North American Pultrusion Conference

Increasing Grid Resiliency With FRP Utility Poles

Dustin Troutman

Creative Composite Group

ACMA American Composites Manufacturers Association | EPTA

Addressing Resiliency With Fiberglass Reinforced Polymer Structures

Current Situation

- Electric and communication providers are being tasked to rebuild aging infrastructure and to expand their services based on current and future demand.
- At no other time in history has civilization relied so much on communication and electricity.
- A major thrust to prepare for ***electric vehicle electric demand*** and decarbonization is forcing a major rebuild and buildout of the current grid.
- Utility material sourcing issues exist and will continue to do so…
- Fiber reinforced polymer (FRP) poles are playing a major role in resiliency.

Addressing Resiliency

Today, I'll discuss:

- Why FRP systems are resilient
- The roles FRP poles are playing in resiliency and grid hardening
- How FRP structures are performing
- Grid hardening strategies

Example: FRP Pipe Piles Are Used For Energy Absorption Applications

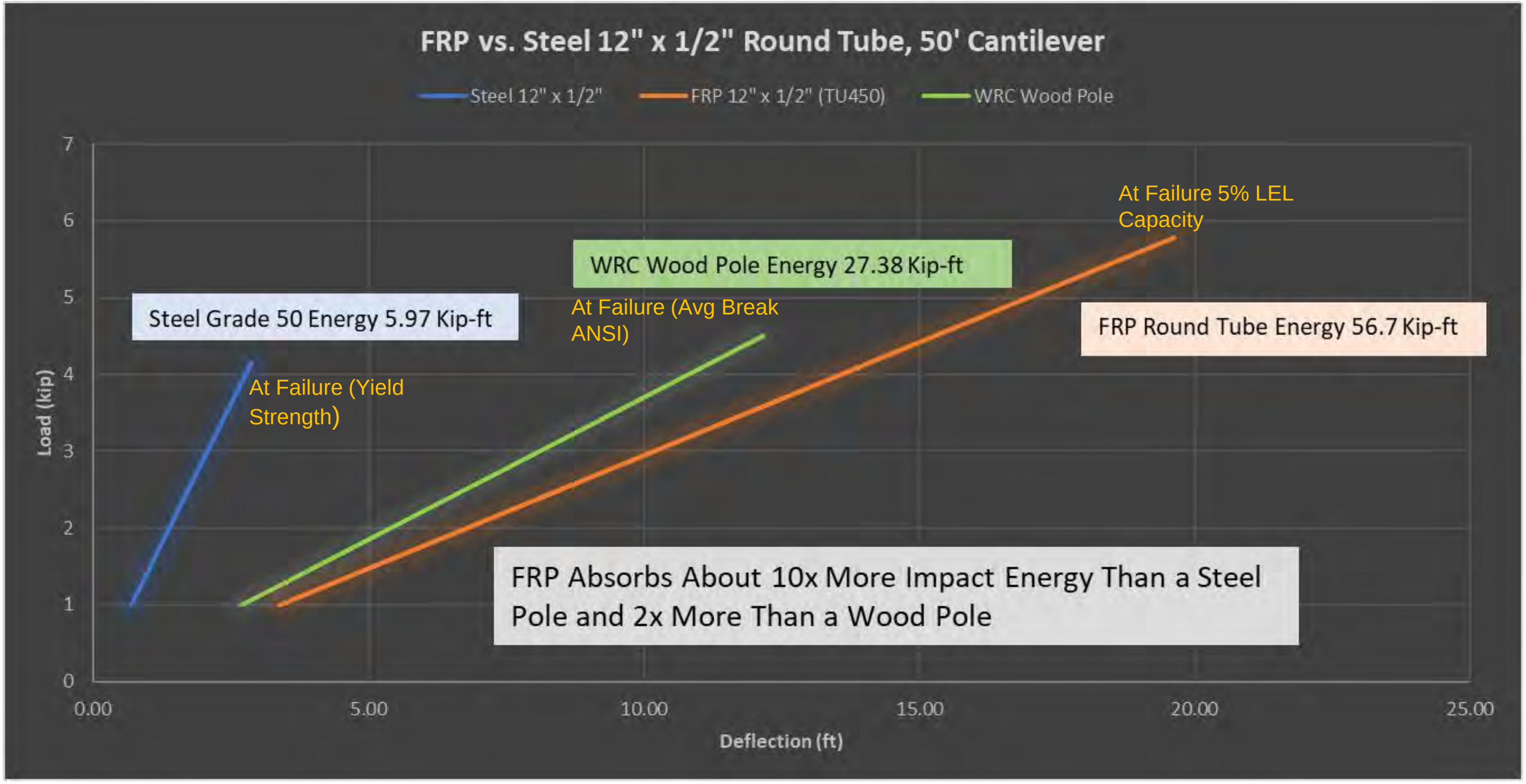
WHY?
High Strength / Moderate Modulus Attributes Are Ideal For Energy Absorption Applications

Energy Absorption Comparison

Area Under the Load/Displacement Plot Equates to the ***Energy Absorption*** Capacity of a Material

This allows us to compare legacy systems to FRP poles

Assumed Class 1-4,500 lbf Grade B FRP Equiv. 2,925 lbf.



