



Fiberglass Rebar



Technically referred to as *Glass Fiber Reinforced Polymer, or GFRP Rebar*

Benefits of GFRP Rebar

- Impervious to chloride ion and low pH chemical attack
- Tensile strength greater than steel
- 1/4th weight of steel reinforcement
- Transparent to magnetic fields and radio frequencies
- Non-conductive
- Thermally non-conductive

Where should GFRP Rebar be considered?

- Any concrete member susceptible to corrosion of steel reinforcement by chloride ion or chemical corrosion
- Any concrete member requiring non-ferrous reinforcement due to electro-magnetic considerations
- As an alternative to epoxy, galvanized or stainless steel rebar
- To strengthen un-reinforced masonry

Corrosive Applications

Concrete Exposed to De-Icing Salts

Bridge decks, Median barriers, Approach slabs, Parking structures, Railroad crossings, Salt storage facilities

Concrete Exposed to Marine Salts

Seawalls, Buildings & structures near waterfronts, Aquaculture operations, Artificial reefs and water breaks, Floating marine docks

Tunneling and Mining Applications

Soft-eye openings for tunnel boring machines (TBM's) and temporary works, Rock nails, Electrolytic and ore extraction tanks

Electromagnetic Applications

MRI rooms in hospitals
Airport radio & compass calibration pads
Concrete near high voltage cables, transformers and substations

Masonry Strengthening

Seismic, wind or blast strengthening of unreinforced masonry, increase flexural and shear strength.

Other Corrosive Applications

- Concrete used in chemical plants and containers
- Any polymer concrete requiring reinforcement
- Architectural precast and cast stone elements
- Thin concrete sections where adequate cover is not available
- Swimming Pools

Contact Information

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Physical Properties - Aslan 100, 101 GFRP Rebar

Aslan 100 Vinyl Ester Matrix GFRP Rebar - Diameters #2 (6mm) through #8 (25mm)

Aslan 101 Polyester Matrix GFRP Rebar for non-portland cement and temporary use applications.

I. Tensile Stress, Nominal Diameter & Cross Sectional Area

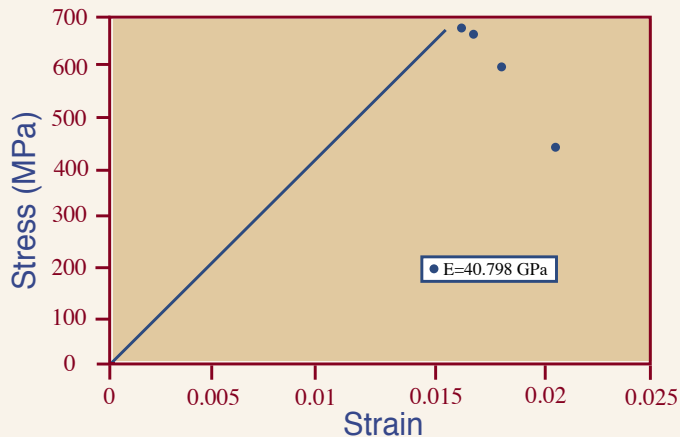
Bar Size (mm) (inches)	Cross Sectional Area*		Nominal Dia.		Guaranteed Tensile Strength		Tensile Modulus of Elasticity	
	(mm ²)	(in ²)	(mm)	(in)	(MPa)	(ksi)	GPA	psi 10 ⁶
6 #2	33.23	0.0515	6.35	0.25"	825	120	40.8	5.92
9 #3	84.32	0.1307	9.53	0.375"	760	110	40.8	5.92
13 #4	144.85	0.2245	12.70	0.50"	690	100	40.8	5.92
16 #5	217.56	0.3372	15.88	0.625"	655	95	40.8	5.92
19 #6	295.50	0.4580	19.05	0.75"	620	90	40.8	5.92
22 #7	382.73	0.5932	22.23	0.875"	586	85	40.8	5.92
25 #8	537.90	0.8337	25.40	1.0"	550	80	40.8	5.92
29 #9	645.00	1.0000	28.65	1.123"	517	75	40.8	5.92
32 #10	807.34	1.2513	31.75	1.25"	480	70	40.8	5.92

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 herein is considered representative of current production and is believed to be reliable and to represent the best available characterization of the product as of October, 2002.

*By water displacement, varies within tolerances over time throughout production run (± 0.030 " from nominal).



Typical Stress / Strain Curve for GFRP Rebar



Bond Stress

Bond of GFRP to concrete is controlled by friction due to surface roughness of the GFRP rods and mechanical interlock of the GFRP rod against the concrete.

Maximum Bond Stress.....11.6 MPa (1679 psi)

Based on pull out tests performed using the Penn State method.

Coefficient of Thermal Expansion:

Transverse Direction $18.7 \times 10^{-6}/^{\circ}\text{F}$
 $33.7 \times 10^{-6}/^{\circ}\text{C}$
 Longitudinal Direction $3.66 \times 10^{-6}/^{\circ}\text{F}$
 $6.58 \times 10^{-6}/^{\circ}\text{C}$

Specific Gravity:

2.0 per ASTM D792

Shear Stress:

Shear stress measured on 5/8" diameter bars using a double shear test fixture; 22,000 psi (152 MPa)

Barcol Hardness:

60 per ASTM D2583

Glass Fiber Content by Weight:

70% minimum per ASTM D2584

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Durability

Potential durability versus traditional steel reinforcement is one of the chief benefits of GFRP Rebar. However, being a relatively new material for use as a concrete reinforcement, decades of performance data are not available.

