ASLAN™ 200

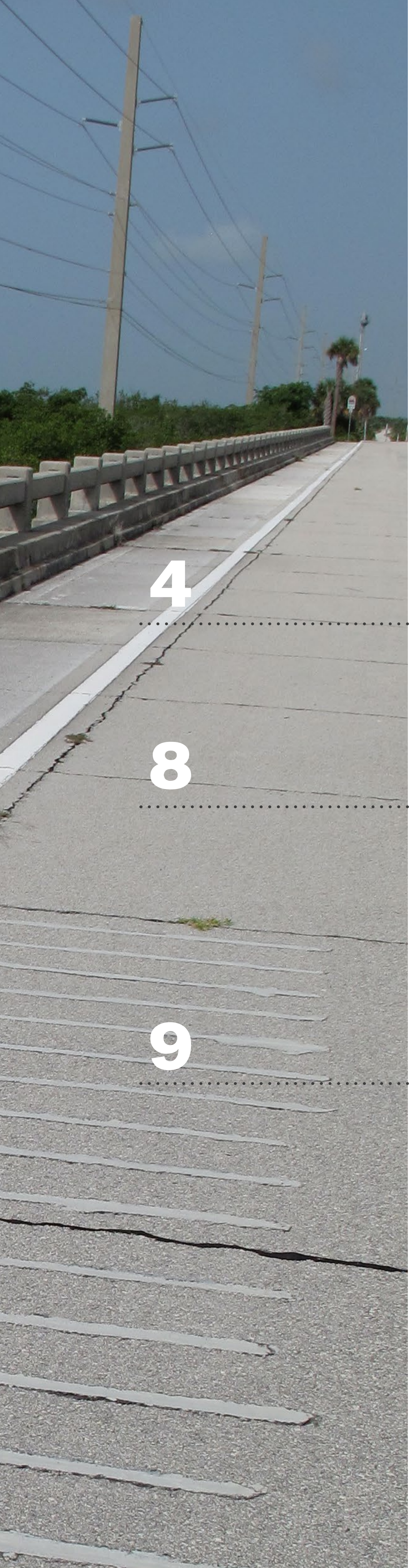
CARBON FIBER REINFORCED POLYMER (CFRP) BARS
FOR STRUCTURAL STRENGTHENING

COMPOSITE REINFORCING FOR LONG LASTING CONCRETE STRUCTURES

- DRAMATICALLY **INCREASE FLEXURAL** & **SHEAR CAPACITY**
- EXTEND THE **LIFE OF THE STRUCTURE**
- USED IN **THE NEAR SURFACE MOUNT TECHNIQUE**
- ALTERNATIVE TO **FIELD WET LAY UP**

Aslan FRP®

EXAMPLES USING **ASLAN™** SOLUTIONS



ASLAN™ 200 CFRP BARS

BENEFITS & **MECHANICAL** PROPERTIES

BENEFITS

- > Impervious to Chloride Ion and chemical attack
- > Tensile strengths greater than steel
- > Modulus approaching that of steel & much greater than GFRP
- > Can withstand greater sustained loads
- > 1/5th the weight of steel rebar
- > “Consumable” by excavating equipment

Aslan™ 200 bars and tendons are typically used to strengthen existing structural members (concrete, wood, stone or masonry) in flexure and shear. Structures that are deficient due to either a structural flaw, deterioration or because of a change in use can often be brought to a useful capacity using Aslan™ 200 series Carbon Fiber Reinforced Polymer (CFRP). Due to their extremely high strength and stiffness, along with the fact that they will not rust or corrode and are very light weight, Aslan™ 200 bars are often added to the concrete cover of an existing structure using a technique called "Near Surface Mount" or NSM strengthening. The method is analogous to adding "band aid" rebar to the structure. When combined with a proprietary factory applied anchorage, the Aslan™ 200 bars can be used as pre-stressing or un-bonded post tension tendons or earth anchors. Occasionally, the Aslan™ 200 bars are used as traditional concrete reinforcing bars, typically in restoration or repair situations.

Since 1993, we have been at the forefront of worldwide academic and industry efforts to define consensus FRP standards and methods. Hundreds of structures have extended service lives due to Aslan™ 200 Carbon Fiber Reinforced Polymer (CFRP).

