

### Recommended Practice Guidelines for FRP Bars in Pre-Engineered Projects







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### PREFACE

The ACI Recommended Practice Guidelines for FRP Bars in Pre-Engineered Projects provide practical information on how to work with and install non-metallic glass fiber-reinforced polymer (GFRP) reinforcement. It details the key considerations for where to use GFRP reinforcement, the types of GFRP reinforcement available, and how to plan for installing this type of reinforcement. The key attributes of GFRP reinforcement and its proper use are also discussed.

In addition, the ACI Recommended Practice Guidelines for FRP Bars in Pre-Engineered Projects provides prescriptive design tables for common applications such as residential foundation walls and slabs-on-ground. The tables presented are similar to the prescriptive tables in "Code Requirements for Residential Construction and Commentary" (ACI 332). They are meant to allow contractors to understand how to select the appropriate size, location, and spacing of GFRP reinforcement for a project and to compare the layout of GFRP reinforcement to steel reinforcement.

The storage, handling, and installation of GFRP reinforcement is presented with focus on the requirements in "Construction with Glass Fiber-Reinforced Polymer Reinforcing Bars—Specification" (ACI SPEC-440.5).

The appendix to this guide provides additional detailed information from FRP bar manufacturers on commercially available products and solutions.

Each chapter of this manual was reviewed by at least two reviewers, who provided valuable comments, suggestions, and insights. This manual would not be possible without the contributions of these reviewers, and their efforts are highly appreciated. The following reviewers are acknowledged and thanked:

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**Keywords:** compressive strength; cover; durability; fire; footings; foundations; GFRP reinforcement; modulus of elasticity; reinforcement; slabs; splicing; walls.

William J. Gold Managing Editor

### **CHAPTER 1—INTRODUCTION**

This manual aims to provide guidance for the use of glass fiber-reinforced polymer (GFRP) reinforcing bars in common concrete construction applications, including basement foundation walls and flatwork. The guidance is based on the code requirements provided in ACI CODE-440.11-22, "Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars—Code and Commentary." It uses the requirements in this document to modify the tables provided for steel-reinforced concrete in ACI 332-20, "Code Requirements for Residential Concrete and Commentary." Combining the requirements of these two documents provides a set of preengineered design tables for GFRP bars in a range of common residential and light commercial applications. Note that these tables only apply to buildings assigned to Seismic Design Categories A, B, or C as defined in ACI 332 Section 1.1.7.

Additionally, this manual aims to provide an overview of GFRP bars and fiber-reinforced polymer (FRP) materials broadly. A basic understanding of the material properties, strengths, and limitations of these materials, their history of use and research, and typical applications can help guide decisions on where and how to use these bars.

Lastly, construction with GFRP bars differs from the use of traditional steel reinforcement. Application guidance and examples are provided in this manual to facilitate the safe and proper use of GFRP bars in reinforced concrete construction.

### 1.1—Application and research history

The use of GFRP reinforcement began in the late 1970s as a nonmetallic alternative to steel reinforcement. Much of the initial interest in GFRP reinforcement was due to applications that demanded nonmetallic reinforcement. These include reinforcement of structures around magnetic resonance imaging (MRI) units in hospitals and in magnetic levitating (magley) trains, as shown in Fig. 1.1a. In both of these applications, ferrous materials can interfere with the operation of the equipment, and GFRP reinforcement—as a nonmetallic, non-ferrous alternative—has become a standard construction practice for these applications. Some of the largest early applications of GFRP reinforcing bars were in the Gonda Building at the Mayo Clinic in Rochester, MN, built in 2001, and at the National Institutes of Health in Bethesda, MD, built in 1984, both involving reinforcing concrete elements in close proximity to MRI units.

During this time, there was also interest in the noncorrosive nature of GFRP reinforcement and an increasing aware-

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### **APPENDIX**

The appendix to this manual provides properties of bars supplied by several manufacturers. The properties listed are current as of the publication of this manual and are subject to change. It is recommended to consult with specific manufacturers for the most up-to-date product information.

