Marine Fiberglass Reinforced Polymer Pipe Piling for Bridge/Dock Fenders and Foundations

TRB
Innovative Technologies for a Resilient Marine Transportation System

1E: Innovative Technology, *Auditorium*
Hota GangaRao, West Virginia University, *Moderator*

Presented by: Dustin Troutman - Director of Marketing and Product Development

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PULTRUDED FIBERGLASS REINFORCED POLYMER PIPE PILES

CREATIVE PULTRUSIONS

STATUE OF LIBERTY HURRICANE SANDY REBUILD WITH FRP PIPE PILES - FHWA PROJECT

CREATIVE PULTRUSIONS

306 SUPERPILE BEARING PILES 12”Ø 48’ LONG

CREATIVE PULTRUSIONS

STATUE OF LIBERTY DOCK REBUILD

CREATIVE PULTRUSIONS

STATUE OF LIBERTY DOCK COMPLETE

CREATIVE PULTRUSIONS

VIRGINIA DOT TWIGG BRIDGE COMPOSITE FENDER SYSTEM

CREATIVE PULTRUSIONS

VIRGINIA DOT TWIGG BRIDGE
COMPOSITE FENDER SYSTEM

116 SUPERPILES 16"Ø

CREATIVE PULTRUSIONS

VIRGINIA DOT TWIGG BRIDGE COMPOSITE FENDER SYSTEM

CREATIVE PULTRUSIONS

VIRGINIA DOT TWIGG BRIDGE
COMPOSITE FENDER SYSTEM

CREATIVE PULTRUSIONS

PINELLAS BAYWAY BRIDGE PIPE PILE FENDER INSTALLATION

104 16”Ø 67’ LONG SUPERPILES

CREATIVE PULTRUSIONS

CRANEY ISLAND PORTSMOUTH, VA
FUEL PIER U.S. NAVY

95’ PILES, HDPE SLEEVES,
FILLED WITH CONCRETE

CREATIVE PULTRUSIONS

CRANEY ISLAND PORTSMOUTH, VA
FUEL PIER U.S. NAVY

CREATIVE PULTRUSIONS

WHARF CHARLIE, MAYPORT FLORIDA
U.S. NAVY

72’ PILES, HDPE SLEEVES, FRP INSERT

CREATIVE PULTRUSIONS

OCCIDENTAL PETROLEUM BARGE LANDING FENDER LONG BEACH, CA

CREATIVE PULTRUSIONS

SAN FRANCISCO
WEST HARBOR RENOVATION PROJECT
SAN FRANCISCO, CA

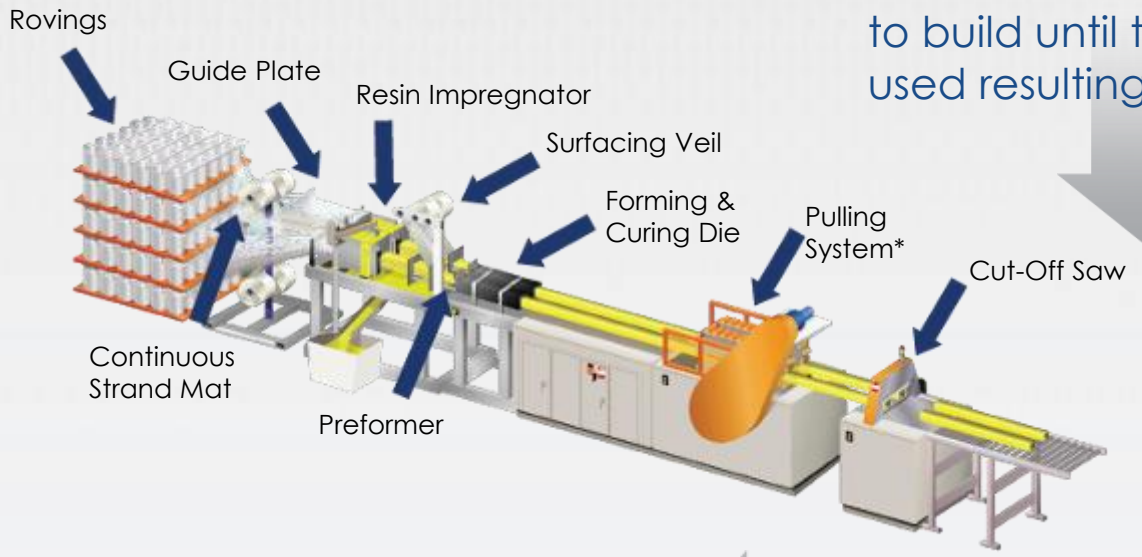
MOORING & FENDER PILES

CREATIVE PULTRUSIONS

SUPERPILE PROFILES ARE MANUFACTURED BY THE PULTRUSION PROCESS

1. Resin and glass fiber reinforcements are combined and formed into the shape of the die on a continuous process.

2. The resin is initiated by the thermal decomposition process. The initiator is heated until a chemical bond dissociation produces two radicals. The chain continues to build until the monomer is used resulting in a cured resin.



**Caterpillar Pullers (shown) or Reciprocating Pullers*

3. The profiles are pulled through a die.

4. Pultruded profiles are cut to length during the continuous manufacturing process.

SUPERPILE PRODUCTION

High strength fiberglass is pulled into the heated die.

The fibers are injected with a high strength polyurethane resin and cure in a continuous process.

Finished product is pulled through the die and into the cut-to-length saw where it is cut and prepared for shipment to the job site.