Unlike Wood Poles FRP Poles Are Tested to Failure to Establish the 5% Lower Exclusion Limit Design Strengths

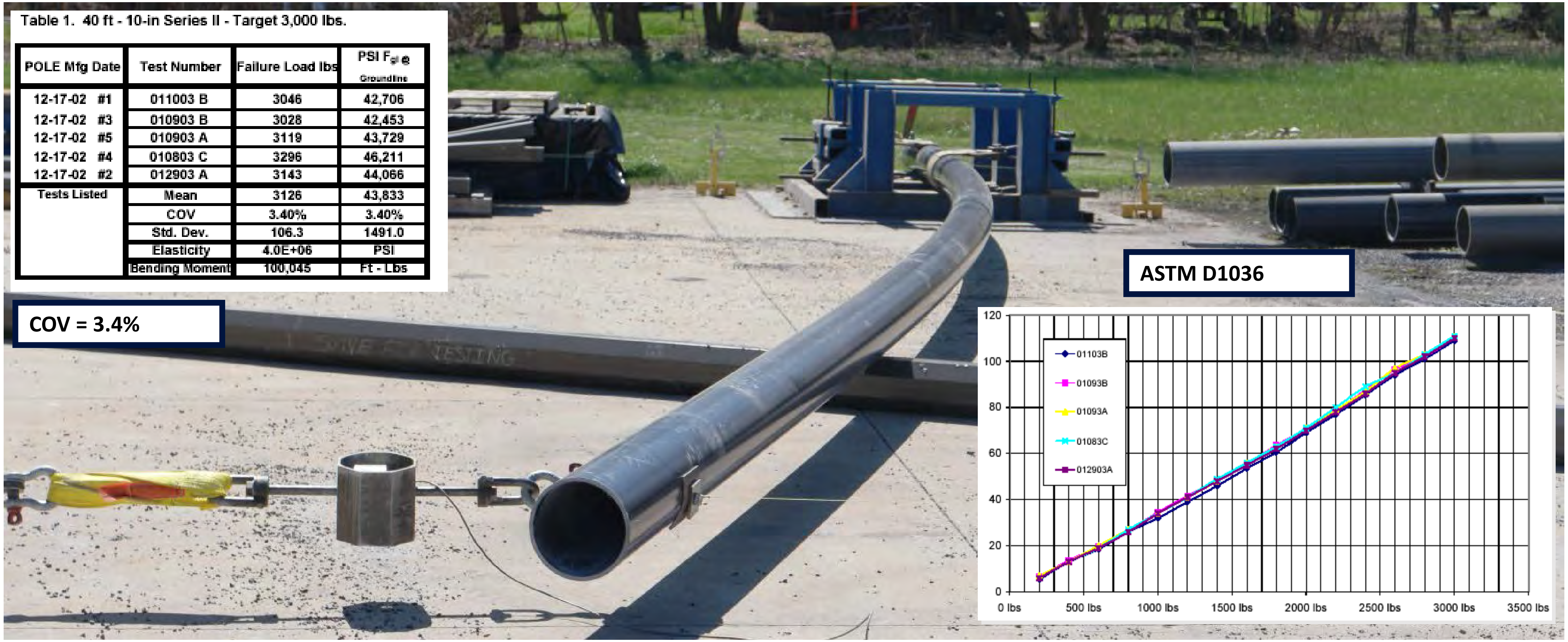


Table 1. 40 ft - 10-in Series II - Target 3,000 lbs.

POLE Mfg Date	Test Number	Failure Load lbs	PSI F_{pl} @ Groundline
12-17-02 #1	011003 B	3046	42,706
12-17-02 #3	010903 B	3028	42,453
12-17-02 #5	010903 A	3119	43,729
12-17-02 #4	010803 C	3296	46,211
12-17-02 #2	012903 A	3143	44,066
Tests Listed	Mean	3126	43,833
	COV	3.40%	3.40%
	Std. Dev.	106.3	1491.0
	Elasticity	4.0E+06	PSI
	Bending Moment	100,045	Ft - Lbs

COV = 3.4%

ASTM D1036

Load-deflection very near linear

Reliability in the Numbers

- FRP pole strengths are published based on a 5% Lower Exclusion Limit
- Wood poles exhibit a coefficient of variation (COV) of 20% (ref: USDA Designated Fiber Stress for Wood Poles FPL-GTR-158)
- ANSI O5.1 wood pole classifications are based on the **average** ultimate tip load strengths
- NESC calls out a .65 and .85 strength reduction factor, for wood poles, dependent upon the grade of construction
- FRP pole strengths are published based on a 5% lower exclusion limit, not the average breaking strengths (code requirement)
- FRP poles exhibit a COV of approximately 5%, as opposed to 20% for wood in terms of pole strength repeatability

NESC Wood Strength Equivalent Example –
Reliability in Strength Probability

- Grade B construction requires a strength reduction factor of .65 for wood poles.
- Fiberglass Reinforced Polymer poles are to be designed with a strength factor of 1.0 referencing Table 261-1 NESC
- FRP poles are an engineered, factory manufactured products. Therefore, in order to match the ANSI class of a wood pole, the FRP pole can break at a lessor load.
- The equivalent strength required of an FRP pole, to that of a wood pole is determined, in this example, by multiplying a class 1 ANSI pole strength of 4,500 lbf by the ratio of .65/1.0 = 2,925 lbf