It is important to reiterate that the prescriptive tables in this manual are all based on using ASTM D7957/D7957M minimum material properties. ACI CODE-440.11 does allow engineers to design using either ASTM D7957/D7957M minimum properties or the properties reported by manufacturers (properties must be reported according to ASTM D7957/D7957M standards). Because manufacturer's properties often exceed the minimum values required by ASTM D7957/D7957M, the use of a specific manufacturer's properties may result in less reinforcement being required than values in the prescriptive tables in this manual. Consideration of specific material properties of a given manufacturer (such as those reported in this appendix) would require additional engineering design by a licensed design professional.

The values reported in this appendix were obtained directly from the manufacturers listed. The contribution of material characteristics from the following manufacturers is acknowledged and thanked:

CompKing, Inc. – GBar®

Dextra Group – Durabar™ and ASTEC™

Galen-Panamerica/Binevir Composites

Isam Kabbani Plastic & Insulation Factory – IKK

Mateenbar™

MST Rebar, Inc. – MST-BAR®

Neuvokas Corporation – GatorBar®

Owens Corning Infrastructure Solutions – PINKBAR®+
Fiberglas™ Rebar

### www.compking.com, +1 843 906-8049, email: ccr@compking.com 850 Euclid Avenue, Suite #819 Cleveland, OH 44112 USA CompKing, Inc.

### Design Values - GBar

	No. 10 No. 11 No. 12 No. 13	[M38] [M40]												
	No. 9 No.	_												
Bar Size	No. 8	[M25]	0.87	[561]	105.0	[467]	10300	[71]	NI / A	N/A	25.7	[177]	1,110	[7.7]
Bar	No. 7	[M22]												
	No. 6	[M19]	0.48	[310]	46.5	[207]	0026	[67]	V/1V	N/A	25.5	[176]	1,600	[11.0]
	No. 5	[M16]	0.36	[232]	39.9	[177]	10300	[71]	V/1V	N/A	26.4	[182]	1,870	[12.9]
	No. 4	[M13]	0.24	[155]	29.2	[130]	10300	[71]	A1/A	N/A	20.7	[143]	2,080	[14.3]
	No. 3	[M10]	0.13	[84]	16.1	[71.6]	10800	[74]	N1/A	N/A	27.8	[191]	1,110	[7.7]
	No. 2	[M6]												
		Test Method	ASTM	D7205 11.2.5.1	ASTM	D7205	ASTM	D7205	ASTM	D7914	ASTM	D7617	ASTM	D7913
		Property		Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	Guaranteed Ultimate Tensile Force,	kip [kN]	Mean Tensile Modulus of Elasticity,	ksi [GPa]	Guaranteed Ultimate Tensile Force of	Bent Portion of Bar, kip [kN]	Guaranteed Transverse Shear Strength,	ksi [MPa]	Commutes of Board Street Att. mil BAB	Guaranteed Bond Strength, ps. [MF4]

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	213 to 255°F [100 to 124°C]
Alkali Resistance	ASTM D7705 Procedure A	82 to 94%
Degree of Cure	ASTM E2160	99.41 to 100%
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	8-week range 0.42 to 0.89%

# Head Office = 5th Floor, Lumpini II Bldg., 247 Sarasin Road, Lumpini, Pathumwan, Bangkok, 10330, Thailand www.dextragroup.com, +66 2 021 3800, email: marketing@dextragroup.com Dextra Group

