RHINO™

CARBON FIBER REINFORCEMENT PRODUCTS

ICC ES™

PROUD MEMBERS OF

ICRI INTERNATIONAL CONCRETE REPAIR INSTITUTE

Basement Health

aci American Concrete Institute

TABLE OF CONTENTS

Company Profile

RHINO
CARBON FIBER
REINFORCEMENT PRODUCTS

COMPANY PROFILE

About Us

Established in Heath, Ohio, the **Rhino Carbon Fiber** company is an industry leader in producing concrete crack repair and structural strengthening products, and has been for over 20 years. Supported by a dedicated testing and research center, as well as manufacturing facilities in the US and Canada, we not only produce some of the highest quality products available in the industry but we continually work to improve our products. Our engineering and R&D departments put all of their energy and expertise into ensuring that we offer products that are reliable, easy-to-install and long-lasting. We work hard every day to make this a reality for our customers. We work closely with our customers to meet and exceed their expectations for their projects through our word-class, value-added service.

We are a privately held company and a division of AGT Products, Inc., a trusted name in the building materials industry. When you partner with the **Rhino Carbon Fiber** company, you are backed by our international distribution network and brand strength. We work actively within the industry, keeping our finger on the pulse, so we can better serve our customers. We are proud members of the International Concrete Repair Institute (ICRI), the Basement Health Association (BHA) and the American Concrete Institute (ACI).

Vision

Be the company that relentlessly adds value to everyone we touch

Mission

We exist to make people's lives better by creating better spaces for living, through advanced building materials

Values

- Integrity
- Excellence
- Entrepreneurialism
- Customer Centric
- Winning Attitude

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Contact us today to review our extensive line of structural strengthening products!

1-888-684-3889 www.rhinocarbonfiber.com info@rhinocarbonfiber.com

Product Line

RHINO 560 GSM BIDIRECTIONAL BOWED WALL REPAIR KITS

ITEM # RCF-7000 | FG20030	ITEM # RCF-8000 | FG20031	ITEM # RCF-9000 | FG20032
•(3) 560 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions	•(3) 560 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions	•(3) 560 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions

ITEM # RCF-1000 | FG20029	10 FT BOWED WALL REPAIR KIT
COMPONENTS	•(3) 560 GSM Carbon Fiber Straps •(3) Tubes of Epoxy Adhesive •(3) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions

RHINO 400 GSM UNIDIRECTIONAL BOWED WALL REPAIR KITS

ITEM # RCF-7040 | FG20035	ITEM # RCF-8040 | FG20036	ITEM # RCF-9040 | FG20037
•(3) 400 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions	•(3) 400 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions	•(3) 400 GSM Carbon Fiber Straps •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions

ITEM # RCF-1040 | FG20034	10 FT BOWED WALL REPAIR KIT
COMPONENTS	•(3) 400 GSM Carbon Fiber Straps •(3) Tubes of Epoxy Adhesive •(3) Static Epoxy Nozzles •(3) Sill Plate Brackets •Bolts and washers •Gloves and instructions

RHINO CORNER WALL REPAIR KIT

ITEM # RCF-CNRK | FG20039	ITEM # RCF-CNRK-UNI | FG20125
•(4) 10 Foot 560 GSM Carbon Fiber Straps •(4) Tubes of Epoxy Adhesive •(4) Static Epoxy Nozzles •Gloves and Instructions	•(4) 10 Foot 400 GSM Carbon Fiber Straps •(4) Tubes of Epoxy Adhesive •(4) Static Epoxy Nozzles •Gloves and Instructions

RHINO CRACK REPAIR KITS

ITEM # RCF-VCRK | FG20055	VERTICAL WEAVE CRACK REPAIR
COMPONENTS	•(1) 10 Foot (12' wide) Vertical Carbon Fiber Strap •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •Gloves and Instructions

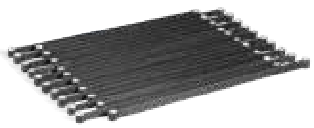
ITEM # RCF-HCRK | FG20054	HORIZONTAL WEAVE CRACK REPAIR
COMPONENTS	•(1) 10 Foot (12' wide) Horizontal Carbon Fiber Strap •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •Gloves and Instructions

ITEM # RCF-8BCR | FG20053	8' BIDIRECTIONAL CRACK REPAIR
COMPONENTS	•(1) 8 Foot (12' wide) Bidirectional Carbon Fiber Strap •(2) Tubes of Epoxy Adhesive •(2) Static Epoxy Nozzles •Gloves and Instructions

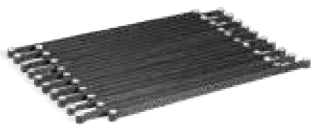
RHINO CONCRETE CRACK LOCK® KIT

ITEM # RCF-CCLK | FG20040	20 PACK CONCRETE CRACK LOCK® KIT
COMPONENTS	•(20) Concrete Crack Lock® Stitches •(1) Tube of High Strength Epoxy Paste •(1) Static Epoxy Nozzle •Gloves and instructions

RHINO CONCRETE CRACK LOCK® STITCHES



ITEM # RCF-CCL10 | FG20000	10 PACK RHINO CONCRETE CRACK LOCK® STITCHES
COMPONENTS	•(10) Concrete Crack Lock® Stitches



ITEM # RCF-CCL500 | FG20000	500 PACK RHINO CONCRETE CRACK LOCK® STITCHES
COMPONENTS	•(500) Concrete Crack Lock® Stitches

RCF STRUCTURAL EPOXY INJECTION RESIN KITS

ITEM # RCF-10CI | FG20047	10 FOOT CRACK INJECTION KIT
COMPONENTS	•(1) Tube of Injection Resin •(1) Tube of High Strength Epoxy Paste •(2) Static Epoxy Nozzles •(10) Ports •Gloves and instructions

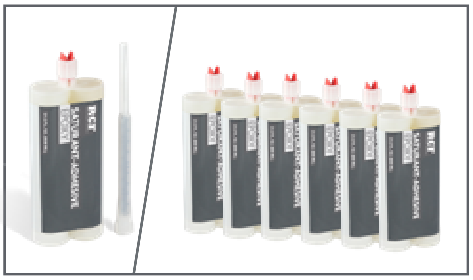
ITEM # RCF-30CI | FG20049	30 FOOT CRACK INJECTION KIT
COMPONENTS	•(3) Tube of Injection Resin •(3) Tube of High Strength Epoxy Paste •(6) Static Epoxy Nozzles •(30) Ports •Gloves and instructions

RCF POLYURETHANE INJECTION EXPANDING FOAM KITS

ITEM # RCF-10EF | FG20048	10 FOOT POLYURETHANE EXPANDING FOAM CRACK INJECTION KIT
COMPONENTS	•(1) Tube of Polyurethane Expanding Foam •(1) Tube of High Strength Epoxy Paste •(2) Static Epoxy Nozzles •(10) Ports •Gloves and instructions

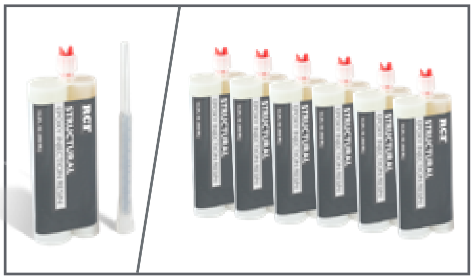
ITEM # RCF-30EF | FG20050	30 FOOT POLYURETHANE EXPANDING FOAM CRACK INJECTION KIT
COMPONENTS	•(3) Tube of Polyurethane Expanding Foam •(3) Tube of High Strength Epoxy Paste •(6) Static Epoxy Nozzles •(30) Ports •Gloves and instructions

RCF SATURANT-ADHESIVE EPOXY



ITEM #	RCF-EPXA | FG20017	RCF-6EPX | FG20074
COMPONENTS	•(1) Tube of Epoxy Adhesive •(1) Static Epoxy Nozzle	•(6) Tubes of Epoxy Adhesive •(6) Static Epoxy Nozzles

RCF STRUCTURAL EPOXY INJECTION RESIN



ITEM #	RCF-IREP | FG20019	RCF-6IRE | FG20076
COMPONENTS	•(1) Tube of Injection Resin •(1) Static Epoxy Nozzle	•(6) Tubes of Injection Resin •(6) Static Epoxy Nozzles

RCF POLYURETHANE INJECTION EXPANDING FOAM

ITEM #	RCF-EXFO | FG20020	RCF-6EXF | FG20077
COMPONENTS	•(1) Tube of Polyurethane Expanding Foam •(1) Static Epoxy Nozzle	•(6) Tube of Polyurethane Expanding Foam •(6) Static Epoxy Nozzle

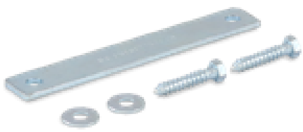
RCF HIGH STRENGTH ANCHORING EPOXY PASTE

ITEM #	RCF-HSEP | FG20018	RCF-6HSP | FG20075
COMPONENTS	•(1) Tube of High Strength Epoxy Paste •(1) Static Epoxy Nozzle	•(6) Tubes High Strength Epoxy Paste •(6) Static Epoxy Nozzles

RHINO DUAL-CARTRIDGE EPOXY GUN

ITEM # RCF-GUN0 | FG20023	RHINO EPOXY GUN
COMPONENTS	•(1) Dual Epoxy Dispenser

RHINO SILL PLATE BRACKET



ITEM # RCF-SPB0 | FG20061	RHINO SILL PLATE BRACKET
COMPONENTS	•(1) Zinc Coated Sill Plate Bracket •Bolts and washers

ITEM #	QUANTITY
RCF-PORT | FG20025	•(10) ports
RCF-250P | FG20080	•(250) ports

RHINO STATIC EPOXY MIXING NOZZLES

ITEM # RCF-STNO | FG20081	STATIC NOZZLE
COMPONENTS	•(10) Static Mixing Nozzles

RHINO BULK KITS

ITEM # RCF-5RK0 | FG20057	5.5" 560 GSM BIDIRECTIONAL ROLL KIT
COMPONENTS	•164' of 5.5" 560 GSM Bidirectional Carbon Fiber •(15) Tubes of Epoxy Adhesive •(15) Static Epoxy Nozzles •1 Box of Gloves

ITEM # RCF-4RK0 | FG20060	6" 400 GSM UNIDIRECTIONAL ROLL KIT
COMPONENTS	•328' of 6" 400 GSM Bidirectional Carbon Fiber •(30) Tubes of Epoxy Adhesive •(30) Static Epoxy Nozzles •1 Box of Gloves

ITEM # RCF-12BR | FG20056	12" BIDIRECTIONAL WEAVE ROLL KIT
COMPONENTS	•164' of 12" Bidirectional Carbon Fiber •(30) Tubes of Epoxy Adhesive •(30) Static Epoxy Nozzles •1 Box of Gloves

ITEM # RCF-12HR | FG20058	12" HORIZONTAL WEAVE ROLL KIT
COMPONENTS	•328' of 12" Horizontal Weave Carbon Fiber •(45) Tubes of Epoxy Adhesive •(45) Static Epoxy Nozzles •1 Box of Gloves

ITEM # RCF-12VR | FG20059	12" VERTICAL WEAVE ROLL KIT
COMPONENTS	•328' of 12" Vertical Weave Carbon Fiber •(45) Tubes of Epoxy Adhesive •(45) Static Epoxy Nozzles •1 Box of Gloves

Technical Data Sheets

RHINO CARBON FIBER REINFORCEMENT PRODUCTS

Technical Data Chart

Product Category	TDS
Bowed Wall Repair	Rhino Carbon Fiber 560 GSM Bidirectional
	Rhino Carbon Fiber 400 GSM Unidirectional
	RCF Saturant -Adhesive Epoxy
Corner Wall Repair	Rhino Carbon Fiber 560 GSM Bidirectional
	Rhino Carbon Fiber 400 GSM Unidirectional
	RCF Saturant -Adhesive Epoxy
Crack Repair / CFRP	Rhino Carbon Fiber 560 GSM Bidirectional
	Rhino Carbon Fiber Unidirectional
	RCF Saturant -Adhesive Epoxy
	RCF Structural Epoxy Injection Resin
	RCF Polyurethane Injection Expanding Foam
Concrete Crack Lock® Stitches	Rhino Carbon Fiber Concrete Crack Lock® Stiches
	RCF High Strength Anchoring Epoxy Paste

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01: PRODUCT IDENTIFICATION

8383 Riley Street,
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Product Name: Rhino Carbon Fiber 560 GSM Bidirectional

Product Code:

(Type-Width-Weight)	Weave Weight	
BD-5.5-560	1.03 lb/SY	(560 g/m2)
BD-12-560	1.03 lb/SY	(560 g/m2)
BD-24-560	1.03 lb/SY	(560 g/m2)

02: DESCRIPTION

Rhino Carbon Fiber 560 GSM Bidirectional is a high-strength, bidirectional carbon fiber fabric. Material is field laminated using RCF Saturant-Adhesive Epoxy to form a carbon fiber reinforced polymer (CFRP) system used to strengthen structural concrete elements.

03: WHERE TO USE

Load Increases	•Increased loading capacity •Installation of heavy machinery in industrial buildings •Vibrating structures •Changes of building utilization •Meeting of changed standards or specifications
Seismic Strengthening	•Column wrapping •Masonry walls
Damage to Structural Parts	•Aging of construction material •Vehicle impact •Fire and blast resistance •Prevention of defects caused by earthquakes
Change in Structural System	•Removal of walls or columns •Removal of slab sections for openings
Design or Construction Defects	•Insufficient reinforcements •Insufficient structural depth

04: ADVANTAGES

•Used for shear, confinement or structural strengthening
•Flexible, can be wrapped around complex geometries
•High-Strength
•Lightweight
•Non-corrosive
•Alkali Resistant
•Low aesthetic impact
•Fiber orientation tailor-made

05: TYPICAL DATA

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Storage Conditions	Store dry at 40° - 95°F (4° - 35°C)
Shelf Life	10 years from date of production
Color	Black (red string)
Primary Fiber Direction	0° (Bidirectional) - Carbon
Areal Density / Weight:	560 g/m^2 (16.52 oz/yd^2)

DRY FIBER PROPERTIES

	Imperial	Metric
Thickness	-0.02205 in	-0.56 mm
Tensile Strength	≥493 ksi	≥ 3400 MPa
Tensile Modulus	≥ 33359 ksi	≥ 230 GPa
Elongation at Break %	1.6%	1.6%

TECHNICAL INFORMATION & COMPOSITE PROPERTIES

	Tested/Experimental Average Value		Design Value		Testing Method
	Imperial	Metric	Imperial	Metric	
Thickness	0.019 in.	0.48 mm	0.019 in.	0.48 mm	ASTM D3039
Tensile Strength	111 ksi	768 MPa	94 ksi	647 MPa	ASTM D3039
Tensile Modulus	6890 ksi	47.5 GPa	5750 ksi	39.7 GPa	ASTM D3039
Elongation at Break %	1.60%	1.60%	1.25%	1.25%	ASTM D3039
Tensile Strength per Unit Width	2259 lbs/in.	0.396 kN/mm	1945 lbs/in.	0.341 kN/mm	ASTM D3039

[A]Load and Chord Stiffness per Unit are computed based on CFRP laminate specimen width

*20 sample coupons per test series

[1]Average value of test series

[2]Average value minus 3 standard deviations per ACI440

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06: HOW TO USE – SURFACE PREP

Surface must be clean, sound, and dry. Remove a light layer of concrete from the surface to allow the epoxy to penetrate the substrate (Refer to ICRI 310-2R for additional information). Typical methods include shot blasting or grinding to achieve this open textured surface. Consult the epoxy adhesive data sheets for additional information on surface preparation.

Existing uneven surfaces must be filled with an appropriate repair mortar/hydraulic cement. The adhesive strength of the concrete must be verified after surface preparation by random pull-off testing (ASTM D-4541) at the discretion of the engineer. Minimum tensile strength, 200 psi (1.4 MPa) with concrete substrate failure.

Round all corners to 1/2" radius in certain "contact critical" applications and at the engineers discretion, a thorough cleaning of the substrate using low pressure sand or water blasting may be sufficient.

07: APPLICATION

Application prior to placing the fabric, scarify the concrete surface using dustless grinding system. The fabric may also be manually saturated using your hand, a roller prior or scraper to placement. In either case, installation of this system should be performed only by a trained contractor.

08: TOOLING & FINISHING

Fabric can be cut to appropriate lengths by using scissors. Since the dull or worn cutting implements can damage, weaken or fray the fabric, their use should be avoided.

09: LIMITATIONS

- Design calculations must be made and certified by an independent licensed professional engineer.
- System is a vapor barrier. Concrete should not be fully encapsulated in areas of freeze/thaw.

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01: PRODUCT IDENTIFICATION

8383 Riley Street,
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Product Name: Rhino Carbon Fiber 400 GSM Unidirectional

02: DESCRIPTION

Rhino Carbon Fiber 400 GSM Unidirectional is a high-strength, unidirectional carbon fiber fabric equipped with weft fibers that keep the fabric stable. The material is field laminated using RCF Saturant-Adhesive Epoxy to form a carbon fiber reinforced polymer (CFRP) system used to strengthen structural concrete elements.

03: WHERE TO USE

- Increase load capacity of structural elements (Beams, Slabs, Columns, Walls, Etc.)
- Restore structural integrity of damaged or deteriorated structural elements
- Repair for damaged or missing reinforcing steel/post tensioning
- Improved blast resistance of concrete, masonry, or stone in mining operations
- Additional Reinforcement to repair/withstand seismic events

04: ADVANTAGES

- Used for shear, confinement or flexural strengthening
- Flexible, can be wrapped around complex geometries
- High-Strength
- Lightweight
- Non-corrosive
- Alkali Resistant
- Low aesthetic impact
- Economical

05: TYPICAL DATA

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Storage Conditions	Store dry at 40° - 95°F (4° - 35°C)
Shelf Life	2 years from date of production
Color	Black
Primary Fiber Direction	0° (Unidirectional) - Carbon
Areal Density / Weight	400g/m^2 (11.80 oz/yd^2)

DRY FIBER PROPERTIES		
	Imperial	Metric
Thickness	-0.00866 in	-0.22 mm
Tensile Strength	≥493 ksi	≥ 3400 MPa
Tensile Modulus	≥33358 ksi	≥230 GPa
Elongation at Break %	1.6%	1.6%

TECHNICAL INFORMATION & COMPOSITE PROPERTIES					
	Tested/Experimental Average Value		Design Value		Testing Method
	Imperial	Metric	Imperial	Metric	
Thickness	0.027 in.	0.68 mm	0.027 in.	0.68 mm	ASTM D3039
Tensile Strength	150 ksi	1033.5 MPa	129 ksi	887.8 MPa	ASTM D3039
Tensile Modulus	10620 ksi	73.2 GPa	8790 ksi	60.6 GPa	ASTM D3039
Elongation at Break %	1.40%	1.40%	1.17%	1.17%	ASTM D3039
Tensile Strength per Unit Width	4047 lbs/in.	0.709 kN/mm	3477 lbs/in.	0.609 kN/mm	ASTM D3039

[A]Load and Chord Stiffness per Unit are computed based on CFRP laminate specimen width
*20 sample coupons per test series
[1]Average value of test series
[2]Average value minus 3 standard deviations per ACI440

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06: HOW TO USE – SURFACE PREP

Surface must be clean, sound, and dry. Remove a light layer of concrete from the surface to allow the epoxy to penetrate the substrate. Typical methods include shot blasting or grinding to achieve this open textured surface. Consult the epoxy adhesive data sheets for additional information on surface preparation.

Existing uneven surfaces must be filled with an appropriate repair mortar/hydraulic cement. The adhesive strength of the concrete must be verified after surface preparation by random pull-off testing (ASTM D-4541) at the discretion of the engineer. Minimum tensile strength, 200 psi (1.4 MPa) with concrete substrate failure.

Round all corners to 1/2" radius in certain “contact critical” applications and at the engineers discretion, a thorough cleaning of the substrate using low pressure sand or water blasting may be sufficient.

07: APPLICATION

Apply a prime coat of epoxy to the substrate, work the carbon fiber into the epoxy, then add final layer of epoxy to ensure the material is properly saturated. The fabric may also be pre saturated using accepted industry techniques. In either case, installation of this system should be performed only by a trained contractor. In fiber direction, overlapping of the fabric must be at least 6 in or as per the project specifications. Overlapping sections of additional layers should be distributed in location free of other laps.

08: TOOLING & FINISHING

Fabric can be cut to appropriate lengths by using sharp heavy duty shears. Dull or worn cutting implements can damage, weaken or fray the fabric and their use should be avoided.

09: LIMITATIONS

•Design calculations must be made and certified by an independent licensed professional engineer.
•System is a vapor barrier. Concrete should not be fully encapsulated in areas of freeze/thaw.

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01: PRODUCT IDENTIFICATION

RHINO PRODUCTS USA
8383 Riley Street,
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Product Name: Rhino Carbon Fiber 200 GSM Unidirectional

02: DESCRIPTION

Rhino Carbon Fiber 200 GSM Unidirectional is a high strength, unidirectional carbon fiber fabric, equipped with weft fibers that keep the fabric stable. The material is field laminated using RCF Saturant-Adhesive Epoxy to form a carbon fiber reinforced polymer (CFRP) used to strengthen structural concrete elements.

03: WHERE TO USE:

Load Increases	• Increased loading capacity • Installation of heavy machinery in industrial buildings • Vibrating structures • Changes of building utilization • Meeting of changed standards or specifications
Seismic Strengthening	• Column wrapping • Masonry walls
Damage to Structural Parts	• Aging of construction material • Vehicle impact • Fire and blast resistance • Prevention of defects caused by earthquakes
Change in Structural System	• Removal of walls or columns • Removal of slab sections for openings
Design or Construction Defects	• Insufficient reinforcements • Insufficient structural depth

04: ADVANTAGES

- Used for shear, confinement or structural strengthening
- Flexible, can be wrapped around complex geometries
- High Strength
- Light Weight
- Non-corrosive
- Alkali Resistant
- Low aesthetic impact
- Fiber orientation tailor-made

05: DATA

Results may differ based upon statisical variations depending on mixing methods and equipment, temperature, application methods, test methods, actual site conditions and curing conditions.

