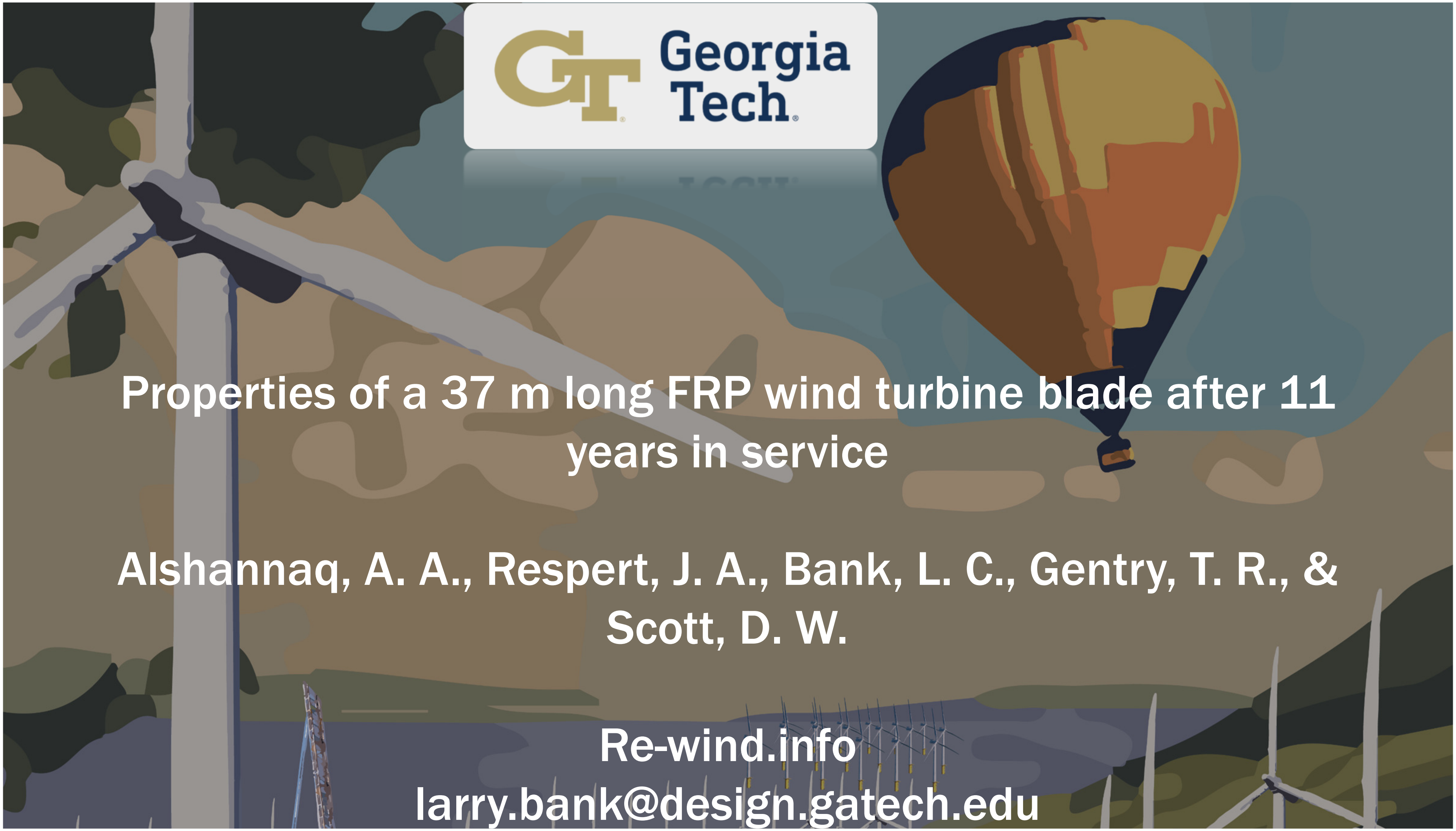

Properties of a 37 m long FRP wind turbine blade after 11 years in service

Alshannaq, A. A., Respert, J. A., Bank, L. C., Gentry, T. R., & Scott, D. W.

