Comparison of Basalt, Glass, and Carbon Fiber Composites using the High Pressure Resin Transfer Molding Process

Ian Swentek, Jeffrey Thompson
Gleb Meirson, Vanja Ugresic, Frank Henning

Western
UNIVERSITY · CANADA

in cooperation with

Fraunhofer

Fraunhofer Project Centre for Composites Research

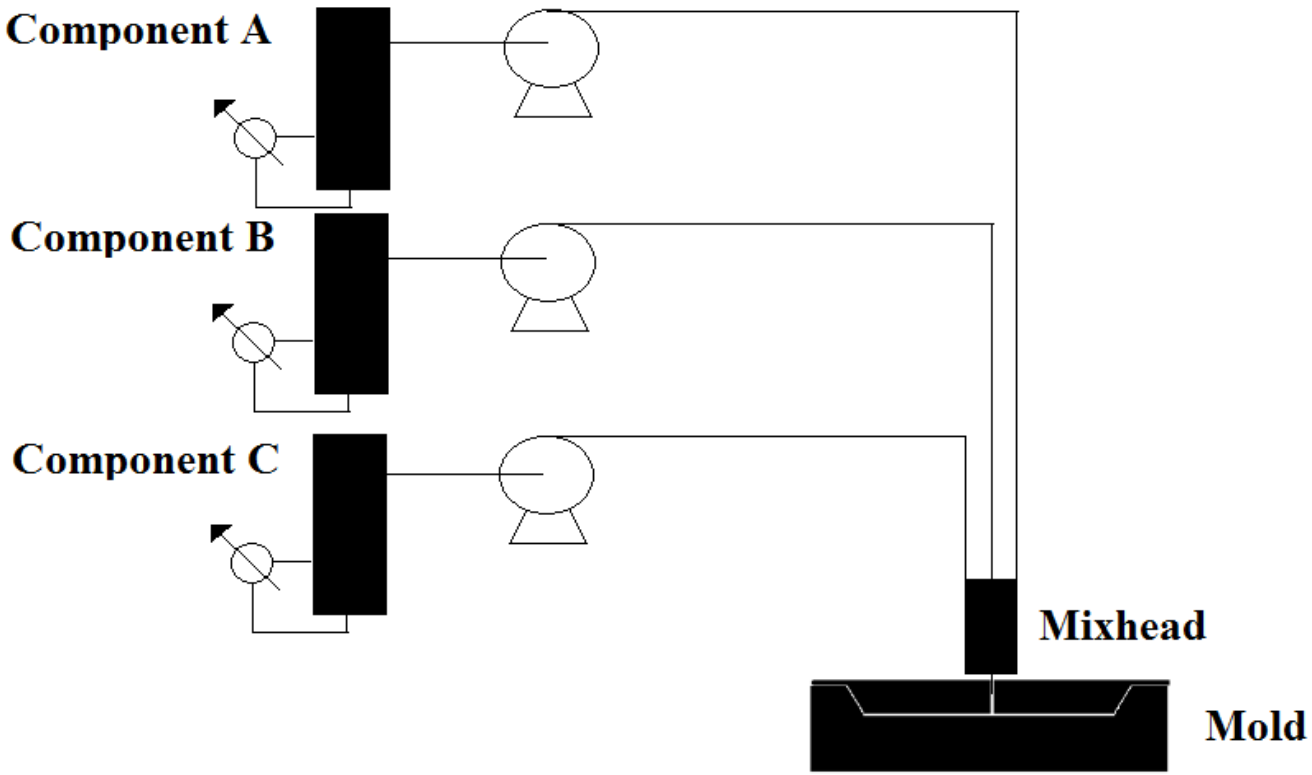
FPC @ Western

A joint venture between:

Western University, London, Ontario, Canada
And
Fraunhofer Gesellschaft, Munich, Germany;
Institute for Chemical Technology (ICT), Pfinztal, Germany

Contact: vugresi@uwo.ca
www.eng.uwo.ca/fraunhofer

RTM- Part 1



Two or more components are moved from separate heated tanks by high pressure pumps into the mix-head where they are mixed and injected into the mold.

