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Development of lightweight Sandwich Composites with improved Reaction to Fire and UV resistance for Double Curvature Façade Panels

24TH INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS

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1. INTRODUCTION

Buildings with **double curvature façades** can be aesthetically pleasing, being capable of enchanting both architects and the general public. Though, manufacturing of such façades can be a challenge in both technologic and economic terms. **Traditional molding technologies demand a unique mold for each panel geometry**, resulting in **substantial costs** related to raw materials and storage space, and **long lead times for designing and manufacturing**. A **reconfigurable multipoint mold** has been identified to solve this issue, where an array of moving pins can have their height quickly adjusted to form the required shape and molding surface. Another present technological challenge is the **highly demanding fire resistance requirements**. Certain European countries require that public and civil buildings comply with the highest grades of EN 13501 standard, A2, s1, d0 and B, s1, d0. That is a serious constraint when developing lightweight sandwich fiber reinforced polymer (FRP) composites, as polymeric materials do not naturally present good reaction to fire behavior. Furthermore, the polymeric raw materials should present suitable **processability** with the reconfigurable multipoint mold and supporting processing equipment and allow the manufacturing of **sandwich structures**. Sandwich composites structures are **lightweight** solutions with high stiffness, consisting of two composite laminate faces, separated by a lightweight core material, commonly made of foam or honeycomb.

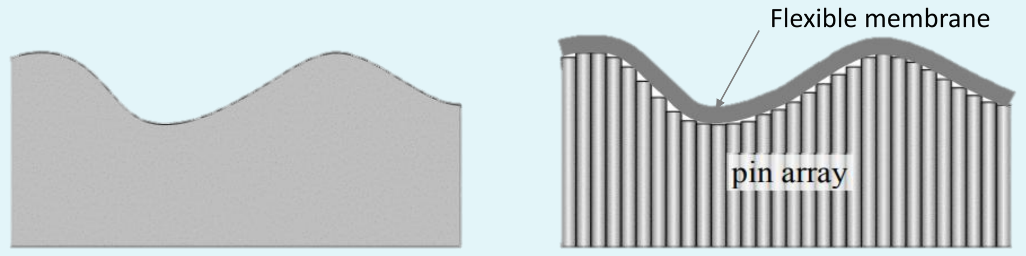


Fig. 1 traditional rigid mould versus reconfigurable multipoint mould

2. OBJECTIVES

The project aims at selecting adequate polymeric based materials for the manufacture of **lightweight double curvature lightweight sandwich** panels, with a **minimum curvature radius of 300 mm**, using a reconfigurable multipoint mould, considering the following **requirements** and **constraints**:

1. Processing temperatures below 200 °C;
2. Processable by Vacuum Assisted Resin Infusion (VARI) or Vacuum assisted Thermoforming (VAT);
3. Thermoformable rigid foam core to conform to the double curvature molding surface;
4. High drapability fabrics (e.g. twill) to conform to the minimum curvature radius;
5. Compliant with the highest grades of EN 13501 standard (A2, s1, d0 and B, s1, d0);
6. Long term UV radiation resistance.

Furthermore, this project aims at optimizing the manufacturing processes of the double curved sandwich panels and developing the attachment solution to the building walls.

Fig. 2 Buildings inspiring the development of this project: (left) Heydar Aliyev Center, Baku – Azerbaijan, Architect Zaha Hadid (2013) and (right) Central Park OfficeTower, Utrecht – The Netherlands, Architects: Group A

3. METHODOLOGY

This work is testing several material combinations to obtain (a) fully thermoplastic and (b) thermoset based composite sandwich for double curvature panels solutions. All tested sandwich composites used a thermoformable foam.