Storage Conditions	Store dry at 40° - 95°F (4° - 35°C)
Shelf Life	Unlimited, if stored properly in original, unopened, undamaged packaging
Color	Black
Primary Fiber Direction	0° (Unidirectional) - Carbon
Areal Density / Weight	200 g/m^2 (5.9 oz/yd^2)

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DRY FIBER PROPERTIES		
Property	**Imperial**	**Metric**
Tensile Strength	~ 711 ksi	~ 4900 Mpa
Tensile Modulus	~ 36259 ksi	~ 250 GPa
Elongation at Break %	1.9%	

TECHNICAL INFORMATION & COMPOSITE PROPERTIES		
	Tested/Experimental Average Value	
Property	**Imperial**	**Metric**
Thickness	0.0087 in	0.22 mm
Tensile Strength	493 ksi	3400 MPa
Tensile Modulus	33359 ksi	230 GPa
Elongation at Break %	1.6%	

06: LAYOUT: SURFACE PREP

Surface must be clean and sound. It may be dry or damp, but free of standing water and frost. Remove a light layer of concrete from the surface work areas. Consult the current product data sheets for Rhino Carbon Fiber for additional information on surface preparation.

Existing uneven surfaces must be filled with an appropriate repair mortar/hydraulic cement. The adhesive strength of the concrete must be verified after surface preparation by r testing (ASTM D-4541) at the discretion of the engineer. Minimum tensile strength, 200 psi (1.4 MPa) with concrete substrate failure.

Preparation Work: Concrete - Blast clean, shot-blast or use other approved mechanical means to provide a roughened, open-textured surface.

Round all corners to ½" radius in certain “contact critical” applications and at the engineers discretion, a thorough cleaning of the substrate using low pressure sand or water blasting may be sufficient.

07: APPLICATION

Scarify the concrete surface using a dustless grinding system prior to placing the fabric. The fabric may be manually saturated using a plastic putty knife. Installation of this system should be performed only by a trained contractor. If overlapping the fabric, it must be overlapped 6" (15 cm).

08: TOOLING & FINISHING

Fabric can be cut to appropriate lengths by using scissors. Since dull or worn cutting implements can damage, weaken or fray the fabric, their use should be avoided.

09: LIMITATIONS

Design calculations must be made and certified by an independent licensed professional engineer. System is a vapor barrier. Concrete should not be fully encapsulated in areas of freeze/thaw.

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1.DESCRIPTION

RCF Saturant-Adhesive Epoxy is a two-component, 100% solids, moisture-tolerant, low to medium viscosity, high strength, low modu-lus, multi-purpose liquid epoxy adhesive. It meets the current ASTM C881 and AASHTO M235 Types I, II, IV,& V Grade 2, Classes B & C specifications.

2. WHERE TO USE

RCF Saturant-Adhesive Epoxy can be used for wet lay-up structural repairs with carbon fiber reinforced polymer (CFRP), fiberglass reinforced polymer (GFRP) and injections. Use to bond freshly mixed concrete to hardened concrete, to fill voids and cracks in concrete, masonry and other substrates. It can also be used as a binder in epoxy mortar, as an anchoring adhesive, or as a binder for high friction surface treatments (HFST) on concrete, asphalt or other substrates.

3. ADVANTAGES

- •High strength/low modulus structural adhesive
- •Made in America
- •Rapid cure formula
- •Convenient 1:1 mix ratio by volume

4. SHELF LIFE / STORAGE

24 month shelf life when stored in unopened containers in dry conditions and stored at 40°F-95°F (4°C-35°C)

5. TECHNICAL DATA

RCF™ Saturant-Adhesive Epoxy Technical Data	
Storage Conditions:	40°F – 95°F (5°C – 35°C).
Condition material to:	65°F – 85°F (18°C – 29°C) before using.
Mix Ratio	1:1 by volume
Viscosity	2,000 cps @77°F (25°C)
Gel Time (60 g mass)	25 minutes
Tack Free Time (73°F or 23°C)	3 to 5 hours
Tensile Properties (ASTM D638), 7 day cure Tensile Strength: Tensile Elongation:	 2,800 psi (19.3 MPa) 40%
Bond Strength (ASTM C882) 2 day cure: 14 day cure:	2,000 psi (13.8 MPa) 2,800 psi (19.3 MPa)
Compressive Properties (ASTM D695), 7 day cure Compressive Strength: Compressive Modulus:	 5,000 psi (34.5 MPa) 110,000 psi (760 MPa)
Compressive Strength (ASTM C579) 3 hour cure: 24 hour cure:	 1.500 psi (10.3 MPa) 5,000 psi (34.5 MPa)
Bond Strength (ASTM C1583/ACI 503R)	300 psi (2.0 MPa)
Flexural Strength (ASTM D790)	3,000 psi (20.9 MPa)
Shrinkage on Cure (ASTM D2566)	0.2%
Thermal Compatibility (ASTM C884)	Pass
Heat Deflection Temperature (ASTM D648)	120°F (49°C)
Water Absorption (ASTM D570)	0.2% (24 hr)
Chloride Ion Permeability (AASHTO T277)	0.0 coulomb

*NOTE: Epoxy cure is affected by temperature. Low temperatures will increase cure time, higher temperatures with decrease cure time.

6. MINIMUM CURING TIME

TEMPURATURE	50°	60°	70°	80°	90°
MINIMUM CURE TIME	10 HRS	6 HRS	4 HRS	3 HRS	2 HRS

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7. APPLICATION TEMPERATURE

Substrate and ambient air temperature between 40°F and 100°F (4°C and 38°C)

8. CONDITION PRODUCT

Condition cartridge and contents to a temperature of 65°F to 85°F (18°C to 29°C) for easier dispensing.

9. LIMITATIONS & WARNINGS

Minimum substrate temperature is 50⁰F (10⁰C). Do not thin. Solvents will prevent proper cure. Use oven-dried aggregate. Material is a vapor barrier after cure.

10. MANUFACTURER'S PRINTED INSTALLATION INSTRUCTIONS

For complete installation instructions on various applications using RCF Saturant-Adhesive Epoxy visit www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889.

11. SURFACE PREPARATION

RCF Saturant-Adhesive Epoxy is specially formulated for use as a saturant epoxy for CFRP. New concrete must be a minimum of 28 days old. Surfaces must be clean of all dirt, oil, debris, wax, grease or dust must be removed. Prepare the surface mechanically using a scarifier, sand blast, shot blast, bush hammer or other equipment that will provide a minimum surface profile of CSP3, as defined by ICRI 310.2R. A roughened surface that exposes the aggregate and/or pores of the substrate is imperative for good adhesion.

12. CLEAN UP

Clean tools and equipment with Tough Wipes by Rhino Carbon Fiber , a biodegradable formula that removes and neutralizes the epoxy. Do not allow epoxy to harden on equipment as cured material can only be removed mechanically.

13. SAFETY

Please refer to the SDS for RCF Saturant-Adhesive Epoxy published on our Website, www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889. This TDS sheet is not intended to list all Safety and Health Requirements necessary for the installation of these products. All Health and Safety Requirements required by OSHA shall be followed.

14. WARRANTY

Rhino Products warrants to the Buyer that this product is in good quality and conforms to the manufacturer's specifications in force on the date of manufacture and when used in accordance with the Installation Instructions and when stored as directed in the technical literature.

Manufacturer cannot warrant or guarantee any particular method of use, performance or application under any particular condition and Buyer is responsible for determining the suitability of intended purpose and assumes all risks therein. RCF shall not be liable for any injury, loss, cost of labor or consequential damages either directly, indirectly or incidentally, arising out of the use or misuse of any product sold by RCF or another distributor. If the product is proven to be in non-conformance, the Buyers sole remedy shall be a refund of the purchase price or replacement of product.

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1.DESCRIPTION

RCF Structural Epoxy Injection Resin is a two-component, 100% solids, moisture-insensitive, ultra-low viscosity, high strength, high modulus, multi-purpose liquid epoxy adhesive. It meets the current ASTM C881 and AASHTO M235, Type I, II, IV & V Grade 1, Classes B & C specifications.

2. WHERE TO USE

Use for pressure-injection of hairline cracks in structural concrete, masonry, etc. Can also be used for delamination injection, gravity feed filling of cracks in horizontal concrete and masonry. It is useful as an epoxy resin binder for epoxy mortar patching and overlay of interior, horizontal surfaces.

3. ADVANTAGES

- •Structurally restores integrity of concrete
- •High strength, high modules structural adhesive
- •Moisture tolerant
- •Solvent free
- •Ultra low viscosity for deep penetration
- •Convenient 2:1 mix ratio by volume
- •Made in America

4. SHELF LIFE / STORAGE

24 month shelf life when stored in unopened containers in dry conditions and stored a t 40°F-95°F (4°C-35°C)

5. TECHNICAL DATA

RCF™ Structural Epoxy Injection Resin Technical Data	
Storage Conditions:	40˚F – 95˚F (5˚C – 35˚C).
Condition material to:	65˚F – 85˚F (18˚C – 29˚C) before using.
Mix Ratio	2:1 by volume
Viscosity	100-500 cps
Gel Time (60 g mass)	45 minutes
Tack Free Time (73°F or 23°C)	3 to 5 hours
Tensile Properties (ASTM D638), 7 day cure Tensile Strength: Tensile Elongation:	 10,000 psi (67.0 MPa) 1.2%
Bond Strength (ASTM C882) 2 day cure: 14 day cure:	2,100 psi (14.5MPa) 2,200 psi (15.2 MPa)
Compressive Properties (ASTM D695), 7 day cure Compressive Strength: Compressive Modulus:	 11,000 psi (75.9 MPa) 300,000 psi (2,070 MPa)
Shear Strength (ASTM D732)	6,000 psi (41.4 MPa)
Flexural Strength (ASTM D790)	7,500 psi (51.7 MPa)
Shrinkage on Cure (ASTM D2566)	.001
Thermal Compatibility (ASTM C884)	Pass
Heat Deflection Temperature (ASTM D648)	123˚F (50˚C)
Water Absorption (ASTM D570)	0.3% (24 hr)

*NOTE: Epoxy cure is affected by temperature. Low temperatures will increase cure time, higher temperatures with decrease cure time.

6. APPLICATION

To pressure inject cracks:	Dispense product thru an appropriate static mixing nozzel into injection ports.
To Gravity feed cracks:	Blow v-notched crack with oil-free compressed air. Seal underside if cracks reflect through. Pour or dispense mixed epoxy into cracks. Repeat until completely filled.
To patch and grout:	Prime substrate with neat mixed epoxy. Place epoxy mortar using trowels before primer becomes tack-free.

7. CONDITION PRODUCT

Condition cartridge and contents to a temperature of 65°F to 85°F (18˚C - 29˚C) for easier dispensing.

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8. LIMITATIONS & WARNINGS

Minimum substrate temperature is 50˚F (10˚C). Do not thin. Solvents will prevent proper cure.

9. MANUFACTURER'S PRINTED INSTALLATION INSTRUCTIONS

For complete installation instructions on various applications using RCF Structural Epoxy Injection Resin visit www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889.

10. CLEAN UP

Clean tools and equipment with Tough Wipes by Rhino Carbon Fiber , a biodegradable formula that removes and neutralizes the epoxy. Do not allow epoxy to harden on equipment as cured material can only be removed mechanically.

11. SAFETY

Please refer to the SDS for RCF Structural Epoxy Injection Resin published on our Website, www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889. This TDS sheet is not intended to list all Safety and Health Requirements necessary for the installation of these products. All Health and Safety Requirements required by OSHA shall be followed.

12. WARRANTY

Rhino Products warrants to the Buyer that this product is in good quality and conforms to the manufacturer's specifications in force on the date of manufacture and when used in accordance with the Installation Instructions and when stored as directed in the technical literature.

Manufacturer cannot warrant or guarantee any particular method of use, performance or application under any particular condition and Buyer is responsible for determining the suitability of intended purpose and assumes all risks therein. RCF shall not be liable for any injury, loss, cost of labor or consequential damages either directly, indirectly or incidentally, arising out of the use or misuse of any product sold by RCF or another distributor. If the product is proven to be in non-conformance, the Buyers sole remedy shall be a refund of the purchase price or replacement of product.

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1. DESCRIPTION

RCF Polyurethane Injection Expanding Foam is a two-component, low viscosity, self-expanding polyurethane foam designed for sealing cracks in structural materials including concrete, masonry and wood through low pressure, gravity feeding injection. It has been designed to expand approximately 15 times its volume in non-confined, dry spaces.

2. WHERE TO USE

Use to fill voids and cracks in concrete, masonry or other substrates.

3. ADVANTAGES

•Ideal for vertical repairs through injection ports
•Interior and exterior applications
•Conveniently fits dual cartridge epoxy gun
•Expands to fill voids with or without water
•No messy self-mixing through static mixer nozzle
•Low viscosity – easy to inject and flows into small cracks
•Moisture tolerant and blocks moisture

4. SHELF LIFE / STORAGE

Shelf Life is 1 year from date of manufacture.

5. TECHNICAL DATA

PROPERTY	VALUE (MIXED)
Expansion (in dry conditions, unconfined)	15 times original volume
Color	Yellow - Brown
Solids (%)	100
Brookfield viscosity (cPs, RCVF #6 spindle @ 20 rpm, max)	450
Initial point of expansion/working time (77°F or 25°C)	3 minutes

NOTE: The above properties are typical characteristics not to be considered as specifications.

6. CURING TIME

RCF Polyurethane Injection Expanding Foam has a working time of 3 minutes at 77°F (25°C). At temperatures below 77°F (25°C) this product will take proportionately longer time to begin expanding. At temperatures above 77°F (25°C) it will take a proportionately shorter time to begin expanding. Thin layers (5 mil) will become tack-free in approximately 45 minutes 77°F (25°C).

7. APPLICATION TEMPERATURE

40°F (5°C) to 110°F (43°C). If ambient temperature is below 70°F (21°C), condition the cartridge to 70-75°F (21-24°C) for at least 1 hour before using it.

8. CONDITION PRODUCT

When the work environment or substrate falls below 70˚F (21˚C) condition the product to 70-75˚F (21˚C - 24˚C) prior to use. Temperature will affect the workability and cure time of epox y.

9. APPLICATION

Dispense product through the supplied static mixing nozzles into injection ports.

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10. LIMITATIONS & WARNINGS

- Minimum age of concrete must be 21-28 days from date of placement depending on curing and drying conditions.
- Subject to discolouration upon exposure to UV light

11. MANUFACTURER'S PRINTED INSTALLATION INSTRUCTIONS

For complete installation instructions on various applications using RCF Polyurethane Injection Expanding Foam visit www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889.

12. SURFACE PREPARATION

Remove dust, dirt, grease, laitance, curing compounds and other foreign matter by sandblasting, mechanical abrasion or hydro blasting. For drilled holes, clean with a nylon bristle brush. Remove all water and dust with clean compressed prior to installation. RCF Polyure-thane Injection Expanding Foam has a low viscosity to reach most cracks, and upon expansion and will penetrate all thin cracks.

13. CLEAN UP

Clean tools and equipment with Tough Wipes by Rhino Carbon Fiber , a biodegradable formula that removes and neutralizes the epoxy. Do not allow epoxy to harden on equipment as cured material can only be removed mechanically.

14. SAFETY

Please refer to the SDS for RCF Polyurethane Injection Expanding Foam published on our Website, www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889. This TDS sheet is not intended to list all Safety and Health Requirements necessary for the installation of these products. All Health and Safety Requirements required by OSHA shall be followed.

15. WARRANTY

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01: PRODUCT IDENTIFICATION

RHINO PRODUCTS USA
8383 Riley Street,
Zeeland, MI USA 49694

Product Name: Rhino Carbon Fiber Concrete Crack Lock® stitch

02: DESCRIPTION

The Rhino Carbon Fiber Concrete Crack Lock® stitch (CCL) is a revolutionary new product that was developed to improve concrete crack repair. The CCL is installed by making a single blades width cut across the crack and drilling two holes along the cut at the appropriate locations. Once the preparation is complete and free of dust, it is filled with RCF High Strength Anchoring Epoxy Paste and the CCL is inserted. Once installed, the CCL permanently bonds both sides of the crack together. Due to the unique shape of the CCL and the preparation in the concrete, the tensile strength of the carbon fiber is relied upon as well as the epoxy bond strength along its length.

03: WHERE TO USE:

The Rhino Carbon Fiber Concrete Crack Lock® stitch has been engineered to stop cracks in concrete slabs, poured walls, masonry, concrete block foundations, columns, industrial buildings, bridges, and foundations. The Rhino Carbon Fiber Concrete Crack Lock® stitch is designed for cracks of various sizes under virtually any circumstance. It can also be used to increase seismic strength to repairs after an earthquake.

04: ADVANTAGES

- •High Strength
- •Non-Corrosive
- •Alkali Resistant
- •Minimal Aesthetic Impact
- •Minimally Intrusive
- •Shape Maximizes Strength

05: TYPICAL DATA

RESULTS MAY DIFFER BASED UPON STATISTICAL VARIATIONS DEPENDING UPON MIXING METHODS AND EQUIPMENT, TEMPERATURE, APPLICATION METHODS, TEST METHODS, ACTUAL SITE CONDITIONS AND CURING CONDITIONS.

Storage Conditions	Store dry at 40° - 95°F (4° - 35°C)
Shelf Life	10 years
Color	Black
Primary Fiber Direction	unidirectional

FIBER PROPERTIES		
Property	English	Metric
Tensile Strength		
Tensile Modulus	36.3 Msi	250 GPa
Strain	2%	2%
Density	0.065 lbs / in3	1.79 g/cm3
Nominal Fiber Thickness	0.0175 in.	0.4445 mm

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Concrete Crack Lock® stitch properties		
Property	English	Metric
Tensile Strength	180,000 psi	1241 MPa
Web Thickness	.048 in	1.40 mm
Web Width	.455 in	10.67 mm

06: LAYOUT: SURFACE PREP

The surface of concrete must be clean and free of loose debris. Lay out the individual crack locks by marking the crack every 8" to 12". Then trace the crack locks at each location and orient them at roughly 90 degrees to the crack (a simple template may also be used). Vary the angle at each location slightly to reinforce the crack from moving in all directions.

Once the layout is complete, make the cuts across the crack using a .08 (2mm) thick cutting wheel and ensure that you are cutting to a minimum deph of 5/8" (16mm) for the entire length. This will allow sufficient epoxy cover over the CCL's. Once the cuts are made, drill 1/2" (13mm) diameter holes at the appropriate locations on the ends of the cuts to accept the CCL.

Hint: once one end is drilled, re-check the spacing prior to drilling the second end. Also 5/8" (16mm) diameter holes may be drilled to help ensure proper fit even with a slight misalignment but this will use slightly more epoxy.

07: APPLICATION

Clean all loose debris from the preparation and fill with RCF High Strength Anchoring Epoxy Paste. Once the preparation is filled with epoxy, work the CCL into the preparation ensuring that all voids around it are filled and scrape any excess epoxy off of the surface. This material can be worked into the crack between the CCL. The crack needs to be filled by this method or by injection to stop any movement between the opposite sides of the crack.

08: TOOLING & FINISHING

Any tool that will accept a diamond saw blade suitable for cutting concrete will work to make the cuts across the crack. A tuck point grinder or slotting tool with dust shroud works best to minimize dust while allowing you to set the depth of the cut. Use any hammer drill with a ½" diameter masonry drill bit to drill the holes. Larger bits can be used but will require additional epoxy to fill the larger holes.

09: LIMITATIONS

•Design calculations must be made and certified by an independent licensed professional engineer.

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1. DESCRIPTION

RCF High Strength Anchoring Epoxy Paste is a two-component, 100% solids, moisture-insensitive, high strength, high modulus, multi-purpose liquid epoxy gel adhesive. It meets the current ASTM C881 and AASHTO M235 Types I, II, IV & V Grade 3, Classes B & C specifications. It has passed 4 million cycles of simulated seismic tension test.

2. WHERE TO USE

Use as an adhesive for setting/bonding subsurface or external reinforcements to concrete masonry or other substrates. Can also be used for reinforcing steel dowels, threaded rods, bolts, and inserts into existing concrete. Use as a multipurpose bond adhesive for structural bonding fresh or hardened concrete to hardened concrete, sealing cracks, setting injection ports prior to injection grouting, and as a pick-proof sealant.

3. ADVANTAGES

- Moisture tolerant
- High strength, high modules structural adhesive
- Made in America
- Convenient 1:1 mix ratio by volume
- Rapid cure formula
- Agency Independent testing lab certification
- Solvent free
- No-sag gel consistency

4. SHELF LIFE / STORAGE

24 month shelf life when stored in unopened containers in dry conditions and stored at 40°F-95°F (4°C-35°C)

5. TECHNICAL DATA

RCF High Strength Anchoring Epoxy Paste Technical Data	
Storage Conditions:	40˚F – 95˚F (5˚C – 35˚C).
Condition material to:	65˚F – 85˚F (18˚C – 29˚C) before using.
Mix Ratio	1:1 by volume
Viscosity	¼ inch no-sag gel
Gel Time (60 g mass)	10 minutes
Tack Free Time (73°F or 23°C)	2 to 3 hours
Tensile Properties (ASTM D638), 7 day cure Tensile Strength: Tensile Elongation:	 7,500 psi (51.7 MPa) 1.2%
Bond Strength (ASTM C882) 1 day cure: 7 day cure:	2,000 psi (13.8 MPa) 2,500 psi (17.2 MPa)
Compressive Properties (ASTM D695), 7 day cure Compressive Strength: Compressive Modulus:	 12,500 psi (86.2 MPa) 300,000 psi (2,070 MPa)
Shear Strength (ASTM D732)	2,800 psi (19.3 MPa)
Shrinkage on Cure (ASTM D2566)	0.001
Thermal Compatibility (ASTM C884)	Pass
Heat Deflection Temperature (ASTM D648)	140˚F (60˚C)
Water Absorption (ASTM D570)	0.1% (24 hr)

*NOTE: Epoxy cure is affected by temperature. Low Temperatures will increase cure time, higher temperatures with decrease cure time.

6. CONDITION PRODUCT

Condition cartridge and contents to a temperature of 65°F to 95°F (18˚C - 35˚C) for easier dispensing.

7. LIMITATIONS & WARNINGS

Minimum substrate temperature is 40˚F (5˚C). Do not thin. Solvents will prevent proper cure.

8. MANUFACTURER'S PRINTED INSTALLATION INSTRUCTIONS

For complete installation instructions on various applications using RCF High Strength Anchoring Epoxy Paste visit www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889.