HP-RTM- Part 2

RTM mold

Preform transfer into mold, mold closing

15 sec

Resin injection and curing

90 sec

Opening and demolding

15 sec

Two minute cycle time

Thanks to new resins this technology is now ready for high volume production structural applications

Composite Manufacturing

Dieffenbacher PreformCenter

- Precise cutting of MD and UD fiber fabrics at any cutting angle
- CNC cutting without paper underlay and vacuum foil
- Continuous endless cutting to reduce material waste
- Short cycle times

Composite Manufacturing

RTM Rimstar Thermo 8/4/8 with 2 Mixing Heads

- Self-cleaning mixing head design
- Separate mixing heads for epoxy and polyurethane systems
- Internal mold release system can be used for third injection component
- Precision dosing between 0.05 - 2.0 g/s
- Mixing pressures between 60 and 180 bar
- Resin flow rates: 20 - 120 g/s
- Active pressure/flow monitoring

Composite Manufacturing

Dieffenbacher CompressPlus DCP-U 2500

- Parallel motion control system
- Maximum closing force of 25,000 kN (using full parallel motion control force)
- Minimum closing force of 250 kN
- Rapid motion up to 800mm/s ram speed
- Precision closing speeds up to 80mm/s at low force and 20mm/s at high force

Introduction-Common Fiber Types

Glass Fiber

Basalt Fiber

Carbon Fiber

Use of basalt fiber has gained momentum as an alternative to traditional carbon and glass fiber.

Introduction to Basalt

- Basalt rock was lava that rapidly cooled to form igneous rock
- Basalt rock about is one third of Earth's crust
- Basalt forms natural wonders like the Giants Causeway in Northern Ireland

Photo by code poet on Flickr

Fiber Properties

	Basalt	E-Glass	S-Glass	Carbon
Tensile strength [MPa]	3000-3400	2700-3000	3500-4400	3800-4400+
Elastic modulus [GPa]	86-90	72-76	83-87	230+
Elongation at break [%]	3.1-3.3	4.8	5.7	0.5-1.5
Maximum temperature of application [°C]	~600	380	500	400

Key Basalt Advantages

- Bridges the performance gap between glass and carbon fibers
- Great thermal or electric insulator
- Strong and durable in harsh environments
- Impressive performance for Advantageous price

Fiber Fabric Properties

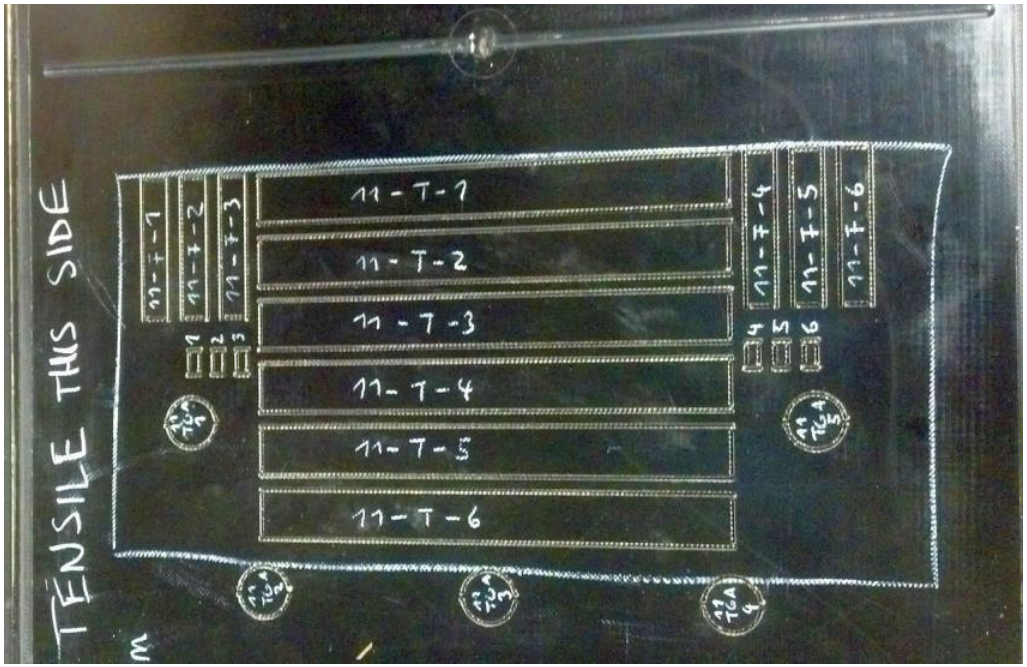
	Weave	Areal weight [g/cm^2]	Layers [50%wt 2mm]	Density [g/cm^3]	Fiber modulus [GPa]
Glass Fiber	Plain	450	6	2.60	73
Mafic Basalt	Plain	340	8	2.65	90
Carbon fiber	2x2 twill	300	6	1.81	230