Re-wind.info
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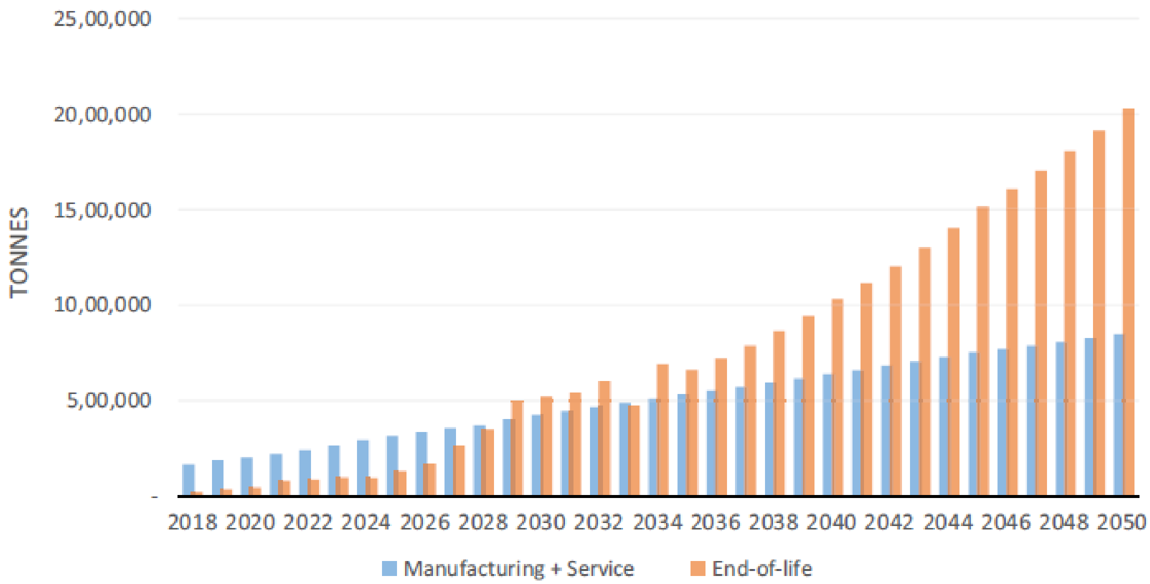
Introduction and Motivation

- Large amounts of wind blade composite materials are expected to be disposed of in the upcoming years



*Liu, Pu, and Claire Y. Barlow (2017). "Wind turbine blade waste in 2050." *Waste Management* 62: 229-240.

- These are non-biodegradable materials, and are harmful to the environment to dispose of them. Sustainable solutions to deal with wind blade waste are needed.

Introduction and Motivation

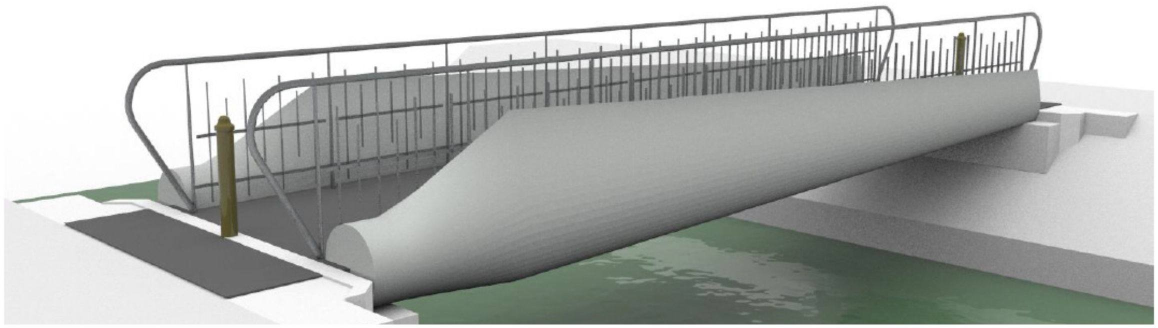
How do we deal with Wind Blade Waste?

- “DISPOSAL” through incineration or landfilling
  - Environmentally harmful option with no positive societal impact

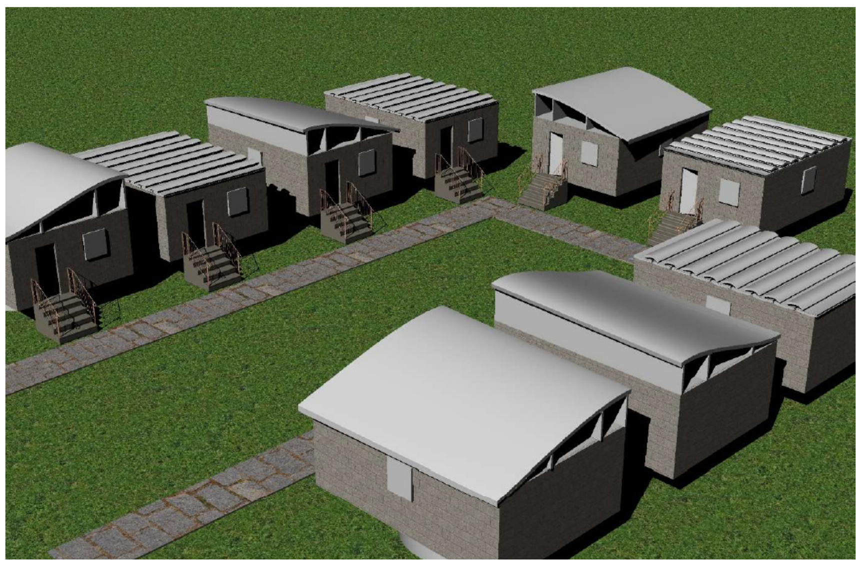
- “RECYCLING” using mechanical, thermal or chemical processing
  - Replacements for virgin constituents in new composites or cementitious mortars and concretes
  - Economical viability and reduced properties are the main drawbacks