	Grade B	Grade C
Strength factors for use with loads of Rule 250B (combined ice and wind district loading)		
Metal and prestressed-concrete structures, crossarms, and braces [6]	1.0	1.0
Wood and reinforced-concrete structures, crossarms, and braces [2] [4]	0.65	0.85
Fiber-reinforced polymer structures, crossarms, and braces [6]	1.0	1.0
Support hardware	1.0	1.0
Guy wire [5] [6]	0.9	0.9
Guy anchor and foundation [6]	1.0	1.0
Strength factors for use with loads of Rules 250C (extreme wind) and 250D (extreme ice with concurrent wind loadings)		
Metal and prestressed-concrete structures, crossarms, and braces [6]	1.0	1.0
Wood and reinforced-concrete structures, crossarms, and braces [3] [4]	0.75	0.75
Fiber-reinforced polymer structures, crossarms, and braces [6]	1.0	1.0
Support hardware	0.8	0.8
Guy wire [5] [6]	0.9	0.9
Guy anchor and foundation [6]	1.0	1.0

Principles of Reliability

Reliability Index for a *normally-distributed variable* is defined by:

$$\beta = M_R - M_W / (\sigma_R^2 + \sigma_W^2)^{1/2}$$

where:

M_R = Mean value of Resistance

M_W = Mean Value of Applied Load Effects

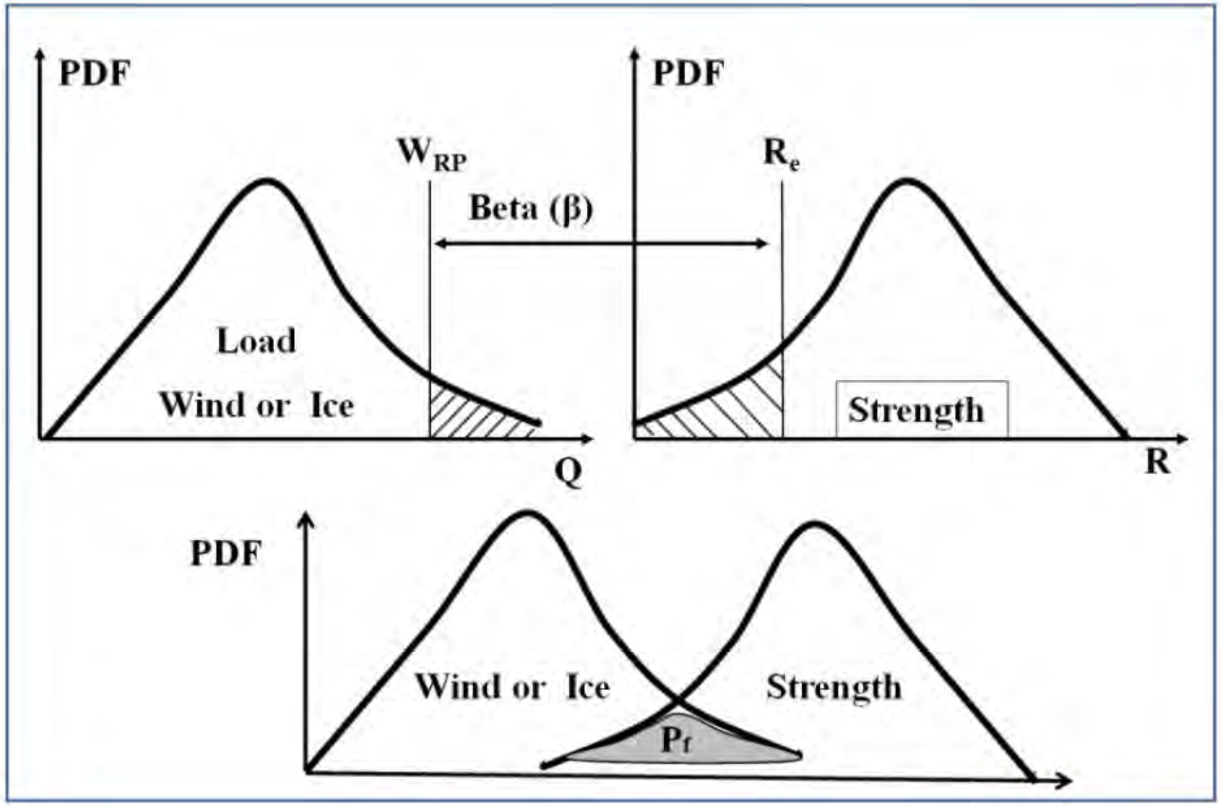
σ_R = Standard Deviation of Resistance = $(COV_R) * (M_R)$

σ_W = Standard Deviation of Load Effect = $(COV_W) * (M_W)$

COV_R = Coefficient of Variation of Resistance

COV_W = Coefficient of Variation of Load Effect

- Resistance can be of any type: axial, shear, torsion, tension, compression or **flexural**.
- Load Effect, M_W, as it refers to the focus of this study, is the bending moment at the ground line (GL) due to a prescribed lateral load P applied near the pole top.
- Resistance, M_R, as it refers to the focus of this study, is the bending moment *capacity* at the ground line (GL) estimated using the section, elastic properties at the location.



