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Ministry of Housing, Communities and Local Government Final Research Report

Fire Performance of Cladding Materials Research

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Executive Summary

The authors of this report are employed by BRE Global. The work reported herein was carried out under a Contract placed by the Ministry of Housing, Communities and Local Government. Any views expressed are not necessarily those of the Ministry of Housing, Communities and Local Government.

The Technical Policy Division of the Ministry of Housing, Communities and Local Government (MHCLG) commissioned BRE Global to carry out a research project, titled “The fire performance of cladding materials”, MHCLG contract reference CCZZ17A36.

The aim of this project was to investigate the burning behaviour of selected types of non-ACM (non-aluminium composite material) cladding products using physical testing at intermediate scale in a laboratory setting to identify materials/products of potential concern so that MHCLG can consider the risk of their contribution to external fire spread when used as part of a system and ensure that its guidance is adequate.

The specific objectives of the project were:

- To improve the understanding of the burning behaviour for selected cladding materials/product samples
- To improve the understanding of safety levels within the buildings in which the selected cladding materials/products are installed
- To identify cladding materials/products that require further investigation.

The research was led by BRE Global and included contributions from experts from the Universities of Edinburgh and Lund who provided valuable input and review to all the deliverables produced over the course of the project.

The work also involved the active participation of a Project Steering Group of industry experts.

The project was broken down into a number of specific tasks:

- Task 1 Start up
- Task 2 Project Steering Group activities
- Task 3 Literature review
- Task 4 Agree types of cladding materials/products for the experimental programme
- Task 5 Agree experimental methodology and performance analysis
- Task 5a Numerical design of the experimental rig and performance
- Task 6a Construction and design of experimental rig and carry out calibration exercise
- Task 6 Carry out main experimental programme
- Task 7 Analysis of experimental results
- Task 8 Preparation of publishable report (this report)
- Additional task Supplementary experimental programme.

This Final Research Report consists of a short main summary report and supporting Appendices containing the full technical details. This Final Research Report provides an overview of the whole project and summarises the work conducted, the analysis and conclusions.

A literature review was undertaken to establish the current state of knowledge concerning the fire performance of cladding materials/products.

A prioritised list of types of cladding materials/products for the experimental programme was drawn up and the experimental methodology and the analysis of performance were developed.

The experimental rig was designed and constructed, and a calibration exercise was carried out prior to the main experimental programme.

Numerical modelling and a series of calibration burns using first a propane burner and then timber cribs were undertaken to define the appropriate timber crib ignition source for the experimental programme.

As a part of the material calibration procedure and to establish a system for ranking different materials, it was necessary to assess performance in relation to a material with a known level of performance in terms of gross heat of combustion. For this reason, aluminium composite material (ACM) was chosen to provide the likely range of expected outcomes. The thickness of the ACM material was 4.0 mm, consisting of 0.5 mm aluminium faces on both sides and a 3.0 mm solid core. Three different types of ACM were used, incorporating polyethylene core (PE), fire retardant core (FR) and limited combustibility core (A2). Six ACM calibration burns were undertaken, consisting of two samples of each of the three ACM categories.

The main experimental programme was carried out, involving the analysis of the fire performance of five generic product typologies used to provide the external face of cladding systems. These generic product typologies were identified and prioritised based on the input and discussion within the Project Steering Group (with representation from across the construction sector) and with MHCLG. During the course of the project two additional product typologies (zinc composite material and copper composite material) were selected by MHCLG and included in the experimental programme.

The generic product typologies experimentally examined were: aluminium honeycomb panels, high pressure laminate panels, zinc composite panels, copper composite panels, reconstituted stone and brick slip systems. Twenty two individual materials/products were subjected to a fire exposure designed to impose a level of heat flux to the samples corresponding to that imposed during a real post-flashover fire incident where the cladding panels are exposed to flames emerging from a window opening.

A supplementary experimental programme was carried out at the request of MHCLG to evaluate the fire performance of untreated timber and a broader range of high pressure laminate types. These materials/products were subsequently added to this work programme to provide additional data for the analysis of the fire performance.

The samples included repeat exposures for specific types where there was no variation in thickness. Where products were supplied to the market with different constituent materials or a range of thicknesses, these variations were incorporated into the experimental programme.

In each case, the results from the experiments were compared with the base contribution from the ignition source and the measured contribution from polyethylene aluminium composite material (PE ACM) panels investigated as part of the calibration process used to develop the experimental methodology. In each case, the performance analysis was based on the overall contribution to fire growth and the potential for development of a cavity fire incident. The performance analysis was based on quantifiable measurements of heat release rate, total heat release, heat flux and temperatures close to the samples and within the cavity space behind the samples and also visual observation of damaged area and extent of flame spread.