## Design Values - Durabar DIY

							Bar Size	Size					
		;	;	;	;	;	t ;	ç ;	;	;	;	;	;
Property	Test Method	No. 2 [M6]	No. 3 [M10]	No. 4 [M13]	No. 5 [M16]	No. 6 [M19]	No. 7 [M22]	No. 8 [M25]	No. 9 [M29]	No. 10 [M32]	No. 11 [M38]	No. 12 [M40]	No. 13 [M50]
Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	ASTM D7205 11.2.5.1	0.049	0.11	0.20 [129]	0.31								
Guaranteed Ultimate Tensile Force, kip [kN]	ASTM D7205	5.85 [26.0]	11.9 [53.0]	19.6 [87.0]	29.2 [130]								
Mean Tensile Modulus of Elasticity, ksi [GPa]	ASTM D7205	6530 [45]	6530 [45]	6530 [45]	6530 [45]								
Guaranteed Ultimate Tensile Force of Bent Portion of Bar, kip [kN]	ASTM D7914	N/A	N/A	N/A	N/A								
Guaranteed Transverse Shear Strength, ksi [MPa]	ASTM D7617	N/A	N/A	N/A	N/A								
Guaranteed Bond Strength, psi [MPa]	ASTM D7913	N/A	N/A	N/A	N/A								

Guaranteed and mean values are as defined in ASTM D7957.

Value	N/A	N/A	N/A	N/A
Test Method	ASTM E1356	ASTM D7705 Procedure A	ASTM E2160	ASTM D570, subsection 7.4
Property	Glass Transition Temperature	Alkali Resistance	Degree of Cure	Moisture Absorption to Saturation

Head Office = 5th Floor, Lumpini II Bldg., 247 Sarasin Road, Lumpini, Pathumwan, Bangkok, 10330, Thailand www.dextragroup.com, +66 2 021 3800, email: marketing@dextragroup.com Dextra Group

## Design Values - Durabar SLIM

							Bar Size	Size					
		No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No.	No. 9	No. 10	No. 11	No. 12	No. 13
Property	Test Method	[M6]	[M10]	[M13]	[M16]	[M19]	[M22]	[M25]	[M29]	[M32]	[M38]	[M40]	[M50]
Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	ASTM D7205 11.2.5.1	0.049	0.11	0.20 [129]	0.31								
Guaranteed Ultimate Tensile Force, kip [kN]	ASTM D7205	6.52 [29.0]	13.3 [59.0]	21.6 [96.0]	32.0 [143]								
Mean Tensile Modulus of Elasticity, ksi [GPa]	ASTM D7205	6820 [47]	6820 [47]	6820 [47]	6820 [47]								
Guaranteed Ultimate Tensile Force of Bent Portion of Bar, kip [kN]	ASTM D7914	N/A	N/A	N/A	N/A								
Guaranteed Transverse Shear Strength, ksi [MPa]	ASTM D7617	N/A	N/A	N/A	N/A								
Guaranteed Bond Strength, psi [MPa]	Pa] ASTM D7913	N/A	N/A	N/A	N/A								

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	N/A
Alkali Resistance	ASTM D7705 Procedure A	N/A
Degree of Cure	ASTM E2160	N/A
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	N/A

### Galen-Panamerica/Binevir 1206 Stirling Rd, Ste 6A/B, Dania Beach, FL 33004 USA http://galenpanamerica.com, +1 305-833-7066, email: info@galenpanamerica.com

## Design Values - Fiberglass Rebar

							Bar Size	Size					
		7 oN	No. 3	No. 4	No. 5	No. 6	No. 7	× cZ	6 ON	No. 10		No. 12	No. 13
Property	Test Method	[M6]	[M10]	[M13]	[M16]	[M19]	[M22]	[M25]	[M29]	[M32]	[M38]	[M40]	[M50]
Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	ASTM D7205 11.2.5.1		0.146 [94]	0.247	0.386	0.536 [346]							
Guaranteed Ultimate Tensile Force, kip [kN]	ASTM D7205		17.9	26.8	44.1	49.3							
Mean Tensile Modulus of Elasticity, ksi [GPa]	ASTM D7205		8,290	8,170	8,520	8,050							
Guaranteed Ultimate Tensile Force of Bent Portion of Bar, kip [kN]	ASTM D7914		N/A	16.4	N/A	N/A							
Guaranteed Transverse Shear Strength, ksi [MPa]	ASTM D7617		29.3 [202]	27.3 [189]	25.8 [178]	23.9							
Guaranteed Bond Strength, psi [MPa]	ASTM D7913		1,400 [10.0]	2,000 [14.0]	1,400 [10.0]	1,100 [8.0]							

