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Review of techniques for identifying the chemical composition of Aluminium Composite Cladding cores

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ABSTRACT: The Grenfell disaster of June 14, 2017 brought into sharp focus the dangers posed by combustible façade materials. Polyethylene core panelling has been implicated in numerous fires such as The Address Downtown, the Saif Belhasa in Dubai and the Lacrosse building in Melbourne. Due to the large number of buildings with potentially combustible cladding, there is significant pressure to find an accurate and fast method to identify such cladding and any associated insulation as part of the overall assessment process. Over the past year, several different approaches to identification have been proposed and in this paper, we recount our experiences in developing a methodology to achieve this and discuss the limitations of this method and of competing methods.

KEYWORDS: aluminium composite panels, ACP, flammable cladding, combustible cladding, alumina trihydrate

1 INTRODUCTION

Over the last eight years at least 153 people have died in fires attributable to combustible cladding and insulation (Nguyen, et al., 2016). Public outcry has brought considerable political pressure to bear on building owners, designers, builders and others in the supply chain to prevent the installation of combustible materials on new buildings. But what about existing structures? How can asset owners be assured that there is no combustible cladding on their building?

The current process is to identify the cladding if not by brand, then by type. Any insulation and affixation details are also recorded along with any pertinent fire engineering documents. These are then assessed by a fire engineer whose recommendations will be one of either leave, replace or retain with mitigation measures. In this paper we will focus on the identification of the cladding (Peng, et al., 2013).

If buildings kept accurate records this would be a very simple exercise. Unfortunately, in our experience few buildings keep accurate, usable records clearly detailing the type, brand and location of cladding on the building. In such circumstances, the only solution is to physically inspect the cladding and sample it for assessment at a laboratory.

2 CLADDING – A PRIMER

Many materials can be used for external cladding. Common traditional examples include aluminium plate, profiled steel and fibre cement. The last decade has seen a surge in the popularity of Aluminium Composite Panel (ACP) cladding.

2.1 *What is ACP?*

ACPs come in many shapes, sizes and colours. Typically, they are composed of two 0.5mm thick sheets of aluminium glued to either side of a 2-3 mm thick central polymeric core (ie; three layers). They are popular because they have a high stiffness to weight ratio, are lighter than equivalent metal products, do not suffer ‘oil canning’, are relatively impact tolerant, are easy to fabricate and cheap to produce.

ACP cores can be either Bakelite (also known as phenolic or phenol formaldehyde), polyester, polyethylene (PE), ethylene vinyl acetate (EVA) or even a mixture of polymers. Cores may be unfilled, or mineral filled. Corrugated or ‘honeycomb’ cores are available where a three dimensional sheet of aluminium is sandwiched between two flat sheets of aluminium and held together by a thin layer of glue.

2.2 *Insulation and Insulated Panels*

It is not uncommon for ACP (indeed any sheet cladding) to be accompanied by loose fill insulation located between the cladding and building membrane. The insulation may be glass wool, rock wool, polyethylene terephthalate (PET), polyisocyanurate (PIR), polyurethane (PUR), expanded polystyrene (EPS), extruded polystyrene (XPS) or phenolic. The insulation may be in the form of a foam, fibres, batts or prills.

Identification of any attendant insulation is integral to the correct evaluation of the total cladding system with regard to its fire performance. For example, BRE (Building Research Establishment) testing has shown that a *compliant* cladding in conjunction with *combustible* insulation, will not pass a full-scale fire test (Ministry of Housing, 2017).

Sometimes the insulation is integral to the cladding itself. Such products are known as insulated or sandwich panels. They may consist of one of the insulation types mentioned above, bonded between two metal skins, often steel but occasionally aluminium or other materials.

They can be recognised by their very high thickness (20-120 mm) or sometimes by the profiled surface of the outer skin employed to compensate for the lack of stiffness of the insulation. Sometimes the insulation itself has sufficient rigidity to act as panelling without the need for an outer metallic skin. For example, rendered expanded polystyrene or fully dense phenolic board.