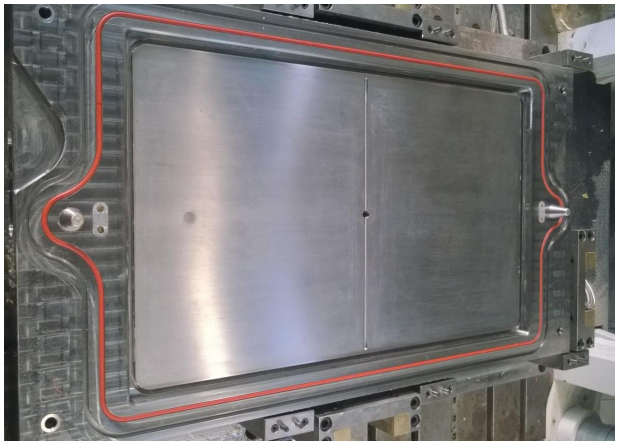
Manufacturing Conditions

- Hexion's epoxy system Epikote 6150/Epikure 6150
- Mold temperature set to 120◦C
- 5 min curing time
- 1500 kN press force during injection
- 4500 kN press force during cure

Composite Properties

Sample layout





Composite Properties- Measurement Techniques

Tensile testing

Test Method		ASTM D3039
Nominal	Thickness	2.0 mm
Sample	Width	25 mm
Dimensions	Length	250 mm
Load Frame, MTS C45.105E		100 kN
Load Cell, MTS LPS.105		100 kN
Displacement rate		2 mm/min

Composite Properties- Measurement Techniques

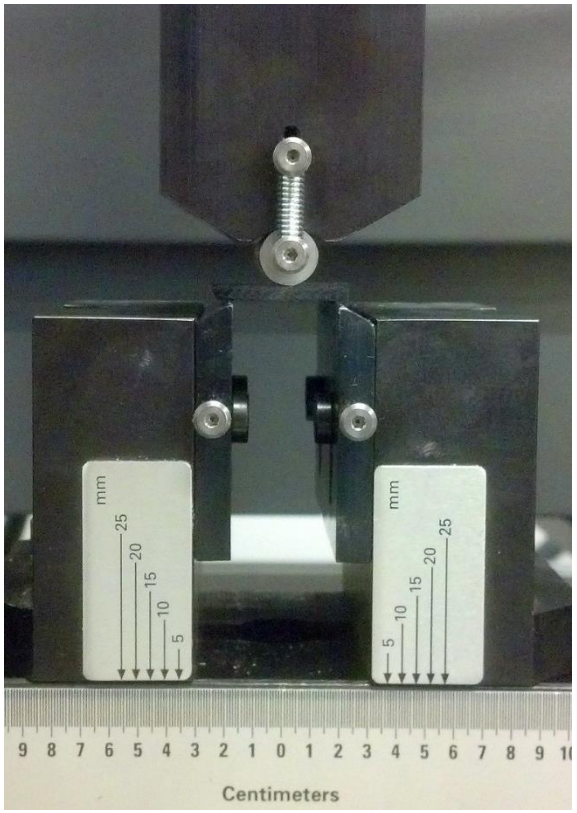
Flexure testing

Test Method		ASTM D7264
Nominal	Thickness	2.0 mm
Sample	Width	15 mm
Dimensions	Length	100 mm
Load Frame, MTS C45.105E		100 kN
Load Cell, MTS LPS.104		10 kN
Displacement rate		5 mm/min
Fixture Rollers		5 mm radius
Span width		80 mm