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9. SURFACE PREPARATION

RCF High Strength Anchoring Epoxy Paste is an ideal bonding agent for multiple surfaces including concrete, brick, stone, block, and metal. Surfaces must be clean and profiled or textured. New concrete must be a minimum of 28 days old. All dirt, oil, debris, wax, grease or dust must be removed. Prepare the surface mechanically using a scarifier, sandblast, shot blast, bush hammer or other equipment that will give the surface profile needed for the application. A roughened surface that exposes the aggregate and/or pores of the substrate is imperative for good adhesion.

10. CLEAN UP

Clean tools and equipment with Rhino Carbon Fiber Tough Wipes, a biodegradable formula that removes and neutralizes the epoxy. Do not allow epoxy to harden on equipment as cured material can only be removed mechanically.

11. SAFETY

Please refer to the SDS for RCF High Strength Anchoring Epoxy Paste published on our Website, www.rhinocarbonfiber.com or call Rhino Products for more information at 1-888-684-3889. This TDS sheet is not intended to list all Safety and Health Requirements necessary for the installation of these products. All Health and Safety Requirements required by OSHA shall be followed.

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Certifications

CERTIFICATIONS

Our products meet the requirements of ACI 440.8

PROUD MEMBERS OF

560 GSM Bidirectional CFRP Tensile Test

400 GSM Unidirectional CFRP Tensile Test

Bond Strength Test

Full-Scale Structural Test

Glass Transition Temperature for Saturant-Adhesive

ICC-ES Evaluation Report

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June 2, 2016

Letter Report No. 102604618TOR-001
Project No. G102604618

AGT Products
2311 Royal Windsor Dr.
Mississauga, ON
L5J 1K5

Ph: 905 491 3884

Subject: Tensile Testing of Carbon Fibre Strips

This letter represents the results of tensile tests performed on five carbon fibre strips submitted directly to Intertek by AGT Products. Ten 1" wide x 10" long by 0.090" thick carbon fibre specimens were received at the Intertek laboratory in Mississauga, Ontario on May 26, 2016. Five of the ten specimens were cut in 2-1/2" lengths and served as pads when epoxied to the ends of the remaining five specimens. The specimens were tested June 1, 2016. This testing was authorized by signed proposal number Qu-0065608, dated May 11, 2016. Testing was conducted at the Intertek facility located at 6225 Kenway Drive, Mississauga, Ontario.

Each specimen consisted of one 1" wide x 10" long by 0.090" thick carbon fibre strip having two 2-1/2" long pads epoxied to and sandwiching the ends. Tests were performed in basic accordance with ASTM D3039/D3039M, "*Standard Test Method for Polymer Matrix Composite Materials*".

The following table summarizes the results of the tensile tests performed on the subject carbon fibre strips.

Specimen Number	Width (inches)	Thickness (inches)	Area (sq. inches)	Ultimate Load (lbf)	Tensile Strength (psi)	Failure Mode & Code
1	0.975	0.082	0.0799	7651	95,700	1" from top tab. LWT
2	0.974	0.088	0.0857	7439	86,800	Start of bottom tab. LAB
3	0.983	0.096	0.0944	8443	89,440	3/8" from top tab. LWT
4	0.996	0.096	0.0956	7283	76180	Start of top tab. LAB
5	0.972	0.088	0.0855	8424	98,530	1/2" from top tab. LWT
					Avg.89,330	

The average tensile strength of the five carbon fibre specimens was 89,330 psi.

Equipment Description	Intertek Equipment ID	Calibration due date
Baldwin/UTS Universal Testing Machine	280-01-0015	August 16, 2016
Digital Caliper	273 01 1196	May 19, 2017

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the undersigned.

Please note this Letter Report does not represent authorization for the use of any Intertek certification marks.

Reported by:	Vern Jones	Reviewed by:	Riccardo DeSantis
Title:	Senior Technologist, Building Products	Title:	Manager, Building Products Canada
Signature:		Signature	

CERTIFIED TEST REPORT

EVALUATION OF TENSILE PROPERTIES OF Rhino Carbon Fiber®
- Per ASTM D3039 -

Report Number: R-5.10_RCF_03-05-19
Date: March 5, 2019

REPORT PREPARED FOR:

RHINO
CARBON FIBER
REINFORCEMENT PRODUCTS

Rhino Products, INC
8383 Riley Street,
Zeeland, MI USA 49464
info@rhinocarbonfiber.com;
www.rhinocarbonfiber.com

Quality System: The Structures and Materials Laboratory (SML) maintains a quality system in compliance with ISO 17025-2017, accredited under International Accreditation Service (IAS), testing laboratory TL-478 and qualified laboratory by the Florida Department of Transportation (FDOT) number ISM028. All the test results presented herein are linked through unbroken chain data. Analyzed data is obtained directly from the recorded raw data during testing, from which the test results are presented. This report contains analyzed tabulated data results.

Procedures: All tests and services are done in accordance with the SML Quality Manual (Version 3.0) revised January 31, 2017; relevant standard operating procedures (SOPs); and with the applicable requirements of the reference standard test methods, unless otherwise stated.

Disclosure: This document may contain confidential information; please contact an authorized entity prior to distributing. Conclusions reached and opinions offered in this document are based upon the data and information available to at the time of its issue, and may be subject to revision as additional information or data becomes available.

Controls:	
Superseded Report	New report
Reason for Revision Effective Date	n/a March 5, 2019

Test Report Approval Signatures:	
Quality review Approval	I indicate that I have reviewed this Test Report and agree with the contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Francisco De Caso Signature: Date: March 5, 2019
Technical review Approval	I indicate that I have reviewed this Test Report and agree with the technical contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Antonio Nanni Signature: Date: March 5, 2019

1. TENSILE PROPERTIES – ASTM D3039

1.1. TEST SUMMARY INFORMATION

Project Name:	Quality control product evaluation
Test Objective:	Tensile Properties of Polymer Matrix Composite Materials
Test Standard Method/s:	ASTM D3039/D3039M – 17, Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials
Test Set-up:	Uniaxial tensile load was applied via a hydraulic universal test frame under displacement control rate of 2 mm/min (0.05 in./min); with a average grip pressure of 17.24 MPa (2500 psi). Refer to Figure 1.1.
Product:	Rhino Carbon Fiber®
Test Location:	Structures and Materials Laboratory, SML, University of Miami, 1251 Memorial Dr., MEB108 Coral Gables, FL, 33146
Analyst/s:	Montale Tuen
Technical Test Record:	TDS_D3039_RCF_400-330
Text Matrix:	Refer to Table 1.1
Sample Dimensions:	Length 254 mm (10 in.) and average measured thickness of 0.64 mm (0.025 in.). Width provided in results, Section 1.2.
Sample Preparation:	Rhino Products, INC. Refer to Figure 1.2.
Sample Conditioning:	24+ hours at 23 ± 1°C (73 ± 3°F) and 60 ± 5% RH
Specimen ID:	Specimens are labeled and uniquely identified for quality and traceability using the format PPPP_MMM_XX, where P is the product (RCF); M is the mechanical property (TNS for tensile strength); and X is specimen repetition number (1 to 18).

Table 1.1 – Test matrix for tensile testing

Specimen ID	Material Identification Lot /Batch/Roll # and Fabrication	Test date (mm.dd.yy)
RCF_TNS_01 to 05	N/A	02.27.18
RCF_TNS_06 to 10	N/A	02.28.19
RCF_TNS_11 to 18	N/A	03.04.19

1.2. TEST RESULTS

Table 1.2 - Tensile test results for Rhino Carbon Fiber® FRP system, per ASTM D3039

Specimen ID	Average width, w		Area, A		Peak load, P^{max}		Load/unit width, P^{max} / w		Strength, F^{tu}		Modulus, E^{chord}		Ultimate Strain, ε_u	Failure Mode*
	mm	in.	mm²	in²	kN	lbs	kN/mm	lbs/in.	MPa	ksi	GPa	Msi	%	
RCF_TNS_01	8.99	0.354	5.71	0.009	5.60	1260	0.62	3558	981.2	142.3	79.6	11.55	1.23	SGM
RCF_TNS_02	9.88	0.389	6.27	0.010	6.25	1405	0.63	3613	996.3	144.5	92.9	13.48	1.07	SGM
RCF_TNS_03	11.43	0.450	7.26	0.011	7.83	1759	0.68	3908	1077.9	156.3	77.6	11.26	1.39	SGM
RCF_TNS_04	9.80	0.386	6.23	0.010	6.54	1470	0.67	3808	1050.2	152.3	79.5	11.53	1.32	SGM
RCF_TNS_05	10.26	0.404	6.52	0.010	7.49	1682	0.73	4164	1148.4	166.6	84.7	12.29	1.36	SGM
RCF_TNS_06	9.70	0.382	6.16	0.010	6.68	1502	0.69	3932	1084.4	157.3	83.7	12.15	1.29	SGM
RCF_TNS_07	9.80	0.386	6.23	0.010	6.50	1461	0.66	3784	1043.6	151.4	78.9	11.45	1.32	SGM
RCF_TNS_08	9.58	0.377	6.08	0.009	6.38	1433	0.67	3802	1048.4	152.1	78.9	11.45	1.33	SGM
RCF_TNS_09	9.75	0.384	6.19	0.010	6.19	1392	0.63	3624	999.4	144.9	79.7	11.57	1.25	SGM
RCF_TNS_10	10.31	0.406	6.55	0.010	6.43	1445	0.62	3558	981.3	142.3	78.5	11.39	1.25	SGM
RCF_TNS_11	9.50	0.374	6.03	0.009	6.35	1426	0.67	3813	1051.5	152.5	77.1	11.19	1.36	SGM
RCF_TNS_12	9.86	0.388	6.26	0.010	7.06	1587	0.72	4089	1127.8	163.6	86.5	12.55	1.30	SGM
RCF_TNS_13	9.63	0.379	6.11	0.009	6.99	1571	0.73	4144	1142.8	165.8	97.6	14.16	1.17	SGM
RCF_TNS_14	9.09	0.358	5.77	0.009	6.56	1474	0.72	4118	1135.7	164.7	85.5	12.41	1.33	SGM
RCF_TNS_15	10.34	0.407	6.56	0.010	7.45	1675	0.72	4114	1134.7	164.6	78.8	11.44	1.44	SGM
RCF_TNS_16	8.23	0.324	5.23	0.008	5.45	1226	0.66	3783	1043.2	151.3	75.2	10.91	1.39	SGM
RCF_TNS_17	9.80	0.386	6.23	0.010	6.02	1352	0.61	3503	966.2	140.1	81.0	11.75	1.19	SGM
RCF_TNS_18	9.73	0.383	6.18	0.010	5.62	1263	0.58	3298	909.5	131.9	77.8	11.29	1.17	SGM
Average	**9.76**	**0.384**	**6.20**	**0.010**	**6.52**	**1466**	**0.67**	**3812**	**1051.3**	**152.5**	**81.9**	**11.88**	**1.29**	
S_{n-1}	0.65	0.026	0.41	0.001	0.66	147	0.04	253	69.7	10.1	5.8	0.84	0.09	
CV((%)	6.7	6.7	6.7	6.7	10.1	10.1	6.6	6.6	6.6	6.6	7.1	7.1	7.3	

**Failure mode based on ASTM D3039 FIG.4, refer to this report Figure 1.3 for representative failure mode.*

1.3. VISUAL DOCUMENTATION

Figure 1.1 – Test set-up

Figure 1.2 – Representative test specimen prior testing
Scale in inches**.**

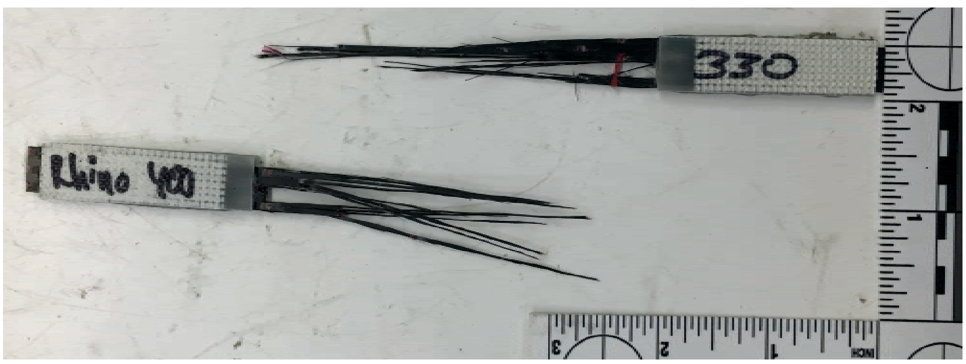


Figure 1.3 – Representative SGM failure mode, where ‘S’ is for longitudinal splitting;
‘G’ is at the gauge and ‘M’ middle. Scale in inches**.**

♦ END OF TEST REPORT ♦

CERTIFIED TEST REPORT

EVALUATION OF TENSILE BOND PULL-OFF STRENGTH OF EXTERNALLY BONDED COMPOSITE FRP SYSTEM

- Per ASTM D7234 / C1583 -

Report Number: R-5.10_RCF_03-15-19
Date: March 22, 2019

REPORT PREPARED FOR:

RHINO
CARBON FIBER
REINFORCEMENT PRODUCTS

Rhino Products, INC
8383 Riley Street,
Zeeland, MI USA 49464
info@rhinocarbonfiber.com;
www.rhinocarbonfiber.com

Quality System: The Structures and Materials Laboratory (SML) maintains a quality system in compliance with ISO 17025-2017, accredited under International Accreditation Service (IAS), testing laboratory TL-478 and qualified laboratory by the Florida Department of Transportation (FDOT) number ISM028. All the test results presented herein are linked through unbroken chain data. Analyzed data is obtained directly from the recorded raw data during testing, from which the test results are presented. This report contains analyzed tabulated data results.

Procedures: All tests and services are done in accordance with the SML Quality Manual (Version 3.0) revised January 31, 2017; relevant standard operating procedures (SOPs); and with the applicable requirements of the reference standard test methods, unless otherwise stated.

Disclosure: This document may contain confidential information; please contact an authorized entity prior to distributing. Conclusions reached and opinions offered in this document are based upon the data and information available to at the time of its issue, and may be subject to revision as additional information or data becomes available.

Controls:	
Superseded Report	New report
Reason for Revision Effective Date	n/a March 22, 2019

Test Report Approval Signatures:	
Quality review Approval	I indicate that I have reviewed this Test Report and agree with the contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Francisco De Caso Signature: [signature] Date: March 22, 2019
Technical review Approval	I indicate that I have reviewed this Test Report and agree with the technical contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Antonio Nanni Signature: [signature] Date: March 22, 2019

1. BOND STRENGTH: TENSION (BTU) – ASTM D7234

1.1. EXECUTIVE SUMMARY

The externally bonded carbon fiber reinforced polymer (FRP) strengthening system evaluated herein meets and exceeds the minimum required bond strength to substrate in accordance to the requirements of ICC Evaluation Service (ICC-ES) ‘Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer Composite Systems’ (AC 125); as well as within the American Concrete Institute (ACI) Committee 440, ‘Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures’ (ACI 440.2R-17); which states that in bond-critical applications, the tensile bond strength should be at least 200 psi (1.4 MPa) and should exhibit failure of the concrete substrate determined by suing the pull-off type adhesion test.

1.2. TEST SUMMARY INFORMATION

Test Objective:	Determine the tensile bond, pull-off adhesion strength of externally bonded fiber reinforced polymer (FRP) matrix composite systems on concrete masonry substrate.
Test Standard Method/s:	ASTM D7234-12, Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers. ASTM C1583/C1583M-13, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method).
Product:	Unidirectional carbon FRP system compoased of UD-24V-400 fiber sheet and epoxy saturant, applied on solid plain concrete masonry units. The substrate surface was strengthened with one ply of the FRP system under evaluation.
Test Location:	Structures and Materials Laboratory, SML, University of Miami, 1251 Memorial Dr., MEB108 Coral Gables, FL, 33146.
Analyst/s:	Jose Manuel Palacios.
Specimen Preparation:	Structures and Materials Laboratory.
Specimen ID:	Specimens are labeled and uniquely identified for quality and traceability using the format PPPP_MMM_XX, where P is the product (UC-400); M is the mechanical property (BTU for bond tension on concrete masonry units); and X is specimen repetition number (1 to 8).
Text Matrix:	A total of eight tests per product were completed. Refer to Table 1.1.

Test Set-up:	Uniaxial tensile load was applied to a steel disk attached to a scoring area of the test specimen, using a coupling device, via an electro-mechanical universal test frame. Uniform load was applied via a displacement control rate of 1.27 mm/min (0.05 in./min).
Sample Dimensions:	Bonded surface diameter of 2026 mm^2 (3.14 in^2.) and maximum grove depth of 12mm (0.5 in.).
Sample Conditioning:	24+ hours at 23 ± 1°C (73 ± 3°F) and 60 ± 5% RH.
Technical Test Record:	TDS_D7234_RCF

Table 1.1 – Test matrix for bond tensile testing

Specimen ID	Material Identification Lot /Batch/Roll # and Fabrication	Test date (mm.dd.yy)
RCF-UC-400 BTU 01 to 08	UD-24V-400 RCF Saturant-Adhesive epoxy Sample made: 03/11/19	03.21.19

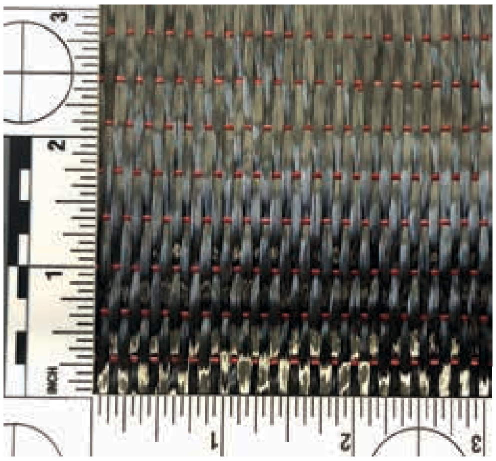
1.3. TEST RESULTS

Table 1.2 - Tabulated results for tensile bond pull-off adhesion tests for UC-24V-400, per ASTM D7234

Specimen ID	Area		T_l		T_S		Failure Mode	*Acceptance Criteria**
	mm^2	in^2	N	lbf	*MPa*	psi		
RCF-UC-400 BTU-01	2026	3.14	4806	1080	2.4	344	A	Pass
RCF-UC-400 BTU-02	2026	3.14	4258	957	2.1	305	A	Pass
RCF-UC-400 BTU-03	2026	3.14	4784	1075	2.4	342	A	Pass
RCF-UC-400 BTU-04	2026	3.14	4170	937	2.1	299	A	Pass
RCF-UC-400 BTU-05	2026	3.14	5114	1150	2.5	366	A	Pass
RCF-UC-400 BTU-06	2026	3.14	4307	968	2.1	308	A	Pass
RCF-UC-400 BTU-07	2026	3.14	4136	930	2.0	296	A	Pass
RCF-UC-400 BTU-08	2026	3.14	3952	888	2.0	283	A	Pass
Average	**2026**	**3.14**	**4441**	**998**	**2.2**	**318**		
S_{n-1}	0	0.00	407	92	0.2	29		
CV((%)	0.0	0.0	9.2	9.2	9.2	9.2		

**Condition of acceptance is minimum tensile bond strength of 200 psi (1.4 MPa) and should exhibit failure of the concrete substrate (failure type A).*

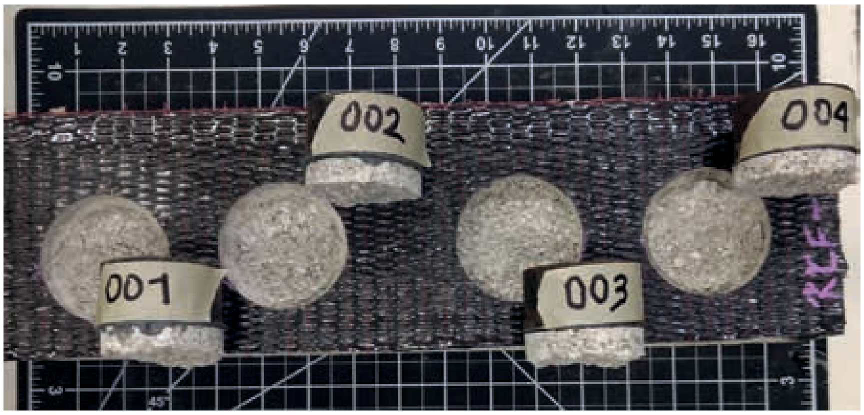
1.4. VISUAL DOCUMENTATION



(a)

(b)

Figure 1.1 – (a) Unidirectional carbon fiber sheet, UD-24V-400; and
(b) Representative test specimen prior attachment of circular disk. Scale in inches



(a)

Figure 1.2 – Representative cohesive type failure modes (within the substrate)

♦ END OF TEST REPORT ♦

CERTIFIED TEST REPORT

STRUCTURAL EVALUATION OF *Rhino Carbon Fiber* FRP STRENGTHENING COMPOSITE SYSTEM FOR MASONRY CONCRETE WALL UNDER OUT-OF-PLANE LOADING

- Per ICC-ES AC125 -

Report Number: R-5.10_RCF_01-16-19
Date: November 15, 2019

REPORT PREPARED FOR:

RHINO
CARBON FIBER REINFORCEMENT PRODUCTS

Rhino Products, INC
8383 Riley Street,
Zeeland, MI USA 49464
info@rhinocarbonfiber.com;
www.rhinocarbonfiber.com

Quality System: The Structures and Materials Laboratory (SML) maintains a quality system in compliance with ISO 17025-2017, accredited under International Accreditation Service (IAS), testing laboratory TL-478 and qualified laboratory by the Florida Department of Transportation (FDOT) number ISM028. All the test results presented herein are linked through unbroken chain data. Analyzed data is obtained directly from the recorded raw data during testing, from which the test results are presented. This report contains analyzed tabulated data results.

Procedures: All tests and services are done in accordance with the SML Quality Manual (Version 3.0) revised January 31, 2017; relevant standard operating procedures (SOPs); and with the applicable requirements of the reference standard test methods, unless otherwise stated.

Disclosure: This document may contain confidential information; please contact an authorized entity prior distributing. Conclusions reached and opinions offered in this document are based upon the data and information available to at the time of its issue, and may be subject to revision as additional information or data becomes available.