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The findings of this work have shown that:

- None of the samples investigated shows the same or a similar type of fire performance to that of the PE ACM panels, whether in relation to contribution to fire growth, fire spread or potential issues with breakthrough of fire and initiation of cavity fires.
- Based on the results from the experimental programme, metal composite panels containing polyethylene (not included in the experimental programme) may be expected to give a similar fire performance to PE ACM panels. However, it was not possible to validate this as it was not possible to procure such panels for this project as they were not available in the market.
- There is no evidence based on the experiments conducted that any of the materials/products studied represent a similar risk to the PE ACM panels.
- In terms of relative performance, zinc composite material exhibited the highest contribution to fire growth and shortest time to burn through. The most significant cavity fire and the largest measured heat flux at the top of the specimen was recorded for the copper composite panels where no breakthrough of the panels took place.
- The aluminium honeycomb panels, the reconstituted stone panels and the brick slip systems exhibited a relatively low contribution to fire development characterised by heat release rate and fire spread.
- The results for the HPL samples classified C – s1, d0 and intended for internal use and one of the timber cladding samples exhibited sustained vertical fire spread beyond the area of direct flame contact produced by the crib ignition source. In each of these cases, the extent of horizontal (or lateral) fire spread appears to have been constrained by the metal framing system to which the samples were fixed. This suggests that the results in these experiments are particularly sensitive to the mounting and fixing arrangements and in the case of the HPL samples, the location of the vertical joint relative to the crib ignition source. The vertical joint on the centreline of the crib ignition source appears to represent the worst case in terms of penetration of the fire into the cavity.

Based on the detailed results from the work carried out in this project, it is recommended that further work is conducted to establish the impact of the joint location on the outcome from the experiments as well as the relationship between some of the materials/products in conjunction with different types of insulation in the cavity. This work would require both intermediate and large-scale investigation to establish the impact of variables such as insulation type, thickness and cavity depth on an intermediate scale and then large-scale tests to validate the impact of scale. This further analysis should include metal composite materials and standard and FR HPL panels.

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1 Acknowledgements

The authors would like to thank other members of the Project Team including colleagues at BRE Global, the University of Edinburgh and the University of Lund.

A Project Steering Group was established at the start of the project. The Group met twice: the first meeting was held on 12 April 2018 and the second meeting was held on 9 October 2019. At the first meeting of the Project Steering Group, the finalised scope was presented and input to the project was requested. Steering Group members provided details of relevant information for the literature review, details of products/materials currently being used as elements within a cladding system and views or comments on the proposed methodology for the experimental programme. At the second meeting of the Project Steering Group, the experimental programme results were presented and discussed.

The following organisations were represented on the Project Steering Group:

- Ministry of Housing, Communities and Local Government (MHCLG)
- BRE Global (Project team)
- University of Edinburgh (Project team)
- University of Lund (Project team)
- Association of Consultant Approved Inspectors (ACAI)
- Association of Specialist Fire Protection (ASFP)
- Build UK
- Chartered Association of Building Engineers (CABE)
- Construction Products Association (CPA)
- Fire Brigades Union FBU
- Fire Industry Association (FIA)
- Fire Sector Federation (FSF)
- FMDC Ltd
- Government's Expert Panel
- Institution of Fire Engineers (IFE)
- The Insulated Render and Cladding Association (INCA)
- Local Authority Building Control (LABC)
- Metal Cladding and Roofing Manufacturers Association (MCRMA)
- National Fire Chiefs Council (NFCC)
- National House Builders Council (NHBC)
- The Peabody Trust

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- Building Control Professional Group, RICS
- Society of Façade Engineering (SFE)
- Scottish Government
- Welsh Government

The authors would also like to acknowledge the companies who provided material and product panels for this project.

2 Introduction

The Technical Policy Division of the Ministry of Housing, Communities and Local Government (MHCLG) commissioned BRE Global to carry out a research project, titled “The fire performance of cladding materials research”, MHCLG contract reference CCZZ17A36.

The aim of this project was to investigate the burning behaviour of selected types of non-ACM (non-aluminium composite material) cladding products using physical testing at intermediate scale in a laboratory setting to identify materials/products of potential concern so that MHCLG can consider the risk of their contribution to external fire spread when used as part of a system and ensure that its guidance is adequate.

The specific objectives of the project were:

- To improve the understanding of the burning behaviour for selected cladding materials/product samples
- To improve the understanding of safety levels within the buildings in which the selected cladding materials/products are installed
- To identify cladding materials/products that require further investigation.

