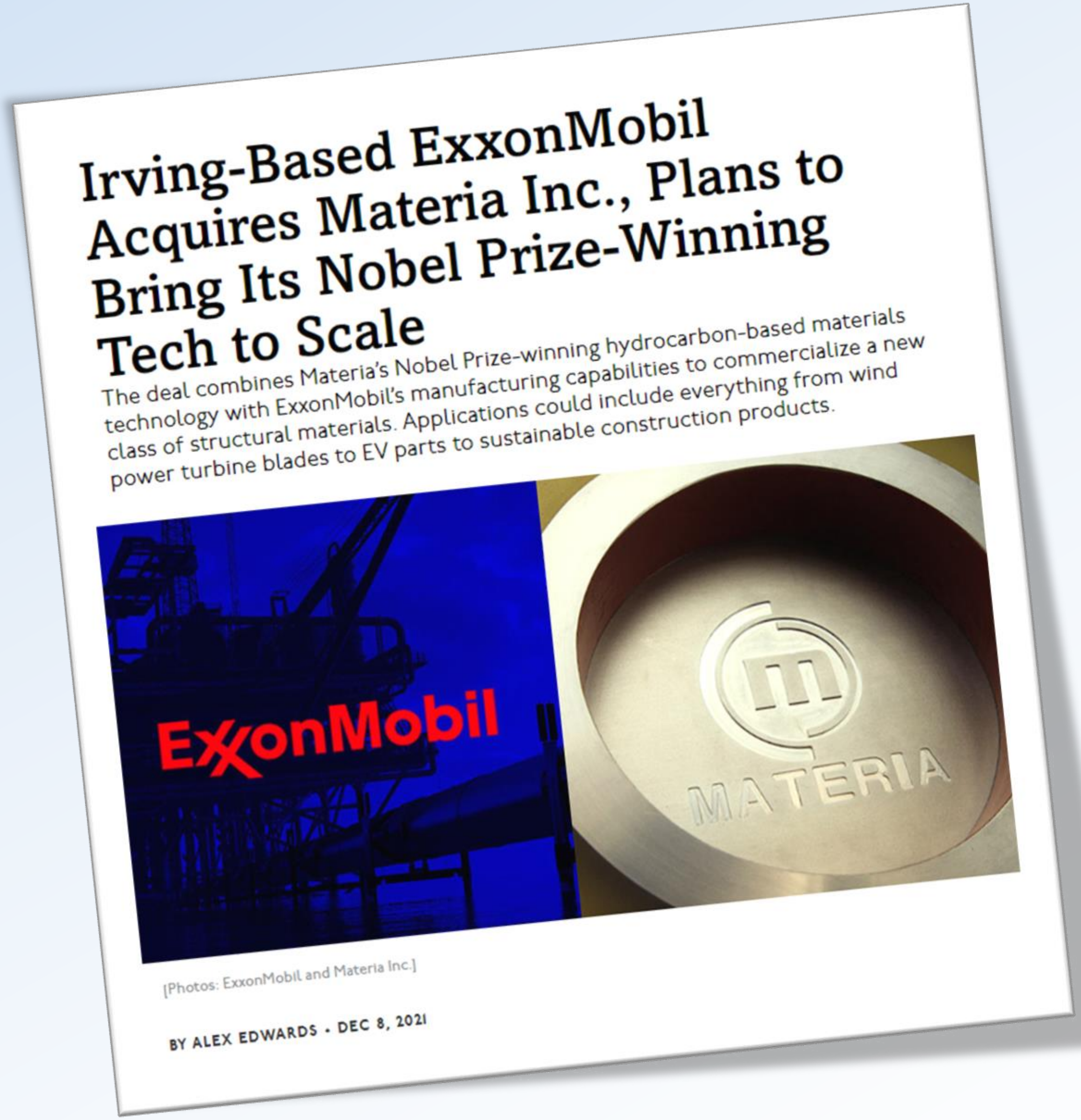
Proxxima™

Proxxima™ thermoset polyolefins for GFRP bars

ExxonMobil

Materia, Inc. joins the ExxonMobil family


Irving-Based ExxonMobil Acquires Materia Inc., Plans to Bring Its Nobel Prize-Winning Tech to Scale

The deal combines Materia's Nobel Prize-winning hydrocarbon-based materials technology with ExxonMobil's manufacturing capabilities to commercialize a new class of structural materials. Applications could include everything from wind power turbine blades to EV parts to sustainable construction products.

[Photos: ExxonMobil and Materia Inc.]

BY ALEX EDWARDS • DEC 8, 2021

Materia™ brings:

- Technology company emanating from Caltech
- Advanced thermoset resin technology based on Grubbs catalyst
- Proven application base

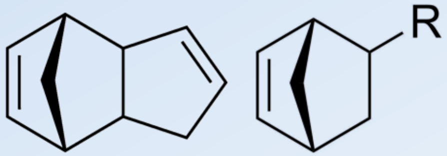
ExxonMobil brings:

- Global marketing capability
- Capital to invest in scaling a business
- Access to feedstocks

… a love and heritage in all things polyolefin

Proxxima™ resin systems

CYCLIC OLEFIN RESINS

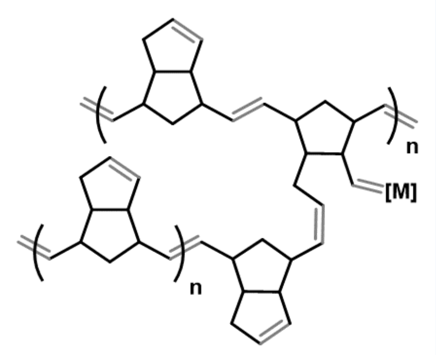


+

GRUBBS CATALYST

=

THERMOSET POLYOLEFINS



Fast processing

Tunable snap-cure

Ultra-low viscosity

Durable

Ultra tough

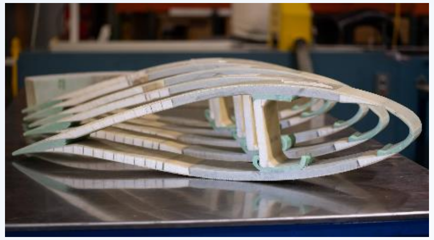
Chemical resistant

Water resistant

Sustainability Benefits

Enables re-thinking of manufacturing process

Rebar



Wind

Coatings

Corrosion resistance in harsh environments

Chlor-alkali cell tops

Subsea insulation & CUI coatings

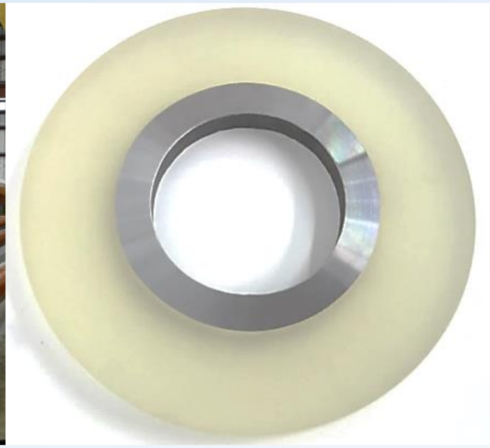
Ultra tough

Ballistics panel

Downhole tools

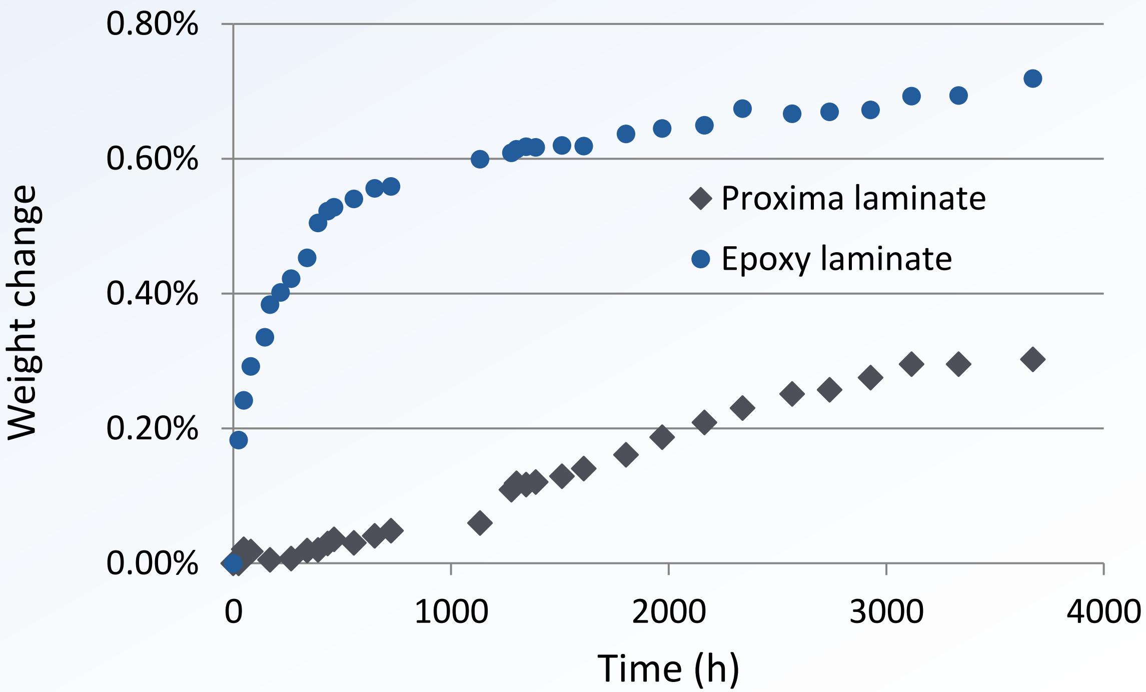
ExxonMobil

Water resistance vs. epoxy



Proxxima™ resin selected as insulation material for high temperature subsea pipeline applications

Proxxima™ polymers exhibit low water uptake with strong hot/wet performance[1]



[1]Hu, Y.; Li, X.; Lang, A.W.; Zhang, Y.; Nutt, S.R. Water immersion aging of polydicyclopentadiene resin and glass fiber composites. *Polymer Degradation and Stability* 2016, *124*, 35-42.

ExxonMobil

Chemical resistance

Proxxima™ polymers have excellent chemical and corrosion resistance

Chemical	Temperature	12 Month
Sulfuric Acid (50%)	60 °C	Pass
Sodium Hypochlorite (15%)	60 °C	Pass
Chlorine Dioxide (3 g/L)	60 °C	Pass
Phosphoric Acid (70%)	90 °C	Pass
Sodium Hydroxide (50%)	90 °C	Pass
Hydrochloric Acid (30%)	90 °C	Pass
Propylene Glycol	90 °C	Pass

Tested by or on behalf of Materia Inc.

Polymer performance
Test method: ASTM C581-15
Pass: <5% decrease in properties

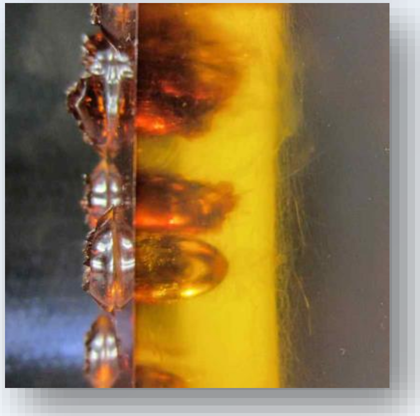
Proxxima™ cell tops provide 9+ year service life in caustic environment of chlor-alkali electrolysis

Toughness vs. epoxy

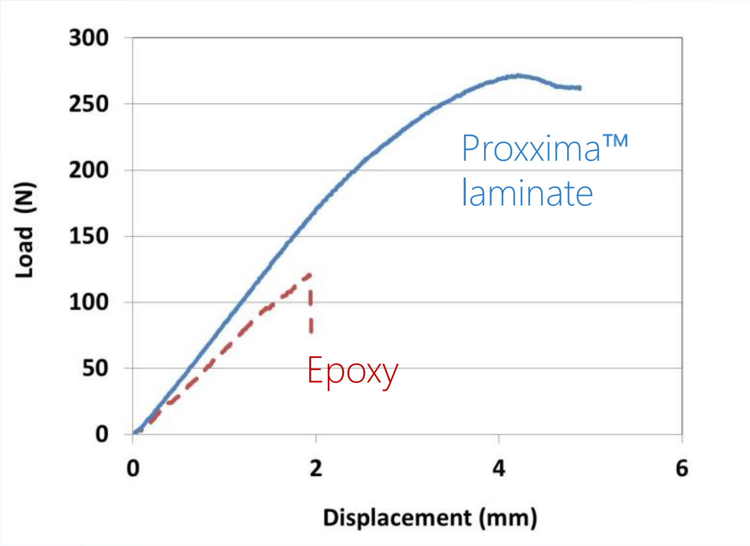
~5x better crack resistance + ductile failure mode

~50% smaller impact zone

Enables wider manufacturing tolerances

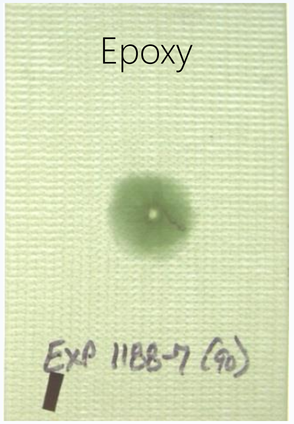


Proxxima™ polymer absorbing 9mm projectile



Tested by or on behalf of Materia Inc.

Crack Resistance via G1c
ASTM D5528
Data treatment per Reeder and Crews (NASA)



Impact Strength via Falling Weight Impact
Tested by Delsen Testing Laboratories per ASTM D7136-07

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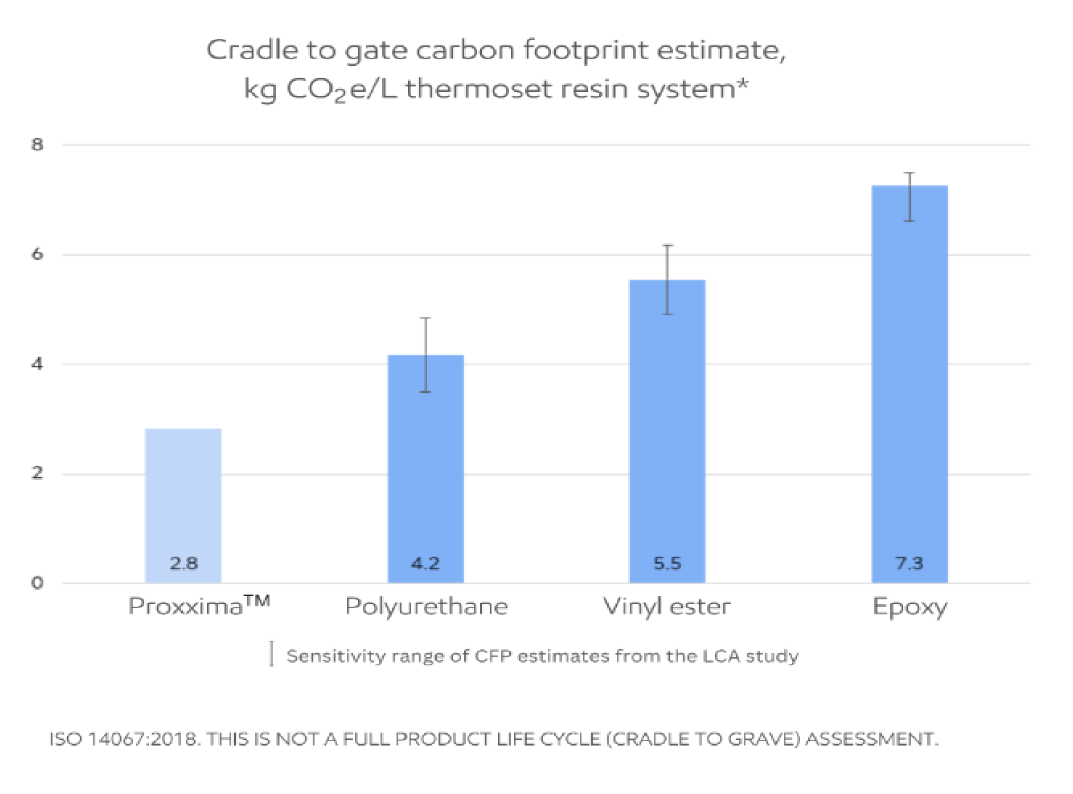
Cradle to gate carbon footprint estimate*

ExxonMobil

SEE DISCLAIMERS ON SLIDE 22



Proxxima™ resin system has a carbon footprint of product (CFP) estimate ~60% lower than comparable epoxy resin**

Proxxima™

*Source: Comparative Carbon Footprint of Product - ExxonMobil's Proxxima™ Resin System to Alternative Resin Systems, June 2023, prepared by Sphera Solutions, Inc. for ExxonMobil Technology and Engineering Company. The study was confirmed to be conducted according to and in compliance with ISO 14067:2018 (Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification) by an independent third party critical review panel.
**All resins assessed in this Life Cycle Assessment (LCA) study were of the type used in molding applications. Specifically, the epoxy resin system was of the type used in VARTM wind blade production. The resin systems are representative of formulated resin systems and include any required curing hardeners or catalysts. Sensitivity ranges of CFP estimates from the LCA study for polyurethane, vinyl ester, and epoxy systems are based on literature review and data from Sphera Solutions, Inc.

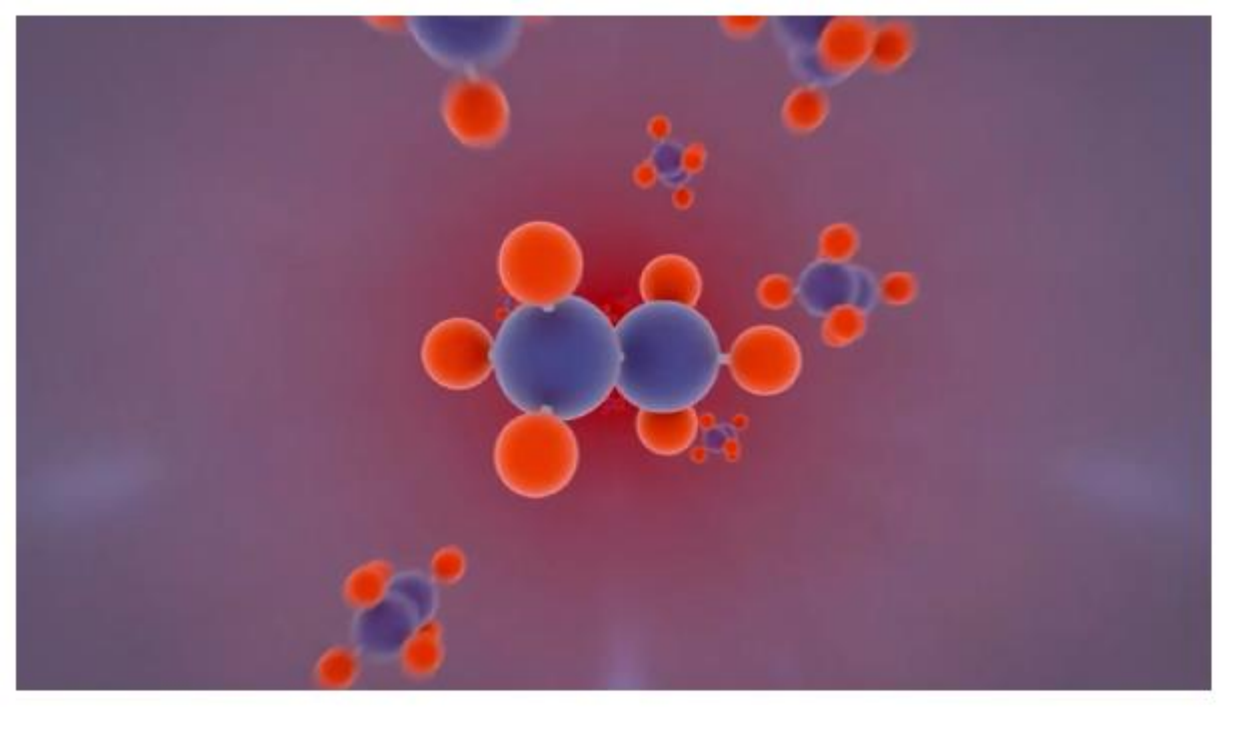
For additional information, please refer to the LCA study summary here.

Advancing plastics circularity

ExxonMobil

Proxxima™ polymer & infusion mixed plastic scrap are being evaluated for their compatibility with Exxtend™ technology for advanced recycling.

ExxonMobil has ambitions for up to 500kta of additional advanced recycling capacity to be added by year-end 2026 across multiple sites globally.



Proxxima™

8

GatorBar® FRP rebar w/ Proxxima™ resins

Low-cost rebar

Proprietary innovative manufacturing process
Line speed over 75 m/min (250 ft/min)
Meets US building code standard (ICC-ES AC 454 certification)

Low-risk opportunities to discover constructability and sustainability benefits

Lightweight + corrosion resistance offer constructability & sustainability
Lower cost enables low-risk non-structural flatwork applications

Scalability

Proxxima™

An ExxonMobil Product

Test methods

2027 2028

Test Methods

- G_1C – ASTM D5528
- Falling Weight Impact – ASTM D7136-07
- Water uptake[1]
- Chemical Resistance – ASTM C581-15

[1]Test method used by Steve Nutt et al. in: Hu, Y.; Li, X.; Lang, A.W.; Zhang, Y.; Nutt, S.R. Water immersion aging of polydicyclopentadiene resin and glass fiber composites. Polymer Degradation and Stability 2016, 124, 35-42

ExxonMobil

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Unanswered Questions About GFRP Bars

Borna Hajimiragha

CEO, MST Rebar Inc.

SPONSORED BY:

PULTRALL V-ROD FIBERGLASS innovations

ALTAIR

MST BAR MAXIMUM STRENGTH GFRP

SFTec®

ACMA American Composites Manufacturers Association FRP Rebar Manufacturers Council

UNIVERSITÉ DE SHERBROOKE

NSERC CRSNG

UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

FDOT

AGENDA

- Brief introduction and past projects
- Third-party Tastings on Mechanical Properties
- UV Exposure
- GPR Scan of GFRP Reinforced Concrete
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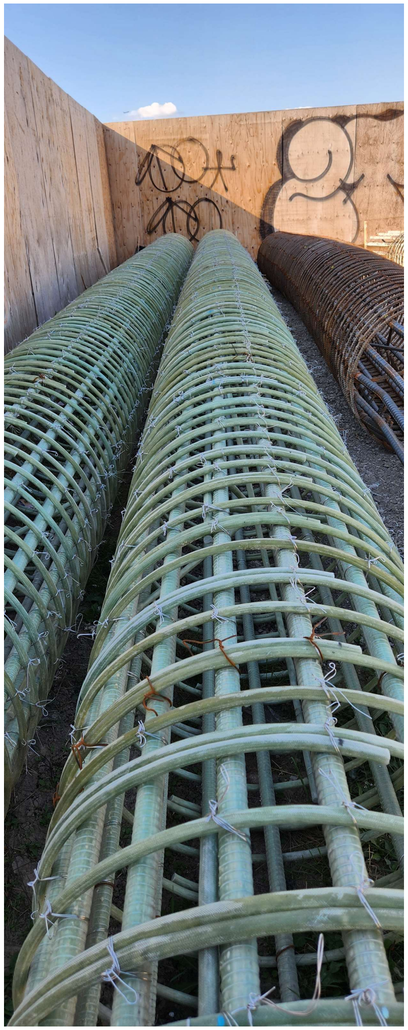
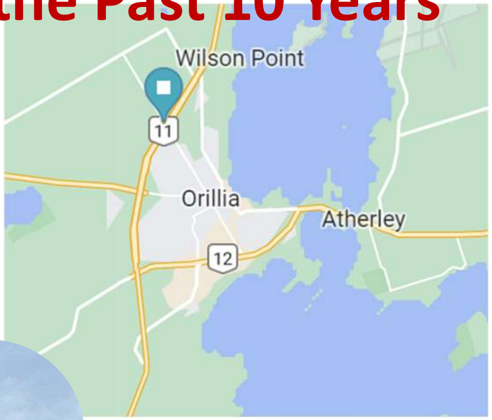
- Bond Strength
- TL-5 GFRP-REINFORCED CONCRETE BRIDGE BARRIER-DECK
- MST-BAR Traceability
- Qualifications and Certificates

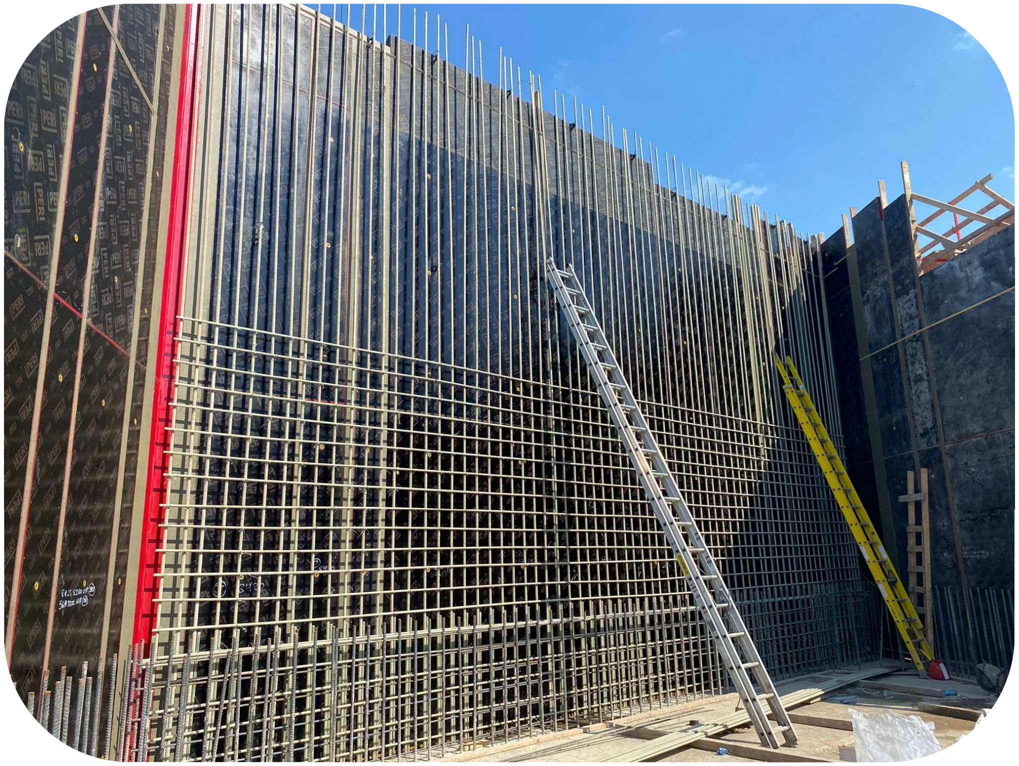
MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years

MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years



MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years





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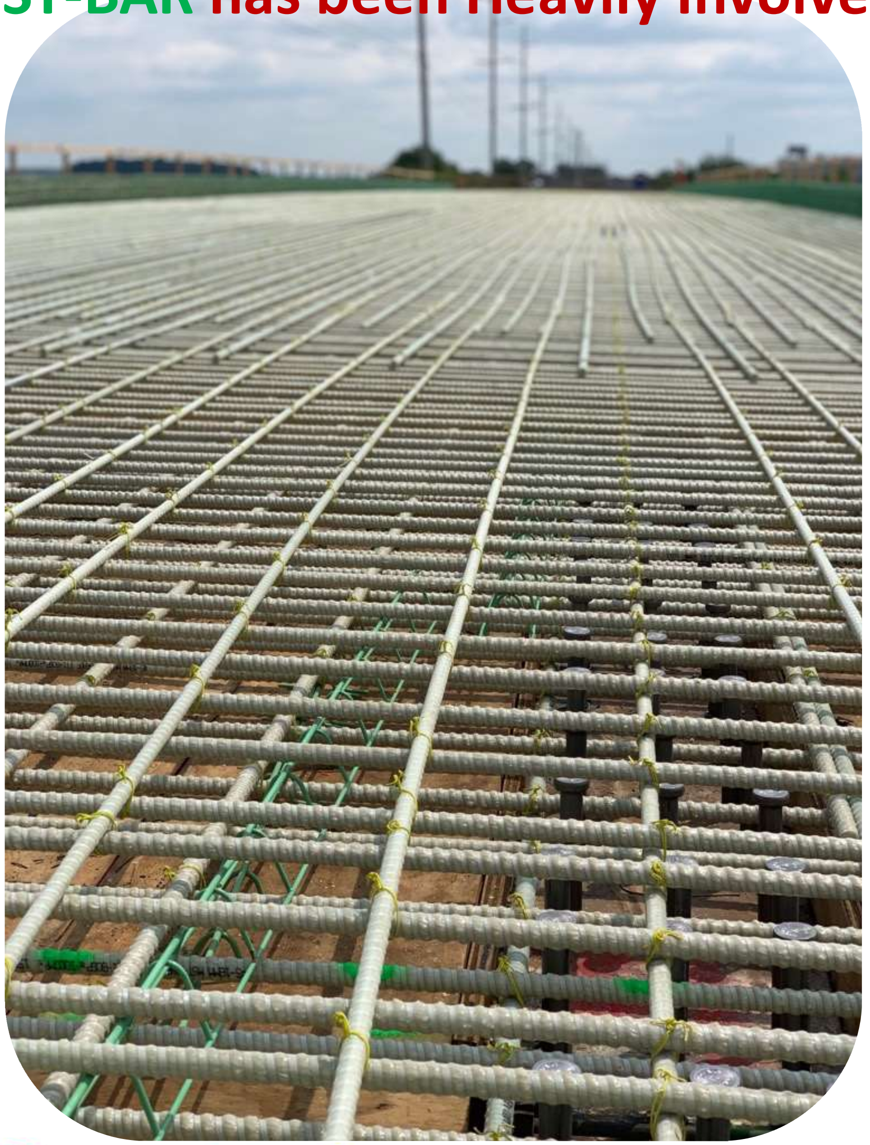

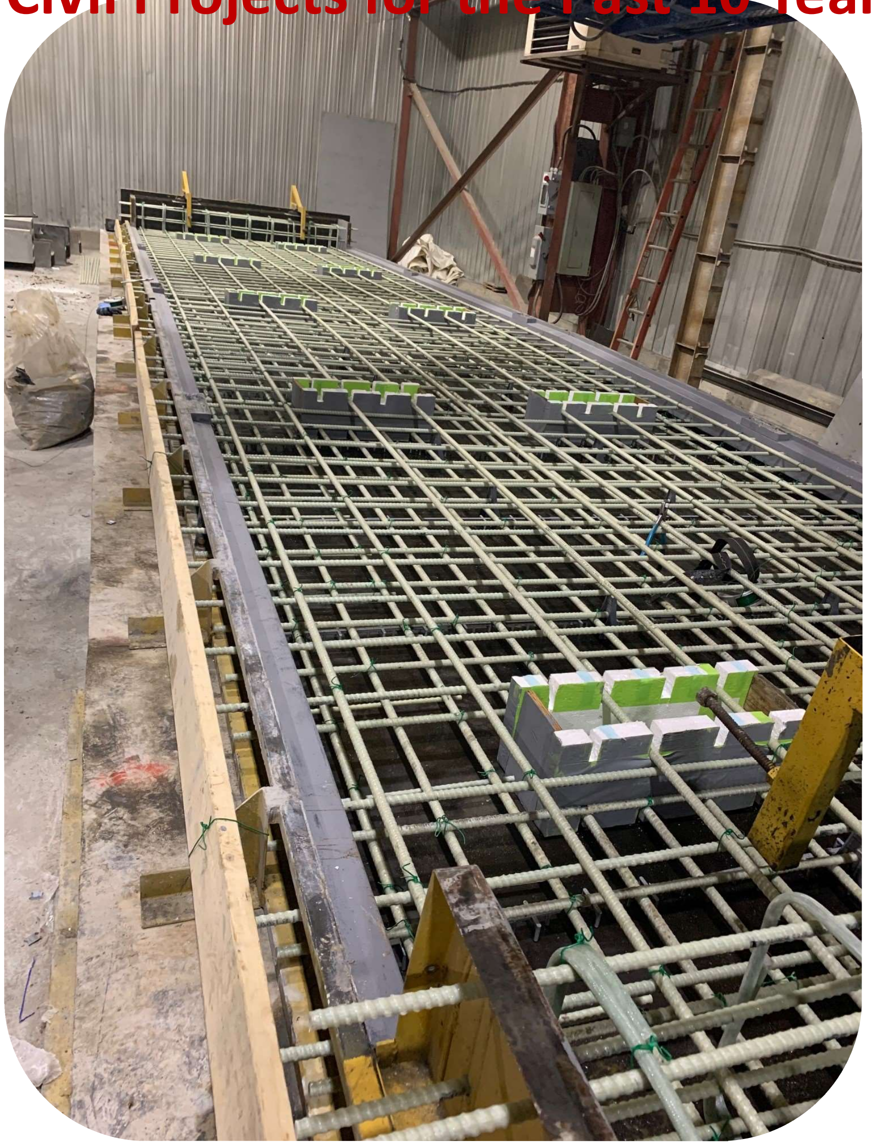

MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years

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MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years

MST-BAR has been Heavily Involved in Civil Projects for the Past 10 Years

Residentials

Residentials

Residentials

Industrials

Industrials

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Alkali Resistance in High pH Solution with and without Load

UNIVERSITÉ DE SHERBROOKE

NSERC Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure

Certification of MSTBAR Glass Fibre-Reinforced Polymer (GFRP) Rebars of Size 15 mm (Production Lots No 1, No 2, and No 3): Alkali Resistance in High pH Solution with Load

Technical Report No 35

Prepared by:

K. Mohamed, and B. Benmokrane, P. Eng., Ph.D.
NSERC Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure
Department of Civil Engineering
University of Sherbrooke
Sherbrooke, Quebec
CANADA J1K 2R1
Phone: (819) 821-7758
Fax: (819) 821-7974
E-mail: Brahim.Benmokrane@USherbrooke.ca

Submitted to:

Borna Hajimiragha
President
B&B FRP Manufacturing Inc.
T: (416)740-0377
E-mail: Borna.H@bandbfrp.com
Website: www.bandbfrp.com

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Alkali Resistance in High pH solution without Load of MST GFRP Bars of Size No. 4 (13 mm Diameter): (Three Production Lots)

Technical Report

Prepared by:

Patrice Cousin, Ph.D., and Brahim Benmokrane, P. Eng., Ph.D.
NSERC Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure
Department of Civil Engineering
University of Sherbrooke
Sherbrooke, Quebec
CANADA J1K 2R1
Phone: (819) 571-6923
E-mail: Brahim.Benmokrane@USherbrooke.ca

Submitted to:

Borna Hajimiragha,
President, B&B Manufacturing Inc.
40 Millwick Dr #9, North York
ON, Canada, M9L 1Y3; T: (416)740-0377
E-mail : Borna.H@bandbfrp.com

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NSERC Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure

Alkali Resistance of MST-BAR Glass Fibre-Reinforced Polymer (GFRP) Bars of Size No.3 in High pH Solution without Load: (Three Production Lots)

Technical Report

Prepared by:

Brahim Benmokrane, P. Eng., Ph.D.
NSERC Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure
Department of Civil Engineering
University of Sherbrooke
Sherbrooke, Quebec
CANADA J1K 2R1
Phone: (819) 571-6923
E-mail: Brahim.Benmokrane@USherbrooke.ca

Submitted to:

Borna Hajimiragha
President
B&B Manufacturing Inc.
40 Millwick Dr #9, North York
ON, Canada, M9L 1Y3; T: (416)740-0377
E-mail : Borna.h@mstbar.com

Alkali Resistance in High pH Solution with and without Load

Tensile strain of 3000 micro-strain.

Tested part is inside PVC containers filled with an **alkaline solution** with a **pH of 13**

Conditioned in an environmental chamber at a **temperature of 60°C (140°F)** for a period of **three months.**

Alkali Resistance in High pH Solution with and without Load

Lot #	Specimens	Average Tensile Capacity (MPa)	Tensile Capacity Retention R_{et}	Average Elastic Modulus (GPa)	Elastic Modulus Retention R_{et}
#1	Reference specimens	1077	89%	69.0	101%
	Conditioned specimens	960		69.5	
#2	Reference specimens	1084	91%	69.5	100%
	Conditioned specimens	982		69.4	
#3	Reference specimens	1067	92%	69.2	101%
	Conditioned specimens	981		69.6	

#5 with Load

The average strength retention of 91%.

CSA S807 limit = 75%

The average modulus retention of 100%.

Creep Rupture Strength

UNIVERSITÉ DE SHERBROOKE
Industrial Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure

Creep Rupture Strength of MST-BAR (GFRP)
Bars Size No. 3 (10 mm)
(24 Tests from 3 Production Lots)

Final Report

Prepared by:

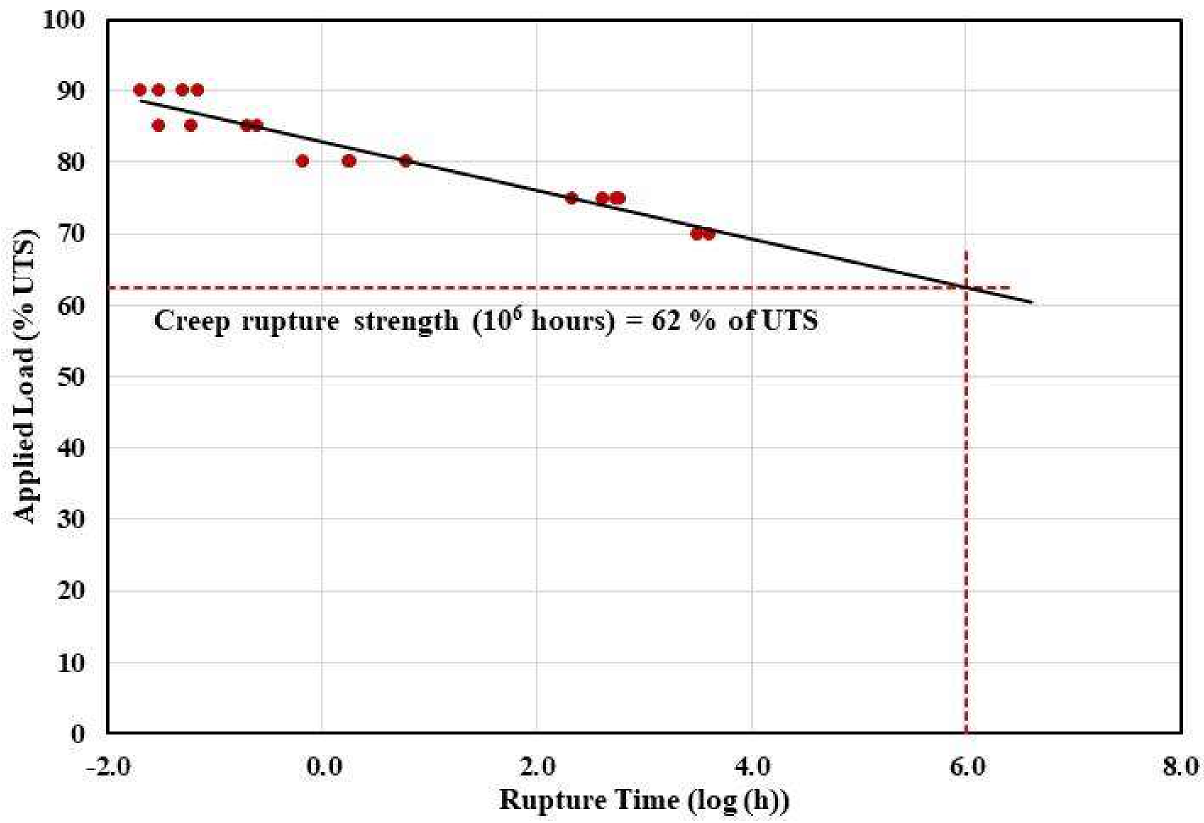
Professor Brahim Benmokrane, P. Eng., Ph.D.
Industrial Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure
Canada Research Chair in Advanced Composite Materials for Civil Structures
Department of Civil & Building Engineering
University of Sherbrooke
Sherbrooke, QC
Canada J1K 2R1
Phone: (819) 571-6923
E-mail: Brahim.Benmokrane@USherbrooke.ca

Submitted to:

Borna Hajimiragha
President
B&B Manufacturing Inc.
40 Millwick Dr #9, North York
ON, Canada, M9L 1Y3; T: (416)740-0377
E-mail: Borna.h@mstbar.com

April 2022, REVISED September 2022

Creep Rupture Strength



Creep rupture strength, at <u>1 million hours (114 years)</u>, of <u>62% of Ultimate Tensile Strength</u>.

CSA S807:19 Limit = 35%
ACI 440.11-22 Code Limit = 30%

Strength of Bent Portion

AGENDA

Table 2 - Tensile Strength of Bent Portions of MST GFRP Bent Bars #6 (Nominal Area 284 mm²)

Specimen	Lot #	Maximum load (kN)	Ultimate tensile strength (MPa)
1	1	254	894
2		262	923
3		278	979
4		258	908
5		251	884
6		243	856
7		267	940
8		251	884
Average		258	908
SD		10.9	38.5
COV %		4.2	4.2
1	2	263	926
2		241	849
3		250	880
4		233	820
5		229	806
6		231	813
7		248	873
8		242	852
Average		242	853
SD		11.4	40.2
COV %		4.7	4.7

132 ksi

124 ksi

Figure 2 – Typical failure of bent portions the tested MST GFRP bent bars of #6

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UV EXPOSURE

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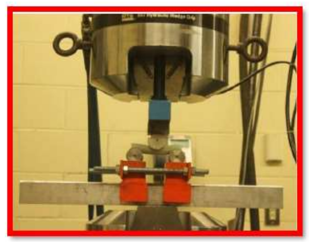
Industrial Research Chair in Innovative FRP Reinforcement for Concrete Infrastructure

Summary of Test Results of #3 MSTBAR GFRP Bars Exposed to UV Waves

Technical Report (DRAFT)



Prepared by:

Professor Brahim Benmokrane, P. Eng., Ph.D.
Industrial Research Chair in Innovative FRP Composite Materials for Infrastructure
Department of Civil Engineering
University of Sherbrooke
Sherbrooke, Quebec
CANADA J1K 2R1
Phone: (819) 571-6923
Fax : (819) 821-7974
E-mail : Brahim.Benmokrane@USherbrooke.ca

Submitted to:
Borna Hajimiragha
President
MST Rebar Inc.
200A Hanlan Rd, Woodbridge,
ON, Canada L4L 3R7
E-mail: Borna.h@mstbar.com

February 8, 2024

Reference (UV Protection)

Reference (Non-UV Protection)

1500 hrs (UV Protection)

1500 hrs (Non-UV Protection)

3000 hrs (UV Protection)

3000 hrs (Non-UV Protection)

UV EXPOSURE

Scanning Electron Microscopy (SEM)

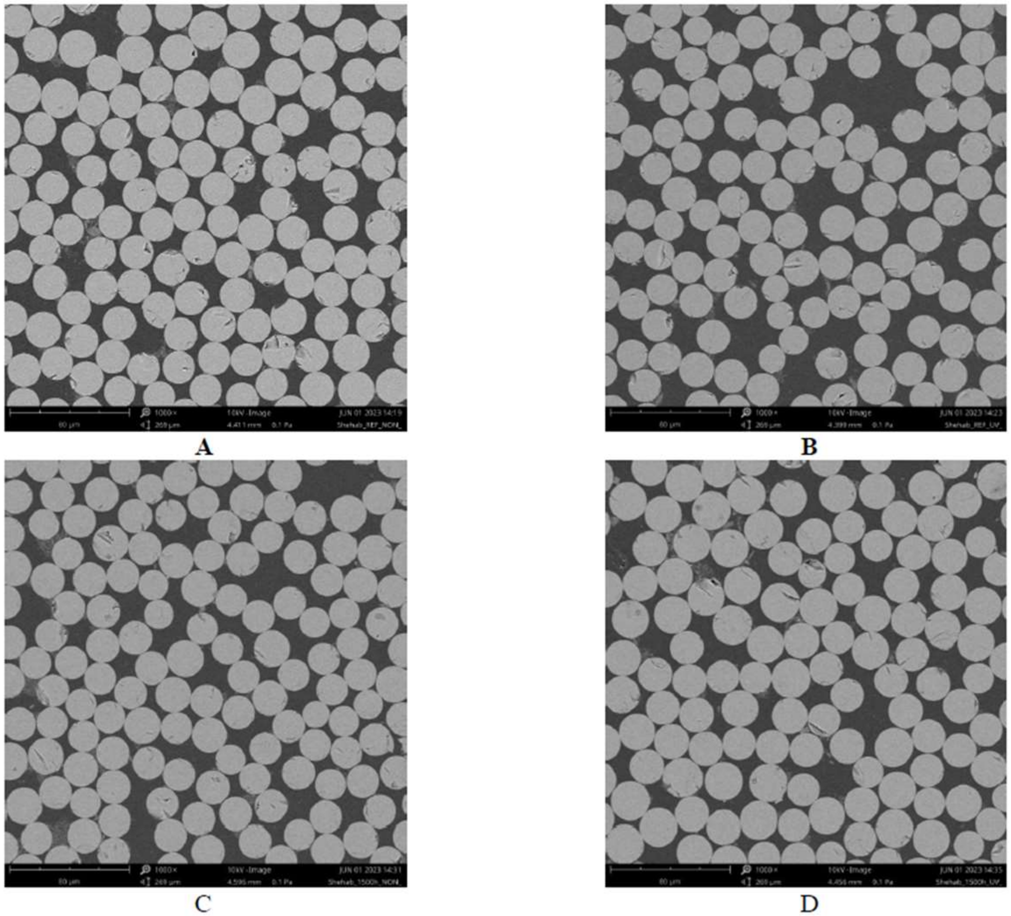


Fig. 3. SEM of bar #3: A: Ref (Non-UV Protection); B: Ref (UV Protection); C: 1500 hrs conditioning (Non-UV Protection); D: 1500 hrs conditioning (UV Protection).

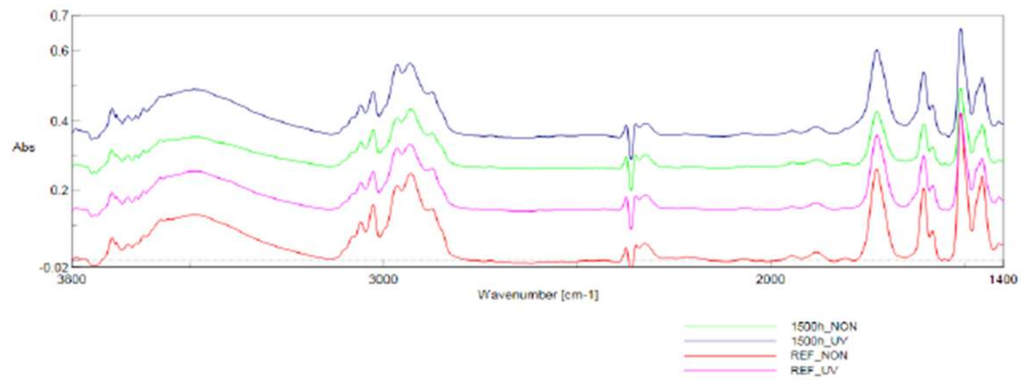


Fig. 2. FTIR spectra of the GFRP specimens.

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UV EXPOSURE

Test results of #3 MSTBAR GFRP bars (Reference bars)

Specimen	Condition	Maximum load (kN)	Bar Diameter	Inter-laminar shear strength (MPa)
1	Ref (UV Protection)	6.9	9.5	65.0
2		6.0	9.5	56.3
3		6.6	9.5	62.0
4		6.2	9.5	58.7
5		6.9	9.5	65.0
Average		6.5		61.4
SD		0.4		3.9
COV (%)		6.3		6.3
1	Ref (Non-UV Protection)	6.0	9.5	56.4
2		6.1	9.5	57.3
3		5.8	9.5	54.9
4		5.0	9.5	47.0
5		6.1	9.5	57.1
Average		5.8		54.6
SD		0.5		4.3
COV (%)		7.9		7.9

Test results of #3 MSTBAR GFRP bars exposed to UV waves for 1500 hrs

Specimen	Condition	Maximum load (kN)	Bar Diameter	Inter-laminar shear strength (MPa)
1	1500 hr (UV Protection)	7.3	9.5	68.3
2		7.4	9.5	69.4
3		7.1	9.5	66.4
4		7.3	9.5	68.9
5		6.7	9.5	63.1
Average		7.1		67.2
SD		0.3		2.6
COV (%)		3.8		3.8
1	1500 hr (Non-UV Protection)	6.2	9.5	57.9
2		6.3	9.5	59.0
3		6.2	9.5	57.9
4		6.6	9.5	61.7
5		6.1	9.5	57.6
Average		6.3		58.8
SD		0.2		1.7
COV (%)		2.9		2.9

Interlaminar Shear Strength (MPa)					
With UV Protection			W/O UV Protection		
Ref	1500 hrs	3000 hrs	Ref	1500 hrs	3000 hrs
61.4	67.2	70.2	54.6	58.8	58.4

Test results of #3 MSTBAR GFRP bars exposed to UV waves for 3000 hrs

Specimen	Condition	Maximum load (kN)	Bar Diameter	Inter-laminar shear strength (MPa)
1	3000 hr (UV Protection)	7.3	9.5	68.7
2		7.9	9.5	74.3
3		7.6	9.5	71.5
4		7.3	9.5	68.7
5		7.2	9.5	67.7
Average		7.5		70.2
SD		0.3		2.7
COV (%)		3.9		3.9
1	3000 hr (Non-UV Protection)	5.9	9.5	55.5
2		6.1	9.5	57.4
3		6.2	9.5	57.9
4		6.3	9.5	59.3
5		6.6	9.5	62.1
Average		6.2		58.4
SD		0.3		2.5
COV (%)		4.2		4.2

Approximately 10% increase in interlaminar shear strength

UV EXPOSURE

Conclusions

According to the test results, UV conditioning of the #3 MSTBAR GFRP bar samples has no influence/effect on the horizontal shear strengths- results.

Moisture absorption tests showed good behavior of the tested GFRP bars when immersed in water for 24 hrs. The water absorption values were well below the limits provided by CSA S807-19 and ASTM spec.

The mean glass transition temperature was above 100°C for both unconditioned and UV-conditioned GFRP bars, meeting the 100°C limit of CSA S807-19 and ASTM spec.

FTIR analysis confirmed that the GFRP bars had not been chemically degraded by UV conditioning.

The Scanning Electron Microscopy (SEM) analysis of unconditioned and conditioned GFRP bars exposed to UV showed that no defects in polymer matrix, fibers, or interfaces were observed.

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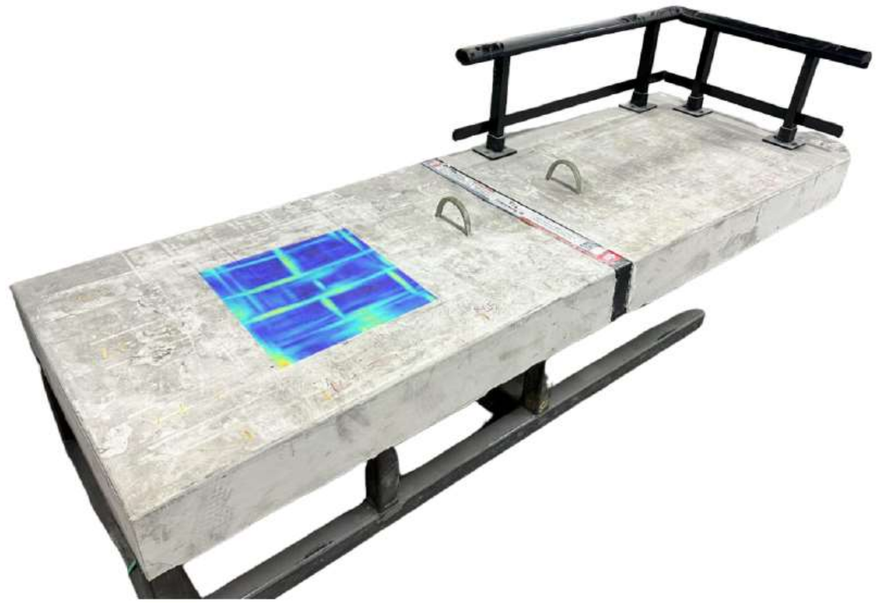


GPR Scan of GFRP Reinforced Concrete

MST Bar - 260 Hanlan Road, Woodbridge, ON

Feasibility Study

FPrimeC Project Number: 202311-04

FPrimeC SOLUTIONS

GPR Scanning

Figure 3 - GPR Scanning using Conquest 100 System.

GPR Scanning

Figure 4 - GPR Scanning using GS8800 system.

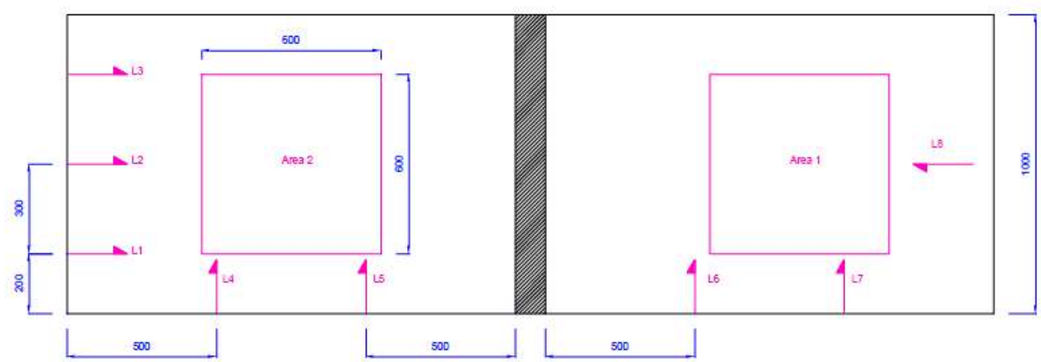


Figure 5 - Approximate location of GPR line and Area Scans.

GPR Scanning

Table 1 - Key observations from the GPR scans.