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	223°F (106°C)
Alkali Resistance	ASTM D7705 Procedure A	>80% retention
Degree of Cure	ASTM E2160	%86
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	0.54%

# Isam Kabbani Plastic & Insulation Factory (IKK Mateenbar)

Isam Kabbani Plastic & Insulation Factory (IKK Mateenbar), Dammam 3rd Industrial City, Saudi Arabia, www.ikkmateenbar.com, +966 138923537, email: mateenbar@ikkgroup.com

# Design Values - Mateenbar™ 52 GPa

שמוססיים ווומיססיים	2												
							Bar	Bar Size					
		No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13
Property	Test Method	[M6]	[M10]	[M13]	[M16]	[M19]	[M22]	[M25]	[M29]	[M32]	[M38]	[M40]	[M50]
	ASTM	0.049	0.11	0.20	0.31	0.44	09.0	0.79	1.0	1.27	1.66	1.88	3.01
Cross Sectional Area, in. [mm]	D /205 11.2.5.1	[32]	[71]	[129]	[199]	[284]	[387]	[510]	[645]	[819]	[1071]	[1213]	[1942]
Guaranteed Ultimate Tensile Force,	ASTM	10.4	16.4	28.6	39.3	55.1	69.7	92.1	116	148	193	204	328
kip [kN]	D7205	[46.3]	[72.9]	[127]	[175]	[245]	[310]	[410]	[516]	[659]	[859]	[607]	[1460]
Mean Tensile Modulus of Elasticity,	ASTM	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
ksi [GPa]	D7205	[52]	[52]	[52]	[52]	[52]	[52]	[52]	[52]	[52]	[52]	[52]	[52]
Guaranteed Ultimate Tensile Force of	ASTM	5.0	8.2	14	19	27	34	45	N1/A	NI/A	NI/A	A / 1 /	A1/A
Bent Portion of Bar, kip [kN]	D7914	[22.2]	[36.5]	[62.3]	[84.5]	[120]	[151]	[200]	IN/A	IN/A	IN/A	N/A	N/A
Guaranteed Transverse Shear Strength,	ASTM	22	22	22	22	22	22	22	22	22	19	19	19
ksi [MPa]	D7617	[152]	[152]	[152]	[152]	[152]	[152]	[152]	[152]	[152]	[131]	[131]	[131]
Guaratand Dand Stromath and IMDal	ASTM	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160
Oualaineed Boild Stieligul, psi [ivir a]	D7913	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]	[8.0]
Giorgian A CTM D7057	A STIM IN 7057												

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	>212°F [>100°C]
Alkali Resistance	ASTM D7705 Procedure A	%08<
Degree of Cure	ASTM E2160	>97%
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	<0.1%

# Isam Kabbani Plastic & Insulation Factory (IKK Mateenbar), Dammam 3rd Industrial City, Saudi Arabia, www.ikkmateenbar.com, +966 138923537, email: mateenbar@ikkgroup.com Isam Kabbani Plastic & Insulation Factory (IKK Mateenbar)