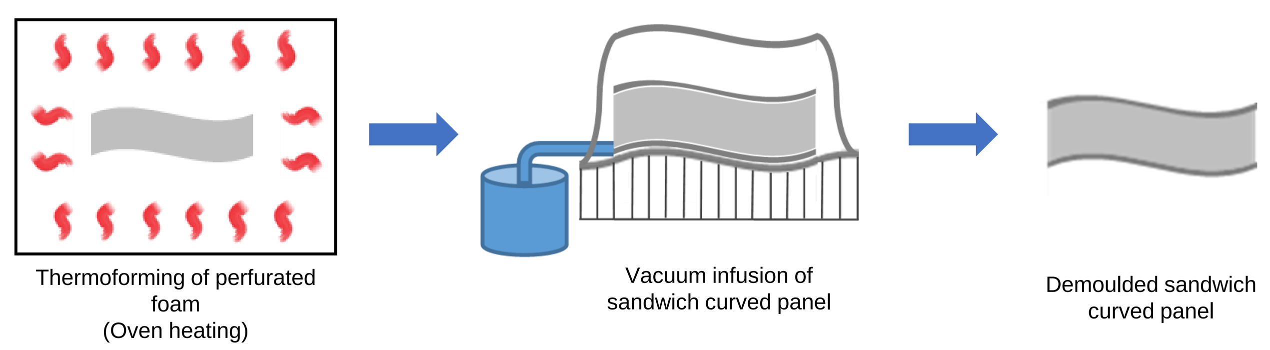
In a first stage, flat sandwich panels were manufactured to assess their reaction to fire, observed during ignition tests, conducted according to ISO 11925-1 standard, and to assess UV radiation resistance of different coating formulations.

Sandwich manufacturing was parallelly optimized on a small scale rigid mould. Depending on the constituent materials, either one of two manufacturing methods were conducted:

1. VARI when liquid thermoset matrices are used for the manufacturing of composite faces;
2. VAT when thermoplastic films are used for the manufacturing of composite faces.

MATERIALS and MANUFACTURING PROCESSES

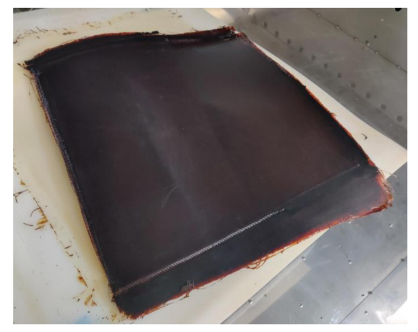
Vacuum Assisted Resin Infusion



Fibre fabric reinforcements
- Basalt fibre with 2/2 twill structure and areal weight of 220 g/m^2
- Glass fibre fabric reinforcements with 2/2 twill structure and areal weight of 195 g/m^2

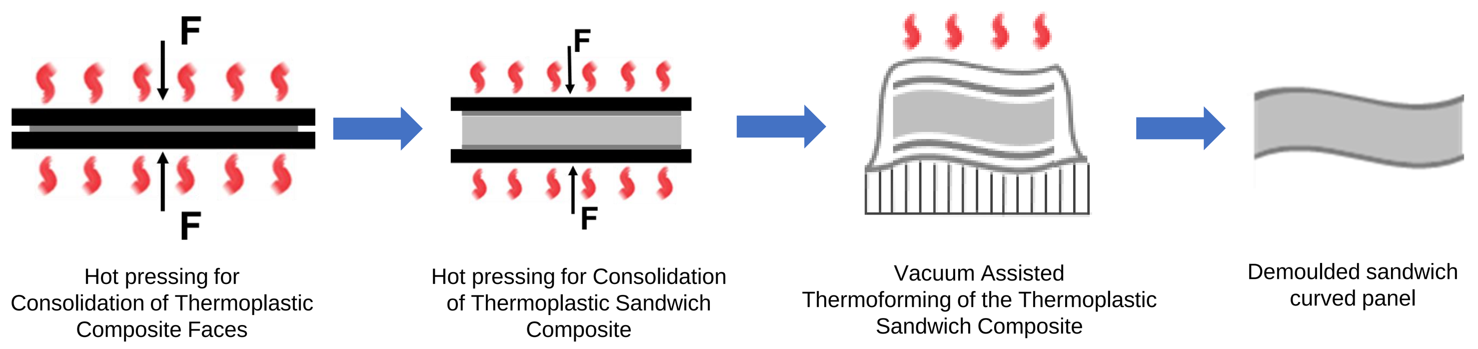
Foam core: Fire-retardant structural Airex® T90 PET foam from 3A Core Materials, 25 mm thick

Matrices:
- Fire-retardant epoxy resin system SR1124/SD4771, with SGi 128 gelcoat from Sicomin
- Biobased furan resin Furolite 106A25 2ST from TFC, with H3PO4 (85 wt% phosphoric acid) and HM 1448 (85 wt% (2-hydroxyethyl) ammonium nitrate)



