire spread on interior wall and ceiling linings resulting in flashover.

AS ISO 9705[56] is applied in Australia by the NCC BCA DTS Vol 1 regulate interior wall and ceiling linings based on material group number.

Room corner tests should be applied for determination of group numbers of ACP for application as internal wall or ceiling linings.

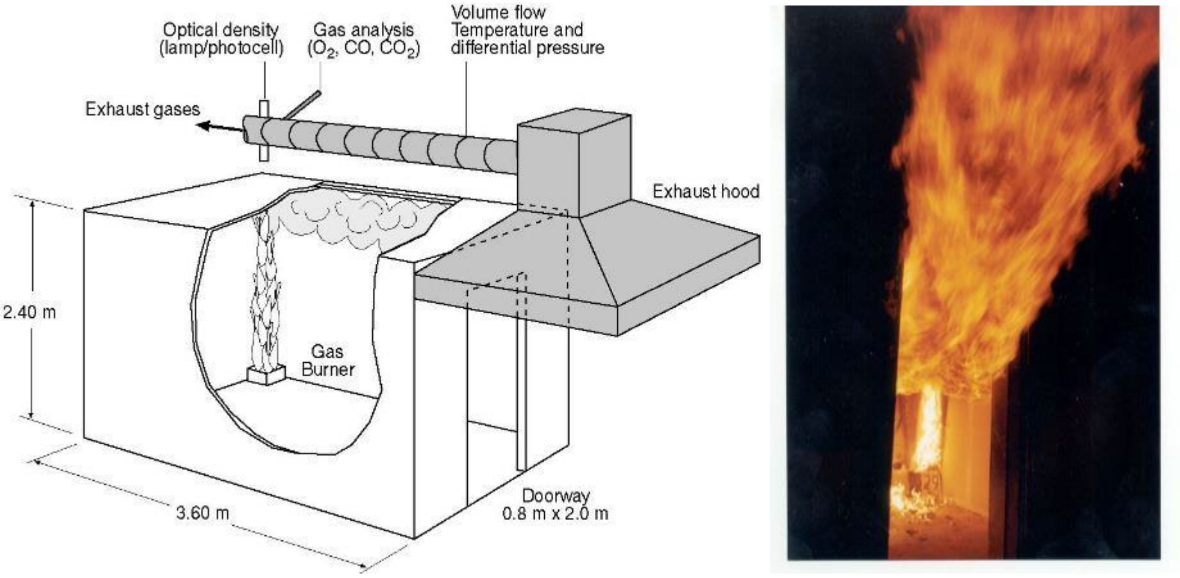


Figure 20. ISO 9705 room corner test layout and resulting flashover (CSIRO)

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 this test method.

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[56]	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

A.7 ISO 13785:2002 Part 1 – Intermediate scale facade test[57]

The test façade is installed as a re-entrant corner "L" arrangement with a total specimen height of 2.4 m, a rear wall width of 1.2 m and side wall width of 0.6 m. The façade is installed representing the end use with all cavity insulation, air gaps and fixings include. The fire source is a linear propane burner 1.2 m x 0.1 m in area which is located 0.25 m below the bottom edge of rear wall. The burner has a constant 100 kW output which is sufficient to achieve direct flame impingement on the bottom 200 mm of the rear wall façade. Temperatures are measured vertical intervals of 0.5 m on the centre of both façade wall surfaces. Heat Flux is measured at the top of the rear façade wall. Fire spread is observed.