CREATIVE PULTRUSIONS

SUPERPLIE CONSTRUCTION

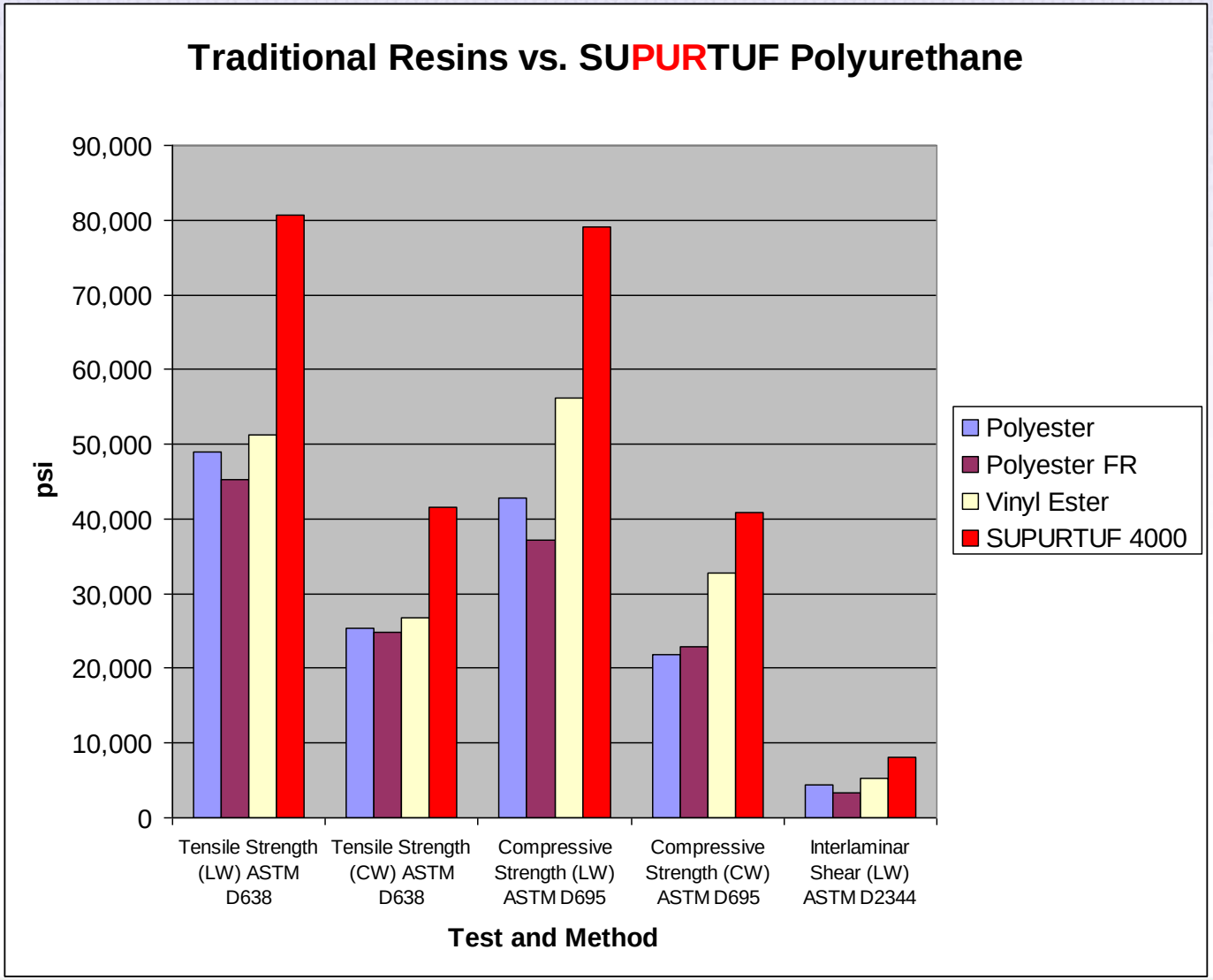
High strength E-glass engineered reinforcements provide superior strength and stiffness in the 0°, +45°, -45° and 90° directions.

High pressure injected SUPURTUF™ polyurethane matrix provides the extraordinary strength and toughness of the SUPERPILE.

CREATIVE PULTRUSIONS

WHAT MAKES SUPERPILE PERFORM?
SUPURTUF™ POLYURETHANE RESIN!

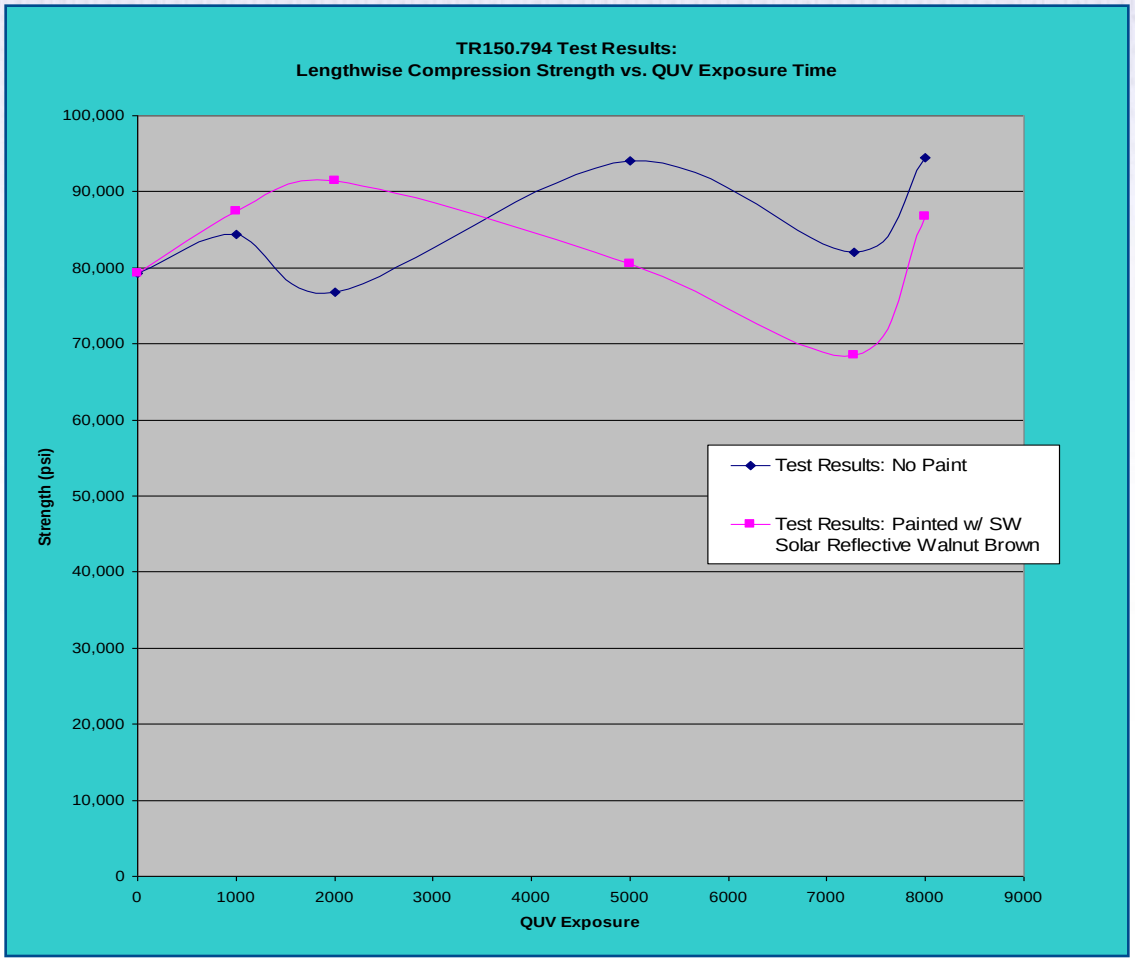
- Superior Strength
- Superior Chemical Resistance
- Superior Impact Strength
- Superior Toughness
- Superior Energy Absorption



