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Effect of fire retardancy materials in fibre reinforced composite plate for false ceilings- A Review

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Abstract. The use of fillers in composite material development and manufacturing has been in commercial use for decades. These fillers induce and/or enhance desirable characteristics in the composite matrix. Flammability is a major deterrent contributing to the reduced scope of utility of completely biodegradable composites. The ability of any material to act as a flame retardant is influenced not only by explicit factors such as the material's melting temperature and thermal degradation factor, but also by various implicit factors such as the multiple transformations taking place in the material and the compounds that are generated due to the material's exposure to elevated temperatures. The paper studies and compares the mechanism of fire retardancy of four popular fillers and aims to determine their effectiveness in introducing fire retardancy in biodegradable false ceiling materials. The results show that the properties of fire retardancy can be measured in terms of heat release rates, limiting oxygen indexes and thermogravimetric analyses. Final comments are on the testing standards used to check fire retardancy

1. Introduction

False ceiling, also known as dropped ceiling, is a secondary roof on the inside of the room. It is suspended from the main roof of the room or building. The addition of a false ceiling offers multiple advantages like temperature regulation by providing an additional layer of insulation between the room and the external surface of the building. Lights, electrical wiring and networking cables can be routed through the false ceiling, and can be reconfigured with minimal investment and efforts. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and Plaster of Paris ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) are extensively used as primary materials in making false ceilings. Common construction materials (wood, glass, metal, fibre, composites) are also used in enhancing aesthetic appeal and for specialised applications.

Intumescent and flame retardant materials can be used in conjunction to improve retardancy in false ceilings. Intumescence is a material characteristic where exposure to heat results in the material's increased volume with decreased density, which is a method of passive fire resistance. In comparison, flame retardancy retards or prevents the propagation of fire by forming a preventive film on exposed areas or by opposing underlying chemical reactions causing the flame. The ability of any material to act as a flame retardant is influenced not only by explicit factors such as the material's melting temperature and thermal degradation factor, but also by various implicit factors such as the multiple transformations taking place in the material and the compounds that are generated due to the material's exposure to elevated temperatures. An example to support this point is ceramics. They have poor thermal conductivity and high melting temperatures, allowing them to effectively act as insulators, but their fire resistance is not notable. On the other hand, fire inhibiting materials have low conductivity in degrees of heat, but in the presence of high flame, they insulate heat effectively and deter the spread of flames.

Polymeric materials demonstrate flammability mainly due to the occurrence of thermal degradation due to exposure to heat. The mechanisms of fire-retardant systems for countering polymer flammability are yet to be



comprehensively studied at the fundamental level. The shift of focus towards risk mitigation has led to recent innovations that address concerns that have been neglected in the past.

Four fire retardants were shortlisted after conducting a literature survey of the subject. Their techniques of retarding flammability are discussed below.

1. *Magnesium hydroxide* undergoes endothermic (heat absorbing) decomposition accompanied by hydration (water released as a product) in the temperature range of polymer degradation.
2. *Ammonium polyphosphate* works on the principle of intumescence. A carbon char layer having low density is formed when the surface area is exposed to heat. This carbon layer acts sacrificially to avoid further material breakdown by shielding the material from the heat source.
3. *Boric acid* acts as a dehydration catalyst, causing the water component in the composite to break down while simultaneously eliminating oxygen from the compounds at lower temperatures of heat exposure. This prevents the availability of oxygen from the composite at elevated temperatures, resulting in a faster drop in burning rate.
4. *Zinc borate* reduces the rate of polymer degradation by restricting the detrimental effect of the heat source on the exposed surface. The retardant creates a vitreous protective layer of residue that induces intumescence in the composite.

2. Flame retardancy testing

Limiting Oxygen Index tests are primarily used to check the combustibility of materials. The test indicates the least percentage of oxygen that must be present in the atmosphere to support combustion of material at a marginal level. This is achieved by placing the sample in a chamber fitted with an ignition wand and filled with a combination of oxygen and nitrogen. The critical level of oxygen is noted by lowering the percentage of oxygen in the test chamber till the burning stops. Samples with a higher critical oxygen percentage are labelled as less flammable. UL-94 testing standards for fire retardancy are to be followed for biodegradable composite materials. The naming standards followed for the classifications of materials are elaborated below. As per the official testing procedure document, "Material classified as 5VA or 5VB is subjected to a flame ignition source that is approximately FIVE Times more severe than that used in the V-0, V-1, V-2 and HB tests." Preconditioning for VB is for 168 hours at 70°C.