	Conquest 100 by Sensors and Software		GP8800 by Proceq	
	Depth (mm)	Spacing (mm)	Depth (mm)	Spacing (mm)
Top Transverse Rebars	90	250	50	250
Top Longitudinal Rebars	60	150	50	150
Bottom Transverse Rebars	150	250	150	250
Bottom Longitudinal Rebars	150	250	150	150

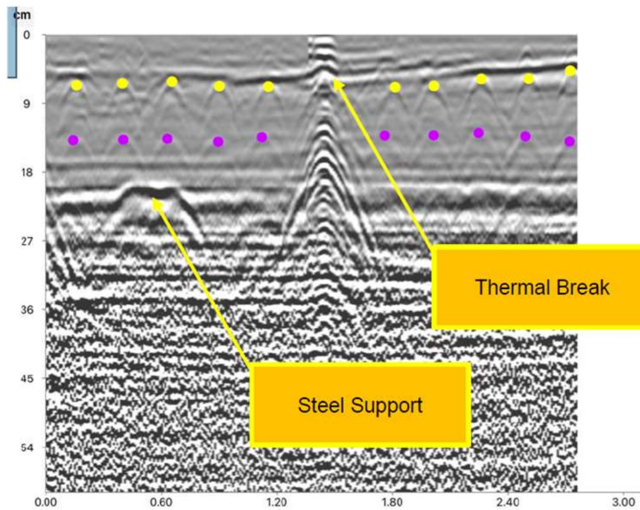


Figure B 1 – Line Scan 1.

AGENDA

- Third-party Tastings on Mechanical Properties
- UV Exposure
- GPR Scan of GFRP Reinforced Concrete
- Environmental Product Declaration (EPD)
- Bond Strength
- TL-5 GFRP-REINFORCED CONCRETE BRIDGE BARRIER-DECK
- MST-BAR Traceability
- Qualifications and Certificates

AGENDA

- Third-party Tastings on Mechanical Properties
- UV Exposure
- GPR Scan of GFRP Reinforced Concrete
- Environmental Product Declaration (EPD)
- **Bond Strength**
- TL-5 GFRP-REINFORCED CONCRETE BRIDGE BARRIER-DECK
- MST-BAR Traceability
- Qualifications and Certificates

BOND STRENGTH

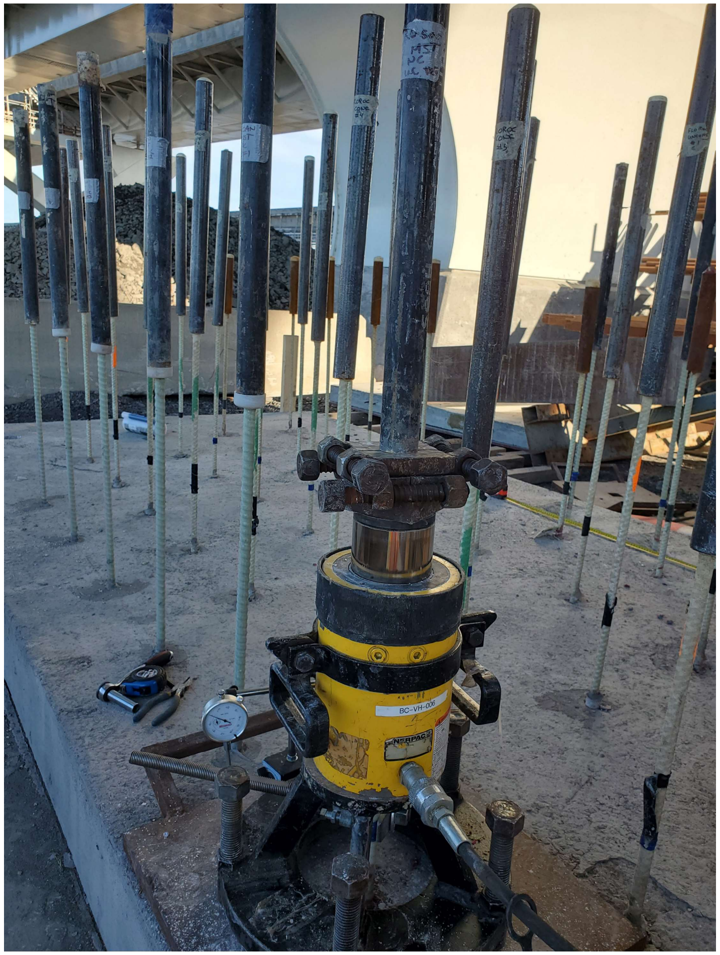
Specimen	Failure Load *kN*	Bond Strength *MPa*	Failure Mode
1	113	29	Concrete Splitting
2	103	26	Concrete Splitting
3	105	26	Concrete Splitting
4	106	27	Test Stopped
5	105	26	Test Stopped
Average	**106.5**	**27**	
Standard Deviation	3.93	1.0	
Coefficient of Variation (%)	3.7	3.7	

CSA S807:19 Limit = 10 MPa (1450 PSI)
ASTM D7957 Limit= 9MPa (1300 PSI)

Failure Load #5 MST: 23.8 Kips (Concrete Splitting)

Yield strength of Steel #5 Grade 60: 60 KSI x 0.31in2 = 18.6 Kips

BOND STRENGTH



AGENDA

- Third-party Tastings on Mechanical Properties
- UV Exposure
- GPR Scan of GFRP Reinforced Concrete
- Environmental Product Declaration (EPD)
- Bond Strength
- TL-5 GFRP-REINFORCED CONCRETE BRIDGE BARRIER-DECK
- MST-BAR Traceability
- Qualifications and Certificates

INVESTIGATION ON THE CAPACITY OF TL-5 GFRP-REINFORCED CONCRETE BRIDGE BARRIER-DECK ANCHORAGE SUBJECTED TO TRANSVERSE VEHICLE IMPACT LOADING

by

Gledis Dervishhasani

BEng, Ryerson University, 2015

A thesis

presented to Ryerson University

in partial fulfillment of the

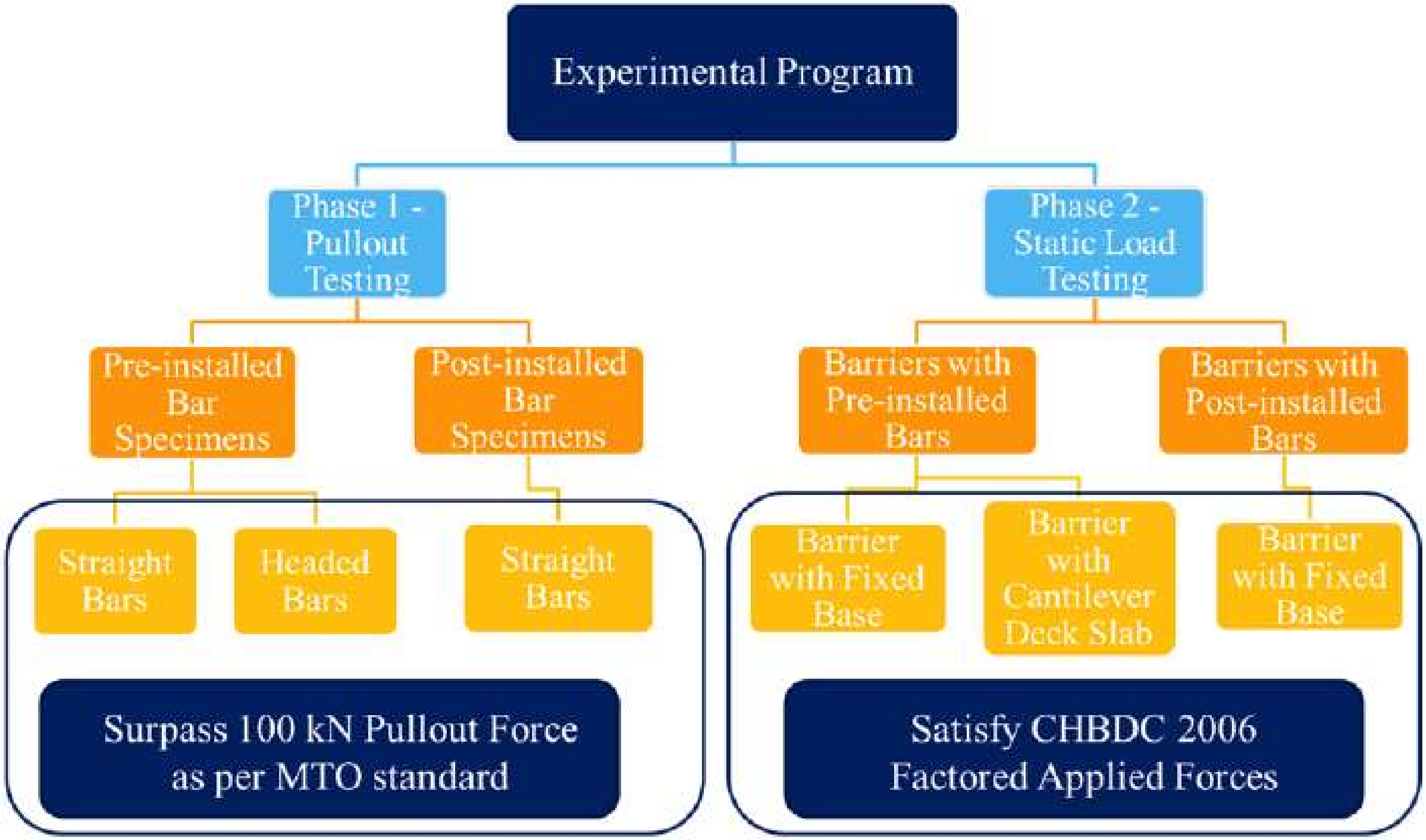
requirements for the degree of

Master of Applied Science

in the program of

Civil Engineering

Toronto, Ontario, Canada, 2018


Experimental Program
Phase 1 - Pullout Testing
Phase 2 - Static Load Testing
Pre-installed Bar Specimens
Post-installed Bar Specimens
Barriers with Pre-installed Bars
Barriers with Post-installed Bars
Straight Bars
Headed Bars
Straight Bars
Barrier with Fixed Base
Barrier with Cantilever Deck Slab
Barrier with Fixed Base
Surpass 100 kN Pullout Force as per MTO standard
Satisfy CHBDC 2006 Factored Applied Forces

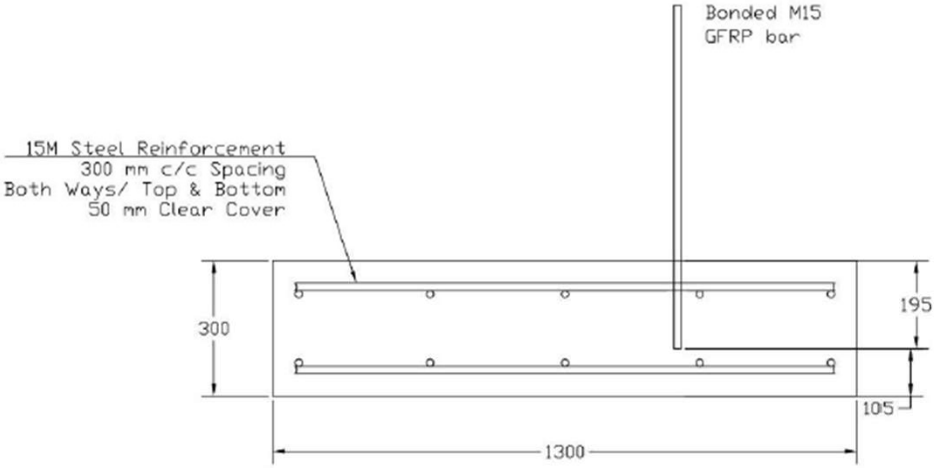


Figure 3.6: Group 1 - Straight fully-bonded GFRP bar in concrete

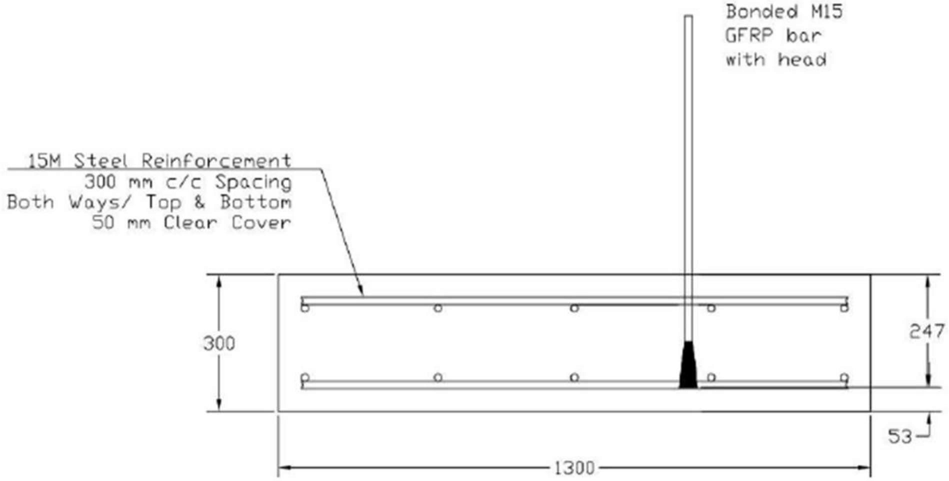


Figure 3.7: Group 2 – Headed-end GFRP bar with fully-bonded straight length in concrete

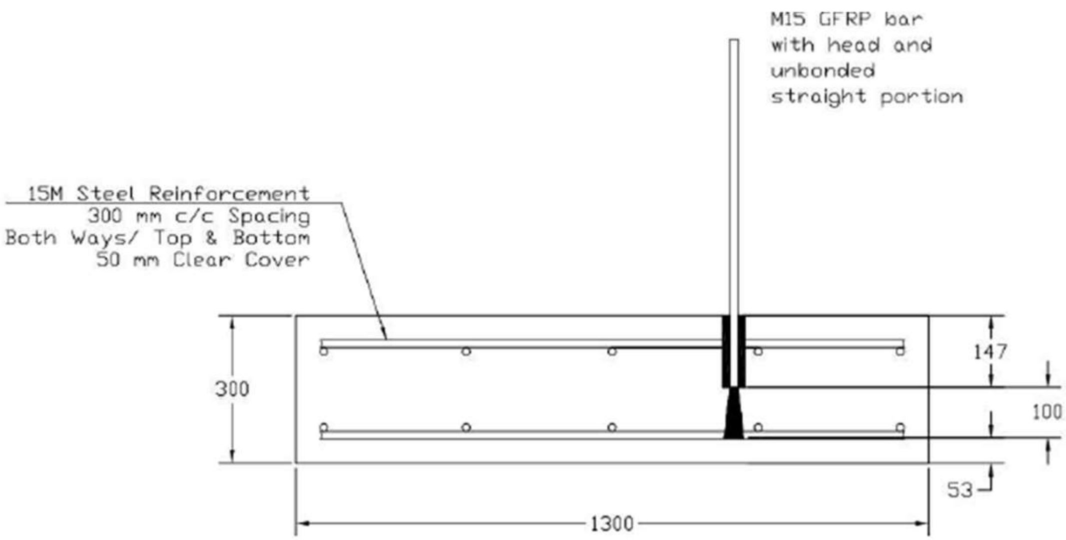
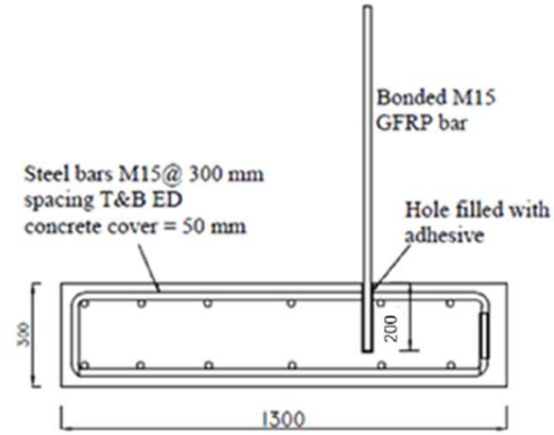


Figure 3.8: Group 3 – Headed-end GFRP bars with unbonded straight portion in concrete



150 mm
175 mm
200 mm

Figure 3.12: Post-installed GFRP bar in concrete slab

Type of construction	Group	Sample	Failure load (kN)	Type of failure	Group average failure load (kN)
Pre-Installed bars	1	A	150.88	Bar crushing at grip	145.48
		B	146.02	Bar crushing at grip	
		C	140.35	Bar crushing at grip	
		D	144.67	Bar crushing at grip	
		E	145.48	Bar crushing at grip	
	2	A	157.89	Bar crushing at grip	148.34
		B	127.67	Bar crushing at grip	
		C	161.94	Bar crushing at grip	
		D	151.69	Bar crushing at grip	
		E	142.51	Bar crushing at grip	
	3	A	137.38	Bar slip from head	131.04
		B	122.00	Bar slip from head	
		C	137.38	Bar slip from head	
		D	127.40	Bar slip from head	
Post-Installed bars	1	A	158.70	Bar crushing at grip	152.49
		B	194.87	Bar slip	
		C	146.83	Bar crushing at grip	
		D	158.97	Bar slip	
		E	103.10	Bar slip	
	2	A	134.68	Bar slip	112.82
		B	96.09	Bar slip	
		C	120.38	Bar slip	
		D	89.61	Bar slip	
		E	123.35	Bar slip	
	3	A	163.56	Bar slip, concrete cone	144.83
		B	116.60	Bar slip	
		C	153.58	Bar crushing at grip	
		D	156.01	Bar crushing at grip	
		E	134.41	Bar slip	

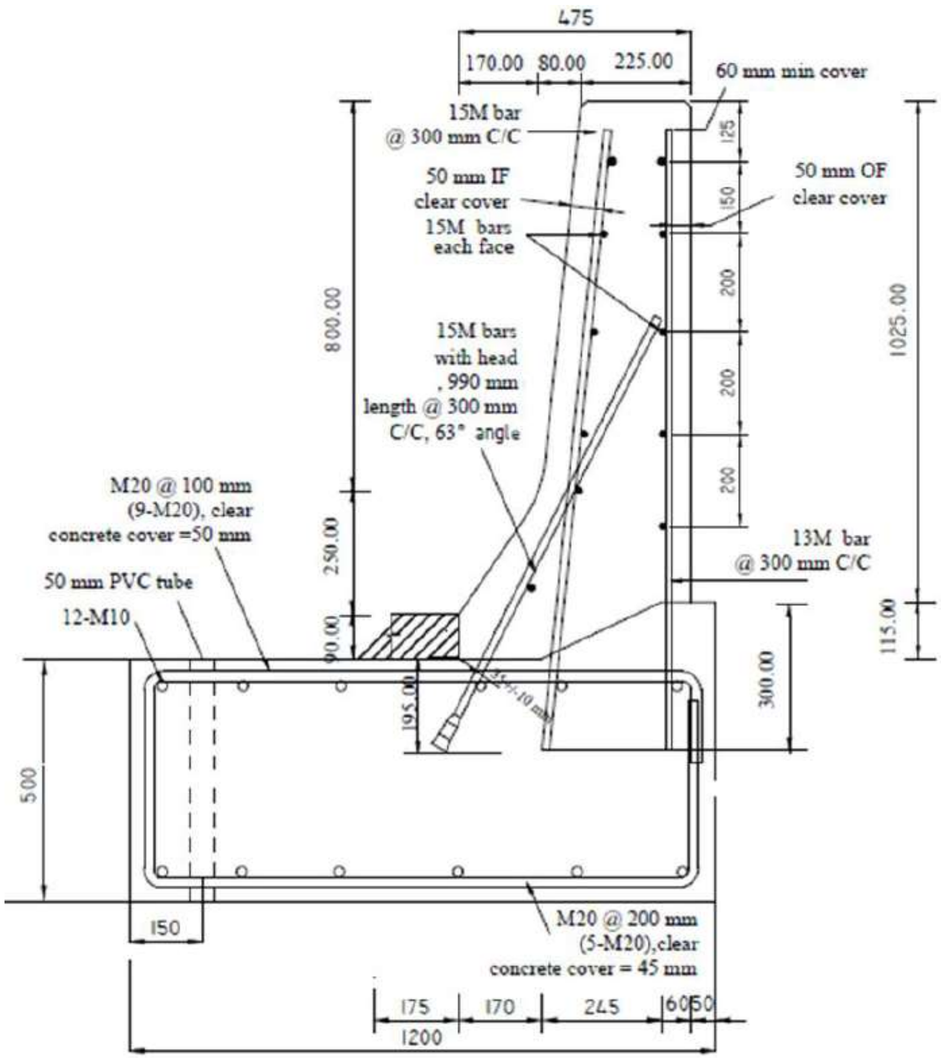


Figure 4.1: Barrier specimen B-1 details (Interior Location - No Cantilever)

B-1

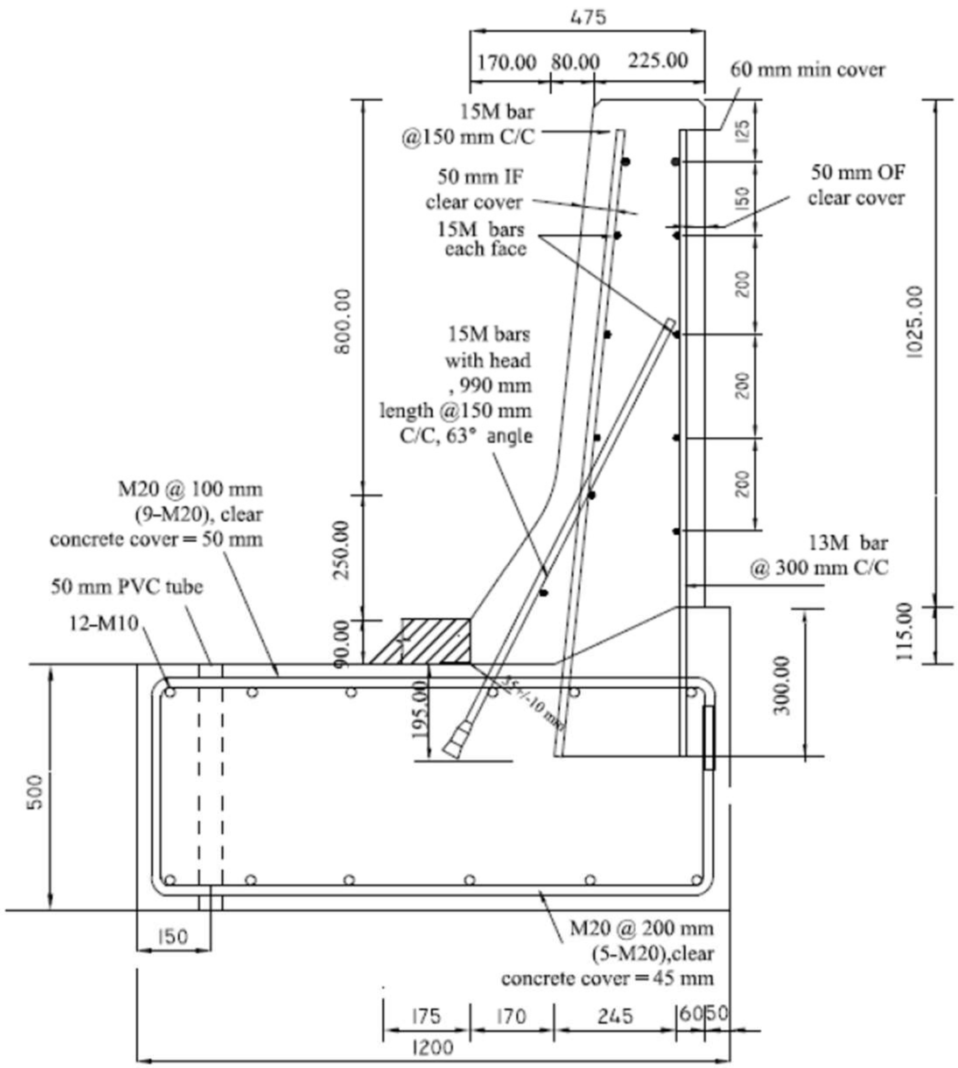


Figure 4.2: Barrier specimen B-2 details (Exterior Location - No Cantilever)

B-2

NSERC CRSNG
MIAMI
FDOT

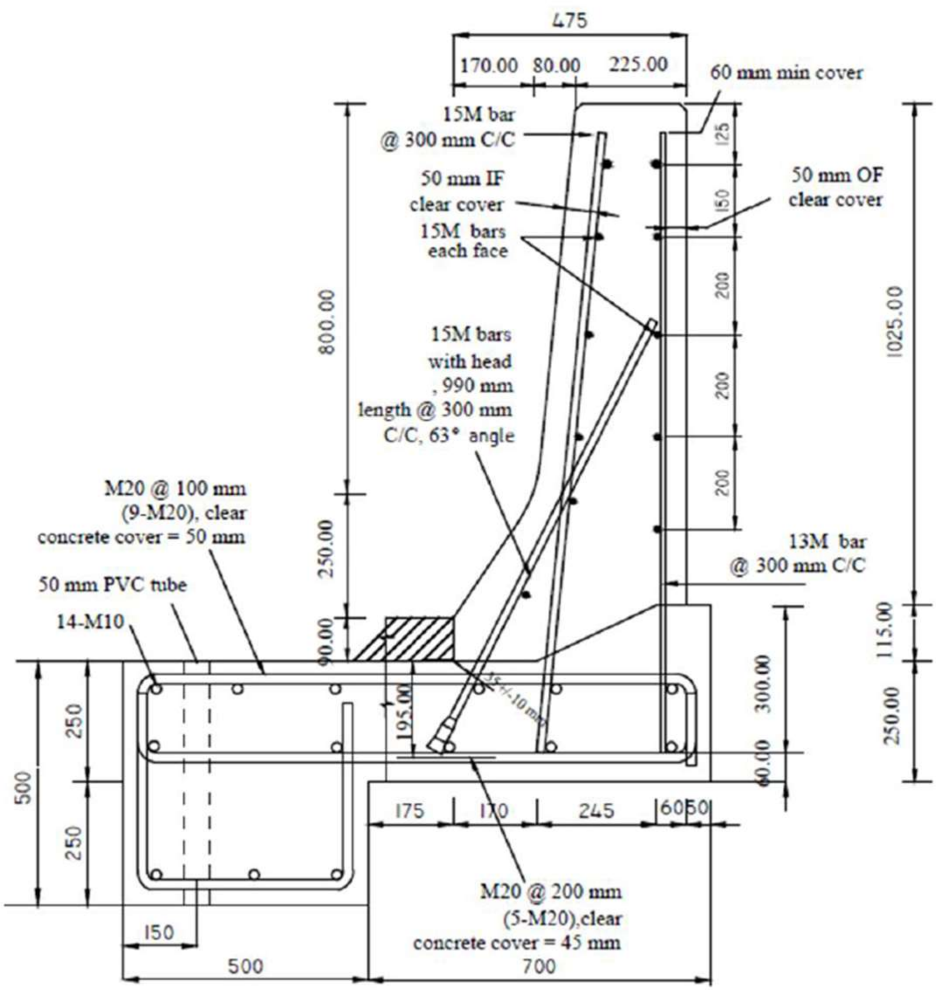


Figure 4.3: Barrier specimen B-3 details (Interior Location - With Cantilever)

