Neuvokas Corporation Design and Installation Manual for GatorBar®

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Questions or Comments can be addressed to Neuvokas Corporation with contact information listed below

Neuvokas Corporation

PO Box 220

3206 #6 Road

Ahmeek, MI 49901

906-934-2661

info@neuvokascorp.com

Company and Product websites

www.gatorbar.com

www.neuvokascorp.com

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1.0 Introduction

The purpose of this design and installation manual is to provide design guidelines as part of ESR-4526 per AC454. This document contains design equations, reference to other design tools, multiple design examples, and installation instructions/guidelines.

This document has been prepared using the following documents.

- ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (318R- -14)," American Concrete Institute, Farmington Hills, MI, 2011
- ACI Committee 440, "Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars
- "Reinforced Concrete with FRP Bars, Mechanics and Design", Nanni, Antonio, Antonio De Luca, and Hany Jawaheri Zadeh, 2014

2.0 GatorBar® FRP Rebar by Neuvokas

2.1 FRP Composite Description

GatorBar® by Neuvokas is a glass fiber reinforced composite rebar that is composed of fiber embedded in a polymer resin. Across the industry these products are known as glass fiber reinforced polymer (GFRP) rebar. At the date of this design manual release GatorBar can be purchased in #3 (0.375 inch) and #4 (0.5 inch) sizes but the ICC-ES evaluation report only covers the #3 rebar size.

2.2 GatorBar® Experimental Properties

The following values have been tested by a certified third party (University of Miami) and a copy of this report is available upon request. Sampling of test specimens was completed per ICC AC85 and ASTM

D7957 requirements. The quantity of specimens for each experimental value were completed following ASTM D7957. Guaranteed properties are equal to the defined ACI 440 nomenclature. It should be noted that the tensile behavior of GFRP bars is characterized by a linear elastic stress-strain relationship until failure.

Property	Test or Calculation Method	Experimental Value	
Fiber Mass Content	ASTM D2584	80	%
Mean glass transition temperature	ASTM E1356	117	DegC
Mean Total Enthalpy of Resin	ASTM E2160	303	J/g
Guaranteed Ultimate Tensile Force	ASTM D7205	17.1	Kip
Tensile Modulus of Elasticity	ASTM D7205	6.81	Msi
Guaranteed Transverse Shear Strength	ASTM D7617	27	Ksi
Guaranteed Bond Strength	ASTM D7913	1.4	Ksi
Mean Moisture Absorption (24 hours)	ASTM D570	0.05	%
Mean Moisture Absorption to Saturation	ASTM D570	0.23	%
Mean Alkaline Resistance	ASTM D7705	80	%
k_b		1.4	

3.0 Installation Instructions

GatorBar® placement in concrete is no different than other composite rebar products. Neuvokas recommends following the American Concrete Institute (ACI) guidelines that are laid out in ACI 440.5-08. Section 3.2 – Bar Placement, which includes the following items

- Tolerances
- FRP reinforcement relocation
- Concrete cover
- FRP reinforcement supports

Other general installation comments are discussed below.

- Field Fabrication. Provide composite reinforcement in accordance with the details shown on the plans. The minimum bending radius is two feet and must utilize the necessary tying and stabilization methods to ensure reinforcement remains in the proper position before and during concrete placement. Field cut reinforcement may be accomplished using high speed grinding cutter, fine blade saw, diamond blade, or masonry blade.
- Handling. Bars can be handled similar to their steel counterparts. Minor scratches and chipping that do not impact performance may be permitted with approval of the Engineer.
- Storage of Reinforcement. Store reinforcement above the surface of the ground on platforms, skids, pallets, or other supports. If stored outside for an extended period of time GatorBar will yellow and it can be covered if desired. Overall strength is not affected by this yellowing and GatorBar does not need to be covered.
- Placing and Fastening. Place all reinforcement within the tolerances recommended in the CRSI "Manual of Standard Practice" unless otherwise specified in the contract documents. Secure reinforcement firmly with mechanical fasteners during the placing and setting of the concrete. Suspend concrete placement and take corrective action if it is observed that the reinforcement is not adequately supported or tied to resist settlement, floating upward, or movement in any direction during concrete placement.
- Ties and Supports. It is recommended that all accessories for use with the bars such as tie wires, bar chairs, supports or clips are either plastic coated steel, stainless steel, galvanized steel or plastic, but that depending on engineering plans or application plain steel may be used. Place all reinforcement in locations as shown on the plans and securely hold in position while placing and consolidating concrete. Fasten bars together with ties at all intersections.
- Lap Splices. Lap splices are the only approved method to tie bars together to make a continuous bar. Mechanical splices are prohibited. Ensure lap length and spacing is as specified in the contract. Provide the same cover clearances for splices that is shown or specified for the reinforcement.

