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Fire Hard Composites for Architectural Applications

by

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Abstract

Composites are used in many industries, including the Architectural industry, as an alternative to metals, concrete and wood. Major advantages of composites are the ease of fabrication, part consolidation, design flexibility, corrosion resistance and weight reduction. To date, most composites used in the architectural industry have been limited to exterior applications because of Fire Codes and apprehension on the durability of composites.

Phenolic composites, due to their excellent Fire/Smoke/Smoke Toxicity (FST) properties and proven durability offer a safe system that can be used for interior applications. This paper will present data and examples of many Architectural applications in Europe and the US, showing it to be an acceptable commodity.

Introduction

Composites offer many advantages for use in architectural applications. However, in case of a fire, composites will burn. Commonly used matrices such as polyester, vinyl ester and epoxy emit high levels of heat, smoke and toxic fumes. Therefore, their use in enclosed areas is restricted.

Phenolic composites, which are known for their excellent high temperature resistance, low flame spread, low heat release rates and low smoke toxicity characteristics are suitable for use in enclosed areas.

Recently developed Phenolic resoles can be processed by conventional means such as Hand lay-up, Spray-up, Filament Winding, RTM, VARTM, SCRIMP, Pultrusion and Press Molding. Although pigmentation of Phenolics has been a problem – pigmentation is possible as long as the desired color is brown or black – recently developed compatible polyester gel coats are available that still provide excellent FST properties of the composite.

Applications

Transit

Phenolics are more prevalently used in Europe, where FST requirements in Mass Transit applications are more stringent than in the US. Figure 1 illustrates the current US Rail Car requirements and what can be achieved with Phenolic. Phenolic composites are ideal for passenger trains and buses that travel through tunnels. Current applications in Europe include London Underground, Chunnel trains, Tilt Trains (SCRIMP) in Norway and shuttle trains in Germany.

Applications in North America include People Movers at Dallas Airport (built in 1984), BART cars, Baltimore subway, Amtrak trains, SEPTA trains and VIA Rail trains in Canada. Resin Transfer Molded Phenolic flooring (with a balsa wood core), replacing plymetal (plywood with a metal skin) for trains and buses are very popular due to the 40-50% weight reduction and increased durability they provide.

Offshore / Marine

Phenolic pultruded grating that have Coast Guard approval are used on Offshore platforms and Navy ships. Pressure pipe for deluge systems on Offshore platforms that withstand jet fuel fire exposure of 1100°C for 20 minutes are filament wound using Phenolic.

Construction

Phenolic fume and exhaust ducting approved per Factory Mutual Research protocol Class # 4922 and 4910 are prevalently used in Clean Rooms for the semiconductor industry. The low Heat Release Rate and Flame Spread of Phenolic allows the ducting to pass without the use of water sprinklers inside the duct. Figure 2 illustrates some of the Fire/Smoke properties of Phenolic composites.

Polyester or vinyl ester composites have been used in outdoor construction for many years and have proven their long term durability. Some exterior applications using Phenolic include the 20' diameter dome of the Law School at Quinnipiac College and the clock tower at City Hall in New York City. Both were built using Hand Lay-up with a balsa wood core. Mechanical and thermal properties of Phenolic, polyester and metals are compared in Figure 3.

Since Phenolic composites meet various European Building Regulations (See Figure 4), Phenolic ceiling panels have been used over an escalator at Liverpool Station in London Underground. Also, the interior panels of School buildings and walkways between different wings of a hospital in London were made of Phenolic.

A recent structure is the United Ccomposites/Hameland AMC project in the Rotterdam Shopping Mall in Netherlands. Ceiling panels, wall panels and columns are made of Phenolic composite – some with Phenolic foam core and some without.

Using a Vacuum Infusion process, such as SCRIMP, Phenolic laminates containing 65 – 70% fiberglass can be produced. Such panels have been tested per ASTM E136 and determined to be Non Combustible (See Figure 5).

The development of compatible polyester gel coats provide color off the mold. The Fire / Smoke properties of gel coated Phenolic composites are still excellent (See Figure 6). This allows simple production techniques such as Hand lay-up, Spray-up and RTM to produce composites of any design without the need for paint.