B-3

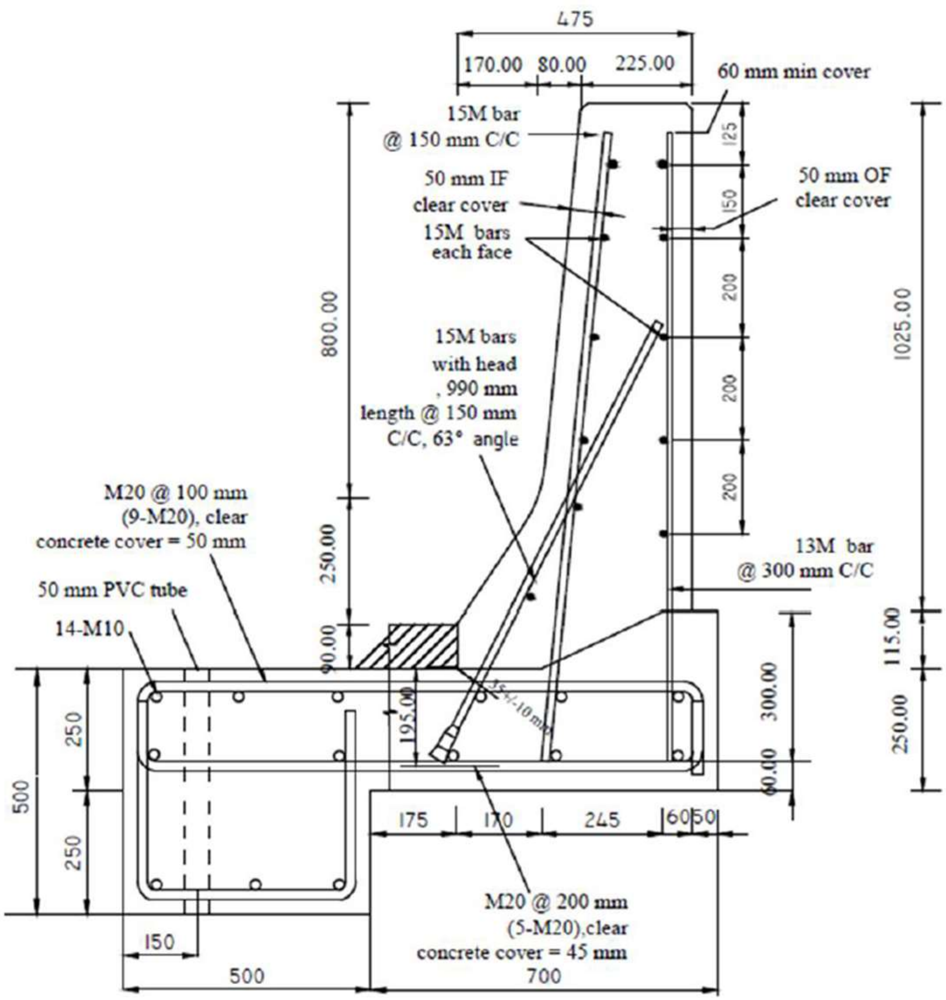


Figure 4.4: Barrier specimen B-4 details (Exterior Location - With Cantilever)

B-4

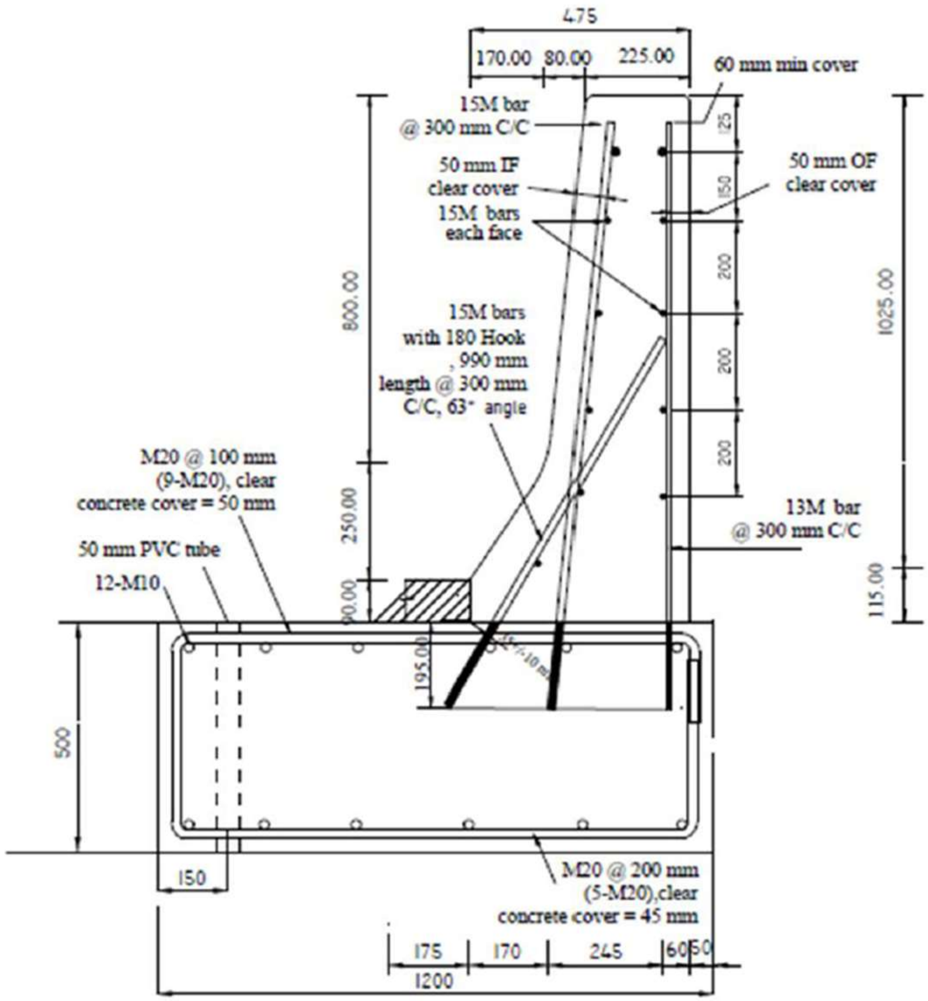


Figure 4.5: Barrier specimen B-5 details (Interior Location - No Cantilever - Post-Installed)

B-5

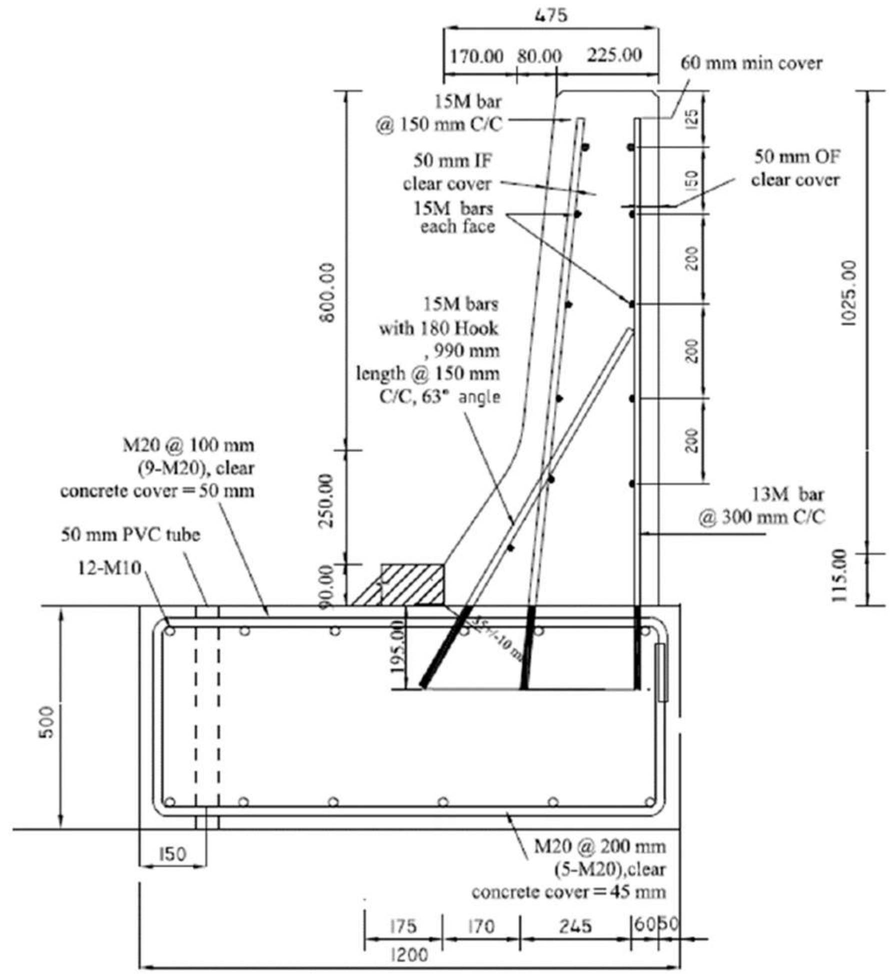


Figure 4.6: Barrier specimen B-6 details (Exterior Location - No Cantilever - Post-Installed)

B-6

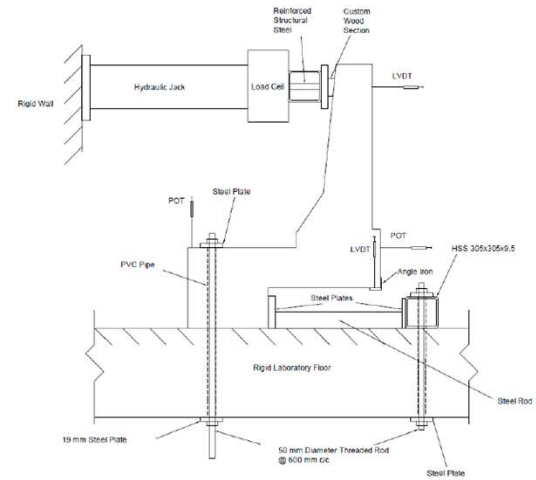
Figure 4.14: Typical GFRP wall mesh at exterior location

e) Barrier with rigid base f) Barrier with deck cantilever g) Barrier handling

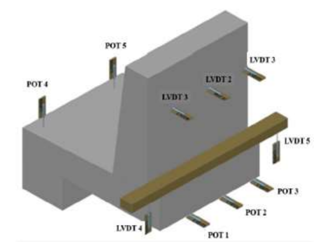
Figure 4.15: Views of typical barriers after removal of formwork and while transporting it to the test rig

Table 4.6: Barrier Labeling Legend

Name	Description
B-1	No cantilever; Interior location (300 mm spacing of front bars)
B-2	No cantilever; Exterior location (150 mm spacing of front bars)
B-3	Cantilever; Interior location (300 mm spacing of front bars)
B-4	Cantilever; Exterior location (150 mm spacing of front bars)
B-5	Post-Installed; No cantilever; Interior location (~~300~~ 150 mm spacing of front bars)
B-6	Post-Installed; No cantilever; Exterior location (300 mm spacing of front bars)



(a) Test setup showing the tie-down system to stabilize the deck slab during testing



(b) Locations of potentiometers (POTs) to measure displacements

Table 4.14: Experimental results benchmarked against CHBDC requirements and safety factors

Criteria	Specimen					
	Fixed base - interior	Fixed base - exterior	Cantilever - interior	Cantilever - exterior	Post-installed -interior	Post-installed - exterior
	B-1	B-2	B-3	B-4	B-5	B-6
Experimental failure load (kN)	168.63	182.63	129.64	163.41	159.74	186.74
Experimental failure load (kN/m)	187.37	202.92	144.04	181.57	177.49	207.49
Experimental resisting moment (kN.m/m)	185.49	200.89	142.60	179.75	175.71	205.41
2006 CHBDC design moment (kN.m/m)	83.00	102.00	83.00	102.00	83.00	102.00
Factor of safety (experimental failure moment/ CHBDC design moment)	2.23	1.97	1.72	1.76	2.12	2.01
Factor of safety (experimental failure moment/ CHBDC design moment) with 0.75 durability factor	1.68	1.48	1.29	1.32	1.59	1.51
Top front displacement (mm)	26.32	23.74	44.75	66.76	8.92	11.28
Bottom back displacement (mm)	3.81	4.27	8.43	13.42	0.73	3.46
Overhang (mm)	-	-	17.57	27.88	-	-
Front uplift (mm)	0.39	1.62	3.66	5.30	0.97	0.96
GFRP micro strain	6503.93	3914.80	7198.86	5494.50	16268.69	7225.97
Concrete micro strain	-818.33	-868.00	-784.67	-1735.00	-893.33	-701.33
Observed failure mechanism	GFRP-concrete anchorage	Diagonal shear in the wall	GFRP-concrete anchorage	GFRP-concrete anchorage	Concrete breakout	Diagonal shear in the wall

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FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Experience of Mechanical Splices for GFRP Rebars

Dextra

Pierre Hofmann

Dextra Group

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ALTAIR

MST BAR MAXIMUM STRENGTH GFRP

SFTec

ACMA American Composites Manufacturers Association FRP Rebar Manufacturers Council

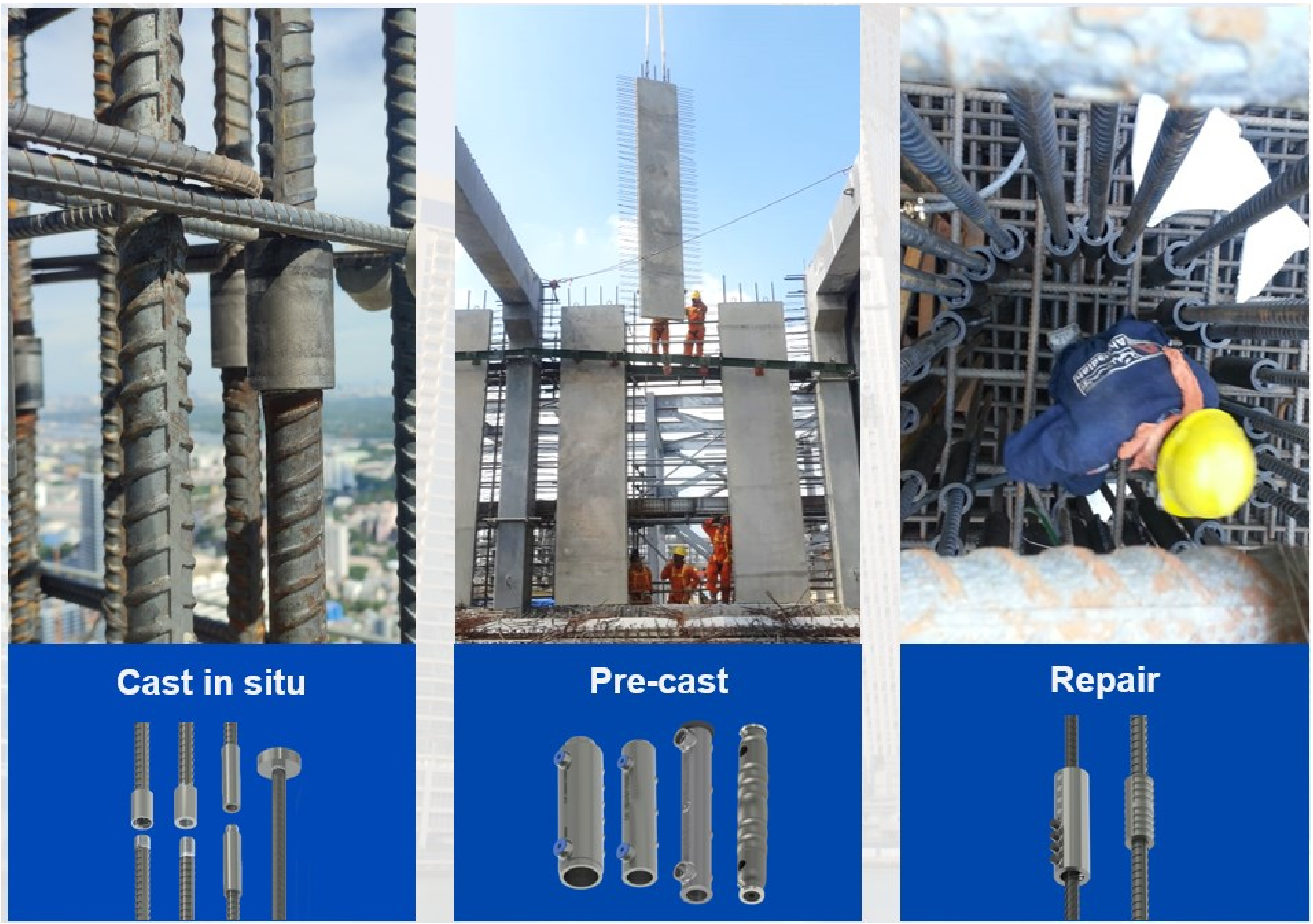
UNIVERSITÉ DE SHERBROOKE

NSERC CRSNG

UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

FDOT

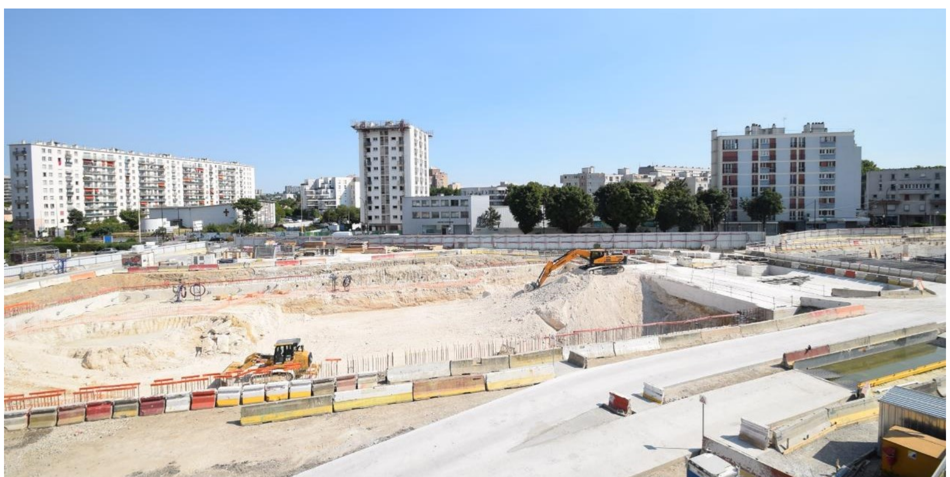


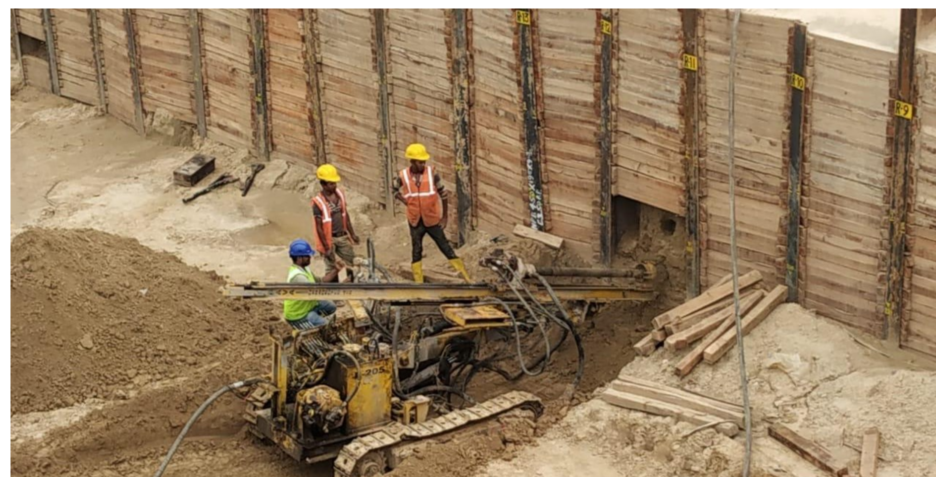
55 Countries

45 Technicians

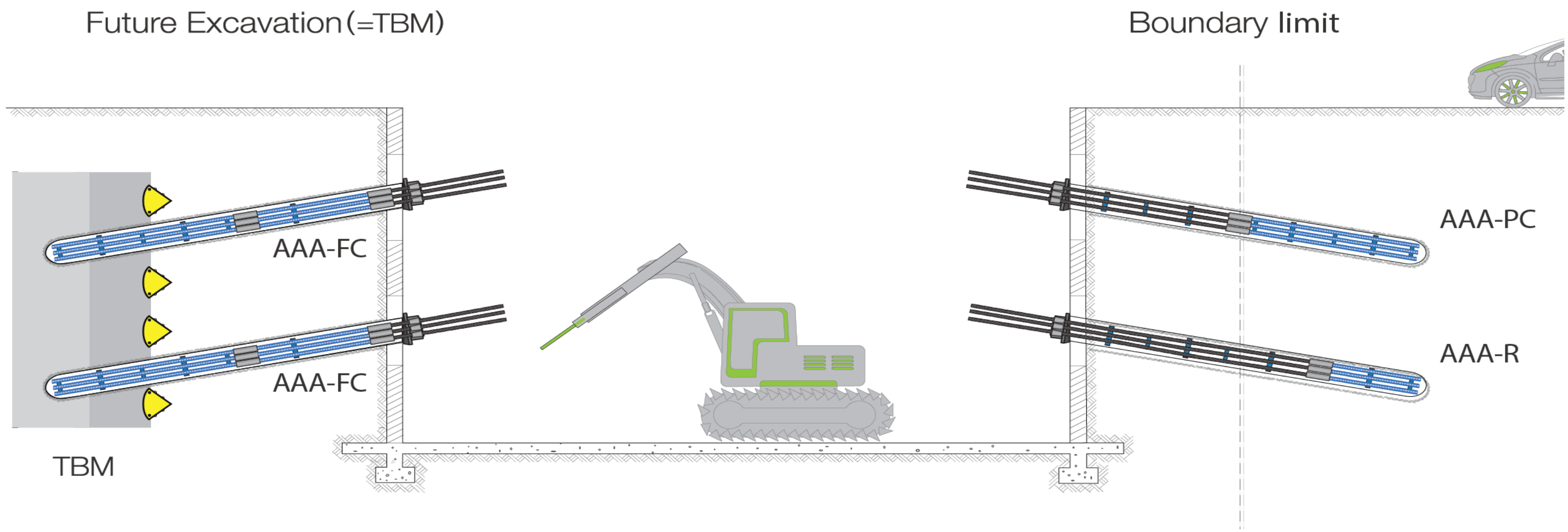
500+ Equipment Sets

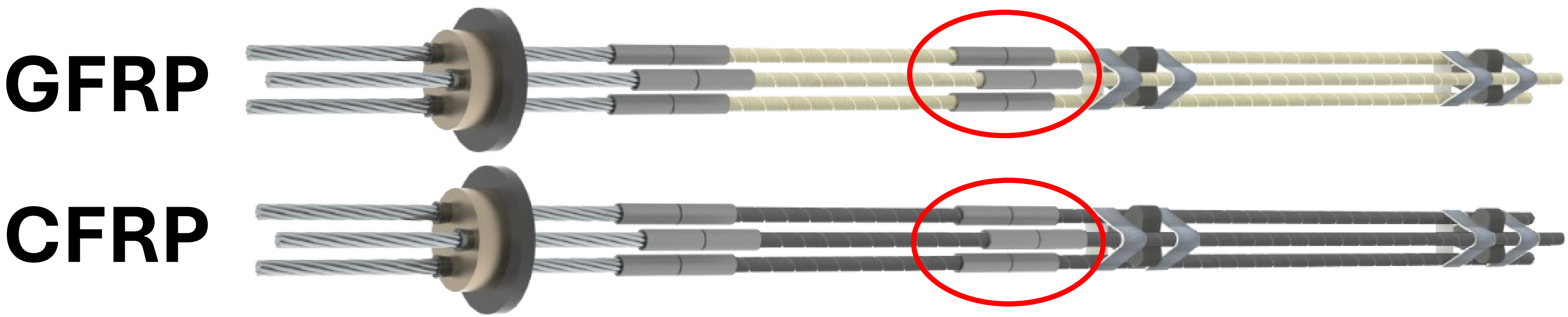
Experience since 2008 = Active Ground Anchor (FRP)





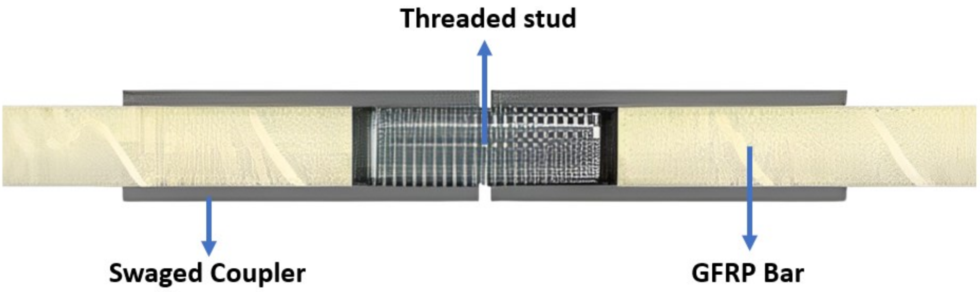
Experience since 2008 = Active Ground Anchor (FRP)





GFRP Bar Splicing System

- The GFRP bar splicing system is a designed solution for the connection of 2 high performance GFRP bars.
- The Dextra couplers are extrusion-swaged onto the GFRP rebar in the factory. The coupler-rebar systems are then installed on-site by threading them together.



GFRP Bar Splicing System

This splicing system can be adjusted to the geometry and finition of the GFRP rebars, such as sand coated, machined threaded and helicoidal rope

Coupler and GFRP rebar before swaging

Coupler and GFRP rebar after swaging

GFRP Bar Splicing System Swaging

The coupler and GFRP rebar is swaged by the automatic swaging machine.

GFRP Bar Splicing System

As displayed by the drawings below, they are various combinations of coupler, bolt and GFRP bar.

