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

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

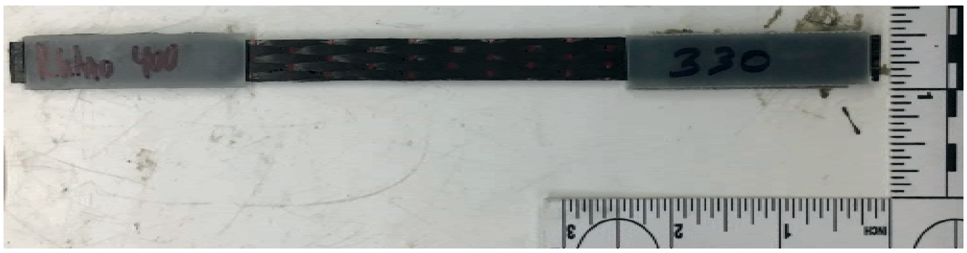

Figure 1.2 – Representative test specimen prior testing
Scale in inches.

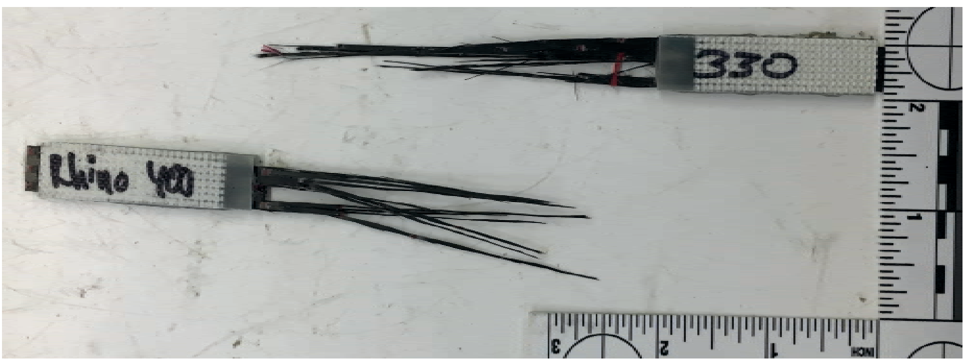

Figure 1.3 – Representative SGM failure mode, where ‘S’ is for longitudinal splitting; ‘G’ is at the gauge and ‘M’ middle. Scale in inches.

♦ END OF TEST REPORT ♦

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#ISM028 #TL-478

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: 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: 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

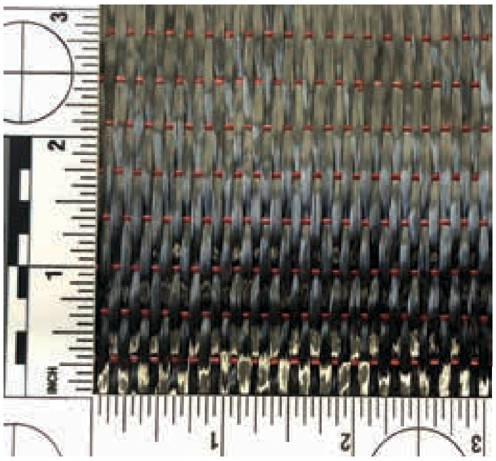
1.3. TEST RESULTS

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).*

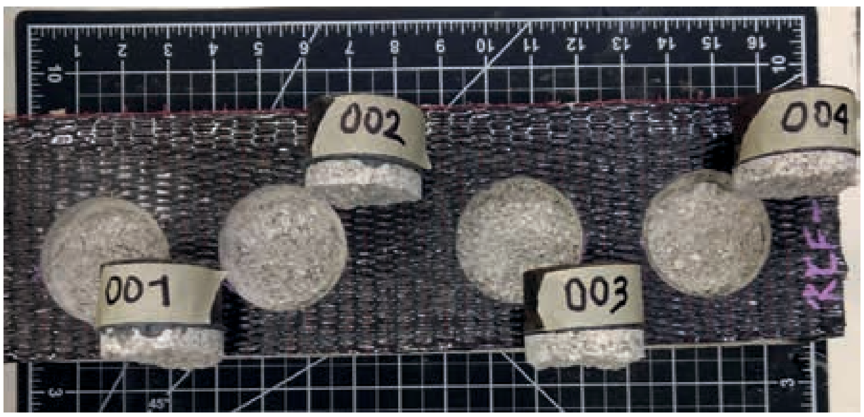
1.4. VISUAL DOCUMENTATION



(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	n/a
Effective Date	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>