Controls:	
Superseded Report	New report
Reason for Revision Effective Date	n/a November 15, 2019

Test Report Approval Signatures:	
Quality review Approval	I indicate that I have reviewed this Test Report and agree with the contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Francisco De Caso Signature: ______________________ Date: November 15, 2019
Technical review Approval	I indicate that I have reviewed this Test Report and agree with the technical contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Antonio Nanni Signature: ______________________ Date: November 15, 2019

EXECUTIVE SUMARY

Based on the qualification test results presented herein, the Rhino Carbon Fiber has met the requirements as externally bonded FRP strengthening system for masonry concrete wall under out-of-plane (flexural/bending) loading, following the guidelines of *Acceptance Criteria for Concrete and Reinforced and Unreinforced Reinforced Strengthening Using Externally Bonded Fiber-Reinforced Polymer Composite Systems* (AC 125) part of the International Code Council Evaluation Service (ICC-ES). Note that the tests resulted provided herein only address structural performance.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. PURPOSE

The purpose of this document is to report the experimental evidence to support the development of an International Code Council Evaluation Service (ICC-ES) Evaluation Report for Rhino Carbon Fiber for use as an externally bonded Fiber Reinforced Polymer (FRP) strengthening system for Concrete Masonry structures. The test plan is designed according to the requirements of the ICC-ES Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer Composite Systems (AC 125).

1.2. STRUCTURES AND MATERIALS LABORATORY (SML)

All tests presented in this report, including material sampling and specimen preparation, were performed by and under the supervision of the University of Miami, College of Engineering, Structures and Materials Laboratory, herein referred to as SML. This testing laboratory has met the requirements of the International Accreditation Service (IAS) AC89 (Accreditation Criteria for Testing Laboratories), has demonstrated compliance with ANS/ISO/IEC Standard 17025:2017, "General requirements for the competence of testing and calibration laboratories, and has been accredited for the test methods listed in the approved scope of accreditation under Testing Laboratory # TL-478.

1.3. DESCRIPTION OF PRODUCTS UNDER EVALUATION

The components of the FRP composite system, which is provided as a wall repair, being considered for structural evaluation and tested per AC125 is summarized below. Refer to Table 1.1 and Figure 1.1 for the summary of the FRP system component under evaluation

1.3.1. <u>Carbon Fabric (RCF-CF)</u>

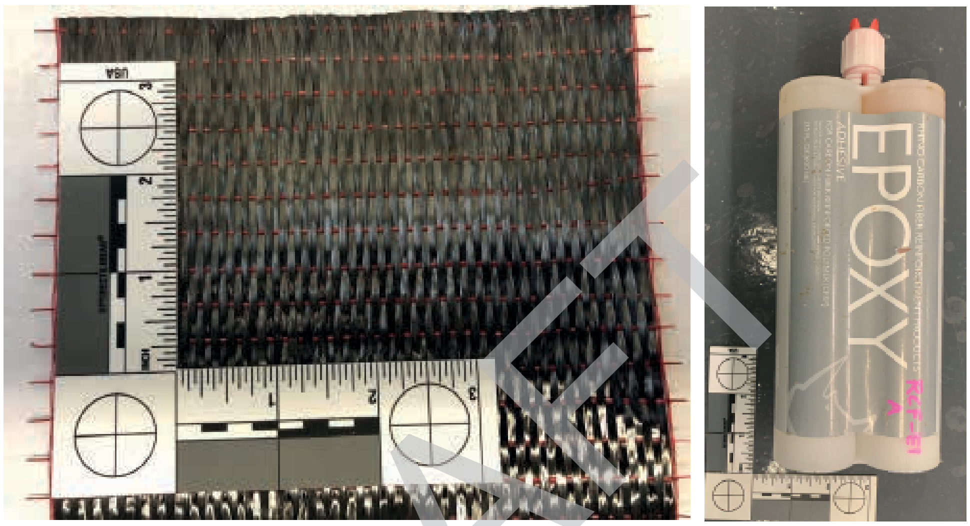
The RCF carbon fiber strap, herein referred to as RCF-CF, a high strength unidirectional carbon fiber fabric equipped with weft fibers that keep the fabric stable and has a minimum nominal fiber density of 400 gsm and a width of 140 mm (5.50 in.).

1.3.2. <u>RCF Epoxy (RCF-AE)</u>

The RCF saturant adhesive epoxy, herein referred to as RCF-AE, is a high strength two-part epoxy resin 100% solids, moisture-tolerant, with a low to medium viscosity. It meets the current ASTM C881 and AASHTO M235 Types I, II, IV,& V Grade 3, Classes B & C specifications per the manufacture. It is used for wet lay-up structural repairs to saturate the carbon fiber RCF-CF, and also used for injecting in voids and cracks on the substrate. RCF saturant adhesive epoxy comes in a cartridge container that uses a self

Table 1.1 - Summary of FRP system components under evaluation and reference ID

Component Description	Component ID
Unidirectional carbon fiber fabric sheet	RCF-CF
Saturant Adhesive Epoxy cartridge (Part A + B)	RCF-AE



(a) (b)

Figure 1.1 – FRP strengthening system under evaluation components:
(a) Carbon fiber, RFC-CF, and (b) Saturant adhesive epoxy cartridge, RCF-AE.

1.4. CLIENT INFORMATION

The test report has been requested by the applicant to the ICC-EC:

Rhino Products, INC
8383 Riley St, Zeeland, MI 49464, USA
888-684-3889
info@rhinocarbonfiber.com;
www.rhinocarbonfiber.com

2. TESTING OF REPRESENTATIVE PRODUCTS

2.1. PRODUCT SAMPLING

2.1.1. Sampling Guidelines

All the products tested and reported herein, were sampled following section 3.1 of AC85 and the SML standard operating procedures referred to in document SOP-5.7 at the manufacturing location under the supervision of SML personnel.

2.1.2. Product Sampling

Sampling RCF carbon fiber strap (RCF-CF) and RCF saturant adhesive epoxy (RCF-AE) was performed under the supervision of Analyst Dr. Francisco De Caso, on September 20, 2019, at the manufacturing location of Rhino Products, INC, at 8383 Riley St, Zeeland, MI 49464, USA. Overall, the products tested are truly representative of the standard manufactured products for which recognition is being sought.

2.1.3. Sampling Data Report

A full detailed sampling data report containing the sampling criteria, method, selection, and product information is described in the attached documents number **R-5.7_09.20.19_RCF.**

2.2. ACKNOWLEDGED AND INSPECTION OF PRODUCTS

Upon arrival of the products for evaluation to the testing laboratory, the packages were acknowledged and identified to account for all the products and their batch numbers for quality assurance purposes. All products were then individually inspected to ensure validity for testing, free of damage, contamination or other criteria deviating from being representative of the standard manufactured products as initially sampled based on SML standard operating procedures.

3. TEST DATA

3.1. RAW DATA

All the test results presented herein are linked through unbroken chain to the raw data files recorded on the day of the test. Details regarding raw data can be found in the technical test record completed at the time of the tests. Raw data is available upon request.

3.2. ANALYZED DATA

Analyzed data are obtained directly from the recorded raw data during testing, from which the test results are presented. This report contains analyzed tabulated data results of each test assessment. Additionally, as part of the standard operating procedures and quality assurance of the SML, intermediate checks of the data analysis are performed at various stages of the data analysis process reducing the possible analysis errors. Fully analyzed data files are available upon request.

3.3. REPORT PRESENTATION OF TEST RESULTS

Test results are presented in the subsequent chapters of this report (indicated with X in Table 3.1), structured in the following chapter sub-sections:

Table 3.1 – Chapter sub-sections structure

Sub-chapter	Title	Description
X.1	TEST SUMMARY	Contains test standard references, objectives, product under evaluation, test location, test technician and reference to test additional information.
X.2	TEST MATRIX	Contains number of specimens reported, specimen ID nomenclature and test matrix table.
X.3	SPECIMEN PREPERATION	Contains specimen size, layout (if applicable), and relevant specimen preparation procedures and conditioning parameters as needed.
X.4	TEST SET-UP	Contains test set-up information as well as the rate and method of loading.
X.5	TEST RESULTS	Contains a brief test summary, modes of failure, calculations and/or graphs results (if applicable), and complete tabulated results for all test specimens.

4. PRODUCT PREPARATION AND INSTALLATION

4.1. PRODUCT PREPARATION

The FRP wall repair strengthening system was installed on concrete masonry substrate. All system components were packaged in individual kits containing the necessary parts including: Instructions, carbon fabric, saturant adhesive epoxy cartridge tubes, and static epoxy mixing nozzle for cartridge tubes. Note that the other kit components not used include the sill plate bracket, bolts and washers. This last component is used as a means to anchor the carbon fabric to the masonry substrate. It was not used since the FRP wall repair strengthening system evaluation wanted to confirm the effectiveness of the FRP systems alone, thus the anchoring component was not part of the scope of work. I any case, anchoring method can improve the performance of FRP strengthening systems by delaying premature delamination. Refer in Figure 4.1, which shows a typical RCF wall repair FRP system components.

Figure 4.1 – RCF wall repair FRP system components

4.2. PRODUCT INSTALLATION

The preparation and production of FRP panels for specimen testing of the product under evaluation was performed by trained personnel following the manufacturer's instructions and recommendations and as highlighted in the installation instructions (Rhino Carbon Fiber Bowed Wall Instructions), the installation process is represented in Figure 4.2.

4.3. QUALITY CONTROL

Quality control checks was performed throughout the experimental testing process from the fabrication of masonry walls to installation of the FRP on substrate. These checks included: proper surface preparation, ensuring manufacture's installation was applied, filling cracks and voids, alignment, removal of air pockets, removal of excess resin, monitoring environmental conditions and proper trained personnel.

4.4. PRODUCT HANDLING

All the FRP material components were handled based on the manufacturer's specifications and laboratory internal procedures. All products have a unique batch number recorded during sampling, this number was tracked to individual test specimens as referenced in this report.

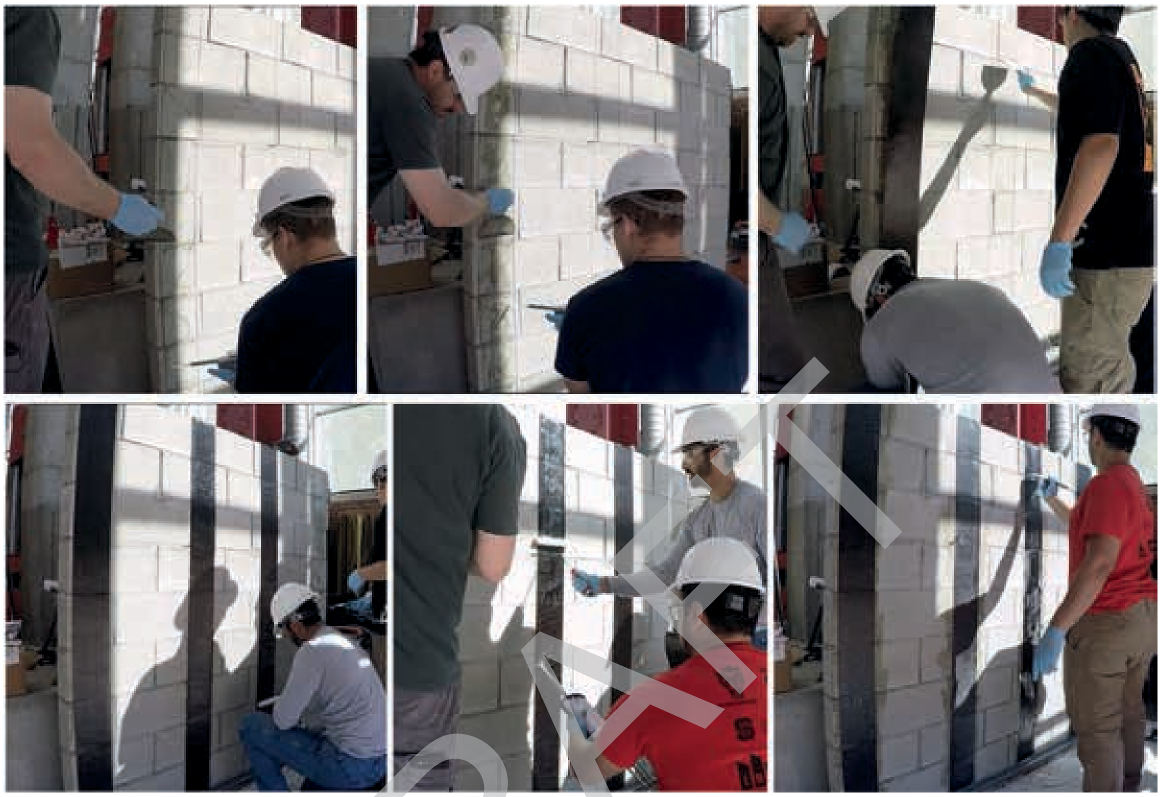


Figure 4.2 – Installation process of RCF FRP system on flexural CMU walls

4.5. SPECIMEN ID NOMENCLATURE

Test specimens have been uniquely labeled and identified for quality and traceability purposes using the following format: CC_TTT-S_RRR_D, where, CC refers to company name, TTT refers to the structural test type and element, S refer to the substrate type, RRR refers to the reinforcement strengthening scheme being used and X is the nominal design extreme limits. The detailed nomenclature is summarized in Table 4.1.

Table 4.1 – Specimen identification for characterization tests

Parameter description	Detail	ID
CC: Company name	Rhino Products, INC	RP
TTT: Structural test and element	Wall Static Flexure (out-of-plane)	WSF
S: Substrate type	Concrete Masonry Unit (CMU)	U
RRR: Reinforcement scheme	Control/benchmark (unstrengthened)	REF
	Rhino Carbon Fiber^{TM}	RCF
D: Design extreme limit (if applicable)	Nominal low design limit	L
	Nominal high design limit	H

5. WALL: FLEXURAL TEST

5.1. TEST SUMMARY

5.1.1. *AC125 Section/s*

Section 5.5.1 for Wall Flexural Tests (Out-of-Plane Load)

5.1.2. *Reference Standard/s*

Since no specific ASTM or other equivalent standard test methods are available, an internal laboratory-developed standard test procedure is used for the flexural wall (out-of-plane loading) tests under static loading, available upon request. The procedure was developed from good laboratory practices and extensive multi-university research test programs of masonry wall testing.

ASTM C90-16a, Standard Specification for Loadbearing Concrete Masonry Units

ASTM C140/C140M-17a, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.

NCMA TEK14-7B, National Concrete Masonry Association, Allowable Stress Design of Concrete Masonry.

5.1.3. *Test Objective*

The objective of the structural tests presented herein is to validate the structural performance of the FRP composite system under evaluation when applied to concrete masonry walls, with extreme FRP strengthening levels, subjected to flexural (out-of-plane) static loads.

5.1.4. *Product/s Under Evaluation*

Rhino Carbon Fiber™

5.1.5. *Test Location*

University of Miami, College of Engineering, Structures and Materials Off-Site Testing Location (OTL) Laboratory located at North Carolina State University at the Construction Facilities Laboratory (CFL).

5.1.6. *Laboratory Technician/s*

Greg Lucier and Francisco De Caso

5.2. TEST MATRIX

5.2.1. *Specimen Number and Identification*

Three concrete masonry unit (CMU) walls were tested, refer to Table 5.1 and Section 5.3 for additional details.

- One control wall (RP_WSF-U_REF);
- One nominal lower-bound design wall, which was composed of two RCF carbon fiber strips (RP_WSF-U_RCF_L); and
- One nominal higher-bound design wall, which was composed of four RCF carbon fiber strips (RP_WSF-U_RCF_H).

5.2.2. *Test Matrix Table*

Table 5.1– Test matrix for flexural CMU wall tests

Specimen ID	Material Identification Lot/Batch/Roll # and Fabrication	Wall Construction (mm.dd.yy)	FRP Installation (mm.dd.yy)	Tested (mm.dd.yy)
RP_WSF-U_REF	N/A	08.06.19	N/A	10.21.19
RP_WSF-U_RCF_L	TBD		10.23.19	11.01.19
RP_WSF-U_RCF_H				10.31.19

5.3. SPECIMEN PREPARATION

5.3.1. *Structural Specimen Properties*

All specimens were 1800 mm (72 in.) square unreinforced masonry walls with a thickness of 92 mm (3.625 in.). Walls were constructed from standard CMU blocks (nominal size 16x8x4 in.; actual dimensions 3-5/8x7-5/8x15-5/8 in.) and Type S mortar. The height to thickness aspect ratio was selected to exceed a magnitude of 14 to avoid arch effects and contributions. Nominal 9.5 mm (0.375 in.) wide bed and head joints were used. No continuous internal steel reinforcement was used, and CMU cores were left unfilled, representative of a conservative, lower bound wall specimen. The nominal compressive strength of masonry block, f'_m, met the required ASTM C90 specifications equal to 17.2 MPa (2490 psi) as provided by the block manufacturer; and the net experimental compressive strength was 18.7 MPa (2713 psi), based ASTM C140, refer to test set up in Figure 5.1.

Figure 5.1 – CMU Masonry block compression testing

5.3.2. *Specimen Layout*

The control (unstrengthen) specimen was tested as-fabricated. Strengthened specimens were used the RCF-CF fabric, saturated with the RCF-AE resin. RCF-CF straps with a width of 140 mm (5.5 in.), and nominal thickness of 1.02 mm (0.04 in.) were continuously installed for the full height of the wall. For the lower-bound design extreme level wall, two straps were bonded to the substrate at 1120 mm (44 in.) on-center; while for the higher-bound design extreme level, four straps were bonded to the substrate at 510 mm (20 in.) on-center the two central straps, and 560 mm (22 in.) the two outside (edge) straps, refer to the schematic in Figure 5.2.

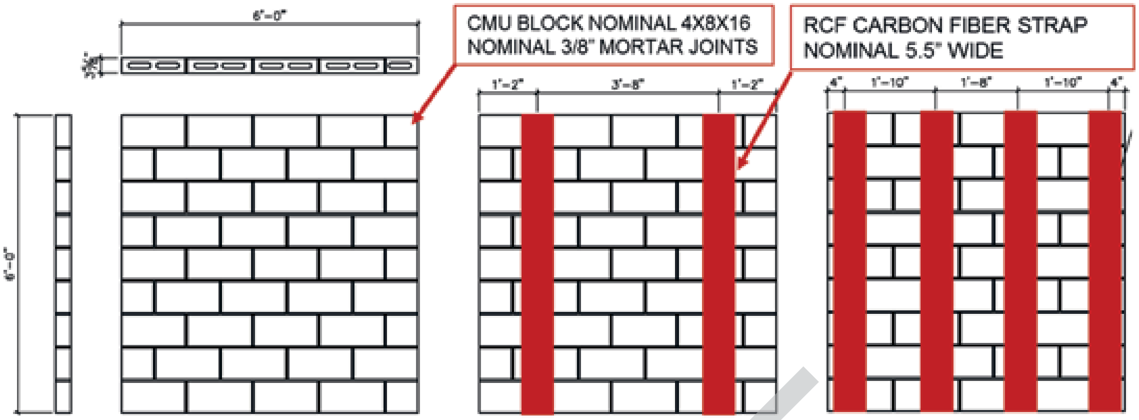


Figure 5.2 – RCF flexural CMU wall test specimens

5.4. TEST SETUP

All wall specimens were tested under an applied uniform distributed load using an airbag at a constant rate, placed between the test specimen and a strong reaction support. The test specimen was anchored back to the reaction support using four threaded rods and two square steel tube sections configured so that the wall would act in simple one-way bending in the height direction. The effective test span of the wall specimens was 1675 mm (66 in.). Strips of neoprene were inserted between the steel support tubes and the face of the specimen to avoid clamping the ends of the FRP strips and to reduce any localized bearing stresses at the reaction points.

The out-of-plane displacement at the mid-height of the wall specimen was measured at mid-width along with the mid-width deflection at each support (top and bottom) to account for initial potential settlements. Adhesively bonded strain gauges where also placed at mid-height of each FRP strap. Air pressure was applied to the bag at a controlled continuous rate directly to failure, and the pressure recorded with a pressure transducer to obtain the resultant applied distributed load. All data were recorded electronically at a rate of 1Hz. Photographs and video were taken of each test. The test setup is shown in Figure 5.3.

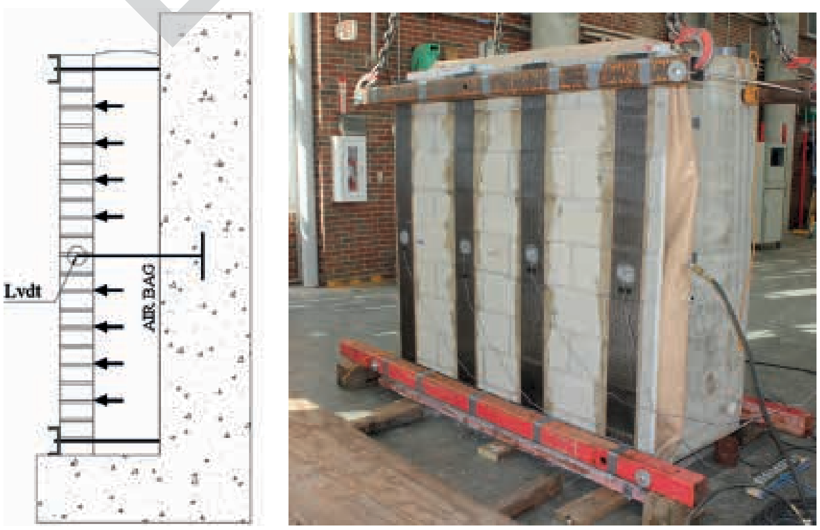


Figure 5.3 – RCF flexural CMU wall test setup, schematic (left) and laboratory view (right)

5.5. TEST RESULTS

5.5.1. Experimental Results Summary

The resultant flexural (out-of-plane) load capacity of the unstrengthen CMU wall was 20.4 kN (4.58 kips). Both strengthening configurations resulted in a significant increase in flexural (out-of-plane) stiffness and load carrying capacity as compared to the control CMU wall (no strengthening). Furthermore, cracking load capacities were also enhanced and a significant pseudo-ductility was observed as the overall increased ultimate out-of-plane deformation. No delamination from the substrate was observed, where the FRP system remained bonded to the substrate after ultimate failure and collapse of the wall. Failure modes of the wall specimens is described in detail in the next section. The results for all tests are summarized in Table 5.2.