Accelerated aging bath studies performed on Hughes Brothers GFRP rebar at Penn State University, Iowa State and Sherbrooke in Canada, indicate that after accelerated aging, Hughes Brothers GFRP Rebar experienced a 16% degradation in tensile strength and a 4% change in modulus of elasticity.

Creep

When subjected to a constant load, all structural materials, including steel, may fail suddenly after a period of time, a phenomenon known as creep rupture. Creep tests conducted in Germany by Bundelmann & Rostasy in 1993, indicate that if sustained stresses are limited to less than 60% of short term strength, creep rupture does not occur in GFRP rods. For this reason, GFRP rebars are not suitable for use as prestressing tendons. In addition, other environmental factors such as moisture can affect creep rupture performance.

Based on proposed ACI 440 design guidelines, it is recommended that the sustained tensile stress not exceed 20% of minimum ultimate tensile stress. For a summary of the recommended design guidelines, refer to AC1440.1R-01 or your controlling national guide.

Stirrups, Shapes and Bends

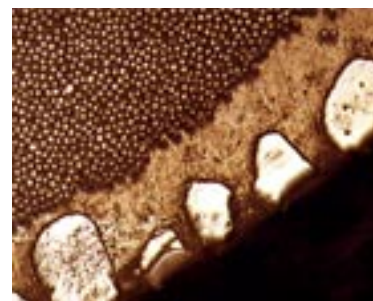
Bends in Hughes Brothers GFRP Rebar are fabricated by shaping over a set of molds or mandrels prior to thermoset of the resin matrix. Field bends are not allowed.

It is recommended that you work with the factory in the early stages of design, as not all standard bends and shapes are readily available. For example, a J-Hook at the end of a 10 meter length of rebar would be achieved by lap splicing (40 times the diameter for splice length) a J-hook piece to the 10 meter rebar.

- The narrowest inside stirrup width is 10", (15 inches for #7 & #8 bar).
- Bends are limited to shapes that continue in the same circular direction. Otherwise lap splices are required.

- All bends must be made at the factory.
- Bent portions of GFRP rebars have a lower tensile strength than straight portions.

For Large Radius Curves			
Bar Diameter		Minimum Allowable Radius	
#2	6mm	34"	864mm
#3	9mm	51"	1295mm
#4	13mm	67"	1702mm
#5	16mm	84"	2134mm
#6	19mm	101"	2565mm
#7	22mm	118"	2997mm
#8	25mm	135"	3429mm
#9	29mm	152"	3861mm
#10	32mm	186"	4267mm



Microscopy photo of Hughes Brothers Rebar - 60 X



Microscopy photo of Hughes Brothers Rebar - 240 X



Some bent shapes are made using appropriate lap splicing.

Available ACI Bends

Dia.	Inside Bend Dia.
#2	3"
#3	4.25"
#4	4.25"
#5	4.5"
#6	4.5"
#7	6"
#8	6"

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Design Considerations

A direct substitution between GFRP and steel rebar is not possible due to various differences in the mechanical properties of the two materials. 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 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. Deflection and crack width serviceability requirements will provide additional warning of failure prior to compression failure of concrete. In many instances, deflection and crack width will control design.

Handling and Placement

- When necessary, cutting of GFRP rebars should be done with a masonry or diamond blade, grinder or fine blade saw. A dust mask is suggested when cutting the bars. It is recommended that work gloves be worn when handling and placing GFRP rebars.
- Sealing of cut ends is not necessary since any possible wicking will not ingress more than a small amount into the end of a rod.

- GFRP rebar has a very low specific gravity and will tend to "float" in concrete during vibration. Care should be exercised to adequately secure GFRP in formwork using chairs, plastic coated wire ties or nylon zip ties.

Lap Splice Length

Approximately 40 bar diameters for GFRP v.s. 30 bar diameters for steel (grade 60ksi, less than #6 diameter)

The current ACI proposed design methodology is incomplete for members under compression

and torsion because adequate research results are yet to be obtained.

Quality Assurance

- To provide for lot or production run traceability, each lot is color coded.
- Individual rebars are tensile tested based on a random statistical sampling, with a minimum of 5 samples per production lot.
- Certification of conformance is available for any given production lot.
- In addition, quality assurance tests are routinely performed to determine:

- Glass content (i.e. impregnation ASTM D2584)
- Die wicking (checking for voids ASTM D5117)
- Barcol hardness ASTM D2583
- Cross sectional area ACI 440-K
- Mass uptake in water ASTM D4475
- Interlaminar shear or shear in flexure ASTM D4475

Masonry Strengthening

Aslan 100 GFRP bars can be used to increase the strength of existing unreinforced masonry walls in flexure (out-of-plane) and shear (in-plane).

This has important implications in areas that are subject to new seismic codes, hurricane wind loading or even blast mitigation schemes. In addition, Aslan 100 GFRP bars can be used to restore or increase the structural strength of existing masonry walls that have already cracked.

In many instances the strengthening procedure can

maintain the visual appearance of the existing masonry, particularly in the case of shear reinforcing.



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