4.0 General Design Considerations

4.1 FRP Bar Arrangement

- For flexural reinforcement, the use of multiple bar layers and bar bundling is permitted.

- For multiple bar layers, the relevant provisions for steel reinforcing bar in ACI 318 also apply to FRP bars. Because FRP materials have no plastic region, the stress in each reinforcement layer varies depending on its distance from the neutral axis. Thus, the analysis of the flexural capacity shall be based on a strain-compatibility approach.

- For bundled bars, all relevant provisions of ACI 318 apply.

5.0 Design Manual

5.1 Flatwork (slab-on-grade)

Neuvokas has worked in this market both commerically and residentially for years and has great success replacing #4 steel rebar with #3 GatorBar and #5 steel with #4 GatorBar. It should be noted that there are a plethora of variables that affect concrete crack control performance and the primary purpose of reinforcement is to control the width and spacing of any crack that forms. Reinforcement does not prevent or eliminate cracking. For additional details on design methods for plain concrete slabs-on-ground ACI 360R can be reviewed.

Utilizing equation A-2b of the ACI 440.1R-15 a slab can be designed for shrinkage and temperature reinforcement. This equation has been modified for composite rebar using an allowable amount of strain and the allowable stress.

$$A_{f,sh} = \frac{\mu L w}{2(.0012 * E_f)}$$

μ = coefficient of subgrade friction

L = Distance between joints, ft

w = dead weight of slab, lbs/ft^2

E_f = Elastic modulus of FRP rebar

$A_{f,sh}$ = cross-sectional area of FRP reinforcement

Using this calculation with an elastic modulus of 6,810,000 psi, dead weight of 145 lbs/ft^3, a 1.5 coefficient of friction, and a distance between control joints of 10 feet a rebar spacing for various concrete thickness can be calculated.

- 4” concrete– 29.9” ocew #3, 53” ocew #4
- 6” concrete – 19.9” ocew #3, 35” ocew #4
- 8” concrete – 15” ocew #3, 26.5” ocew #4

This calculation ensures a sufficient reinforcement to ensure performance of the slab, and to actually calculate the crack width various calculators have been developed to estimate the actual crack width that will form. This calculation is complicated and best determined using these calculators. Once such calculator is the CRCP 10 tool that was developed by the Center for Transportation Research in Austin. Using this tool typically the rebar spacing can be increased by 30% without exceed the recommended crack width recommended by AASHTO for concrete pavements. Based on this in addition to Neuvokas field experience Neuvokas recommends the followings spacing using GatorBar.

- 4” concrete – 24” to 30” #3 GatorBar
- 6” concrete – 18” to 24” #3 GatorBar or 24” to 30” with #4 GatorBar
- 8” concrete – 12” to 18” #3 GatorBar or 18 to 24” with #4 GatorBar

It should be noted that, as is often the case with prescriptive applications, site conditions, load considerations and other items can lead to changing these values for concrete spacing. These values are intended to be starting place for further consideration.

5.2 Footers

In the case of specific design, the engineer of record should be consulted, but in the case of prescriptive footings for light-frame construction (as designated by the IBC) #3 GatorBar can be used replace #4 steel and #4 GatorBar can be used to replace #5 steel.

Little engineering data is available on the current design requirements driving steel requirements and the high strength of GatorBar allows the direct replacement.