BASALT FIBRES AS REINFORCEMENT FOR COMPOSITES

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Introduction

Basalt is a natural material that is found in volcanic rocks. It is mainly used (as crushed rock) in construction, industrial and high way engineering. One can also melt basalt (1300-1700°C) and spin it into fine fibres. [1-3,5-6,8]

When used as (continuous) fibres, basalt can reinforce a new range of (plastic and concrete matrix) composites. It can also be used in combination with other reinforcements (e.g. basalt/carbon). [1,3]

Some possible applications of basalt fibres and basalt-based composites are: thermal and sound insulation/protection (e.g. basalt wool, engine insulation), pipes, bars, fittings, fabrics, structural plastics, automotive parts, concrete reinforcement (constructions), insulating plastics and frictional materials. [1-8]

This wide range of possible applications results from its wide range of good properties. Basalt has good thermal, electrical and sound insulating properties. It can replace asbestos in almost all its possible applications (insulation) since the former has three times the latter's heat insulating properties. Furthermore, the fibre diameter (comparable with E-glass fibres, [5-6]) can be controlled in order to prevent uptake of harmful ultra-fine fibres. Because of its good electrical insulating properties (10 times better than E-glass, [5]), basalt fibres are also incorporated into printed circuit boards, resulting in superior overall properties compared to conventional components made of fibreglass. It is also used in other electro technical applications such as extra fine resistant insulation for electrical cables and underground ducts. Because of its thermal insulating properties it is already used as fire protection in the form of fabrics or tapes [1,5-6,8]. Automobile, aircraft, ship and household appliances are also made. These are made with thermosetting resins, such as epoxy and (phenolic) polyesters. Possible techniques involve prepregs, laying out, winding, direct pressure autoclaving, and vacuum moulding [1,2,3]. Other, structural basalt composite components (such as pipes and rods) are made from unidirectional basalt reinforcement. In combination with its high specific strength (9.6 times as high as steel), high resistance to aggressive media, and high electrical insulting properties, this results in specialty products such as insulators for high voltage power lines. [1]

Basalt composite pipes can transport corrosive liquids and gases. The same equipment as for fibreglass pipes can be used for this. These pipes are reported to be several times stronger than glass-fibre pipes. Next table [1] illustrates this:

Property	Glass-plastic	Basalt-plastic
Tensile σ (MPa)	140	(300)
Tensile E (GPa)	56	70 (160)
Density (kg/m³)	1900	1700
Therm. Cond. (kcal/m h °C)	0.5	0.3
Volume resistivety (Ω/m)	10^{10}	$4x10^{12}$

Values in brackets are for basalt/carbon pipes.

Due to basalt's low thermal conductivity, deposition of salts and paraffin's inside the pipes is also reduced. [1]

Basalt fibres can also be used in machine building because of their good frictional, heat and chemical resistance. [1,5-6,8]

Comparison between glass- and basalt fibres

With regard to their chemical composition glass and basalt fibres are somewhat alike, but for some components there are differences [2,5]:

Compound	w% in E-glass	w% in basalt
SiO_2	52-56	51.6-57.5
Al_2O_3	12-16	16.9-18.2
CaO	16-25	5.2-7.8
MgO	0-5	1.3-3.7
B_2O_3	5-10	-
Na_2O	0.8	2.5-6.4
K_2O	0.2-0.8	0.8-4.5
Fe_2O_3	≤0.3	4.0-9.5

Several basalt compounds may vary, but especially the SiO_2 content may vary largely. Only SiO_2 percentages above 46% ('acid basalt') are suitable for fibre production. [2,5]

Mechanical properties

Typical tensile strengths [2,5-6] vary greatly:

- E-glass: 3.4±0.7 GPa for fibres and 0.86-1.27 GPa for rovings (density: 2.52-2.63 g/cm³)
- Basalt: 1.43±0.59 GPa for fibres and 0.69–0.92 GPa for rovings (density: 2.6-2.8 g/cm³)

Basalt also has a higher modulus (82-110 GPa) than E-glass (68-73 GPa). [5-6]

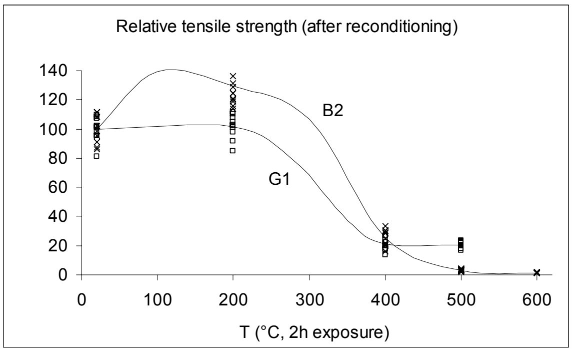
Several basalt ('B') and E-glass ('G') were tested at the Textile Department ('f' for fibre tests and 'r' for roving tests); the results are given in the next table. The basalt fibres were delivered by Basaltex, Masureel Group, Belgium.