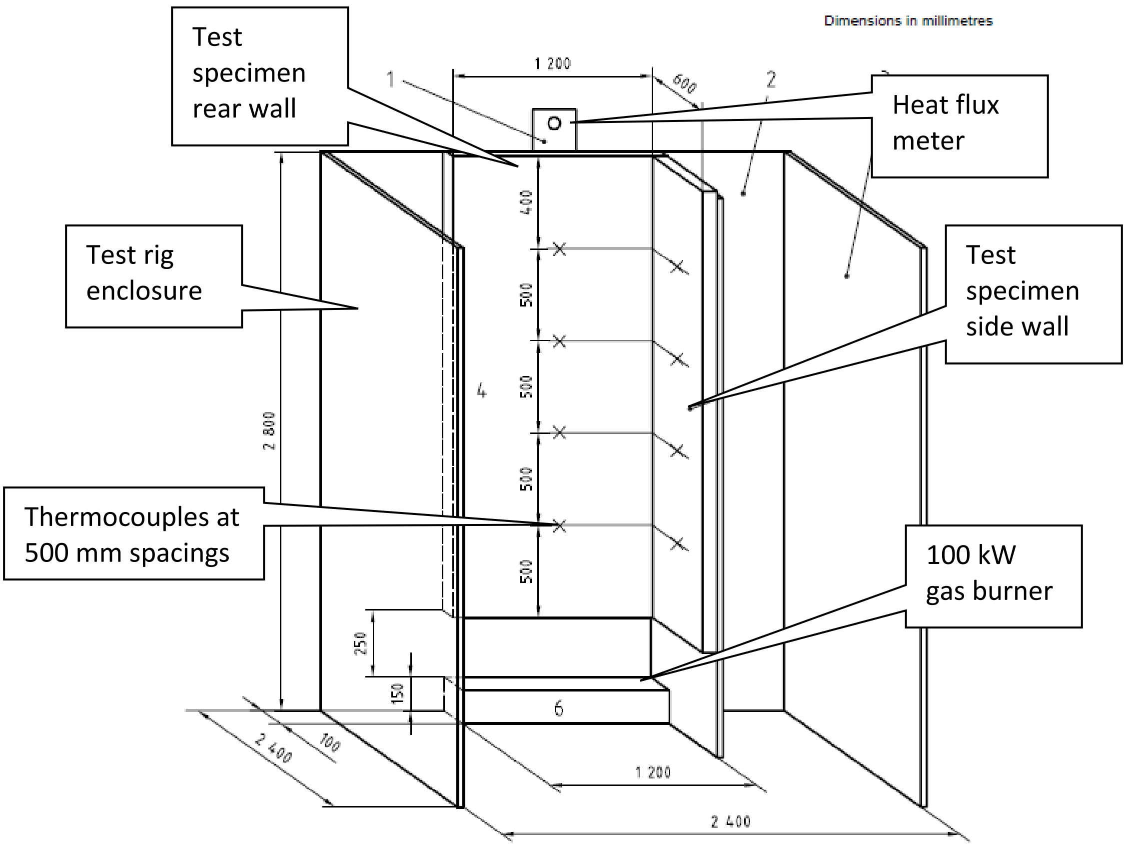


Figure 21. ISO 13785 Part 1 test rig[57]

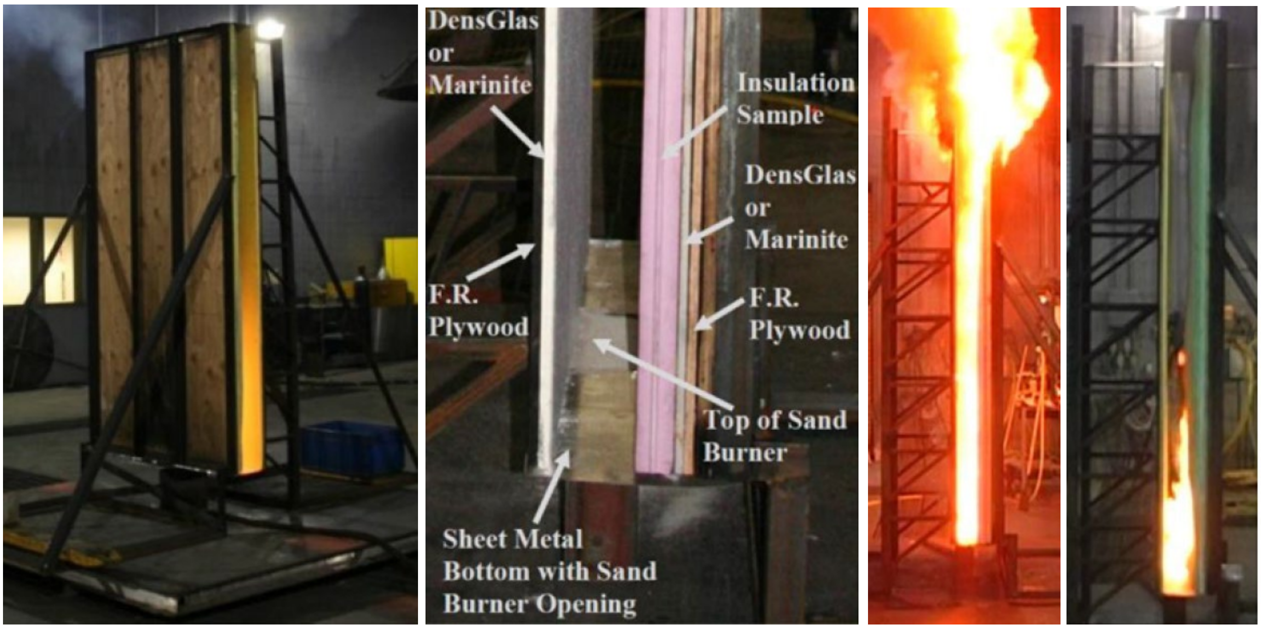
The test standard does not provide any acceptance criteria and does not provide details of any correlation between performance in the Part 1 test and the Part 2 test. The ignition source is significantly smaller than for full scale tests. How this test does provide a useful and less expensive method for quickly screening and comparing alternative systems.

A.8 FM test method for fire spread within cavity wall systems.[30, 58]

FM 4411[30] 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[58]. 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 loc–ted 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 contribution must not exceed an HRR of 100 kW and must not exceed a visible flame height of 1.8 m.



(a) (b) (c) (d)

Figure 22. FM 4411 Cavity fire spread test. (a) and (b), apparatus. (c) poor performing insulation. (d) good performing insulation

FM 4411 applies this test method for approval of combustible cavity insulation tested contained within non-combustible wall lining/cladding. However, this method could potentially have application in assessing/understanding fire spread performance of ACP exposed to small cavity fires where the back face of the ACP is exposed to the cavity (with or without additional combustible insulation).