Table 1: Flame retardancy testing

Class	Orientation	Definition	Permitted time of burn	Particle drops allowed		Plaque holes
				Flaming	Non-flaming	
HB	Horizontal	slow burning	burning rate < 76 mm/min or burning stops before 100 mm for thickness <3 mm			
V-2	Vertically upright	burning stops	30 sec	Yes	Yes	
V-1	Vertically upright	burning stops	30 sec	No	Yes	
V-0	Vertically upright	burning stops	10 sec	No	Yes	
5VB	Vertically upright	burning stops	60 sec	No	No	Yes
5VA	Vertically upright	burning stops	60 sec	No	No	No

3. Boric Acid flame retardancy materials

Boric acid inhibits the discharge of flammable gases from burning plastic materials, like cotton, wood, and paper-based merchandise. Chemical element acid conjointly releases with chemicals guaranteed water to dilute the concentration of transmutation fuel fragments and a carbon char is created that any inhibits combustion. it's used as a flame retardant in plastics, textiles, coatings, and there are different industrial merchandise that contains chemical element acid to strengthen their ability to resist exposure to flames. The glassy coating and also the char shield the substrate from chemical elements and warmth. The physical aspects of a hearth will take the shape of volatile, inflammable gases igniting and any mouldering the solid plenty via transmutation, so making additional inflammable gases till solely a carbon structure is left. The second methodology operates at a lower temperature with the carbon to provide smouldering combustion. Combustion of plastic materials will occur in 2 phases. Within the 1st section, visible flames are present; within the second section, flames are absent and are in an exceedingly vaporise state. Within the latter section, the combustion is remarked as glowing or smouldering,

reckoning on whether or not or not light-weight is emitted from the burning material. chemical element acid works in an exceeding variety of the way to act as a hearth retardant, together with preventing flame combustion, promoting char formation, and suppressing smouldering, glowing and smoke. Boric acid, anon-alkaline salt can react each as a hearth retardant and smoulder drug. Chemical element acid releases water additionally to assist extinguish the hearth, however, it provides char forming price on the surface of the polysaccharide thanks to the presence of its atomic number 5 price. Every sample was kindled with a flame and burned down into the cold material. Then, minimum chemical element concentrations that might support combustion for all samples were recorded as a share.

Table 2: Boric acid fire retardant analysis results by various researchers

S. No	Author	Control	Composition	Approx. reduction in results
1.	Suharty.et.al	recycled PP	rPP/KF/acrylic acid/divinyl benzene/Al. Hyd/Mg. Hyd/ Boric Acid	55% (Burning Rate)
2.	Cavdar.et.al	HDPE/Wood Flour/Wax	HDPE/Borax impregnated Wood Flour/Wax	54% (Burning Rate)
3.	Nagieb.et.al	Wood + 10% urea formaldehyde	Wood + 10% urea formaldehyde + Paraffin wax + 5% (BA + BX)	81% (Glowing Time)

4. Magnesium Hydroxide flame retardancy materials

Magnesium hydroxide (MH) is that the environmentally most favoured, promptly obtainable, non-toxic, and low-value flame retardancys, however, their use is restricted by the requirement for too high loading level (up to quite 60%) and, the MH is stable up to three hundred C. The discharge of vapour upon decomposition of cathartic dilutes the fuel offer gift within the gas part. The comparatively high heat capacities of each cathartic and also the decomposition merchandise fashioned upon decomposition of cathartic cut back the thermal energy obtainable to degrade the plastic. The decomposition merchandise gives exaggerated insulation of the plastic from the warmth supply through char formation. The high filler content sometimes related to metal hydroxide- treated plastics act as a solid part diluting. cathartic (MH) square measure the environmentally most favoured, promptly obtainable, non-toxic, and low-value FRs, however, their use is restricted by the requirement for too high loading level (up to quite 60%). MDH undergoes energy-absorbing decomposition once water is free at 330 °C. The discharge of vapour upon decomposition of cathartic dilutes the fuel offer gift within the gas part. Inorganic flame retardants like atomic number 13 trihydroxide and cathartic square measure believed to decrease the temperature of the chemical compound surface and retard shift of the chemical compound by their energy-absorbing decomposition and water unleash. It absolutely was found that cathartic will effectively cut back the flammability (almost 50%) of fiber stuffed plastic composites. No synergistic impact was ascertained once cathartic was employed in combination with chemical element acid and atomic number 30 salt. Paper sludge/polypropylene composite decomposes at close to 300°C, however Mg (OH) two will therefore at regarding 400°C. Consequently, it will be thought that sizeable decomposition of the composite system already happens before Mg (OH) two acts as a flame retardant. (i) Flammability isn't influenced by the speed of loss of water from the mouldering filler. (ii) Atomic number 8 indices of stuffed chemical compound compounds are also associated with the structure of the parent cathartic, whereas UL94 ratings seem to be freelance of cathartic morphology. (iv) Water doesn't participate in the gas reaction resulting in increased levels of carbon monoxide gas emissions. Reduced levels of carbon monoxide gas evolution square measure ascertained. (v) Carbon volatilisation is promoted by mineral throughout exposure to atomic number 8. (vi) The mineral decomposition product seems to participate in condensed part reactions with adsorbate organic compound fragments.