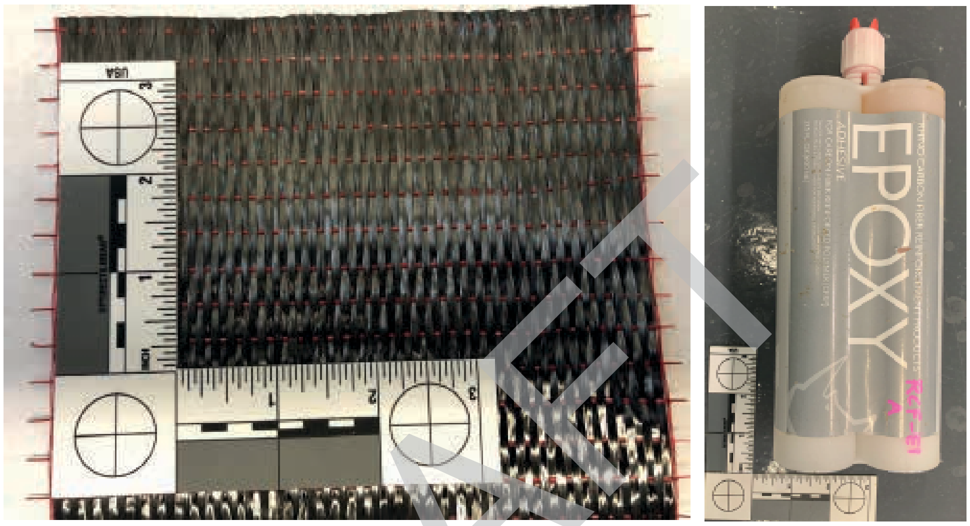
The RCF carbon fiber strap, herein referred to as RCF-CF, a high strength unidirectional carbon fiber fabric equipped with weft fibers that keep the fabric stable and has a minimum nominal fiber density of 400 gsm and a width of 140 mm (5.50 in.).

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.

