

Composites Reinforcement Fibers: I - The Glass Family

Dr. Scott W. Beckwith

SAMPE International Technical Director and President, BTG Composites Inc., Taylorsville, UT

E-mail: swbeckwith@aol.com

Where would FRP and advanced composites be without that reinforcement string being held together with that sticky glue? We all know that most traditional, often commercial composites that fall within the FRP (fiber reinforced plastic) composites almost inherently are produced using E-glass fiber. And we tend to think that most advanced composites are manufactured for high strength performance using S-2 glass fiber materials. Consequently the next couple of Tech Tidbits columns will focus on the reinforcement materials that make up most composites. Since glass fibers dominate the world market in so many ways (carbon is trying to push them aside), the first article will concentrate on the “glass fiber family” and then move on to carbon/graphite fibers, aramid and organic fibers, and, finally Boron and other miscellaneous fibers.

It is often said that glass fibers are produced from batches of “high quality sand or dirt.” While that is not technically true, although silicon dioxide (SiO₂) is the one of the primary ingredients in both sand (good sand anyway) and glass fiber, there are a wide number of other ingredients mixed into the system during processing (see Table 1).

Table 1. Chemical composition of various glass fibers.

Chemical Component	E-glass (%) (Electrical)	A-glass (%) (High Alkali)	C-glass/ECR-glass (%) (Chemical)	S2-glass (%) (High Strength)
SiO ₂	54.3	72.0	64.6	64.2
Al ₂ O ₃	15.2	0.6	4.1	24.8
B ₂ O ₃	8.0	--	4.7	trace
CaO	17.2	10.0	13.2	trace
MgO	4.7	2.5	3.3	10.3
Na ₂ O	0.6	14.2	7.7	0.3
K ₂ O	--	--	1.7	--
Fe ₂ O ₃	--	--	--	0.2
ZnO	--	--	--	--
TiO ₂	--	--	--	--

Glass fibers generally fall into two broad categories that tend to be defined by their modulus (stiffness) and their strength. Glass fibers with a modulus on the order of 10.0-10.5 Msi (69-72 GPa) often have a lower strength. The second category has increased strength and a modulus in the 12.5-13.0 Msi (86-90 GPa) range. Glass fibers traditionally characterized by the low to medium strength range are the E, A, C and ECR versions. The higher strength fibers fall into the S-2 category. Table 2 shows the differences in nominal properties for those classes of materials. Glass fibers in general are considered to be the “heavier” fibers within the reinforcement market although Boron also weighs in at about the same density. However, it is important to remember that the density of aluminum is about 2.8 gm/cm³ and steel about 7.8 gm/cm³. The cost difference between the E-glass fiber set and S2-glass fiber materials are about 8:1 with S2 being the higher price. However, many advanced composites use the S2-glass version because of the higher strength performance while E-glass is the traditional commercial and industrial product that dominates the world consumption in the FRP market.

Table 2. Typical mechanical and physical properties of the majority glass fibers (E, S2).

Fiber Property	E-glass	S2-glass
Density (gm/cm ³)	2.55-2.58	2.46-2.49
Tensile Modulus (Msi)	10.0-10.5	12.5-13.0
Tensile Strength (Strand) (ksi)	500	665
Tensile Strength (Nominal Design) (ksi)	270-390	530-620
Range of Elongation (%)	4.5-5.0	5.4-5.8
Thermal Expansion (10 ⁻⁶ in/in/°F)	3.0	0.9
Fiber Diameter Range (micron)	4-25	5-9

Although glass fibers are not as appealing to the overall aerospace market per se, they obviously dominate the worldwide market from a practical applications standpoint. They have a wide range of performance enhancing properties and economic appeal that make them especially attractive in numerous applications. Some typical attributes are:

- Lowest cost fibers of all available
- Well defined electrical properties:
 - o Low dielectric constants
 - o Good electrical insulator material
- Excellent damage tolerance (second only to aramid and organic fibers)
- Tailorable to meet wide variety of corrosion applications
- Available in wide variety of forms:
 - o Continuous fiber
 - o Mats (Chopped and Continuous)
 - o Fabrics
 - o Veils

In essence, the glass fiber industry dominates a world market that indeed sees the need for both high tech and intermediate technology applications. Hence, this fiber family has made a profound impact on both the traditional FRP and the advanced composites market segments.

References

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