GFRP Bar with 1 Swaged Coupler

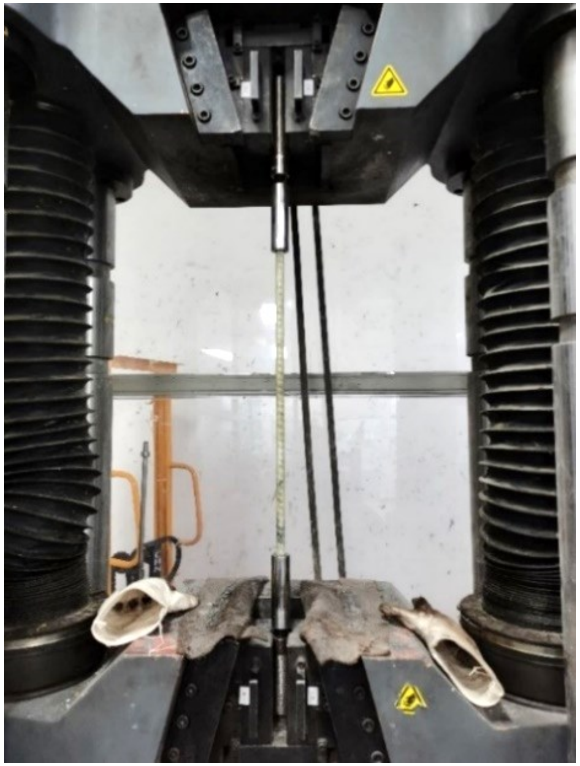
GFRP Bar with 1 Swaged Coupler + 1 Threaded Stud

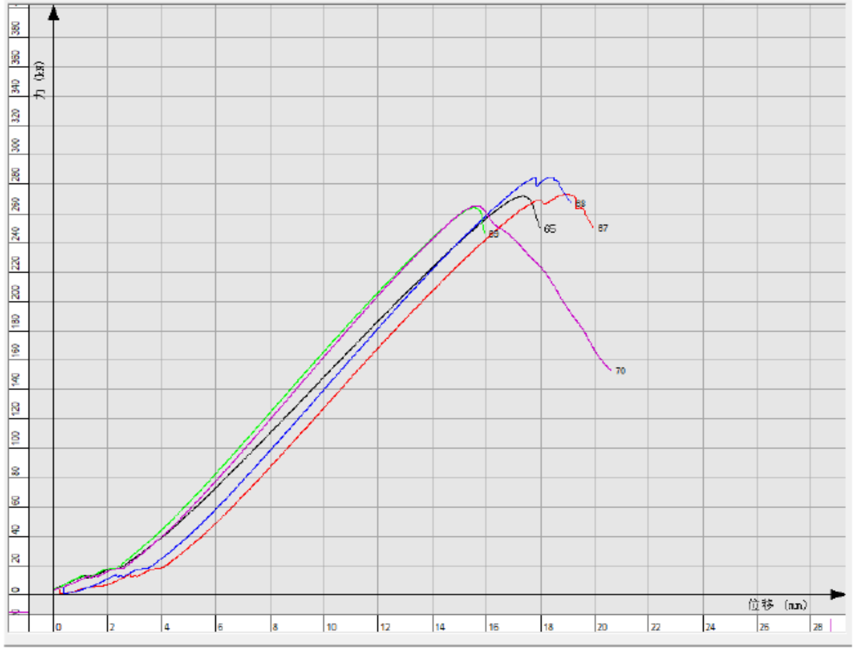
GFRP Bar with 2 Swaged Coupler

GFRP Bar with 2 Swaged Coupler + 1 Threaded Stud

Tensile Tests for the Splicing system

Tensile test for the splicing system as per ASTM D7205M-21.





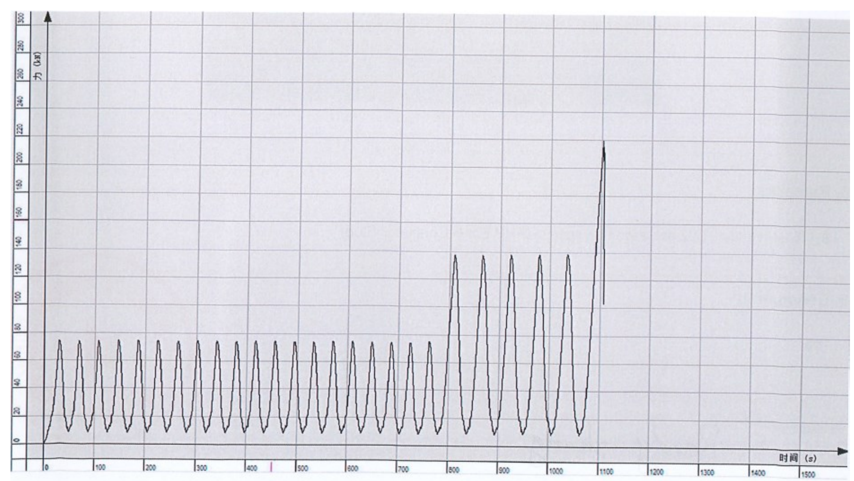
Technical Data Sheet

Dia (mm)	Nominal Dia. (mm)	Ultimate Tensile Strength		
		A - GFRP Bar min. (kN)	B - Coupler min. (kN)	B/A - Retention min. (%)
#4 (13mm)	12.7	135	125	≥90
#5 (16mm)	15.9	186	149	≥80
#6 (19mm)	19.1	300	250	≥80
#8 (25mm)	25.4	428	343	≥80

Cycle Tensile Tests for the Splicing system

Cycle tensile test for the splicing system, $0.4f_{fu}$ for 20 cycles, $0.8f_{fu}$ for 5 cycles.

Stage	Upper Tension	Lower Tension	Cycles
1	$0.40\ f_{fu}$	$0.05\ f_{fu}$	20
2	$0.80\ f_{fu}$	$0.05\ f_{fu}$	5
3	Load in tension to failure, record the failure load and location		



Cycle Tensile Test result for the Splicing system

Cycle tensile test for the splicing system, $0.4f_{fu}$ for 20 cycles, $0.8f_{fu}$ for 5 cycles then load in tension to failure.

Dia (mm)	$0.40\ f_{fu}$ 20 cycles	$0.80\ f_{fu}$ 20 cycles	Failure load (kN)	Failure mode
#4 (13mm) Sand Coated	Passed	Passed	144.8	Bar Break
#5 (16mm) Machine thread	Passed	Passed	143.7	Bar Slip
#6 (19mm) Sand Coated	Passed	Passed	301.2	Bar Break

Possibility to delivery in coil up to OD=13mm

Could be used in pre-stressed / precast concrete girders, in replacement of CFRP tendons ?

Corrosion Mitigation

Options considered:

- Carbon steel sleeves + Stainless steel stud
- Stainless steel sleeves & stud
- Cold-spray galvanization
- Heat shrink sleeve

Dextra

Pierre Hofmann
GM - FRP & Geotec

reliable connections

Questions ?

Don't hesitate to contact us

Dextra

Boris Caro Vargas

GM – North America

reliable connections

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

How to identify a quality GFRP bar for your project

Wenxue Chen Ph.D

President & CEO of SFTec Inc.

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ACMA
AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION
FRP Rebar Manufacturers Council
UNIVERSITÉ DE SHERBROOKE
NSERC CRSNG
UNIVERSITY OF MIAMI
Center for Integration of Composites into Infrastructure
FDOT

Introduction

- **FRP Rebar**

Fibre

- GFRP
- BFRP
- CFRP
- AFRP

+

Resin

- Vinyl
- Epoxy
- Polyester

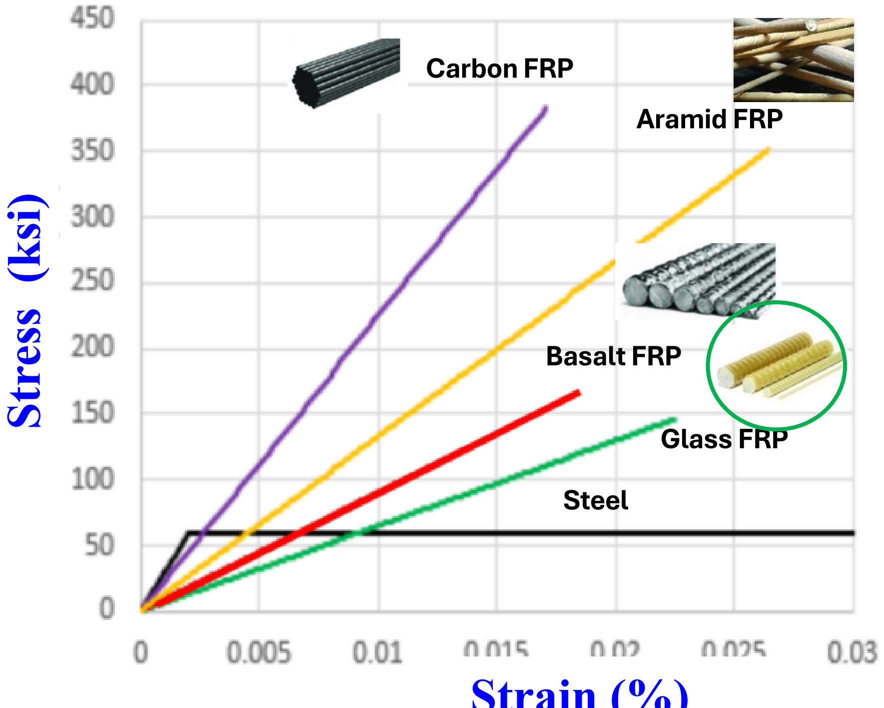
=

- GFRP Rebar
- BFRP Rebar
- CFRP Rebar
- AFRP Rebar

Introduction

- **Types of FRP Materials**

  - **Glass fiber-reinforced polymer (GFRP)**
  - **Carbon fiber-reinforced polymer (CFRP)**
  - **Basalt fiber-reinforced polymer (BFRP)**
  - **Aramid fiber-reinforced polymer (AFRP)**



Typical stress strain for steel and FRP Rebars

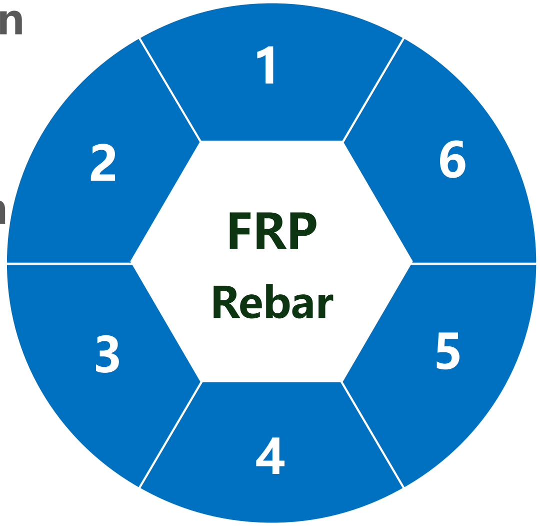
Introduction

- **GFRP Rebar**

Resistant to corrosion
100 years lift span

High tensile strength
Double to steel

Low Co2 emissions
45% comparing with steel



Insulation / heat insulation / electromagnetic wave transmission

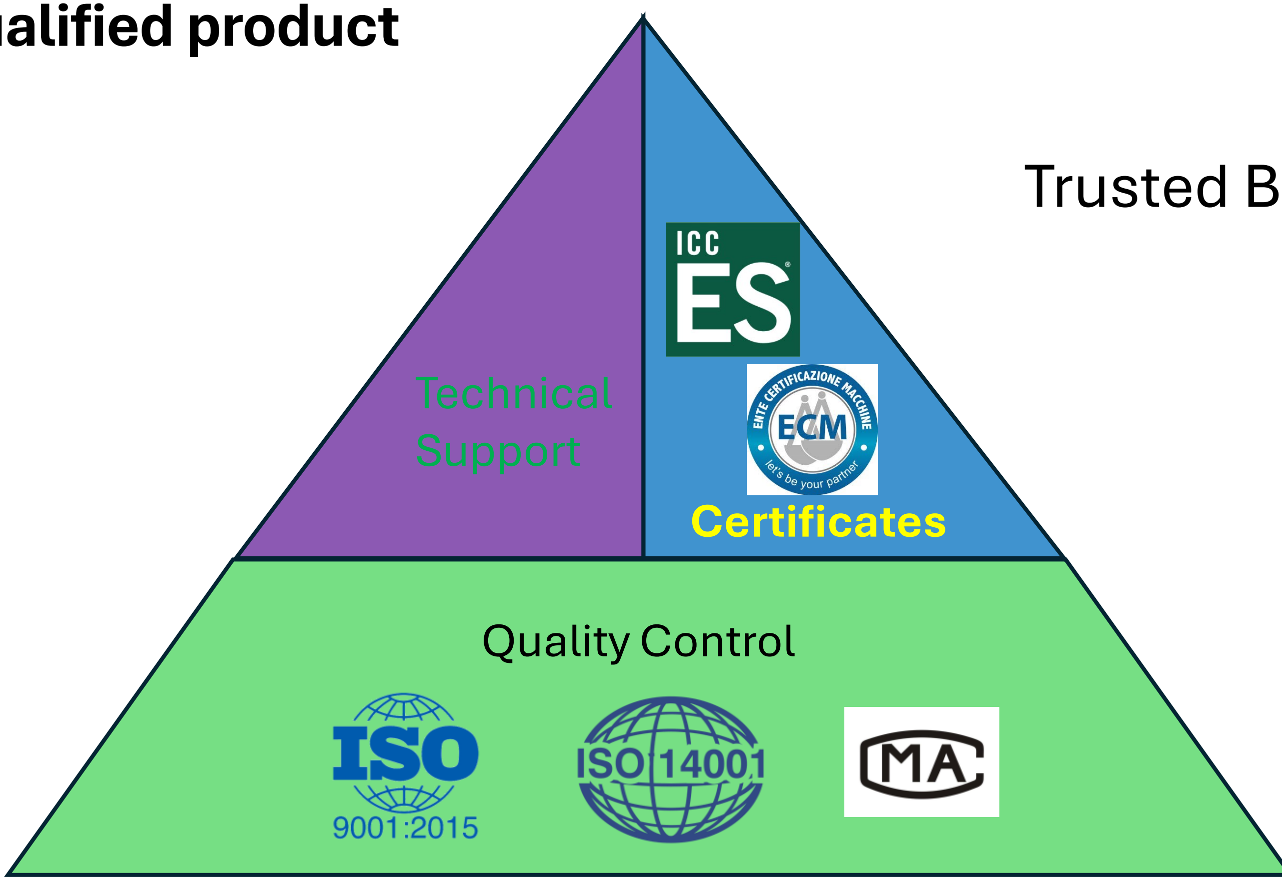
Lighter Weight
¼ comparing with steel

Economic
Initial or/and whole life service span cost

Identify a quality GFRP Rebar

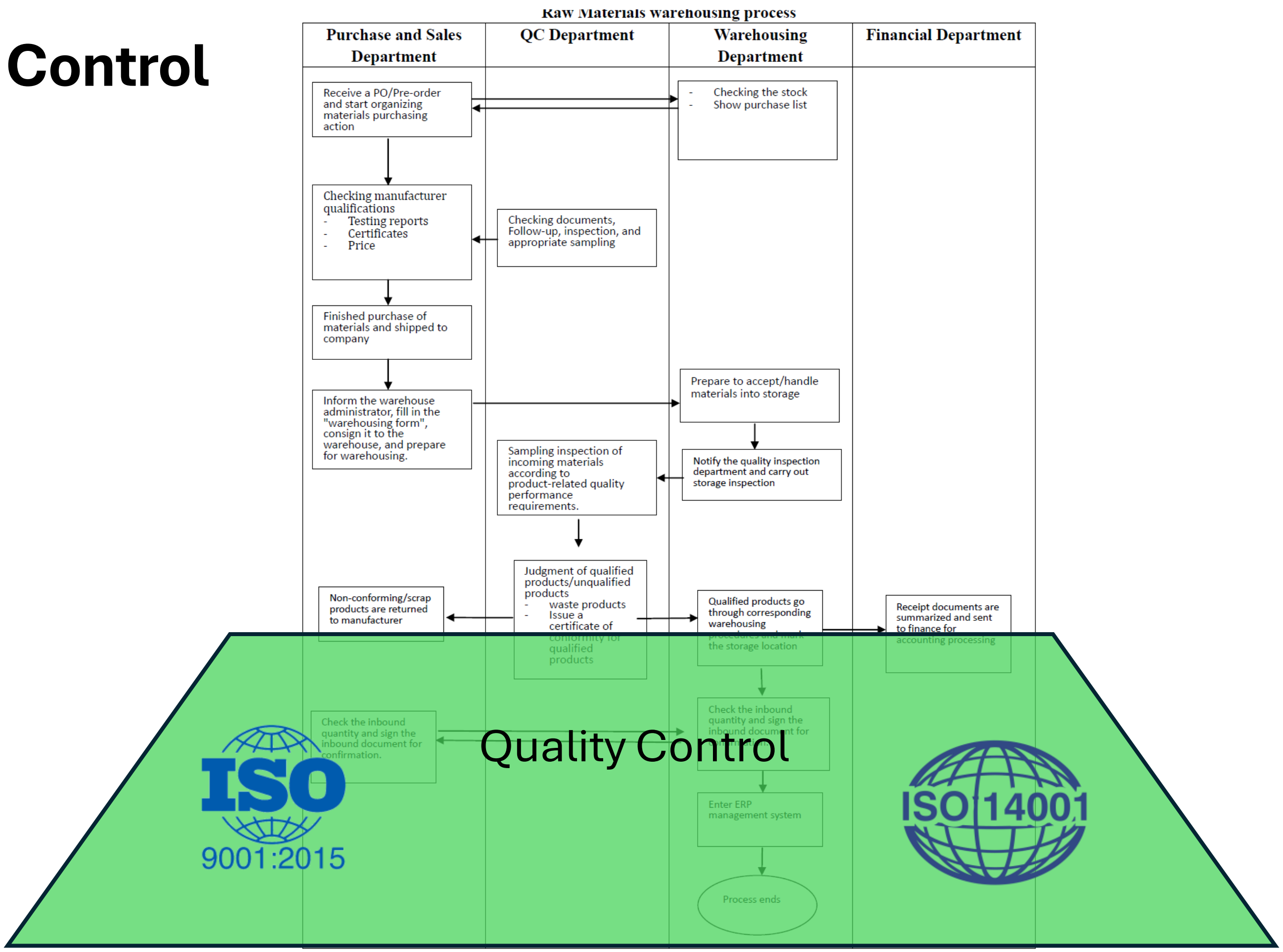
- **Qualified product**

Trusted Brand



Identify a quality GFRP Rebar

- **Quality Control**



Identify a quality GFRP Rebar

- **Certification**

Certificates

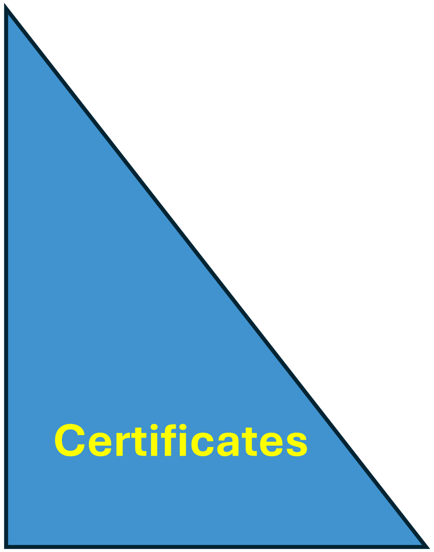
- ICC, ECM, ISO etc.

Compliance to specifications (DSM List)

- CSA, ASTM

MTO, MTQ, FODT, MDOT, NCDOT and so on

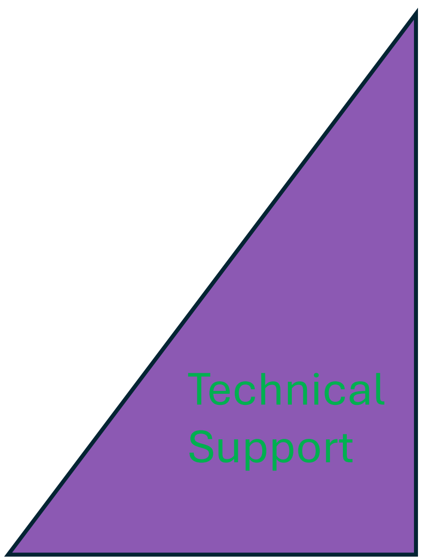
IF all DOTs share the same reorganization process in the future for DSM list?



ICC-ES®_ESR-5081

Identify a quality GFRP Rebar

- **Technical Support**



ICC-ES®_EER-5081

Engineering Design Support
- Training Engineer
- New design or Translating steel design to GFRP design

Equivalency Evaluation Report
- Single family house/duplexes house

Research & Development
- New products of GFRP rebar
- New applications

Identify a quality GFRP Rebar

- **Qualified GFRP rebar**

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Scope and Uses

- **Compliance with:**
  - **2021 and 2018 International Building code® (IBC)**
  - **2021 and 2018 International Residential Code ® (IRC)**
- **SFT-Bar® used as:**
  - **Tension reinforcement (beams, slabs, foundations)**
  - **Vertical reinforcement (columns and walls)**

ICC EVALUATION SERVICE®

ICC-ES Evaluation Report

ESR-5081

Reissued January 2024

This report also contains:
- CBC

Subject to renewal January 2025

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DIVISION: 03 00 00—CONCRETE Section: 03 20 00—Concrete Reinforcing Section: 03 21 00—Reinforcement Bars	REPORT HOLDER: SFTec, INC.	EVALUATION SUBJECT: SFT-BAR®	

1.0 EVALUATION SCOPE

Compliance with the following codes:
- 2021 and 2018 *International Building Code® (IBC)*
- 2021 and 2018 *International Residential Code® (IRC)*

Properties evaluated:
- Physical
- Structural
- Durability

2.0 USES

The SFT-Bar® is used as tension reinforcement in flexural concrete members such as beams, shallow foundations, and one-way or two-way elevated slabs, and as vertical reinforcement in concrete columns and walls in normal-weight concrete, as permitted by Section 104.11 of the IBC. The SFT-Bar® may also be used where an engineering design is submitted in accordance with IRC Section R301.1.3 and where approved by the building official in accordance with IRC Section R104.11.

3.0 DESCRIPTION

The SFT-Bar® is a fiber-reinforced polymer (FRP) bar that is solid and has a circular cross section composed of glass fibers embedded in a resin matrix. Available bar size and properties are provided in Table 1 of this report.

4.0 DESIGN AND INSTALLATION

4.1 Design:

The SFT-Bar® must be designed in accordance with ACI CODE 440.11-22 and Chapter 19 of the IBC, as applicable. The registered design professional must be responsible for determining, through analysis, the strengths and demands of the structural elements, subject to the approval of the building official.

The following limitations also apply:

1. The SFT-Bar® is limited for use as (a) tension reinforcement in flexural concrete members; (b) vertical reinforcement in concrete columns and walls.
2. The SFT-Bar® is limited to concrete members in normal-weight concrete.

Page 1 of 4

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

ICC ES AC454- Acceptance Criteria

- **FRP Bars for internal reinforcement of concrete structures**
- **FRP bar qualification requirements:**
  - **Physical,**
  - **Mechanical, and**
  - **Durability properties**

RECORD　　Page 6 of 19
Document Number: R-4.4_01-27-22_SFT
Qualification Test Plan

Table 1.2 – Summary of standard test methods for the qualification test program

AC 454 Specification Section	Test Description	Test Method Report ID	ASTM Standard Test Reference
1.3.16	Standard Specification	n/a	ASTM D7957/D7957M-17, Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement.
4.1.1	Fiber mass content	FC	ASTM D2584-18 Standard Test Method for Ignition Loss of Cured Reinforced Resins.
4.1.2	Glass transition temperature	TG	ASTM E1356-08 (2014), Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning calorimetry. ASTM E1640-18, Standard Test Method for Assignment of the Glass Transition Temperatures by Dynamic Mechanical Analysis.
4.1.3	Total enthalpy of polymerization	DC	ASTM E2160-04 (reapproved 2018), Standard Test Method for Heat of Reaction of Thermally Reactive Materials by Differential Scanning Calorimetry.
4.1.5	Measured cross-sectional area	MXA	ASTM D7205/D7205M-06 (2016), Standard test method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars. ASTM D792-13, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
4.2.1 4.2.2 4.2.4	Tensile properties	TNS	ASTM D7205/D7205M-06 (2011), Standard test method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars.
4.2.3	Transverse shear strength	TSS	ASTM D7617/D7617M-11 (2017), Standard Test Method for Transverse Shear Strength of Fiber–Reinforced Polymer Matrix Composite Bars.
4.4.4	Horizontal shear strength	HSS	ASTM D4475-02(2008) Standard Test Method for Apparent Horizontal Shear Strength of Pultruded Reinforced Plastic Rods By the Short-Beam Method.
4.2.5	Bond strength	BS	ASTM D7913/D7913M – 14, Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing. ASTM C39-20, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
4.3.2	Alkaline resistance	AR	ASTM D7705/D7705M-12 (2019), Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction, Procedure A
4.3.1	Moisture absorption	MA	ASTM D570-98(2010)e1, Section 7.4 Standard Test Method for Water Absorption of Plastics.