CREATIVE PULTRUSIONS

SUPURTUF™ POLYURETHANE UV PERFORMANCE

- 8,000 Hours QUV Testing.
- No Significant Change In Compression Strength.
- Exterior Will Fade Over Time And Begin To Chalk.
- Piles Can Be Coated With HDPE Sleeve Or Powder Coated With A UV Optimized Polyester Powder Coating.



SUPERPILE FRP PIPE PILE TESTING

PDA Analysis, Virginia

PILE CONSTRUCTION

SUPERPILE Composite Pipe Pile is manufactured with electrical grade fiberglass and high impact, high strength polyurethane resin. The combination of the advanced resin and high strength glass produces a superior strength, highly corrosion resistant pipe pile.

Full Section Pipe Pile Testing, West Virginia University

PILE TESTING

SUPERPILE has undergone extensive testing at CPI, West Virginia University's Constructed Facility Center and in the field. Tests that have been conducted: full section to failure, connection, compression, Pile Dynamic Analysis (PDA) and fatigue.

PDA Testing, Virginia

"I have researched, tested and installed composite systems related to civil infrastructure over my entire career. **I was astonished at the high strength and modulus values achieved with the polyurethane pipe piles manufactured by Creative Pultrusions, Inc.** I expect that the US infrastructure will benefit greatly from this tubular pile technology."

~ Hota GangaRao, PhD, P.E., F. ASCE
West Virginia University

- Tested Per ASTM D6109 Test Standards At West Virginia University (WVU).
- Method To Determine The Full Section Bending Modulus Of Elasticity And The Full Section Bending Strength.
- Tested To Determine The Crush Strength, Pin Bearing Strength, Washer Pull Through Strength And Connection Capacities Both At WVU And At Creative Pultrusions, Inc. (CPI) Test Facility.
- Pile Dynamic Analysis (PDA) Performed By Atlantic Coast Engineering.

CREATIVE PULTRUSIONS

CHARACTERISTIC DESIGN PROPERTIES ARE DETERMINED PER ASTM D7290

WHY ASTM D7290 AND WHY SHOULD I CARE?

It is an internationally recognized standard for evaluating material property characteristic values for polymeric composites for civil engineering structural applications.

The characteristic value is a statistically-based material property representing the 80% lower confidence bound on the 5th percentile value of a specified population.

The characteristic value allows you to use LRFD or Allowable Stress Design techniques and it allows you to fairly compare FRP to other types of piles.

PULTRUDED STRUCTURES DESIGN METHODOLOGY OPTIONS

FULL SECTION BEND TEST

- Full Section Four Point Bend To Failure Per ASTM D6109.
- 20:1 Span To Depth Ratio.
- Established EI Bending Stiffness
- Established Bending Strength.
- Established Energy Absorption Characteristics.
- Nineteen 12"x1/2" And Twelve 16"x1/2" Piles Were Tested To Failure.
- Piles From Several Production Cycles Were Tested.

Flexural Test, WVU

CREATIVE PULTRUSIONS

ENERGY ABSORPTION

Round FRP Pipe Pile TU455 Polyurethane12"x3/8" Metric (305mmx9.52mm)	Round FRP Pipe Pile TU450 Polyurethane12"x1/2" Metric (305mmx12.7mm)	Round FRP Pipe Pile TU460 Polyurethane16"x1/2" Metric (406mmx12.7mm)
Average Energy Absorption kip-in (kN•m) ASTM D6109		
341 (39)	643 (73)	829 (94)
Characteristic Energy Absorption kip-in (kN•m) ASTM D6109		
***** *****	405 (46)	603 (68)

- High Strength And Rather Low Modulus Values, As Compared To Steel, Equate To Very High Energy Absorption Capabilities.
- Ideal For Dock And Bridge Fender Systems Where Energy Absorption Is Critical.
- Derived By Calculating The Area Under The Load/Deflection Curve.

Testing at Ft. Collins, CO

CREATIVE PULTRUSIONS

BOLTED CONNECTIONS FOR FORCES APPLIED PARALLEL TO THE PILE

Characteristic Strengths of Bolted Connections for Forces Applied Parallel to the Pile

Round Polyurethane Piles	Single 5/8" Bolt	Two 5/8" Bolts	Single 3/4" Bolt	Two 3/4" Bolts	Single 1" Bolt	Two 1" Bolts
TU455 12" x 3/8" (305mmx9.52mm)	4,231	8,462	5,077	10,155	6,770	13,540
TU450 12" x 1/2" (305mmx12.7mm)	7,854	15,708	9,425	18,849	12,566	25,132
TU460 16" x 1/2"(406mmx12.7mm)	6,005	12,011	7,206	14,413	9,609	19,217
Octagonal Vinyl Ester Piles	**Single 5/8" Bolt**	**Two 5/8" Bolts**	**Single 3/4" Bolt**	**Two 3/4" Bolts**	**Single 1" Bolt**	**Two 1" Bolts**
CP076 8" x .25" (203mmx6.35mm)	2,606	5,212	3,127	6,255	4,170	8,340
CP074 10" x. 25" (254mmx6.35mm)	3,286	6,572	3,943	7,886	5,257	10,515
CP210 10" x. 275" (254mmx6.98mm)	2,212	4,423	2,654	5,308	3,539	7,077

- Characteristic Design Values Have Been Developed And Published Per ASTM D7290.
- The Capacities Were Developed From Full Section Testing.
- A 1.0" Diameter Bolt Was Used In The Test.
- Failure Load Is Defined As The First Indication Of A Yield In The Load/Displacement Plot.
- Chart Represents The Bolt Being Loaded On One Side Of The Pile.