A.9 AS 5113:2016: Classification of external walls of buildings based on reaction-to-fire performance

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, and
- Building-to-building (BB) – ignition and fire spread performance in response to radiant heat exposure from an adjacent building fire.

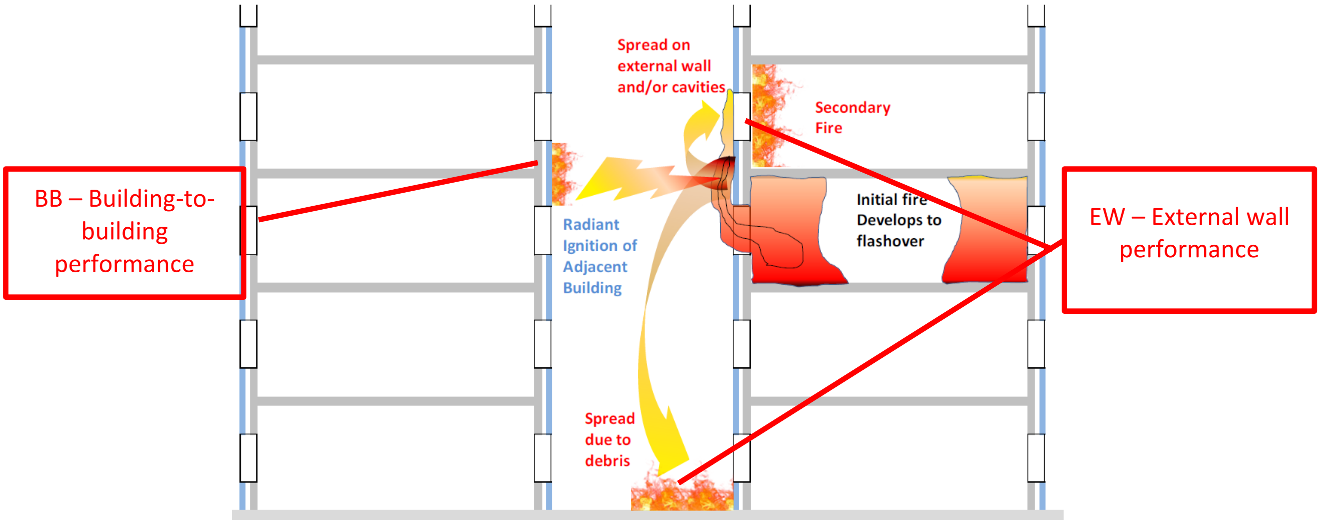


Figure 23. The difference between AS 5113 EW and BB fire performance

<u>External wall (EW) Classification test</u>

External wall (EW) fire tests are required to be performed according to ISO 13785-2 or BS 8414 (with some additional measurement requirements). In practice, all Australian test labs are currently only testing according to BS 8414 as this is more commonly adopted internationally. The VBA's test was performed according to BS 8414-2: 2015+A1:2017.

BS8414-2 is a full-scale fire test for non-load bearing external cladding systems fixed to and supported by a structural steel frame. In the case of the VBA test specimen, this represented a light weight rendered EPS infill wall construction.

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 wall extends at least 6 m above the combustion chamber (simulated window) soffit. The main wall is at least 2.6 m wide and the wing wall is at least 1.5 m wide. The combustion chamber at the base of the main wall is 2 m wide x 2 m high. The façade is installed around the window down to the bottom of the window.

Thermocouples to measure temperatures are installed at the following locations:

- non-fire side (rear of interior facing wall) 900 mm above combustion chamber opening,
- level 1, exposed face 2.5 m above combustion chamber opening, and

- level 2, exposed face and internal wall system cavities and insulation layers 5 m above combustion chamber opening.