5.5.2. Modes of Failure

The observed failure modes are documented in this section and presented in Figure 5.4. The control (un-strengthened) CMU masonry wall specimen failed in bending as expected, due to the imposed out-of-plane loading, resulting in a large, continuous horizontal flexural crack at the joint at mid-height as expected. This crack continued to increase in width until failure was observed as complete collapse of the wall as the top half and bottom half effectively deformed as separate rigid bodies rotating about the horizontal flexural crack.

In the case of the strengthened walls, horizontal flexural cracking was not visually observed. The nominal low design extreme wall specimen (RP_WSF-U_RCF_L), deflected out of plane and continued to carry the load linearly and increasing strain in the FRP, with increasing imposed load. Load continued to increase and deformation was bi-linear and cracks developed diagonally between and across the FRP strips until the wall became unstable after sustaining a peak total applied load of 76.6 kN (17.2 kips), and then continued to deform out of plane until the CMU units at mid-height and mid-width collapsed out-of-plane.

In the case of the nominal high design extreme wall specimen (RP_WSF-U_RCF_H), the wall carried a sustained increasing load linearly without visual cracks until diagonal and horizontal cracks between and across FRP strips developed until sudden failure and collapse of the wall at the cracked locations. The wall ultimately failed after sustaining a maximum total applied load of 166.8 kN (37.5 kips).

(a)

(b)

(c)

Figure 5.4 – Individual failure modes of CMU flexural wall tests:
(a) RP_WSF-U_REF; (b) RP_WSF-U_RCF_L and (c) RP_WSF-U_RCF_H

5.5.3. Graphical Representation of Results

The total resultant applied load versus mid-span displacement (out-of-plane) response for the CMU wall structural test specimens is represented in Figure 5.5.

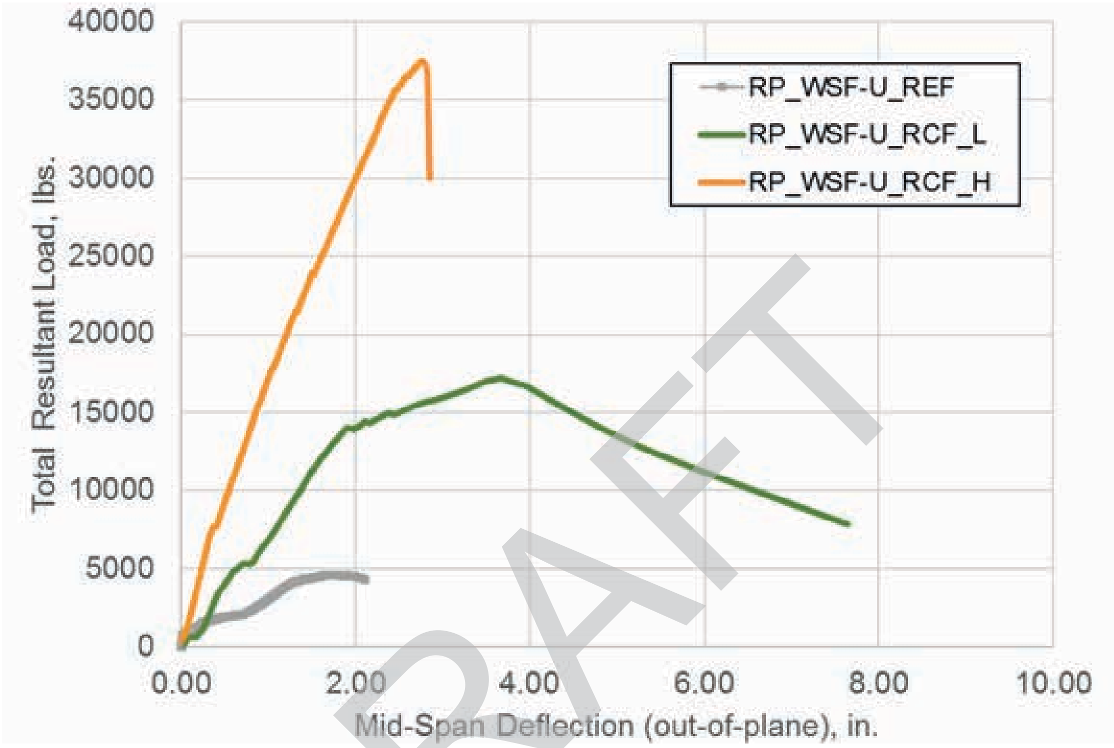


Figure 5.5 – Total resultant applied load versus mid-span displacement (out-of-plane) results for CMU wall flexure specimens

5.5.4. Tabulated Results

Table 5.2 contains the tabulated summary results for the flexural CMU wall shear tests. Table includes: total resultant applied force, unit applied force, resultant experimental moment and shear capacities, failure modes;

5.5.5. Theoretical Predictions

The theoretical predictions for the unstrengthen and strengthen walls are based on AC125, ACI 530 and ACI 440.7R-10, as applicable. The computed theoretical capacities do not reflect design capacities, since theoretical calculations assume FRP reduction, environmental and safety factors (ψf, CE and ϕ) are equal to 1.0, thus approximates to the experiment behavior. **Error! Reference source not found.** presents a summary theoretical capacities, the ratio between the experimental and theoretical capacities and the resultant acceptance criteria result per AC125.

5.5.6. Conclusions

Based on the results presented herein, the Rhino Carbon Fiber meets AC125 criteria as a Fiber Reinforced Polymer (FRP) strengthening system for flexural failure mode was eliminated, capacities were increased, and cracking loads were enhanced.

Table 5.2– Test results for flexural (out-of-plane) CMU walls

Specimen ID	Peak Applied Out-of Plane Load P_{max}		Peak unit load		*Resultant Experimental Moment Capacity* $M_{exp.}$		Resultant Experimental Shear Capacity $V_{exp.}$	
	kN	kips	kN / m / m	lbs / ft / ft	kN.m / m	lbs.ft / ft	kN / m	lbf / ft
RP_WSF-U_REF	20.37	4.58	617	139	217	525	6.08	416
RP_WSF-U_RCF_L	76.61	17.22	2322	522	816	1973	22.85	1435
RP_WSF-U_RCF_H	166.75	37.49	5053	1136	1775	4295	49.73	3124

Specimen ID	*Theoretical Moment Capacity* M_{des}		Theoretical Shear Capacity, V_{the}		Failure Mode	Acceptance Criteria Ratio Experimental to Theoretical*		Acceptance Criteria
	kN.m / m	lbs.ft / ft	kN / m	lbf / ft		Bending/Flexure	Shear	
RP_WSF-U_REF					Flexure	#DIV/0!	0.00	
RP_WSF-U_RCF_L					Shear	#DIV/0!	#DIV/0!	
RP_WSF-U_RCF_H					Shear	#DIV/0!	#DIV/0!	

**Refer to design examples per ACI 530 and ACI 440.7R-10, as applicable acceptance criteria ratio based on controlling failure.*

♦ **END OF TEST REPORT** ♦

CERTIFIED TEST REPORT

EVALUATION OF SATURANT-ADHESIVE EPOXY OF RHINO CARBON FIBER®

Report Number: R-5.10_TG_RCFA
Date: May 3, 2019

REPORT PREPARED FOR:

RHINO
CARBON FIBER
REINFORCEMENT PRODUCTS

Rhino Products, INC
8383 Riley Street,
Zeeland, MI USA 49464
info@rhinocarbonfiber.com;
www.rhinocarbonfiber.com

Quality System: The Structures and Materials Laboratory (SML) maintains a quality system in compliance with ISO 17025-2017, accredited under International Accreditation Service (IAS), testing laboratory TL-478 and qualified laboratory by the Florida Department of Transportation (FDOT) number ISM028. All the test results presented herein are linked through unbroken chain data. Analyzed data is obtained directly from the recorded raw data during testing, from which the test results are presented. This report contains analyzed tabulated data results.

Procedures: All tests and services are done in accordance with the SML Quality Manual (Version 3.0) revised January 31, 2017; relevant standard operating procedures (SOPs); and with the applicable requirements of the reference standard test methods, unless otherwise stated.

Disclosure: This document may contain confidential information; please contact an authorized entity prior to distributing. Conclusions reached and opinions offered in this document are based upon the data and information available to at the time of its issue, and may be subject to revision as additional information or data becomes available.

Controls:	
Superseded Report	New report
Reason for Revision Effective Date	n/a May 3, 2019

Test Report Approval Signatures:	
Quality review Approval	I indicate that I have reviewed this Test Report and agree with the contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Francisco De Caso Signature: Date: May 3, 2019
Technical review Approval	I indicate that I have reviewed this Test Report and agree with the technical contents it presents, and find it meets all applicable laboratory requirements and policies. I approve for its release to the customer. Name: Antonio Nanni Signature: Date: May 3, 2019

1. GLASS TRANSITION TEMPERATURE – ASTM E1640

1.1. TEST SUMMARY INFORMATION

Test Objective:	Determine the glass transition temperature (T_g) of the saturating resin under evaluation based on dynamic mechanical analysis (DMA) without any aging or environmental exposure, using the Loss Modulus procedure per AC125. Minimum 140°F (60°C) is required for control and exposed specimens.
Test Standard Method/s:	ASTM E1640-18 Standard Test Method for Assignment of The Glass Transition Temperature By Dynamic Mechanical Analysis.
Test Set-up:	A heating rate of 1°C/min (1°F/min) and a frequency of 1 Hz was applied, with sub-ambient of liquid nitrogen and elevated nitrogen.
Product:	RCF Epoxy Adhesive for Carbon fiber reinforced polymer (Refer to Table 1.1).
Test Location:	Structures and Materials Laboratory, SML, University of Miami, 1251 Memorial Dr., MEB108 Coral Gables, FL, 33146
Analyst/s:	Miguel Gonzalez.
Technical Test Record:	TDS_E1640_RCF_W01-TG
Text Matrix:	Refer to Table 1.1.
Specimen Dimensions:	Width 4.1 mm (0.16 in.) and thickness 1.9 mm (0.07 in.).
Sample Preparation:	Structures and Materials Laboratory.
Specimen Conditioning:	24+ hours at 23 ± 1°C (73 ± 3°F) and 60 ± 5% RH.
Specimen ID:	Specimens are labeled and uniquely identified for quality and traceability using the format PPPP_MMM_XX, where P is the product (A/B); M is the mechanical property (TG for glass transition temperature); and X is specimen repetition number (1 to 3).

Table 1.1 – Test Matrix For TG Testing

Specimen ID	**Material Identification Lot /Batch/Roll # and Fabrication**	**Test date (mm.dd.yy)**
RCF_TG_01 to 03	RCF Epoxy Adhesive 811152 Sample made: 03/11/19	04.02.19

1.2. TEST RESULTS

Table 1.2 – Tabulated results for glass transition temperature for RCF Epoxy Adhesive, per ASTM E1640

Specimen ID	T_g*	
	°C	**°F**
RCF-TG-01	49	121
RCF-TG-02	51	123
RCF-TG-03	49	120
Average	**50**	**121**
S_{n-1}	1	2
CV((%)	1.9	1.4

Condition of acceptance is equivalent to T_g > 60°C (140°F)

2. TOTAL ENTHALPHY OF POLYMERIZATION (DSC)

2.1. TEST SUMMARY INFORMATION

Test Objective:	Determine the degree of cure and glass transition temperature (Tmg) via differential scanning calorimetry (DSC), without any aging or environmental exposure.
Test Standard Method/s:	ASTM E2160-04 (Re-approved 2012), Standard test method for heat of reaction of thermally reactive materials by differential scanning calorimetry. ASTM D3418-15, Transition temperatures and enthalpies of fusion and crystallization of polymers by differential scanning calorimetry.
Test Set-up:	A heating rate of 10°C/min (50°F/min) and a frequency of 1 Hz was applied, with sub-ambient of liquid nitrogen and elevated nitrogen.
Product:	RCF Epoxy Adhesive for Carbon fiber reinforced polymer (Refer to Table 2.1)
Test Location:	Structures and Materials Laboratory, SML, University of Miami, 1251 Memorial Dr., MEB108 Coral Gables, FL, 33146
Analyst/s:	Miguel Gonzalez.
Technical Test Record:	TDS_E2160_RCF_DSC
Text Matrix:	Refer to Table 2.2.
Specimen Dimensions:	Width 2.6 mm (0.10 in.) and thickness 1.3 mm (0.05 in.)
Sample Preparation:	Structures and Materials Laboratory
Specimen Conditioning:	24+ hours at 23 ± 1°C (73 ± 3°F) and 60 ± 5% RH
Specimen ID:	Specimens are labeled and uniquely identified for quality and traceability using the format PPPP_MMM_XX, where P is the (RCF); M is the mechanical property (DC for Degree of cure and TG for glass transition temperature); and X is specimen repetition number (1 to 3).

Table 2.3 – Test Matrix For DC/TG Testing

Specimen ID	Material Identification Lot /Batch/Roll # and Fabrication	Test date (mm.dd.yy)
RCF-DC/TG_01 to 03	RCF Epoxy Adhesive 811152 Sample made: 03/11/19	04.19.19

2.2. TEST RESULTS

Table 2.4 – Tabulated results for RCF Epoxy Adhesive Samples A and B, per ASTM E2160

Specimen ID	Degree of Cure, DC*	T_g**	
	%	°C	°F
RCF_DC/TG_01	100	71	161
RCF_DC/TG_02	100	85	184
RCF_DC/TG_03	100	91	196
Average	**100**	**82**	**180**
S_{n-1}		10	18
CV((%)		12.1	9.9

** Note that the total heat of reaction (H_t), which is derived from the unreacted resin system (neat resin), is conservatively assumed value of 100 J/g to compute the degree of cure.*
**Condition of acceptance is equivalent to T_g > 60°C (140°F).*

♦ END OF TEST REPORT ♦

ICC-ES Evaluation Report

ESR-4071

Issued March 2022

This report is subject to renewal March 2023.

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DIVISION: 04 00 00—MASONRY
Section: 04 01 00—Maintenance of Masonry
Section: 04 01 20—Maintenance of Unit Masonry

REPORT HOLDER:

RHINO CARBON FIBER

EVALUATION SUBJECT:

RHINO CARBON FIBER™ CFRP SYSTEMS

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:

- Structural
- Durability

2.0 USES

The Rhino Carbon Fiber CFRP Systems are used to externally strengthen existing unreinforced masonry walls out-of-plane flexural strengths as an alternative to those systems permitted in the IBC, as described in Section 4.1 of this report. For structures regulated under the IRC, the Rhino Carbon Fiber CFRP Systems may be used where an engineering design is submitted in accordance with Section R301.1.3 and where approved by the code official in accordance with Section R104.11.

3.0 DESCRIPTION

3.1 General:

The Rhino Carbon Fiber CFRP Systems are externally bonded carbon fiber-reinforced polymer (FRP) composites applied to unreinforced masonry substrates. The Rhino Carbon Fiber CFRP Systems consist of carbon fabric adhered to the substrate with RCF Saturant-Adhesive Epoxy to create a FRP composite system.

3.2 Material:

3.2.1 General: All materials must comply with the approved specifications outlined in the Rhino Carbon Fiber™ CFRP Systems Quality Documentation.

3.2.2 Rhino Carbon Fabrics: The Rhino Carbon Fiber CFRP Systems are composed of 400U unidirectional carbon fiber fabric (400gr/1000m), and 560B bidirectional carbon fiber fabric (560gr/1000m), available in various widths.

3.2.3 Saturant-Adhesive Epoxy: RCF Saturant-Adhesive Epoxy is a two-component, liquid epoxy adhesive resin used to saturate the fabric sheets. The mixing ratio is 1:1 by volume for components A and B, respectively, provided in a self-mixing cartridge.

3.3 Rhino Carbon Fiber CFRP Composites:

3.3.1 Rhino Carbon Fiber CFRP 400U: In the primary direction, the Rhino Carbon FRP Composite has a design ultimate tensile strength of 129 ksi (889 MPa), design tensile modulus of 10620 ksi (73.2 GPa), and a corresponding design elongation of 1.21 percent. The layer thickness is 0.027 inches (0.68 mm).

3.3.2 Rhino Carbon Fiber CFRP (Bidirectional) 560B: In both directions (0º/90º), the Rhino Carbon FRP Composite has a design ultimate tensile strength of 94 ksi (648 MPa), design tensile modulus of 6890 ksi (47.5 GPa), and a corresponding design elongation of 1.36 percent. The layer thickness is 0.019 inches (0.48 mm).

3.4 Storage Recommendations:

The materials must be stored in temperatures between 32ºF and 104ºF (0ºC and 40ºC) with no exposure to moisture. When properly stored under these conditions, unopened adhesive epoxy saturant has a shelf life of 24 months, and carbon fabric has an unlimited shelf life.

4.0 DESIGN AND INSTALLATION

4.1 Design:

4.1.1 General: Design of the composite system must be based on required tensile loads at designated masonry strain values. The strength design requirements for masonry must be in accordance with Chapter 21 of the IBC, as applicable. The registered design professional must be responsible for determining, through analysis, the strengths and demands of the structural elements to be strengthened by the Rhino Carbon Fiber CFRP Systems, subject to the approval of the code official.

4.1.2 Composite Design Properties: Structural design properties for the Rhino Carbon Fiber CFRP Systems can be found in this report and Rhino Carbon Fiber CFRP Systems Design Manual, dated January 1, 2022, Revision 1.

4.1.3 Design Details: Structural design provisions for the composite system, as described in the Rhino Carbon Fiber CFRP Systems Design Manual, are based on test results and principles of structural analysis as prescribed in IBC Section 1604.4. Bases of design include strain compatibility, load equilibrium and limit states. All designs must follow procedures as detailed in the IBC; in the ICC-ES Acceptance Criteria for Concrete and Reinforced and

Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems (AC125), dated October 2019 (editorially revised December 2020); and applicable procedures detailed in the Rhino Carbon Fiber CFRP Systems Manual, dated January 1, 2002 Revision 1, 2022.

4.1.4 Design Strength: The design strengths must be taken as the nominal strength, computed in accordance with Section 4.1.3 of this report, multiplied by the strength reduction factors as prescribed in Chapter 21 of the IBC, as applicable.

4.1.5 Load Combination: The load combinations used in design must comply with Section 1605 of the IBC, as applicable.

4.1.6 Walls:

4.1.6.1 Potential Applications: The Rhino Carbon Fiber CFRP Systems is applied to unreinforced masonry walls to enhance out-of-plane flexural strengths.

4.1.6.2 Structural Design Requirements: Masonry design must comply with the Rhino Carbon Fiber CFRP Systems Design Manual and with Chapter 21 of the IBC, as applicable.

4.1.7 Bond Strength: Where the performance of the FRP composite material depends on bond, as determined by the registered design professional, the bond strength of the Rhino Carbon Fiber CFRP Systems to a properly prepared surface must exceed the tensile strength of the masonry substrate and must not be less than $2.5x(f'_m)^{0.5}$. Testing in accordance with ASTM C237, D7234 or D7522 may be used to estimate the bond strength of bond-critical installations. The test must indicate failure in the masonry wall substrate. Sufficient bond area must be used to prevent bond failure.

4.2 Installation:

4.2.1 General: The Rhino Carbon Fiber CFRP Systems must be installed on unreinforced masonry walls, as detailed in Installation Manual, dated January 1, 2022, Revision 1. A copy of the Installation Manual must be submitted to the code official for approval of each project that uses the Rhino Carbon Fiber CFRP Systems. Installation must be performed by approved applicators trained by the manufacturer in accordance with the published literature. Installation of the system is detailed in the Installation Manual.

4.2.2 Saturation: The Rhino Carbon Fiber CFRP Systems must be saturated with RCF Saturant-Adhesive Epoxy.

4.2.3 Application: The RCF Saturant-Adhesive Epoxy applied to the unreinforced masonry wall substrate using manual methods. Surface preparation, fiber orientation and removal of air bubbles and voids must be done in accordance with the Rhino Carbon Fiber CFRP Systems installation instructions.

4.2.4 Finishing: The Rhino Carbon Fiber CFRP Systems are fully adhered and covered with the RCF Saturant-Adhesive Epoxy which may be coated with paints that may be required for environmental and aesthetic reasons.

4.2.5 Cure Time Prior to Loading: The Rhino Carbon Fiber CFRP Systems must be allowed a minimum of 72 hours of cure time (depending on temperatures) prior to application of superimposed loading onto the structural element. Final determination of required cure time must be made by the registered design professional.

4.3 Special inspection:

Special inspection during the installation of the system must be in accordance with the ICC-ES Acceptance Criteria for Inspection and Verification of Concrete and Unreinforced Masonry Strengthening Using Fiber-reinforced Polymer (FRP) Composite Systems (AC178), dated October 2017 (editorially revised December 2020). A statement of special inspection must be prepared in accordance with Sections 1704.3 of the IBC. Inspection must also comply with Sections 1704 and 1705 of the IBC, as applicable.

5.0 CONDITIONS OF USE

The Rhino Carbon Fiber CFRP Systems described in this report complies with, or is a suitable alternative to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions. In case of conflict, this report governs.

5.1 Design and installation must be in accordance with this report, the manufacturer's Design and Installation Manuals dated January 1, 2022, Revision 1, and the IBC, or IRC, as applicable.

5.2 Copies of the Rhino Carbon Fiber CFRP Systems Design Manual and Installation Manual must be submitted to the code official for approval with each project using the system.

5.3 Complete construction documents, including plans and calculations verifying compliance with this report, must be submitted to the code official for each project at the time of permit application. The construction documents must be prepared and sealed by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.4 Use of Rhino Carbon Fiber CFRP Systems in interior applications where Flame Spread and Smoke Developed Index are required have not been evaluated and is outside the scope of this evaluation report.

5.5 Use of Rhino Carbon Fiber CFRP Systems in fire-resistance-rated assemblies has not been evaluated and is outside the scope of this evaluation report.

5.6 Use of Rhino Carbon Fiber CFRP Systems in full contact with drinking water has not been evaluated and is outside the scope of this evaluation report.

5.7 Special inspection must be provided in accordance with Section 4.3 of this report.

5.8 Application of Rhino Carbon Fiber CFRP Systems to unreinforced masonry walls at a fabricator's facility must be by an approved fabricator complying with Chapter 17 of the IBC, or at a jobsite with continuous special inspections in accordance with Chapter 17 of the IBC and Section 4.3 of this report.

5.9 Rhino Carbon Fiber CFRP Systems are provided by Rhino Carbon Fiber under a quality control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Fiber-reinforced Polymer (FRP) Composite Systems (AC125), dated October 2019 (editorially revised December 2020).

