

**Advanced Composite Materials in New England’s
Transportation Infrastructure:
Design, Fabrication, and Installation of ACM Bridge Drain System**

Dr. Roberto A. Lopez-Anido, PI

Keenan Goslin, P.E, Co-PI

Prepared for:

The New England Transportation Consortium

August 8, 2016

NETCR98

Project No. 09-03

“This report, prepared in cooperation with the New England Transportation Consortium, does not constitute a standard, specification, or regulation. The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the New England Transportation Consortium or the Federal Highway Administration.”

ACKNOWLEDGEMENTS

The following are the members of the Technical Committee that developed the scope of work for the project and provided technical oversight throughout the course of the research:

Dale Peabody, Maine Department of Transportation, Chairperson

Kevin Daigle, New Hampshire Department of Transportation

Alireza Jamalipour, Connecticut Department of Transportation

Christopher Mooney, Vermont Agency of Transportation

Michael Wight, Maine Department of Transportation

Technical Report Documentation Page

1. Report No. NETCR98	2. Government Accession No. N /A	3. Recipient's Catalog No. N /A	
4. Title and Subtitle <i>Advanced Composite Materials in New England's Transportation Infrastructure: Design, Fabrication, and Installation of ACM Bridge Drain System</i>		5. Report Date August 8, 2016	
		6. Performing Organization Code N /A	
7. Author(s) Roberto A. Lopez-Anido and Keenan Goslin		8. Performing Organization Report No. NETCR98	
9. Performing Organization Name and Address Advanced Structures and Composites Center University of Maine 35 Flagstaff Road, Orono, ME, 04469		10. Work Unit No. (TRAIS) N /A	
		11. Contract or Grant No. N/A	
12. Sponsoring Agency Name and Address New England Transportation Consortium C/O Transportation Research Center University of Vermont, Farrell Hall 210 Colchester Ave. Burlington, Vt, 05405		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code NETC 09-03 A study conducted in cooperation with the U.S. DOT	
15. Supplementary Notes N/A			
16. Abstract The project report presents the design and fabrication of a standard fiber-reinforced polymer (FRP) composite drain that can be produced economically for use throughout New England bridges. The installation of the fabricated drain system in representative bridge applications in New England is documented to provide information on its performance, and ease of construction. The major obstacles or gaps for the implementation of FRP drains in highway bridges are the lack of material, fabrication and installation specifications, the unavailability of standard designs, and the unknown performance during service. The proposed standard FRP drain system can be used both for new construction and rehabilitation projects. The following activities were conducted to address the current gaps, and design, fabricate and install the standard FRP composite drain: 1) Establish specific performance requirements for FRP composite drains for highway bridges; 2) Draft standard specifications for FRP drains in bridge applications; 3) Identify and contact qualified composite manufacturers to get input on the standard practice for fabrication and installation of FRP drains; and 4) Identify representative bridges to demonstrate and document the FRP drain installation methods.			
17. Key Words FIBER REINFORCED POLYMER, DRAIN, FRP, COMPOSITE, BRIDGE, SPECIFICATIONS		18. Distribution Statement No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov .	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 57	22. Price N /A

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

Advanced Composite Materials in New England's Transportation Infrastructure: Design, Fabrication, and Installation of ACM Bridge Drain System

Dr. Roberto A. Lopez-Anido, PI

Keenan Goslin, P.E, Co-PI

University of Maine's Advanced Structures and Composites Center

Report Number: 17-3-1202

Abstract

The project report presents the design and fabrication of a standard fiber-reinforced polymer (FRP) composite drain that can be produced economically for use throughout New England bridges. The installation of the fabricated drain system in representative bridge applications in New England is documented to provide information on its performance, and ease of construction. The major obstacles or gaps for the implementation of FRP drains in highway bridges are the lack of material, fabrication and installation specifications, the unavailability of standard designs, and the unknown performance during service. The proposed standard FRP drain system can be used both for new construction and rehabilitation projects. The following activities were conducted to address the current gaps, and design, fabricate and install the standard FRP composite drain: 1) Establish specific performance requirements for FRP composite drains for highway bridges; 2) Draft standard specifications for FRP drains in bridge applications; 3) Identify and contact qualified composite manufacturers to get input on the standard practice for fabrication and installation of FRP drains; and 4) Identify representative bridges to demonstrate and document the FRP drain installation methods.

This report shall not be reproduced, except in full, without the written approval of University of Maine's Advanced Structures and Composites Center.



The University of Maine Advanced Structures and Composites Center is an ISO 17025 accredited testing laboratory, accredited by the International Accreditation Service.

Table of Contents

Introduction	3
Research Problem Statement.....	3
Objectives.....	5
Report Organization.....	6
References.....	7
Task 1 - Review of typical bridge drain details that are representative in New England	8
Summary of NETC-DOT Bridge Drain Physical Design Parameters.....	8
Task 2 – Development of standard drain requirements for new and rehabilitation projects..	10
Criteria for Baseline Mechanical Properties and Durability Requirements	10
FRP Composite Bridge Drain Components Specification	12
Appendix A: FRP composite drain and pipe material requirements.	18
Appendix B: Preferred inlet/scupper sizes and overall geometries.	24
Appendix C: Special provision for FRP Bridge Drains for the Howland-Enfield Bridge, Maine	26
Task 3 - Selection of participating FRP drain suppliers	31
Supplier A: Kenway Corporation	32
Supplier B: FRP Bridge Drain Pipe-Westfall Company	33
Task 4: Qualification of FRP drain suppliers through material testing.....	34
Supplier A: Kenway Corporation	35
Supplier B: FRP Bridge Drain Pipe-Westfall Company	38
Task 5: Documentation of installation of FRP drains in bridges	41
Union Street Bridge, Bangor, Maine	41
Richmond-Dresden Bridge, Maine.....	49
Summary	53

INTRODUCTION

RESEARCH PROBLEM STATEMENT

Advanced composite materials (ACM), also known as fiber-reinforced polymer (FRP) composites, have increasingly been used in bridge applications. FRP composites have been used in the rehabilitation and retrofit of beams, columns and decks. FRP composites are corrosion resistant and lightweight materials, which can be manufactured using different processes. The properties of FRP composites can be optimized for particular structural applications by selecting the type and orientation of fiber reinforcement and the polymer matrix. For these reasons FRP composites have the potential to be a cost-effective and durable solution for specific applications in the transportation infrastructure.

The New England Transportation Consortium (NETC) has conducted two research projects to date to identify those applications within the transportation infrastructure in New England where FRP composites could replace traditional materials used in civil engineering. The primary objective of NETC 01-1 was to identify obstacles for the widespread adoption of FRP composites in New England's transportation infrastructure with the goal of promoting its implementation (Breña et al. 2006).

The second project, NETC 01-1-T2: Phase I, was conducted to identify and select an application for which FRP composites offered a cost-effective alternative to conventional construction materials. The goal was to select a prototype application that could be competitively fabricated and installed in the transportation infrastructure throughout New England. A standard drain system that could be used throughout bridges in New England to eliminate the problems with corrosion and leakage that occurs when using traditional materials, and to extend the service life of bridge drains was selected (Breña and Civjan 2009).

Composite bridge components, such as FRP bridge drains, can be very valuable in extending the life of bridges by preventing corrosion damage. FRP bridge drains is one of the areas where MaineDOT has used composites to extend service life (MaineDOT 2014).

The FHWA Hydraulics Engineering Circular No. 2 provides a manual on design of bridge deck drainage (FHWA-HEC 21 1993). This manual is a compendium of bridge drainage design guidance, which provides guidelines and procedures for designing bridge deck drainage systems, including illustrative examples. The manual emphasizes the use of the most hydraulically efficient and maintenance-free drain systems. The manual also presents the advantages of designing to minimize the complexity of bridge deck drainage systems and discusses the integration of practical drainage details into overall structural design. Drainage system design is approached from the viewpoints of hydraulic capacity, traffic safety, structural integrity, practical maintenance, and architectural aesthetics. System hardware components, such as inlets, pipes, and downspouts, are described.

Conventional steel drainage systems used in concrete bridge decks are typically corroded by deicing chemicals and clogged by debris. The University of Maine (UMaine) in collaboration with Maine Department of Transportation (MaineDOT) and Kenway Corporation designed, prototyped and tested and FRP composite drain, grating and downspout system to replace corroded steel drains in three bridges. Three identical prototypes were fabricated, embedded in concrete slabs, and submitted to a series of laboratory tests to ensure structural integrity and to

optimize the design for long-term durability. The tests included an ice formation study, compression loading tests based on the AASHTO HS25 wheel load specification, 100,000 cycle fatigue tests, ultimate compression tests, and reverse push-out tests. The prototype proved to be acceptable for rehabilitation of highway bridges. The prototype design was improved and approved as a safe, functional, and durable drain system by MaineDOT. Initially, MaineDOT ordered six FRP composite drains to begin replacing damaged steel ones in concrete bridge decks. The FRP drains were fabricated and installed in three highway bridge concrete decks in the state of Maine in 2002. The FRP drains performed satisfactorily in the bridges without requiring maintenance efforts (Lopez-Anido 2004).

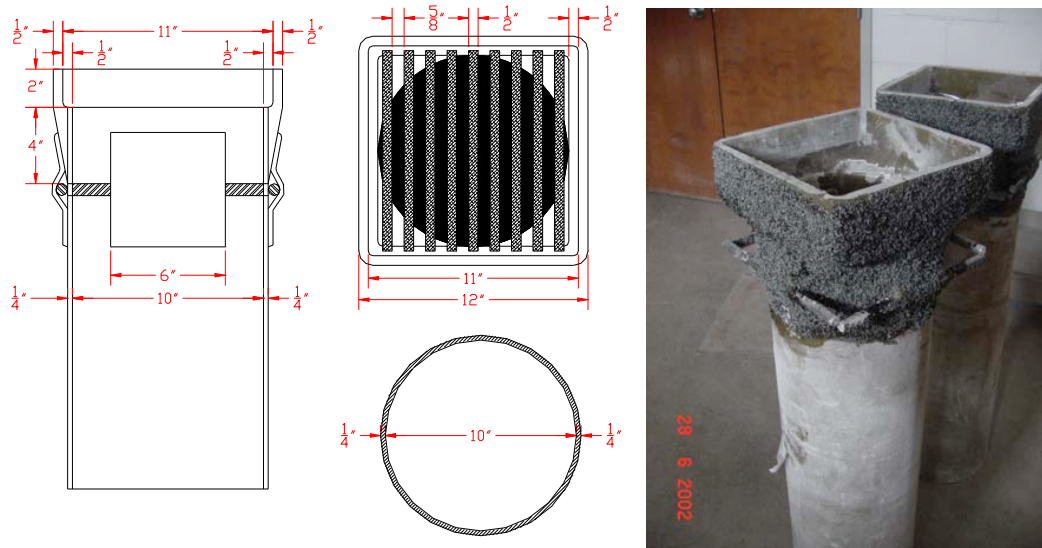


Figure 1. FRP Composite Drain Design for Bridge Rehabilitation Projects (UMaine-Kenway-MaineDOT)

The U.S. Domestic Scan program (NCHRP 20-68A) on leading practices in use of FRP composites in transportation infrastructure (Scan 13-03) was conducted in 2015 at the request of AASHTO (O'Connor and Frankhauser 2016). The scan team reviewed leading-edge applications in transportation structures and other areas of practice adaptable to transportation, considering agencies' experiences with project development and facility performance. The scan findings identified bridge drains and scuppers in lieu of steel or polyvinyl chloride plastic, within the applications of FRP composites for new components and systems. The scan publication presented a photograph of a composite drain from one of the participating FRP drain suppliers selected in Task 3. Furthermore, drain pipes and runoff collection systems were identified by the scan team as one of the applications that might be considered ready for widespread use.

Typical ranges for mechanical properties of FRP laminates manufactured by the filament winding, pultrusion and centrifugal casting processes are reported in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals (2013). The manufacturing process significantly influences the mechanical properties of the FRP laminated material. Two additional factors that affect the mechanical properties of the FRP material are the orientation of the fiber reinforcement and the fiber content.

