



TBM LAUNCH & RECEPTION

Soft Eye Openings

Aslan FRP

A blue graphic element consisting of three wavy lines, resembling a stylized wave or a decorative flourish, positioned below the company name.

Glass Fiber Reinforced Polymer (GFRP) bars have high strength primarily along the length of the bar but can be easily abraded or “consumed” by tunnel boring machines (TBM) or tunneling equipment. This unique “anisotropic” property of these high strength reinforcing bars offers many benefits simplifying TBM launch and reception chambers as well as pre-consolidation in New Austrian Tunneling Method/Sequential Excavation Method (NATM/SEM) tunneling.

In places where the TBM needs to pass through a diaphragm wall, GFRP bars are incorporated in the “soft-eye” opening. This significantly speeds up the construction process and eliminates the need to stop the TBM, lower workers in the area between the TBM and the concrete face, remove the concrete and steel so the TBM can pass.

The result is typically a “hybrid” Steel/FRP cage with GFRP bars used with appropriate tolerance around the TBM diameter. Tolerance adjusted to variation in TBM breakout and variation in placement of cage.

Benefits of Aslan™ GFRP Rebar in Soft-eye Openings



TBM breaking through GFRP Reinforced Diaphragm Walls

- No Grout Block
 - ➡ **Time and Construction Cost Saving**
- TBM passes directly through the diaphragm wall
 - ➡ **Speeds up construction schedule**
- No workers are needed to access the shaft
 - ➡ **Safety improved**
- Fabrication of GFRP cage is easier due to its light weight (1/4 of steel rebar)
 - ➡ **Time and labor cost saving**
- TBM can pass through the diaphragm wall prior to excavation
 - ➡ **Construction Flexibility**
- No wear and tear on cutter machine

ASLAN 100 Fiberglass Rebar





Conventional steel reinforced diaphragm wall— breaking the opening

- A large jet grout block or soil consolidation is often needed in front of the opening
- Several days of construction delay to demolish and cut through steel rebar in the diaphragm wall to allow TBM penetration
- Cost of machine time (TBM idle time & demolition equipment)
- Safety issues with worker access in the shaft
- The deep excavation must be completed before the TBM's arrival
- Driving through steel would damage cutter head

ASLAN FRP™



© February 2007

Hughes Brothers, Inc.

210 N. 13th Street
Seward, NE 68434

Phone: 800-869-0359

402-643-2991

Fax: 402-643-2149

www.hughesbros.com

Email: doug@hughesbros.com

Unique Features of Aslan™ GFRP Soft Eyes: *We provide products and solutions!*



- **Aslan FRP pioneered the use of soft-eye openings** for TBM launch and reception in 1996.
- Aslan FRP has successfully supplied **over 200 soft-eyes openings worldwide**.
- Aslan FRP provides top-quality products verified by **authoritative material test methods**.
- Aslan FRP is very active in international design, test and standard bodies such as ACI, CSA, FIB, ASTM.
- Aslan FRP provides a **professional service including design, consultation and support**. We become part of your team.
- Aslan FRP bars **also used in traditional reinforced concrete structures** such as highway bridges, seawalls, hospitals, etc. This vast experience benefits the Geotech community.



ASLAN 100 Fiberglass Rebar

Aslan FRP Bars have been used in over 200 projects world-wide!



Channel Tunnel Rail Link
London ENGLAND



Docklands Light Rail
London Underground ENGLAND



"Beacon Hill" Project
Seattle, Washington USA

The lower shear strength of the GFRP (glass fiber-reinforced polymer) enables the TBM to pass directly through concrete reinforced with GFRP.



Taipei Rapid Transit System (Metro)



Dulles Airport People Mover
Washington, D.C. USA



Delhi Metro INDIA



Big Pipe C50
Portland, Oregon USA

ASLAN FRP™



Hughes Brothers, Inc.