2.3 *Core Types*

Polymer cores may be unfilled, or mineral filled. The polymer matrix constitutes the organic portion. The mineral (‘filler’) content is inorganic and is classed as either inert or active. Inert means it does not actively retard ignition or combustion, although it does reduce calorific content by displacing polymer from the core. Examples are chalk and sand. Active fillers actively retard ignition and combustion of the organic component by absorbing the energy of the fire. These chemicals are termed fire retarding (FR) agents.

The most common FR agent in the Australian market is aluminium hydroxide also known as alumina trihydrate or ATH. The chemical formula is $Al(OH)_3$, which is empirically equivalent to $Al_2O_3.3H_2O$. The second most common type is magnesium hydroxide also known as MDH. The chemical formula is $Mg(OH)_2$ which is empirically equivalent to $MgO.H_2O$.

Table 1. Properties of common fire retarding chemicals used in ACP panels

Property Unit	Decomp °C	Enthalpy cal/g	Mol Weight AMU	Water loss %	SG g/cm^3
ATH	220	-280	156.006	34.643	2.42
MDH	330	-328	58.319	30.89	2.36

Hydroxide and hydrate will be used interchangeably in this paper and refer to a common compound. The salient properties of FR agents are shown in Table 1. One should appreciate that most commercial ATH panels contain $\geq$ 70 w/w% of ATH or more, with the remainder being PE or more commonly, PE with a proportion of EVA. Such panels are referred to in the industry as ‘FR’ type. This is why most Australian states are moving to ban products with a polymer content exceeding 30% (James, February 8, 2019). 100% PE cores are known in the industry simply as ‘PE’. Panels with ATH > 90% are known as ‘A2’(see Table 4).

Most MDH panels contain 55 w/w% MDH or more, with the remainder PE. Neither concentrations mentioned have any particular significance as concentration levels are not mandated in building codes or standards. Other endothermic compounds such as huntite and hydro-magnesite) may also be encountered as FR agents.

2.4 *Mode of Action*

The fire retarding action is achieved by the endothermic conversion of the hydrate into water vapour as illustrated by equation (1);

$$2\,Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O \qquad (1)$$

The reaction absorbs energy from the combustion process. The greater the enthalpy of the reaction, the more energy that is absorbed. MDH can absorb ~15% more energy than ATH, possibly explaining the lower content observed in such panels (Huber Corporation, 2018). In the face of a sustained ignition source, the retardant will inevitably be exhausted. At that stage, any polymer still remaining will be free to contribute to the fire.

Therefore, in situations where a persistent source of ignition exists (ie; a conflagration), minimisation of the absolute organic content would appear to be the prudent choice.

Other types of fire retardants may be encountered. For example, Bakelite cores come in non-FR and FR versions which employ a non-ATH type retardant.

3 INITIAL SCREENING AND TESTING

To avoid expensive laboratory testing, it is logical to have some sort of basic screening process available to more economically identify which panels require further analysis and which do not. It is not uncommon for wall, column, soffit and parapet cladding to employ different products as different sub-contractors are sometimes used for each area. At $AUD1000/sample, lab testing can be an expensive exercise, particularly for residential or strata ownership complexes.

3.1 *Preliminary Visual Assessment*

Useful information can be gleaned from an initial physical inspection. ACPs are typically factory coated with PVDF (polyvinylidene fluoride) which has a very uniform, glossy appearance. ACP is distinguishable from solid aluminium panels based on edge details and fixing arrangement. ACPs with exposed edges will have the 3 layers clearly visible. Folded edges are created by routing the rear surface and bending the edge over which creates a sharp external corner at the fold.

Solid metal sheets will have more rounded corners and possibly signs of cold working (small cracks) along the folded edge. ACP is a rigid cladding and its appearance will be uniform and flat. Solid metal is more flexible and minor undulations of the surface may be visible, particularly if large sheets have been used.