NEAR SURFACE MOUNT (NSM) STRUCTURAL STRENGTHENING

- Bridge Decks & Railings: cantilevers, negative moment regions, parapets
- Parking Garages
- Floor Slabs
- Column to Slab Connections
- Columns
- Crack Stitching & Adjoining Members

PRE-STRESSING & **POST-TENSIONING**

- Pre-stress Tendons in Corrosive Applications: precast bridge deck panels, concrete poles and marine pilings, stay-in-place formwork
- Un-bonded Post Tensioning: post tensioning of precast members
- King Post Arrangement for Floor Slabs
- Replacement of Corroded Steel Tendons

ACTIVE EARTH ANCHORS & TIE BACKS

- Deep Foundations with Encroachment Issues: "Consumable" & doesn't affect adjacent land use
- Slope Stabilization
- Mining & Tunneling
- Waterfront Construction

CONCRETE SUSCEPTIBLE TO **CORROSION**

- Repair Situations
- Inadequate Concrete Cover
- Historic Preservation

MASONRY STRENGTHENING

MECHANICAL PROPERTIES

Nominal Diameter			Nominal Area		f^*_{fu} Garanteed Tensile Strength		Ultimate Tensile Load		E_f Tensile Modulus of Elasticity		Ultimate Strain
Size	**mm**	**in**	**mm²**	**in²**	**MPa**	**ksi**	**kN**	**kips**	**GPa**	**psi 10^6**	**%**
2	6	1/4	32	0.049	2241	325	71	15.92	124	18	1.81%
3	10	3/8	71	0.110	2172	315	154	34.65	124	18	1.75%
4*	13	1/2	127	0.196	2068	300	262	58.80	124	18	1.67%

We reserve 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 July 2011. Maximum available length is 40ft (12m)

DESIGN TENSILE & **MODULUS** PROPERTIES

Tensile and Modulus Properties are measured per ASTM D7205-06, Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars. The ultimate tensile load is measured and the tensile modulus is measured at approximately 10% to 50% of the ultimate load. The slope of the stress-strain curve is determined as the tensile modulus. Ultimate Strain is extrapolated from the ultimate load divided by the nominal area and modulus. The area used in calculating the tensile strength is the nominal cross sectional area. The "Guaranteed Tensile Strength", f^*_{fu} is as defined by ACI 440.1R as the mean tensile strength of a given production lot, minus three times the standard deviation or $f^*_{fu} = fu_{,ave} - 3\sigma$. The "Design or Guaranteed Modulus of Elasticity is as defined by ACI 440.1R as the mean modulus of a production lot or $E_f = E_{f,ave}$.

MATERIAL **CERTS**

Material test certs are available for any production lot of Aslan™ 200 series bar. In addition to ASTM D7205 Tensile, Modulus and Strain values, the test cert includes a full accounting of various additional properties and lab tests performed on the production lot.

CROSS SECTIONAL AREA

The design properties are determined using "Nominal" diameters and equivalent calculated cross sectional areas. Surface undulations and sand coatings that facilitate bond are accommodated in ASTM D7205, section 11.2.5, with a tolerance of minus zero, plus 20% as determined by the Archimedes method of volume displacement in a fluid.

NEAR SURFACE MOUNT OR NSM ADHESIVE BOND

For NSM strengthening, bond of the strengthening "system" is a function of the properties of the high strength structural adhesive AND the characteristics of the Aslan™ 200 series bar itself. To replicate the typical mode of failure for flexural strengthening, we perform tests using different structural adhesives in an inverted hinged "tee beam". This loading replicates a bond mode component along the axis of the beam in combination with a pull-off mode. The result is a design parameter, τ_b or l_{db} describing the development length for a given adhesive used in conjunction with the Aslan™ 200 series bar. The Aslan™ NSM "system" utilizes several readily available commercial high strength structural adhesives typically purchased locally. Details of the various adhesives are described elsewhere.

DIRECT TENSION BOND – PULLOUT

Often it is necessary to adhesively anchor bars into adjacent members such as at column to slab intersections, wall to slab or to simply anchor an end of the bar into an existing concrete member. The pull-out capacity of the Aslan™ 200 series bar using various adhesives has been measured. Reports are available on request.