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

SFT-Bar® FRP Bar Characterization

Physical	Mechanical	Durability
Cross-sectional area	Tensile properties	Resistance to alkaline environment
Fiber mass content	Transverse shear strength	
Moisture absorption	Bond strength	
Glass transition temperature		

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

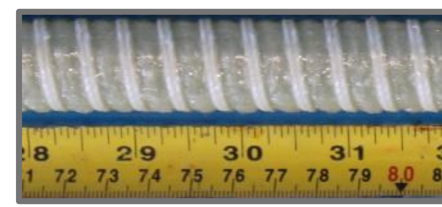
SFT-Bar® Glass FRP Bar

- **Fiber type:** fiberglass
- **Resin matrix:** Vinyl Ester
- **Helical wrapped GFRP bar**

#3 (9.5 mm)

#4 (12.7 mm)

#5 (15.9 mm)



#6 (19.1 mm)

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Physical Properties: Measured Cross-Section Area

- Test Method: **ASTM D7205 and ASTM D792**
- Instrumentation: **Cylinder, water, and weighed with an analytical balance**
- Test specimen: **eight samples from each production lot**
- Test procedure: **Each specimen was weighed and measured. Then, placed in cylinder filled with water and weighed. Finally, cylinder was filled with water and weighed.**
- **Calculations:**

$$D = 0.998\left[M_s / \left(M_s + M_w - M_{sw}\right)\right]$$

$$S_s = \frac{\left(M_s / D\right)}{L}$$

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Physical Properties: Fiber Mass Content

- Test Method: **ASTM D2584-18**
- Instrumentation: **Muffle furnace (600 Celsius), desiccator, and weighed with an analytical balance**
- Test specimen: **five samples from each production lot**
- Test procedure: **Heat specimen at 565 Celsius until carbonaceous material disappear. Remaining residue was cool in a desiccator and weighed.**
- **Calculations:**

$$W_r = \frac{W_1 - W_2}{W_2} \cdot 100$$

Muffle furnace

Desiccator

Balance

GFRP bar before heating

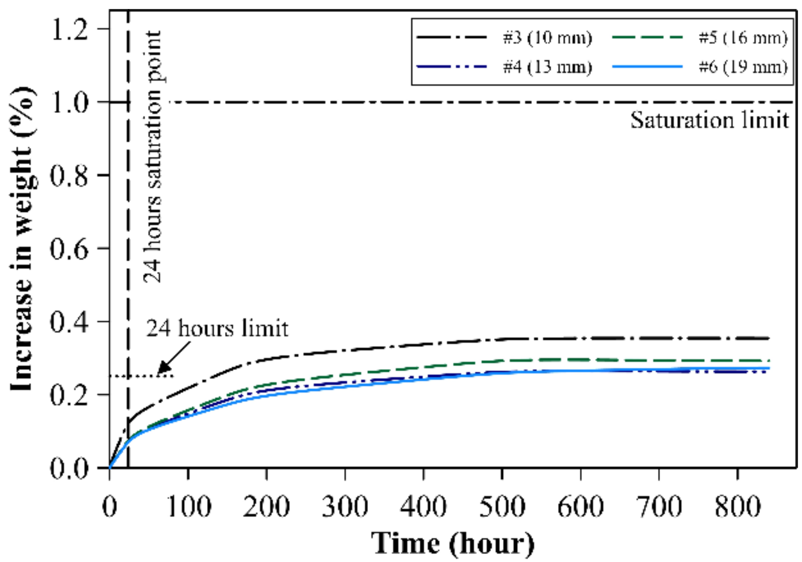
GFRP bar architecture after heating

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Physical Properties: Fiber Mass Content

- Test Method: **ASTM D570-98 (2010), 7.4**



$$\textit{Increase in weight, \%} = \frac{\textit{wet weight-conditioned weight}}{\textit{conditioned weight}} \cdot 100$$

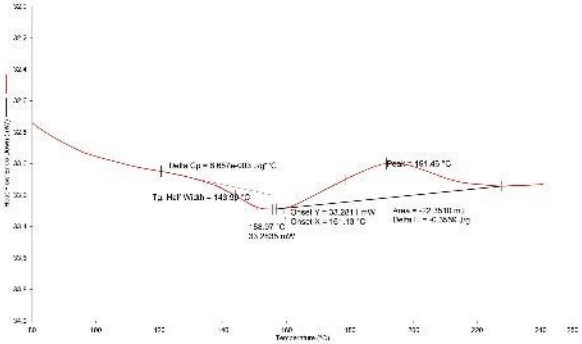
Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Physical Properties: Glass Transition Temperature (Tg)

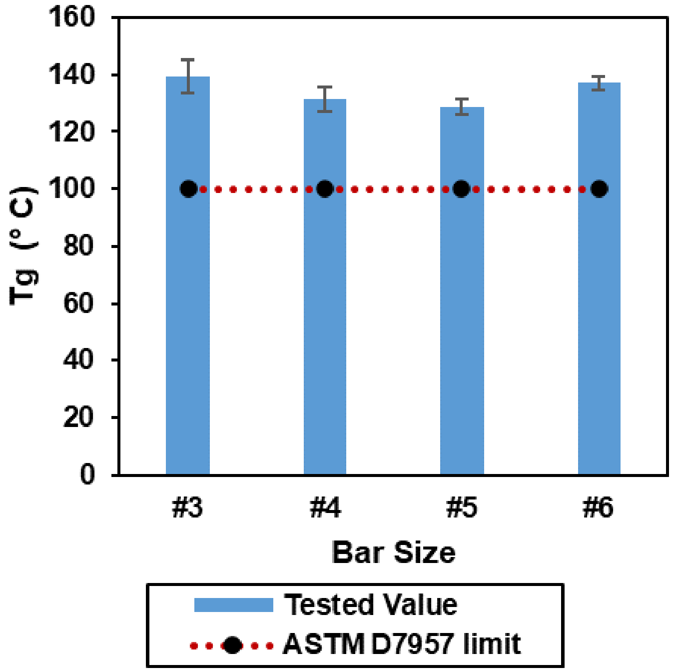
DSC

Test specimen



Determination of glass transition temperature

- Test Method: **ASTM E1356-08 (2014)**

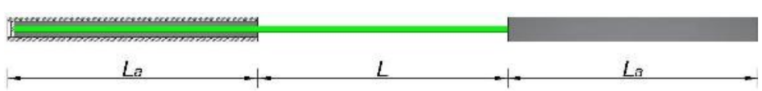


Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Mechanical Properties: Longitudinal Tensile Properties

- Test Method: **ASTM D7205**



Bar designation		Tensile load, F_u (kN)	Modulus of elasticity, E (GPa)	Tensile strain, ε_f (%)	Guaranteed tensile load [ASTM D7957/D7957M] (kN)	Mean modulus of elasticity [ASTM D7957/D7957M] (GPa)	Mean ultimate tensile strain [ASTM D7957/D7957M] (%)
#3 (9.5 mm)*	Ultimate Mean	86	75	1.6	59	≥ 44.8	≥ 1.1
	Guaranteed	71					
#4 (12.7 mm)	Ultimate Mean	149	72	1.6	96		
	Guaranteed	124					
#5 (15.9 mm)	Ultimate Mean	185	60	1.5	130		
	Guaranteed	155					
#6 (19.1 mm)	Ultimate Mean	280	66	1.5	182		
	Guaranteed	237					

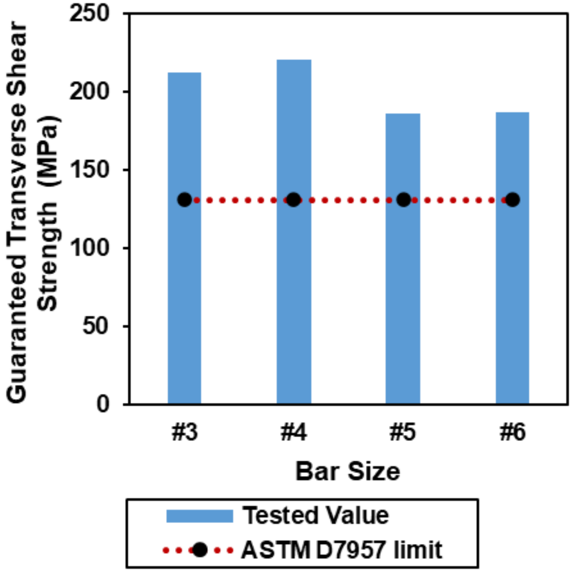
Value in the parentheses are nominal diameters of the GFRP bars.

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Mechanical Properties: Transverse Shear Strength

- Test Method: **ASTM D7617-11 (2017)**



$$\tau = \frac{P}{2A}$$

Transverse shear test setup

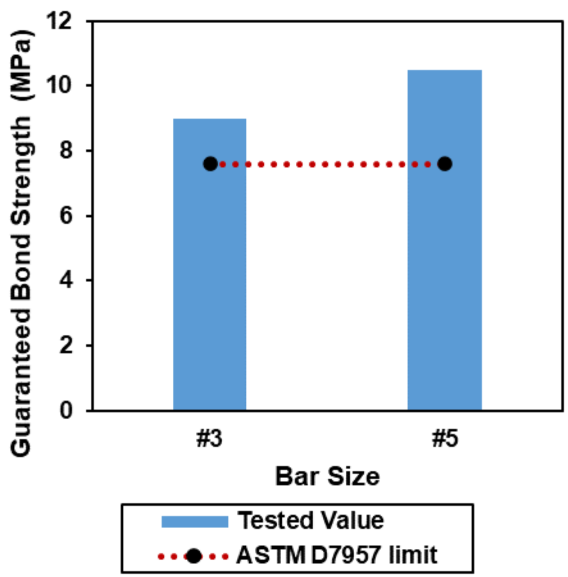
Typical shear failure

Identify a quality GFRP Rebar

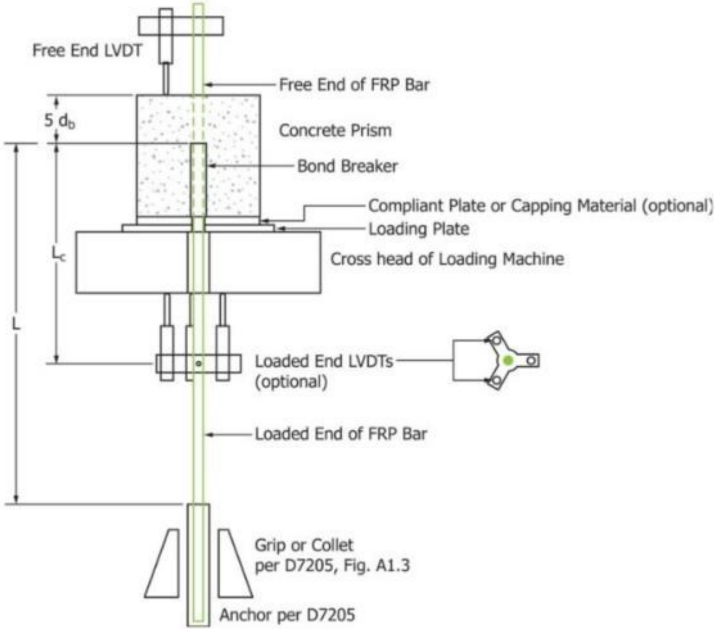
- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Mechanical Properties: Pull-Out Test

- Test Method: **ASTM D7913-14**



$$u = \frac{F_u}{\pi \times d_b \times l_b}$$



Pull-out test specimen (ASTM D7913)

Identify a quality GFRP Rebar

- **SFT-Bar® Certification (ICC-ES®_ESR-5081)**

Durability Property: Alkaline Resistance

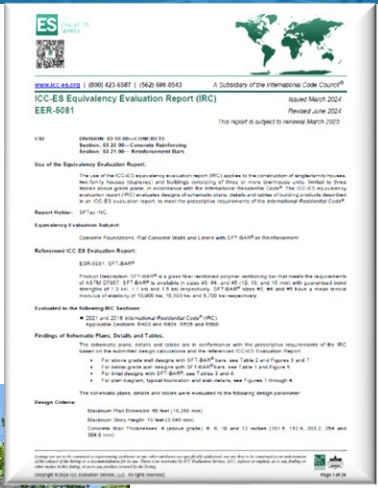
- Test Method: **ASTM D7705, Procedure A**

Bar designation	Mean Tensile load, F_u (kN)	Mean Modulus of elasticity, E (GPa)	Mean Tensile strain, ε_f (%)	Tensile Capacity Retention (%)	Mean Alkaline Resistance [ASTM D7957/D7957M] (%)
#3 (9.5 mm)*	73	74	1.4	84	≥ 80
#5 (15.9 mm)	161	58	1.4	87	

3 Months Alkaline Solution exposure

Specimen preparation

Identify a quality GFRP Rebar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ICC-ES Equivalency Evaluation Report (IRC)
EER-5081

Issued March 2024
Revised June 2024
This report is subject to renewal March 2025

CSI: DIVISION: 03 00 00—CONCRETE
Section: 03 20 00—Concrete Reinforcing
Section: 03 21 00—Reinforcement Bars

Use of the Equivalency Evaluation Report:

The use of the ICC-ES equivalency evaluation report (IRC) applies to the construction of single-family houses, two-family houses (duplexes) and buildings consisting of three or more townhouse units, limited to three stories above grade plane, in accordance with the International Residential Code®. The ICC-ES equivalency evaluation report (IRC) evaluates designs of schematic plans, details and tables of building products described in an ICC-ES evaluation report, to meet the prescriptive requirements of the International Residential Code®.

Report Holder: SFTec INC.

Equivalency Evaluation Subject:

Concrete Foundations, Flat Concrete Walls and Lintels with SFT-BAR® as Reinforcement

Referenced ICC-ES Evaluation Report:

ESR-5081: SFT-BAR®

Evaluated to the following IRC Sections:

- 2021 and 2018 International Residential Code® (IRC)

Findings of Schematic Plans, Details and Tables:

Design Criteria:

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Page 1 of 24

- ICC-ES Equivalency Evaluation Report (IRC)

- ICC-ES® EER-5081
- Using of IRC Report

✓ Applies to the construction of single-family houses.

✓ Applies to the construction of duplexes houses.

✓ Construct buildings of three or more townhouse units, limited to three stories above grade plane.

Identify a quality GFRP Rebar

- **ICC-ES Equivalency Evaluation Report (IRC)**

- **Evaluation of Elements Reinforced with SFT-Bar® GFRP bars.**

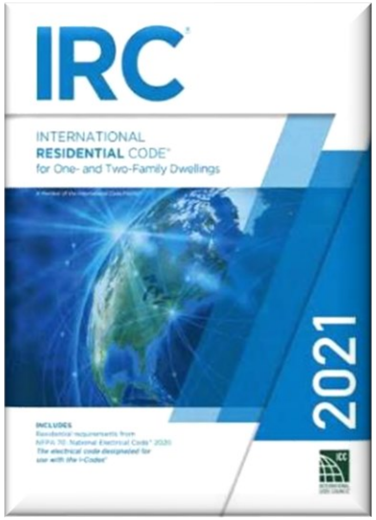
  - ✓ **Concrete foundations**
  - ✓ **Flat concrete walls**
  - ✓ **Lintels**

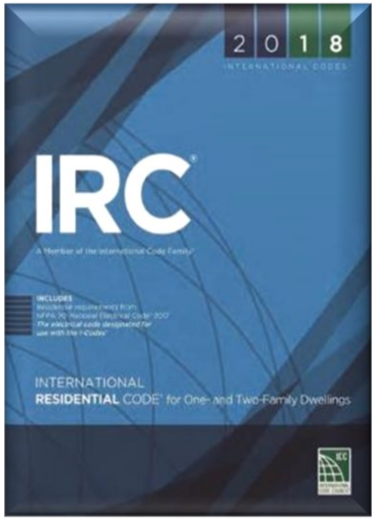
Identify a quality GFRP Rebar

- **ICC-ES Equivalency Evaluation Report (IRC)**
- **What sizes of SFT-Bar® GFRP bars are used in ICC-ES®_EER-5081 applications?**

✓ #3 (10 mm)
✓ #4 (13 mm)
✓ #5 (16 mm)

- **IRC Sections**





All bar sizes characterized based on AC454 acceptance criteria of ICC

Properties of SFT-Bar® are presented in ICC-ES®_ESR-5081

Sections: R403 and R404, R506 and R608

Identify a quality GFRP Rebar

- ICC-ES Equivalency Evaluation Report (IRC)

- **Using Conditions**

✓ The ICC-ES equivalency evaluation report (IRC) addresses only conformance with the noted IRC sections

✓ This report applies only to the design parameters submitted for review by ICC-ES.

✓ Insulated concrete forms (ICF), when used, must comply with IRC requirements, or have an ICC-ES evaluation report.

- **Design Criteria**

✓ Risk category: II

✓ No. of story above grade: 2

✓ Seismic load: A, B, and C (SDC C for basement walls only)

Identify a quality GFRP Rebar

- **ICC-ES Equivalency Evaluation Report (IRC)**
- **What are the benefits for engineers/consultants/distributors, etc.?**

✓ **Easy design.**

✓ **Safe design.**

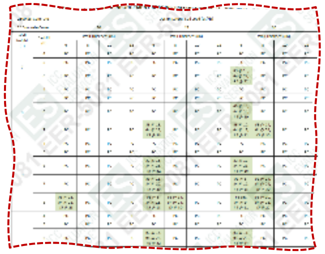
✓ **Using in Canada, USA, and worldwide.**

✓ **Introduced by our expert engineers and top consultant design office.**

Identify a quality GFRP Rebar

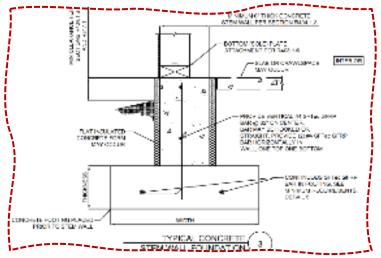
- **ICC-ES Equivalency Evaluation Report (IRC)**

- **Contents of ICC-ES®_EER-5081**



Tables

Drawings details



- ✓ **Wall designs above grade: T. 2 & 6& 7**
- ✓ **Wall designs below grade: T. 1 & 5**
- ✓ **Lintel designs: T. 3 & 4**

- ✓ **Plan diagram: D. 1**
- ✓ **Sections details for typical walls, foundation, and slab: D.2 through 4**

Identify a quality GFRP Rebar

- ICC-ES Equivalency Evaluation Report (IRC)

- Case study:
  - *Comparison between Steel vs. SFT-Bar®:*

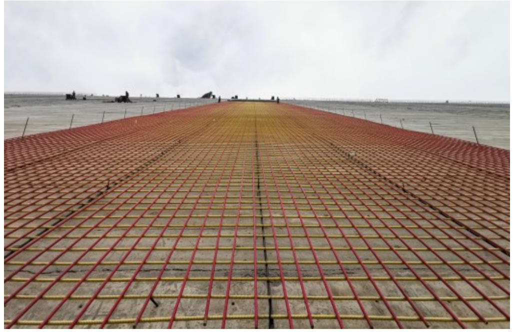
Reinforcement	Vertical			Horizontal		
	Size	QTY (bars)	Total length (ft)	Size	QTY (bars)	Total length (ft)
ICF (steel)	M15	40	320	10M	6	360
SFT-Bar®	No.5	26	205.6	No.3	2	120

SFTec Products

- **SFT-Bar®, connectors and rockbolt**

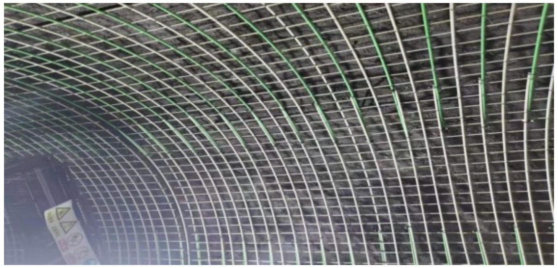
Application

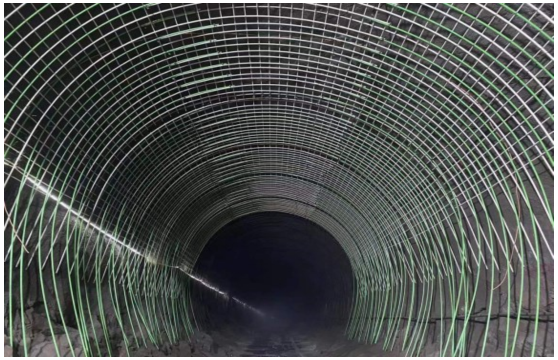
- **SFT-Bar® used in Pumped Storage Dam**


Application

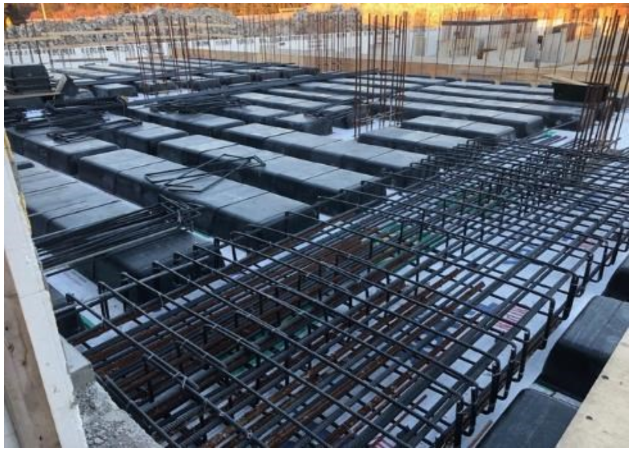
- **SFT-Bar® used in Tunnel**



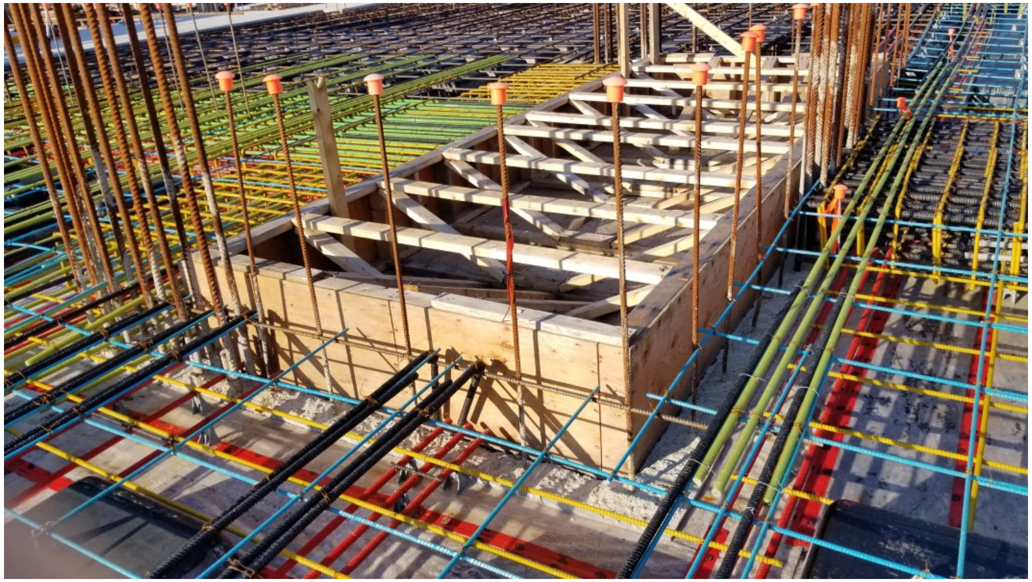


Application

- **SFT-Bar® used in Slabs**



GFRP -RC Waffle flooring slabs



Application

- **SFT-Bar® used in ICF wall**

Application

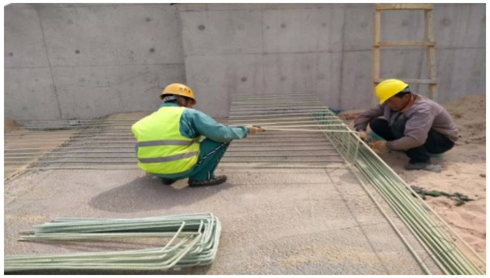
- **SFT-Bar® used in Slab on grade**

GFRP-RC Slab-on grade

Application

- **SFT-Bar® used in Barriers**

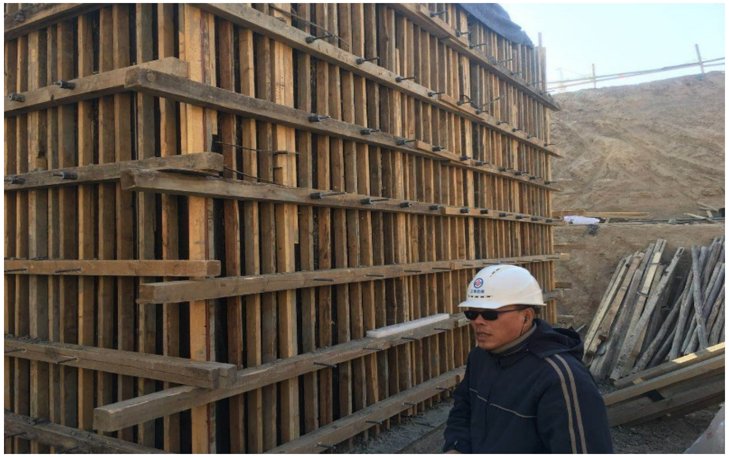



Application

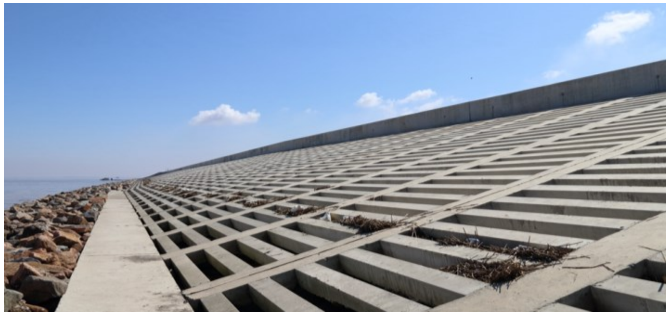
- **SFT-Bar® used in Nonmagnetic room**

Geomagnetic Observation Room



Application

- **SFT-Bar® used in seaside projects**



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THANK YOU!

Environmental Product Declaration / Product Category Rules

4th International Workshop on FRP Bars for Concrete Structures
Friday, August 9, 2024
Toronto, Canada

John P. Busel, FACI, HoF.ACMA

American Composites Manufacturers Association

Introduction

- Sustainability in the U.S. composites industry
- Importance of quantifying and reporting climate impacts
- ACMA programs

Key Terms

- Lifecycle Assessment (LCA)
- Product Category Rules (PCR)
- Environmental Product Declaration (EPD)

What does an LCA provide

- **An overview of your product's environmental impact for key environmental indicators. Examples include, but are not limited to:**
  - Global Warming Potential (kg CO_2 eq.)
  - Acidification (kg SO_2 eq.)
  - Eutrophication (kg N eq.)
  - Ozone Layer Depletion (kg CFC-11 eq.)
  - Water Consumption (m^3)
  - Cumulative Energy Demand (MJ)
  - Ecotoxicity (CTUe) – *(greater uncertainty in human health impacts)*
- **Identifies hot-spots in your product's life cycle**
- **Provides metrics for new product development decisions**
  - Evaluate impacts of material substitutions or process improvements – example: integrating recycled content or biobased content.
- **Carbon footprint data to satisfy customer requests, purchasing requirements, green building standard requirements, etc.**

ACMA
American Composites Manufacturers Association

Primary LCA Governing Standards:

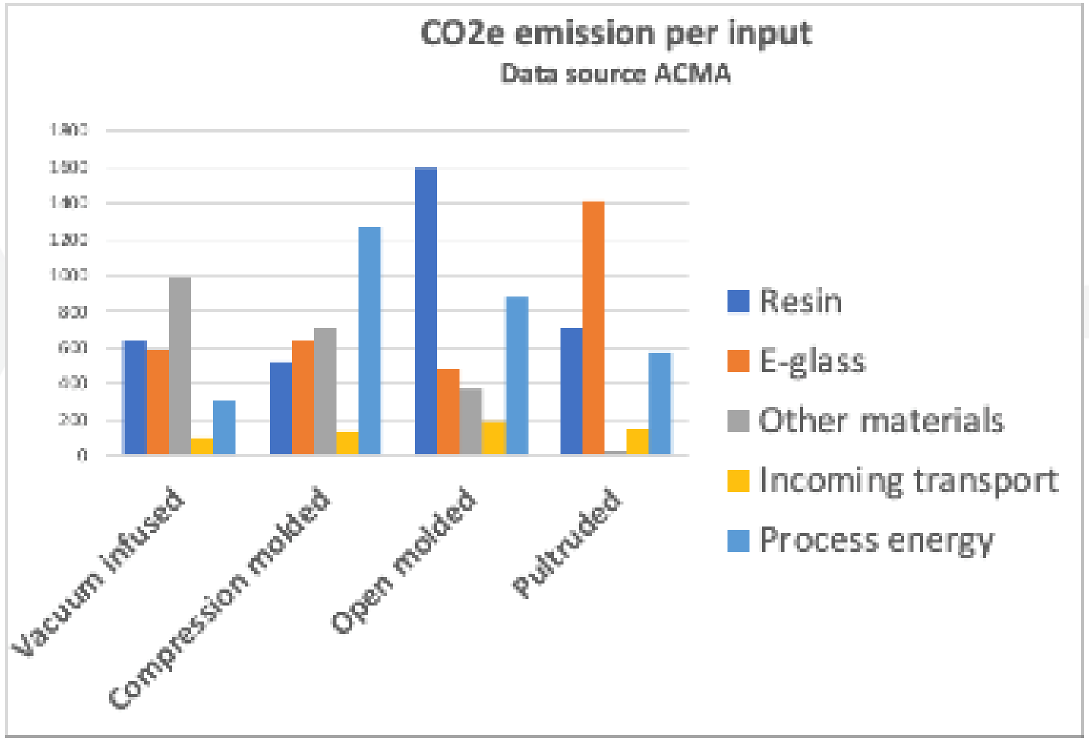
LCA is defined by at least two primary International Standards Organization (ISO):

- **ISO 14040: 2006 -** Environmental management - Life cycle assessment - *Principles and framework*
- **ISO 14044: 2006 -** Environmental management - Life cycle assessment - *Requirements and guidelines*
- **ISO 14025:2011 -** Environmental Labels and Declarations – Type III Environmental Product Declarations – Principles and Procedures.
- **ISO 21930:2017 -** Sustainability in Buildings and Civil Engineering Works – Core Rules for Environmental Product Declarations of Construction Products and Services.
- **EN 15804:2012+A2:2019 -** Sustainability of Construction Works – Environmental Product Declarations – Core Rules for the Product Category of Construction Products.
- **PCR Guidance** -Texts for Building-Related Products and Services,
  - **Part A**: LCA Calculation Rules and
  - **Part B**: Requirements for Product

ACMA
American Composites Manufacturers Association

Lifecycle Assessment (LCA)

- Conducted according to ISO standards
- Estimates climate impact in CO_2 equivalents (CO_2e)



LCA does not provide

- **Product Performance -** An LCA cannot disclose how material changes will impact the structural integrity or performance attributes of your products.
- **Marketing Content for Competitor Claims -** An LCA is not intended as sole basis to market environmental superiority to external industry competitors.