3.2 *Core Appearance*

If exposed cut edges are not available, then cores must be drilled through a representative panel. Sampling usually involves retrieval of a minimum of three samples of no less than 26 mm in diameter for each distinct panel type. Cores smaller than 26 mm may yield insufficient material for XRF. The choice of sample may be based on colour, size, location and the purpose (application) of the panelling. One is kept for physical evaluation and records, one is for flame testing and one is for lab characterisation.

In aesthetically sensitive areas, it is an option to drill a pilot hole. The colour of the turnings produced are usually indicative of the panel type. Bakelite cores are notable for the classic smell of phenol when drilled and their extreme hardness. Pure polymers are mostly homogenous in appearance. Jet black cores with a smooth glossy appearance are typically PE with ~2% carbon black. White or grey cores with a gritty, heterogenous appearance are mostly FR cores thanks to the fact that filler minerals are almost always light in colour with a finite particle size.

Whilst core colour is often useful for identifying the core, we note that in ~10% of cases the appearance has no bearing whatsoever on the true nature of the core. For example, phenolic cores can vary from a ‘caramel’ colour to almost black. PE can be clear, white or grey depending on the level of strain, porosity and pigmentation. For this reason, colour alone cannot be relied upon for core characterisation.

3.3 *Density Measurement*

Density measurements can be used to confirm visual assessments. Low density polyethylene (LDPE) has a density of 0.91 - 0.94 g/cm^3 and HDPE has a density of 0.93 - 0.97 g/cm^3 (Kutz, 2011). A PE panel containing 70% ATH will have a density of 1.64 g/cm^3 (Figure 1).

3.4 *Float Method*

As water has a density of 1 g/cm^3, pure PE will float, while as little as 10% filler will result in the sample sinking. With small samples, it is important to use a wetting agent to prevent false readings caused by the natural surface tension of water. This method assumes that the FR agent is close to pure. For distinguishing ‘FR’ from PE panels, a simple ‘float’ test is quite incontrovertible.

3.5 *Dimension Method*

The as-received sample itself (including skin) can be used directly for dimension based density determination. This volumetric test relies heavily on the sample being symmetric and undamaged. The dimensions, weight and thickness of the component layers is all that is required. Note that the contribution of the aluminium skins has to be mathematically subtracted to get the actual core density. Knowledge of the polymer and filler types and purities are assumed.

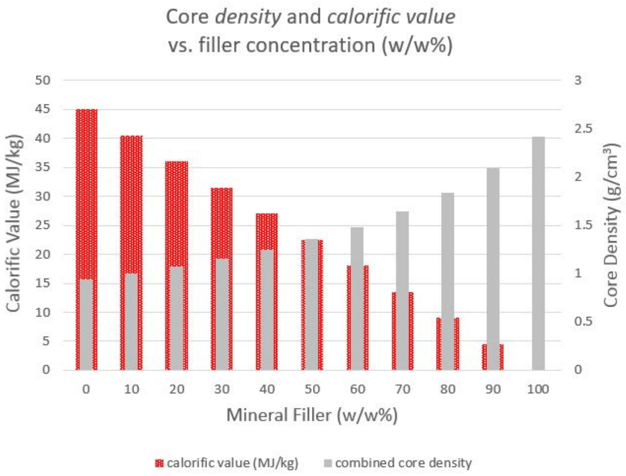

Figure 1. Variation in density and calorific content of polyethylene with increasing filler percentages (example is ATH).

3.6 *Hydrostatic Method*

If it is desired to remove the aluminium skin, dissolution in concentrated alkali or [mineral] acid will achieve this. PE cores are quite immune to either chemical. This is necessary if hydrostatic testing is employed. This method requires a special hydrostatic balance, the inputs for which are described in equation (2);

$$\rho core = \frac{\rho water}{1 - (\frac{Ww}{Wa})} \qquad (2)$$

$\rho core$ = density of the core, $\rho water$ = density of water (which is 1 g/cm^3), Ww = the weight of the core in water and Wa = the weight of the core in air. By core, we mean the inner core free of the aluminium. The w/w% filler content can then be derived using equation (3);

$$w/w\%\ filler = \frac{100\, \rho_f(\rho_{PE} - \rho_{Core})}{\rho_{core}(\rho_{PE} - \rho_f)} \qquad (3)$$

where $\rho core$ = density of the core, ρ_f = density of the filler and ρ_{PE} = density of the polyethylene. This test is totally independent of the sample geometry and highly accurate. It assumes knowledge of the filler and polymer and the purity of both.