Bolted Connection Test - Parallel

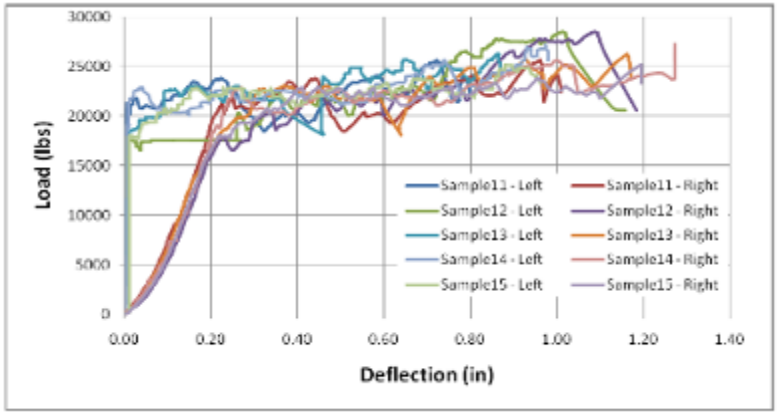
CREATIVE PULTRUSIONS

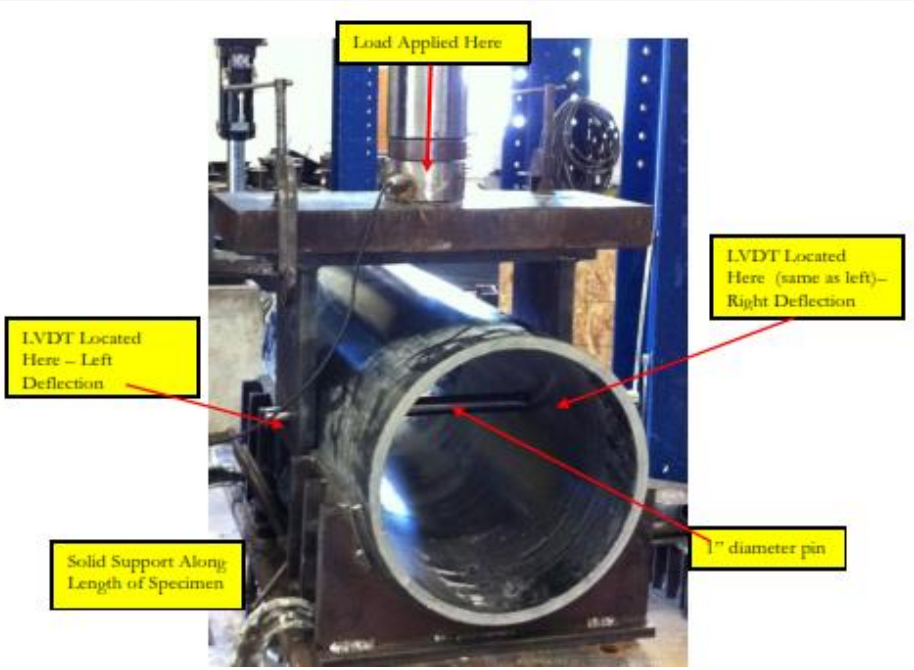
BOLTED CONNECTIONS FOR FORCES APPLIED TRANSVERSE TO THE PROFILE

Characteristic Strengths of Bolted Connections for Forces Applied Perpendicular to the Pile

Round Polyurethane Piles	Single 5/8" Bolt	Two 5/8" Bolts	Single 3/4" Bolt	Two 3/4" Bolts	Single 1" Bolt	Two 1" Bolts
TU455 12" x 3/8" (305mmx9.52mm)	2,917	5,835	3,501	7,001	4,668	9,335
TU450 12" x 1/2" (305mmx12.7mm)	3,921	7,841	4,705	9,410	6,273	12,546
TU460 16" x 1/2"(406mmx12.7mm)	6,491	12,982	7,789	15,578	10,386	20,771
Octagonal Vinyl Ester Piles	**Single 5/8" Bolt**	**Two 5/8" Bolts**	**Single 3/4" Bolt**	**Two 3/4" Bolts**	**Single 1" Bolt**	**Two 1" Bolts**
CP076 8" x .25" (203mmx6.35mm)	1,271	2,541	1,525	3,049	2,033	4,066
CP074 10" x .25" (254mmx6.35mm)	912	1,825	1,095	2,190	1,460	2,919
CP210 10" x .275" (254mmx6.98mm)	937	1,875	1,125	2,249	1,500	2,999

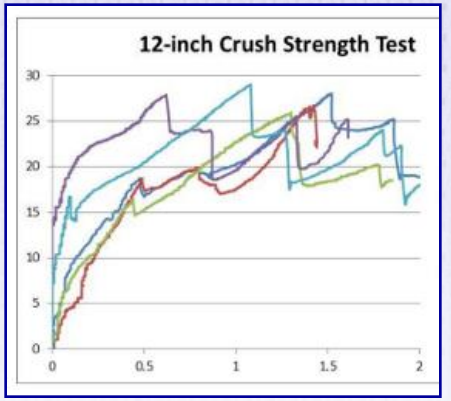
- 1" Diameter Pin.
- Failure Mode, Pin Bearing Of FRP Tube.
- Chart Represents The Bolt Capacity Loaded On One Side Of The Pile.





FULL SECTION CRUSH STRENGTH

SUPERPILE Crush Strength with a 10" x 10" (24.5mm x 24.5mm) Thermoplastic Wale					
Round FRP Pipe Pile TU455 Polyurethane12"x3/8" Metric (305mm x 9.52mm)		Round FRP Pipe Pile TU450 Polyurethane12"x1/2" Metric (305mm x 12.7mm)		Round FRP Pipe Pile TU460 Polyurethane16"x1/2" Metric (406mm x 12.7mm)	
Average Crush Strength lb (kg)					
10,600	(4,808)	17,970	(8,151)	16,600	(7,530)
Characteristic Crush Strength lb (kg)					
8,060	(3,656)	13,782	(6,251)	11,667	(5,292)



- Crush Strength Derived By Applying A Transverse Load Into The SUPERPILE Through A 10"x10" Wale Section.
- The Ultimate Load Is Defined As The First Yield Point On The Load Vs. Displacement Plot.

