Commercialization of Glass Fiber Reinforced Polymer (GFRP) Rebars.

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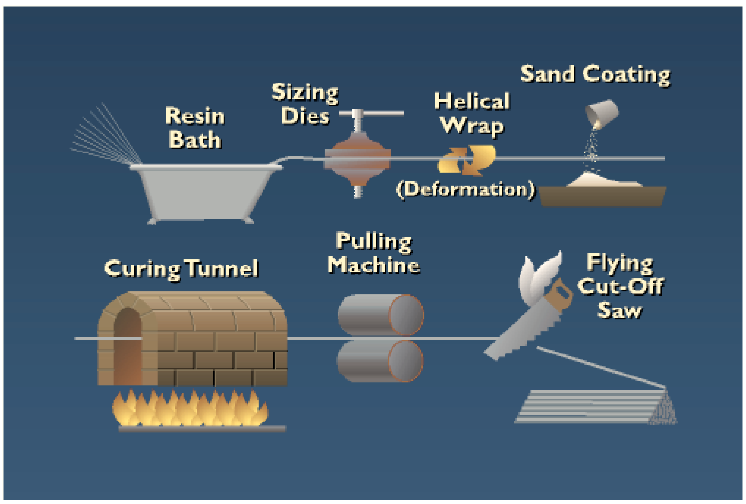
July 1999
SEAOH Convention 1999 "Concrete for the New Millennium"

Commercialization of Glass Fiber Reinforced Polymer (GFRP) Rebars is finally beginning after many years of research. Typical applications seeing commercial consumption are low risk, non-primary load bearing concrete members. This is a prudent course of commercialization and enables the concrete industry as a whole to evaluate the potential long term benefits of this new technology.

One of the principal vendors of GFRP Rebar is Hughes Brothers of Seward, NE USA. Hughes Brothers is a family owned enterprise, that has been manufacturing structures for overhead power line construction since 1921. Wood, steel and fiberglass are used as structural materials. In recent years, the company has diversified into the manufacture and supply of prefabricated timber bridge systems and fiberglass rebar.



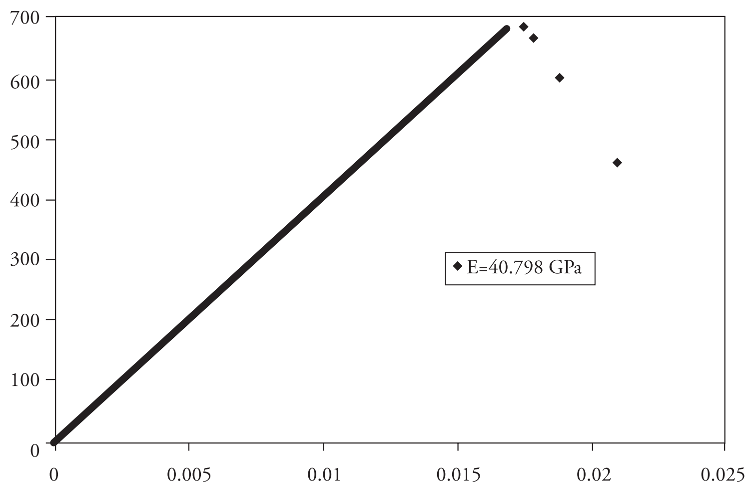
Most glass fiber reinforced polymer (GFRP) rebars are manufactured by some variation of the pultrusion process. Individual strands or rovings of e-glass fibers are drawn through a resin bath, pulled through dies, heated and given some type of surface treatment to enhance bond characteristics with the concrete. The resins used are typically thermoset resins that once cured can not be returned to a malleable state without doing irreparable damage to the end product. Regardless of the product, the individual glass strands comprise the tensile strength for the product while the polymer matrix is a binder to hold the strands in place. Higher glass content of the product will result in superior end product characteristics. A glass content of 75% volume by weight in 25% polymeric resin is about the maximum achievable and ideal ratio. Production process variables such as the type of resin used, line process speeds, curing temperatures, glass content and other subtle variables play a key role in producing a consistent, high quality GFRP Rebar. Any GFRP Rebar manufacturer should be capable of documenting individual production lot quality with traceability and lot certification.

Physical Properties
I. Tensile Stress, Nominal Diameter & Cross Sectional Area

Bar Size		Cross Sectional Area		Nominal Dia.		Tensile Stress	
(mm)	(inches)	(mm^2)	(in^2)	(mm^2)	(in^2)	(MPA)	(ksi)
6	#2	38.84	0.054	6.35	0.25	900	(130)
9	#3	84.52	0.131	9.53	0.375	900	(130)
12	#4	150.32	0.233	12.70	0.50	740	(110)
16	#5	220.64	0.342	15.88	0.625	655	(95)
19	#6	308.39	0.478	19.05	0.75	655	(95)
22	#7	389.67	0.604	22.23	0.875	480	(85)
25	#8	562.58	0.872	25.40	1.0	520	(75)
32	#10	830.32	1.287	31.75	1.25	580	(70)

Hughes Brothers reserves the right to make improvements in the product and/or process which may result in benefits or changes to some physical-mechanical characteristics. The data contained herin considered representative of current production and is believed to be reliable and to represent the best available characterization of the product as of July, 1999.