BOND – AS REBAR

When used as passive reinforcing bar in concrete, bond to the concrete is achieved in the Aslan™ 200 series by means of an external helical wrap along with a sand coating. There are many different methods for measuring the bond characteristics of a bar with each test method providing a different value depending on the influences of the testing apparatus and method. As a means of determining "characteristic" bond strength, block pullout tests are often used as a relative gage of bond performance. However, to accurately define the bond strength it is necessary to perform full -scale beam or beam lap splice tests on a bar. In consensus design guidelines such as ACI, CSA and AASHTO, perfect bond is assumed for flexural design. With any of the test methods for bond, caution is urged as a very wide scatter of statistical results is found depending on the strain in the bar in the test and inaccuracies involved in the measuring of crack widths. Aslan™ 200 bars have been used in many of the basic research studies that appear in peer review papers establishing the consensus design equations for serviceability, flexural capacity, crack widths and development lengths for FRP bars. The designer is urged to follow consensus equations in authoritative publications such as ACI 440.1R or for pre-stressing tendons in ACI 440.4R.

DURABILITY / CREEP RUPTURE / SUSTAINED LOADS

FRP bars subjected to a constant load over time can suddenly fail after a time period called the endurance time. The endurance time of Carbon FRP is generally not as affected by environmental conditions in comparison to Glass FRP. For instance the environmental reduction factors for Aslan™ 200 bar are $C_E = 1.0$ for concrete not exposed to earth and weather and $C_E = 0.9$ for exposed concrete. Accordingly, consensus design guides, such as ACI 440.1R for reinforced concrete, 440.2R for structural strengthening and 440.4R for prestressing, all allow a creep rupture stress limit of 0.55 f_{fu} or f_{pu}.

GLASS TRANSITION TEMPERATURE OF RESIN (T_g)

Known as the "glass transition temperature" or the temperature at which the resin changes from a "glassy state" and begins to soften. $T_g = 230°F$ (110°C)

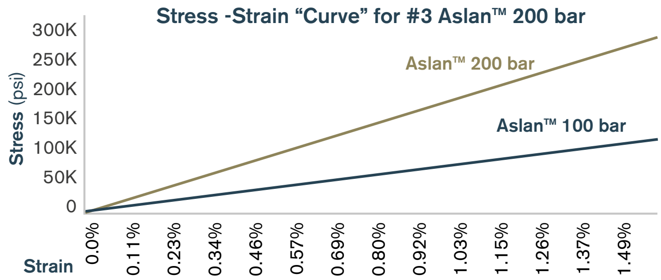
DENSITY

CFRP bars are approximately one fifth the weight of steel rebar.

Nominal Diameter			Unit Weight / length	
Size	mm	in	kg/m	lbs/ft
2	6	$^1/_4$	0.052	0.035
3	10	$^3/_8$	0.112	0.075
4	13	$^1/_2$	0.186	0.125

DESIGN CONSIDERATIONS

Although the FRP bars themselves are not ductile, an FRP reinforced concrete section is characterized by large deformability i.e. significant deflections and crack widths are a warning of pending failure of the section. The designer should follow the recommendations in the appropriate consensus design guideline. To aid the designer who might not be familiar with these guides and standards, we maintain a staff of registered professional engineers to assist the engineer of record in safely implementing our products.



DESIGN GUIDES

> **ACI 440.1R "Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars"** The American Concrete Institute 440 guide is a mature and living document that has undergone a number of revisions since its first publication in 2001. Companion documents to the 440.1R design guide include the ACI 440.3R "Guide Test Methods for FRP's for Reinforcing or Strengthening Concrete Structures" which is intended as an interim document superseded by new ASTM test methods as they become available. The ACI 440.5 "Specification for Construction with Fiber Reinforced Polymer Reinforcing Bars" and ACI 440.6 "Specification for FRP Bar Materials for Concrete Reinforcement" give guidance in mandatory language for the use and specification of FRP bars.

> **ACI 440.2R "Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures"** Provides authoritative, consensus guidelines that include provisions for flexural strengthening using Near Surface Mount Strengthening.

> **ACI 440.4R "Prestressing Concrete Structures with FRP Tendons"** An ACI "Emerging Technology Series" document provides state of the art guidance for prestressing with FRP Tendons.

> **ACI 440.7R "Guide for the Design and Construction of Externally Bonded Fiber-Reinforced Polymer Systems for Strengthening Unreinforced Masonry Structures"** An ACI "Emerging Technology Series" document provides state of the art guidance for masonry strengthening with FRP bars.

NSM INSTALLATION ASLAN™ 250 TENDONS

HANDLING & **PLACEMENT**

Authoritative guidance for the specifier, in mandatory language, is given in ACI 440.5-08 “Specification for Construction with FRP Bars”, which details submittals, material delivery, storage, handling, permitted damage tolerances, bar supports, placement tolerances, concrete cover, tie-wire, field cutting and more. In general, the field handling and placement of FRP bars is similar to coated steel rebar (epoxy or galvanized), but with the benefit of weighing one-fifth the weight of steel.