Example of small scale sandwich prototype with double curvature made of furan resin/ glass fibre composite skins and PET structural foam, 500 mm x 500 mm, manufactured by VARI,

Vacuum Assisted Thermoforming



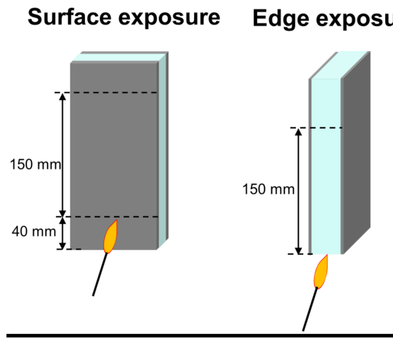
Fibre fabric reinforcements
- Basalt fibre with 2/2 twill structure and areal weight of 220 g/m^2
- Glass fibre fabric reinforcements with 2/2 twill structure and areal weight of 195 g/m^2

Foam core: Fire-retardant structural Airex® T90 PET foam from 3A Core Materials, 25 mm thick

Matrices:
- Fire retardant low density polyethylene (FR-LDPE) film, 60 µm thick
- Fire retardant polypropylene (FR-PP) film, 125 µm thick

Example of small scale sandwich prototype with double curvature made of FR-LDPE/ glass fibre composite skins and PET structural foam, 500 mm x 500 mm, manufactured by VAT

IGNITION TESTS



Test conditions (ISO 11925-2 standard)
- Three specimens for each condition, measuring approximately 250 mm x 90 mm, with thicknesses between about 27 – 29 mm
- Flame application for 30 seconds
- Verify whether the flame front reaches 150 mm above the application point, and recording of incurring time
- Presence of flaming droplets/particles
- Presence of flaming droplets/particles which caused ignition of the filter paper

Sample	Exposure condition	Occurrence of ignition	Fs > 150 mm	t150 (s)	Presence of flaming droplets/ particles	Ignition of the paper
Furan resin/ Basalt fibres – Airex T90 PET foam	Front face	yes	no	-	no	no
	Lateral bottom edge				yes	
Furan resin/ Glass fibres – Airex T90 PET foam	Front face	yes	no	-	no	no
	Lateral bottom edge				yes	
Epoxy resin/ Basalt fibres – Airex T90 PET foam	Front face	yes	no	-	no	no
	Lateral bottom edge				yes	
Epoxy resin/ Glass fibres – Airex T90 PET foam	Front face	yes	no	-	no (except for 1 specimen)	no
	Lateral bottom edge				yes	
FR-LDPE/ Glass fibres – Airex T90 PET foam	Front face	yes	no	-	no	no
	Lateral bottom edge				yes	

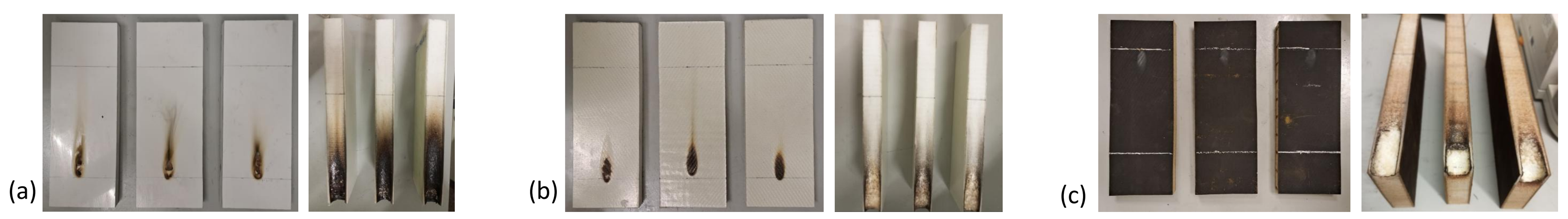


Fig. 3 Example of specimens exposed to ignitions tests (a) Epoxy resin/ Glass fibres – Airex T90 PET foam; (b) FR-LDPE/ Glass fibres – Airex T90 PET foam and (c) Furan resin/ Glass fibres – Airex T90 PET foam

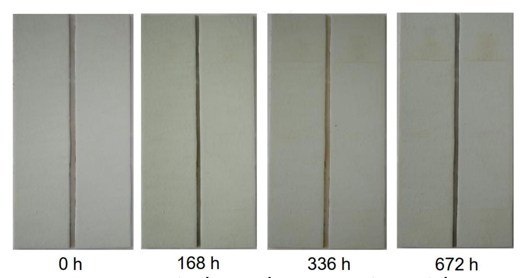
EXPOSURE TO FLUORESCENT UV LAMP RADIATION

Test conditions (ISO 4892-3 standard)
Cycles of Exposure to UVA-340 (type 1A) lamp, with irradiance of 0.76 W.m^{-2} x nm^{-1} at 340 nm, for 8 hours, at 60 ± 3 °C, followed by 4h period of condensation, with UV lamps off, at 50 ± 3 °C. Cycling test conducted for a total of 672 h.