Composite Properties- Measurement Techniques

Interlaminar Shear Strength

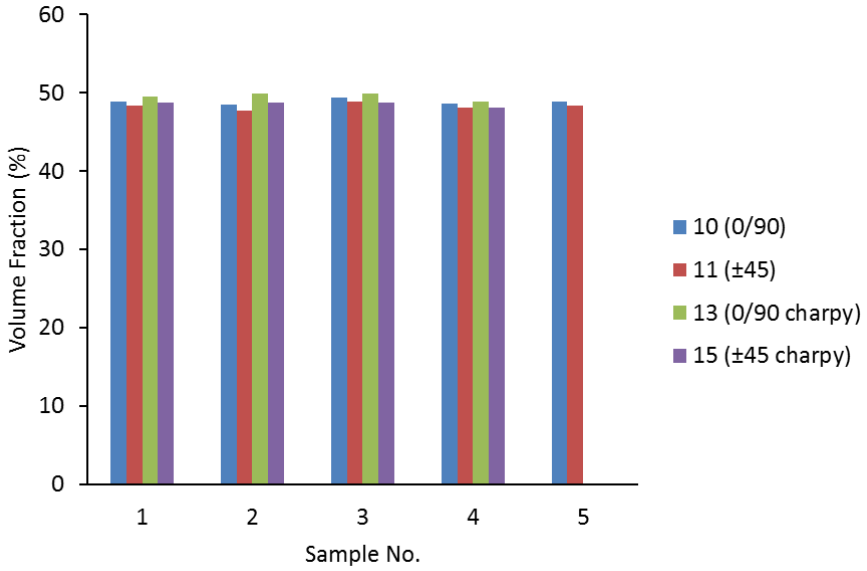
Test Method		ASTM D2344
Nominal Sample Dimensions	Thickness	3.1 mm
	Width	12 mm
	Length	24 mm
Load Frame, MTS C45.105E		100 kN
Load Cell, MTS LPS.104		10 kN
Displacement rate		2 mm/min
Fixture Supports		1 mm radius
Span width		20 mm



Composite Properties

Property		Unit	0/90 fiber orientation	±45 fiber orientation
	Density	[g/cm^3]	1.88±0.01	1.87±0.01
	Fiber volume fraction	[%]	48.90±0.30	48.30±0.40
Tensile	Modulus	[GPa]	26.50±1.40	13.30±0.60
	Strength	[MPa]	572±11	202±9
	Failure strain	[%]	2.74±0.15	19.20±0.70
Flexure	Modulus	[GPa]	24.80±0.40	13.80±0.40
	Strength	[MPa]	563±16	204±3
	Failure strain	[%]	2.90±0.21	3.60±0.12
Interlaminar shear	Strength	[MPa]	49.30±1.30	29.70±1.60

Composite Properties- Volume Fraction



Results were normalized to 50% according to equation:

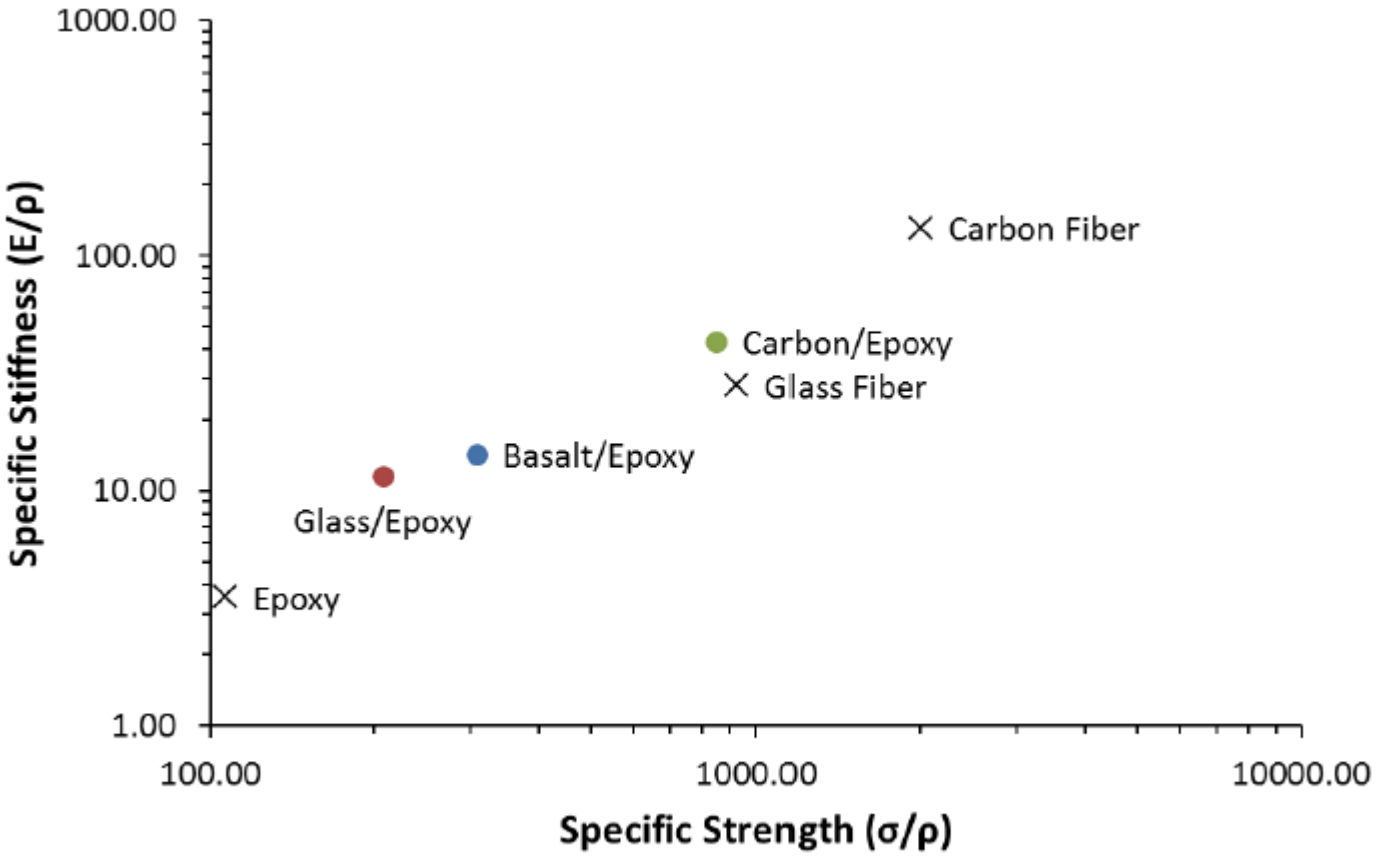
$$X_{normalized} = X_{test} \frac{v_{f\,selected}}{v_{f\,actual}}$$

Composite Properties

Properties for 50% volume fraction composites

Property		Unit	Glass	Mafic Basalt	Carbon
	Weave		Plain	Plain	2x2 twill
	Density	[g/cm^3]	1.88	1.9	1.46
Tensile	Modulus	[GPa]	21.6	27.2	62.8
	Strength	[MPa]	389	585	1240
Flexure	Modulus	[GPa]	23.5	25.3	78.2
	Strength	[MPa]	509	576	1240
Interlaminar shear	Strength	[MPa]	42.5	50.5	58.2