FULL SECTION CRUSH STRENGTH ENHANCEMENT

SUPERPILE, with FRP Insert, Crush Strength with a 10"x 10" (25.4mm x 25.4mm) Thermoplastic Wale		
Round FRP Pipe Pile TU455 Polyurethane12"x3/8" Metric (305mmx9.52mm)	Round FRP Pipe Pile TU450 Polyurethane12"x1/2" Metric (305mmx12.7mm)	Round FRP Pipe Pile TU460 Polyurethane16"x1/2" Metric (406mmx12.7mm)
Average Crush Strength lb (kg)		
***** *****	73,780 (33,466)	44,213 (20,055)
Characteristic Crush Strength lb (kg)		
***** *****	51,370 (23,301)	***** *****

- Crush Strength Can Be Increased With The Addition Of An FRP Insert.
- Crush Strength Can Be Increase To 74 Kips Or Higher When Needed.
- The Addition Of Concrete, In Localized Sections, Can Be Used To Increase The Crush Strength. Testing Has Indicated That The Crush Strength Can Be Increased To 180+ Kips.

CREATIVE PULTRUSIONS

SUPERPILE BOLT PULL THROUGH STRENGTH WITH CURVED WASHER

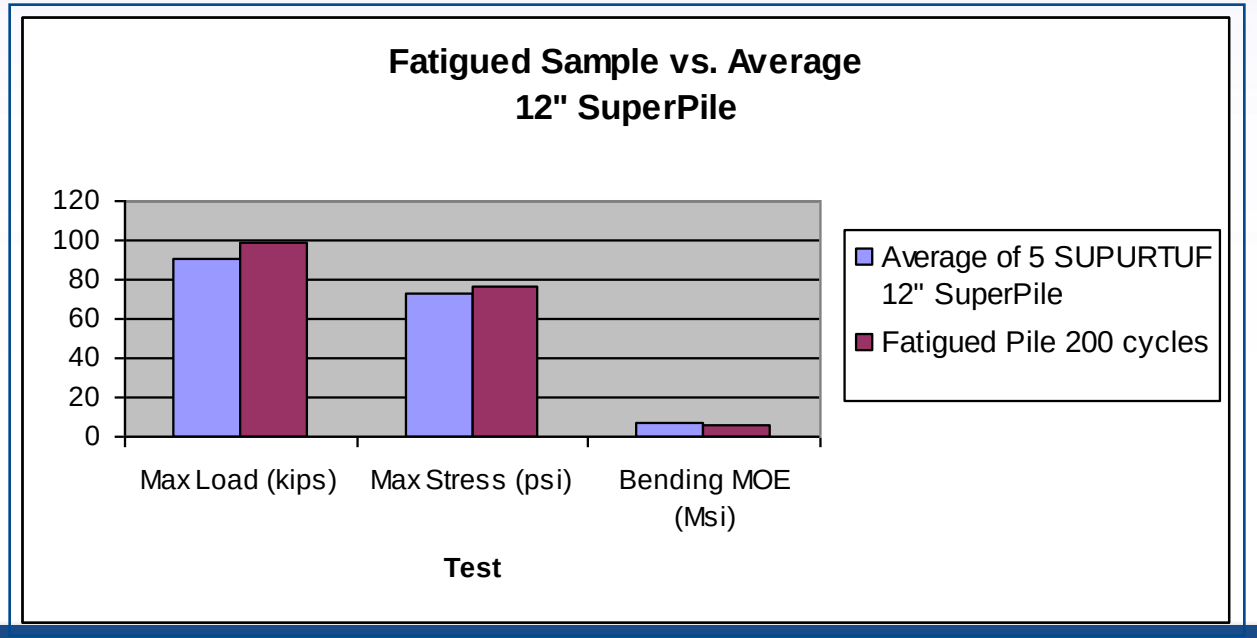
SUPERPILE Washer Pull Through Strength with a 6"x1/2" (152mm x12.7mm) Steel Washer					
Round FRP Pipe Pile TU455 Polyurethane12"x3/8" Metric (305mm x 9.52mm)		Round FRP Pipe Pile TU450 Polyurethane12"x1/2" Metric (305mm x 12.7mm)		Round FRP Pipe Pile TU460 Polyurethane16"x1/2" Metric (406mm x 12.7mm)	
Average Pull Through Strength lb (kg)					
26,084	(11,832)	30,686	(13,919)	27,582	(12,511)
Characteristic Pull Through Strength lb (kg)					
22,107	(10,028)	26,815	(12,163)	25,103	(11,387)

- Average And Characteristic Washer Pull Through Strengths Have Been Developed.
- The Values Are Based On 6"x1/2" And 6"x3/8" Curved Washers For The Round Piles And 4"x3/8" Washers For The Octagonal Piles.
- Washers Can Be Used To Increase The Crush Resistance.