Conclusion

It has been demonstrated that Phenolic composites can provide all the advantages of composites plus
Fire / Smoke / Smoke Toxicity safety.
As a result, the use of Phenolic composites for exterior and interior Architectural applications can provide easy fabrication and cost reduction without compromising on Fire Safety:

- Part Consolidation / Design Flexibility
- Quick assembly / Use of smaller cranes
- Lower Insurance rates – in case of fire, earthquakes
- Taller buildings – high load to weight ratio
- Corrosion resistance

Figure 1 – Current Passenger Rail Equipment Requirements*
Compared to Phenolic Capability

TEST	Requirement	Painted Phenolic (35% glass)
ASTM E 162 Flame Spread Is	≤ 35	0.85
ASTM E 662 Smoke Density Ds (1.5 minutes) Ds (4.0 minutes) Ds (Maximum) Time to Maximum Ds (Minutes)	≤ 100 ≤ 200 - -	0.6 15 51 14
NBS Smoke Chamber Gas Analysis (ppm) CO HF NO_2 HCl HCN SO_2	≤ 3500 ≤ 200 ≤ 100 ≤ 500 ≤ 150 ≤ 100	100 0 0 0 0 80

* Federal Register / Vol. 64, No. 91 (May 12, 1999) (also FTA/UMTA 1984 and 1993)

Figure 2 – Factory Mutual Research Protocol
Class Number 4922

ASTM E-84	
Flame Spread	5
Smoke Density	10
Oxygen Bomb Calorimeter	7235 Btu/lb (1.682 x 10^4 kJ/kg)
Autoignition Temperature	887°F (475°C)

The maximum thermocouple reading taken 1 ft (0.3 m) from the exhaust end of the duct was 639°F (337°C). Maximum allowable: 1000°F (538°C)

Figure 3 – Comparison of the Performance of Phenolics, Polyester and Metals

PROPERTY	Phenolic FRP	FR Polyester FRP		Mild Steel (painted)	Aluminum (painted)
		Unfilled	Filled		
Density (g/ml)	1.4 – 1.5	1.4 – 1.5	1.6 – 2.3	7.8	2.7
Tensile Strength Mpa	100 - 140	100 – 140	30 - 75	410 – 480	80 - 430
Tensile Modulus (Gpa)	5.5 – 7.5	6 – 7.5	7 - 19	210	70
Elongation @ Break (%)	1.8 – 2.5	1.8 – 2.5	0.4 – 1.7	20 – 35	3 - 18
Flexural Strength (Mpa)	150 - 200	150 – 200	100 - 125	200 (yield)	65 – 220 (yield)
Flexural Modulus (Gpa)	6 - 8	6 – 8	6 - 15	210	70
Izod Impact Strength (KJ/m^2)	65 - 75	50 – 75	20 - 50	-	-
Coefficient of Thermal Conductivity (W/m/K)	0.20 – 0.24	0.20 – 0.23	0.22 – 0.30	46	140 – 190
Coefficient of Thermal Expansion (°C x 10^{-6})	10 – 15	25 – 35	18 - 25	11 – 14	22 – 24
Temperature Index (BS 6853)	> 420°C	Fail	< 365°C	> 420°C	> 420°C
UK Building Regs. (BS 476 Parts 6 & 7)	Class 1/0	Class 2/3	Class 1/0	Class 1/0	Class 1/0
3 Meter Cube Smoke Test (BS 6853)	Category 1	Fail	Category 2	Category 1	Category 1

Figure 4 – European Building Regulations

Country	Regulation	Class
Netherlands	NEN 6064, 6065 & 6066	Class 1
Germany	DIN 4102	Class B1
United Kingdom	BS476 Part 6 & 7	Class 1 / 0
US	Pittsburgh Toxicity Test 35% glass 65% glass	 61g 92 g

Figure 5 – ASTM E 136 – Non-Combustibility
65 – 70% glass

Requirement	Result
30 seconds into the test – No Flame	No Flame
Maximum Chamber Temperature Increase - 30°C Starting Temperature Ending Temperature	 750°C 774°C
Maximum Weight Loss - 50%	12%

Figure 6 – Gel Coated Phenolic (35 - 40% glass)

TEST	RESULT
ASTM E-162	19.2
ASTM E-662 Ds (1.5 minutes)	2.8
Ds (4.0 minutes)	31.3
ASTM E-1354 Cone Calorimeter @ 50 KW/m^2	
Time to Sustained Flame	80.7 secs.
Total Heat Release	10.6 MJ/m^2
Average Effective Heat of Combustion	7.7 MJ/Kg
Average Mass Loss Rate	9.5 g/m^2/sec
Smoke Average Specific Extinction Area	531.8 m^{2}Kg
Peak Heat Release Rate	205 KW/m^2
Average Heat Release Rate for 60 seconds	97.4 KW/m^2
180 seconds	44.2 KW/m^2
300 seconds	35.8 KW/m^2

Biography:

Aram Mekjian is President of Mektech Composites Inc, a Distributor for Borden Chemical Inc's Phenolic resins. He is the exclusive North American Distributor for Cellobond Phenolic resins, now owned by Borden Chemical, which he introduced to the US market in 1990 as Business Manager for BP Chemicals. Prior to that, Aram was the Technical Director and Product Manager for Aristech Polyesters for 13 years. He received a BS in Chemistry from Valdosta State College, a MS in Chemistry and MBA in Marketing from Fairleigh Dickinson University.

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