Composite Properties



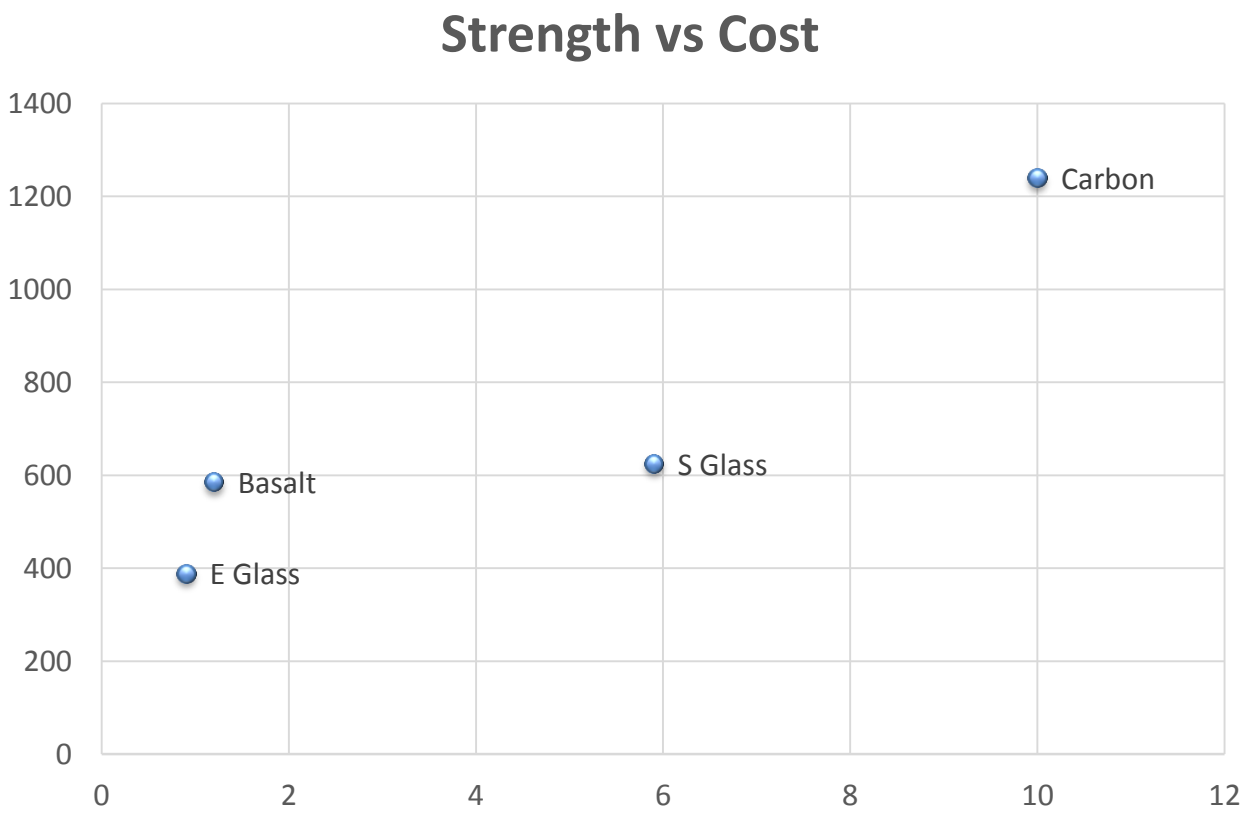
Summary

- Mafic basalt fabric was molded in HP-RTM system with epoxy and its properties were compared to composites with glass and carbon fiber
- Basalt fabric composites performed on the intermediate level between glass and carbon composites
- Basalt fiber composite offers a direct increase in performance over glass fiber composite.

Acknowledgments

- This work was done in collaboration and funded by Mafic, www.mafic.com
- We would like to thank Steve Greydanus of Hexion for the donation of trial materials and his support toward the determination of process settings. www.hexion.com

MAFIC VALUE PROPOSITION



MAFIC AND PARTNER PRODUCTS