Do Not Shear FRP bars. When field cutting of FRP bars is necessary, use a fine blade saw, grinder, carborundum or diamond blade. Sealing the ends of FRP bars is not necessary. Support chairs are required at two-thirds the spacing of steel rebar. Plastic coated tie wire is the preferred option for most projects. Carbon bars are semi-conductive and NOT appropriate for non-magnetic applications. For specific handling, use and installation instructions for Near Surface Mount strengthening, see this section contained herewith. For specific handing and use requirements for Aslan™ 250 series tendons (250 series designates a factory applied anchorage is furnished with the bar), see this section contained herewith.

NEAR SURFACE MOUNT OR NSM STRENGTHENING

NSM strengthening is a superior method in situations that allow the ability to cut shallow groves into the concrete cover. The method eliminates many of the surface preparation issues, critical to successful implementation and efficacy, associated with field lay-up externally bonded FRP systems. Since the bar is bonded to the member on three sides, development length is much shorter and it is possible to utilize the full strength of the bar. The Aslan™ 200 NSM bar is furnished to the job site precured with verifiable design properties. Unlike field layup FRP systems, there is no need for highly skilled and trained FRP installation experts. Design is dictated by ACI 440.2R.

NSM INSTALLATION INSTRUCTIONS

> **Step #1** Grooves are cut after marking the layout as per the Engineer of Records' specifications. Generally the final groove dimension is 1.5 times the bar diameter in depth and width. Dado cuts are also effective if possible. Note: Proper equipment such as diamond crack chasing blades, guide rails and sufficiently sized power tools make cutting of the grooves easier. Rather than cut the groove in a single pass, sometimes its more effective to cut parallel grooves and remove the concrete between the saw cuts.

> **Step #2** Chisel any remaining concrete between cut paths.

> **Step #3** Clean the groove and eliminate any residual dust with compressed air or vacuum. Note: It is not necessary to roughen the interior of the groove with additional abrasion, or brushing.

> **Step #4** For a clean appearance, mask the concrete adjacent to the groove. Note: A time saving tip is to mask over the groove and then trim the masking to each edge.

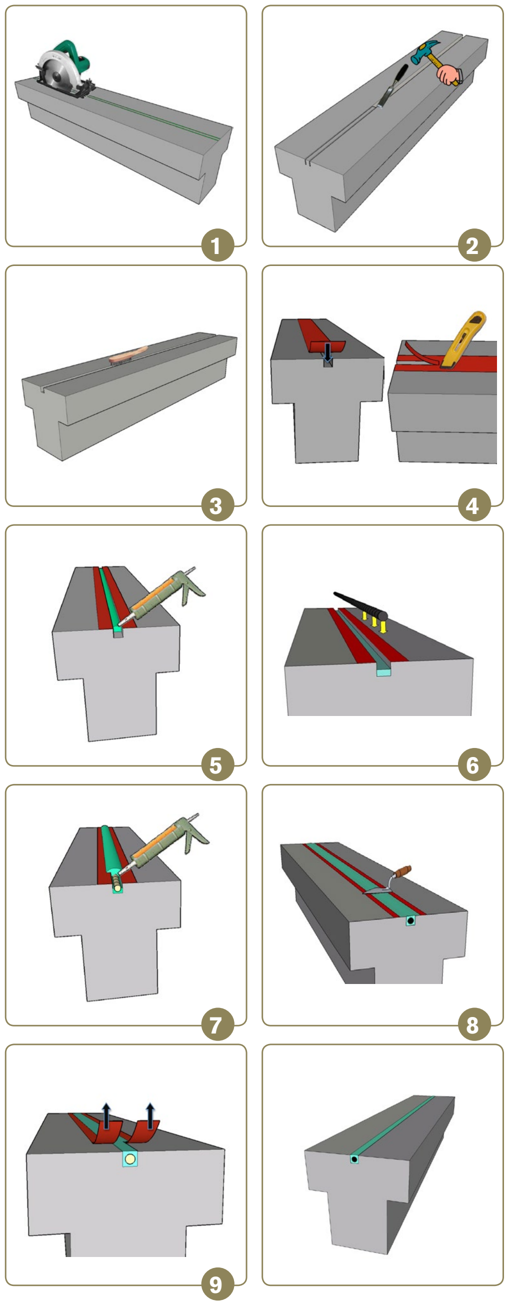
> **Step #5** Fill the groove approximately half way with adhesive. Note: Consider bulk dispensing of adhesive when making your choice of adhesive for the project.