- A new option explored in this research: “REPURPOSING”
  - Which includes characterizing, developing, analyzing, and prototyping applications where large-scale/full-scale parts of the wind blades are utilized in civil infrastructure

Introduction and Motivation



*Suhail, Raj, Jian-Fei Chen, T. R. Gentry, B. Tasistro-Hart, Y. Xue, and L. C. Bank (2019). "Analysis and design of a pedestrian bridge with decommissioned FRP windblades and concrete." *Fiber Reinforced Polymers in Reinforced Concrete Structures FRPRCS14.*

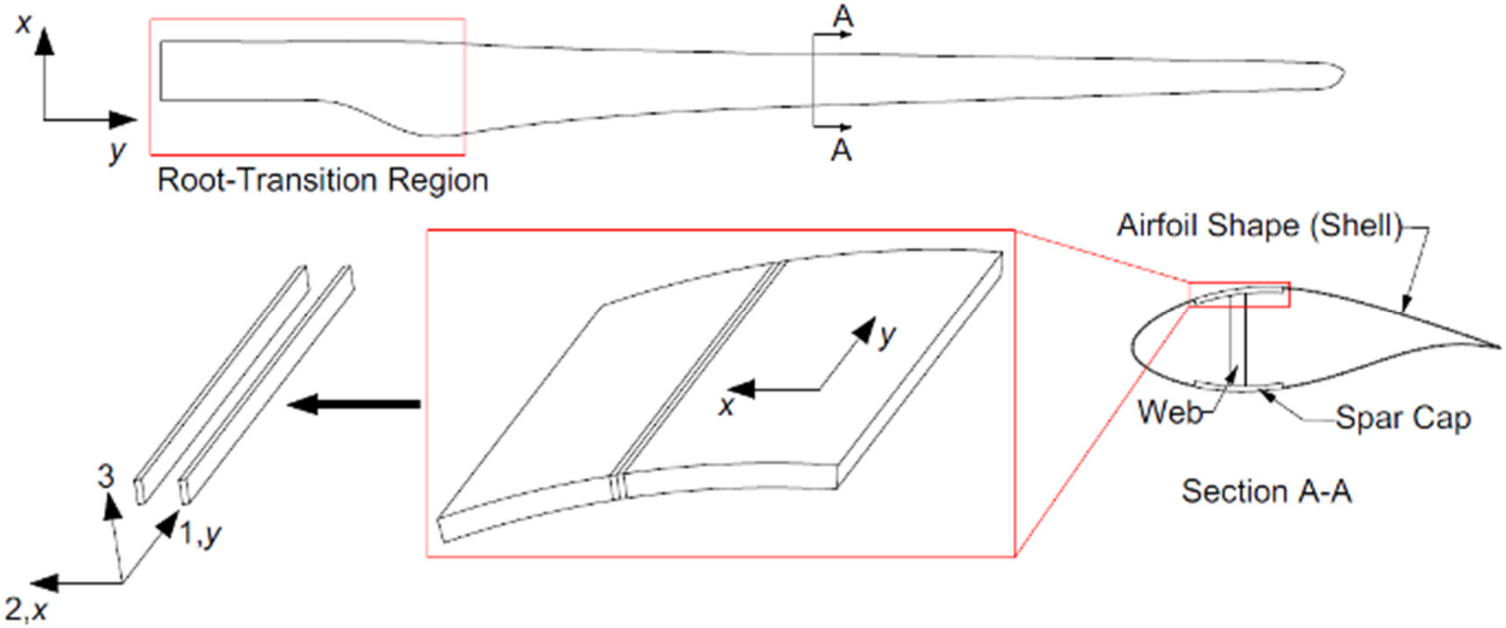


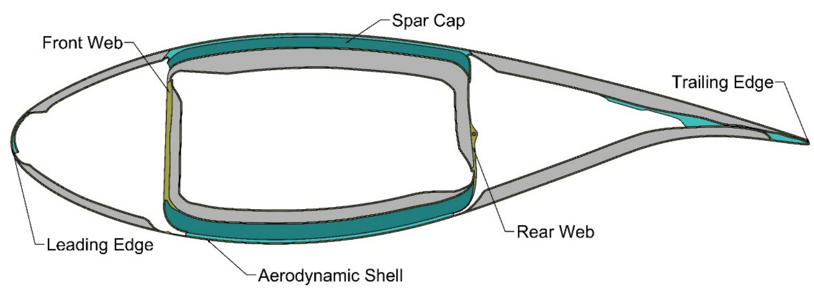