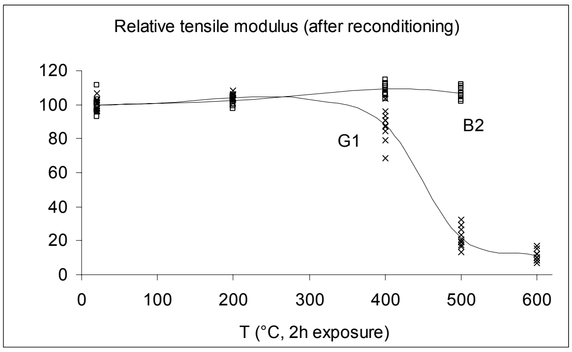
Sample	Tensile σ (MPa)	Tensile E (GPa)
B1 (r)	860 ± 63	76.6 ± 3.3
B2 (r)	835 ± 83	73.5 ± 2.5
B3 (r)	650 ± 68	70.4 ± 7.4
B3 (f)	1662 ± 599	74.8 ± 3.6

G1 (r)	1630 ± 136	63.1 ± 3.2
G2 (r)	1115 ± 51	75.9 ± 1.5
G2 (f)	1362 ± 412	67.6 ± 2.1

As expected, basalt has a lower strength and a higher modulus than E-glass. In non-standard conditions, however, basalt could prove to be stronger than E-glass (see further on).

Thermal properties
Basalt can be used over a wide temperature range, from about -260/-200 to about 650/800°C (compared to E-glass: from -60 to 450/460°C). Figures depend upon the reference [2,5-7].
Residual relative strengths (after heat treatment) are greater for basalt than for E-glass [5]. In relative terms, (stressed) basalt outperforms E-glass in the 300-500°C range. When unstressed (used as fire/heat barrier) basalt can maintain integrity up to 1250°C [6].

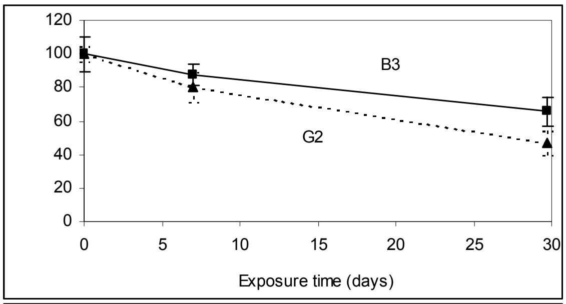


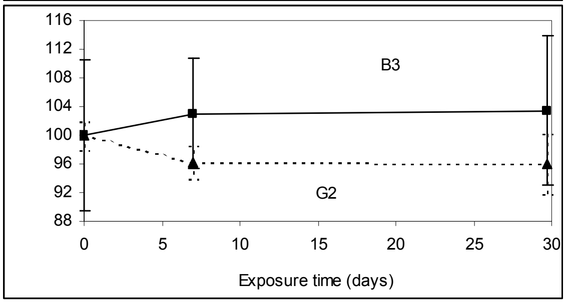


Previous figures are the result of tensile tests (on rovings B2 and G1) after thermal treatment (2h), carried out at the Textile Department. All values are relative (initial values set to 100%). One may conclude that basalt can retain its properties over a greater temperature range than glass. At temperatures over 400-500°C it becomes weaker than glass, but it does retain integrity and still provides protection against heat (better than glass, see introduction). Values over 100% may be caused by removal of weakening sizings and also by the great variation on the results.

Chemical properties
Basalts are more stable in strong alkalis than glass, while they are slightly less stable in strong acids [2,3,6]. Weight loss in boiling water, alkali and acid is also significantly lower for basalt [5].

Tensile tests (on fibres and rovings) after immersion in 0.4N KOH (in saturated $Ca(OH)_2$, pH = 13.2, simulation of concrete conditions) were carried out at the Textile Department. The results on rovings were the most evident ones:





These results confirm basalt's better resistance to alkali, compared to E-glass.

Conclusion
The presented data indicate that basalt has potential for replacing E-glass in several composites, especially when resistance to extreme conditions is required. However extra research may be needed (e.g. on the adhesion with different resins).

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