Durability property requirements are presented in the AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members (2012). This guide states that commercial grades of vinyl ester and epoxy resin systems are permitted provided the finished product meets the physical and durability requirements. Two durability properties are

considered: moisture absorption at a water temperature of 122°F, and resistance to alkaline environment.

FRP material requirements including mechanical testing and durability acceptance criteria are detailed in the AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements (2012). This guide requires that the characteristic value of the tensile failure strain in the direction corresponding to the highest percentage of fibers shall not be less than one percent. Durability is assessed by conditioning the FRP material in four different environments for a specified periods of time: 1) water immersion at 100°F, 2) alternating ultraviolet light and condensation humidity, 3) alkaline solution (ph ≈11) immersion at 73°F, and 4) freeze-thaw cycling. After conditioning in the four different environments, guide requires the characteristic values retain 85 percent of the baseline value.

The American Composites Manufacturing Association (ACMA) was contacted as part of the review of the state-of-the-art. ACMA collaborated with the project by contacting member companies that fabricate FRP drains and pipes to provide input for drafting guidelines with standard practice for fabrication and installation of FRP drains in highway bridges. ACMA developed a Code of Standard Practice for Fabrication and Installation of Pultruded FRP structures (2011), which presents relevant technical information. Furthermore, ACMA provides expertise in the implementation of FRP composite products in infrastructure, and seeks market opportunities for its members to expand the application of the standard FRP drains nationwide.

Two composites manufactures, that commercialize FRP drains and pipes for bridge applications in the New England states, participated in the project: Kenway Corporation, from Augusta, ME, and Westfall Company (FRP Bridge Drain Pipe), from Eureka, MO.

OBJECTIVES

The main objectives of the project are to:

1. Design and fabricate a standard FRP drain that can be produced economically for use throughout New England bridges; and
2. Install the fabricated drain system in representative bridge applications in New England to provide information on its performance, and ease of construction.

The major obstacles or gaps for the implementation of FRP drains in highway bridges are the lack of material, fabrication and installation specifications, the unavailability of standard designs, and the unknown performance during service. The value of the project is to address these gaps. FRP drain systems can be used both for new construction and rehabilitation projects.

To attain the project objectives and address the current gaps the following activities were conducted:

1. Establish specific performance requirements for fiber-reinforced polymer (FRP) composite drains for highway bridges;
2. Draft standard specifications for FRP drains in bridge applications;
3. Identify and contact qualified composite manufacturers to get input on the standard practice for fabrication and installation of FRP drains.
4. Identify representative bridges to demonstrate and document the FRP drain installation methods.

REPORT ORGANIZATION

The project is organized in tasks as follows:

- Task 1: Review of typical bridge drain details that are representative in New England.
- Task 2: Development of standard drain requirements for new and rehabilitation projects
- Task 3: Selection of participating FRP drain suppliers
- Task 4: Qualification of FRP drain suppliers through material testing
- Task 5: Documentation of installation of FRP drains in bridges

REFERENCES

Breña, S.F., Civjan, S.A., and Goodchild, M., “Advanced Composite Materials for New England’s Transportation Infrastructure: A Study for Implementation and Synthesis of Technology and Practice, NETC 01-1,” Report No. NETCR62, New England Transportation Consortium, Nov. 2006. http://www.uvm.edu/~transctr/pdf/netc/netcr62_01-1.pdf

Breña, S.F., and Civjan, S.A., “Advanced Composite Materials in New England’s Transportation Infrastructure: Technology Transfer Phase 1 Selection of Prototype, NETC 01-1 T2 Phase 1,” Report No. NETCR77, New England Transportation Consortium, Nov. 2009. http://www.uvm.edu/~transctr/pdf/netc/netcr77_01-1_t2.pdf

MaineDOT, “Keeping Our Bridges Safe,” Report, Augusta, Maine, 2014. <http://www.maine.gov/mdot/pdf/kobs2014.pdf>

FHWA - HEC 21, “Design of Bridge Deck Drainage,” Hydraulics Engineering Circular No. 21, FHWA-SA-92-010, NTIS # PB94-109584, May 1993. <http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec21.pdf>

Lopez-Anido, R. “Fiber-Reinforced Polymer Composite Drain for Highway Concrete Bridge Decks,” Technical Report, Advanced Structures and Composites Center, University of Maine, Orono, ME, 2004.

O’Connor, J.S. and Frankhauser, W. “Advances in Fiber-Reinforced Polymer Composites in Transportation Infrastructure,” Transportation Research Record: Journal of the Transportation Research Board, No. 2592, Transportation Research Board, Washington, D.C., 2016, pp. 56–64. DOI: 10.3141/2592-07. <http://trrjournalonline.trb.org/doi/pdf/10.3141/2592-07>

AASHTO, “Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals,” Sixth Ed., 2013.

AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members, 2012.

AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, First Ed., 2012.

ANSI Standard “Code of Standard Practice for Fabrication and Installation of Pultruded FRP structures,” American Composites Manufacturers Association (ACMA), Arlington, VA, 2011. <http://www.acmaeducationhub.org/products/1036/ansi-standard-code-of-standard-practice-industry-guidelines-for-fabrication-and-installation-of-pultruded-frp-structures-digital-download>

TASK 1 - REVIEW OF TYPICAL BRIDGE DRAIN DETAILS THAT ARE REPRESENTATIVE IN NEW ENGLAND

SUMMARY OF NETC-DOT BRIDGE DRAIN PHYSICAL DESIGN PARAMETERS

A survey of New England state transportation agencies was conducted to investigate the variety of materials and geometries presently being used as bridge drains. This survey included a questionnaire to representatives from transportation agencies as well as a literature review of standard specifications and details.

A summary of this survey is given in Table 1. The goal of this task was to use this knowledge as a building block for Task 2 where common standards could be combined to develop an accepted specification for FRP bridge drains across New England.

Table 1 - Summary of NETC-DOT Bridge Drain Physical Design Parameters

Characteristic	Maine	New Hampshire			Rhode Island	Vermont	
Basic Data							
Type	One Piece Composite Scupper/Pipe	Welded Steel Hopper & HSS Drain Tubes	Offset Steel Scuppers w/HSS Drain Tubes	Offset Steel Scuppers w/HSS Drain Tubes	Cast Iron Offset Scupper	Offset Hopper used to collect runoff from expansion joint	Steel Fab. Curb Downspout
Outer Dimensions	33 7/16" x 13 1/8"	18" x 6"	17"x 9 "	18"x12"	31 7/8" x 16 3/4"	18"x12"	32" x 8"
Inlet Area (sq ft)	3	0.75	1	1.5	3.2	1.5	1.8
Pipe Area (sq ft)	0.29	0.21	0.34	0.56	0.31	0.2	0.39
Drain Pipe							
Drain Opening	Ø8 in	6" x 6"	8" x6"	12" x 8"	8" Nom Dia.	6" Nom Dia	8" x 8"
Pipe Material	3/8" thk Derakane 510C-350	6x6x1/4 HSS Structural Tube	8x6x1/4 TS Structural Tube	12x8x3/8 TS Structural Tube	8" Schedule 80 PVC Pipe	Fiberglass Construction	8x8x1/4 HSS Tube
Layup	N-MMMM-MRM	N/A	N/A	N/A	N/A	?	N/A
Connection Method	one piece construction	Welded Spliced Coupling	Bolted Welded Flange	Welded all around	Bolted PVC Pipe Flange	Glued Joint	Welded Joints

Table 1 (contd.) - Summary of NETC-DOT Bridge Drain Physical Design Parameters

Characteristic	Maine	New Hampshire			Rhode Island	Vermont	
Collector							
Design	Scupper Inlet	In line Hopper	Scupper	Offset Scupper	Offset Scupper	Non Symmetric Hopper	Flat Scupper
Box length	32.6875"	18"	17"	18"		18"	31.5"
Width (drain side)	12.125"	6"	9"	12"	31 7/8"	12"	7.5"
Width (far side)	12.125"	6"	9"	12"	16 3/4"	12"	14"
Depth	12"	4"	7.125"	11.25"	10"	12"	8"
Min Slope	3.5/12	2/3	2.625/12	2/5	1/4	4/9	0 - Flat Bottom
Material	3/8" thk Derakane 510C-350	1/4" Steel	3/8" Steel	3/8" Steel	3/4" Cast Iron AASHTO M105	Fiberglass Construction	1/4" Steel Plate
Layup	N-MMMM-MRM	N/A	N/A	N/A	N/A	?	N/A
Reinforcing	#5 rebar	N/A	N/A	N/A	N/A	N/A	N/A
Connection Method to Pipe	one piece construction	Welded Spliced Coupling			Bolt Circle to PVC Flange	Glued Joint	Welded MiterCut
Connection Method to Bridge Surface	8 - #5 rebar lugs	Bonding Agent/No Lugs	Bonding Agent + 4 - 1/2" Lugs	Bonding Agent + 5 - 1/2" Lugs	No Lugs	Not Embedded. Hangers only	4- 3/4"x8" Studs
Grate							
Material	GHB 150 Galvanized Steel		Welded Steel Bars	Welded Steel Bars	Cast Iron ASTM A536	N/A	No Detail
Slot Size	1 3/16" x 4"		7.75" x 2.4"	12.875" x 2.43"	13"x 1.6" Bike Friendly		
Depth	1 1/2"		2.5"	2"	1 1/2"		
AASHTO Class/Capacity	HS 25				Grade 60-40-1B		
Other							
Color	gray						
Material and Workmanship Standards	ASTM C 582						
Cleanout		14"x 4" Steel Access Plate					
Coatings		Galv. per AASHTO M-111	Galv. per AASHTO M-111	Galv. per AASHTO M-111	Polyurethane + Waterproof Fabric Membrane	Special Prov. (Bridge Fiberglass Drain System)	

TASK 2 – DEVELOPMENT OF STANDARD DRAIN REQUIREMENTS FOR NEW AND REHABILITATION PROJECTS

Based on the information collected in Task 1, and in consultation with members of the technical committee assigned to the project, the following activities were completed:

- a) Establish specific performance requirements for fiber-reinforced polymer (FRP) composite drains for highway bridges;
- b) Develop guidelines with standard practice for fabrication and installation; and
- c) Draft standard specifications for FRP drains for bridge projects within the New England region.

The guidelines and specification are applicable for both new bridge construction projects and rehabilitation projects. The standard specification, which were written based on the findings from Task 1, are appended.

CRITERIA FOR BASELINE MECHANICAL PROPERTIES AND DURABILITY REQUIREMENTS

Tensile and compressive mechanical properties for production validation are reported for both the axial and hoop directions of the tubular components, or the transverse and longitudinal directions of inlet bodies (see Section A.5.1 Test Samples), as follows:

- 1) Tensile strength, tensile modulus of elasticity and ultimate tensile strain are determined in accordance with ASTM D 3039 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials, and
- 2) Compressive strength and ultimate compressive strain are determined in accordance with ASTM D 6641 Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture.

The mechanical properties are obtained by testing coupons cut from FRP laminates (witness plates) manufactured with the same process, lay-up, fiber reinforcement, resin matrix, fiber content and thickness than the FRP drain scupper bodies, inlets and pipes.

The minimum allowable values for the baseline mechanical properties presented in Table A.5.4.b are established as follows:

- 1) The ultimate tensile strain of 0.01 in/in (1%) is based on the requirements from the AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements (2012).
- 2) The allowable tensile strength of 16,000 psi and compressive strength of 22,000 psi are minimum acceptable values for FRP laminates with multidirectional reinforcement and typical manufacturing processes, fiber content and resin systems used for FRP bridge drains.
- 3) The tensile modulus of elasticity of 1,600 ksi is determined based on assuming a linear elastic relationship between tensile stresses and strains until failure.
- 4) The compressive strain is reported at the required compressive strength of 22,000 psi, instead of at ultimate, because experience with compression testing indicates that beyond

this value it is unreliable to measure compressive strains. For simplicity, a minimum compressive strain value of 0.01 in/in (1%) is adopted.

The minimum allowable values for the durability mechanical properties after conditioning in the four different environments, presented in Tables A.5.4.c-f are based on the requirements of the AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements (2012). The requirements are:

- 1) Retain 85% of the average baseline values of tensile strength, tensile modulus of elasticity and compressive strength, and
- 2) Retain 85% of the minimum allowable values of tensile strain and compressive strain.