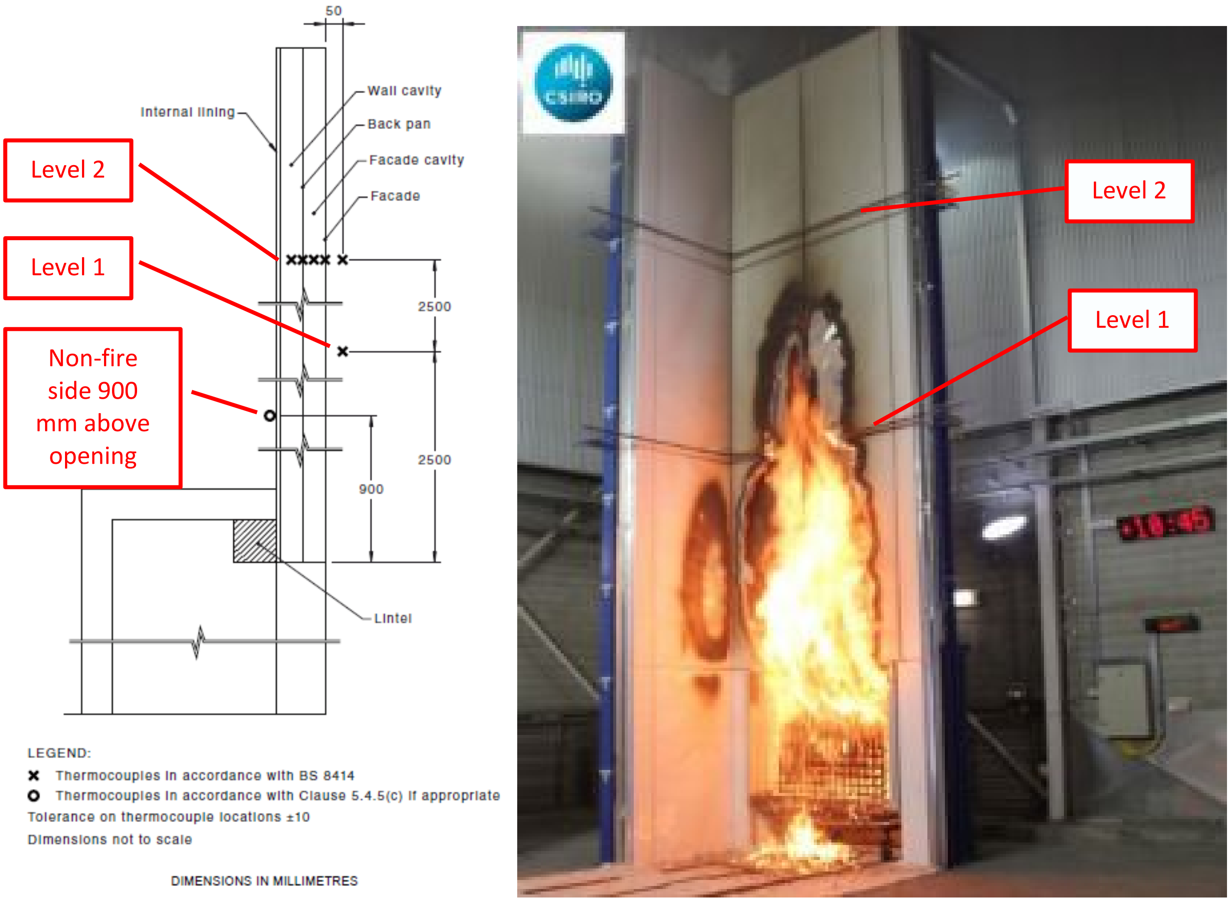


Figure 24. AS5113 thermocouple locations (left), Example of CSIRO AS5113/BS8414 test rig (right)

The standard fire source is a large timber crib which has:

- dimensions 1.5 m wide x 1 m deep x 1 m high
- mean mass of ~ 400 kg, and
- peak HRR of ~ 3±0.5 MW.

The crib is removed/extinguished 30 minutes after ignition, or earlier where flame spread beyond the extents of the test specimen occurs.

Start time (t_s) is defined in BS 8414 to account for time taken for crib fire to grow from ignition to a sufficient size to impact upon the face of the test wall system as early crib development time can be variable. Start time (t_s) is defined to be the time any external thermocouple at level 1 height is ≥ 200 °C above ambient temperature for at least 30 seconds.

The EW classification criteria relating to BS8414 tests is specified in Clause 5.4 of AS 5113:2016. The criteria and the risk mitigation intent is summarised below.

Table 19 AS 5113:2016 EW classification criteria applied to BS 8414 test method:[3]

Classification Criteria		Related classification measure	Risk mitigation intent of criteria
5.4.5(a) T_{w5m}	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 seconds.	≤600°C	Prevention of fire spread to the two floor levels above fire.
5.4.5(b) $T_{layer5m\text{ - }Cavity}$	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 seconds.	≤250°C	Prevention of incipient fire spread to the two floor levels above fire.
5.4.5(b) $T_{layer5m\text{ – }insulation}$			
5.4.5(c) $T_{unexposedside0.9m}$	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.	≤180 K rise	Prevention of fire spread to the floor above if wall not fire resistant.
5.4.5(d) flaming	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.	No flaming	
5.4.5(d) openings		No openings	
5.4.5(e) spread	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.	No Spread beyond specimen	Prevent fire spread to two floor levels above fire and lateral spread
5.4.5(f) debris flaming	Continuous flaming on the ground for more than 20 s from any debris or molten material from the specimen shall not occur.	≤20 s	Prevent fire spread to floors below
5.4.5(g) debris mass	The total mass of debris falling in front of the specimen shall not exceed 2kg. The mass shall be measured after the end of the test result.	≤2 k	Limit debris impact with fire fighters, occupants and passers-by

All of the above criteria must be met for a wall system to achieve the AS 5113:2016 EW classification.

Building-to-building classification test

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/m^2
BB80	80
BB40	40
BB20	20
BB10	10

[3] AS 5113:2016 Clause 5.4.5 and Table B4.1(B) of Attachment B.

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.