The research was led by BRE Global and included contributions from experts from the Universities of Edinburgh and Lund who provided valuable input and review of all the deliverables produced over the course of the project.

The work involved the active participation of a Project Steering Group of construction industry experts.

The project was broken down into a number of specific tasks:

- Task 1 – Start up
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- Task 7 – Analysis of experimental results
- Task 8 – Preparation of publishable report (this report)
- Additional task – Supplementary experimental programme.

This Final Research Report consists of a short main summary report and supporting Appendices containing the full technical details. This Final Research Report provides an overview of the whole project and summarises the work conducted, the analysis and conclusions.

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3 Project summary

The research reported here was commissioned by the Ministry of Housing, Communities and Local Government (MHCLG) to investigate the burning behaviour of selected types of non-ACM (non-aluminium composite material) cladding products using physical testing at intermediate scale in a laboratory setting to identify materials/products of potential concern so that MHCLG can consider the risk of their contribution to external fire spread when used as part of a system and ensure that its guidance is adequate.

Following on from the Grenfell Tower fire and a number of high-profile external fire incidents throughout the world involving cladding materials, there is a need for regulators to assess the potential risk in relation to external fire spread of materials/products currently used on buildings.

This project has focused specifically on the potential performance in the event of a fire exposure representative of direct flame impingement from a fully developed fire breaking out of a compartment through a window opening on the materials/products forming the external panels of a cladding system. It should be noted that the interaction of the various components of a cladding system such as insulation products, fillers, gaskets, cavity depth or cavity fire barriers have not been considered.

The summary of the research programme is presented as the outcome from a series of specific tasks. The detailed information related to the main project tasks is provided in the individual Appendices to this summary report.

3.1 Literature review

A literature review was undertaken covering a number of specific areas related to the fire performance of cladding materials/products and systems used in the construction of cladding to the external facades of buildings. These areas were: examples of fire spread from real fire incidents; a description of the regulatory framework with regard to external fire spread; a description of the test and assessment procedures used to determine the compliance of cladding materials/products and systems in fire and a summary of relevant research in this area.

The literature review is found in Appendix A.

3.2 Types of cladding product typologies for the experimental programme

A prioritised list of types of cladding product typologies for the experimental programme was drawn up, based on consultation with MHCLG and the input of the Project Steering Group.

Details of the types of cladding product typologies selected for the experimental programme and the input provided by the Project Steering Group are found in Appendix B.

There was a difference between the initial list and the product typologies examined in the experiments. This reflected the dynamic nature of the project. Zinc composite material and copper composite material were identified by MHCLG during the course of the project and were included in the experimental programme.

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3.3 Experimental methodology and performance analysis

The experimental methodology and the analysis of performance were developed by the BRE Global Project team with input from the Project Steering Group. The approach adopted was based on the following principles:

- The samples were supported on a steel frame to allow for rapid assembly/disassembly to minimise the time required for installation and maximise the number of experiments conducted.
- The imposed heat flux to the surface of the materials/products was representative of that expected from a fully developed post-flashover compartment fire scenario.
- The evaluation of performance was based on the contribution of the specific materials/products to flame spread, heat release and incident heat flux, as well as the maintenance of integrity.
- The performance was evaluated in relation to the fire performance characteristics of PE ACM panels known to constitute an unacceptable risk of rate of fire growth and fire spread.
- The methodology adopted was designed specifically to consider the performance of external cladding panels in isolation from other system components.

Details of the proposed experimental methodology and performance analysis are found in Appendix C.

3.4 Construction and design of experimental rig and calibration exercise

Numerical modelling was undertaken to provide initial input into the definition of a credible and repeatable fire source for use in the experimental programme.

The experimental rig was constructed from a hot rolled steel frame made up of rectangular, hollow steel sections. Vertical mild steel angles were fixed to the frame and used as the support for aluminium T rails mechanically fixed back to the steel angles and used as the primary fixing locations for all subsequent samples. A non-combustible substrate, calcium silicate board, was fixed to the back of the rig to facilitate installation of instrumentation and to provide a cavity space behind the experimental samples.

A series of calibration burns was undertaken using initially a propane burner and subsequent timber cribs as ignition sources and the results were used to define the appropriate ignition source for the experimental programme. On the basis of the results from the calibrations, a crib ignition source, consisting of 40 sticks of 50 mm by 50 mm by 500 mm softwood, placed in contact with the centre of the experimental sample, was selected as the chosen ignition source to provide an incident heat flux of between 45 and 75 kW/m^2 on the non-combustible board at a point 1 m above the crib on the centre line.