Design Values - Mateenbar<sup>TM</sup> 60 GPa

							Bar Size	Size					
Property	Test Method	No. 2 [M6]	No. 3 [M10]	No. 4 [M13]	No. 5 [M16]	No. 6 [M19]	No. 7 [M22]	No. 8 [M25]	No. 9 [M29]	No. 10 [M32]	No. 11 [M38]	No. 12 [M40]	No. 13 [M50]
Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	ASTM D7205 11.2.5.1	0.049	0.11	0.20 [129]	0.31	0.44 [284]	0.60	0.79			,	,	,
Guaranteed Ultimate Tensile Force, kip [kN]	ASTM D7205	10.4 [46.3]	19.8	29.1	41.8	57.5 [256]	78.4 [349]	103 [459]					
Mean Tensile Modulus of Elasticity, ksi [GPa]	ASTM D7205	8,700 [60]	8,700 [60]	8,700 [60]	8,700 [60]	8,700 [60]	8,700 [60]	8,700					
Guaranteed Ultimate Tensile Force of Bent Portion of Bar, kip [kN]	ASTM D7914	5.0 [22.2]	9.8 [43.6]	14 [62.3]	20 [89.0]	28 [125]	39 [174]	50 [222]					
Guaranteed Transverse Shear Strength, ksi [MPa]	ASTM D7617	22 [152]	22 [152]	22 [152]	22 [152]	22 [152]	22 [152]	22 [152]					
Guaranteed Bond Strength, psi [MPa]	ASTM D7913	1160 [8.0]	1160 [8.0]	1160 [8.0]	1160 [8.0]	1160 [8.0]	1160 [8.0]	1160 [8.0]					

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	>212°F [>100°C]
Alkali Resistance	ASTM D7705 Procedure A	%08<
Degree of Cure	ASTM E2160	>97%
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	<0.1%

# MST Rebar, Inc. 200A Hanlan Road Woodbridge, Ontario L4L 3R7 www.mstbar.com, +1 855-740-0377, email: info@mstbar.com

# Design Values - MST-BAR® Grade III GFRP

Cross Sectional Area, in. <sup>2</sup> [mm²] ASS  Guaranteed Ultimate Tensile Force, ASS  kip [kN] D77  Guaranteed Ultimate Tensile Force of ASS  Sectional Ass  Ksi [GPa] D77  Guaranteed Ultimate Tensile Force of ASS  Bent Portion of Bar, kip [kN] D75  Guaranteed Transverse Shear Strength, ASS  Character ASS  Guaranteed Transverse Shear Strength, ASS  Character ASS  Character ASS  ASS  ASS  Bent Portion of Bar, kip [kN] D75  D77  Character ASS  Character ASS  Character ASS  ASS  ASS  ASS  ASS  Character ASS  ASS  ASS  Character ASS  ASS  ASS  ASS  Ch	ASTM	No. 3 [M10]	No. 4 [M13] 0.20 0.20 [129] 30.4 [135] 8700 [60] 18.2 [81.0] 33 33 [228]	No. 5 [M16] 0.31 [199] 45.0 (200] 8700 [60] 27 [1120] 33	No. 6 [M19] 0.44 [284] 65.0 65.0 [289] 8700 [60] 40 [178] 33	No. 7 No. 7 No. 6 No. 7 No. 6	No. 8 [M25] 0.79 (510] 114 [507] 8700 [60] 68.6 [305]	No. 9 [M29] 1.0 [645] 145 [645] 8700 [60] N/A	No. 10 [M32] 1.27 1.27 [819] 8700 [60] N/A	No. 11 [M38] 1.66 [1071] 226 [1005] 8700 [60] N/A	No. 12 [M40]	No. 13 [M50]
Guaranteed Bond Strength, psi [MPa] D79	ASTM D7913	3300	3300	3300	3000	3000	3000	3000	3000	3000		
1	61,		[ [ ]							-		

Guaranteed and mean values are as defined in ASTM D7957.