The rationale is that 85% retention of strength and modulus (stiffness) with respect to the baseline values is indicative of the long-term durability of the FRP laminate. Since there is typically greater experimental variability in the measurement of ultimate strains, the corresponding requirement is to retain 85% of the minimum allowable value.

FRP COMPOSITE BRIDGE DRAIN COMPONENTS SPECIFICATION

1.0 Description

This work consists of items related to the design and manufacture of bridge drains using FRP (Fiber Reinforced Polymer) composite materials. It calls out the minimum material properties and tests, recommended standard geometric scupper design sizes and tolerances, provisions for geometric deviations, tolerances for construction and measurement, practices for installation and attachment, supplier qualifications, acceptance and payment. It does not prescribe specific fiber/matrix materials, lay-ups, grates, attachment hardware, or construction techniques.

1.1 Applicable Standards and References

The design and construction of FRP composite bridge drain components shall be in accordance with this Methods Specification and the relevant requirements of the following standards and specifications, unless otherwise stipulated in this specification. Standards and specifications specifically cited in the body of the specification establish requirements that shall have precedence over all others. Should the requirements in any reference conflict with those in another, the reference highest on the list shall govern. It is the Design-Builder's responsibility to obtain clarification of any unresolved ambiguity prior to proceeding with the design or construction.

1.2 Specifications

- A.) Standard Specifications.
- B.) FHWA Hydraulics Engineering Circular No.21 (HEC 21) Design of Bridge Deck Drainage, May 1993.
- C.) AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members, 2012.
- D.) AASHTO LRFD Bridge Design Specifications 6th Ed with 2013 Interims, 2012.
- E.) American Composites Manufacturing Association, ACMA Code of Standard Practice, First Edition, 2011.
- F.) ISO/IEC Guide 58, Calibration and Testing Laboratory Accreditation Systems - General Requirements for Operation and Recognition.
- G.) ISO/IEC 17025 General Requirements for the Competence of testing and Calibration Laboratories.
- H.) NBS Voluntary Product Standard PS15-69. Custom Contact-Mold Reinforced Polyester Chemical-Resistant Process Equipment. The Society of the Plastics Industry, Inc., 355 Lexington Ave., N.Y., N.Y. 10017

2.3 Standards

- A.) ASTM D 2584. *Standard Test Method for Ignition Loss of Cured Reinforced Resins*. American Society for Testing and Materials, West Conshohocken, PA.
- B.) ASTM D 3039. *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*. American Society for Testing and Materials, West Conshohocken, PA.

- C.) ASTM D 6641. *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture*. American Society for Testing and Materials, West Conshohocken, PA.
- D.) ASTM D 3171. *Standard Test Methods for Constituent Content of Composite Materials*. American Society for Testing and Materials, West Conshohocken, PA.
- E.) ASTM D 4385. *Standard Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products*. American Society for Testing and Materials, West Conshohocken, PA.
- F.) ASTM D 570. *Test Method for Water Absorption of Plastics*. American Society for Testing and Materials, West Conshohocken, PA.
- G.) ASTM E 1356. *Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry*. American Society for Testing and Materials, West Conshohocken, PA.
- H.) ASTM E 1640. *Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis*. American Society for Testing and Materials, West Conshohocken, PA.
- I.) ASTM C 582. *Standard Specification for Contact-Mold Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment*. American Society for Testing and Materials, West Conshohocken, PA.

2.0 Material

Materials shall conform to the following Section:

FRP composite drain and pipe material requirements

Appendix A

3.0 Construction Requirements

3.1 Scope

Section 3 describes the process of design, design approval, manufacture and quality procedures required specifically for development and manufacture of FRP composite drain components.

3.2 Allowed Processes

The contractor/manufacturer of FRP composites may use any process available to manufacture FRP composite drain components providing the process yields components that conform to the material composition and properties set forth in Section 2 and design provisions pursuant to Section 3.

3.3 Contractor/Manufacturer Qualifications

All manufactures or fabricators associated with the development of specifications and manufacture/fabrication of FRP bridge drain systems/components are required to have a minimum of 3 years of experience in providing FRP composite structural grade products to the general market and are encouraged to provide documentation that personnel involved in the development of specifications and manufacture/fabrication hold and maintain ACMA certifications in a minimum of two of the following disciplines; 1) Open Molding, 2) Corrosion, 3) Vacuum Infusion, 4) Closed Molding and that the Manufacturer/Fabricator have an ISO

9001:(current year) or other independent certification to ensure that the Manufacturer's process has been independently audited for conformance.

3.4 Design Guide for FRP Composite Scupper Bodies/Drain Inlets

3.4.1 Scope

This section provides general guidelines for the geometric design of pre-established sizes and recommended geometric criterion for custom scupper and inlet bodies. The scupper body and inlet bodies as set forth may be modified with various flanges and extensions as dictated by the owner.

3.4.2 Design Guide for Scupper and Inlet Bodies

The Design Guide does not prescribe specific designs, but is intended as a means to provide some preferred "off the shelf" sizes for FRP composite scupper and inlet bodies while allowing various manufacturing techniques to be employed. The design guide is not all encompassing but may act as a check list during the design and design review process. It is specifically for FRP composite designs and meant to complement FHWA Hydraulics Engineering Circular No.21 (HEC 21) Design of Bridge Deck Drainage, May 1993 and AASHTO LRFD Bridge Design Specifications.

3.4.2a Preferred inlet/scupper sizes and overall geometries.

The preferred drain inlet body design parameters are of the following forms; 1) offset scupper bodies and 2) symmetric inlets as provided in Appendix B.

3.4.2b Deck/interface drain holes.

As an option drain holes may be required along the scupper side to capture moisture at the interface between the deck and pavement. Three holes one half inch in diameter spaced at 6 inches on center and three and one quarter inches on center below the top of the grate, or pavement thickness, shall be placed on both sides of the scupper. If the holes are created after the molding process by punching, drilling or other mechanical means the holes shall be sealed using a compatible epoxy compound.

3.4.2c Grates

Grates to be bicycle friendly and designed for HL-93 unless otherwise specified. Elongations shall be oriented such that the long axis of the elongation is perpendicular to the normal flow of bicycles on that roadway and gaps shall have a maximum clear width of two inches. Grates are to comply to FHWA Hydraulics Engineering Circular No.21 (HEC 21) Design of Bridge Deck Drainage, May 1993. Grates are to be galvanized steel or FRP specifically designed and approved for the HL-93 requirements. Grates shall be designed so that they may be removed by mechanical means. Fasteners for grates shall be stainless. Where selected grates require orientation to flow, the grates will have orienting features included as required, i.e. for orders of paired drains one drain would have left hand orientation and the other right hand orientation.

3.4.2d Grate Frames

Grate frames may be either integrated FRP composite or of galvanized steel construction attached to the scupper/inlet body in a matter consistent with the physical design parameters.

3.4.2e Anchoring provisions

Scupper/inlet anchoring shall be bonded to the grate framing in a manner that provides a load path into the concrete decking. Anchor details to be specified in the project plans and design reviews. Drain pipe anchoring shall follow standard practice for areas not subject to flooding. Anchoring of drain pipes located over streams where flooding may occur shall be designed to meet loads related to floating debris and/or ice flows.

3.4.2f Cross and Longitudinal Slope Compensation

The scupper/inlet designs shall provide a means to match the grate to the deck angles while maintaining the downspout in a plumb orientation. If purchased in pairs one left handed version will be required for each right handed version. This may be achieved when a down spout portion is bonded to the scupper body, through the frame attachment to the scupper body or through any other viable option.

3.4.3 Provisions for Custom Design Scupper and Inlet Bodies

The Design Guide does offer provisions for custom designs. Any design acceptable to the owner that complies to FHWA Hydraulics Engineering Circular No.21 (HEC 21) Design of Bridge Deck Drainage, May 1993 is acceptable provided the material composition and properties set forth in Section 2 of this standard are complied to and the wall thicknesses are greater than or equal to 1/4 inch.

3.4.4 FRP Composite Drain Sections

Bridge deck downspouts, bridge drain deck extensions, elbows and pipe for under drains are recommended to be constructed using circular cross sections, however other cross sections are allowed upon engineering approval. Drain sections shall comply to the material requirements set forth in Section 2 and maintain wall thickness of no less than 1/8 inch for dry crossings and no less than 1/4 inch over stream crossings where ice flows or floating debris may pose a problem during flood events.

3.4.5 FRP Composite Deck Drain Extensions.

Down spout drain extensions may be integrated and bonded directly to the scupper bodies without additional lateral supports for lengths up to 4 feet. Downspouts extensions between 4 feet and 8 feet require additional support and shall be attached to the bridge deck or components that move in direct relation to the scupper/inlet body.

Where additional supports cannot be anchored to locations that move directly with the scupper/inlet body or an extension greater than 8 feet is required, a hopper style inlet necked down to the down spout diameter shall be used. Hoppers shall be designed to encircle the downspout with a one inch concentric clearance and down spout inserted to a minimum of 2 inches into the catch hopper. Fastening schedules of the drain piping to be designed according to the manufacturers recommendations.

3.4.6 Transitions through Connections and Components.

All transitions and joints to be manufactured through the use of smooth radius molds. Miter joint and edged transitions are not allowed. All internal joint connections are to be smooth and continuous.

3.4.7 Pigmented FRP Composite Drain Components

Pipes, fittings, bodies and all FRP composite drain system components shall be pigmented through the wall. Color to be standard concrete-grey or other neutral color as agreed within the contract documents. Paint, gel-coat or any other exterior coating shall not be accepted.

3.4.8 Joint Connections

Joints may be welded using manufacturer recommended adhesives in accordance to the adhesive manufacturer's application procedures. Adhesives must be compatible with the FRP resins, applied in a way that ensures complete bonding and liquid tight sealing of the resins, and be compatible with the environmental conditions such as temperature, freeze thaw conditions, and wet alkaline environments.

3.4.9 Design Review

The contractor/manufacturer of FRP composite drain components shall submit approval drawings to the Resident Engineer providing design and manufacturing details relevant to the application and standard specifications. The Resident Engineer shall be allowed 7 working days to review the submittal.

3.4.9a Submitted Drawings

Drawings shall include dimensions and tolerances necessary for manufacture and installation, all hardware, orienting features, anchor details, fastener details, gasket details, cross and longitudinal matching features, joint details, transition details, material lay-up/composition as to be certified under Section 2, other items as listed in Section 3 and any other information as requested by the Resident Engineer.

3.4.9b Manufacturing Control Plan

The manufacturer shall submit a manufacturing and inspection control plan to the Resident Engineer for review. Inspection dimensions should correspond to dimensions on the drawings.

3.4.9c Authorization to Manufacture

After design review and sign off of the drawings and control plans the constructor shall proceed with manufacturing and supply of components per the agreed manufacturing plan and design.

3.4.10 Inspection of Components

The manufacturer of components shall supply all agreed inspection data and manufacturing composition data per Table 2.5.4a to the Resident Engineer prior to and with the shipping of components. All agreed inspection dimensions and items per control plans shall be in conformance of the plans. In the case of non-conformities the contractor will not be allowed to ship unless a signed deviation waiver is granted by the resident engineer.

3.4.11 Packaging, Storage and Shipping of Components

FRP drains shall be stored and handled in accordance with the manufacturer's recommendation. Shipping shall meet the schedule as set forth by the purchasing agreement and/or needs for installation.

3.4.12 Receipt and Inspection of Components

FRP drains are to be received and stored at the contractors installation sight per the purchasing agreement in accordance to the manufacturer's recommendation. Inspection of the components may be conducted to verify the inspection dimensions provided by the manufacturer.

3.4.13 Installation

The contractor will shall install the FRP drains in accordance to the manufacturer's installation procedures and in accordance to the contractor's installation drawings. Any repairs to the drains

as a result of mishandling at the installation sight shall be done at the expense of the contractor in accordance to the manufacturer's recommendations.

4.0 Measurement and Payment

4.1 Method of Measurement

FRP Bridge Drains will be measured by the number of units, for fabrication and delivery. Installation for the drains will be incidental to the Structural Concrete Superstructure item.