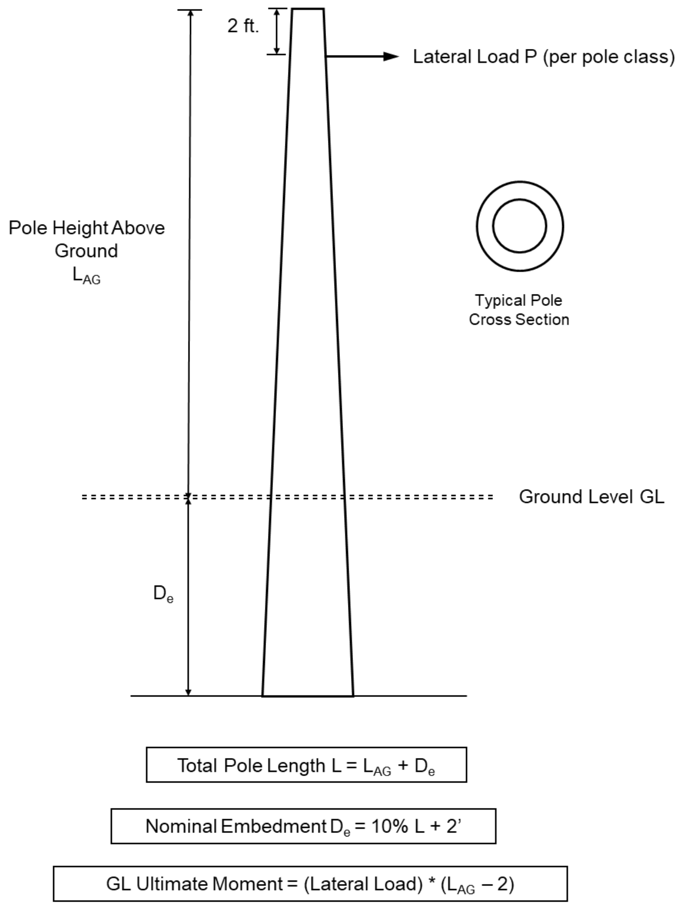
Coefficients of Variation

Wood Pole COV = 0.20 applied to the maximum bending stress or Modulus of Rupture (MOR) in wood

FRP Pole COV = 0.05 applied to the maximum flexural stress in composite material

Reference: *Reliability Assessment of Transmission Poles*

Load & Resistance Determination



Measure of Load Effects

For all poles, the Load Effect parameter can be expressed in terms of the Ground Line (GL) Bending Moment of the pole:

$M_W = (P) * (L_{AG} - 2)$

where:

L_{AG} = Pole Height Above Ground

P = P_U (ultimate) or P_S (serviceability)

Measure of Resistance

For circular cross sections, the Resistance parameter can be expressed in terms of the Ground Line (GL) Bending Moment Capacity of the pole from basic mechanics of sections.

Wood

$M_{RWood} = (S) * (MOR) = (\pi * d_{gl}^3/32) * (MOR)$

S = Section Modulus

d_{gl} = Pole Diameter at GL

MOR = Modulus of Rupture or Wood Fiber Strength

I = Moment of Inertia = $(\pi * d_{gl}^4/64)$

FRP

$M_{RFRP} = (S) * (FS) = (0.786 * d_{gl}^2 * t) * (FS)$

S = Section Modulus

d_{gl} = Pole Diameter at GL

t = pole module thickness at GL

FS = Flexural Strength of the pole module at the GL

I = Moment of Inertia = $0.393 * d_{gl}^3 * t$

Note: FRP pole properties refer to Bulk Properties.

Reference: *Reliability Assessment of Transmission Poles*

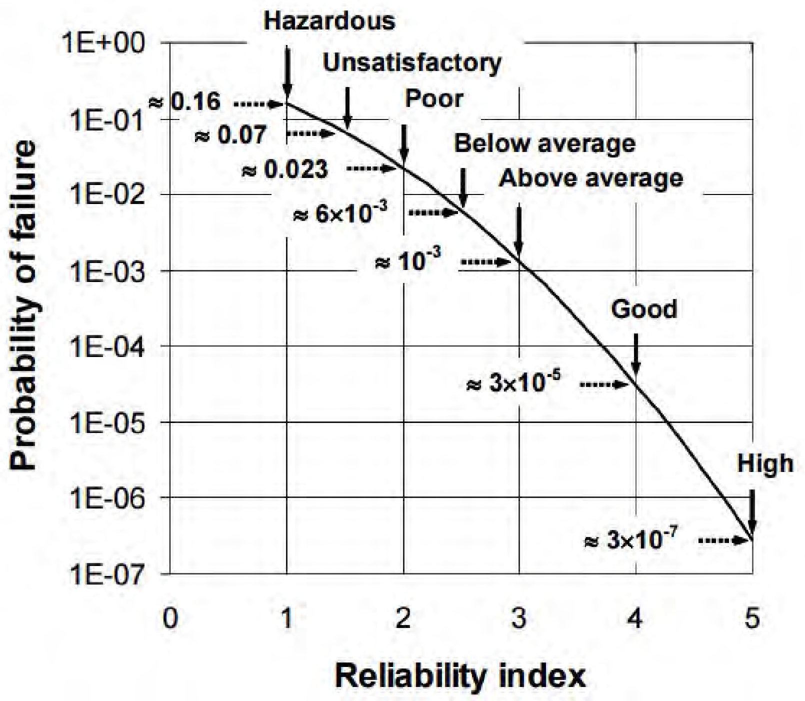
Reliability Calculation Result

FRP Composite: Probability of Failure P_f is less than 0.000001 for β = 5.142

Wood: Probability of Failure P_f is 0.0751 for β = 1.616

Using the prior assumptions:

- For every 1000 poles considered, wood poles would experience 75 failures whereas FRP poles would experience no failures at all.
- In real world terms, this translates to significantly less repair and/or replacement costs for FRP poles compared to wood.
- Composite represents a *significant* increase in reliability and resiliency



USACE (1997). "Risk-based Analysis in Geotechnical Engineering for Support of Planning Studies, Engineering and Design", US Army Corps of Engineers, Department of Army, Washington, DC 1997. 20314–100.

Reference: *Reliability Assessment of Transmission Poles*

Guelph Hydro – Toronto, Canada

Why FRP Poles? Concrete Poles Failed Due To De-icing Salts Along Roadway

United Electric - NW PA

Why FRP Poles? Limited Access, Reliability, Woodpecker Prone Areas

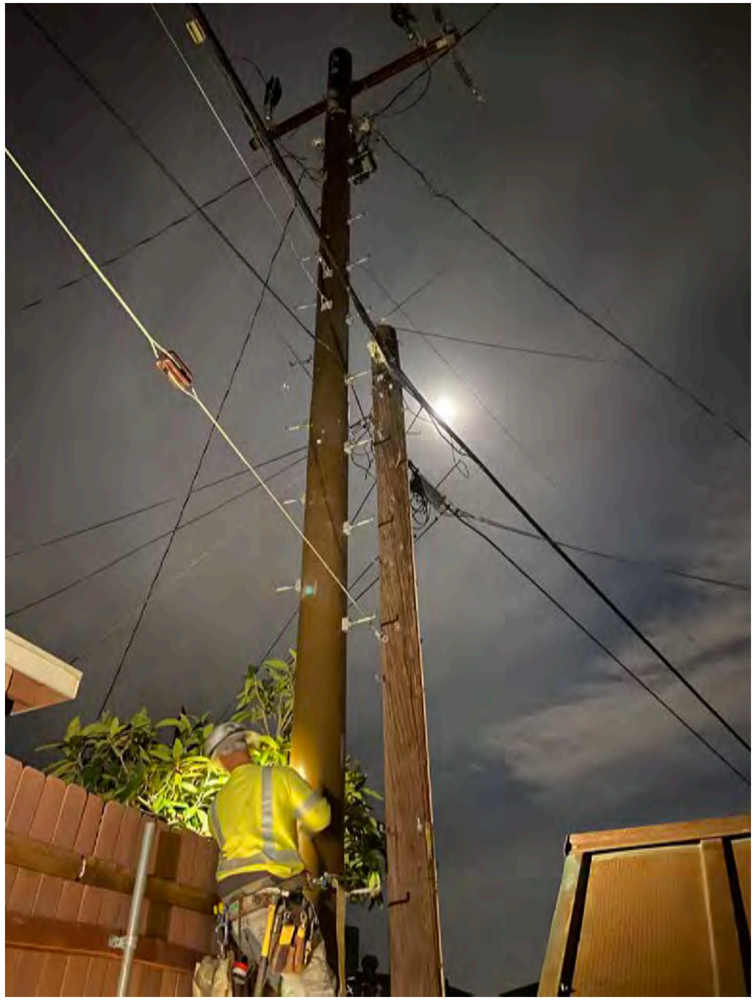