Table 3: Magnesium Hydroxide fire retardant analysis results by various researchers

Author	Control specimen	Ideal Composition	Approx. reduction in results
Marosfoi.et.al	Polypropylene	PP/Organomodified clay/SEP (soft white clay)	57.7% (Burning Rate)

Jang.et.al	Paper sludge/ polypropylene (50:50 by weight)	Saytex8010 30 phr and antimony trioxide10 phr (phr= per hundred resin)	96% reduction in burning time
Chiu.et.al	Polypropylene	PP/APP/Penta- erythritol/Melamine/Mg(OH) ₂	Max HRR (86.09%) kw/m ² Avg. HRR (82.88%)
Hornsby.et.al			Burning rate of composite with 25% of magnesium hydroxide decreases to 50% composite B and is even less than polypropylene.
Braun.et.al	High Impact Polystyrene	HIPS/Mg(OH) ₂ /Red Phosphorous	Max HRR (72.6%) kw/m ² Avg. HRR (59.6%)

5. Ammonium Phosphate flame retardancy materials

Ammonium Polyphosphate (APP) is found in the solid state at STP and has a high percentage of phosphorous (upto 30%). APP is moderately soluble in water and has a high melting point. APP is commonly available in several crystalline forms and is sold to several industrial clients for use in intumescent paints. The market names and compositions differ in crystalline dimensions, solubility in different agents and mol. wt. On contact with a heat source, the phosphorous forms residue in the form of a coating that acts to protect the surface from flames. [5]. APP displays hydrolysis and gets converted to monoammonium phosphate (orthophosphate). When APP is exposed to greater elevated temperatures or to water for longer periods, the process of hydrolysis is expedited. Short chain APP begins to decompose at temperatures above 150 °C. This allows APP to cater to a wider range of fire retardancy applications in the composite industry.

Table 4: Ammonium Phosphate fire retardant analysis results by various researchers

S. No	Author	Control specimen	Ideal Composition	Approx. reduction in results
1.	Chiu.et.al	Polypropylene	PP/APP/Penta- erythritol/Melamine (100/23/14/13)	Max HRR (84.2%) kw/m ² Avg. HRR (81.5%)
2.	Zhao.et.al	The composition was varied.	PVA/APP/Ni-Al LDH (85/14.7/0.3)	LOI (-29.3%)
3.	Guo.et.al	Polypropylene	EG/ WPC and M- APP/WPC	LOI (-66.52%)

6. Zinc Borate flame retardancy materials

Zinc borate (ZnB) could be an element-based mostly flame agent compatible with several chemical compound matrices. Its effective each within the solid section and within the gas section and its robust smoke suppressing action, helps to boost time of rescue just in case of fireside. ZnB is an associate chemical compound, a salt of Zn. it's a white crystalline or amorphous powder insoluble in water. Its toxicity is low. Its freezing point is 980 °C. ZnB, thanks to the delicate bond mediate filler's surface and matrix and since of their inherent incompatibility, decrease lastingness. ZnB thermal decomposition and consequently steam generation within the method causes the formation of cavities at intervals the matrix that all over again decreases lastingness. ZnB acts as a flame agent in each condensed and gas phases of the combustion method. At elevated temperatures, this compound decomposes, emotional crystallization water molecules (about 15 August 1945 by weight of water within the temperature vary of 290–450°C) that dilutes the concentration of H radicals and organic volatiles within the flame, reducing its temperature. Once decomposition, the residual salt maintained within the rotten compound can kind a vitreous-like layer that slows the permeation of volatile compounds through the surface and restricts them from getting into the gas section. ZnB decreases the utmost rate of warmth unleash (RHR) and delays the second heat unleash peak. Throughout these tests, the formation of a char layer at the surface of the flame-retarded polymers is discovered. ZnB in an associate chemical reaction at a temperature varies of 290 °C up to 450 °C releases fifteen World Trade Centre steam. Thermal decomposition and consequently steam generation within

the method causes the formation of cavities at intervals the matrix that all over again decreases lastingness. ZnB addition to composites has improved composite flame retardancy property.

Table 5: Zinc Borate fire retardant analysis results by various researchers

S.No	Author	Ideal composition	Approx reduction in result
1.	Braun.et.all	PolyAmide 6,6/GF-Aluminium Phosphinate	Max. HRR(52.134%)
2.	Durin.et.al	20%Mg(OH) ₂ + 20% BZn + 20% Talc	LOI (-35.7%)
3.	Ramazani.et.al	R40-ZnB-ATH30(Allumina trihydrate)-(ZnB=0.2ATH)-MAPP(Maleic Anhydride grafted polypropylene)	LOI(-37.5%)

7. Conclusion

The ability of any material to act as a flame retardant is influenced not only by explicit factors such as the material's melting temperature and thermal degradation factor, but also by various implicit factors such as the multiple transformations taking place in the material and the compounds that are generated due to the material's exposure to elevated temperatures. The paper shows the comparison between the mechanisms of fire retardancy of four conventionally used fire retardant fillers and aims to determine their effectiveness in introducing fire retardancy in biodegradable false ceiling materials. Addition of fire-retardant additives should result in an increase in limiting oxygen index (LOI), and therefore improved flame retardancy in the tested composite. The rate of water released by the retardants would increase by virtue of higher temperatures and longer periods of subjection to elevated temperatures. Due to the nature of composites, some degree of reduction in the mechanical properties would be observed due to the reduced percentage of strength inducing components. The working mechanism of intumescent additives is a chemically induced physical process that achieves fire retardancy by forming a high volume, low density buffer for protecting the area exposed to elevated temperatures.

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