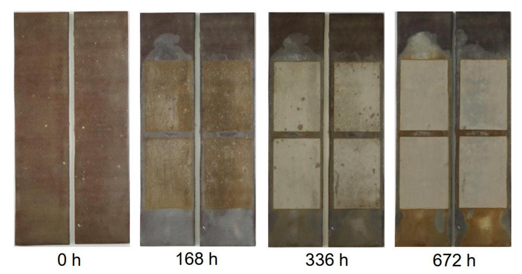
The surface chalking was measured prior to and at the end of testing, and measurement of gloss, color coordinates (L*, a*, b*) and color change (ΔL*, Δa*, Δb*, ΔEab*) and FTIR-ATR analysis conducted at 0, 168, 336 and 672 hours of testing.

Sample	Coating formulation	Chalking	Gloss 60º (GU)		Color difference at 672h			
			0h	672h	ΔL*	Δa*	Δb*	ΔE*ab
PP/ glass fibres	PU	2.9%	7.0	6.6	0.0	0.1	0.3	0.3
	PU + ATH + APP	7.5%	2.3	2.3	0.4	0.1	0.4	0.5
	PU + ATH + APP + UVASORB®	5.5%	2.4	2.4	0.3	0.2	0.6	0.7
	Epoxy + ATH + APP + UVASORB®	63.4%	28.6	2.1	-20.1	24.8	-8.2	33.0
Furan resin/ glass fibres	PU	4.1%	6.1	3.4	-0.2	0.1	0.4	0.5
	Epoxy + ATH + APP + UVASORB®	56.1%	27.0	1.7	30.2	-3.8	1.7	30.5

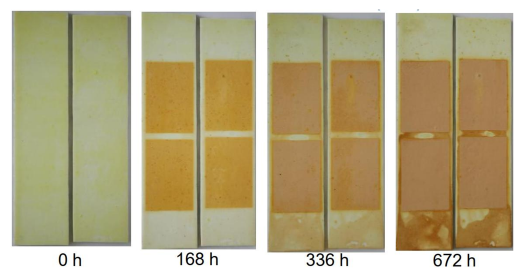
Polyurethane (PU), Aluminium Trihydroxide (ATH), Ammonium polyphosphate (APP), UVASORB® 3C is a benzophenone derivative UV absorber



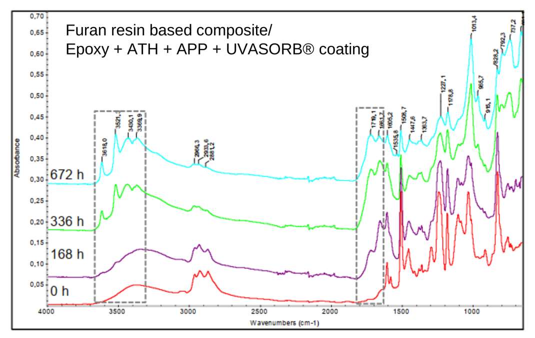
Furan resin based composite with PU coating



Furan resin based composite with Epoxy + ATH + APP + UVASORB® coating



PP based composite with Epoxy + ATH + APP + UVASORB® coating



Main Conclusions
- All PU based coating formulations did not show considerable surface changes when subjected to the mentioned conditions, with the exception of the Furan resin based composite with PU coating which showed a colour change on the non-exposed region of the specimens;
- The epoxy based coating formulations revealed chalking, decrease of gloss and severe colour change. Changes on the FTIR spectra are also noticeable, indicating the occurrence of photodegradation reactions on the surface of the coating.

FUTURE WORK

Single Burning Item (SBI) test to be conducted, following EN 13823

Manufacturing of full scale (2000 mm x 1000 mm) sandwich panels with double curvature

ACKNOWLEDGEMENTS

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