*Bank, Lawrence C., Franco R. Arias, Ardavan Yazdanbakhsh, T. Russell Gentry, Tristan Al-Haddad, Jian-Fei Chen, and Ruth Morrow (2018). "Concepts for reusing composite materials from decommissioned wind turbine blades in affordable housing." *Recycling* 3, no. 1.

Introduction and Motivation

- Can a decommissioned wind blade be used as a POWER POLE?

Wind Blade Shape

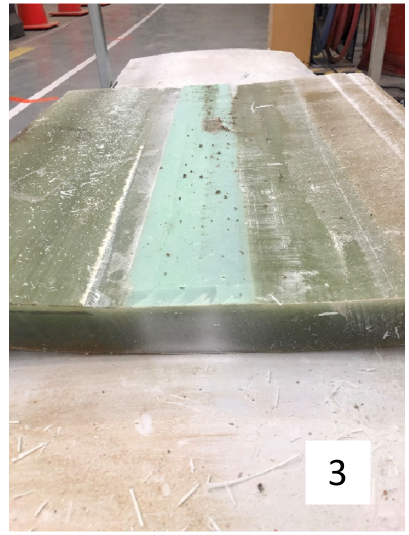




Specimens Preparation

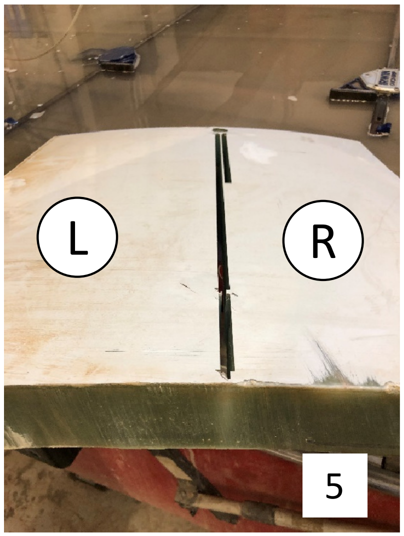
- 1.5 MW GE 37 Wind Turbine Blade

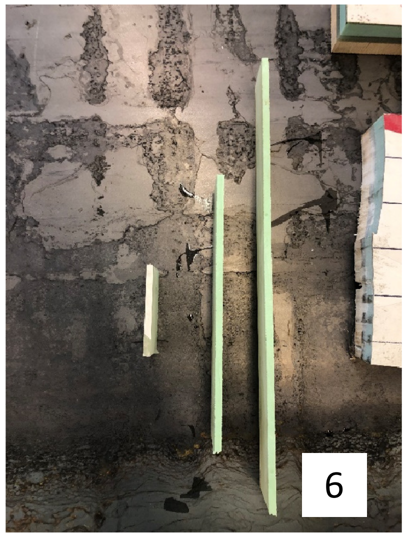
Specimens Preparation



1. As-received spar cap materials from Logisticus.
2. Initial cross-cutting of spar cap slabs.
3. Assessment of specimen flatness and removing central bonding material.
4. Fixturing of materials on waterjet cutter.