3.7 *Pycnometer Method*

The fourth method utilises a pycnometer. However, because of our typically small sample sizes, we were unable to achieve good results with this method.

3.8 *Combustion Screening*

Different polymers exhibit different behaviours when burnt (smell, colour, by-products) which can be helpful in confirming the matrix type (Forrest, 2001). Polyethylene is known to ignite rapidly and burn fiercely with flaming droplets and will continue to burn even after the removal of the flame.

A fire-retardant core will ignite only with difficulty and will expand and foam vigorously as the hydrate evolves to steam. This is possible because the FR agent does not decompose until the polyethylene is fully in the molten state (MP ~120 to 160°C). Such cores normally self-extinguish once the flame is removed – at least until the FR agent is exhausted. Rather than melt and burn, phenolics tend to char and blacken with the emission of a strong phenolic smell (Braun, 2010, 5th Edition). Such tests are used for screening and are not to be confused with fire engineering or performance testing.

4 LABORATORY CHARACTERISATION

Cores that are not obviously flammable are then sent for laboratory testing. A minimum of three tests are needed to unequivocally confirm the type of core, including the nature and quantity of the filler, if present.

4.1 *Infrared Spectroscopy*

The first is Infrared Spectroscopy (ATR-FTIR). Most organic and inorganic materials exhibit characteristic resonances to infrared excitation. PE displays two strong peaks at wavenumbers 2917, 2849 and two single peaks at 1468 and 719 cm^{-1}. ATH shows a characteristic cluster at 3619, 3524, 3452 and 3373 cm^{-1}, with a strong single peak at 1016 cm^{-1} (Kloprogge, et al., 2002), (Rodgers, 1993).

Table 2. Characteristic peak wavenumber (cm^{-1}) locations

Phenolic	3328 (b), 2875 (w), 1020 (s),
PE	2917 (s), 2849 (s), 1468 (m) and 719 (m)
ATH	3619 (w), 3524 (w), 3452 (w), 3373 (w), 1016 (s)
MDH	3694 (s)

Absorbance: s = strong, m = moderate w = weak, b = broad

Figure 2. FTIR spectrum of a typical phenolic resin ACP core. (Excelplas1, 2019)

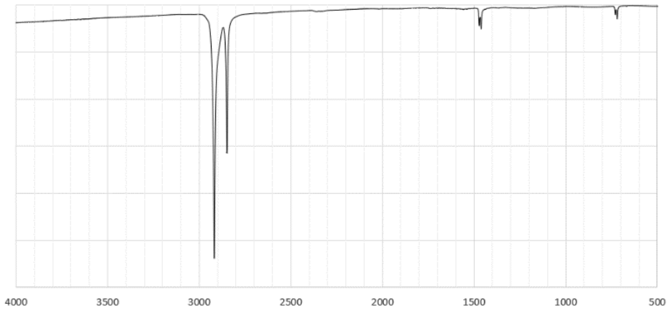

Figure 3. FTIR spectrum of polyethylene. (FTIR Search, n.d.)

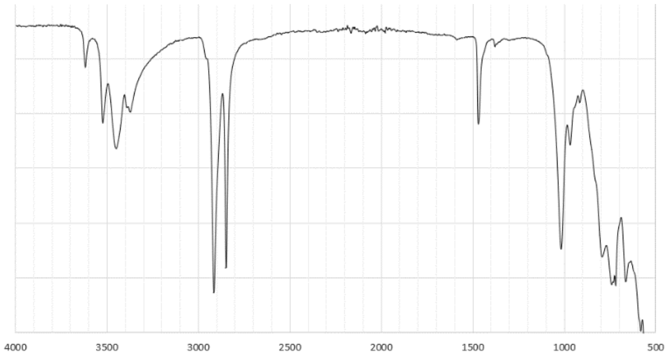

Figure 4. FTIR spectrum of a typical ATH-filled PE core. (Excelplas2, 2019)