> **Step #6** Press the Aslan™ 200 bar into the groove partially filled with adhesive. The objective is to ensure adhesive is well consolidated around the bar without air pockets. Note: Some contractors have developed their own system based on epoxy crack injection methods using a low viscosity epoxy crack injection resin.

> **Step #7** Completely fill the groove with adhesive ensuring the bar is fully covered.

> **Step #8** Level off the excess adhesive with a trowel or putty knife.

> **Step #9** Remove masking. Note: pull the masking off before adhesive is fully cured.

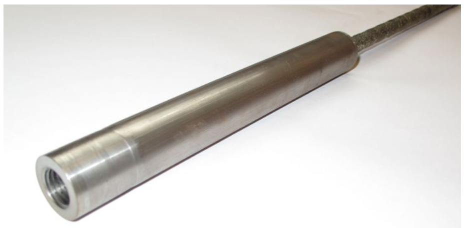


ASLAN™ 200 NSM "SYSTEM" ~ SUGGESTED ADHESIVES

The following high strength structural adhesives have been used successfully.

> Hilti RE 500
> Pilgrim Magmaflow CF
> BASF Concresive 1420 & Concresive LPL
> DeNeef Enforce CFL Gel
> Unitex Pro-poxy 400

ASLAN™ 250 SERIES
TENDON / “ACTIVE REMOVABLE” EARTH ANCHOR



A proprietary steel anchorage can be affixed to an Aslan™ 200 CFRP bar, which develops the full tensile capacity of the bar. The addition of a factory-affixed anchorage makes the designation “Aslan™ 250 series”. In addition to its inherent non-corrosive nature, the unique “anisotropic” property of CFRP bars makes them strong in tension, but easily consumed by excavation machinery of all types. For this reason, they can be considered “Removable Anchors” in the sense that they remain in place and do not disrupt future or adjacent construction activities. The Aslan™ 250 series is considered an “active” pre-stressed system. Sustained load limits in the table shown below are the same as those used in ACI 440 guidelines. The designer may choose to be less conservative based on their judgment of the circumstances.

MECHANICAL LOAD RATINGS ~ Aslan™ 250 Tendon + anchorage

Size		Diameter		Area		Ultimate Load		Jacking Load = 0.65 f_{pu}		Prestress Load	
Imp.	**SI**	**in**	**mm**	**in²**	**mm²**	**kips**	**kN**	**kips**	**kN**	**kips**	**kN**
#3	10	0.375	9.5	0.110	71	34.65	154	22.49	100	17.15	76
#4	13	0.500	12.7	0.196	127	58.80	262	38.22	170	29.10	129

Ultimate Load rating defined as in ACI440.1R-06 & 440.4R-04 fpu* = guaranteed ultimate tensile strength (as measured by ASTM D7205 test methods) X Ce = 0.85 environmental degradation factor. Sustained Load ratings based on ACI440.1R-06 guidance: ffu* X Ce X 0.55 Creep Rupture Strain limits. Material lot test reports available upon request.

> **Relaxation** Relaxation losses (REL) of the Aslan™ 250 tendon are negligible at Jacking Loads.

> **Deviators** Harping or draping of the tendons need to incorporate padded, friction reducing surfaces such as UHMW on deviators. Friction losses from harping are defined by ACI 440.4R.

HANDLING AND USE

Aslan™ 250 CFRP Tendons must be handled carefully to avoid damage and abrasion. The CFRP bar is extremely strong along its axis, but is susceptible to strength reduction due to stress concentrations or nicks, cuts and abrasions along its length.

Aslan™ 250 tendons are furnished with a proprietary anchorage affixed at the factory. The tendon can be stressed by means of a high strength threaded connection on the end or by wedge grips applied directly the barrel of the anchorage itself. Note that the tensile strength of the Aslan™ 250 tendon is typically much stronger than available high strength bolts. Often is it desirable to have a transition box from the stressing rod in the tendon to the more traditional steel strand chucks.

MULTI-TENDON

Combining multiple Aslan™ 250 tendons with a steel load bearing head allows for much higher load capacities and enables the use of traditional jacking systems in the field. The Aslan™ 250 tendons are corrosion free and due to their “anisotropic characteristics” will not encumber future adjacent land use. Corrosion mitigation is only necessary at the face where it can be monitored.

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Pub. 10022288. Aslan 200 CFRP brochure_ww_01-2018_Rev1_EN. January 2017

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