4.2 Basis of Payment

FRP Bridge Drains will be paid for at the contract unit price. Such payment will include compensation for the fabrication and delivery of the drains in accordance with this specification.

Payment will be under:

<u>Pay Item</u>		<u>Pay Unit</u>
XXX.XX	FRP Bridge Drain Description	Each

APPENDIX A: FRP COMPOSITE DRAIN AND PIPE MATERIAL REQUIREMENTS.

A.1 Scope

This section specifies the material composition, properties, test requirements and reports that shall be submitted and approved prior to and after product certification of each FRP composite drain component type, e.g. scupper body or pipe component. The manufacturer is responsible for testing using an approved independent lab per section A.5.3. Once certified the approved product may be manufactured with only internal testing provided the manufacturing process and laminate composition do not change. Changes to process and or composition do require additional testing and product certification. The manufacturer shall report the individual test results per section A.5.3. If the strength is less than the required properties certification will not be granted.

A.2 Material/Laminate Composition

A.2.1 Fibers

Fiber sizings and coupling agents shall be compatible with the resin system used to impregnate them.

A.2.2 Matrix Resins

Commercial grades of vinyl ester and epoxy resin systems are permitted provided the finished product meets the material property requirements before and after durability conditioning as set forth in Section A. Styrene is permitted to be added to the polymer resin during processing. Added styrene shall be less than 10 percent by mass of the polymer resin. The amount of styrene, as a mass percentage of the polymer resin, added during processing shall be reported per Section A.5.3.

A.2.3 Fillers and Additives

Commercial grade inorganic fillers such as kaolin clay, calcium carbonate, and alumina tri-hydrate shall not exceed 20 percent by mass of the polymer resin constituent. Commercial grade additives and process-aids, such as release agents, low profile shrink additives, initiators, promoters, hardeners, catalysts, pigments, fire-retardants, and ultra-violet inhibitors are permitted and depend on the processing method. Shrink additives, if used, shall be less than 20 percent by mass of the polymer resin. Commercial grade inorganic or organic non-woven surfacing mats or veils are permitted.

A.2.4 Fiber Content

Fiber content shall be measured by ASTM D 3171 or ASTM D 2584. Fiber content shall be high enough to meet the mechanical property requirements of the FRP system laminate. The manufacturer shall report the fiber content of the end product by volume or by mass in accordance to the method used. If fiber content is not provided by the manufacturer, then the manufacturer shall provide material data sheets with the weight per unit area of the fiber reinforcement used to manufacture the part.

A.2.5 Glass Transition Temperature

The characteristic value of the glass transition temperature of the composite system, determined in accordance with ASTM E1640, shall be at least 40 degrees Fahrenheit higher than the maximum design temperature, $T_{MaxDesign}$, defined in section 3.12.2.2 of the AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes for Flexural and Axial Members,

2012. FRP drain systems may not be used in environments with a service temperature higher than the glass transition temperature of the resin used for their manufacturing.

A.2.6 Longitudinal and Transverse Coefficients of Thermal Expansion (CTE)

The coefficient of Thermal Expansion (CTE) of the tube may vary in the longitudinal and circumferential directions of the component depending on the laminate architecture and type of fibers and resins.

A.3 Mechanical Properties

A.3.1 Tensile Properties

The tensile strength, tensile modulus of elasticity, and ultimate tensile strain shall be determined for both the axial and hoop directions of the tubular components or in transverse and longitudinal directions of inlet bodies, see Section A.5.1 Test Samples. The tensile strength as reported by the manufacturer for product certification shall be measured according to ASTM Test Method D 3039, or other tension test method designed to determine tensile properties of composite laminates at the approved frequency and number of specimens as specified in section A.5.

A.3.2 Compressive Properties

The compressive strength and ultimate compressive strain shall be determined for the longitudinal directions of the tube laminate. The compressive strength and ultimate compressive strains shall be derived from specimens tested in accordance with ASTM Test Method D 6641, or other approved compression test method designed to determine compressive properties of the composite.

A.4 Durability Properties

Material properties shall retain 85% of their baseline values for the material properties listed in Section 2.3 after conditioning for all the durability tests listed below. Durability test methods are adopted from AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, 2012.

Durability property testing is only required for initial product certification and not required for subsequent production orders. The testing is the responsibility of the manufacturer and shall be conducted by an approved independent testing lab per section A.5.2.

A.4.1 Moisture Absorption

Samples will be immersed in distilled water having a temperature of 100 +/-3 degrees Fahrenheit and tested after 1,000 hours of exposure.

A.4.2 Resistance to Alkaline Environment

Samples will be immersed in a saturated solution of calcium hydroxide (pH-11) at ambient temperature of 73 +/-3 degrees Fahrenheit for 1,000 hours prior to testing. The pH level will be monitored and the solution will be maintained as needed.

A.4.3 Alternating Ultraviolet Light and Condensation Humidity

Samples will be conditioned in an apparatus under Cycle I-UV exposure condition according to ASTM G154 Standard Practice. Samples will be tested within two hours after removal from the apparatus.

A.4.4 Freeze-Thaw

Samples will be exposed to 100 repeated cycles of freezing and thawing in an apparatus meeting the requirements of ASTM C666.

A.5 Sampling, Testing & Results.

A.5.1 Test Samples.

The manufacturer is responsible for testing and may use samples in accordance to the test methods and needs of test equipment available. Test coupons may be cut from manufactured products or prepared using identical processes, e.g., wet lay-up, vacuum infusion, etc. in a flat sheet, or witness plate, in which test coupons may be cut. Approval of the engineer shall be required for acceptance of test specimens produced by a different manufacturing method. Samples derived from special coupon test sheets shall be taken interior to edge sections 1.5x the width of the required coupon width. Samples shall be prepared from samples oriented with the directions illustrated in figures 1 and 2 for scupper body and drain pipes. For samples from filament wound pipes, samples shall be constructed over polygon mandrels allowing for flat panels to be removed for test purposes. Each test shall use a quantity of three samples. See Tables A.5.4 for tests, material requirements and sample breakdown.

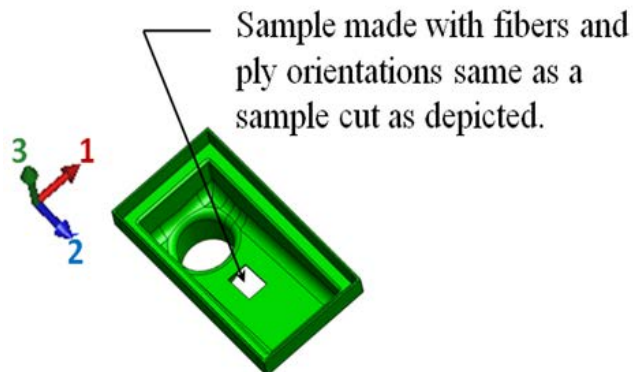


Figure 1.) Scupper Body
Sample Orientations.

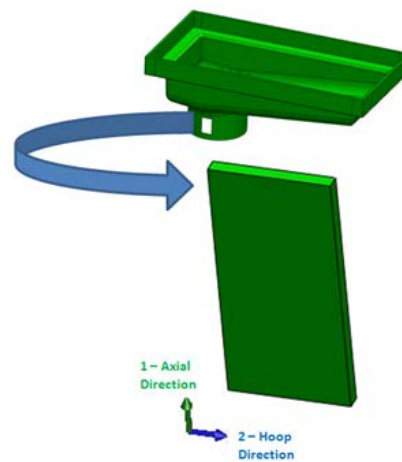


Figure 2.) Drain Pipe
Sample Orientations.

A.5.2 Test Lab Requirements.

All testing of FRP material properties is to be conducted in accordance to specified standards. Internal or external testing is to be conducted through laboratory facilities in accordance to ISO/IEC Guide 58, *Calibration and Testing Laboratory Accreditation Systems - General Requirements for Operation and Recognition* and ISO/IEC 17025 *General Requirements for the Competence of testing and Calibration Laboratories* as related by AASHTO document R18 "Recommended Practice for Establishing and Implementing a Quality System for Construction Materials Testing Laboratories."

A.5.3 Production Validation (PV) Testing.

Certification of materials used in FRP drain products must undergo PV testing of the specified material properties before and after environmental conditioning as set forth in Section A.5.4 by

an independent lab. PV tests may be conducted internally by the manufacturer for development but are not acceptable for certification. Reported values for the material composition is be recorded and reported by the manufacturer, no independent audit is required.

A.5.4 Production Validation Sample Quantities, Minimum Material Properties and Reported Values

The following data shall be reported for material certification. Note that the tables shown use orientations related to FRP scupper or inlet bodies as set forth in Figure 1 of Section A.5.1, orientation direction 2 as shown in Figure 2 of Section A.5.1 shall be substituted for orientation direction 3 when evaluating tubular sections. The required number of samples has been reduced from ASTM requirements.

Table A.5.4.a PV Reported Material Composition Data (Recorded by the manufacturer during the manufacturing process)

Section No.	Characteristic	Applicable Test Standard	Number of Samples	Tolerance	Reported
A.2.2	Styrene, mass percentage of polymer resin	per tolerance	N/A	10% max	
A.2.3	Inorganic fillers, mass percentage of polymer resin.	per tolerance	N/A	20% max	
	Shrink additives, mass percentage of polymer resin.	per tolerance	N/A	20% max	
A.2.4	Fiber Content	ASTM D3171 or ASTM D2584	3	Sufficient to meet mechanical properties	
A.2.5	Glass Transition Temperature	ASTM E1640	3	> Max Design Temperature	

Table A.5.4.b PV Reported Baseline Mechanical Properties

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	16,000					
				Tensile Modulus of Elasticity (ksi)	1,600					
				Ultimate Tensile Strain (in/in)	0.01					
	2	ASTM D3039	3	Tensile Strength (psi)	16,000					
				Tensile Modulus of Elasticity (ksi)	1,600					
				Ultimate Tensile Strain (in/in)	0.01					
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	22,000					
				Compressive Strain at 22,000-psi (in/in)	0.01					
	2	ASTM D6641	3	Compressive Strength (psi)	22,000					
				Compressive Strain at 22,000-psi (in/in)	0.01					

Table A.5.4.c PV Reported Durability Mechanical Properties after 1000 hs. Moisture Immersion Conditioning per Section A.4.1

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					

Table A.5.4.d PV Reported Durability Mechanical Properties after 1000 hs. of Alkaline Environment Conditioning per Section A.4.2

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					

Table A.5.4.e PV Reported Durability Mechanical Properties after UV Light Conditioning per Section A.4.3 (ASTM G154)

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					
				85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
	2	ASTM D6641	3	Compressive Strain at 22,000-psi (in/in)	0.0085					
				85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					

Table A.5.4.f PV Reported Durability Mechanical Properties after 100 Freeze-Thaw Cycles Conditioning per Section A.4.4 (ASTM C666)

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	0.85 * (baseline average value)					
				85% Baseline Tensile Modulus of Elasticity (ksi)	0.85 * (baseline average value)					
				Ultimate Tensile Strain (in/in)	0.0085					
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					
				85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
	2	ASTM D6641	3	Compressive Strain at 22,000-psi (in/in)	0.0085					
				85% Baseline Compressive Strength (psi)	0.85 * (baseline average value)					
				Compressive Strain at 22,000-psi (in/in)	0.0085					

APPENDIX B: PREFERRED INLET/SCUPPER SIZES AND OVERALL GEOMETRIES.

The preferred body sizes are intended as a basic design from which modifications to the wall heights, frame, downspouts and other parts may be made to accommodate a variety of needs such as catch hoppers, inlets with extended downspouts, etc.