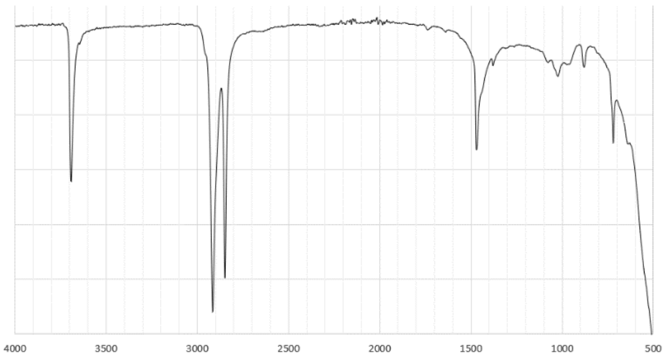

Figure 5. FTIR spectrum of a typical MDH-filled PE core. (Excelplas3, 2019)

MDH has a diagnostic peak at 3694 cm^{-1} (Schroeder, 2002). Phenol formaldehyde has weak diagnostic peaks at 1610 and 1504 cm^{-1} connected with the aromatic ring (Krajnc & Poljanšek , 2005). However most phenolic cores are cellulose reinforced which gives rise to peaks at 3328, 1020 and 2800-2970 cm^{-1} (Auta, 2017). These peak wavenumbers are summarised in Table 2 and the example spectra are displayed from Figure 2 to Figure 5. Note that commercial products are not pure and other signals may be present.

We have observed on a number of occasions, that the defining peak in the MDH FTIR has not appeared, despite a clear XRF signal. We are unaware of the cause. Be aware also that the broad FTIR signal from carbon black in a black core PE sample will mask the PE peaks. To get a clear scan for the PE, it is advisable to dissolve a portion of the core in trichlorobenzene, recast it and then run the FTIR on the isolated polymer.

Aluminium hydroxide (ATH) has 4 polymorphs. In practice however, commercial $Al(OH)_3$ comes almost exclusively in the gibbsite form. In an analogous manner, commercial $Mg(OH)_2$ is mainly brucite. The relevance of this is that the different mineral forms have different spectra which can otherwise complicate spectral interpretation.

4.2 *Gravimetry*

While FTIR is useful for identification, it is generally insufficient for quantifying the filler material and for that gravimetric means are necessary. Ashing is the pyrolysis of the exposed core at 600°C in air. All organic matter is combusted (lost as H_2O and CO_2), leaving behind most inorganic material as oxides.

All hydroxides are converted to their oxides. For example; $2Ca(OH)_2 \rightarrow 2CaO + 2H_2O$. Existing oxides will naturally be unaffected. This simplifies the calculations required for determining the FR content as competing reactions such as the decomposition of calcium carbonate will not occur (its decomposition temperature is higher than the ashing temperatures). Ashing at a higher temperature (circa 800°C) is preferred however, as the question of competing or partial reactions is eliminated. But this may require XRD to differentiate the contributions from multiple compounds.

The inorganic fraction is expressed simply as a percentage (w/w%) of the total weight of the submitted core. A complication exists in that during the ashing process or pyrolysis, the original ATH or MDH agent will lose its waters of hydration. However, as the ratio of the oxide to the hydrate in the parent chemical has a fixed relationship, we are able to 'back-calculate' to the original mass of fire retardant in the core that gave rise to the oxide. There is one last hurdle and that is that the mineral content is rarely pure. Typically, 1-

10% of the mineral fraction is something other than fire retardant.

One potential flaw with this methodology is if there is ‘native’ alumina (or magnesia) in the as-received filler. This will artificially inflate the apparent level of FR agent as will be understood from section 4.3. We have found little evidence however of alumina (or magnesia) present in the as received core. Quantitative X-Ray Diffraction (XRD) of the as-received core, suggests levels much less than 1%.