Many of the physical & mechanical characteristics of GFRP rebar are different than that of steel. GFRP Rebar is one and one half to two times stronger in tension as steel rebar at only one fourth the weight. GFRP rebar is non-conductive and magnetically transparent. It is also completely inert to chloride ion degradation. One of the chief disadvantages of GFRP rebar is that its modulus of elasticity is significantly lower than that of steel. And, while impervious to chloride ion attack, e-glass fibers are susceptible to alkaline degradation if not properly encapsulated in the polymeric resin. While its light weight makes it wonderful to handle in the field, this low density allows it to float in vibrated concrete and it must be tied into position when placing concrete.



When considering a design utilizing GFRP Rebar, the differences in physical properties and performance characteristics must be taken into account. Of chief importance to the designer is the fact that all FRP's are linear elastic up to failure and exhibit no ductility or yielding. In traditional steel reinforced concrete design, a maximum amount of steel reinforcing has been specified so that the steel is the weak link in a structure. When weakened, the steel rebars stretch or yield and give a warning of pending failure of the concrete member. When using GFRP Rebars, ACI committee 440's design guidelines will recommend a minimum amount of GFRP rebar rather than a maximum. If a member fails, the concrete will be the weak link and will crush in compression. The crushing concrete will serve as the warning of failure and there will still be ample reserve tensile capacity in the GFRP reinforcing.

Another major difference is that serviceability will be more of a design limitation in GFRP reinforced members than in steel reinforced members. Due to its lower modulus of elasticity, deflection and crack width will affect the design. Excessive deflection and crack widths will provide additional warning of failure prior to compression failure of the concrete. In many instances, deflection and crack width will control design.

FRP Rebar can be considered for use in any concrete member susceptible to corrosion of steel reinforcement through chloride ion or chemical corrosion. Also, any concrete member requiring non-ferrous reinforcement due to electro-magnetic considerations is a candidate for FRP Rebar.

Some general corrosive applications in which concrete is exposed to de-icing salts are;

- highway bridge decks
- median barriers
- approach slabs
- parking structures
- railroad crossings
- salt storage facilities

Applications in which concrete is exposed to marine salts are;

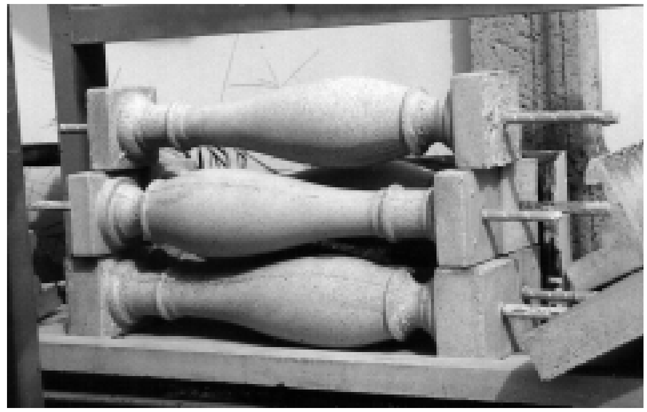
- seawalls, buildings and structures near waterfronts
- aqua culture operations
- artificial reefs and water breaks

Additional corrosive concrete applications include;

- concrete used in chemical plants and containment structures
- pipeline and chemical distribution facilities
- swimming pools
- mining applications such as rock nails and ore extraction tanks In addition, any polymer concrete requiring reinforcement is an excellent candidate for FRP Reinforcement.

Applications of FRP Rebar utilized for its electro-magnetic transparency include;

- MRI additions to hospitals
- airport radio and compass calibration pads
- electrical high voltage transformer vaults
- concrete near high voltage cables and substations



In summary, GFRP Rebar can be considered in applications that presently call for the use of epoxy coated steel rebar, galvanized steel or stainless steel reinforcement.

There are some popular preconceptions about FRP rebar with respect to price, applications and field bending. In general, GFRP Rebar competes well on price with coated steel reinforcement but should only be considered if coated steel reinforcement is required. If black steel rebar can be used, it should. GFRP Rebar must be furnished with bends manufactured at the factory. This has not been a serious impediment to sales in most cases. Most coated steel rebar must also be factory bent and/or shipped to a separate location for coating after being formed. Factory bending utilizing lap splices of common shapes can satisfy most job requirements.

Further commercialization of GFRP Rebar will be aided by drafts of design codes under review by the American Concrete Institute (ACI) and published codes in Canada and Japan and design guidelines in Britain. Government bodies throughout the world are interested in the potential benefits associated with improved longevity of civil engineering structures which may be made possible by GFRP Rebar.

In conclusion, GFRP Rebar products have been available for several years but are now seeing growing use in non-primary load bearing members. Research continues to validate excellent short term performance. A great deal of research is engaged in attempting to predict the durability and long term performance of GFRP reinforced members. Design guidelines are coming which will aid designers in the use of this new material which requires new ways of thinking about reinforced concrete design. GFRP Rebar is truely a structural material for the new millennium.