Appendix B EPS Concrete density measurement

B.1 Scope

This Appendix provides guidance on amethod for measuring the bulk density of EPS concrete specimens sampled from buildings. This method is intended to provide practical field measurement of bulk density with a coarse accuracy sufficient for the purposes of comparison against the typical known range of fire tested EPS concrete product. This method is not intended to provide high accuracy measurements.

B.2 References

The following documents informed this Appendix.

Reference	Description
Van Keulen, J. "Density of porous solids." Matériaux et Construction 6.3 (1973): 181-183.	Paper presents various different methods for measuring density of porous solids and discusses their pro's and cons.
Berger, M. B. (2010). The importance and testing of density/porosity/permeability/pore size for refractories. In The Southern African Institute of Mining and Metallurgy Refractories Conference (pp. 101-116)	Paper presents various different methods for measuring density of porous solids and discusses their pro's and cons.
AS ISO 10545.3:2020, "Ceramic Tiles – Method 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density"	This standard describes how to measure bulk density of porous tiles based on mass measurement and water displacement. A key difference is that tiles are denser than water whereas EPS concrete is less dense than water.
ASTM D729-07. Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement	Applies to non-porous plastics. Uses an immersion vessel supported on top of balance with specimen hung and submerged in vessel from above. Attaches a sinker (of known volume) to specimen where specimen density is less than density of water.
ISO 1183-1: Plastics — Methods for determining the density of non-cellular plastics	Similar methods to ASTM D729-07. Applies to non-porous plastics.
OIML G 14: 2011 "DENSITY MEASUREMENT - GUIDANCE FOR INSPECTORS", Organisation Internationale de Metrologie Legale	A range of different density measurement methods. Primary focused on measuring density of pre-packaged food products.
ASTM D7263 – 21. Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens	Focused on density of compacted soil (core) specimens. Provides method for coating exterior of sample in wax and then measuring volume/density by water displacement.
ASTM B 962-08. Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle	Density measurement of porous metal products by oil impregnating the product (to fill pores) and then measuring volume by water displacement.
ISO 12154:2014(en) Determination of density by volumetric displacement.	Skeleton density by gas pycnometry. Measures true/skeleton density not bulk density.

B.3 Definitions

Bulk density $\rho_{Bulk}(m^3/kg)$	The mass of a material per unit external volume, including the volume taken up by any internal voids or pores within the material. Also known as Apparent Density.
Bulk Volume $V_{Bulk}(m^3)$	External volume of a material, including the volume taken up by any internal voids or pores within the material.
True density	The mass of a material per unit real volume excluding all internal voids or pores (skeletal volume). Also known as absolute density.
$\emptyset_{Outer}$	Outer diameter of hole saw sample (mm)
$\emptyset_{Inner}$	Inner diameter of hole saw sample, measure across central arbour drill hole (mm)
$m(g)$	Mass of specimen (grams)

B.4 Principle

Simply weigh the specimen and calculate the bulk volume based on external dimensional measurement.

A previous version of this report did provide guidance on an alternative method of density measurement based on immersion of specimens in water and measurement of displacement of water. However it was concluded that due to variable and partial absorption of water into voids within specimens this method is not appropriate and is not recommended. This method has been removed from this revision of the report.

B.5 Apparatus

1. Balance – minimum resolution /accuracy of 0.1 g. Recommended measuring range of 0-2000 g
2. Vernier or digital callipers with a minimum resolution/accuracy of 0.1 mm.
3. Steel rule with 1 mm increments.
4. Hand saw for cutting specimen to right angled cuboid shape.

B.6 Test specimens

Note –it is possible that there may be some variation in bulk density between batches of product used on a building. For this reason, it is ideally recommended that specimens be sampled from at least 3 different locations on a subject building if practical/possible.

The intention is to measure the bulk density of the product in its normal condition as used on the subject building. As a practical field test, drying or conditioning of the specimens at controlled temperature and humidity prior to measurement is not required. However, measurement should not be undertaken on any specimens that have obvious signs of being exposed to high levels of moisture or water.

For all methods, the render layer must be completely removed so that only the bulk density of the core material is measured.

Specimens must ideally be a right-angled cuboid shape with minimum dimensions of approximately 100 mm x 100 mm x complete thickness of EPS concrete cladding panel (typically~ 50 mm). Alternatively a circular core sample using a hole saw at least ~ 100 mm in diameter and 50 mm in depth is recommended. Note: Measurement of a single specimen of this size from each sample location is sufficient.

- Avoid using a hole saw with a centre arbor bit that may make removal of the core specimen without crumbling, and the density calculations more challenging and less accurate. This would typically require the use of a hole saw guide plate to be used at the external surface of the wall to stop the hole saw from wandering.

- Care must be taken when removing samples from hole saws to prevent them from breaking or crumbling as volume and density can only be accurately measured for regular shaped specimens.
- Avoid taking from areas with high exposure to moisture to avoid errors in mass and potential future moisture penetration of the building.
- Smaller specimens of the order of 40 mm -50 mm hole saw samples are not recommended for density measurement as they are prone to crumbling into irregular shapes and the smaller specimen reduces the accuracy of the measurement. 40-50 mm samples are only recommended for laboratory tests such as solvent dissolution, FTIR, XRD etc.