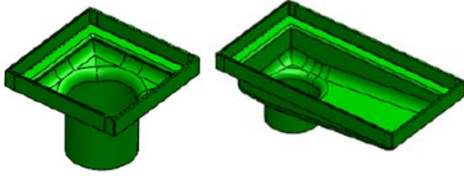


Figure B1) Symmetric Inlet & Offset Scupper Configurations

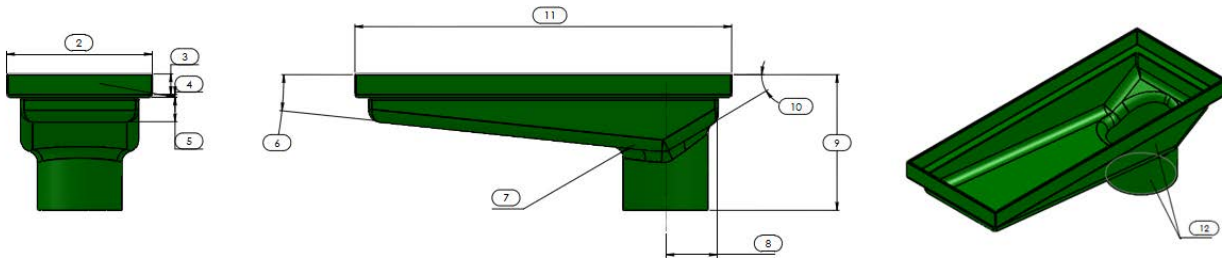


Figure B2) Guideline Dimensions to Design within for Preferred Sizes

Table B1 Preferred Symmetric FRP Composite Inlet Bodies

Size Designation		A	B	C		
Size Dimensions (Grate Length x Width, Down Spout Diameter)		12x12x ϕ 8	14x14x ϕ 10	18x18x ϕ 12		
Number	Dimension Name	Nominal Dimensions			Nominal Design Tolerance	Manufacturing Tolerance
1	Down Spout Inner Diameter	8"	10"	12"	min	+/- 0.015"
2	Grate Frame Width	12"	14"	18"	+/- 1"	+/- 0.025"
3	Grate Frame Height	As required to contain grate and recessed from deck surface				
4	Grate Frame Flange & Wall Thickness	0.25"	0.25"	0.25"	min	+/- 0.025"
5	Scupper Toe Depth	4"	4"	4"	+1"/-0"	+/- 0.1"
6	Scupper Toe Slope	1:10	1:10	1:10	min	+ 1 degree
7	Scupper Body Radii	2"	2"	2"	min	+0.1"
8	Down Spout Position to Heel	6"	6"	6"	+/- 0.5"	
9	Height	18"	18"	18"	Open	+/- 0.25"
10	Scupper Heel Slope	1:10	1:10	1:10	min	+0.1"
11	Grate Frame Length	12"	14"	18"	+/- 1"	+/- 0.025"
12	Scupper and Down Spout Wall Thickness	0.25"	0.25"	0.25"	min	+0.015"

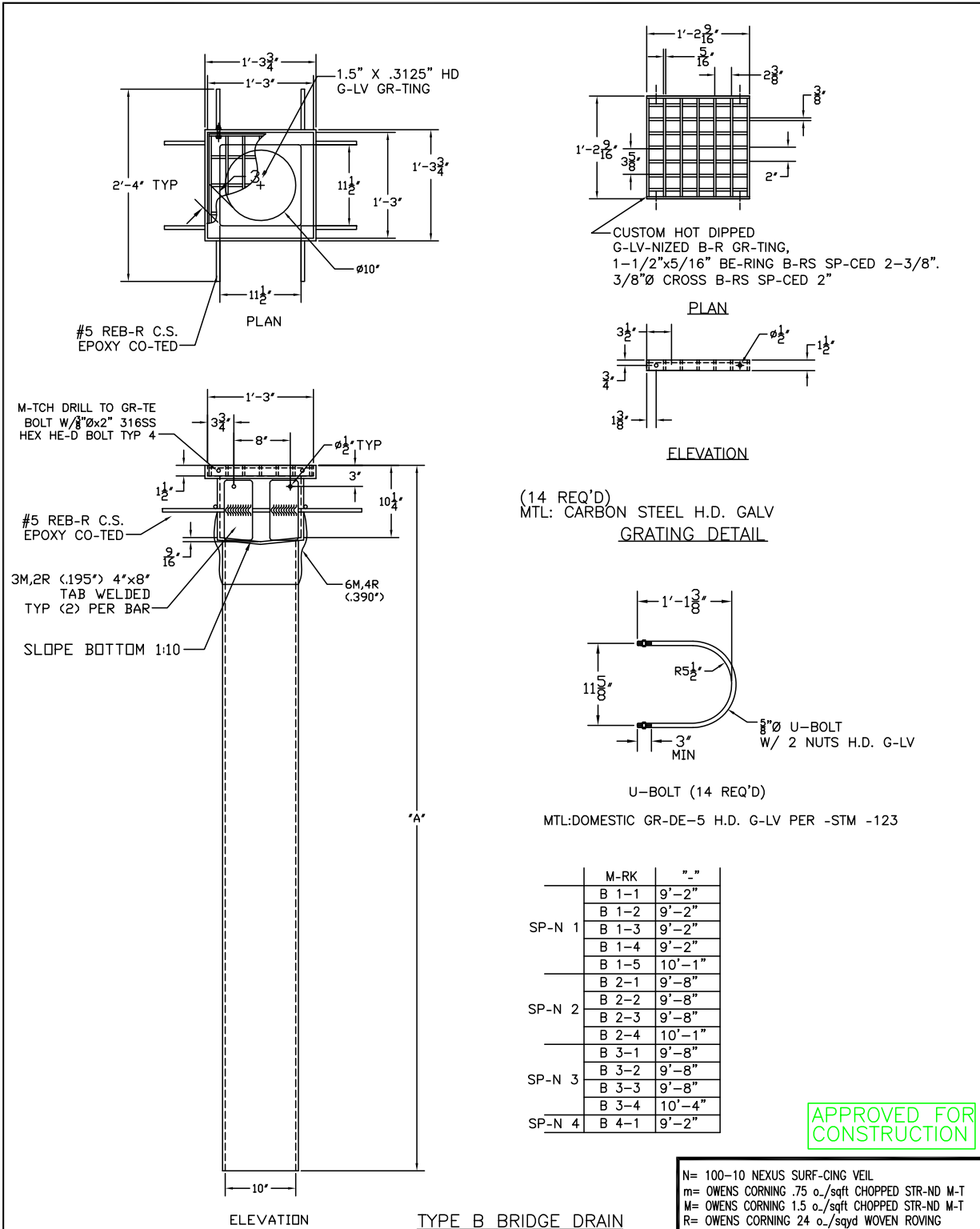
Table B2 Preferred Offset FRP Composite Scupper Bodies

Size Designation		D	E	F	G		
Size Dimensions (Grate Length x Width, Down Spout Diameter)		24x12xØ8	30x12xØ10	36x12xØ10	42x12xØ12		
Dimension		Nominal Dimensions				Nominal Design Tolerance	Manufacturing Tolerance
Number	Name						
1	Down Spout Inner Diameter	8"	10"	10"	12"		
2	Grate Frame Width	12"	12"	12"	12"	+ 2"/-0"	+/- 0.025"
3	Grate Frame Height	As required to contain grate and recessed from deck surface					
4	Grate Frame Flange & Wall Thickness	0.25"	0.25"	0.25"	0.25"	min	+/- 0.025"
5	Scupper Toe Depth	4"	4"	4"	4"	+1"/-0"	+/- 0.1"
6	Scupper Toe Slope	1:10	1:10	1:10	1:10	min	+ 1 degree
7	Scupper Body Radii	2"	2"	2"	2"	min	+0.1"
8	Down Spout Position to Heel	6"	6"	6"	6"	+/- 0.5"	
9	Height	13.5"	16"	18"	18"	Open	+/- 0.25"
10	Scupper Heel Slope	1:10	1:10	1:10	1:10	min	+0.1"
11	Grate Frame Length	24"	30"	36"	42"	+ 2"/-0"	+/- 0.025"
12	Scupper and Down Spout Wall Thickness	0.25"	0.25"	0.25"	0.25"	min	+0.015"

APPENDIX C: SPECIAL PROVISION FOR FRP BRIDGE DRAINS FOR THE HOWLAND-ENFIELD BRIDGE, MAINE

MaineDOT implemented the FRP bridge drain specifications developed in this NETC 09-03 project for the Howland-Enfield Bridge (WIN 016705.00) as a Special Provision, Section 502, Structural Concrete. Maine DOT replaced an existing bridge over the Penobscot River between the towns of Howland and Enfield with a four span 940 foot composite steel and concrete bridge. The contractor is Reed & Reed and the contract completion date is December 30, 2017.

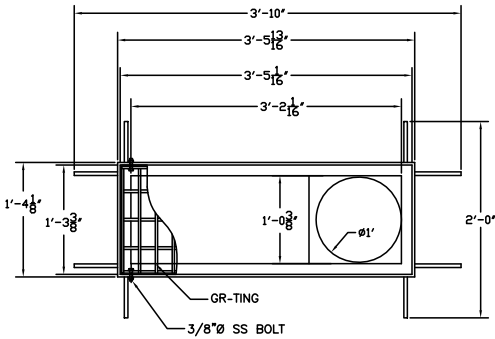
The shop drawings prepared by Kenway Corp. for of Type B and Type G FRP drains are appended. The laminate lay-up is shown in the drawings.



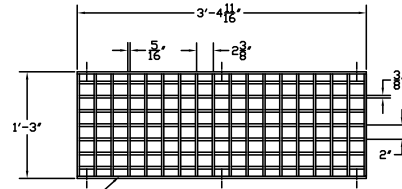
Custom Composites Fabricator For Industry

K KENWAY CORPORATION
681 Riverside Drive
Augusta, Maine 04330
Voice (207) 622-6229
Fax (207) 622-6611

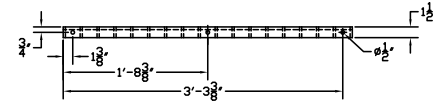
REV.	D-TE	DESCRIPTION	CUSTOMER: HOWL-ND-ENFIELD BRIDGE	DR- ING NO. 8789-1
3	9/15/15	CH- GED LENGTH OF DOWNSPOUTS	RESIN: DER-K-NE 510C-350	D-TE: 3/27/15
2	6/22/15	RLCTD DR-IN HOLES, GR-TING DET-LL -DDED 1:10 SLOPE	L-YUP SCHEDULE: N-mmM-MRMRM	DR- N: P-UL D
1	5/29/15	CH- GED OVER-LL LENGTHS	STRUCTUR-L THK: .25	WORK ORDER: 8789
			COLOR: GR-Y	SC-LE: NONE
			PROJECT NO: WIN 16705.00	



PL-N

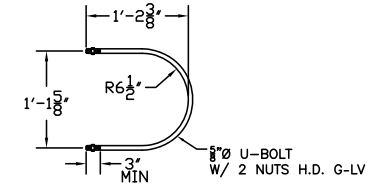
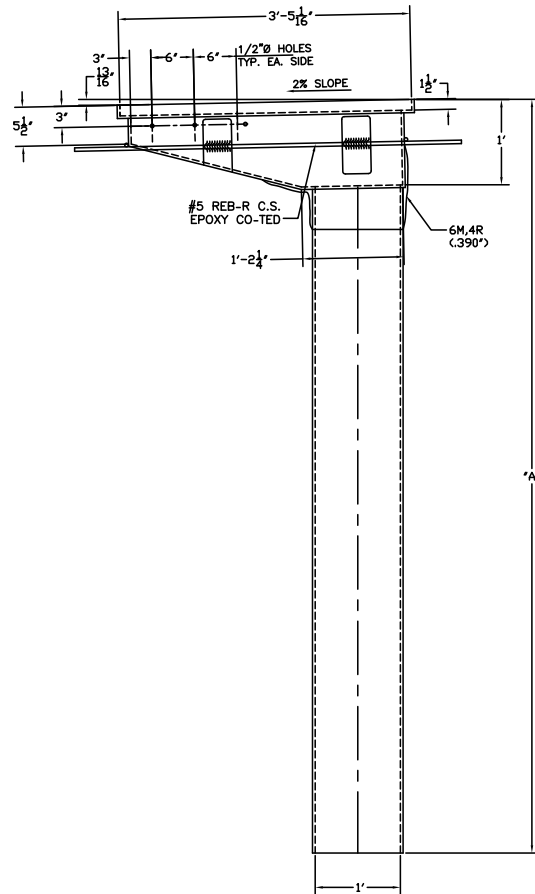