210 N. 13th Street
Seward, NE 68434

Phone: 800-869-0359

402-643-2991

Fax: 402-643-2149

www.hughesbros.com

Email: doug@hughesbros.com

Physical Properties

Aslan 100/101 GFRP Rebar

Aslan 100 Vinyl Ester Resin matrix for better durability in permanent installations.
 Aslan 101 Polyester Resin matrix GFRP Rebar for soft-eye and temporary applications.

1. Tensile Stress, Nominal Diameter, Cross Section Area & Modulus of Elasticity

Size	Diameter		Area		Guaranteed Tensile Strength		Ultimate Tensile Load		Tensile Modulus of Elasticity	
	(mm)	(in)	(mm ²)	(in ²)	(MPa)	(ksi)	kN	kips	(GPa)	(psi 10 ⁶)
2	6	1/4	31.67	0.049	825	120	26.2	5.89	40.8	5.92
3	10	3/8	71.26	0.110	760	110	54.0	12.1	40.8	5.92
4	13	1/2	126.7	0.196	690	100	87.3	19.6	40.8	5.92
5	16	5/8	197.9	0.307	655	95	130	29.1	40.8	5.92
6	19	3/4	285.0	0.442	620	90	177	39.8	40.8	5.92
7	22	7/8	387.9	0.601	586	85	227	51.1	40.8	5.92
8	25	1	506.7	0.785	550	80	279	62.8	40.8	5.92
9	29	1-1/8	641.3	0.994	517	75	332	74.6	40.8	5.92
10	32	1-1/4	791.7	1.227	480	70	382	85.9	40.8	5.92

Aslan FRP 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 May 2007.

2. Bond Stress to Concrete

The bond stress to concrete is based on pull out tests performed using test methods proposed in ACI440.3R-04.

Bond of GFRP to concrete is controlled by the following internal mechanisms: chemical bond, friction due to surface roughness of the GFRP rods, mechanical interlock of the GFRP rod against the concrete, hydrostatic pressure against the GFRP rods due to shrinkage of hardened concrete and swelling of GFRP rods due to moisture absorption and temperature change. Friction and mechanical interlock are considered to be the primary means of stress transfer.

Maximum Bond Stress.....11.6MPa (1,679 psi)

Based on pull out tests performed using the ACI 440.3R-04 method.



Trial Test Breakthrough at Herrenknecht Factory, Germany

3. Glass Fiber Content by Weight:

70% minimum per ASTM D2584

4. Specific Gravity: 2.0 per ASTM D792

5. Shear Stress:

Shear stress measured on 16mm using a double shear test fixture 152 MPa (22,000 psi) per ACI 440.3R-04 B.4.



Full scale D-wall unit strip testing, University of Missouri Rolla.

ASLAN 100 Fiberglass Rebar

Stirrups, Shapes and Bends

Bends in Aslan GFRP Rebar must be fabricated at the factory. Field bends are not allowed.

- * Bent portions of GFRP rebars have a lower tensile strength than straight portions.
- * Authoritative design guides take this property into account. However, it is recommended that you work with the factory in the early stages of design to ensure practical and economical rebar detailing.

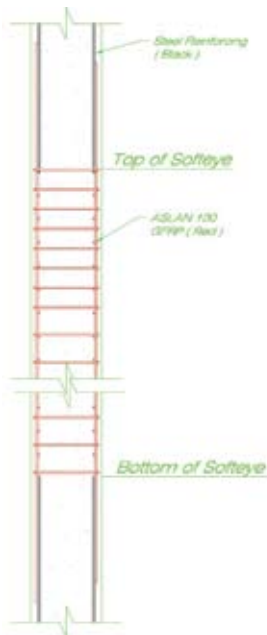
Other shapes such as hoops, spirals, and complete FRP panel end stops (stay in place) can be fabricated as required.