4.3 *X-ray Fluorescence*

Establishing the purity of the isolated inorganic content requires one last test: X-ray Fluorescence (XRF). The ash from the gravimetry is fluxed with lithium borate and fused at 1050°C. This has the effect that all compounds including carbonates are reduced to the oxide.

The concentration of each element is expressed as a mass percent (w/w% oxide) of the inorganic portion - not total core weight. An expression for calculating the w/w% fire retarding hydroxides in the as-received core can be found in equation (4);

$$\%\,FR\ agent\ =\frac{M.A}{100-W} \tag{4}$$

Where *M* is the inorganic portion of the core, *A* relates to the purity of the inorganic portion (in terms of percent alumina or percent magnesia) derived from XRF analysis and *W* is the theoretical hydrate loss for that oxide, obtained from Table 1. All values are expressed as percentages. Any other thermally sensitive chemicals will also have to be converted back to their parent compound using equation (7). One can also report the organic component of the core (in w/w%) using equation (5) if the FR agent decomposition is the only such reaction;

$$\%Polymer = 100 - M\left(A\left(\frac{1}{100-W}-\frac{1}{100}\right)+1\right) \tag{5}$$

The definitions from equation (4) are the same. Note that *%FR* + *%Polymer* will add to 100%, unless oxide impurities are present in the core.

It is worth noting that handheld FTIR and XRF devices are available which have moderate success in differentiating core types in the field. The panel aluminium skin however can cause interference due to the penetrating power of the X-rays. Such devices are expensive and qualitative only but could be useful for field screening.

4.4 *X-Ray Diffraction*

Consider the case of a pure metal hydroxide that undergoes thermal decomposition upon heating. Using the mass of the ashed core and the purity from XRF, it is relatively easy to back-calculate to the original mass in the as received core.
But what if the metal exists in multiple forms simultaneously?

For example, CaO, $Ca(OH)_2$ and $CaCO_3$? High temperature ashing converts all these forms to the oxide (eg CaO). The purity of ATH in panels is usually high so the effect of other metal compounds is insignificant. MDH panels however contain significant ‘other’ elements, usually calcium, carbonates and silicates. Reliance on XRF may result in an underestimate of the as-received weight of the filler as the contribution of impurity metal hydroxides and carbonates is not accountable.

This is where X-Ray Diffraction (XRD) can prove useful. XRD can effectively identify and give the relative proportions of all minerals in the inorganic phase. However as amorphous materials like polymers are invisible to X-rays, it is impossible to quantitate the proportion of the polymer. Therefore, an ashing step is still required. This must be carried out at >1000°C to ensure all elements are converted to the oxide. The mass of minerals (metal compounds) in the as received core is given by equation (6).

$$m_c = \frac{100 \times m_{ash}}{\left(\frac{\%A_C MW_{AO}}{MW_A}+\dots+\frac{\%N_C MW_{NO}}{MW_N}+\dots\right)} \tag{6}$$

Where m_c = the weight (g) of metal compounds in the as-received core, m_{ash} = weight (g) of the metal compound(s) after ashing, MW_N = the molecular weight of the metal compound ‘N’ before decomposition, MW_{NO} = the molecular weight of the metal compound ‘N’ after decomposition (both in mols/g) and $\%N_c$ = the w/w% N of the metal compound phase in the as-received core as determined by XRD (not as a percent of the core overall). Each unique metal is assigned a label A, B, C… to N in the equation. It is important to understand that the XRD is only carried out on the as-received core. The assumption that all compounds convert to the oxide may be wrong in which case a confirmatory XRD after ashing would be needed to verify the end form.

Note this equation is only valid if all the mineral components are identified (add to 100%) including those that undergo no decomposition (ie; $MW_N = MW_{NO}$). The *%PE* is simply 100% times the core weight less m_c. If any amorphous material like silica is present, it will not be detected by XRD and the mineral mass will be underestimated. In such a case, the normal process using XRF of the ash can be used. Note that if mineral N is present alone, then it obviously makes up 100% of the mineral contribution so that equation (6) simplifies to equation (7);

$$m_c = m_{ash} \times \frac{MW_N}{MW_{NO}} \qquad (7)$$

If $MW_N = MW_{NO}$ (ie; the mineral undergoes no change during pyrolysis), then equation (7) simplifies further to $m_c = m_{ash}$ as one would anticipate.