As a part of the calibration procedure and to establish a system for comparing different materials, it was necessary to assess performance in relation to a material/product with a known level of performance in terms of gross heat of combustion and large scale behaviour. For this reason, aluminium composite material (ACM) was chosen. The thickness of the ACM material was 4.0 mm, consisting of 0.5 mm aluminium faces on both sides and a 3.0 mm solid core. Three different types of ACM were used, incorporating polyethylene core (PE), fire retardant core (FR) and limited combustibility core (A2). Six ACM calibration burns were undertaken consisting of two samples of each of the three ACM categories.

Details of the construction and design of the experimental rig and the calibration exercise are found in Appendix D.

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3.5 Main experimental programme

Twenty two experimental fires were conducted for various product typologies including aluminium honeycomb panels, high pressure laminate panels, zinc composite material panels, copper composite panels, reconstituted stone panels and brick slip systems. The samples were subject to identical conditions in terms of the overall geometry and the location of the ignition source.

There was some variation in the location of the vertical panel joints between samples. The difference was a function of the supplied width of the panels. In effect, this meant that, generally the vertical panel joint was offset from the ignition source for most of the experiments while for certain samples (PE ACM panels used for calibration, zinc and copper composite panels) the vertical panel joint was coincident with the centre of the ignition source. The impact of varying the joint location in the experiments has not been systematically examined at this time as there was insufficient material available.

Details of the experimental programme are found in Appendix E.

3.6 Analysis of experimental results for the main experimental programme

Details of the analysis of experimental results for the main experimental programme are found in Appendix F.

The evaluation of performance has been undertaken based on generic groupings and related to the base level contribution provided by the ignition source and the measured and observed performance for the PE ACM samples considered during the calibration process. Analysis has focused on the measurements, heat release rate, total heat release, incident heat flux and temperature, and visual observations in relation to spread of fire, nature and extent of the damage to the panels and visible flaming within the cavity.

The evaluation of the performance of the individual cladding panels is complex and depends on the combination of the results from the quantifiable measurements and the observed behaviour. Consideration of one aspect in isolation may lead to a misinterpretation of the nature of the potential hazard.

Based on the experiments conducted and subject to the constraints of the approach adopted, the following conclusions can be drawn:

- None of the samples investigated shows the same or a similar type of fire performance to that of the PE ACM panels, whether in relation to the contribution to fire growth, fire spread or potential issues with breakthrough of fire and initiation of cavity fires. All the samples included in this main experimental study to date had an indicative (based on information from manufacturers' websites) reaction to fire performance of at least Class B (European classification) or Class 0 (national classification).
- Although not included in the current experimental programme due to the unavailability of zinc composite panels with PE core, the results and the comparison between the FR zinc composite material (ZCM) and the FR ACM suggest that zinc composite panels with a polyethylene core may give a similar fire performance to PE cored ACM panels.
- The copper composite panels did not behave in a similar way to the aluminium or zinc composite panels and should therefore be considered separately,
- There is no evidence for any of the samples investigated in this experimental programme to indicate that the products represent a similar risk to the PE ACM panels.
- In terms of relative performance, the zinc composite material exhibited the highest contribution to fire growth and shortest time to burn through. However, it should be borne in mind that the most significant cavity fire and the largest measured heat flux at the top of the specimen was recorded for the copper composite panels where no breakthrough of the panels took place.

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- Aluminium honeycomb panels and reconstituted stone and brick slip systems exhibited a relatively low contribution to fire development and fire spread.

Based on the results from the experiments carried out to date, it is recommended that further work is conducted to establish the relationship between (FR) zinc and copper composite panels in conjunction with different types of insulation in the cavity. If this were to be carried out at an intermediate scale, a programme of work would be necessary to determine the level of correlation with large-scale fire performance of a cladding system which incorporates cavity barriers. The programme should also be extended to consider the performance of a range of HPL panels (standard and FR) under similar conditions.

The location of the joints between panels also requires further study to determine its impact on the fire performance characteristics of the materials. In most cases, the vertical joint between panels was offset from the centre to correspond with the width of the panels supplied. For the PE ACM panels used in the calibration and for the FR metal composite panels included in the project, the panel widths were 1 m and the central joint was located on the centre of the ignition source.

3.7 Supplementary experimental programme and analysis of results

Details of the supplementary experimental programme and the analysis of these results are found in Appendix G.