10-year-old wood pole

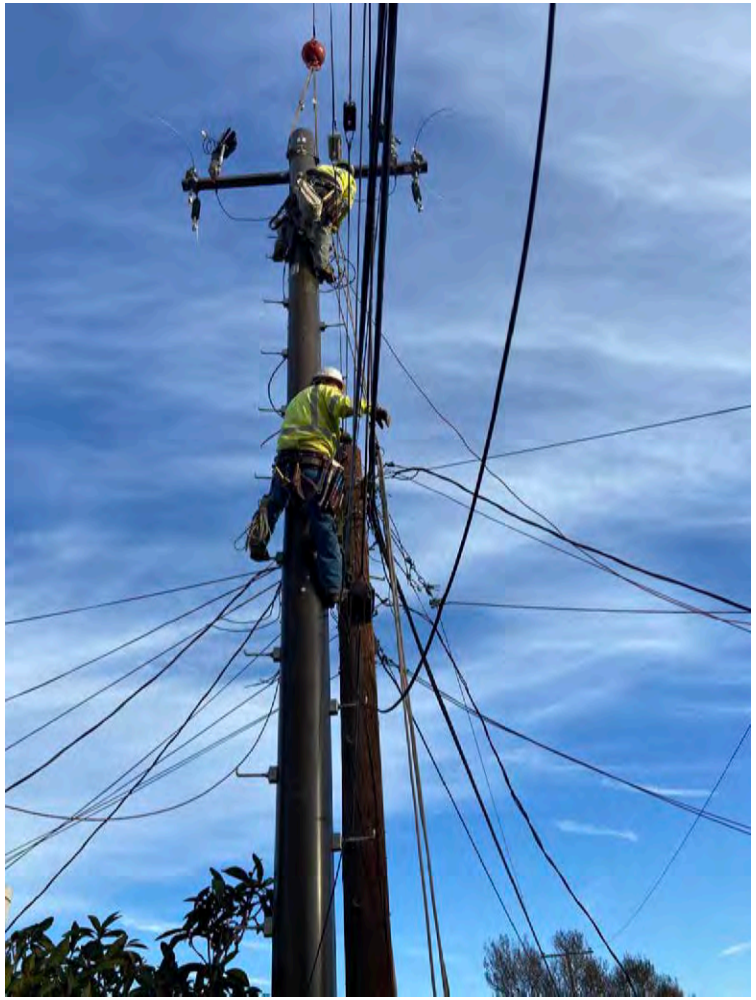
Hawaii Electric

Why FRP Poles? Termites Destroy Wood Poles in Less Than Ten Years

Southern California Edison

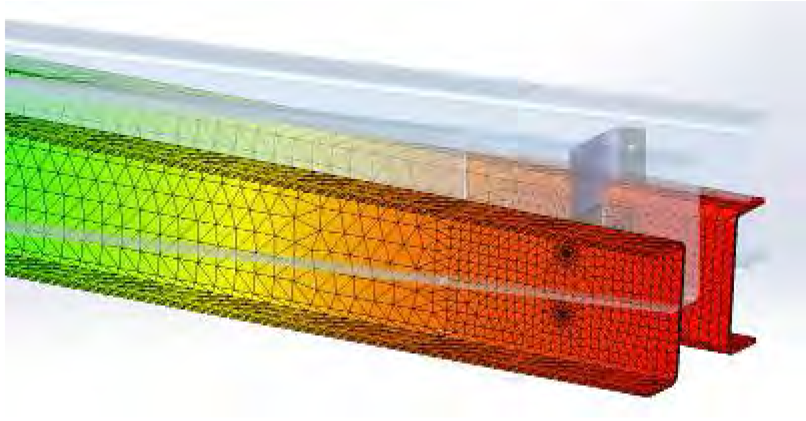
Why FRP Poles? High Fire Risk Areas





BC Hydro 287kV Transmission Arms

Why FRP Transmission Arms? Dielectric Strength, Light Weight, Resilient, Life Cycle of Wood Has Decreased



BC Hydro 287kV Transmission Arms

Pultruded FRP Pole Advantage

✓ ROT PROOF

✓ TERMITE PROOF

✓ WOODPECKER PROOF

- No rot or decay
- No termite control necessary
- Ideal for coastal locations
- No woodpecker damage repair

Composite Pole Actual Fire Exposure

Fire Approach

Composite Pole
Engulfed In Flames

Fire Dispersed

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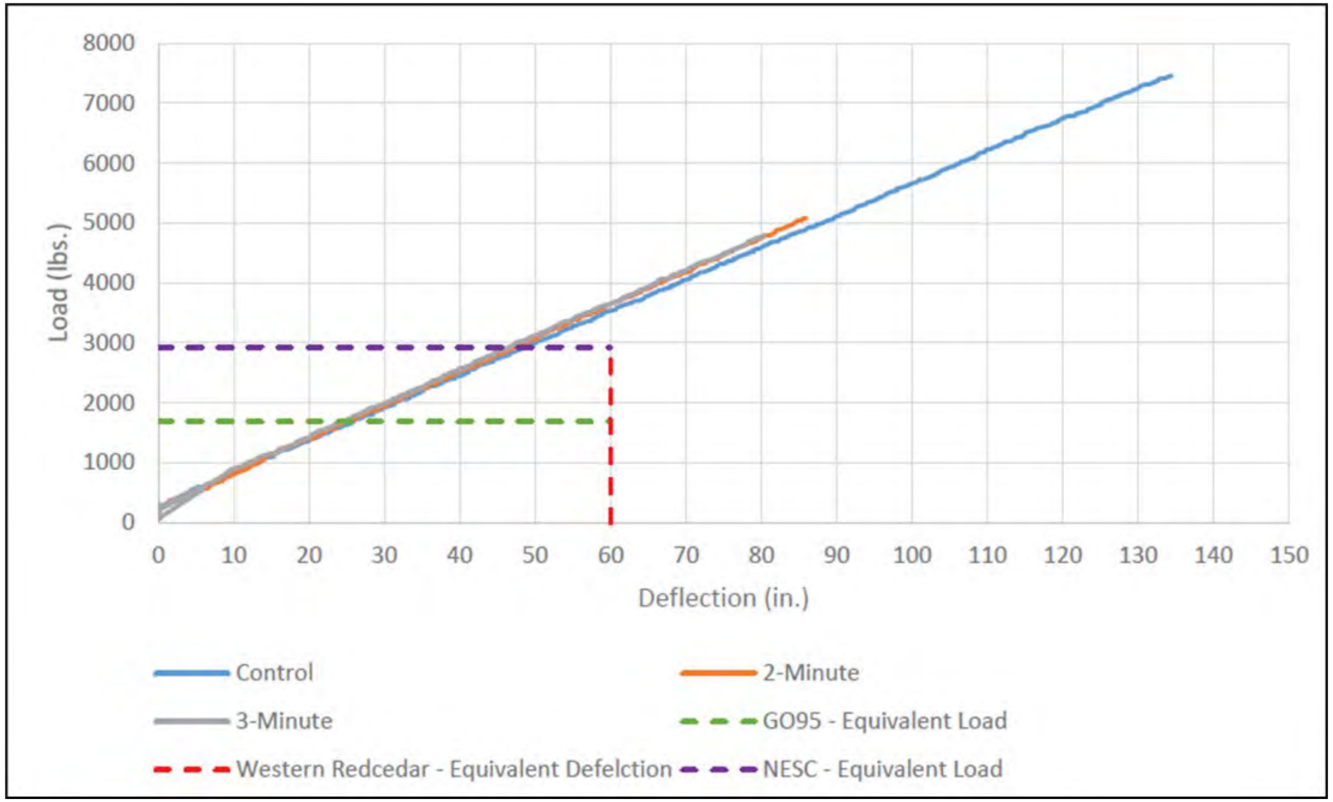
Lab Test