Product Category Rules (PCR)

- <u>Provide</u> the **rules, requirements, and guidelines** for developing an EPD for a specific product category.
- <u>Developed</u> by **Program Operators** (UL Environment, NSF, ASTM, SCS, International EPD System, IBU, SmartEPD)
- **Engagement** from stakeholders encouraged in the development process
  - Material suppliers, manufacturers, trade associations, purchasers, users, LCA practitioners, etc.
- Typically, **valid for five years** (North America)

A1 – A3 = Production stage (Cradle to Gate)
A4 – A5 = Construction stage
B1 – B7 = Use stage
C1 – C4 = End of Life stage

Cradle to Grave

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

PCR Structure

- **Part A**
  - Disseminates ISO 21930 requirements along with the individual program operator's requirements into a general product category rule.
- **Part B**
  - Defines what products are covered.
  - Defines the functional unit, technical aspects, functionality of individual categories of products.
  - Defines certain assumptions for consistency

Product Category Rules (PCR)

- **Standardize EPDs for specific product groups**
- **Developed with industry consensus**
- **ISO 14025: Responsibilities of Program Operators:**
  - Preparing, maintaining, and communicating general program instructions.
  - Publishing the names of the organizations involved as interested parties in the program development (not individual names).
  - Ensuring Type III environmental declaration requirements are followed.
  - Publishing PCR documents and Type III environmental declarations within the program.
- **ACMA's role in developing PCRs for composites**

Sustainable Minds Transparency Report [EPD]™ Program

Sustainable Minds

Part B: Product group definition | Utility poles | Part B #23-007

This Part B conforms to the ACLCA PCR Open Standard version 1.0 (May 2022) at the following level:
☒ 1 – Transparency ☐ 2 – Procurement ☐ 3 – Data source

Initiated by	American Composites Manufacturers Association (ACMA) - https://acmanet.org/		
Working group members	Jim Mellentine, Thrive ESG (PCR committee chair) John Schweitzer, American Composites Manufacturers Association (ACMA) John Busel, American Composites Manufacturers Association (ACMA) La'Kia Phillips, American Composites Manufacturers Association (ACMA) Chris Bolin, AquAeTer, Inc. Natalie Tarini, Wood Preservation Canada Jeff Miller, Treated Wood Council Kevin Ragon, Southern Pressure Treaters' Association (SPTA) Cheryl Smith, Owens Corning Mike Schoenoff, Geotek Dan Mastrocola, Hydro Quebec Jonathan Jordan, EDM International, Inc. Kelsy Valko, Creative Composites Kevin Schmit, Enduro Composites Galen Fecht, RS Poles Scott Holmes, RS Poles Danny Lonergan, Valmont Eric Haddad, Valmont Natasha Jeremic, Canadian Wood Council Rodney McPhee, Canadian Wood Council Kerry Sutton, Slag Cement Association Tiffany Reed-Villarreal, National Ready Mixed Concrete Association (NRMCA) Kyle Cassidy, Stella-Jones Corporation Heath Huschak, Koppers Inc.		
Public notices of development/ outreach	• Public notice on the Sustainable Minds website announcing the development of new Part B on June 1, 2023: http://www.sustainableminds.com/transparency-report-program/part-b • Email blast on May 12, 2023 to mailing lists of LCA professionals, building and construction industry and trade associations, concrete manufacturers, and others identified by ACMA as having a potential interest in participating, requesting participation on the PCR committee. • Email blast on November 2, 2023 to the same mailing lists requesting public comment.		
Non-participating parties	All interested parties who requested participation were invited to join the working group.		
New Part B?	Yes	**Part B version number**	1.0
Publication date	February 7, 2024		
Validity period	02/07/2024 – 02/06/2029		
Expected renewal schedule	Sustainable Minds intends to notify the working group and post update/renewal information on its website approximately four months prior to expiration to determine update, extension, or expiration options for this Part B.		

Product group

Name	Utility poles	**CSI MasterFormat® #**	33 71 16 Electrical Utility Poles 33 81 19 Communication Utility Poles
Description	Poles used to support overhead electric utilities and related equipment for transmission, distribution, and telecommunications applications. Finishes such as paints and coatings shall be included. Standard hardware accessories such as top caps, base plates, fasteners, and ID tags shall be included if relevant. If the product design requires specific materials to be used for installation, those materials shall be included in the installation stage.		
Exclusions	No exclusions identified		
Geographic representativeness	North America		

PCR for FRP Rebar

- **Sponsor: ACMA**
- **Program Operator: NSF International**
- **Ongoing effort in 2023/2024**

Product Category Rule

for Environmental Product Declarations

PCR for Fiber Reinforced Polymer Composite Rebar --- Draft

Program Operator
NSF International
National Center for Sustainability Standards
Valid through Month Day, Year
ncss@nsf.org

NSF Confidential

Working Group

Busel, John	ACMA
Schweitzer, John	ACMA
Hernandez, Edgardo	AOC
Binoy, Brian	Aramco Americas
Snapp, Travis	Benchmark International
Troutman, Dustin	Creative Composite Group
Ohnstad, Tom	Marshall Composite Technologies
Haji, Bari	MST Rebar
Seracino, Rudolf	North Carolina State University
Mutnuri, Bhyrav	Strongwell
Lopez-Anido, Roberto	University of Maine
De Caso, Francisco	University of Miami
Benmokrane, Brahim	University of Sherbrooke

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

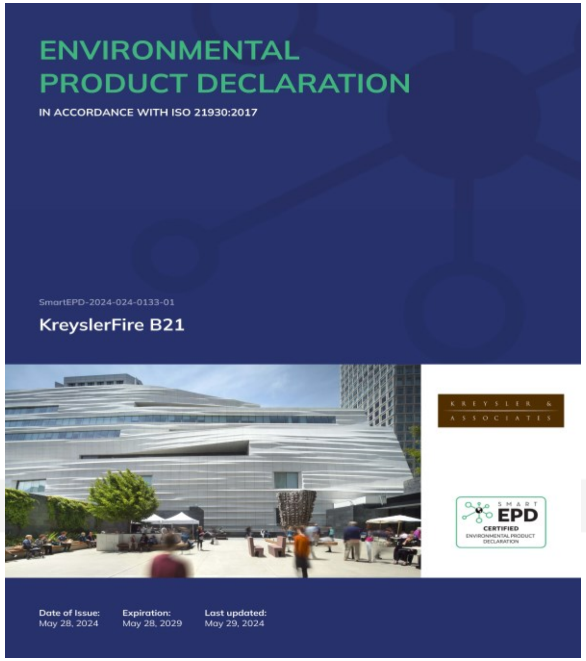
Scope

- This sub-category product category rules (PCR) addresses fiber reinforced polymer composite products – rebar and dowel, and documents the goal, scope, and other requirements of LCAs for this product category in order to produce EPDs according to ISO 14025:20061 and ISO 21930:2017.1
- This PCR includes the life cycle modules A1-A3, in order to obtain the raw materials and manufacture discrete reinforcing bars.
- This PCR uses a declared unit on the basis of a cradle-to-gate system boundary instead of a functional unit.

Additional Environmental Information (section 8)

- Annex developed to characterize in-service life expectation
- Laboratory experiments tend to be **more severe** on GFRP bars than real-world environmental conditions.
- It was concluded that the extracted GFRP bar samples exhibited a **reduction in tensile strength of 2.5% after 17 years of service**.
- Extrapolating this result to a 100-year service life, **the predicted tensile strength would be reduced by 12.5%,** which remains within the threshold values specified by the design codes for the rate of degradation of GFRP bars in reinforced concrete.
- **It is evident that GFRP bars can be used for a cradle-to-grave timeline equivalent to 100 years of service life.**

Environmental Product Declaration (EPD)



- **Standardized format for LCA information**
- **Used for construction and infrastructure products**
- **Cradle-to-gate vs. cradle-to-grave EPDs**
- **Valid for five years, EPD presents**
  - Promotes transparency
  - quantified environmental data for products based on information from an LCA.
  - EPDs are developed based on the requirements of ISO 14025 and product category rule (PCR) –
  - ISO 21930:2017 and EN 15804:2012+A2:2019
- **NOT intended for comparative claims to industry competitors.**

Benefits of Composite Construction Products

- **Advantages: lower maintenance, longer service life**
- **Lifecycle emissions comparison: steel vs. composites**

Construction & infrastructure products

Tanks	CIPP	Railings
Pipe	Drainage channels	Concrete forms
Rebar	Siding	Fascia/Cladding
Panels	Columns	Manhole covers
Girders	Piles	ADA tiles (crosswalks)
External concrete strengthening	Poles	Bridge decks
Grating	Utility poles & crossarms	
Utility vaults		

Comparison of steel and functionally equivalent FRP composite components

	CO2e emission per year of service life (kg/yr)		Ratio (steel/GFRP)
	Steel	GFRP	
Concrete bridge deck: steel vs. FRP rebar - Case-1	170	18	9.7
Concrete bridge deck: steel vs. FRP rebar - Case-2	1300	130	10
Concrete columns: steel vs. GFRP rebar	8.3	3.4	2.4
Concrete frame with steel. vs. GFRP	160	83	1.9
Concrete beam with steel vs. GFRP rebar	14	5.3	2.6
Steel beam vs. GFRP beam	11	7.3	1.5
Concrete bridge portal frame with steel vs. GFRP	97	37	2.7
Roof truss with steel vs. GFRP	44	28	1.5
Highway truss with steel vs. GFRP	240	170	1.4
Steel signpost vs. GFRP signpost	28	42	0.67

ACMA
American Composites Manufacturers Association

Comparison of steel and functionally equivalent FRP composite components

Comparison of full lifecycle environmental impacts of a highway bridge built with traditional steel components v. with composite components HTTPS://doi.org/10.1520/acem20180113			
	FULL LIFECYCLE EMISSIONS (CRADLE-TO-GRAVE)		IMPACTS RATIO (steel/FRP)
	STEEL	FRP	
Ozone depletion, kg CFC-11 eq	0.125	0.534	0.23
Global warming, kg CO2 eq	1,480,000	1,090,000	1.4
Photochemical oxidant creation, kg O3 eq	83,500	71,700	1.2
Acidification, kg SO2 eq	5,680	5,390	1.1
Eutrophication, kg N eq	3,510	1,760	2.00

American Composites Manufacturers Association

EPA's Role in Sustainability

- 2022 legislation for construction product labeling
- EPA's criteria for sustainability assessment
- Impact on market access for suppliers

ACMA's Sustainability Program

Upcoming LCA/EPD generator

LCA + EPD GENERATOR

POWERED BY ACMA

ACMA American Composites Manufacturers Association

ACMA SUSTAINABILITY

IRA/EPA/EPD grant

ACMA and IACMI were selected to receive a $6 million grant for programs to support EPD preparation

Conclusion

- ACMA's sustainability program provides tools and resources for composites manufacturers to prepare LCA and EPD for their products
- Outlook for composites industry sustainability

Acknowledgements

- John Schweitzer, ACMA
- Nicole Meyer & Marquis Miller, Sustainable Solutions Corp.

American Composites Manufacturers Association

Thank you!

John P. Busel, ACMA
Jbusel@acmanet.org

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Innovative Thermoplastic Bendable GFRP Rebar

Dextra

Pierre Hofmann - Dextra

Paul Boothe - Arkema

ARKEMA

SPONSORED BY:

PULTRALL V-ROD FIBERGLASS Innovations

ALTAIR

MST BAR MAXIMUM STRENGTH GFRP

SFTec

ACMA American Composites Manufacturers Association FRP Rebar Manufacturers Council

UNIVERSITÉ DE SHERBROOKE

NSERC CRSNG

UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

FDOT

Bendable FRP rebar with Elium® resin

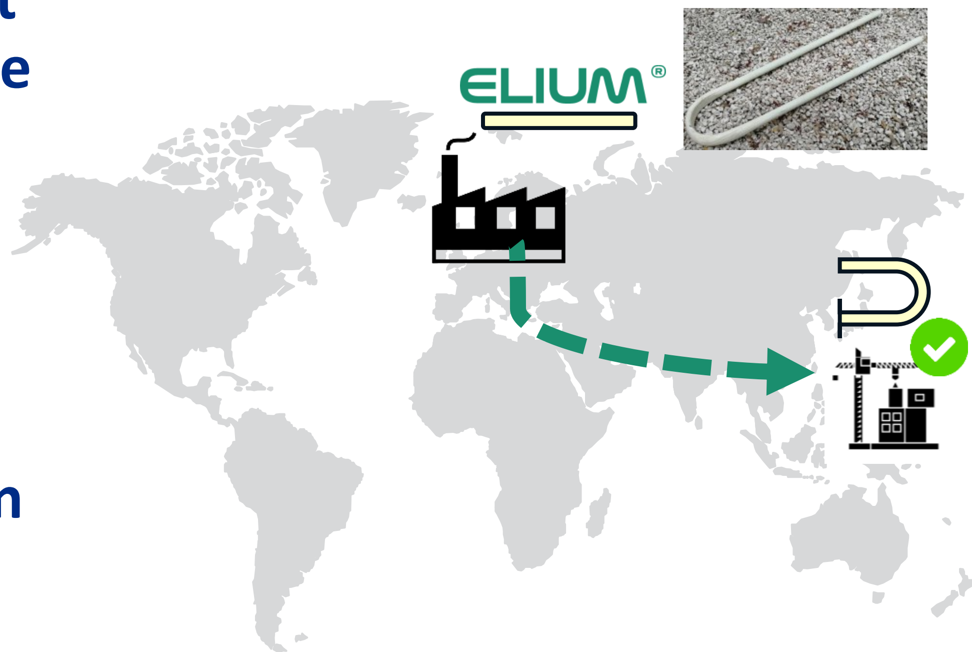
- **Thermoset FRP rebars cannot be bent near construction site**

  Linear rebar continuous production; bent thermoset rebar must be produced batchwise at fixed angles.

- **Thermoplastic Elium® resin allows continuous production of straight rebars that can be bent to desired angle**

  Elium® resin is compatible with standard FRP pultrusion.

  Final shaping can be done locally, reducing lead time and errors.



Thermoset FRP rebar = custom order
Elium® FRP rebar = simplified planning

ARKEMA ELIUM®

Elium® the liquid thermoplastic designed for recycling

"a unique ***liquid thermoplastic*** *solution for manufacturing* ***composite parts*** *using standard thermoset processes, including the major particularity of* ***design for recycling****"*

Liquid
Resin is a liquid polymer and reactive monomer blend with processing additives.

Thermoplastic
Polymer is high strength, high toughness, durable and lightweight. Final parts can be thermoformed, overmolded or welded.

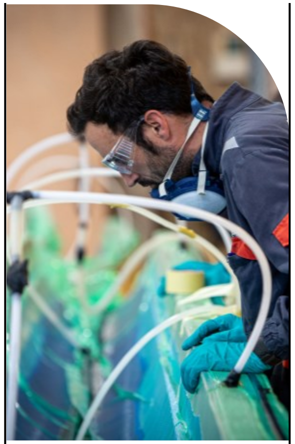
Design for recycling
The high molecular weight thermoplastic FRP is fully recyclable. Elium® resin is styrene free, BPA free and Cobalt salt free.

ARKEMA ELIUM®

Elium® applications and markets

Infusion

Wind
Marine

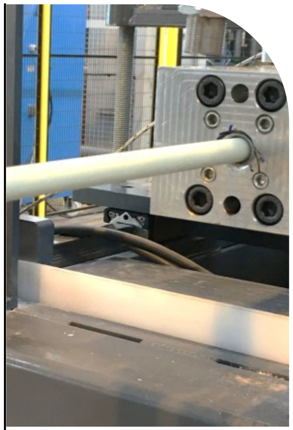


Casting

Cladding
Sanitary
Industrial applications

Pultrusion

Building
Wind

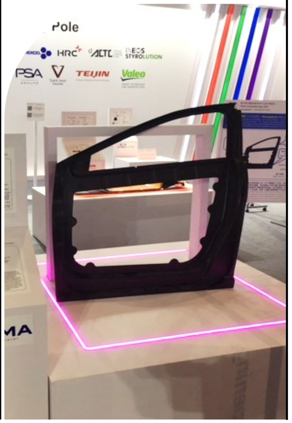


Filament Winding

Pressure vessel
Tanks
Pipes

C-RTM & Compression

Automotive

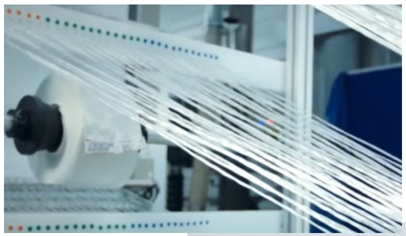


SMC

Automotive
Aero
Appliances

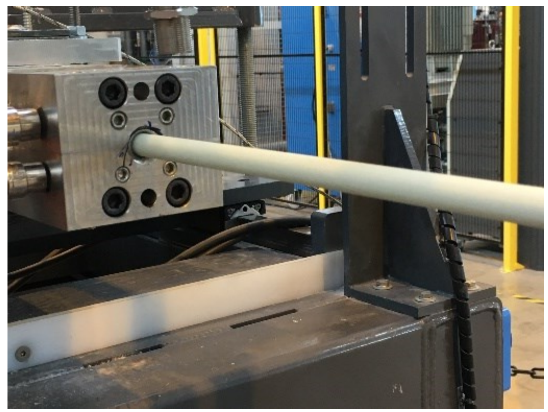
Elium® FRP via standard pultrusion processes

FIBER ROVING



ELIUM®
RESIN

FORMING DIE + HEAT



- Elium® resin is compatible with current pultrusion line of FRP Rebar
- Compatible with resin bath or injection head
- Suitable for Glass, Carbon and Basalt fibers

IRT M2P Institut de Recherche Technologique Matériaux Métallurgie et Procédés

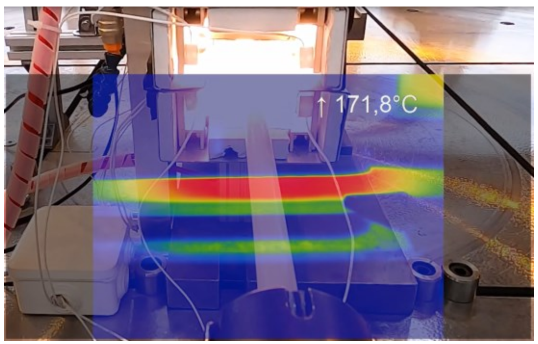
ARKEMA ELIUM®

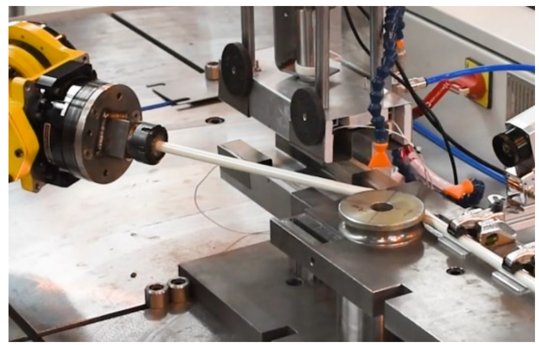
Bending process with Elium® rebars

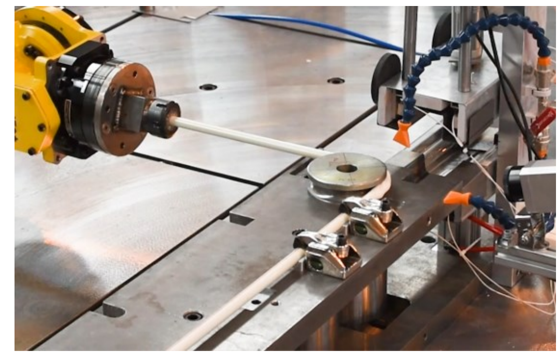
1 Heat locally to ≈180˚C

2 Controlled deformation

3 Cooling







- Process development in collaboration with IRT M2P Institut de Recherche Technologique Matériaux Métallurgie et Procédés
- Requires correct forming process to ensure quality, dimensions stability and safety
- Complete process in less than 2 minutes
- Development of an industrial bending machine on-going at WAFIOS

ARKEMA ELIUM®

NSERC CRSNG MIAMI FDOT

Thermoformable rebar with Elium® resin

- **Elium® C599 E for rebar**

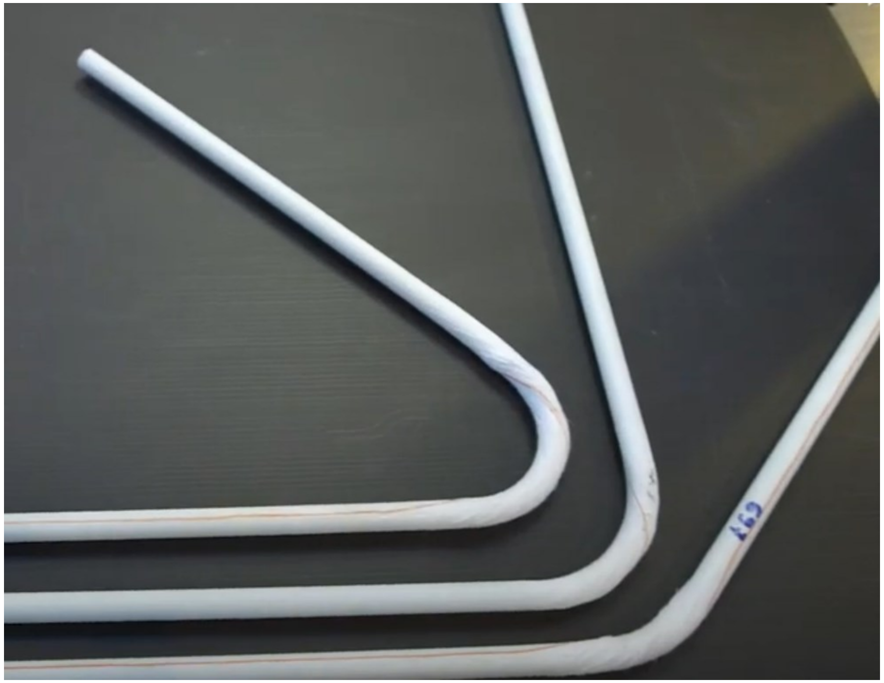
  Elium® fulfills technical acceptance criteria for rebar applications (ASTM D7957)

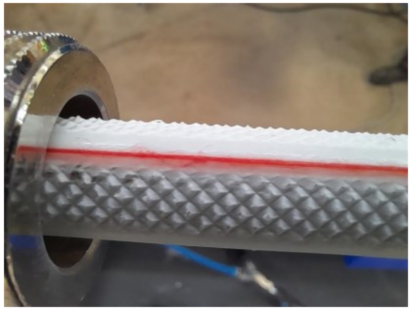
- **New bending designs possible**

  Smaller bending radius using Elium® (3x the rebar diameter)

- **Concrete adhesion**

  Classical methods (sand-coating, filament winding, machining) or "Thermoplastic" method by calendaring





IRT M2P Institut de Recherche Technologique Matériaux Métallurgie et Procédés

ARKEMA ELIUM®

NSERC CRSNG

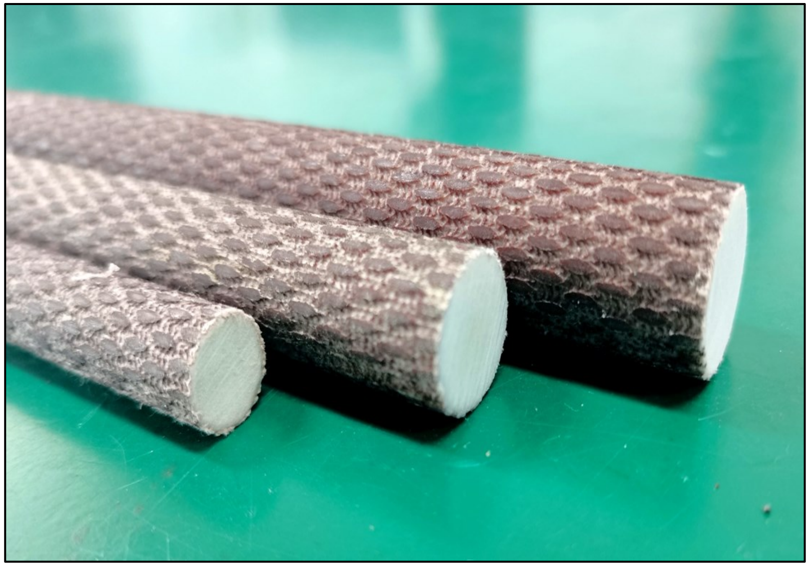
MIAMI

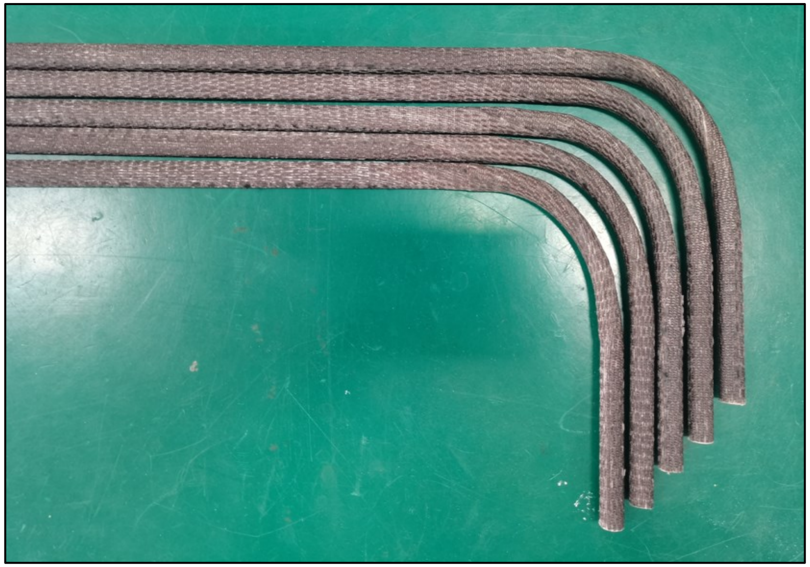
FDOT

Background

- The thermoset (vinyl-ester or epoxy) GFRP bars have numerous advantages, but there is a specific drawback that they cannot be reshaped after cured which affects the industry. Therefore, bendable GFRP bars at the construction site is a major challenge.
- To use thermoplastic resins to replace the thermoset resins would be potential solution since it possesses a two-dimensional network microstructure consisting of linear polymeric chains and a tendency to soften at elevated temperature.