7.0 IDENTIFICATION

7.1 The components of the Rhino Carbon Fiber CFRP Systems described in this report are identified with a label indicating the name and address of the manufacturer (Rhino Carbon Fiber CFRP Systems), product names (fabric & saturant), saturant expiration date, and evaluation report number (ESR-4071).

7.2 The report holder's contact information is the following:

RHINO CARBON FIBER
8383 RILEY STREET
ZEELAND, MICHIGAN 49464
(888) 684-3889
www.rhinocarbonfiber.com

Case Studies

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REINFORCEMENT PRODUCTS

CASE STUDIES

PROJECT NAME	LOCATION	ENGINEER/CLIENT/CONSULTANT	PROJECT TYPE
Basement Crack Repair with Injection and CFRP Case Study	Oakville, Ontario	Pro Waterproofers	Concrete Repair and Waterproofing
Below Grade Gymnasium Wall Stabilization	Lincoln, Nebraska	Epp Concrete Construction	Concrete Strengthening
Block Wall Corner Repair	Pittsburgh, Pensylvania	Concrete Chiropractor	Concrete Strengthening
Case Studies Stadium Support Column Repairs	Jasper, Indiana	LAN Concrete Technology	Concrete Strengthening
Crack Repair and Confinement	Houston, Texas	Gadberry Construction Company	Concrete Strengthening
Flexure Beam Test	Heath, Ohio	Internal Test	Concrete Strengthening
High Rise Crack Repair	Nashville, Tennessee	Ground Up Builders, Inc.	Concrete Strengthening
Historical Water Tower Strengthening with CFRP	Clay City, Kansas	N/A	Concrete Strengthening
Masonry Wall Reinforcement Blast Loading Upgrade	Akron, Ohio	WALLFORCE Foundation Support Systems	Concrete Strengthening
Mission Home Services Crack Repair	Walkersville, Maryland	Mission Home Services	Concrete Strengthening
Pool Deck Crack Repair	San Francisco, California	American Restoration	Concrete Strengthening
Residential Bowed Wall Repair Case Study	Hastings, New York	EcoSpect, Inc.	Concrete Strengthening
Salt Barn Wall Failure Repairs	Cambridge, Ohio	The City of Cambridge, Ohio	Concrete Strengthening
Shoprite Facility Concrete Beam Strengthening - Trianon Shopping Park	Mauritius Island	PND Contracting	Concrete Strengthening
Slab Strengthening with Concrete Crack Lock® Stitches	Vaudreuil-Dorion, Quebec	N/A	Concrete Strengthening
Strengthening Concrete Silos with CFRP	Cupertino, California	N/A	Concrete Strengthening

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CRACK INJECTION & CFRP CASE STUDY

BASEMENT CRACK REPAIR WITH INJECTION AND CFRP

LOCATION
Oakville, Ontario

CLIENT
Pro Waterproofers

PRODUCTS USED

- RCF Polyurethane Injection Expanding Foam Kit
- Rhino Carbon Fiber Crack Repair Kit (Bidirectional)

ICC ES

CASE BACKGROUND

The owner of Pro Waterproofers was called out to inspect a water leak in the basement of a residential home in Oakville, Ontario after the homeowner noticed wet drywall in one corner of the basement. The homeowner also noticed a crack that extended above the soil line which was visible from the backyard. The wet drywall and insulation were removed, revealing a foundation crack.

Pro Waterproofers concluded that the **RCF Polyurethane Injection Expanding Foam Kit** along with the **Rhino Carbon Fiber Crack Repair Kit (Bidirectional)** would be the best option for the repair due to the bidirectional carbon fiber's strength in all directions.

Pro Waterproofers suggested to the homeowner that the crack be filled with expandable polyurethane foam to fill all the concrete capillaries and to waterproof the area, and then the entire crack would be strengthened with carbon fiber reinforced polymer (CFRP) to prevent the crack from expanding. The homeowner was thrilled to learn that CFRP is high-strength, cost-effective, resists corrosion and is easy-to-apply. Pro Waterproofers was hired by the homeowner to be the applicator for this repair.

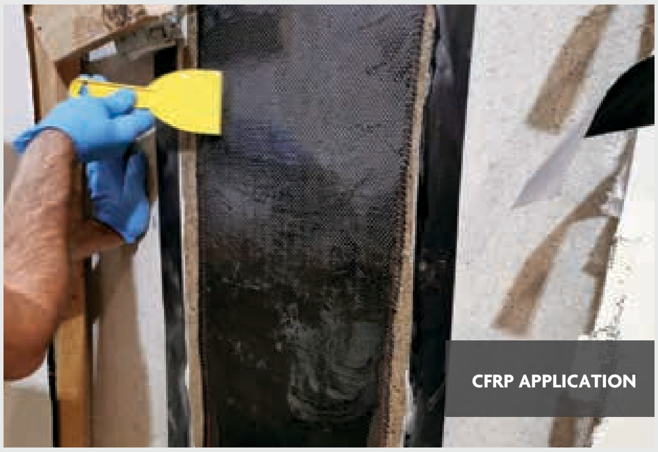
THE SOLUTION

The concrete surface was prepared prior to application. Pro Waterproofers used a rotary hammer and chisel to remove any loose debris in and around the crack, filled small cracks at the bottom of the main crack with quick-setting structural repair mortar, then used a grinder with dust-collection shroud to create a clean and rough surface to ensure a strong epoxy bond (a dust extractor with HEPA filter was used to keep the dust to a minimum).

Injection ports were then applied over the crack approximately 18" apart with **RCF High Strength Anchoring Epoxy Paste** . Once the anchoring epoxy paste adhering the ports to the wall cured, the **RCF Polyurethane Injection Expanding Foam** was slowly injected into the ports one at a time, starting at the bottom, until the entire cavity was filled. Water in the crack acted as a catalyst for the polyurethane foam as it expanded to 15x its volume, preventing further leakage. Polyurethane foam extruded from the top of the wall as well as from the other side of the crack in the backyard. Once the polyurethane foam cured, the injection ports were cut off with a saw as to not disturb the smooth and cured anchoring epoxy paste around the ports, and the port cavities were filled with more anchoring epoxy paste to create a smooth application surface for CFRP. As a final step, the **Rhino Carbon Fiber Crack Repair Kit (Bidirectional)** was applied over the surface of the crack. The 8-foot long, 12-inch wide strap of CFRP covered the entire crack as well as some of the surface area on either side of the crack. Most crack repairs stop at the injection stage but the crack can continue to spread as the main purpose of injection material is waterproofing and not structural strengthening. Strengthening the cracked area with CFRP is an essential step to prevent further movement and crack expansion, and adds an additional layer of protection for waterproofing. The homeowner was very pleased with how neat and professional the repair turned out.


CRACK PREPARATION


CRACK INJECTION


CFRP APPLICATION


COMPLETED REPAIR

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RHINO CARBON FIBER REINFORCEMENT PRODUCTS

CFRP CASE STUDY

BELOW GRADE GYMNASIUM WALL STABILIZATION

LOCATION
Lincoln, Nebraska

CLIENT
Epp Concrete Construction

PRODUCTS USED

- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM, 24" Wide
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The Epp Concrete Construction company was contracted to repair a bowing gymnasium wall in a below grade project they were working on. They determined that CFRP was the appropriate solution for the repair. Typically, bowed wall repair systems are installed on walls from crawl space height to anywhere from 7' to 10' in height; in this case, the wall was 18' tall. To complicate matters further, there were four large windows on the wall.

Prior to addressing the bowing wall, a drainage issue on the exterior of the building had to be addressed since the saturated soil had been a major contributor to bowing walls. There was a parking lot adjacent to the gymnasium which sloped such that the runoff was directed toward the back of this wall. The drainage issue was remedied by removing a portion of the parking lot and installing a paved gutter.

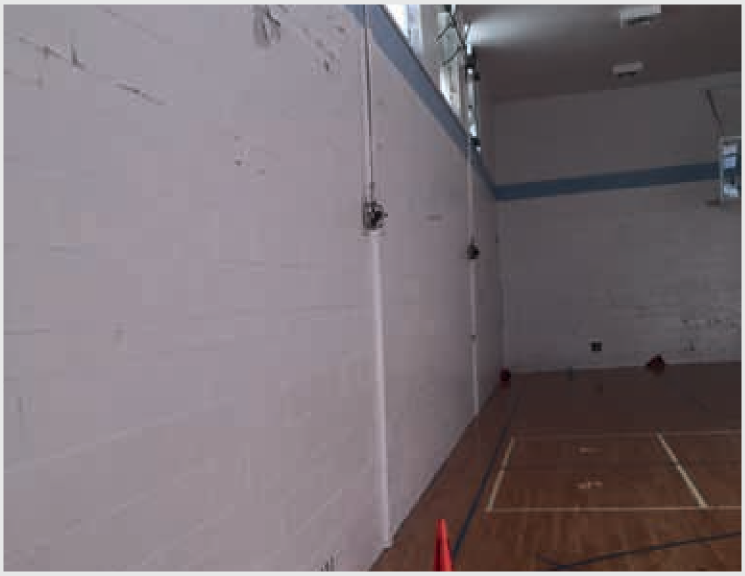
THE SOLUTION

Once the water issue was addressed, it was time to strengthen the wall to prevent any further movement. 400 GSM, 24" wide **Rhino Carbon Fiber CFRP (Unidirectional, Vertical)** was applied with **RCF Saturant-Adhesive Epoxy**. CFRP was also installed under the windows to transfer the load.

Due to the size of the wall and the amount of surface preparation work required for the CFRP installation, the Epp Concrete Construction company elected to bring in a subcontractor to sandblast the entire wall. Per ICRI 310-2R, the surface profile of the concrete prior to CFRP installation should be a CSP 4. Once the blasting was completed, the crew was able to proceed with the CFRP installation.

By utilizing CFRP, the Epp Concrete Construction company was able to stabilize the wall without adding any obstructive bracing material to the interior thus minimizing the footprint of the repair.

BOWING GYMNASIUM WALL



RHINO CARBON FIBER CRFP (UNIDIRECTIONAL, VERTICAL)

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CORNER WRAP CASE STUDY

BLOCK WALL CORNER REPAIR

LOCATION
Pittsburgh, Pensylvania

CLIENT
Concrete Chiropractor

PRODUCTS USED

- Hydraulic Cement
- Rhino Carbon Fiber CFRP (Unidirectional, Horizontal): 400 GSM, 24" Wide
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM, 12" Wide
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

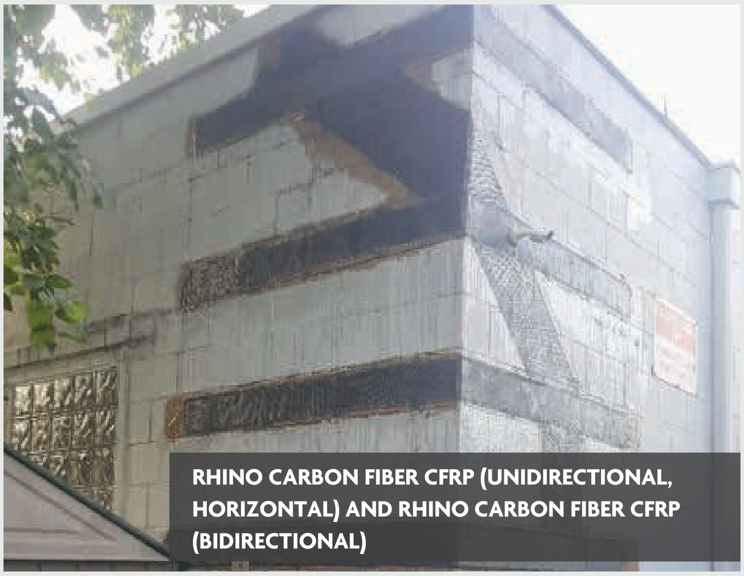
The exterior wall of a building in Pittsburgh, Pensylvania was built using concrete blocks, and over time cracks started to form. Attempts had been made to repair the structure, but each time the cracks reopened and got worse. The Concrete Chiropractor, a concrete repair contractor, was called in to discuss repair options on the structure.

THE SOLUTION

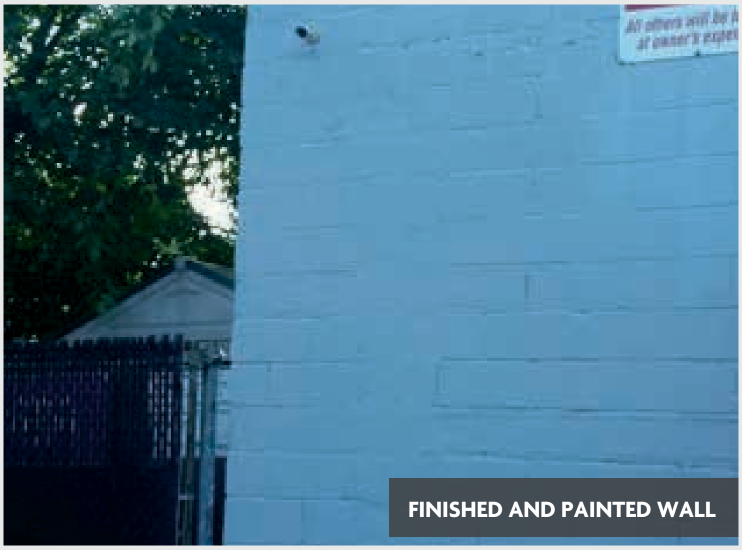
The Concrete Chiropractor reviewed the project and their analysis determined that the best solution was to install 400 GSM, 24" wide **Rhino Carbon Fiber CFRP (Unidirectional, Horizontal)** over the crack and 560 GSM, 12" wide **Rhino Carbon Fiber CFRP (Bidirectional)** over the corner applied with **RCF Saturant-Adhesive Epoxy**. This solution was determined to be the best option because if slight movement in the block wall joints remained, CFRP would resist this movement and remain intact.

The block wall was prepped and all mortar joints were filled with hydraulic cement, then the CFRP was installed. The repair avoided using traditional methods that involve excavation and a large footprint, and the project was completed in a timely manner. High quality products from **Rhino Carbon Fiber** enabled the the Concrete Chiropractor to repair a problem crack that was holding up the sale of the property. Once repainted, the repair blended nicely, effectively restoring the aesthetic appeal and structural integrity of the building.

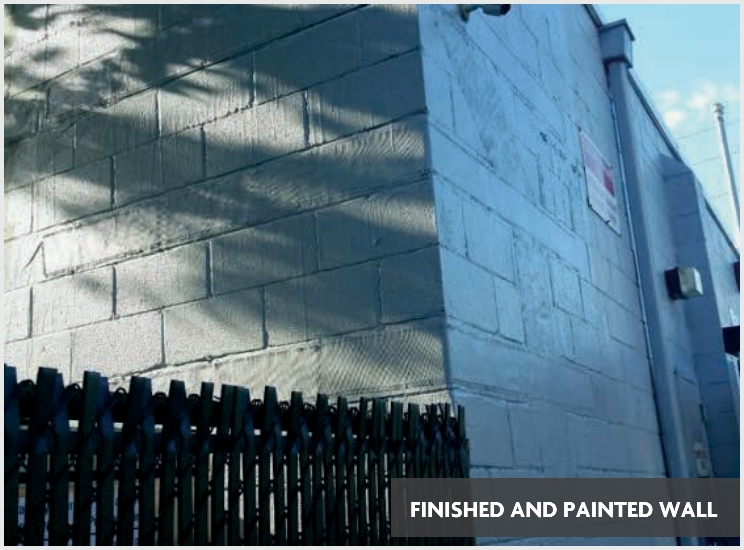
BLOCK WALL CORNER CRACKS FILLED WITH HYDRAULIC CEMENT



RHINO CARBON FIBER CFRP (UNIDIRECTIONAL, HORIZONTAL) AND RHINO CARBON FIBER CFRP (BIDIRECTIONAL)



FINISHED AND PAINTED WALL



FINISHED AND PAINTED WALL

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CFRP CASE STUDY

STADIUM SUPPORT COLUMN REPAIR

LOCATION
Jasper, Indiana

CLIENT
LAN Concrete Technology

PRODUCTS USED

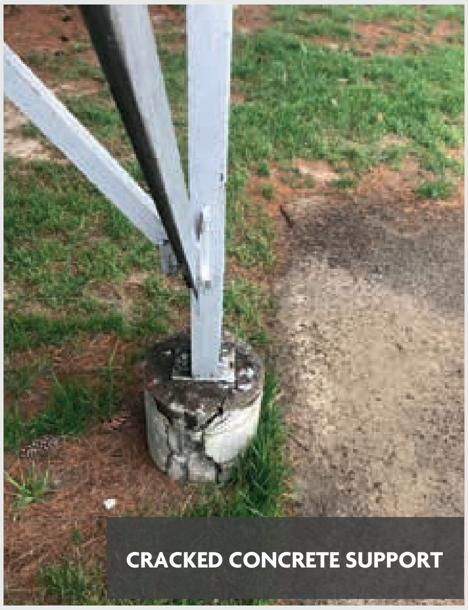
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM, 12" Wide
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The LAN Concrete Technology company was awarded the contract to repair and reinforce cracking concrete supports for the bleachers at Alumni Stadium in Jasper, Indiana. The project consisted of encasing 58 concrete supports, but due to access issues and a tight construction schedule, this was not an easy task. The LAN Concrete Technology company recognized that the project would be a good candidate for a CFRP repair.

THE SOLUTION

The concrete supports were badly deteriorated and in need of repair, and the LAN Concrete Technology company determined the supports would be excavated one foot below grade so that CFRP could be installed around each support. The supports were wrapped with 560 GSM, 12" wide **Rhino Carbon Fiber CFRP (Bidirectional)** and applied with **RCF Saturant-Adhesive Epoxy**. This method repaired and strengthened the supports, effectively restoring the integrity of the structure. After the CFRP installation, the supports were coated in a UV Resistant Coating which made the repairs look aesthetically pleasing. By using **Rhino Carbon Fiber** products, the LAN Concrete Technology company was able to eliminate the access issues with transporting concrete to each one of the support locations and was able to provide an aesthetically appealing CFRP repair.


CRACKED CONCRETE SUPPORT


1 FOOT BELOW GRADE EXCAVATION


COMPLETED REPAIR


CRACKED CONCRETE SUPPORT


COMPLETED REPAIR

CFRP CASE STUDY

CRACK REPAIR & CONFINEMENT

LOCATION
Houston, Texas

CLIENT
Gadberry Construction Company

PRODUCTS USED

- RCF Structural Epoxy Injection Resin
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM, 24" Wide
- RCF Saturant-Adhesive Epoxy
- Elastomeric Stucco

CASE BACKGROUND

The Gadberry Construction Company out of Houston, Texas determined that repairs on the thrust blocks on a basketball pavilion they were working on could be completed with CFRP. The pavilion consisted of a basketball court with an arched roof over top of it that was supported by steel arches, and these arches sat on thrust blocks on both sides of the court.

During the erection of the arches, the base plates had to be slid over anchor bolts that were cast into the thrust blocks and some cracking occurred around the anchor bolts on a few of the thrust blocks.

Per Item 786 in the Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, the Texas Department of Transportation requires bidirectional high-strength carbon fiber fabric, fully saturated with compatible epoxy resin per manufacturer's recommendations, to form a CFRP system when making concrete repairs.

THE SOLUTION

The Gadberry Construction Company worked with The City of Houston's structural engineers to come up with the appropriate solution for the thrust block repairs. They determined that the best solution was to first inject the thrust blocks with **RCF Structural Epoxy Injection Resin**, and then wrap the blocks with 560 GSM, 24" wide **Rhino Carbon Fiber CFRP (Bidirectional)** applied with **RCF Saturant-Adhesive Epoxy** . The Gadberry Construction Company hired Olshan Foundation Repair Co. of Houston, LLC to complete the repair.

After the CFRP installation per sub paragraph 2 of Item 786 of the standard, the contractor had to provide appearance coating recommended by a CFRP system manufacturer to protect the CFRP from ultraviolet radiation, and match color of the protective appearance coating to adjacent concrete. Elastomeric stucco was used to protect the CFRP and give the City a maintenance free coating that would not crack over time.

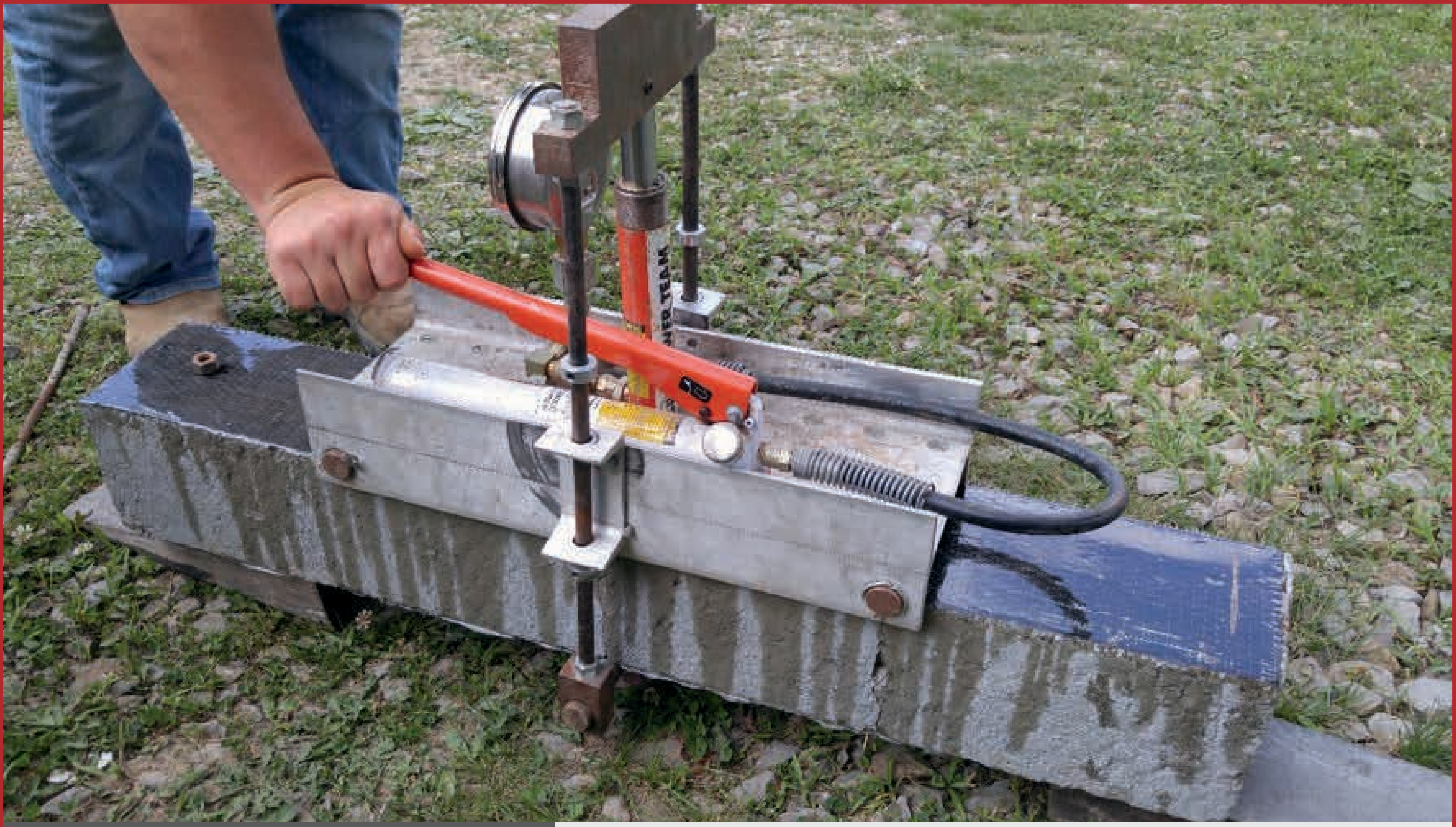
CRACKED THRUST BLOCK


RHINO CARBON FIBER CFRP (BIDIRECTIONAL)


ELASTOMERIC STUCCO

CFRP CASE STUDY

BEAM FLEXURE STRENGTH TEST



LOCATION
Heath, Ohio

CLIENT
Internal Test

PRODUCTS USED

- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM, 6" Wide
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

In bridge construction, due to schedule restraints and the fast paced nature of the work, beam flexure tests are used quite often to verify that newly poured concrete has reached sufficient strength to support the necessary construction loads prior to full cure.