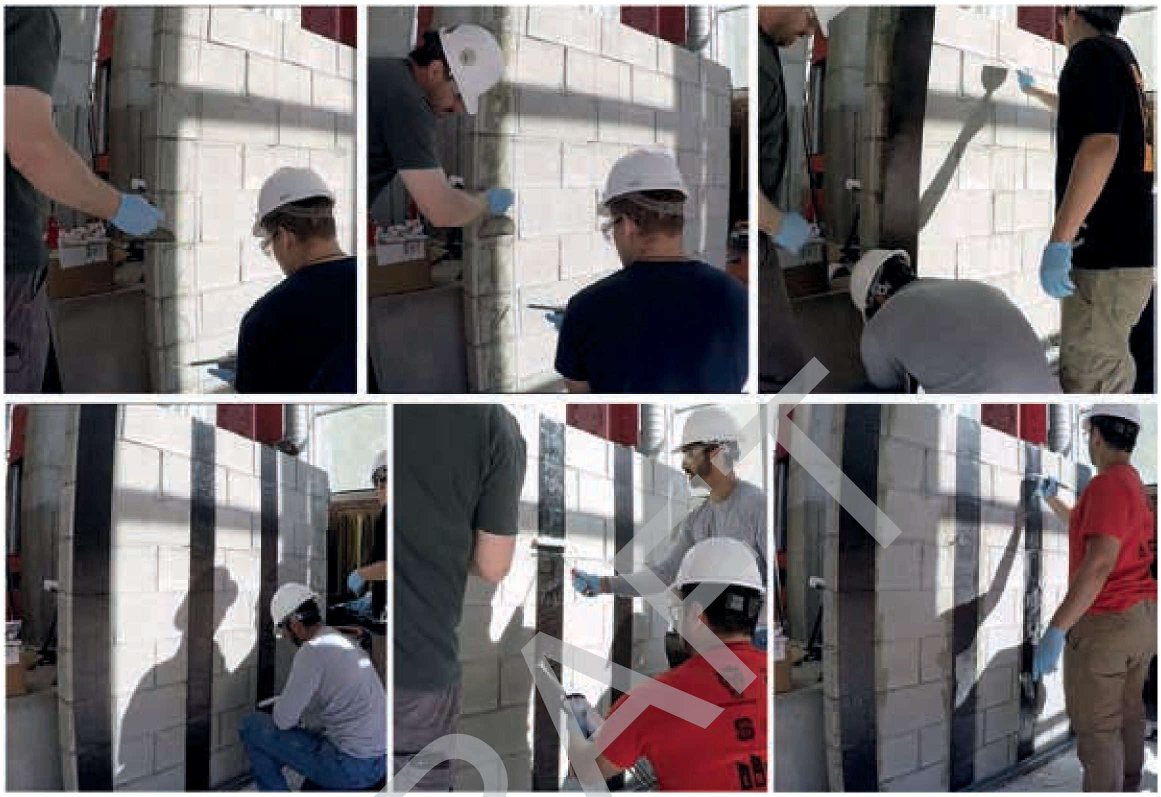


Figure 4.2 – Installation process of RCF FRP system on flexural CMU walls

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™	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.

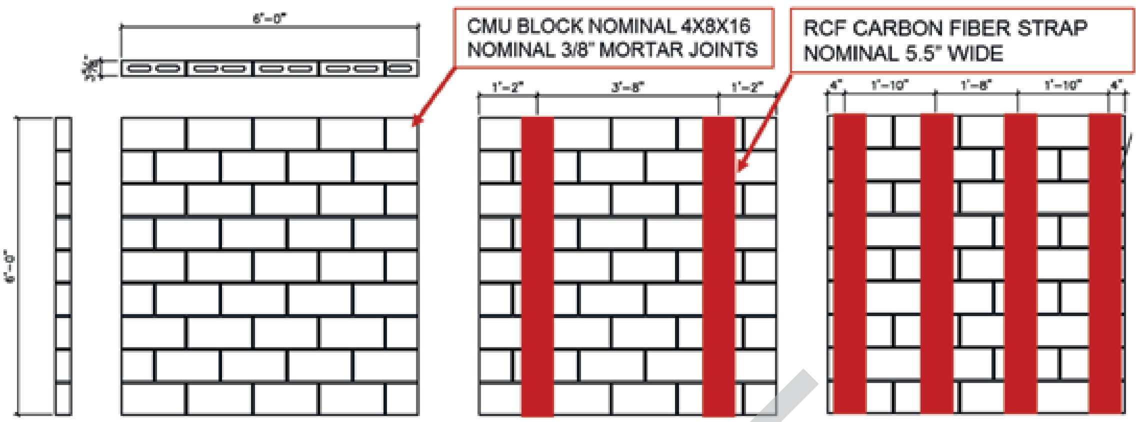


Figure 5.2 – RCF flexural CMU wall test specimens

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.