4.5 *Thermal Methods*

There are various other analytical methods for characterising polymeric and inorganic materials. Differential Scanning Calorimetry (DSC) provides information about the core because all polymers have characteristic thermal properties such as glass transition temperature, melting temperature, thermal decomposition temperature and heat capacity at each of these transitions. Minerals also have characteristic thermal behaviours (Table 3). Such effects however are so subtle to be of limited value in core determination.

Table 3. Decomposition temperature of common impurities

Chemical/Mineral	Formula	Decomp Range (°C)*
calcium hydroxide	$Ca(OH)_2$	400-500
magnesium carbonate	$MgCO_3$	400-500
calcium carbonate	$CaCO_3$	700-850
dolomite	$CaMg(CO_3)_2$	700-850

*Depends on heating rate, particle size, etc

Thermogravimetric Analysis (TGA) is where the sample weight is continuously monitored in air or nitrogen while the furnace temperature is gradually increased past the oxidation (or pyrolysis) temperature of the polymer, which for polyethylene is ~400°C. The organic fraction is simply the difference between the start and end weights in air, provided the inorganic fraction is stable to temperature. Where hydrates or carbonates are present, calculations are required to account for their decomposition. Pyrolysis in nitrogen will cause organic material to carbonise rather than to combust, which can be useful for further differentiation.

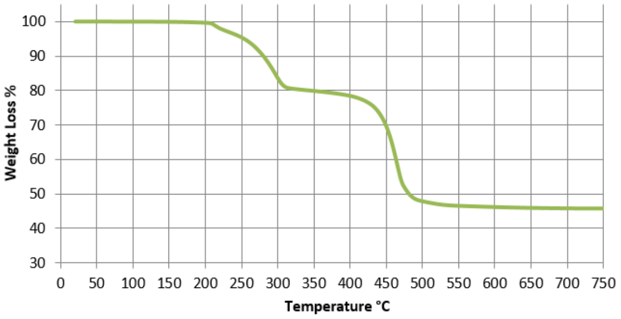

Figure 6. Thermal decomposition behaviour of an approximately 70% ATH filled LDPE sample.

Gravimetry is unable to determine the filler purity and therefore will overestimate the FR content if 100% purity is assumed. Typical outputs are the temperature at which the filler thermally decomposes, and the weight loss associated with that decomposition (see Figure 6). By coupling the TGA to a Mass Spectrometer (MS), the decomposition products (eg; water) can be assessed over time, yielding yet more information. In TGA, both filler and polymer decompose over a finite range which may overlap. Polymer mixtures add further complexity. This makes interpretation of the curves rather subjective and not suitable for anything other than very basic formulations.

4.6 *SEM with EDX*

Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-Ray Analysis (EDX) is a commonly promoted testing combination. It is possible to estimate the w/w% filler in a sample cross-section, by image analysis of the secondary phase (the mineral) within the primary phase (the polymeric matrix).

If the filler particle is mostly equiaxial, the area fraction of the filler will roughly approximate the volume fraction (expressed as v/v%). It is then a simple matter to convert the v/v% to w/w% with knowledge of the polymer and FR agent densities using Equation (8).

$$w/w\%\ FR = \frac{100}{\frac{\rho PE}{\rho FR} \times \frac{v/v\%PE}{v/v\%FR} + 1} \qquad (8)$$

where *v/v% FR* is the volume fraction occupied by FR particles expressed as a percent, *v/v% PE* = 100 - *v/v% FR*, *ρFR* = density of FR mineral and *ρPE* = the density of polyethylene (both in g/cm^3). EDX of filler particles gives the elemental concentrations of the constituent elements allowing one to identify the phase and even purity with a reasonable level of confidence.