B.7 Procedure

Note that all measurements in the procedure below (except for the final calculated bulk density) are in millimetres and grams as these are the most convenient units for the specimen sizes used. The final bulk density calculated is in the units kilograms per meter cubed (kg/m^3).

1. Ensure that the specimen has been cut to a regular shape that bulk volume can be easily calculated for.
2. Measure and record all external dimensions required to calculated bulk volume. It is recommended to measure each dimension at three evenly spaced locations across the given measurement axis of the specimen and apply the average for each dimension required for the volume calculation. It is recommended to take photos of specimens with measurement device showing measurements as a record.
3. Calculate and record the bulk volume in ml:
    a. For right angle cuboid specimens:
    $$V_{Bulk}(m^3) = \frac{width(mm) \times length(mm) \times height(mm)}{10^9}$$
    b. For hole saw section specimens:
    $$V_{Bulk}(m^3) = \frac{\pi \times \left[\left(\frac{\emptyset_{Outer}}{2}\right)^2 - \left(\frac{\emptyset_{Inner}}{2}\right)^2\right] \times length(mm)}{10^9}$$
    Where:
    $\emptyset_{Outer}$= Outer diameter of hole saw sample (mm)
    $\emptyset_{Inner}$= Inner diameter of hole saw sample, measure across central arbour drill hole (mm).
4. Measure and record mass of specimen *(m)* in grams. It is recommended to take photos of specimens on balance showing measurements as a record.
5. Calculate and record bulk density:
$$\rho_{Bulk}(kg/m^3) = \frac{m(g)/1000}{V_{Bulk}(m^3)}$$
6. If measuring density of multiple specimens sampled from the same location, repeat the above steps for each specimen and calculate the average and standard deviation for all specimens sampled from the same location.

B.8 Accuracy and repeatability

No formal accuracy or repeatability has been calculated for the above method. CSIRO conducted some preliminary trials of the above method (see section B.10). The results of these trials have been used to inform a very rough estimation and discussion of accuracy as follows:

- Applied to large specimens (~ 100 x 100 x 50 mm or greater) – The accuracy is most dependant on how accurately square the specimen is cut and measured. If care is taken (eg using set squares to mark and cut the specimen) then the accuracy is estimated to be ~ ±2-3%.
- Applied to small specimens (~ 40 mm x 40 mm x 20 mm or 50 mm hole saw sections cut to consistent length) – in the trial, the average bulk density calculated via this method was within less than 2% of the bulk density calculated for the larger specimen they were cut from. Each individual specimen bulk density calculated did not vary more than 3% from the measurement of the larger specimen they were cut from. The standard deviation of the three measurements for each specimen was 6.0 or less. Accuracy is dependent on how accurately the specimen is cut square and measured. The accuracy is reduced due to the reduced specimen size. Overall accuracy is estimated to be ~ ±5%. However this accuracy assumes that the specimen is cut to a regular shape without significant crumbling. If the specimen is an irregular or crumbled shape then measurement of the volume is likely to have an unacceptable error.

B.9 Reporting of results

The following details should be reported.

1. Name and address of the laboratory or organisation conducting the measurement
2. Address of building specimens were sampled from, and details of each sample location, including photos showing the sample location if samples were taken by the testing organisation
3. The date the specimens were sampled from the subject building and/or received by the testing organisation
4. The date the specimen bulk density measurements were undertaken.
5. The name of the person undertaking the measurements and writing the report.
6. A unique specimen numbering for each specimen tested and a description of the physical appearance and colour of the specimens including photos of each specimen.
7. Details of the measurement method and equipment used.
8. For each specimen, clearly present the individual measurements and calculated results as specified in the procedure above. Where multiple specimens from the same location are tested, the average bulk density measurement and standard deviation must also be reported. All measurements and results should ideally be recorded in a table format.
9. The following clarifying statement "*The methods applied are intended to provide practical field measurement of bulk density with a coarse accuracy sufficient for the purposes of comparison against the typical known range of fire tested EPS concrete product. These methods are not intended to provide high accuracy measurements.*"

B.10 Preliminary trials on two types of EPS concrete

To trial the above methods, CSIRO conducted trial tests on two different types of EPS concrete material. The results are recorded below

Table 21. Test organisation details

Name and address of the laboratory or organisation conducting the measurement	CSIRO, Infrastructure Technologies: Private bag 10, Clayton South, VIC, 3169, Australia
The date the specimen bulk density measurements were undertaken	4/08/2021
The name of the person undertaking the measurements and writing the report	Nathan White