Typical bent shapes

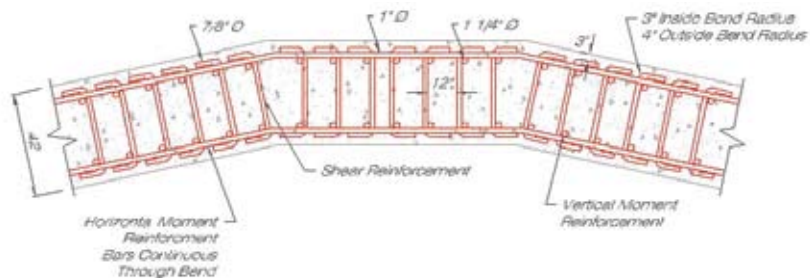


Consumable FRP stay in place panel end stop.



Available ACI Bends

Dia.#	[mm]	Inside Bend Dia.	
#2	[6]	3"	76 mm
#3	[9]	4.25"	108 mm
#4	[13]	4.25"	108 mm
#5	[16]	4.5"	114 mm
#6	[19]	4.5"	114 mm
#7	[22]	6"	152 mm
#8	[25]	6"	152 mm



ASLAN FRP™

Hughes Brothers, Inc.

210 N. 13th Street
Seward, NE 68434

Phone: 800-869-0359

402-643-2991

Fax: 402-643-2149

www.hughesbros.com

Email: doug@hughesbros.com

Design Considerations



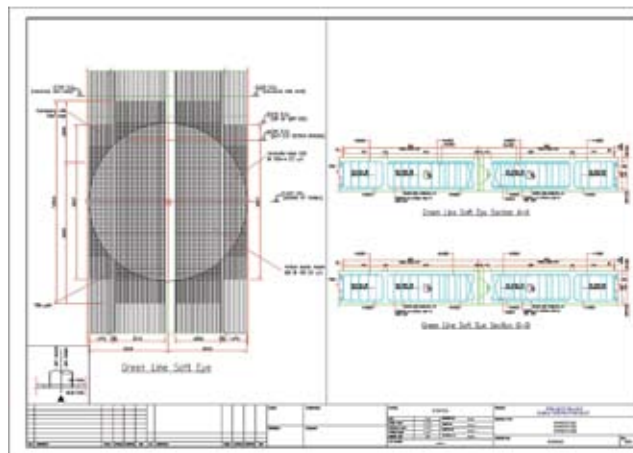
In February of 2006, ACI committee 440 published ACI440.1R-06 “Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars”. This latest revision represents the most authoritative consensus design guidance available for the use of FRP bars and is based on worldwide research. Additional consensus design standards are available in the Canadian CSA S806 and from the Japanese Society of Civil Engineering, JSCE. Aslan FRP bases all its design recommendations on the guidelines of these authoritative publications and not on proprietary design schemes that expose the engineer of record to extraordinary liability.

A direct substitution between GFRP and steel rebar is not possible due to various differences in the mechanical properties of the two materials.

All FRP design guidelines must take into account 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 is specified so that the steel will yield and give warning of pending failure of the concrete member. ACI440.1R-06 gives the option of two failure modes to the designer, an over reinforced section where compression failure of the concrete is the preferred mode of failure. Or, failure by rupture of the FRP reinforcing in which case serviceability requirements, deflection and crack widths, must be satisfied in order to give a warning of pending failure. In either case, the suggested margin of safety against failure is higher than that used in traditional steel-reinforced concrete design.

Another major difference is that serviceability will be more of a design limitation in GFRP reinforced members than with steel. Due to its lower modulus of elasticity, deflection and crack widths will affect the design.

Aslan FRP only guarantees the performance of its material to meet minimum ultimate requirements as listed. The use of competent experienced engineering personnel should always be employed in the design and construction of concrete reinforced structures. Material properties are validated by ASTM D7205 test methods.



Typical shop drawing

Subjects covered in the ACI440.1R-06 design guide include:

- * Flexure
- * Shear
- * Temperature and shrinkage reinforcement
- * Development and splices of reinforcement

Current knowledge restricts the use of FRP bars in:

- * Compression reinforcement in both beams and columns
- * Seismic zones
- * Moment frames
- * Zones where moment redistribution is required
- * Structures subject to high temperature

In Soft-eye designs:

The environmental reduction factor CE is taken =1. As stated in ACI440.1R-06, section 7.2, the factor CE is to consider the “long-term exposure to various types of environments can reduce the tensile strength and creep rupture and fatigue endurance of FRP bars”. As the GFRP soft-eye will be opened by a TBM shortly after construction, the chance of creep rupture, fatigue and long-term exposure is low. Typically the environmental durability factor “CE = 1” is an appropriate balance of safety and cost effectiveness.