Six additional experimental fires were conducted for untreated timber and standard (non FR) grade HPLs. Two separate sources of the standard (non FR) grade HPL samples were procured for this supplementary work to increase the range of types of HPL samples from different manufacturers. The specification sought through procurement from the first source was standard (non FR) exterior grade HPL with thicknesses of 6mm and 10mm and a manufacturer's declared reaction to fire performance of class D-s2, d0[1]; the specification sought through procurement from the second source was standard (non FR) interior grade HPL with thicknesses of 6mm and 10mm and a declared reaction to fire performance of class C- s1, d0. In the experimental programme, the samples were subject to identical conditions in terms of the overall geometry and the location of the ignition source.

There was some variation in the location of the vertical panel joints between samples. The difference was a function of the supplied width of the panels. In effect, this meant that generally, the vertical panel joint was offset from the ignition source for the untreated timber and HPL samples with manufacturers' declared classification D[1] while for the HPL samples with distributer's classification C, the vertical panel joint was coincident with the centre of the ignition source. The impact of varying the joint location in the experiments has not been systematically examined at this time as there was insufficient material available.

The evaluation of performance has been undertaken related to the base level contribution provided by the ignition source and the measured and observed performance for the PE ACM samples considered during

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[1] According to the manufacturer, these HPL panels are marketed as class D standard (non FR) grade suitable for external use. Examination of the classification report supplied by the manufacturer shows that the reaction to fire classification D – s2, d0 is the worst performance achieved from testing and classifying a range of different types of standard exterior grade HPL panels when fixed to timber battens. After further investigation it was established that the 6mm thick panel achieves a reaction to fire classification D – s2, d0 (Note: the parameters used for determining the classification indicate that the total heat release rate measured in the BS EN 13823 test method exceeds the class C limit by 4%) and the 10mm thick panel achieves a reaction to fire classification C – s2, d0.

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the calibration process. Analysis has focused on the measurements of heat release rate, total heat release, incident heat flux and temperature, and visual observations in relation to spread of fire, nature and extent of the damage to the panels and visible flaming within the cavity. The results showed when comparing the 6 mm thick HPL sample intended for internal use (worst performing product tested in this supplementary experimental programme) that the PE ACM samples showed a peak HRR almost 3 times greater.

The evaluation of the performance of the individual types of cladding panels is complex and depends on the combination of the results from the quantifiable measurements and the observed behaviour. Consideration of one aspect in isolation may lead to a misinterpretation of the nature of the potential hazard.

Based on the supplementary experiments conducted and subject to the constraints of the approach adopted, the following conclusions can be drawn:

- None of the additional samples investigated shows the same or a similar type of fire performance to that of PE ACM panels, whether in relation to contribution to fire growth, fire spread or potential issues with breakthrough and initiation of cavity fires. The samples included in the supplementary experimental programme had an indicative (based on information directly from the manufacturer or the distributer's website) reaction to fire performance of Class C or D (European classification) (HPLs) or no classification declared (untreated timber).

- There is no evidence for any of the additional samples investigated to indicate that the products represent a similar hazard to the PE ACM panels.

- The results for the HPL samples classified C – s1, d0 and intended for internal use and one of the timber cladding samples exhibited sustained vertical fire spread beyond the area of direct flame contact produced by the crib ignition source. In each of these cases, the extent of horizontal (or lateral) fire spread appears to have been constrained by the metal framing system to which the samples were fixed. This suggests that the results in these experiments are particularly sensitive to the mounting and fixing arrangements and in the case of the HPL samples, the location of the vertical joint relative to the crib ignition source. The vertical joint on the centreline of the crib ignition source appears to represent the worst case in terms of penetration of the fire into the cavity.

Based on the detailed results from the work carried out in this project, it is recommended that further work is conducted to establish the impact of the joint location on the outcome from the experiments as well as the relationship between some of the materials/products in conjunction with different types of insulation in the cavity. This work would require both intermediate and large-scale investigation to establish the impact of variables such as insulation type, thickness and cavity depth on an intermediate scale and then large-scale tests to validate the impact of scale. This further analysis should include metal composite materials and standard and FR HPL panels.

4 General discussion

The research work has provided the following outcomes/conclusions:

- An intermediate-scale experimental methodology has been developed to evaluate the performance of materials/products used as the external element of a cladding system.
- The experimental methodology evaluates the performance of essentially flat materials with an exposed surface area of approximately 6 m² to an ignition source representative of the impact of flames impinging on an external façade from a fully developed post-flashover fire within a compartment.
- The evaluation of performance is based on a combination of quantitative measured data related to fire growth and visual observation.
- Evaluation of performance is referenced to both the initial ignition source and the performance of materials/products known to constitute an unacceptable hazard in terms of fire spread and contribution to fire growth

5 Conclusion

This research project has provided information on the burning behaviour of selected types of commonly used non-ACM cladding materials/products using physical intermediate-scale experiments.

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Report Ends