Table 22 Specimen description

	Material Type 1	**Material Type 2**
Material description	EPS concrete – manufacturer/product name unknown - Not a QT product. Based on materials characterization testing and visual inspection by CSIRO the product appears to be a different product to QT wall systems having a significantly different Cementitious mineral composition. The mineral content has been assessed to be 78-96% mass with the major mineral component identified as similar to magnesium oxychloride type minerals being either Chlorartinite ($Mg_2(CO_3)Cl(OH)\cdot3(H_2O)$) or Magnesium chloride hydroxide hydrate. The exact manufacturer/brand of the product used has not been determined. Visually it is noted that on external side of panel there is more cementitious material and less EPS beads. This indicates the product may have been produced by pouring/casting the panels with some settling of EPS away from one side of the panel. This can impact density measurement dependant upon how the specimens are cut.	Grey core QT Conpolcrete® EPS beads is homogenously mixed in grey cement matrix with the major mineral components identified as Quartz, Portlandite and Calcite.
Photo		
Address of building specimens were sampled from, and details of each	Not disclosed – Specimens sampled from existing building. Details not to be identified in this report	Sample product provided as reference specimen to CSIRO by QT wall systems. Not sampled from existing building

sample location		
Date specimens received	Specimens received by CSIRO during June 2021	Provided to CSIRO in 2019

All density measurement methods as stated in procedure above were applied for both materials.

Trial measurements were repeated in two rounds for both materials

Note that the density measured for material 1 in round 1 and round 2 is significantly different. This is because there was more cementitious material and less EPS beads at the external surface of the material 1. For round 1 this denser cement layer was left on the specimens. For round 2 the specimens were cut to remove this layer of denser cement material, reducing the panel thickness from 48mm to 42 mm and reducing the total bulk density of the specimen.

Table 23. Specimen numbers and measurement methods applied

Material type	Specimen number	Specimen details
Round 1		
Material Type 1	FE2977-9-MAT1 – Bulk1	Large specimen (prior to cutting larger specimen into 3 smaller specimens below)
	FE2977-9-MAT1 – Spec1	Small specimens
	FE2977-9-MAT1 – Spec2	
	FE2977-9-MAT1 – Spec3	
Material Type 2	FE2977-9-MAT2 – Bulk1	Large specimen (prior to cutting larger specimen into 3 smaller specimens below)
	FE2977-9-MAT2 – Spec1	Small specimens
	FE2977-9-MAT2 – Spec2	
	FE2977-9-MAT2– Spec3	
Round 2		
Material Type 1	FE2977-9-MAT1 – Bulk2	Large specimen (prior to cutting larger specimen into 3 smaller specimens below)
	FE2977-9-MAT1 – Spec4	Small specimens
	FE2977-9-MAT1 – Spec5	
	FE2977-9-MAT1 – Spec6	
Material Type 2	FE2977-9-MAT2 – Bulk1	Large specimen (prior to cutting larger specimen into 3 smaller specimens below)
	FE2977-9-MAT2 – Spec4	Small specimens
	FE2977-9-MAT2 – Spec5	
	FE2977-9-MAT2 – Spec6	

Table 24. Round 1 – Material 1 Results

Density measurement applied to larger specimen prior to cutting into smaller specimens					
Specimen number	FE2977-9-MAT1 – Bulk1				
width (mm)	48				
Depth (mm)	44				
height (mm)	100.5				
mass (g)	75.7				
Calculated bulk volume (ml)	212.3				
Calculated bulk density (kg/m3)	356.6				
Density measurement applied to small specimens cut from larger specimen above					
Specimen	FE2977-9-MAT1 – Spec1	FE2977-9-MAT1 – Spec2	FE2977-9-MAT1 – Spec3		
width (mm)	48.2	44.9	43.7		
Depth (mm)	44.4	48.3	48.5		
height (mm)	32.6	31.3	33.6		
M_1 - mass prior to submersion in water (g)	25.3	23.8	25.3		
Bulk volume (ml)	69.8	67.9	71.2	Average	St Dev
bulk density	362.6	350.6	355.3	356.2	6.1
Percent difference from method 1 large specimen (%)	1.65%	-1.72%	-0.39%	-0.13%	

Table 25. Round 1 – Material 2 Results

Method 1 - Applied to larger specimen prior to cutting into smaller specimens					
Specimen number	FE2977-9-MAT2 – Bulk1				
width (mm)	50.9				
Depth (mm)	101				
height (mm)	202				
mass (g)	399.1				
Calculated bulk volume (ml)	1038.5				
Calculated bulk density (kg/m3)	384.3				
Method 1 – Applied to small specimens cut from larger specimen above					
Specimen	FE2977-9-MAT2 – Spec1	FE2977-9-MAT2 – Spec2	FE2977-9-MAT2 – Spec3		
width (mm)	55.6	54.7	50.7		
Depth (mm)	50.7	50.7	55.1		
height (mm)	33.6	33.4	31.3		
M_1 - mass prior to submersion in water (g)	35.7	34.6	33.4		
Bulk volume (ml)	94.7	92.6	87.4	Average	St Dev
bulk density	376.9	373.5	382.0	377.5	4.2
Percent difference from method 1 large specimen (%)	-1.96%	-2.89%	-0.61%	-1.81%	