Pultruded Fire Sleeve – Pole Configuration (TEST ONE): Jan 2021

Fire Testing - January 2021		**Burner Location:**	**15 inches from face**	
		Burner Fuel Flow:	**50 SCFH**	
		Hot Face Temp. at Start:	**2116°F**	
Test One:				
	Sample ID	**Thermalcouple Temp °F Next to ITL marker**	**ITL Thermal Marker Temp °F on Pole**	**Time (min)**
1	Ref:12" long pultruded fire sleeve	225		1
	Shielding TU450 pole	331	280	2
		317		3
2	Ref:12" long pultruded fire sleeve	208		1
	Shielding TU450 pole	312	300	2
		320		3
3	Ref:12" long pultruded fire sleeve	198		1
	Shielding TU450 pole	295	280	2
		341		3
	Average of Tests 1 and 2 (at 3 minutes)	**319**	**290**	**3**

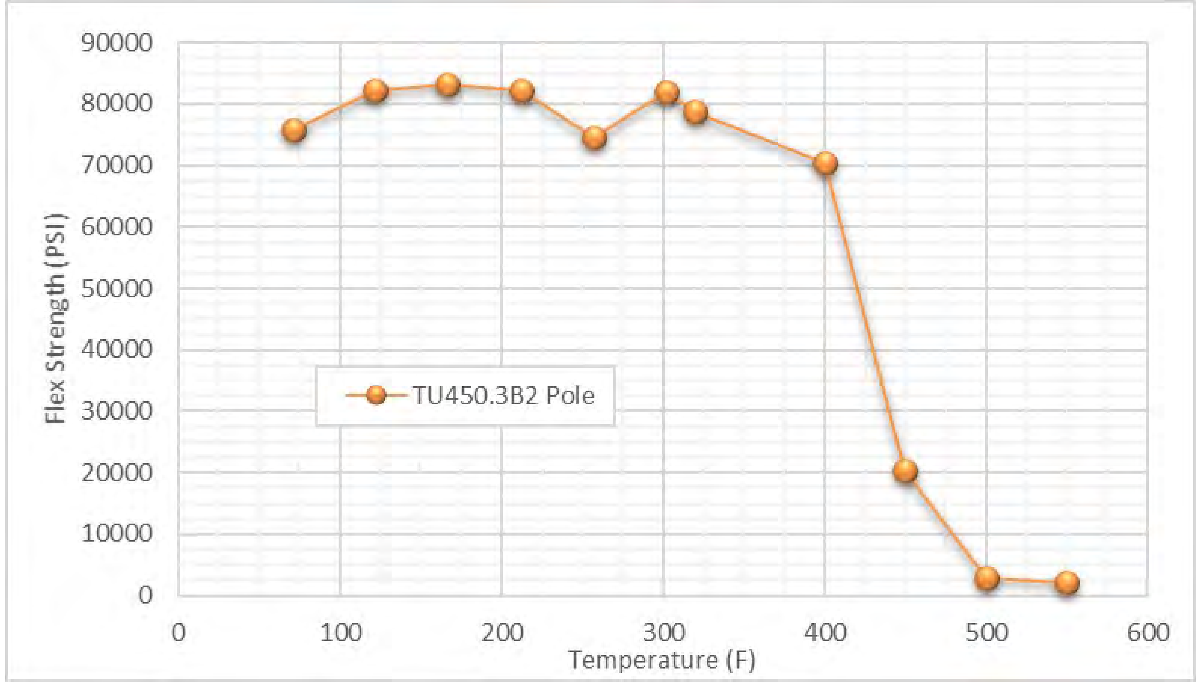
Pultruded Pole Brush Fire Tested For Three Minutes At Approximately 2,100˚f, Followed Up By Full Section Testing

Class One – 45’ Burnt Pole Exceeded the GO95 and NESC Strength Requirements



Post Fire Inspection

- CCG developed a technology that permanently records the maximum temperature during a fire event.
- Post fire inspection requires accessing the temperature recorder to verify that the temperature of the pole did not exceed the limit of the laminate.