PL-N



ELEV-TION

(4 REQ'D)
MTL: C-RBON STEEL H.D. G-LV
GRATING DET-IL



U-BOLT (4 REQ'D)
MTL: DOMESTIC GR-DE-5 H.D. G-LV PER -STM -123

	M-RK	"-"
SP-N 1	G 1-1	9'-2"
	G 1-2	10'-2"
SP-N 2	G 2-1	10'-2"
SP-N 3	G 3-1	10'-6"

N= 100-10 NEXUS SURF-CING VEIL
m= OWENS CORNING .75 o./sqft CHOPPED STR- D M-T
M= OWENS CORNING 1.5 o./sqft CHOPPED STR- D M-T
R= OWENS CORNING 24 o./sqyd WOVEN ROVING

TYPE G BRIDGE DR-IN

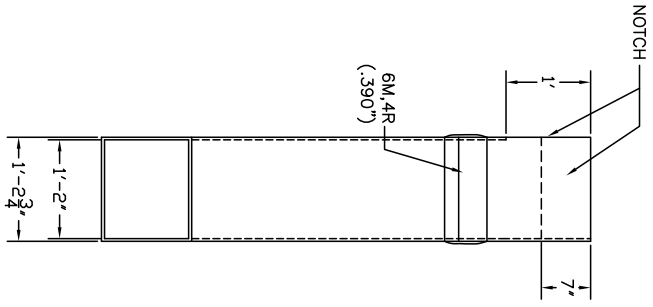
APPROVED FOR CONSTRUCTION

Custom Composites Fabricator For Industry

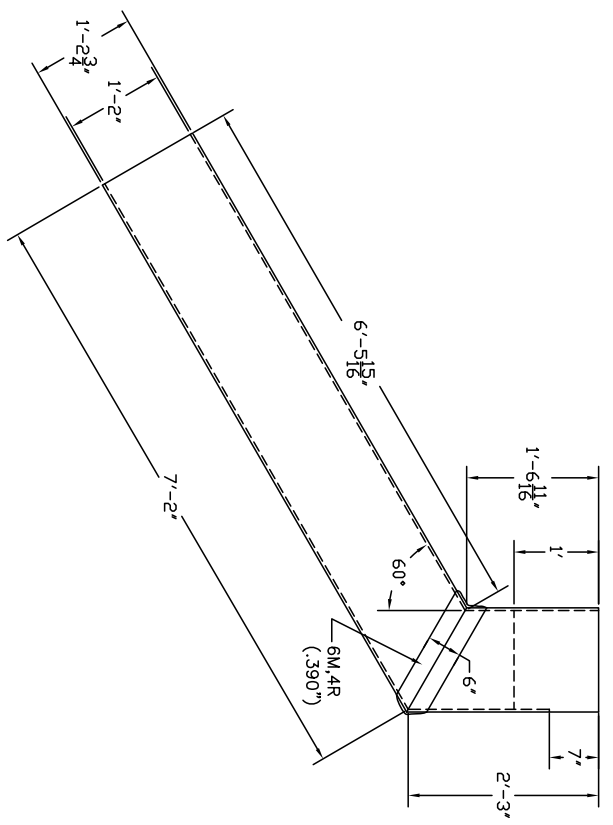


KENWAY CORPORATION
681 Riverside Drive
Augusta, Maine 04330
Voice (207) 622-6229
Fax (207) 622-6611

REV.	D-TE	DESCRIPTION	PROJECT: HOWL- D-ENFIELD BRIDGE	D-TE: 3/27/15
3	9/15/15	CHANGED LENGTH OF DOWNSPOUTS	RESIN: DER-K-NE 510C-350	DR- N: P-UL D
2	6/22/15	RLCTD DR-IN HOLES, CHNGD GR-TING DET-IL	L-YUP SCHEDULE: N-mmM-MRMRM	WORK ORDER: 8789
1	5/29/15	CHANGED OVER-LL LENGTHS	STRUCTUR-L THK: .25	SC-LE: NONE
			COLOR: GR-Y	
			PROJECT NO: 16705	
			DR- ING NO. 8789-2	



LEFT ELEVATION




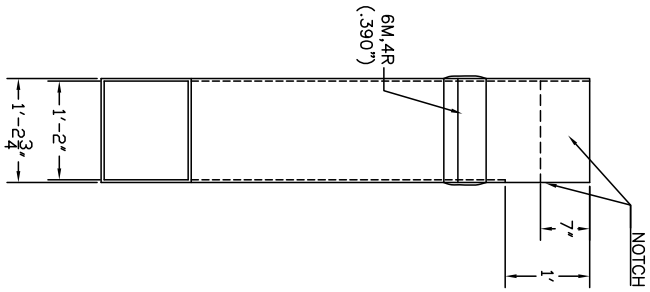
ELEVATION

APPROVED FOR CONSTRUCTION

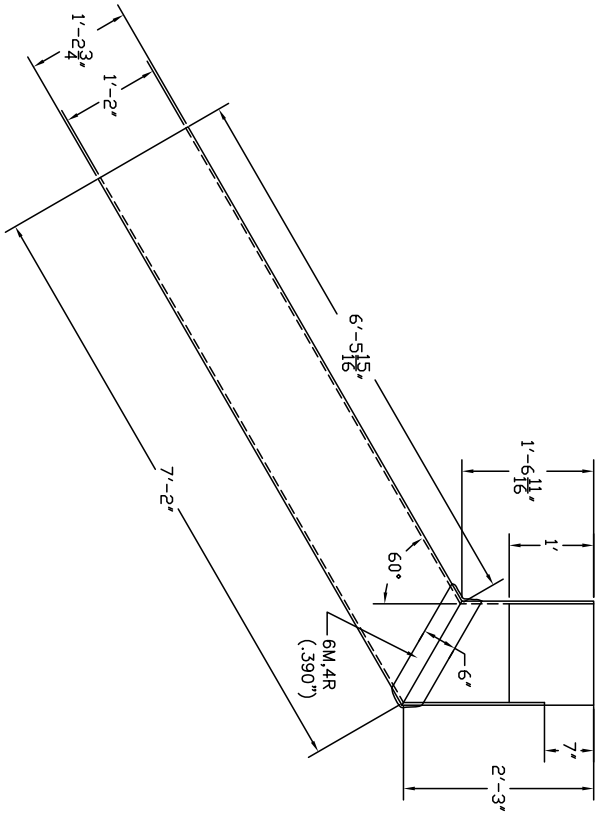
N= 100-10 MENS SURF-CMG VETL
 1P= OTHER CORNING 7/3 G./SPT CHAPPED STR- D M-T
 R= OTHER CORNING 24 G./SPT CHAPPED STR- D M-T
 Re OTHER CORNING 24 G./SPT WOVEN ROVING

DOWNSPOUT AT ABUTMENT 2 (1 REQ'D)

 Custom Composites Fabricator For Industry KENWAY CORPORATION 681 Riverside Drive Augusta, Maine 04330 Voice (207) 622-6228 Fax (207) 622-6611		RESIN: DER-K-KNE 510G-350 L-YUP SCHEDULE: N-mmM-WRMW-MRM STRUCTUR-L THK: 3/75 COLOR: GR-Y PROJECT NO: 18705	QTY: 2 D-TE: 3/27/15 DR- N: P-UL D WORK ORDER: 8789 SG-LE: NONE
REV: 1	6/22/15	CHANG NOTCH ORIENT-ION INC-SD LENGTH TO 7'2"	CUSTOMER: HOWL-D-FIELD BRIDGE DR- ING NO. 8789-3



LEFT ELEVATION



ELEVATION

APPROVED FOR CONSTRUCTION

DOWNSPOUT AT ABUTMENT 1 (1 REQ'D)

N= 108-10 MENS SURF-CING VAIL
 1P= OTHER CORNING 7/2 cu/sqft CHAFFED STR- D M-1
 2P= OTHER CORNING 24 cu/sqft CHAFFED STR- D M-1
 Re OTHER CORNING 24 cu/sqft WOVEN ROWING

Custom Composites Fabricator For Industry
KENWAY CORPORATION
 681 Riverside Drive
 Augusta, Maine 04330
 Voice (207) 622-6229
 Fax (207) 622-6611

REV.	D-TE	DESCRIPTION	CUSTOMER	RESIN	DER-K-NE 510C-350	QTY	2
			HOW- D-EMFELD BRIDGE	L-YUP SCHEDULE: N-mmM-MRM-M-IRM			
				STRUCTUR-L THK: 3/2			
				CO OR: GR-Y			
				PROJECT NO: 16705			
				D-TE: 6/22/15			
				DR- N: P-UL D			
				WORK ORDER: 8789			
				SC-LE: NONE			
				DR- ING NO. 8789-4			

TASK 3 - SELECTION OF PARTICIPATING FRP DRAIN SUPPLIERS

A comprehensive search of FRP bridge drain suppliers was conducted by contacting transportation agencies and the American Composites Manufacturing Association. The criteria for selecting the FRP suppliers considered:

- a) Manufacturing capabilities for supplying both the scupper and the drainage piping;
- b) Experience supplying and installing FRP drains in bridge projects with transportation agencies in the Northeast; and
- c) Interest in participating in the qualification program by supplying material samples.

Two FRP drain suppliers were selected with the approval of the NETC Technical Committee: a) Kenway Corporation, and b) FRP Bridge Drain Pipe-Westfall Company. The suppliers contributed in-kind to the project by:

- a) Providing information regarding prior bridge drain experience;
- b) Providing technical expertise regarding the dimensions and requirements for FRP bridge drains;
- c) Reviewing the draft specifications; and
- d) Providing composite material samples for testing and qualification.

SUPPLIER A: KENWAY CORPORATION

Contact information:

Ian D. Kopp, President/COO
Kenway Corporation
681 Riverside Drive Augusta, Maine 04330-9714
Phone: (207) 622-6229
Fax (207) 622-6611
kenway@kenway.com
www.kenway.com

Kenway Corp. specializes in custom composite manufacturing and field service.

A list of Supplier A completed FRP drain bridge projects in the New England states is summarized:

Date	Location	Project #	Quantity
2010	Falmouth Railroad Bridge, ME		9
2013	Martins Point Bridge, ME	1673(100)	15
2014	Bangor Union Street Bridge, ME	16682	8
2014	Auburn-Oakdale Bridge, ME	BH-1833(500)	2
2014	Milton Bridge, VT	IM 089-3(66)	6
2014	Steep Falls, ME	BH18232	6
2014	Richmond-Dresden Bridge, ME	12674	4
2015	Thomaston Bridge, ME	16755	8
2015	Westbrook Bridge, ME	19282	8
2015	Auburn-Oakdale Bridge, ME	18336	1
2016	Howland-Endfield Bridge, ME	16705	20

SUPPLIER B: FRP BRIDGE DRAIN PIPE-WESTFALL COMPANY

Contact information:

Nathan L. Peters, Bridge Drain Manager
FRP Bridge Drain Pipe-Westfall Company
124 Workman Court Eureka, MO 63025
Phone: (636) 938-6313
Fax: (636) 938-3120
npeters@westfallcompany.com
www.frpbridgedrainpipe.com

The manufacturer of the FRP composite material for Supplier B is:
Grace Composites, 351 Ruth Rd, Lonoke, AR 72086.

A list of Supplier B completed FRP drain bridge projects in the New England states is summarized:

Date	Location	Project #	Quantity
2012	Bourne, MA	U.S. Army Corps of Engineers Sagamore and Bourne Bridges	2400LF 6” Pipe & Miscellaneous Fittings
2013	New Britain, CT & Newington, CT	CTDOT Project #088-178 – Hartford Busway	420LF 8” Pipe & Miscellaneous Fittings
2014 & 2015	Boston, MA	MASSDOT Project #607351 - Miscellaneous Improvements to Structures	1800LF 6” Pipe & 1900LF 8” Pipe & Miscellaneous Fittings
2016	Boston, MA	MASSDOT Project #607984 – Miscellaneous Improvements to Structures	1000LF 6” Pipe & 200LF 8” Pipe & Miscellaneous Fittings

TASK 4: QUALIFICATION OF FRP DRAIN SUPPLIERS THROUGH MATERIAL TESTING

Suppliers A and B provided composite material samples for testing and qualification for use in FRP Bridge drains according to Appendix A of the specification presented in Task 2. This one time series of tests was conducted to ensure materials used would be durable and meet the requirements of bridge projects. The goal of these tests was to prequalify FRP drain suppliers and expedite the process of demonstrating these advanced composite materials for bridge installations.