Design Assistance

To aid the designer unfamiliar with the new ACI440.1R-06 guide, Aslan FRP maintains a team of in-house engineers to provide comprehensive recommendations.



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 recommended 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 may “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.

ASLAN FRP™

Hughes Brothers, Inc.

210 N. 13th Street
Seward, NE 68434

Phone: 800-869-0359

402-643-2991

Fax: 402-643-2149

www.hughesbros.com

Email: doug@hughesbros.com

Fabrication of GFRP Diaphragm Wall Cage

In general, placing GFRP bars is similar to placing steel bars. Lathers will greatly benefit from the fact that FRP bars are 1/4th the weight of steel bars. The GFRP cage is constructed in the same manner as the fabrication of ordinary steel diaphragm wall cages. Recommended practices and tolerances for construction and materials should apply with some exceptions for the specifications prepared by the engineer as noted:

1. Cage should be fabricated on steel or wooden support blocks to prevent the cage from being laid directly on the ground. This prevents the GFRP rebars from being contaminated by substances on ground, which in turn affects the bond. Note that due to the relative lower stiffness of GFRP rebars, the supports for fabrication should be placed at closer spacings at the GFRP rebar portion of the cage.
2. On site bending of GFRP bars on site is not permitted, because they are made with thermoset resin.
3. Lap splices between vertical steel and GFRP rebars are needed in the outside periphery of the soft eye opening (bored area). Steel U-bolts or steel straps are recommended for fixing the lap splices between steel and FRP bars. The number of U-bolts or straps should be enough to develop sufficient strength of the connection to hold its self weight during the lifting operation and this should be determined by the site engineer.
4. For tying bar intersections other than lapping of vertical rebars, ordinary steel wires, coated tie wires or plastic snap ties can be used. Also, Aslan FRP bars can be connected to steel bars via a proprietary swaged coupler that develops the full capacity of the FRP bar.
5. Due to the lower stiffness of GFRP rebars compared to steel, the hybrid rebar cage should be stiffened before lifting. A temporary bracing frame, commonly made of steel rebars diameter 32 or 40 mm, or temporary "strong-back" frame is typically used. A frame should be attached to the cage by using U-bolts or other temporary means such that the support frame can be easily removed then the cage is lowered into position.



U-bolt Fixture

Installation of GFRP Soft Eye Cage



1. The fabricated hybrid rebar cage must be first lifted to vertical. During this lifting operation, care should be taken to ensure the stability and integrity of the cage is maintained. Lifting loops should be provided at the top of the cage during fabrication. The cage should be suspended with the crane hooks in at least 2 points: one close to the top and another one close to the bottom of the cage. For larger cages, one more lifting points and the use of a spreader bar may be necessary at the middle of the cage to prevent the excessive bending.
2. Once the cage is in vertical plane, move the cage to the excavation position. The temporary bracing frame must be removed prior to the cage being lowered into the slurry.

ASLAN FRP™

Hughes Brothers, Inc.
210 N. 13th Street
Seward, NE 68434

Phone: 800-869-0359
402-643-2991
Fax: 402-643-2149
www.hughesbros.com



Lifting cage using a temporary support frame.

Aslan FRP



Hughes Brothers

Aslan FRP
210 North 13th Street
Seward, Nebraska 68434
Phone 800.869.0359 or 402.643.2991
Fax 402.643.2149
www.hughesbros.com
Email doug@hughesbros.com

Aslan FRP Europe
Grasbos 50
3294 Molenstede
Belgium
Phone 321.332.6873
Fax 321.332.6874
Email info@fortius.be