Value	235°F [113°C]	90% retention	100%	0.18%
Test Method	ASTM E1356	ASTM D7705 Procedure A	ASTM E2160	ASTM D570, subsection 7.4
Property	Glass Transition Temperature	Alkali Resistance	Degree of Cure	Moisture Absorption to Saturation

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### Design Values - GatorBar®

							Bar Size	ize					
		6	,	5	2		t	5	5	5	:	5	5
Property	Test Method	No. 2 [M6]	No. 3 [M10]	No. 4 [M13]	No. 5 [M16]	No. 6 [M19]	No. / [M22]	No. 8 [M25]	No. 9 [M29]	No. 10 [M32]	No. 11 [M38]	No. 12 [M40]	No. 13 [M50]
Cross Sectional Area, in. <sup>2</sup> [mm <sup>2</sup> ]	ASTM D7205 11.2.5.1		0.11	0.20 [129]									
Guaranteed Ultimate Tensile Force, kip [kN]	ASTM D7205		17.1 [76.1]	30.4 [135]	£1								
Mean Tensile Modulus of Elasticity, ksi [GPa]	ASTM D7205		6800 [47]	7100 [49]	ming ner 202								
Guaranteed Ultimate Tensile Force of Bent Portion of Bar, kip [kN]	ASTM D7914		N/A	N/A									
Guaranteed Transverse Shear Strength, ksi [MPa]	ASTM D7617		26.8 [185]	26.8 [185]									
Guaranteed Bond Strength, psi [MPa]	ASTM D7913		1400 [10.0]	Test Pending									
Crowden to the second s	A CTIME IN 7057												

Guaranteed and mean values are as defined in ASTM D7957.

Value	243°F [117°C]	>80% of initial mean ultimate tensile force	%9.66	< 1.0%
Test Method	ASTM E1356	ASTM D7705 Procedure A	ASTM E2160	ASTM D570, subsection 7.4
Property	Glass Transition Temperature	Alkali Resistance	Degree of Cure	Moisture Absorption to Saturation

### www.owenscorning.com/pinkbar+, +1 855-OC-Rebar, email: https://www.owenscorning.com/en-us/contact-us One Owens Corning Parkway, Toledo, OH 43659 Owens Corning Infrastructure Solutions

Design Values – PINKBAR®+ Fiberglas™ Rebar

)	)												
							Bar	Bar Size					
		No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13
Property	Test Method	[M6]	[M10]	[M13]	[M16]	[M19]	[M22]	[M25]	[M29]	[M32]	[M38]	[M40]	[M50]
C 1 4 2 F 21	ASTM		0.11	0.20	0.31	0.44	09:0	0.79					
Cross Sectional Area, in. [mm*]	D/205 11.2.5.1		[71]	[129]	[199]	[284]	[387]	[510]					
Guaranteed Ultimate Tensile Force,	ASTM		16.0	24.7	41.8	57.3	78.3	102					
kip [kN]	D7205		[71.2]	[110]	[186]	[255]	[348]	[453]					
Mean Tensile Modulus of Elasticity,	ASTM		6,800	008'9	8,700	8,700	8,700	8,700					
ksi [GPa]	D7205		[47]	[47]	[60]	[60]	[60]	[09]					
Guaranteed Ultimate Tensile Force of	ASTM		A1/A	23.2	36.0	44.7	6.09	80.2					
Bent Portion of Bar, kip [kN]	D7914		N/A	[103]	[160]	[199]	[271]	[357]					
Guaranteed Transverse Shear Strength,	ASTM		22	22	22	22	22	22					
ksi [MPa]	D7617		[152]	[152]	[152]	[152]	[152]	[152]					
Consumeration Dand Steements and PADE	ASTM		1400	1400	1400	1400	1100	1100					
Guaranteed Bond Suengui, ps. [Mr a]	D7913		[10.0]	[10.0]	[10.0]	[10.0]	[8.0]	[8.0]					
Gueranteed and mean values are as defined in A STM D7057	V STM D7057												

Guaranteed and mean values are as defined in ASTM D7957.

Property	Test Method	Value
Glass Transition Temperature	ASTM E1356	212°F [100°C]
Alkali Resistance	ASTM D7705 Procedure A	>85%
Degree of Cure	ASTM E2160	>75
Moisture Absorption to Saturation	ASTM D570, subsection 7.4	<0.75%