CREATIVE PULTRUSIONS

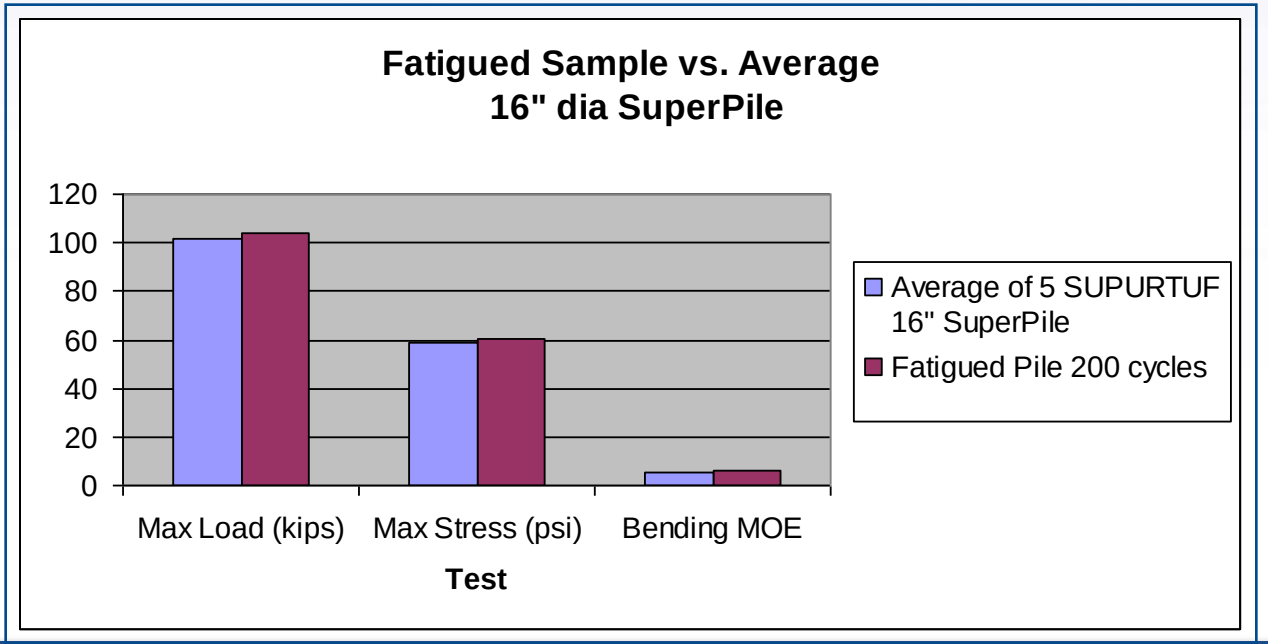
SUPERPILE FATIGUE TESTING 12” DIA. SUPERPILE

- 200 Cycles.
- Max Load 40% Of Ultimate.
- Results, No Significant Decrease In Strength Or Stiffness.



SUPERPILE FATIGUE TESTING 16” DIA. SUPERPILE

- 200 Cycles.
- Max Load 40% Of Ultimate.
- Results, No Significant Decrease In Strength Or Stiffness.



CONNECTION DETAILS PILE TO PIER CONNECTION

SUPERPILE Dock Connection Capacity for Fender Applications					
Round FRP Pipe Pile TU455 Polyurethane12"x3/8" Metric (305mm x 9.52mm)		Round FRP Pipe Pile TU450 Polyurethane12"x1/2" Metric (305mm x 12.7mm)		Round FRP Pipe Pile TU460 Polyurethane16"x1/2" Metric (406mm x 12.7mm)	
Average Connection Capacity lb (kg)					
26,084	(11,832)	30,686	(13,919)	27,582	(12,511)
Characteristic Connection Capacity					
22,107	(10,028)	26,815	(12,163)	25,103	(11,387)

- Connection Detail Decreases The Point Load Stress.
- Hollow Composite Pipe Piles Require Attention To The Connection Details.
- Excessive Point Loads Should Be Avoided.

SUPERPILE Typical Dock to Pile Connection

CREATIVE PULTRUSIONS

PDA ANALYSIS PERFORMED BY ATLANTIC COAST ENGINEERING

LOCATION: CROFTON SERVICES YARD
PORTSMOUTH, VA

Depth	Condition	SPT N-values
2'- 12'	Fill Sands/Gravels	4-7 blows/foot
12'-36'	Soft Clay	0-1 blows/foot
36'-45'	Loose Clayey Fine Sands	0-1 blows/foot
45'-80'	Medium Dense Silty Fine Sands	9-18 blows/foot

CREATIVE PULTRUSIONS

PDA ANALYSIS

Hammer	Rated Driving Energy	Typical Energy Expected to be Delivered to Pile
Vulcan 01	15 kip-ft	6-9 kip-ft
APE D30-32	74 kip-ft	20-40 kip-ft

- An 18" Dia. ½" Thick Steel Tube Was Bolted To The End Of The SUPERPILE To Increase The Driving Resistance.
- A Vulcan 01 (5,000 Lb Ram With A Stroke Of 3 Ft.) Was Utilized To Drive The Piles To Refusal.
- An Ape D30-32 (6,600 Lb Ram With A Stroke Of 11.25 Ft.) Was Utilized To Drive The Pile To Failure.

CREATIVE PULTRUSIONS

PDA ANALYSIS SUMMARY

The test pile driven with the Vulcan 01 Impact Hammer, to refusal, demonstrated a driving resistance of 160 kips, a driving energy of 8 kip-ft., and a compressive driving stress of 8 ksi.

The pile was extracted, inspected and revealed no signs of damage.

CREATIVE PULTRUSIONS

PDA ANALYSIS SUMMARY

The test pile driven with the larger APE D30-32 impact hammer was driven through the same soils at a blowcount of 9 blows/ft. Ending at a blowcount of 12 blows/ft., which was evaluated to represent a resistance of 200 kips with a compressive stress of 11 ksi.

No evidence of damage was observed.