Big Pine Keys
Small Cell Tower Installation

Location Details
Big Pine Keys, Florida

Experienced 130 mph wind gusts from Cat 5 Hurricane Irma with no damage to the pole.

Development of Codes and Standards Increase Reliability

Designation: D8019 – 15

Standard Test Methods for Determining the Full Section Flexural Modulus and Bending Strength of Fiber Reinforced Polymer Crossarms Assembled with Center Mount Brackets[1]

This standard is issued under the fixed designation D8019; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of the flexural modulus and bending strength of both tangent and deadend arms bent about their minor and major axes. One method covers testing of assembled tangent crossarms including the tangent bracket and relative hardware. The other method covers testing of assembled deadend crossarms with a deadend bracket and relative phase loading hardware. The failure modes and associated stresses can be used for predicting the phase load capacities of pultruded crossarms specific to certain conductor loading scenarios.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

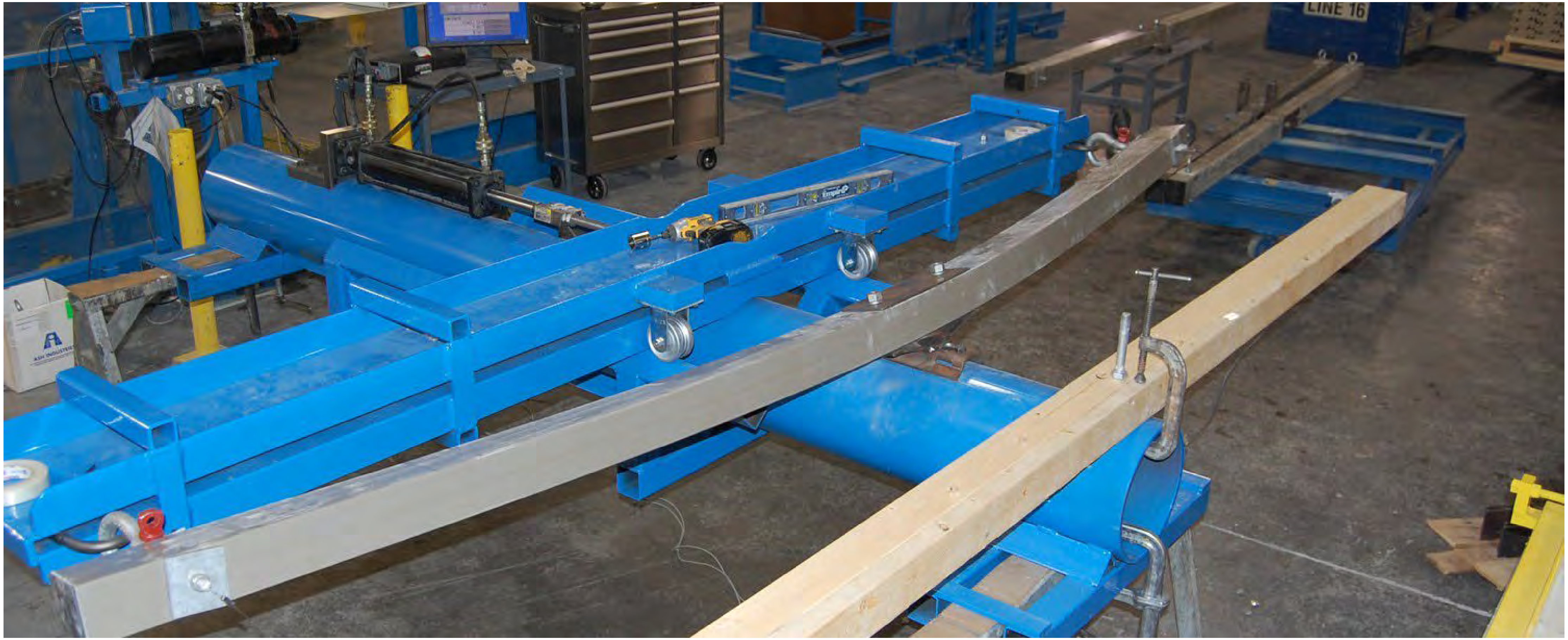
NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4968 Guide for Annual Review of Test Methods and Specifications for Plastics

Tangent Arm Test Set Up



Concluding Points

- FRP poles and crossarms can project energy absorption capabilities over that of legacy materials of construction.
- Building a more resilient grid involves implementing engineered products with known statistically derived reliability factors.
- FRP poles have been utilized for 25 years and longer with great storm survivability.
- Developing codes and standards centered around FRP products in conjunction with the utility industry will further enhance the grid reliability.

Resources

Presenter:

Dustin Troutman
Creative Composites Group
DTroutman@Pultrude.com
814.839.4186 Ext. 237

Grid Hardening Strategies:

Anthony Hurley
Critical Preparedness, LLC
Tony@CriticalPreparedness.com
216.554.0558

Reference Papers:

Reliability Assessment of Transmission Poles:
https://www.ej-eng.org/index.php/ejeng/article/view/2900

ASCE 111 Reliability-Based Design OF Utility Pole Structures
Search Results for "ASCE 111" (techstreet.com)

USACE (1997). "Risk-based Analysis in Geotechnical Engineering for Support of Planning Studies, Engineering and Design", US Army Corps of Engineers, Department of Army, Washington, DC 1997. 20314–100.

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