This section presents the test reports of coupons cut from FRP laminated plates manufactured with the same process and laminate composition of the composite drain components (scupper body or pipe). The tests were conducted by the University of Maine's Advanced Structures and Composites Center, which is an ISO 17025 accredited testing laboratory.

The reported values for suppliers A and B exceeded the minimum allowable values for the baseline mechanical properties (Table A.5.4.b). Supplier A exceeded the minimum allowable values for the durability mechanical properties for the four environmental conditions specified (Table A.5.4.c-f).

Supplier B exceeded the minimum allowable values for the durability mechanical properties for the four environmental conditions specified (Table A.5.4.c-f) with two exceptions. The average value of tensile strength for Supplier B after 1000 hours of water immersion at 100°F was 25,807 psi, which is 74% of the corresponding baseline value. However, this retained value exceeds the baseline minimum allowable value of 16,000 psi. Since all other retained values for this environmental condition exceeded the minimum allowable values, the production validation is considered satisfactory. The second exception for Supplier B is the retained average compressive strain at 22,000 psi of 0.0083 after UV light conditioning, which is slightly lower than the minimum allowable value of 0.0085. This small difference is within the typical experimental variability for strain measurements.

The average thickness of the Supplier A material was 0.237 in, and for the Supplier B material was 0.308 in. The production validation tables for baseline and durability mechanical properties for suppliers A and B are presented.

SUPPLIER A: KENWAY CORPORATION

Table A.5.4.b PV Reported Baseline Mechanical Properties

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	16,000	25,237	26,465	26,423	26,042	2.7%
				Tensile Modulus of Elasticity (ksi)	1,600	2,026	1,999	2,045	2,023	1.1%
				Ultimate Tensile Strain (in/in)	0.01	0.0157	0.0169	0.0161	0.016	3.9%
	2	ASTM D3039	3	Tensile Strength (psi)	16,000	21,911	19,776	21,054	20,914	5.1%
				Tensile Modulus of Elasticity (ksi)	1,600	1,622*	1,734	1,761	1,705	4.3%
				Ultimate Tensile Strain (in/in)	0.01	0.0178*	0.0146	0.0163	0.02	14.2%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	22,000	39,501	35,535	40,907	38,648	7.2%
				Compressive Strain at 22,000-psi (in/in)	0.01	0.0128	0.0130	0.0132	0.0130	1.4%
	2	ASTM D6641	3	Compressive Strength (psi)	22,000	36,321	37,113	31,260	34,898	9.1%
				Compressive Strain at 22,000-psi (in/in)	0.01	0.0131	0.0142	0.0142	0.0138	4.5%

Note: * Sample 1, Direction 2, Modulus and strain values based on cross-head displacement.

Table A.5.4.c PV Reported Durability Mechanical Properties after 1000 hs. Moisture Immersion Conditioning per Section A.4.1

Supplier A: Kenway Corporation

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	22,136	22,257	22,801	22,469	22,509	1.2%
				Tensile Modulus of Elasticity (ksi)	1,720	1,871	1,732	1,788	1,797	3.9%
				Ultimate Tensile Strain (in/in)	0.0085	0.0146	0.0146	0.0154	0.0149	3.1%
	2	ASTM D3039	3	Tensile Strength (ksi)	17,777	21,163	20,211	19,401	20,258	4.4%
				Tensile Modulus of Elasticity (psi)	1,450	1,839	1,730	1,742	1,770	3.4%
				Ultimate Tensile Strain (in/in)	0.0085	0.0149	0.0153	0.0138	0.0147	5.3%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	32,851	36,152	36,952	39,504	37,536	4.7%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0131	0.0122	0.0117	0.0124	5.8%
	2	ASTM D6641	3	Compressive Strength (psi)	29,663	32,992	35,260	33,557	33,937	3.5%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0129	0.0137	0.0139	0.0135	3.9%

Table A.5.4.d PV Reported Durability Mechanical Properties after 1000 hs. of Alkaline Environment Conditioning per Section A.4.2

Supplier A: Kenway Corporation

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	22,136	28,225	28,224	26,675	27,708	3.2%
				Tensile Modulus of Elasticity (ksi)	1,720	1,967	1,955	2,099	2,007	4.0%
				Ultimate Tensile Strain (in/in)	0.0085	0.0185	0.0183	0.0157	0.0175	9.0%
	2	ASTM D3039	3	Tensile Strength (psi)	17,777	21,197	21,967	21,521	21,562	1.8%
				Tensile Modulus of Elasticity (ksi)	1,450	1,899	1,920	1,891	1,903	0.8%
				Ultimate Tensile Strain (in/in)	0.0085	0.0142	0.0150	0.0155	0.015	4.4%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	32,851	38,758	35,764	38,442	37,655	4.4%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0113	0.0103	0.0102	0.0106	5.5%
	2	ASTM D6641	3	Compressive Strength (psi)	29,663	37,624	37,546	36,456	37,209	1.8%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0126	0.0131	0.0131	0.0129	2.3%

Table A.5.4.e PV Reported Durability Mechanical Properties after UV Light Conditioning per Section A.4.3 (ASTM G154)

Supplier A: Kenway Corporation

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	22,136	25,429	24,542	23,767	24,579	3.4%
				Tensile Modulus of Elasticity (ksi)	1,720	2,132	1,972	1,937	2,014	5.2%
				Ultimate Tensile Strain (in/in)	0.0085	0.01480	0.01507	0.01433	0.01473	2.6%
	2	ASTM D3039	3	Tensile Strength (psi)	17,777	21,239	21,138	21,206	21,194	0.2%
				Tensile Modulus of Elasticity (ksi)	1,450	1,685	1,783	1,764	1,744	3.0%
				Ultimate Tensile Strain (in/in)	0.0085	0.0184	0.0163	0.0170	0.0172	6.2%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	32,851	33,419	33,711	41,414	36,181	12.5%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0130	0.0124	0.0136	0.0130	4.6%
	2	ASTM D6641	3	Compressive Strength (psi)	29,663	38,102	40,092	41,360	39,851	4.1%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0119	0.0127	0.0119	0.0121	3.7%

Table A.5.4.f PV Reported Durability Mechanical Properties after 100 Freeze-Thaw Cycles Conditioning per Section A.4.4 (ASTM C666)

Supplier A: Kenway Corporation

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	22,136	26,841	24,835	26,059	25,912	3.9%
				Tensile Modulus of Elasticity (ksi)	1,720	1,853	1,873	1,924	1,883	2.0%
				Ultimate Tensile Strain (in/in)	0.0085	0.0180	0.0164	0.0165	0.017	5.3%
	2	ASTM D3039	3	Tensile Strength (psi)	17,777	20,028	19,322	20,610	19,987	3.2%
				Tensile Modulus of Elasticity (ksi)	1,450	1,754	1,713	1,706	1,724	1.5%
				Ultimate Tensile Strain (in/in)	0.0085	0.0143	0.0143	0.0160	0.015	6.7%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	32,851	39,505	36,319	42,360	39,395	7.7%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0108	0.0126	0.0116	0.0117	7.7%
	2	ASTM D6641	3	Compressive Strength (psi)	29,663	33,736	34,932	36,964	35,211	4.6%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0137	0.0142	0.0144	0.0141	2.3%

SUPPLIER B: FRP BRIDGE DRAIN PIPE-WESTFALL COMPANY

Table A.5.4.b PV Reported Baseline Mechanical Properties

Supplier B: FRP Bridge Drain Pipe – Westfall Company – Grace Composites

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	Tensile Strength (psi)	16,000	34,222	35,134	34,610	34,656	1.3%
				Tensile Modulus of Elasticity (ksi)	1,600	2,165	2,284	2,203	2,217	2.7%
				Ultimate Tensile Strain (in/in)	0.01	0.0209	0.0204	0.0251	0.0221	11.6%
	2	ASTM D3039	3	Tensile Strength (psi)	16,000	32,975	32,127	32,684	32,595	1.3%
				Tensile Modulus of Elasticity (ksi)	1,600	2,084	2,060	2,029	2,058	1.3%
				Ultimate Tensile Strain (in/in)	0.01	0.0220	0.0212	0.0223	0.0218	2.7%
A.3.2	1	ASTM D6641	3	Compressive Strength (psi)	22,000	36,339	34,180	35,368	35,296	3.1%
				Compressive Strain at 22,000-psi (in/in)	0.01	0.0092	0.0086	0.0107	0.0095	11.4%
	2	ASTM D6641	3	Compressive Strength (psi)	22,000	32,508	32,973	31,801	32,427	1.8%
				Compressive Strain at 22,000-psi (in/in)	0.01	0.0106	0.0106	0.0098	0.0103	4.3%

Table A.5.4.c PV Reported Durability Mechanical Properties after 1000 hs. Moisture Immersion Conditioning per Section A.4.1

Supplier B: FRP Bridge Drain Pipe – Westfall Company – Grace Composites

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	29,458	25,771	25,087	26,564	25,807**	2.9%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,885	2,132	2,120	2,091	2,114	1.0%
				Ultimate Tensile Strain (in/in)	0.0085	0.0143	0.0150	0.0161	0.0151	6.1%
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	27,706	34,572	29,075	31,403	31,683	8.7%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,749	2,213	2,113	2,383	2,236	6.1%
				Ultimate Tensile Strain (in/in)	0.0085	0.0209	0.0167	0.0181	0.0186	11.6%
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	30,002	31,968	37,956	33,530	34,485	9.0%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0103*	0.0075*	0.0098	0.0098	n/a
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	27,563	36,421	33,492	37,881	35,931	6.2%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0100	0.0074*	0.0066*	0.0100	n/a

Notes: * This strain value is the maximum strain signal.
 ** This average strength value is less than the minimum allowable value.

Table A.5.4.d PV Reported Durability Mechanical Properties after 1000 hs. of Alkaline Environment Conditioning per Section A.4.2

Supplier B: FRP Bridge Drain Pipe – Westfall Company – Grace Composites

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	29,458	33,861	33,148	30,808	32,605	4.9%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,885	2,281	2,188	2,289	2,253	2.5%
				Ultimate Tensile Strain (in/in)	0.0085	0.0189	0.0198	0.0170	0.0186	7.9%
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	27,706	31,169	32,888	29,719	31,258	5.1%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,749	2,076	1,982	2,104	2,054	3.1%
				Ultimate Tensile Strain (in/in)	0.0085	0.0195	0.0291	0.0180	0.0222	27.1%
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	30,002	39,680	34,920	34,670	36,423	7.8%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0088*	0.0085*	0.0086	0.0086	n/a
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	27,563	34,428	34,269	33,501	34,066	1.5%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0102	0.0110	0.0097	0.0103	6.8%

Note: * This strain value is the maximum strain signal.

Table A.5.4.e PV Reported Durability Mechanical Properties after UV Light Conditioning per Section A.4.3 (ASTM G154)

Supplier B: FRP Bridge Drain Pipe – Westfall Company – Grace Composites

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	29,458	24,713	36,134	34,064	31,637	19.2%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,885	2,331	2,303	2,414	2,349	2.5%
				Ultimate Tensile Strain (in/in)	0.0085	0.0139	0.0201	0.0176	0.0172	18.1%
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	27,706	36,322	34,898	35,288	35,503	2.1%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,749	2,259	2,285	2,270	2,271	0.6%
				Ultimate Tensile Strain (in/in)	0.0085	0.0223	0.0212	0.0212	0.0216	3.0%
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	30,002	38,551	38,784	40,669	39,335	3.0%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0093	0.0086	0.0069	0.0083**	14.9%
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	27,563	34,672	34,423	37,052	35,382	4.1%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0087	0.0095	0.0093	0.0092	4.5%

Note: ** This average strain value is less than the minimum allowable value.