CREATIVE PULTRUSIONS

PDA ANALYSIS SUMMARY

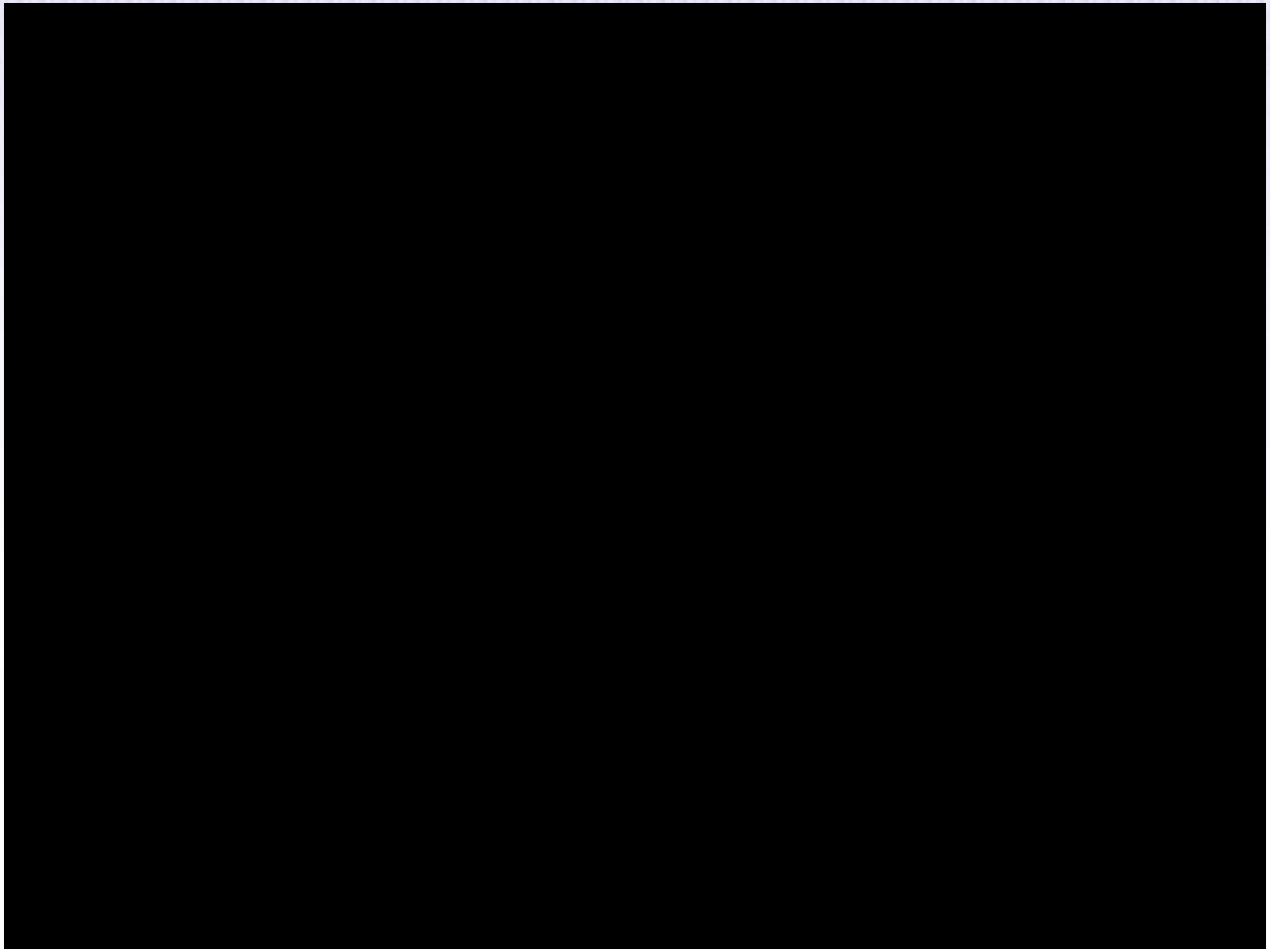
After a One Day Set Up Period, the Pile was Re-Driven with the APE D30-32 Impact Hammer at a Substantially Greater Resistance.

At 235 blows/ft., a Driving Resistance of 340-370 kips, an Average Energy Transfer of 30 ksi and a Recorded Compressive Driving Stress of 13-15 ksi, the Pile Head Split and the Pile Failed.

Prior to the Pile Head Splitting, a CAPWAP® Analysis Indicated an Ultimate Axial Compressive Capacity of 350 kips.