The **Rhino Carbon Fiber** company obtained a beam that had been broken twice in a flexure test from a local project, and pulled it back together with a ratchet strap.

THE SOLUTION

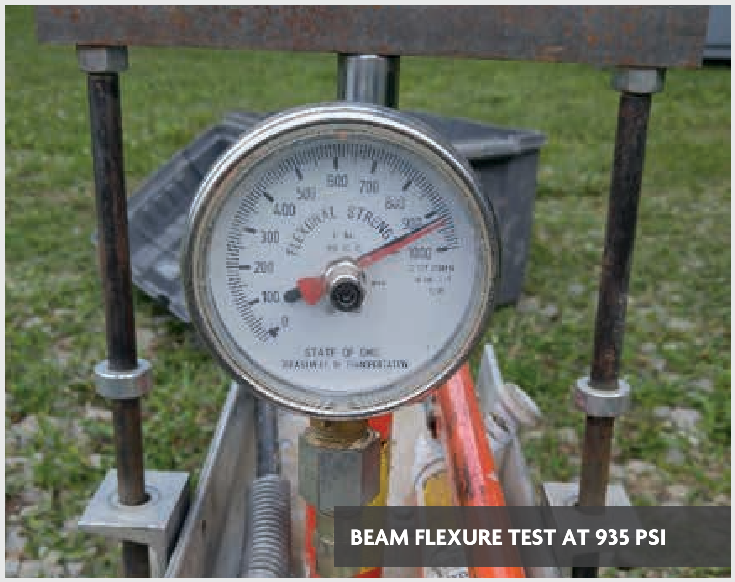
400 GSM, 6" wide **Rhino Carbon Fiber** CFRP (Unidirectional, Vertical) was applied to the beam with **RCF Saturant-Adhesive Epoxy**. Once the epoxy was cured, the same flexure test was performed on the beam that broke originally. The load was placed at the location of the prior break and taken up to 650psi, the strength required to proceed with loading newly poured concrete on Ohio Department of Transportation (ODOT) projects. The result of this test was that the concrete had gained strength although the beam was already broken.

The load was then taken up to 935 psi and the test was performed over both of the prior breaks - the carbon fiber did not fail.

Since the concrete was already broken at the test locations, the flexural resistance that we saw was solely showing the strength of the CFRP in conjunction with epoxy, and its bond to the concrete. This is just one illustration of the potential use of **Rhino Carbon Fiber** products for concrete crack repair and structural strengthening. Results may vary and each case is unique. Consult your engineer to determine if **Rhino carbon Fiber** products are right for your project.

BEAM FLEXURE TEST PREPARATION

RHINO CARBON FIBER CFRP (UNIDIRECTIONAL, VERTICAL)



BEAM FLEXURE TEST AT 935 PSI

RHINO
CARBON FIBER
REINFORCEMENT PRODUCTS

CFRP CASE STUDY

HIGH RISE CRACK REPAIR

LOCATION
Nashville, Tennessee

CLIENT
Ground Up Builders, Inc.

PRODUCTS USED

- RCF Structural Epoxy Injection Resin
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM, 12" Wide
- RCF Saturant-Adhesive Epoxy

ICC ES

CASE BACKGROUND

On a newly constructed high rise in downtown Nashville, engineers had concerns with cold joints at the top of an exterior wall.

The engineering team hired by the Ground Up Builders company recommended to inject the cracks with epoxy injection resin, then CFRP would be applied with saturant-adhesive epoxy to reinforce and strengthen the structure.

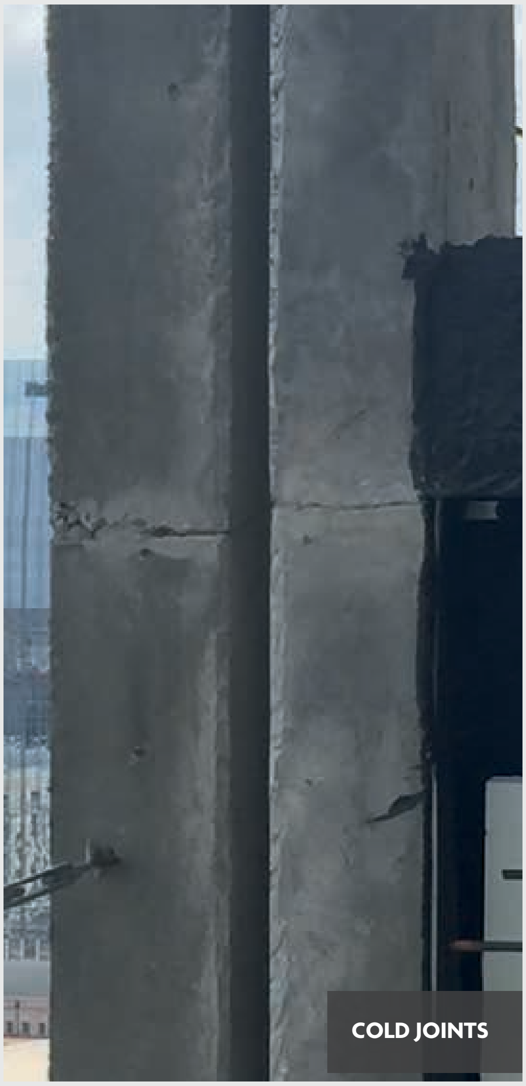
THE SOLUTION

After reviewing the product attributes, they determined that 560 GSM, 12" wide **Rhino Carbon Fiber CFRP (Bidirectional)** would be applied with **RCF Saturant-Adhesive Epoxy** . The bidirectional weave orientation was chosen to provide strength across the crack and help hold the two sections of the wall together.They injected the crack using **RCF Structural Epoxy Injection Resin** and then overlaid it with CFRP.

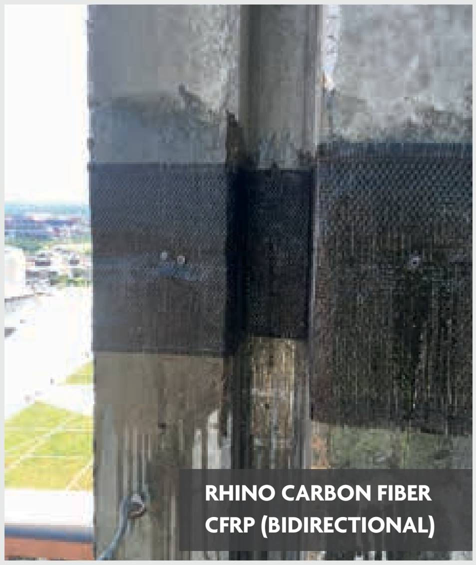
The **Rhino Carbon Fiber** company was able to send all of the products required for the repair overnight and the Ground Up Builders company was able to begin the repairs the following day.

There were also cracks in the newly constructed pool on top of the building and they were able to use the same repair method that was used on the cold joints to address these cracks.

The Ground Up Builders company used **Rhino Carbon Fiber** concrete crack repair and structural strengthening products to meet the needs of the project while staying on schedule and on budget.

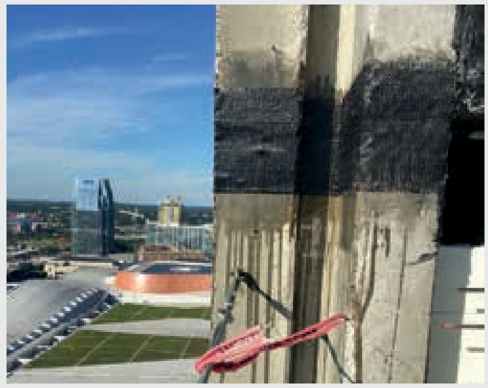


COLD JOINTS



RHINO CARBON FIBER CFRP (BIDIRECTIONAL)

RCF SATURANT-ADHESIVE EPOXY



GROUND UP BUILDERS, INC.

CFRP CASE STUDY

HISTORICAL WATER TOWER STRENGTHENING WITH CFRP

LOCATION
Clay City, Kansas

PRODUCTS USED

- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The Kansas City Public Works Department hired an engineering company to assess needed repairs on a deteriorating historical water tower in Clay City, Kansas that was crumbling due to its old age. There had been 2 previous attempts to strengthen the tower, both of which failed. The first attempt involved patching the concrete cracks with an additional concrete layer. This repair did not last as the concrete continued to shift and deteriorate due to thermal differentiation and thermal cycling; changes in temperature caused the concrete cracks to expand. The second attempt involved using steel reinforcement, but the steel eventually corroded. In addition, it caused further complications as the corrosion from the steel accelerated the corrosion of the structural rebar, compromising its structural integrity.

After seeing two repair attempts fail, the engineering company worked to develop a plan for the repair. The site engineer concluded that CFRP would be the ideal repair solution as it met or exceeded the technical requirements of the repair, in addition to being a cost-effective, non-corrosive solution.

The engineer contacted **Rhino Carbon Fiber** to ascertain the best possible repair, determining that 560 GSM **Rhino Carbon Fiber CFRP (Bidirectional)** in 24-inch widths would be the best option for the repair due to the 560 GSM's strength in all directions.

THE SOLUTION

Before the CFRP could be installed, the concrete required surface preparation, as preparation is key to ensure a strong bond. The entire surface area of the tower was mechanically abraded, all loose concrete and debris were removed, and large gaps were filled with concrete.

Three crews completed the project applying CFRP to the structure. The base pillar of the tower was entirely encapsulated in CFRP. A cementitious coating, or paint that bonds to CFRP, will be applied after the CFRP cured to restore the exterior appearance and to protect the CFRP from UV light. The end result was that the water tower was successfully restored to operational condition, and the repair was virtually invisible, thanks to the superior properties of CFRP.


SCAFFOLDINGS FOR PREP/INSTALL


CONCRETE PREPARATION


RHINO CARBON FIBER CFRP (BIDIRECTIONAL)

CFRP CASE STUDY

MASONRY WALL REINFORCEMENT: BLAST LOADING UPGRADE

LOCATION
Akron, Ohio

CLIENT
WALLFORCE Foundation Support Systems

PRODUCTS USED

- RCF High Strength Anchoring Epoxy Paste
- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM in Various Widths
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in Various Widths
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The WALLFORCE Foundation Support Systems company was responsible for repairing a chemical processing facility that experienced a catastrophic explosion. They reached out to the **Rhino Carbon Fiber** company and reviewed their complete line of concrete crack repair and structural strengthening products and determined that using **Rhino Carbon Fiber** products would be the best solution to repair the structure.

The WALLFORCE Foundation Support Systems company was on a tight schedule to complete the repairs and get the facility operating again, and they engaged Uzman Engineering out of Malvern, PA to put together the structural design to meet the requirements of the project. They determined that they needed to reinforce two sides of a three-story stairwell and several walls in the building.

Upon completion of on-site bond testing in multiple areas within the structure, the WALLFORCE Foundation Support Systems company determined that portions of the existing coating could remain on the walls and that CFRP could be bonded directly to the roughened surface coating. In other areas, the coating bonds failed prematurely or failed between layers so the coating had to be removed before CFRP application.

THE SOLUTION

RCF High Strength Anchoring Epoxy Paste was used to seal large cracks. To strengthen the stairwell and walls to prevent dynamic cracks, 400 GSM in various widths of **Rhino Carbon Fiber CFRP (Unidirectional, Vertical)** and 560 GSM in various widths of **Rhino Carbon Fiber CFRP (Bidirectional)** were used, which were applied with **RCF Saturant-Adhesive Epoxy**. Different areas within the structure required different weave orientations, weights and widths to meet the requirements for the repairs.

Using **Rhino Carbon Fiber** concrete crack repair and structural strengthening products enabled the WALLFORCE Foundation Support Systems company to meet the needs of the project while staying on schedule and on budget. The **Rhino Carbon Fiber** company supported the project by ensuring timely delivery of all materials required for the project.

RHINO CARBON FIBER
CFRP (BIDIRECTIONAL)

RHINO CARBON FIBER
CRFP (UNIDIRECTIONAL, VERTICAL)

RHINO CARBON FIBER
CRFP (UNIDIRECTIONAL, VERTICAL)

CFRP CASE STUDY

RESIDENTIAL HOME CRACK REPAIR

LOCATION
Walkersville, Maryland

CLIENT
Mission Home Services

PRODUCTS USED
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in Various Widths
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The Mission Home Services company out of Walkersville, Maryland was contacted to assess numerous cracks on the exposed CMU basement walls of a 10 year old addition on a 30+ year old home.

When the addition was built, the exterior wall was not tied into the structure properly. The crack that formed where the new exterior wall of the addition met the existing structure was wider at the top than the bottom, indicating settlement had occurred at the corner of the addition. This settlement also caused cracks to form at the door and window along both the back and side walls of the addition.

Drawings stamped by a Maryland Licensed Professional Engineer were required for this project. After determining the appropriate repair method, a drawing detailing these repairs was created and Ingram Engineering Services, Inc., out of West Chester, PA provided the engineering technical report.

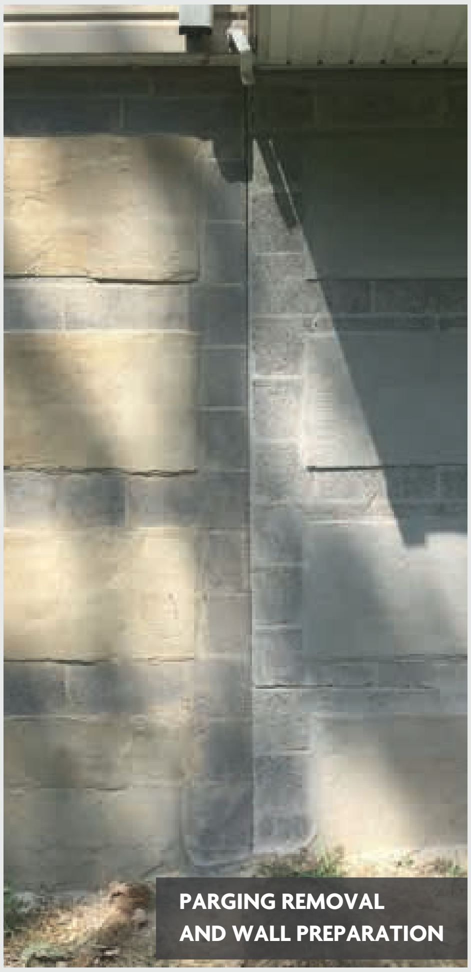
The Mission Home Services company completed an onsite analysis and determined that CFRP would be the best solution for the repair. They contacted the **Rhino Carbon Fiber** company and after reviewing a variety of options from their line of concrete crack repair and structural strengthening products, determined that 560 GSM in various widths of **Rhino Carbon Fiber CFRP (Bidirectional)** would be used on each crack and applied with **RCF Saturant-Adhesive Epoxy** . The bidirectional weave orientation was chosen to provide strength across the cracks and help hold sections of the walls together.

THE SOLUTION

Following the technical report, the Mission Home Services company was able to proceed with the repairs. Parging on the exterior of the wall had to be ground off in order to allow the CFRP to be attached directly to the block.

The CFRP was installed with saturant-adhesive epoxy and after the epoxy had cured, the crew came back in and parged over the CFRP that was installed on the exterior of wall; parging not only protects the CFRP, but provides a seamless repair that can be painted over and blends in with the surrounding parging over time. Even though **RCF Saturant-Adhesive Epoxy** is UV resistant and does not break down when exposed, it is recommended that all exterior structural repairs be covered. CFRP was also installed around the interior windows and on the surrounding cracks for reinforcement.

The mission Home Services company used **Rhino Carbon Fiber** concrete crack repair and structural strengthening products to meet the needs of the project. They were able to select the appropiate products for the repair and next day delivery allowed for the project to be completed on schedule.



PARGING REMOVAL AND WALL PREPARATION

RHINO CARBON FIBER CFRP (BIDIRECTIONAL)

WINDOW CRACKS

COMPLETED REPAIR

RHINO CARBON FIBER CFRP (BIDIRECTIONAL)

CONCRETE CRACK LOCK® STITCHES CASE STUDY

POOL DECK CRACK REPAIR

LOCATION
San Francisco, California

CLIENT
American Restoration

PRODUCTS USED

- Rhino Carbon Fiber Concrete Crack Lock® Stitches
- RCF High Strength Anchoring Epoxy Paste

CASE BACKGROUND

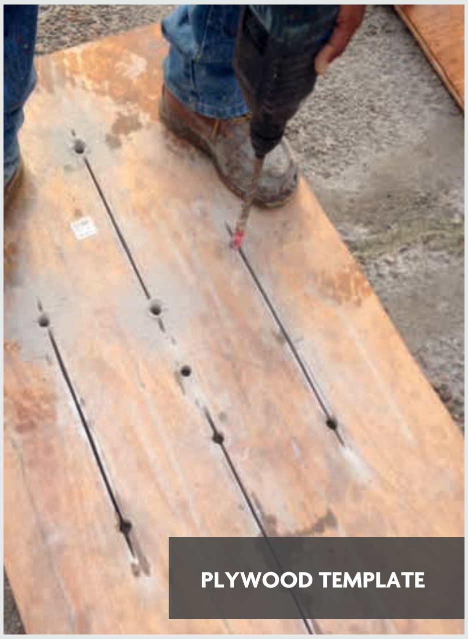
The American Restoration company out of San Francisco, California was hired to repair a cracking concrete slab around a swimming pool. They had two concerns: first, they did not want this crack to re-open through their surface coating and second, they were worried about the possibility of the crack spreading.

The American Restoration company contacted the **Rhino Carbon Fiber** company and after reviewing their crack repair and structural strengthening options, determined the best solution would be to install **Rhino Carbon Fiber Concrete Crack Lock®** stitches in conjunction with **RCF High Strength Anchoring Epoxy Paste** along the crack to satisfy both of these concerns.

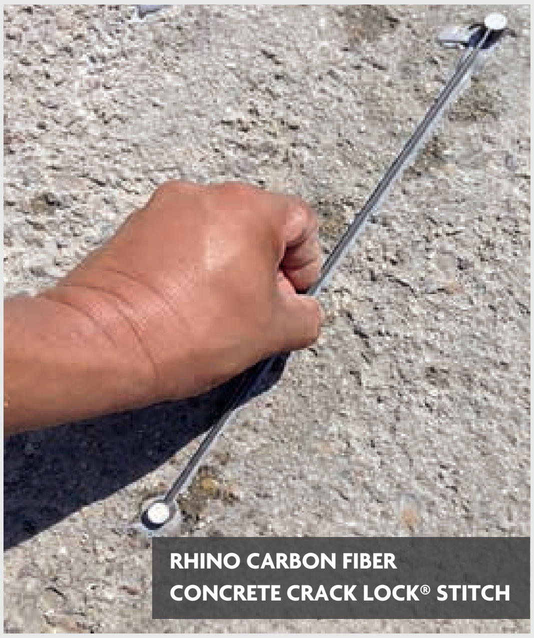
THE SOLUTION

The American Restoration company created a plywood template to aid in the layout and preparation for the installation of **Rhino Carbon Fiber Concrete Crack Lock®** stitches, and then installed the stitches every 8" to 12" along the crack. The stitches were adhered into the concrete and sealed with **RCF High Strength Anchoring Epoxy Paste**.

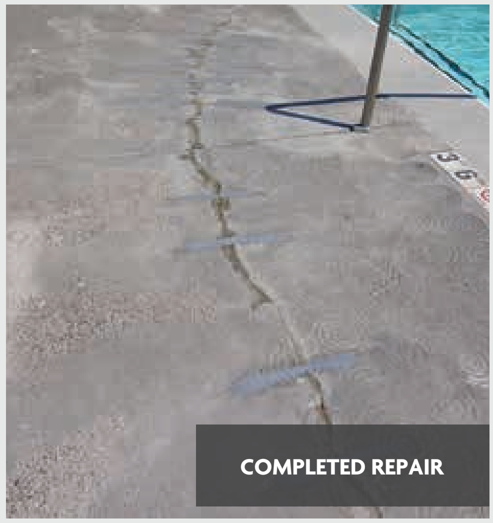
Rhino Carbon Fiber Concrete Crack Lock® stitches have a high tensile strength since they are made from carbon fiber, and there is minimal surface disruption required for the installation due to their thin profile. When installed and finished with a protective coating, no evidence of the installation was present. Using **Rhino Carbon Fiber** products enabled the American Restoration company to successfully refurbish this pool deck on a tight schedule.