Table A.5.4.f PV Reported Durability Mechanical Properties after 100 Freeze-Thaw Cycles Conditioning per Section A.4.4 (ASTM C666)

Supplier B: FRP Bridge Drain Pipe – Westfall Company – Grace Composites

Section No.	Direction	Test Standard	No. of Samples	Characteristic	Minimum Allowable Values	Independent Lab Reported Values				
						Sample 1	Sample 2	Sample 3	Average Value	COV
A.3.1	1	ASTM D3039	3	85% Baseline Tensile Strength (psi)	29,458	33,048	33,147	30,083	32,093	5.4%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,885	2,167	2,119	2,194	2,160	1.8%
				Ultimate Tensile Strain (in/in)	0.0085	0.0186	0.0203	0.0174	0.0188	7.6%
	2	ASTM D3039	3	85% Baseline Tensile Strength (psi)	27,706	31,714	32,492	32,362	32,189	1.3%
				85% Baseline Tensile Modulus of Elasticity (ksi)	1,749	1,998	2,128	2,033	2,053	3.3%
				Ultimate Tensile Strain (in/in)	0.0085	0.0204	0.0201	0.0221	0.0208	5.2%
A.3.2	1	ASTM D6641	3	85% Baseline Compressive Strength (psi)	30,002	31,186	38,188	33,361	34,245	10.5%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0051*	0.0098	0.0055*	0.0098	n/a
	2	ASTM D6641	3	85% Baseline Compressive Strength (psi)	27,563	35,948	35,156	36,993	36,032	2.6%
				Compressive Strain at 22,000-psi (in/in)	0.0085	0.0097	0.0107	0.0089	0.0098	9.4%

Note: * This strain value is the maximum strain signal.

TASK 5: DOCUMENTATION OF INSTALLATION OF FRP DRAINS IN BRIDGES

The installation of FRP drains was documented for two bridges.

UNION STREET BRIDGE, BANGOR, MAINE

Fiber reinforced polymer (FRP) bridge drains were used in the replacement of the Union Street westbound bridge overpass over I-95 in Bangor. This bridge project used the NETC FRP drain specifications. The drains were installed during the week of December 10-14, 2014 by CPM Constructors. One pair of drains was installed at each end of the westbound overpass. The bridge superstructure consists of three Hybrid Composite Beams (HCB).



Figure 1 – Westbound bridge overpass, Union Street, Bangor (2014-12-14)



Figure 2 – HCB beams of the westbound bridge overpass (2014-12-14)

The contact person from CPM Constructors was Bruce Surek. The drains were provided by Kenway Corp. The contact person from Kenway was Paul Dumoulin.

Bruce Surek
Project Manager
CPM Constructors
30 Bonney St, Freeport, ME 04032
Phone: (207) 865-0000

Paul A. Dumoulin
Project Engineer
Kenway Corporation
681 Riverside Drive, Augusta, ME 04330
Tel 207-622-6229

This bridge was inspected three times by the University of Maine researchers. The drain installation of the westbound bridge overpass was inspected on December 14th, 2014, which was before concrete placement. No problems were reported by the contractor during the installation. Photos illustrating the drain system installation are presented.



Figure 3 – Drains installed over formwork (2014-12-14)



Figure 4 – Drains before concrete placement (2014-12-14)

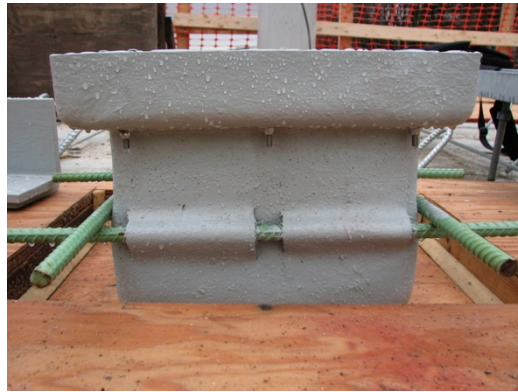


Figure 5 - Drain side detail (2014-12-14)



Figure 6 - Close-up of drain prior to concrete placement (2014-12-14)



Figure 7 - Detail of drain rebar attachment (2014-12-14)



Figure 8 – Drain side holes and rebar (2014-12-14)



Figure 9 - Drain grate (2014-12-14)



Figure 10 - Drain and formwork (2014-12-14)

The second inspection of the FRP drains of the westbound bridge overpass was conducted on June 3rd, 2015, which corresponded to 5 months of service. No visual damage was observed during this inspection.



Figure 11 – Westbound bridge overpass showing drain pipes (2015-06-03)



Figure 12 – Inspection of bridge drain (2015-06-03)



Figure 13 – a) Drain top and grate; b) Detail showing condition of the FRP scupper wall (2015-06-03)



Figure 14 – FRP drains in service (2015-06-03)



Figure 15 – Drain pipes and attachments (2015-06-03)

The drain installation of the eastbound bridge overpass was inspected on October 5th, 2015, which was before concrete placement. No problems were reported during the installation of the eastbound bridge overpass. During this inspection the drains of the westbound bridge overpass, which had been in service for 10 months were also inspected. No visual damage was observed in the FRP drains in the westbound bridge overpass. Photos of the drain system during installation in the eastbound bridge overpass are presented.



Figure 16 - Eastbound bridge overpass during construction (2015-10-05)



Figure 17 – Drains and slab rebar prior to concrete placement (2015-10-05)



Figure 18 – Detail of grate and drain prior to concrete placement (2015-10-05)



Figure 19 – Drain pipe prior to concrete placement (2015-10-05)

Photos of the drain system after 10 months of service in the westbound bridge overpass are presented.



Figure 20 - Westbound bridge overpass after construction (2015-10-05)



Figure 21 – Drain pipes in the westbound bridge overpass (2015-10-05)



Figure 22 – Detail of drain pipe in the westbound bridge overpass (2015-10-05)

RICHMOND-DRESDEN BRIDGE, MAINE

Fiber reinforced polymer (FRP) bridge drains were used in the replacement of the bridge linking Richmond and Dresden over the Kennebec River in Fall 2014. This bridge project did not use the NETC FRP drain specifications and is presented as an example of existing technology. The bridge drains were inspected by the University of Maine researchers.

According to Assistant Engineer Devan Eaton, the cost of the FRP drains came to \$4,000 per drain system. This included the galvanized steel grating and riser, FRP scupper and FRP downspout. The system was supplied by Eagle Manufacturing Co., Inc. of Salem, Connecticut.

Eagle Manufacturing Co., Inc is predominantly a miscellaneous metals supplier and AISC shop for bridge components. They supplied the galvanized metal frame and grating for these drains. The FRP scupper and downspouts were manufactured by United Fiberglass in Springfield, OH, according to their General Manager Paul Harrington.

United Fiberglass is a supplier of fiberglass bridge drain systems as well as FRP conduit and pipe. The contact information is:

Paul Harrington – General Manager
Eagle Manufacturing Co., Inc.
 535 Hartford Rd.
 Salem, CT. 06420
 Phone: 860.885.1563

United Fiberglass
 United Fiberglass of America
 2145 Airpark Drive
 Springfield, OH 45502
 Phone: 937.325.7305 and 888.939.5855

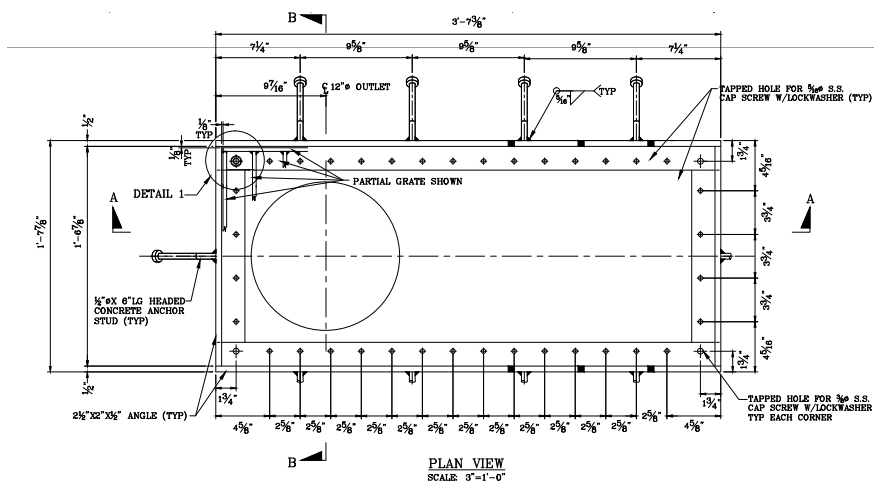


Figure 23- Drain Shop Drawing - Plan View

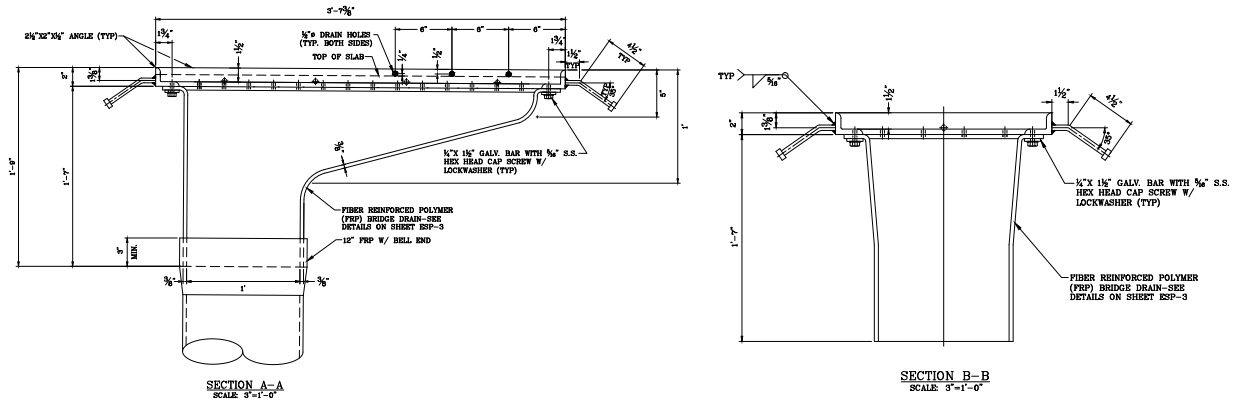


Figure 24 - Drain shop drawing – Sections

Photos illustrating the drain system installation are presented.



Figure 25 - Drain and slab rebar prior to concrete placement

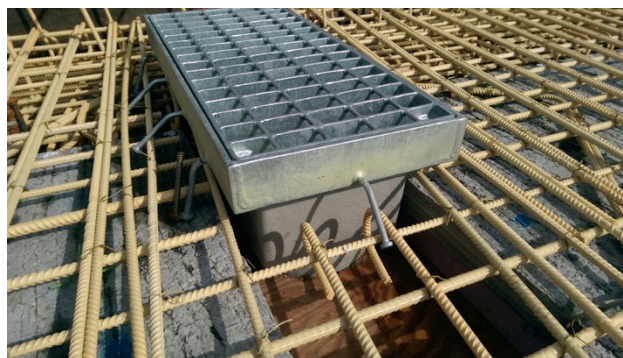


Figure 26 – Close-up of drain prior to concrete placement



Figure 27 - Drain and grate at another location prior to concrete placement



Figure 28 - Drain in place prior to rebar placement



Figure 29 - Drain in place prior to rebar placement



Figure 30 - Drain after concrete placement



Figure 31 - Drain in place after concrete placement

SUMMARY

A standard fiber-reinforced polymer (FRP) composite drain that can be produced economically for use throughout New England bridges was developed. The proposed standard FRP drain system can be used both for new construction and rehabilitation projects.

NETC FRP bridge drain details and specifications have been drafted and are available as part of Task 2 – Development of Standard Drain Requirements for New and Rehabilitation Projects, as follows:

- FRP Composite Bridge Drain Components Specification (page 12)
- Appendix A: FRP Composite Drain and Pipe Material Requirements (page 18)
- Appendix B: Preferred Inlet/Scupper Sizes And Overall Geometries (page 24)

Two FRP drain suppliers (A and B) provided composite material samples for testing and qualification for use in bridge drains according to Appendix A of the specification. This one time series of tests was conducted to ensure materials used would be durable and meet the requirements of bridge projects. The material coupons for the two suppliers met the specification criteria.

FRP drains were inspected on two bridge projects. One of these bridges, the Union Street Bridge in Bangor, ME, used the NETC FRP drain specifications. MaineDOT implemented the FRP bridge drain specifications developed in this NETC project for the Howland-Enfield Bridge; the corresponding shop drawings were presented.