Table 26. Round 2 – Material 1 Results

Method 1 - Applied to larger specimen prior to cutting into smaller specimens					
Specimen number	FE2977-9-MAT1 – Bulk2				
width (mm)	101.8				
Depth (mm)	41.9				
height (mm)	44.5				
mass (g)	63.1				
Calculated bulk volume (ml)	189.8				
Calculated bulk density (kg/m3)	332.4				
Method 1 – Applied to small specimens cut from larger specimen above					
Specimen	FE2977-9-MAT1 – Spec4	FE2977-9-MAT1 – Spec5	FE2977-9-MAT1 – Spec6		
width (mm)	44.7	42.3	42.2		
Depth (mm)	42.6	44.6	43.8		
height (mm)	35.1	34.2	30.7		
M_1 - mass prior to submersion in water (g)	21.8	20.9	19		
Bulk volume (ml)	66.8	64.5	56.7	Average	St Dev
bulk density	326.2	323.9	334.8	328.3	5.8
Percent difference from method 1 large specimen (%)	-1.92%	-2.63%	0.72%	-1.26%	

Table 27. Round 2 – Material 2 Results

Method 1 - Applied to larger specimen prior to cutting into smaller specimens					
Specimen number	FE2977-9-MAT2 – Bulk2				
width (mm)	102				
Depth (mm)	50.9				
height (mm)	44				
mass (g)	87.6				
Calculated bulk volume (ml)	228.4				
Calculated bulk density (kg/m3)	383.5				
Method 1 – Applied to small specimens cut from larger specimen above					
Specimen	FE2977-9-MAT2 – Spec4	FE2977-9-MAT2 – Spec5	FE2977-9-MAT2 – Spec6		
width (mm)	44.4	50.8	43.7		
Depth (mm)	51	43.7	50.9		
height (mm)	32	31.7	37.5		
M_1 - mass prior to submersion in water (g)	27.3	26.9	31.5		
Bulk volume (ml)	72.5	70.4	83.4	Average	St Dev
bulk density	376.8	382.3	377.6	378.9	3.0
Percent difference from method 1 large specimen (%)	-1.8%	-0.3%	-1.5%	-1.2%	

Figure 25 Larger round 2 specimens FE2977-9-MAT1 – Bulk2 (left) and FE2977-9-MAT2 – Bulk2 (right) prior to cutting

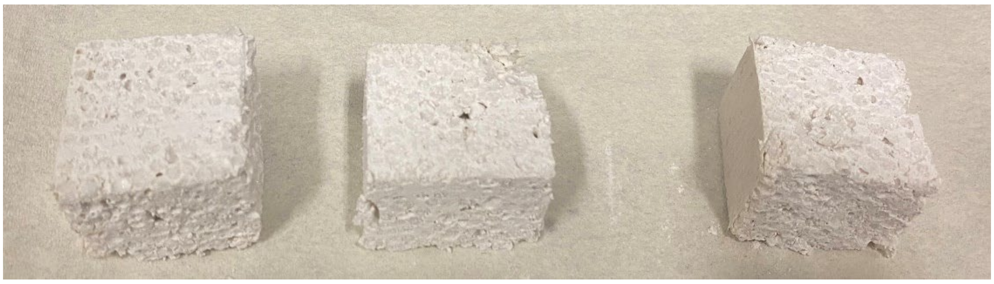


Figure 26. Round 2 material 1 smaller cut specimens. FE2977-9-MAT1 – Spec4 (left), FE2977-9-MAT1 – Spec5 (centre), FE2977-9-MAT1 – Spec6 (right).

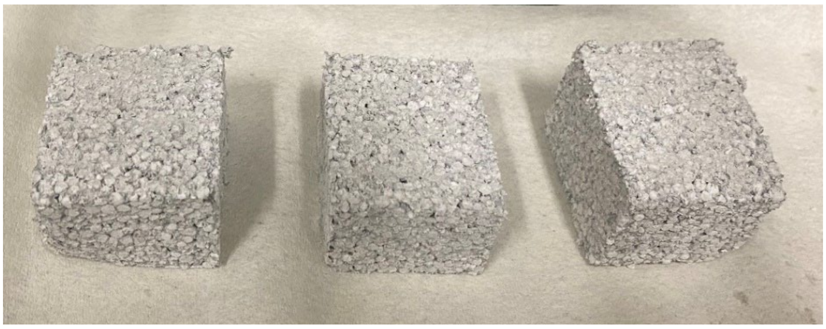


Figure 27. Round 2 material 2 smaller cut specimens. FE2977-9-MAT2 – Spec4 (left), FE2977-9-MAT2 – Spec5 (centre), FE2977-9-MAT2 – Spec6 (right).

CONTACT US

t 1300 363 400
+61 3 9545 2000
e enquiries@csiro.au
w www.csiro.au

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FOR FURTHER INFORMATION

Infrastructure Technologies
Alex Webb
Group Leader Victoria
t +61 3 9545 2584
e alex.webb@csiro.au
w www.csiro.au/en/Portals/Partner/Services/Technical-Services/Industrial-research-services.aspx

Infrastructure Technologies
Mark Burgess
General Manager
t +61 3 9545 2114
e mark.burgess@csiro.au
w www.csiro.au/org/CMSE