PLYWOOD TEMPLATE



RHINO CARBON FIBER CONCRETE CRACK LOCK® STITCH



COMPLETED REPAIR

RCF HIGH STRENGTH ANCHORING EPOXY PASTE

CFRP CASE STUDY

RESIDENTIAL BOWED BLOCK (CMU) WALL REPAIR

LOCATION
Hastings, New York

CLIENT
EcoSpect, Inc.

PRODUCTS USED

- Rhino Carbon Fiber Bowed Wall Repair Kit (Unidirectional, Vertical): 400 GSM in 7-Foot Height and 6-Inch Width
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 12-Inch Width
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

A contractor from EcoSpect out of Syracuse, New York was called out to look at a bowing concrete masonry unit (CMU) wall discovered in the basement during a home inspection being performed for a real estate transaction.

EcoSpect determined that CFRP would be the best solution to strengthen the wall to prevent further inward movement while minimizing the cost, labor and intrusiveness of the repair. When a wall bows more than 2", the repair becomes more cumbersome and costly, so the issue was addressed before the situation became worse.

By using CFRP, EcoSpect was able to provide the homeowners a more cost effective solution than would be possible with traditional methods. Excavating and pushing the wall in would be more expensive and there would be access restrictions to consider. If the homeowners wanted to go through with the expense of pushing the wall back, CFRP would still be applied to strengthen the wall to prevent it from bowing again. Beams and tieback systems were also considered since they provide resistance against deflection but they do not strengthen the entire height of the wall.

Without adding strength from top to bottom, as is achieved with the **Rhino Carbon Fiber Bowed Wall Repair Kit**, failures are still possible. EcoSpect contacted **Rhino Carbon Fiber** and reviewed their line of bowed wall repair kits and determined that the **400 GSM Rhino Carbon Fiber Bowed Wall Repair Kit (Unidirectional, Vertical)** in 7-foot height would be the best solution to reinforce the wall due to the 400 GSM's superior strength in one direction. Three additional walls would also be reinforced as a preventative measure. **The Rhino Carbon Fiber Bowed Wall Repair Kit** bonds CFRP to the sill plate (top) and foundation (bottom) to prevent shear damage and utilize the complete tensile strength of CFRP. This gave EcoSpect confidence in their decision.

THE SOLUTION

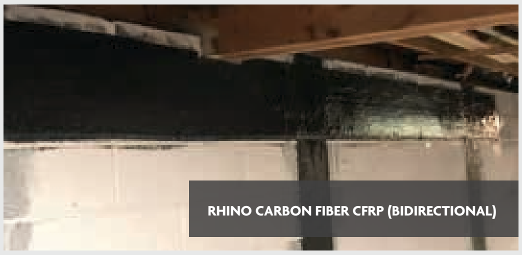
Proper surface preparation is one of the most important steps when installing CFRP. EcoSpect prepared the walls by grinding them to ensure the straps were engaged to their full capacity in order to resist any further inward movement of the wall, and to ensure a strong epoxy bond. Next, they repaired the damaged mortar joints. To complete and ensure the repair was water-resistant, the cracked mortar needed to be knocked out and the joints were tuck-pointed. If the joints were not repaired properly, the walls were at risk of receding during the summer months when the moisture content of the soil is lower. Allowing any movement of the wall will further deteriorate the mortar joints which could create a wrinkle in the carbon fiber, decreasing the effectiveness of the repair.

Nine **Rhino Carbon Fiber Bowed Wall Repair Kits** were applied across the four surface-prepped walls for a total of 26 straps. In addition, a single strap of 560 GSM, 12-inch wide **Rhino Carbon Fiber CFRP (Bidirectional)** was applied along the upper course of block over the mortar joint that had started to open up where the movement manifested. The additional bidirectional strap provided strength in all directions. It was applied to increase the bond strength on the ends of the straps eliminating the possibility of a premature bond failure.

The homeowners were thrilled they wouldn't lose any square footage (due to CFRP's thin profile) as is the case with traditional bowed wall repair methods such as steel beam reinforcement. The CFRP could easily be painted over which meant there would be no visible trace of damage. EcoSpect was able to successfully reinforce the walls quickly and efficiently resulting in a successful real estate transaction for the homeowners.


BLOCK (CMU) WALL PRIOR TO PREP


PREPARED BLOCK (CMU) WALL


RHINO CARBON FIBER CFRP (BIDIRECTIONAL)


RHINO CARBON FIBER BOWED WALL REPAIR KIT (UNIDIRECTIONAL, VERTICAL)

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RHINO CARBON FIBER REINFORCEMENT PRODUCTS

CONCRETE CRACK LOCK® STITCHES & CFRP CASE STUDY

SALT BARN CORNER WALL FAILURE REPAIRS

LOCATION
Cambridge, Ohio

CLIENT
The City of Cambridge, Ohio

PRODUCTS USED

- RCF High Strength Anchoring Epoxy Paste
- Rhino Carbon Fiber Concrete Crack Lock® Stitches
- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM, 24" Wide
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

After a winter with below average snowfall, the City of Cambridge, Ohio was left with an excess of unused road salt on hand in its storage building. Due to its salt contract obligations, it was required to accept and store additional quantities of salt for the following year's winter. This necessitated overfilling its salt storage building, resulting in damage to the structure.

Cracks formed along the back of the storage building structure and the back wall began to tip outward. Initial repairs were performed by first patching the cracks and then adding steel banding to the areas to reinforce the fractures and stop movement. However, since steel is prone to corrosion, these repairs failed incredibly fast. The City then sought another solution.

The first suggested approach by the City was an extensive repair plan that involved new walls being poured to brace the failing wall. When the City Engineer reviewed that repair plan, he had concerns with it, so he looked for an alternative solution and found one utilizing CFRP.

THE SOLUTION

The City Engineer reached out to the **Rhino Carbon Fiber** company and after reviewing the product attributes, studying the technical specifications and contemplating the possible alternatives, he determined that the best solution would be to first patch the cracks with **RCF High Strength Anchoring Epoxy Paste** and non-shrink repair mortar, and then reinforce the cracks with **Rhino Carbon Fiber Concrete Crack Lock®** stitches. The corners were wrapped with 400 GSM, 24" wide **Rhino Carbon Fiber CFRP (Unidirectional, Vertical)** and applied with **RCF Saturant-Adhesive Epoxy**.

After analysis, the City chose the CFRP solution over the method involving pouring new walls which had been previously considered. As a result, the City's maintenance crews were able to complete the repairs in a matter of a few days and at a much lower cost than that of forming and pouring new walls. The **Rhino Carbon Fiber** team responded quickly with the products required, enabling the repairs to be completed prior to temperatures falling so that the salt barn could be used to store salt for the following winter.


SALT BARN WALL CRACK


FAILED STEEL BANDING


FAILED STEEL BANDING


RHINO CARBON FIBER CONCRETE CRACK LOCK® STITCHES


RHINO CARBON FIBER CRFP (UNIDIRECTIONAL, VERTICAL)

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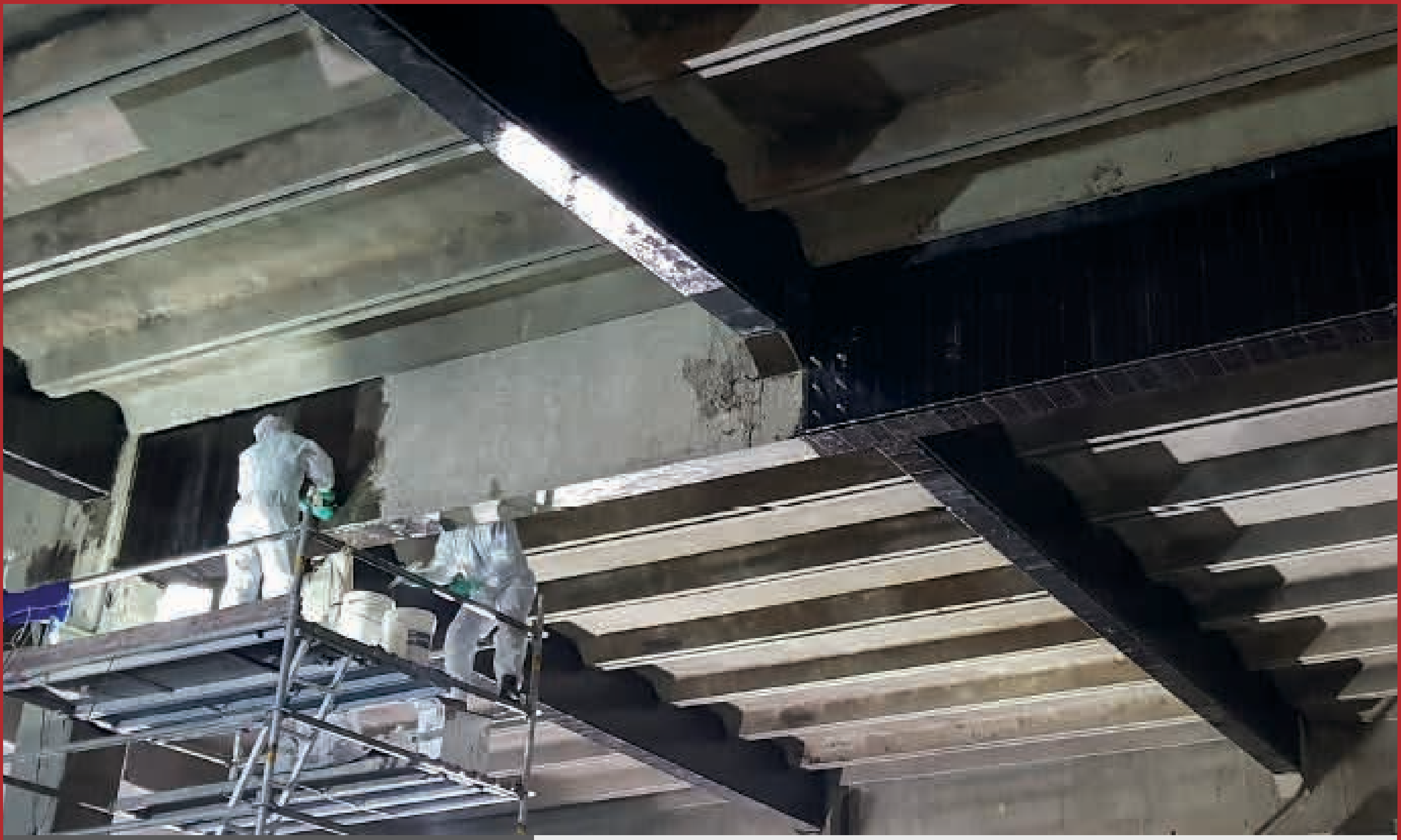
RHINO™ CARBON FIBER REINFORCEMENT PRODUCTS

CFRP CASE STUDY

SHOPRITE FACILITY CONCRETE BEAM STRENGTHENING – TRIANON SHOPPING PARK



LOCATION
Mauritius Island

CLIENT
PND Contracting

PRODUCTS USED

- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM in 6-Inch Widths
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in Various Widths
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

The PND Contracting company out of Mauritius Island was hired to strengthen concrete beams at the Shoprite facility in the Trianon Shopping Park that was damaged due to a catastrophic fire.

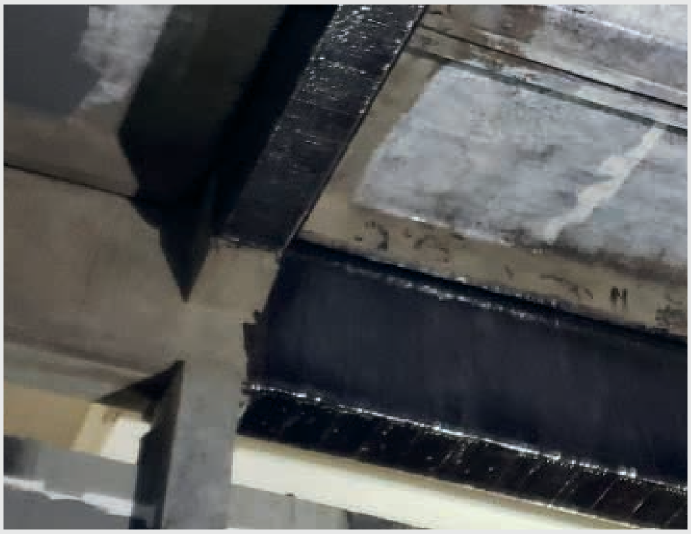
The building owner's engineer discovered damage to the primary and secondary beams that supported the roof. The PND Contracting company determined that using CFRP would be the ideal solution to strengthen the beams based on its high-strength, resistance to corrosion, low-weight, cost-effectiveness, low thermal expansion and high and low temperature tolerance. The PND Contracting company reached out to the **Rhino Carbon Fiber** company to review their CFRP options and determined that using 400 and 560 GSM **Rhino Carbon Fiber CFRP** with **RCF Saturant-Adhesive Epoxy** would be the best solution to strengthen the structure.

THE SOLUTION

The first step was for the building owner's engineer to develop a structural design. Due to the tight schedule and immediate need for materials, the PND Contracting company relied on Rhino's ability to quickly deliver high-quality products that met or exceeded the project specifications outlined in the structural design. **The Rhino Carbon Fiber** company overcame many logistical hurdles to deliver the products on time, such as specific packaging requirements and customs clearance across 3 countries. The project which included over 500 square meters of **Rhino Carbon Fiber CRFP** applied with **RCF Saturant-Adhesive Epoxy** was completed in 11 days using three 4-man crews working off 27' scaffoldings for 16-18 hours per day. The installation included sections with 3, 4 and 5 layers of CFRP to meet the technical requirements of the structural design, which was very difficult due to the humidity, heat and access restrictions.

Upon completion of the installation, the PND Contracting company performed load tests on the beams and observed only a fraction of the deflection that was expected (7-8mm was expected and the beams deflected less than 1mm). The PND Contracting company was able to successfully reinforce and restore the building, while staying on schedule, due to immediate product availability and ease of installation.

RHINO CARBON FIBER CFRP AND RCF SATURANT-ADHESIVE EPOXY



CONCRETE CRACK LOCK® STITCHES CASE STUDY

SLAB STRENGTHENING WITH CONCRETE CRACK LOCK® STITCHES

LOCATION
Vaudreuil-Dorion, Quebec

PRODUCT USED

- Rhino Carbon Fiber Concrete Crack Lock® Kit

CASE BACKGROUND

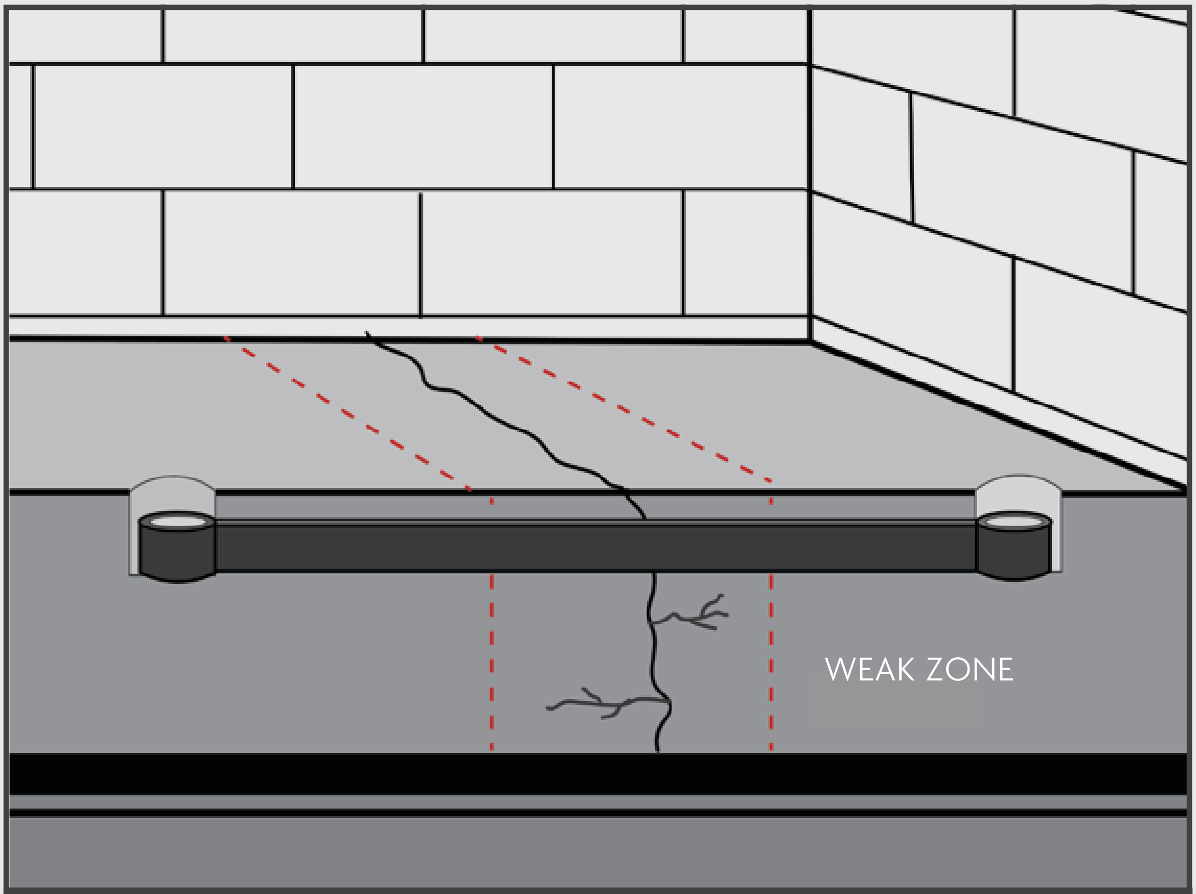
An excavation company in Vaudreuil-Dorion, Quebec noticed dynamic cracks along an 8" thick concrete slab in their warehouse. The warehouse is a storage facility for heavy equipment, and the equipment compacted the soil underneath the slab to a point that the slab started to crack under the load. In addition, the concrete expanded and contracted due to recurring forces that included live loads, freeze and thaw cycles and soil expansion, which made the cracking in the concrete worse. The concrete joints also had not been designed to withstand these forces.

In an effort to avoid the expense of demolishing and re-pouring the concrete, the excavation company chose to stitch the dynamic cracks together to avoid further expansion while strengthening the area. They determined that the **Rhino Carbon Fiber Concrete Crack Lock® Kit** would be the perfect solution for the repair as there were no other viable options that could deliver the benefits the Concrete Crack Lock® stitches did, being cost-effective, high-strength, light-weight, resistant to corrosion and easy-to-install.

THE SOLUTION

The excavation company ordered and received their repair materials quickly, then installed the Concrete Crack Lock® stitches themselves given the ease of installation. They first prepared the concrete surface to ensure a strong epoxy bond. The crack was v-grooved with a grinder at a 45-degree angle, and debris was removed. They inserted the Concrete Crack Lock® stitches along the crack every 8-12 inches, varying the angle of each stitch slightly so that it was roughly perpendicular to the crack, to strengthen the crack in all directions. After the **RCF High Strength Anchoring Epoxy Paste** cured, the v-groove was filled with a hybrid urethane repair liquid to create a smooth and even surface.

Upon completion, the repair was barely noticeable. The excavation company put the newly strengthened slab to the test by driving a 35,700 kg excavator over the repaired area. They continue to use Concrete Crack Lock® stitches in other projects and are recommending the product to contractors within their network.



STRENGTHENING WITH CONCRETE CRACK LOCK® STITCHES

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CFRP CASE STUDY

STRENGTHENING CONCRETE SILOS WITH CFRP

LOCATION
Cupertino, California

PRODUCTS USED

- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

CASE BACKGROUND

A consulting engineer in Northern California was looking for a solution to strengthen three 70-year-old cracking concrete silos in Cupertino, California. The silos are storage facilities for a nearby mine, and some of the materials mined contain corrosive elements. The concrete around the silos deteriorated and formed cracks as a result of these corrosive elements. The now-destabilized silos were leaking and could only be operated at 50-60% of their capacity.

The consulting engineer considered many options for the repair, such as shotcrete, spray-on mortar and concrete patching, but ultimately concluded that using CFRP would be the most reliable solution due to its high-strength, resistance to corrosion, cost-effectiveness, light-weight and ease-of-application. The engineer contacted **Rhino Carbon Fiber** and determined that 560 GSM **Rhino Carbon Fiber CFRP (Bidirectional)** in 24-inch widths would be the best option for the repair due to the 560 GSM's strength in all directions.

THE SOLUTION

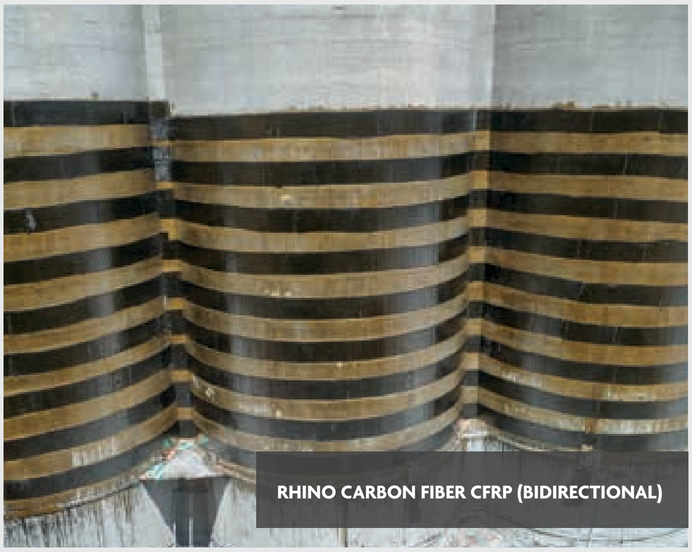
Surface preparation of the concrete is critical to ensure a strong epoxy bond. Two crews of four marked the locations where the CFRP straps would be applied with spray paint. Then the entire surface area was hydro-blasted within the marked areas in order to obtain a clean surface with absence of the laitance layer and with adequate roughness level. They utilized a "hoop-strength reinforcement" method of application for the CFRP, which refers to wrapping around the silos like a belt.

As a final step, the CFRP was covered with a UV-resistant coating to protect the CFRP system from UV light deterioration. Upon completion, the silos were effectively restored and are operating at 100% capacity.


HYDRO-BLASTING


RHINO CARBON FIBER CFRP AND RCF SATURANT-ADHESIVE EPOXY


REPAIR INSPECTION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