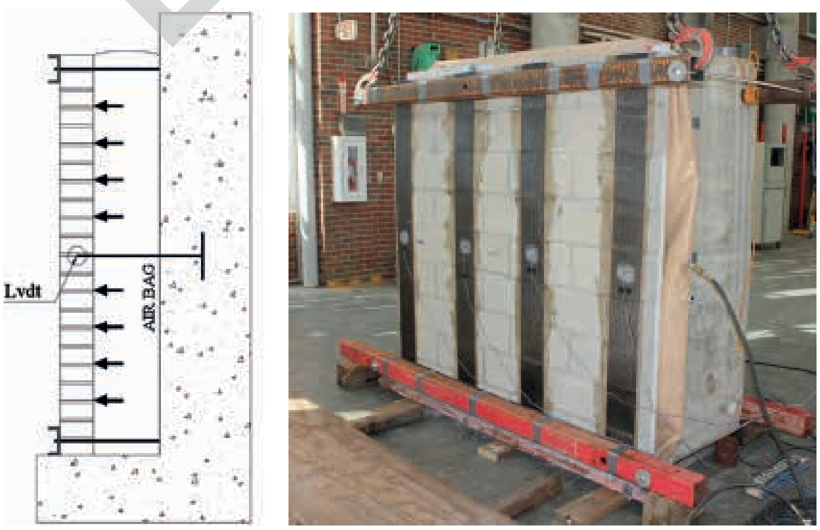


Figure 5.3 – RCF flexural CMU wall test setup, schematic (left) and laboratory view (right)

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. <u>Graphical Representation of Results</u>

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.

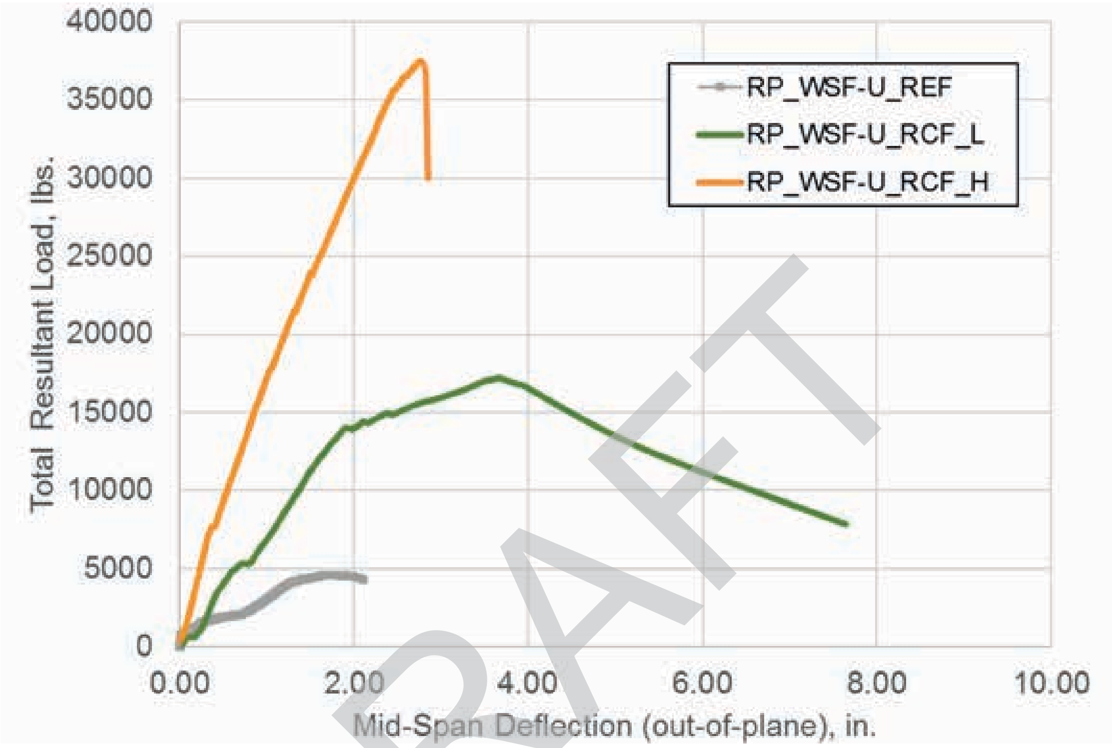


Figure 5.5 – Total resultant applied load versus mid-span displacement (out-of-plane) results for CMU wall flexure specimens

5.5.4. <u>Tabulated Results</u>

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. <u>Theoretical Predictions</u>

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. <u>Conclusions</u>

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 ♦

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#ISM028 #TL-478

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	T_g* °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

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