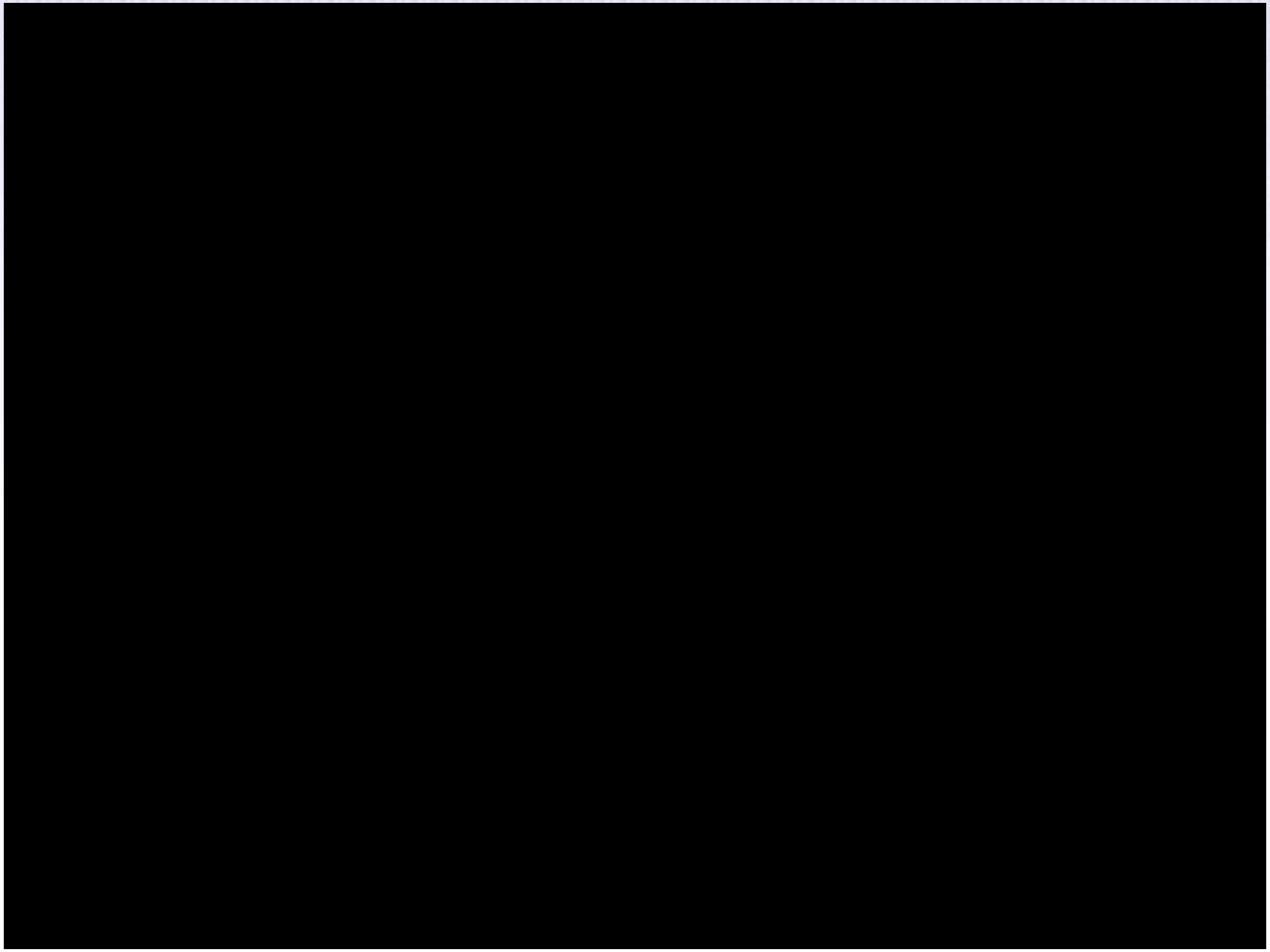
CREATIVE PULTRUSIONS

IMPACT HAMMER INSTALLATION VIDEO



CREATIVE PULTRUSIONS

VIBRATORY HAMMER INSTALLATION



CREATIVE PULTRUSIONS

ACCESSORIES

- Thermoplastic Caps
- FRP Caps
- HDPE Sleeves
- Driving Tips
- Custom Coatings

Polyethylene Pile Cap

FRP Structural Cap

Piles with Driving Tips Ready to Ship

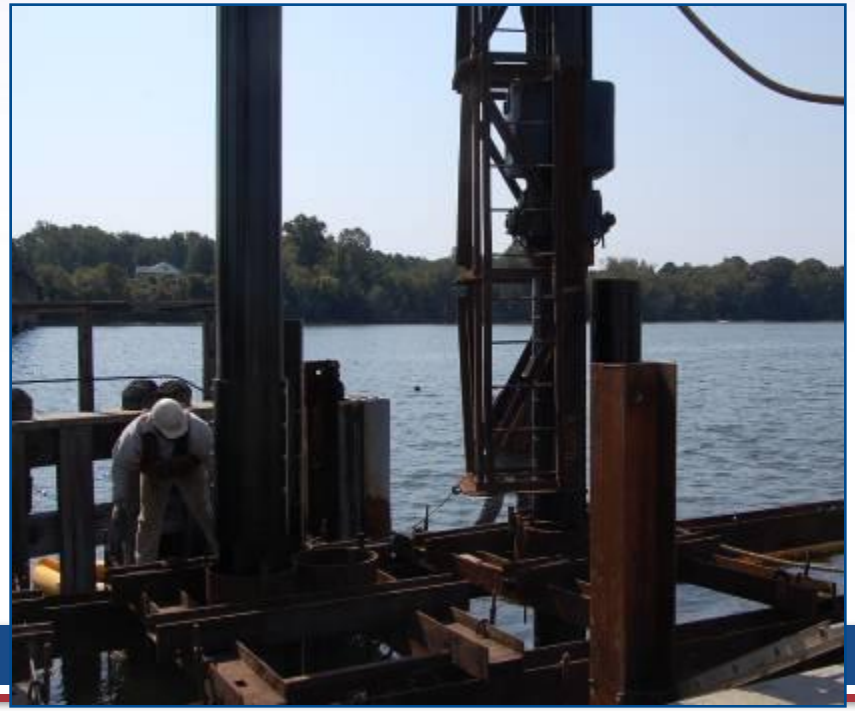
CREATIVE PULTRUSIONS

ACCESSORIES – FRP STRUCTUTAL PROFILES, DECKING AND GRATING

CREATIVE PULTRUSIONS

PILE SPLICE OPTIONS

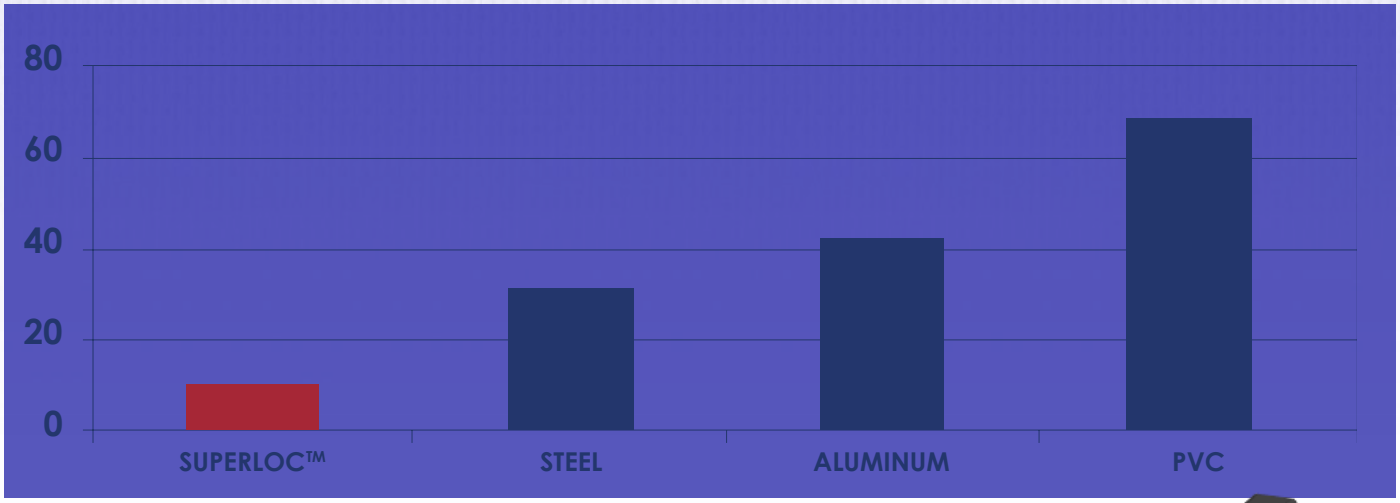
- Steel Pipe Splice Installed at VADOT Rte. 3 Piankatank River Fender Project.
- Connection Tested During PDA Test by Crofton Diving.
- Bolted Connection with Three 1" Diameter Bolts.



CREATIVE PULTRUSIONS

PULTRUSION THE GREEN CHOICE

EMBODIED ENERGY COMPARISON



Will Not Leach

CREATIVE PULTRUSIONS

LONG BEACH, NEW YORK
HURRICANE SANDY REPAIR AND PROTECTION

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CONCRETE PILES REPLACED WITH FRP

CREATIVE PULTRUSIONS

QUESTIONS?

CELEBRATING OVER 41 YEARS OF PROVIDING PULTRUSION SOLUTIONS

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