- **Dextra worked with Arkema develop an Innovative Thermoplastic (TP) Bendable GFRP Rebar.**
- **Physical & Mechanical Properties and Durability Characteristics of this Thermoplastic Bendable GFRP Rebar have been characterized by Sherbrooke University (Benmokrane, et al. Journal of Composites for Construction 28.4 (2024): 06024001.)**





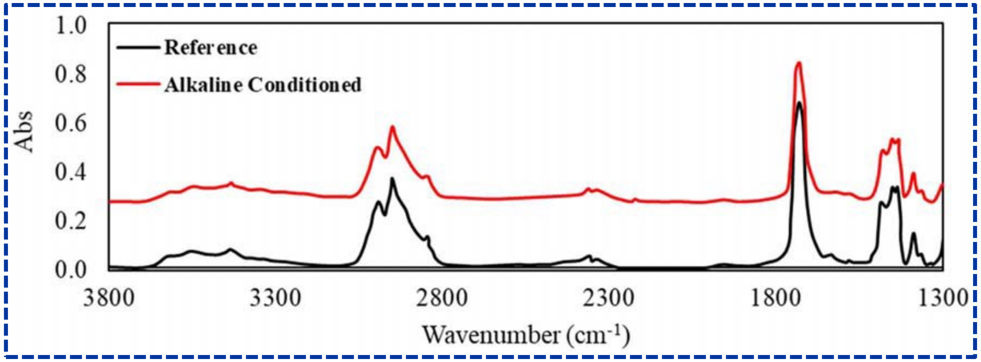
Physical Properties

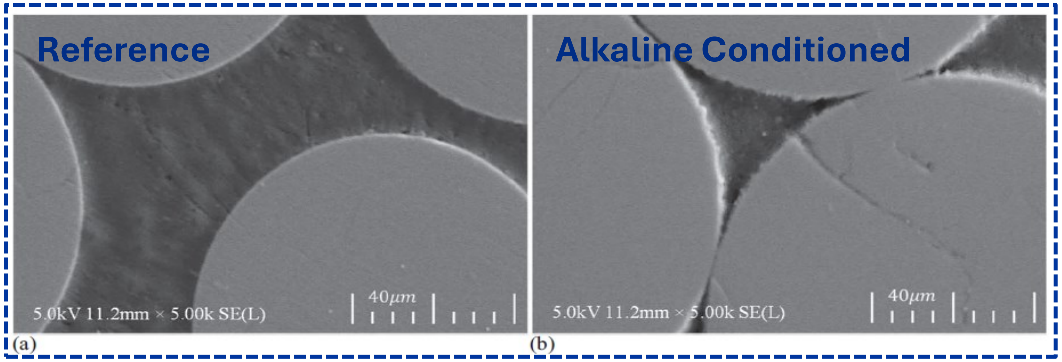
Dia.16mm (No. #5) Thermoplastic Rebar Physical Properties

Item #	Property	Result	Specified limits	
			ASTM D7957	CSA S807
1	Cross-sectional area (mm^2)	**196**	186 - 251	186 - 251
2	Fiber content by weight (%)	**85**	≥ 70	≥ 70
3	Glass transition temperature, Tg (°C)	**107**	≥ 100	≥ 100
4	Water absorption (%) @ 24 h	**0.25**	≤ 0.25	≤ 0.25
5	Water absorption (%) at saturation	**0.37**	≤ 1.00	≤ 1.00

- **All physical properties meet with ASTM D7957 and CSA S807.**

Physical Properties





- **Both FTIR and SEM results indicate that chemical composition, the integrity and interface remained largely unchanged after alkaline conditioning.**

Mechanical Properties - Tensile

Dia.16mm (No. #5) Thermoplastic Rebar Tensile Properties

No.	Tensile Load (kN)	Tensile Strength (MPa)	Tensile modulus (GPa)	Ultimate strain (%)	Specified Tensile Strength Limits (MPa)	
					ASTM D7957	CSA S807 Grade III
1	276	1387	55	2.5	653	1000
2	276	1387	56	2.5	653	1000
3	285	1432	55	2.6	653	1000
4	281	1412	57	2.5	653	1000
5	259	1302	55	2.4	653	1000
6	272	1367	55	2.5	653	1000
7	267	1342	55	2.4	653	1000
8	287	1442	54	2.7	653	1000
Average	**275**	**1384**	**55**	**2.5**	**653**	**1000**
SD	9.3	47	0.9	0.1		
COV (%)	3.4	3.4	1.6	3.8		

- **The TP bars had higher tensile strength and modulus than the TS bars when using with same grade glass fiber. This difference could be attributed to the higher fiber content in TP bars.**

Mechanical Properties - Shear

Dia.16mm (No. #5) Thermoplastic Rebar Transverse Shear Properties

No.	Transverse Shear Load (kN)	Transverse Shear Strength (MPa)	Specified transverse shear strength Limits (MPa)	
			ASTM D7957	CSA S807 Grade I
1	62	156	131	160
2	67	168	131	160
3	69	173	131	160
4	70	176	131	160
5	67	168	131	160
Average	**67**	**168**	**131**	**160**
SD	3.1	8		
COV (%)	4.6	4.6		

- **The TP bars meet the requirements for transverse shear strength for CSA S807 Grade I and ASTM D7957.**

Mechanical Properties - Bond Strength

Dia.16mm (No. #5) Thermoplastic Rebar Bond Strength Properties

No.	Failure Load (kN)	* Bond Strength (MPa)	Specified Bond Strength Limits (MPa)	
			ASTM D7957	CSA S807
1	60.6	15.3	7.6	10.0
2	70.1	17.7	7.6	10.0
3	61.9	15.6	7.6	10.0
Average	**64.2**	**16.2**	**7.6**	**10.0**

Remark: * Bond length = 5*Bar Diameter.

- **The TP bars meet the requirements for Bond strength for CSA S807 and ASTM D7957.**

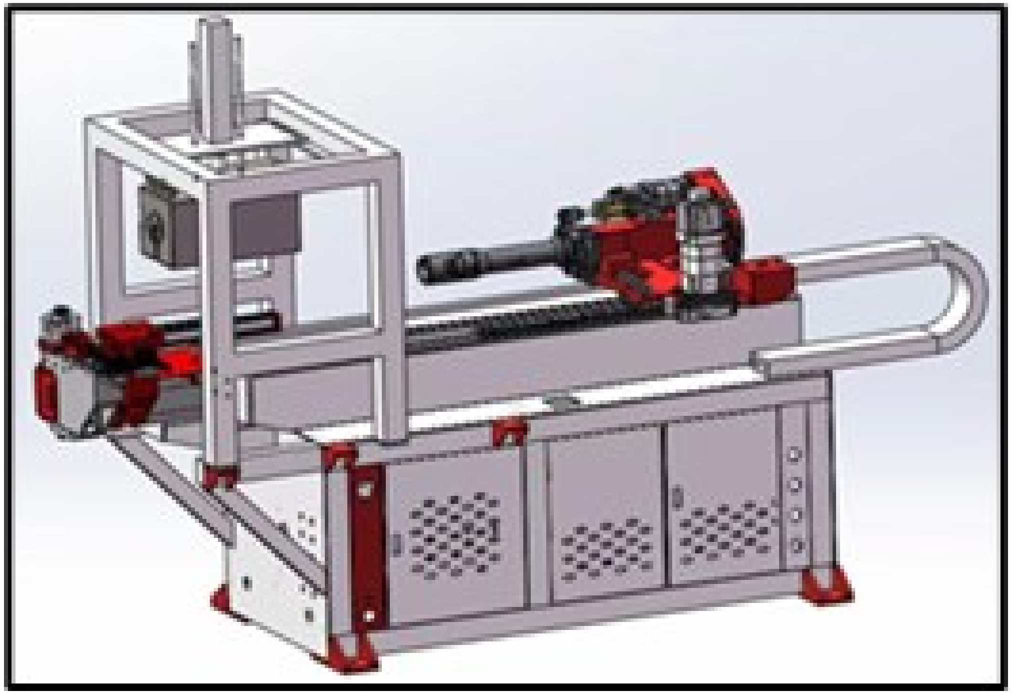
Durability Properties - Alkaline Resistance

Dia.16mm (No. #5) Thermoplastic Rebar Durability Properties

Item #	Tensile Strength (MPa)	Tensile modulus (GPa)	Ultimate strain (%)	Tensile Strength Retention (%)	Specified Tensile Strength Retention limit (%)	
					ASTM D7957	CSA S807 D1
1	1261	55	2.3	91.1	80	85
2	1265	55	2.3	91.4	80	85
3	1251	53	2.4	90.4	80	85
4	1277	54	2.4	92.3	80	85
5	1247	54	2.3	90.1	80	85
6	1260	54	2.3	91.0	80	85
7	1298	55	2.4	93.8	80	85
8	1299	56	2.3	93.9	80	85
Average	**1270**	**55**	**2.3**	**91.7**	**80**	**85**
SD	20	0.9	0.03			
COV (%)	1.6	1.7	1.2			

- **The TP bars showed good alkaline resistance property. The tensile strength retention after 90 days at 60°C of alkaline conditioning was about 92% which meet both CSA S807 D1 and ASTM D7957 requirement.**

Properties - Bending Strength



- **This Innovative Thermoplastic Bendable GFRP Rebar will be as a new solution to conventional reinforcement materials.**
- **It will better promote the application of composite rebar, while solving the problem of its recycling, making it more sustainable and environmentally friendly.**

Dextra

Pierre Hofmann
GM - FRP & Geotec

reliable connections

Questions ?

Don't hesitate to contact us

Dextra

Boris Caro Vargas
GM – North America

reliable connections

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Durostone® from Europe to The Americas
(and beyond)

Bill Davis

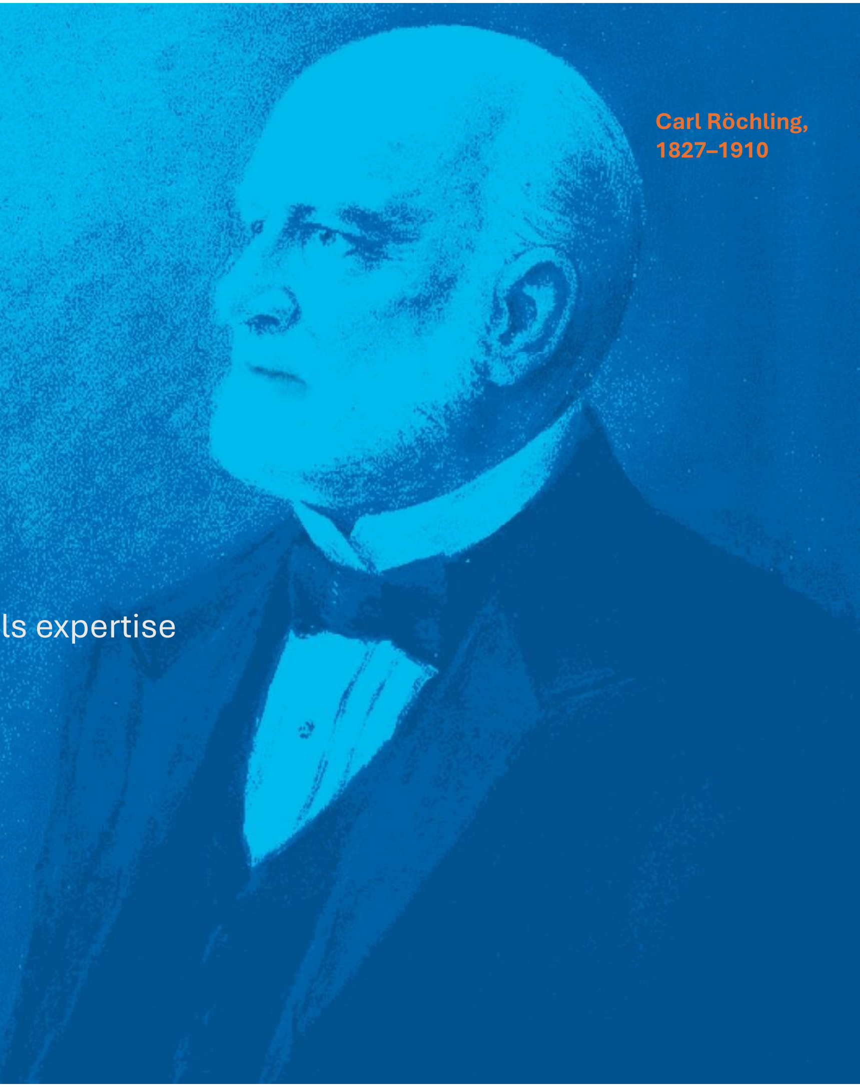
Röchling Industrial

SPONSORED BY:

200 Years Röchling
Pioneering Ever Since
1822

2022

100 years of plastic
200 years of materials expertise



Carl Röchling,
1827–1910

Röchling through the ages

change and progress are part of our DNA.

Carl Röchling, 1827–1910

1822

Departure into the steel and coal era

1921

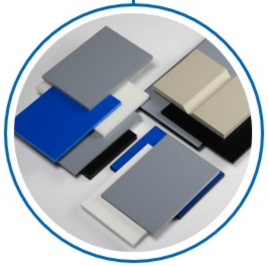
Materials expertise expanded to include plastics

1978

End of the coal era and diversification

2006

Focus on plastics



SINCE 2018

Solution provider of innovative plastics

2022

100 years of plastic

200 years of material expertise

Röchling Group

2023 Figures

2,723
million euro in sales
in 2023

11,988
employees

90
locations

in 25 countries

Close to our customers

Offering high quality and solutions.

Röchling Group

Three strong company divisions.

Industrial

Automotive

Medical

Röchling Industrial

2023 Figures

1,206 million euro sales in 2023

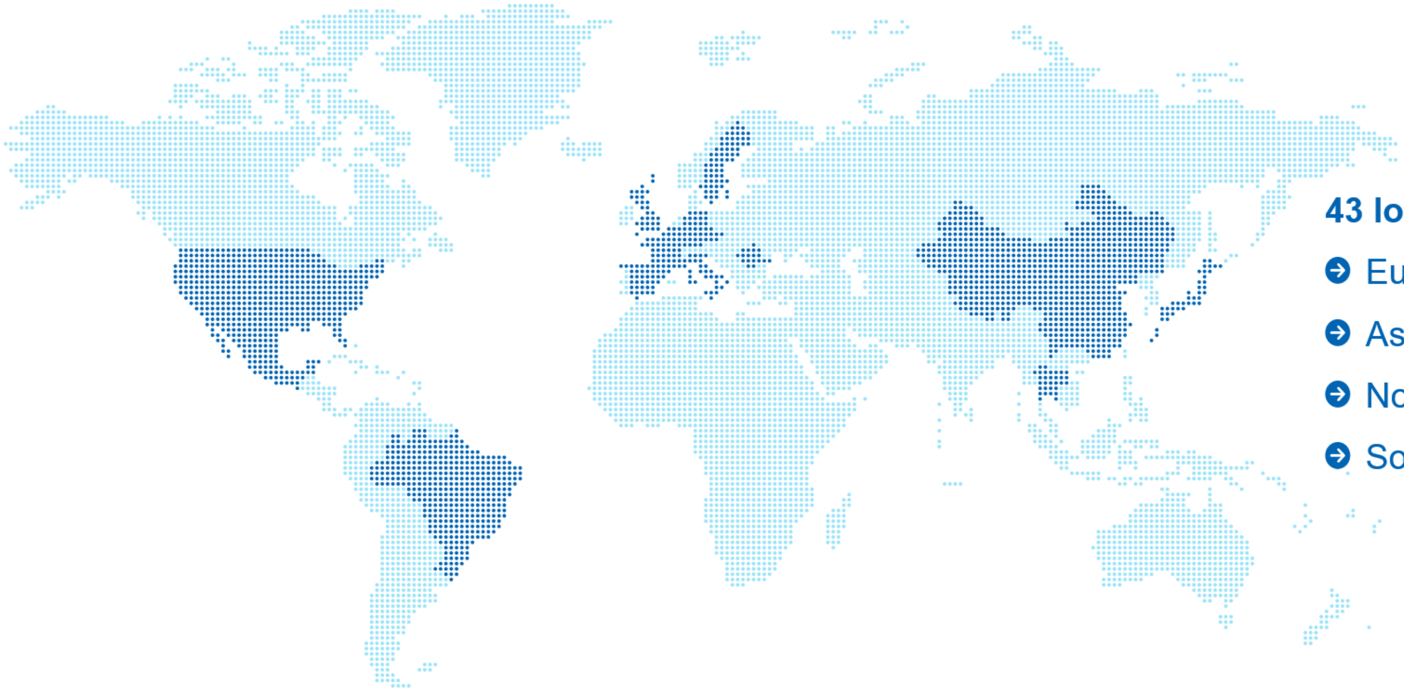
4,515 employees

43 locations

in **20** countries

Global presence

43 Röchling Industrial locations worldwide.



43 locations in…

- Europe
- Asia
- North America
- South America

Röchling Industrial

Parent company based in Haren.

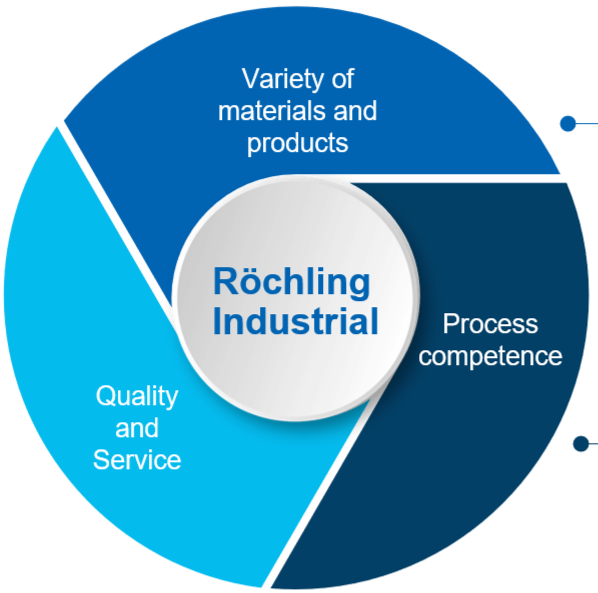
- Over 100 years of experience
- Process and innovation expertise on more than 320,000 square metres
- Bundling of research and development activities
- High-tech materials testing with more than 370 test methods
- Over 170 modern production facilities
- Thermoplastics, composites, and finished parts
- Largest location within the Industrial Division

Our services

capabilities at a glance.

Unique test environments
- Technology Center
- Certified laboratory
- In-house material testing
- Qualified and flexible employees

A wide range of product certifications for the highest quality standards



Unique variety
- >350 materials
- Thermoplastic and composite products
- Semi-finished products and machined components

Wide range of processing options tailored to your products

= Innovative products & competitive advantages

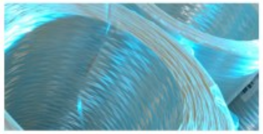
Röchling Group Technologies

Compression moulding

Pultrusion

Machining

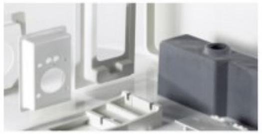
Extrusion



Filament winding

Selective laser sintering

Polymerisation



Press forming

Assembling

Röchling Group Products

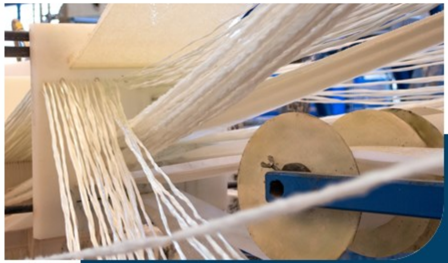
Thermoplastics

- Sheets
- Round rods
- Special & custom cast parts
- Extruded Profiles
- Machined Components
- Additive manufactured parts

Composites

- Sheets
- Pultruded Profiles
- Wound cones and parts
- Fasteners
- Machined components
- Kit-supply

Composite Materials



Fibre reinforced plastics

Fibres
Glas- (GFK), Basalt-, Carbonfibre (CFRP)
Resin systems
Polyester-, Vinylester-, Epoxy, Methacrylat- and Polyurethane resin (UP, UP-Iso, VE, EP, A, PU)

Brand names:
Durostone®
Glastherm®
Permaglas®
Durolight®
DuroProtect®
Glastic®

Laminated densified wood

Beech veneers
(Fagus sylvatica) phenolic glue

Brand names:
Lignostone®
Transformerwood®
Lignostone® cryogenic
LignoProtect®

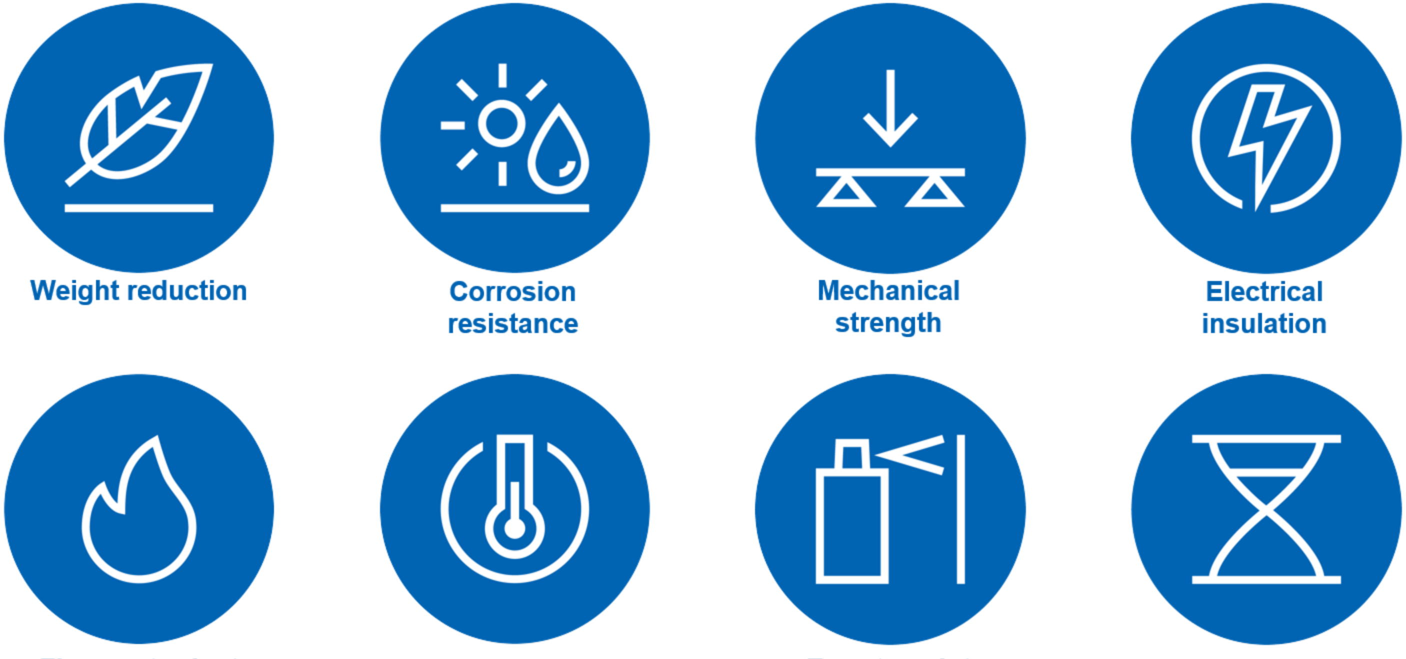
Laminated pressboard

Pure cellulose
(IEC 60641) phenolic glue

Brand name:
Trafoboard®

Composite Materials

Advantages.



Our quality

We offer you security.

Corporate R&D

Coordinated R&D across more than 40 locations and with 15+ engineers and experts.

Technology Center

State-of-the-art and with machines on a semi-industrial scale. Ideal for prototyping and further developing your products.

Material analysis

With our own laboratories, we can optimize the composition of our products according to your requirements.

Quality arises from requirements

Unique testing capabilities: over 15 material experts operate in the internal material testing department, producing more than 4,500 material certificates (EN10204-3.1)

Your industry – Our Know-How

Our focus industries at a glance.

- Chemical Processes
- Oil and Gas
- Mechanical Engineering
- Mining
- Energy
- Electronics
- Construction
- Transportation
- Ship & Boatbuilding
- Semiconductor
- Water
- Healthcare
- Sports and Leisure
- ?

Need & Opportunity

Collaboration

RÖCHLING

ASA.TEC

Contribution:

- Available production facilities in NA
- Access to the NA construction market
- Sales network
- Experience with thermoplastics and composites
- Synergies

Contribution:

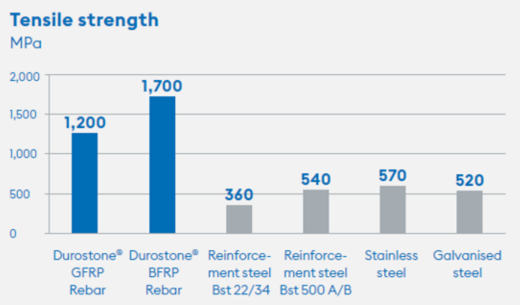
- Rebar manufacturing technology
- Sophisticated FRP Rebar R&D know-how
- Patents and Approvals
- Network of Partner Institutes and Universities for swift certifications
- Time to market cut-down

Röchling ASA.TEC

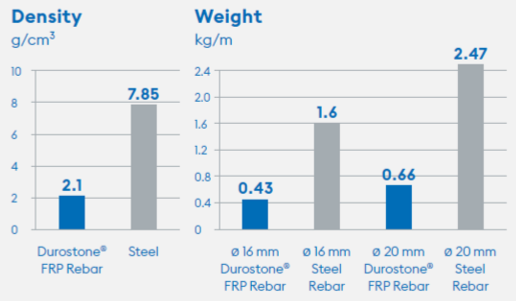
Durostone® GFRP Rebar

Advantages of Durostone® FRP Rebar

- High corrosion resistance
- Permanent Alkali & Chemical resistance
- High tensile strength
- + Significant lighter than steel (± 4x)
- Non-magnetic
- No electric or electromagnetic conductivity
- Thermally non-conductive
- Transparent for radar and radio waves
- Easily machinable
- Reduction of life cycle costs
- Long service life - Sustainable
- Much more environmentally friendly than steel



Durostone® FRP Rebars have a tensile strength three to four times greater than conventional reinforcement bars made of unalloyed steel and stainless steel. Tested according to CSA S806/ASTM D7205.



Durostone® FRP Rebars only have around 27 % of the weight of steel reinforcement bars. This permits lighter structures with maximum stability and less deadweight as well as much easier handling on building sites.

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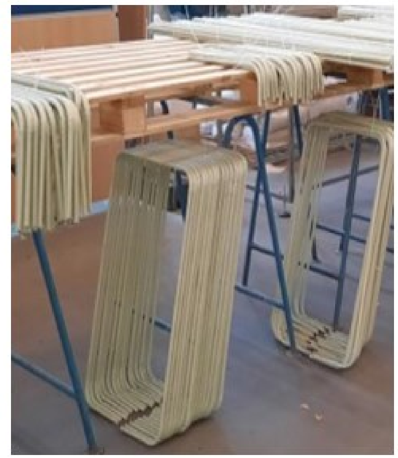
Current Product Range: Durostone® GFRP Rebar



STRAIGHT FRP Rebars

BENT FRP REBARS

- #3-10 mm – #8-25 mm
- < 10 mm possible

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Reaching your goals together.

Thank you for the opportunity!

Bill Davis

Röchling Industrial – North America

Cleveland, Ohio, USA

(330) 221-0305

bdavis@roechling.com