4.7 *Calorific Methods*

In the United Kingdom, it is common to employ EN ISO 1716 (International Standards Organisation, 2010). This is a test for the gross heat of combustion (calorific content) of the panel core. For example, pure polyethylene contains ~45 MJ/kg, while a good quality non-combustible (‘A2’) panel should not exceed 3 MJ/kg, as per Table 4. In one test, it is possible to determine the EN 13501-1 classification (combustibility class), along with the polymer fraction (the calorific content scales linearly with polymer content).

The test suffers from the shortfall that it is unable to distinguish between a core filled with active fire retardant from one filled with an inert material such as chalk, either of which would behave very differently in an actual fire situation. It also requires knowledge of the polymer type.

It is interesting to note that EN13501-1 states the maximum calorific content for Class A products only (European Committee for Standardization, 2007). That is, it provides no specific guidance for other classes and applies to any material, not just PE, despite different polymers having widely different calorific contents.

4.8 *Additional Sources of Error*

It is important to be mindful of the testing errors outside of those already discussed. One source of error is the compounding process used in making the cores. The fire retardant does not exist as a homogeneous dispersion, but rather as finite particles, therefore a natural variance in the actual filler concentration between panels – or even within panels is to be expected.

Density measurements rely on assumptions regarding the porosity, purity and density of the core materials. In addition to the aforementioned, v/v% conversion measurements in the SEM are affected by particle anisotropy, size distribution and the analyser detection threshold used.

Even small errors can be critical as some insurers insist on a fixed minimum level of fire retardant, often taken straight from a manufacturer data sheet without thought given to a tolerance or range. This results inevitably in an excessive rejection rate. Note that the fire-retardant performance of an FR core does not begin or end at some arbitrary filler concentration (Huber Corporation, 2018).

5 FIRE PROPERTIES

In order to appreciate which panel types are appropriate to an application – and which are not - it is necessary to understand how each panel type behaves in a real fire situation. The preferred method for testing the fire performance of a façade cladding system is via full-scale testing with typical test standards being AS 5113 (Standards Australia, 2016), BS 8414 (British Standards Institution, 2015) and NFPA 285 (NFPA, 2019).

While combustibility is an inexact indicator of full-scale performance, it is a convenient tool for identifying ‘deemed to satisfy’ materials. That is materials for automatic acceptance within building codes. AS 1530.1 (Standards Australia, 2016) and EN 13501-1 are typical standards. In EN13501-1, ratings are assigned depending on the combustibility of the material.

For example, thermoset phenolic cores (>6mm) are typically Class C,s2,d0. If fire retardant is added, this can improve to B,s2,d0 (the s refers to smoke generation and the d to flaming droplets).

Table 4. Gross heat of combustion values for three commercial ACP Classes utilising polyethylene

Industry Name	EN13501 Class	Calorific Content MJ/kg	ATH Filler %
‘A2’	A2,s1,d0	3	>93
‘FR’	B,s1,d0	15	~70
‘PE’	D	45	0

A typical full-scale test stand may be several stories high, cost thousands of dollars to run and evaluate and require tens of panels to construct. It must also be run for each distinct panel type of which there may be several per building.

However, by lab testing a sample of an unknown panel and comparing the chemical composition to a known brand product that already carries a combustibility and full-scale fire performance certification - it is not unreasonable to expect the unknown panel to share a similar fire performance to that of the known brand panel. That is, association by proxy. This is why a cheap, accurate and reliable characterisation of the panel core is so attractive compared to performance-based tests.

6 CONCLUSION

In this paper we have hoped to share some of our experiences from the testing and identification of combustible cladding. That includes useful information relating to analytical methods which offer the ability to obtain accurate and reliable data towards assigning an identification to the sample panel and insulation where required. Our recommended method is FTIR with ashing (gravimetry) and XRF.

Note that this is not an advice or guidance. Only an experienced fire engineer can determine the compliance of a cladding system. To do this requires a holistic assessment of the façade materials, their fire performance and building specific information.

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