Specimens Preparation



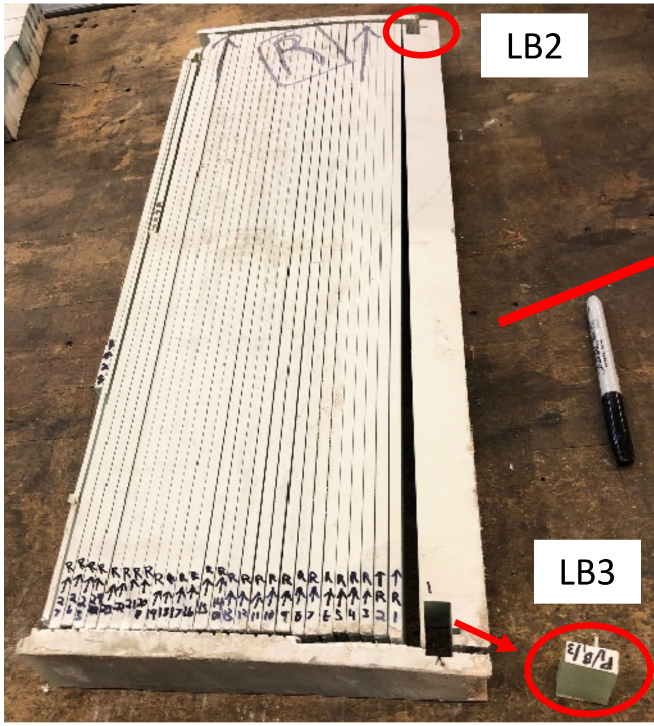


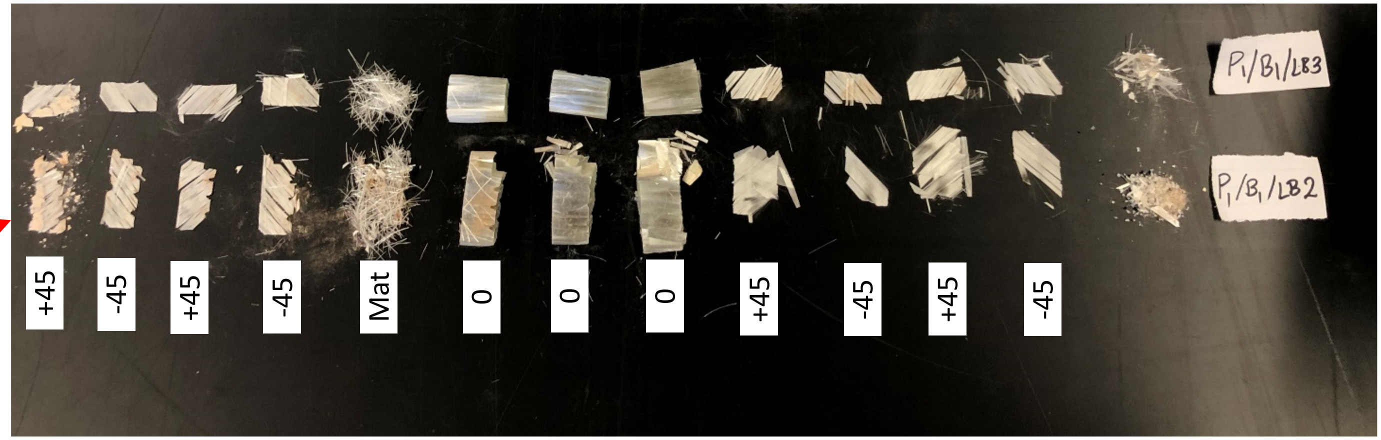
5. First cut to reduce width of spar cap and flatten specimen.
6. Initial coupons removed from specimen.
7. and 8. Specimen fully cut into sections.

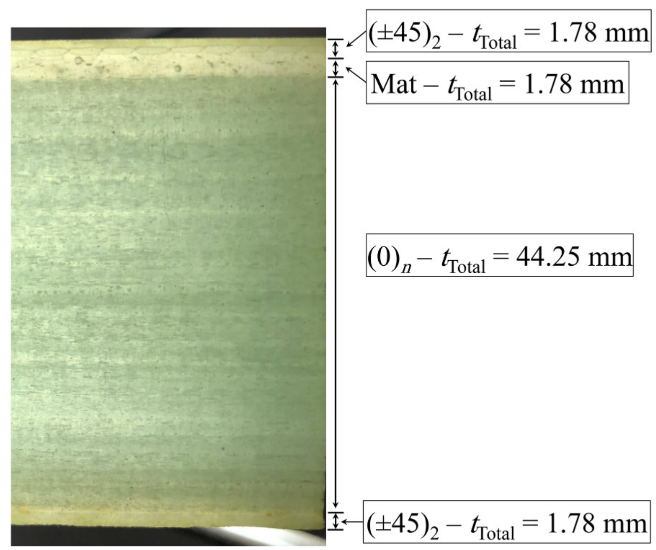
Specimens Preparation

9. Fabrication of Open-Hole Tensile specimen
10. Fabrication for V-Notch Shear testing
11. Fabrication of Dogbone and Straight-Sided Tensile specimens

Laminate Characterization Testing



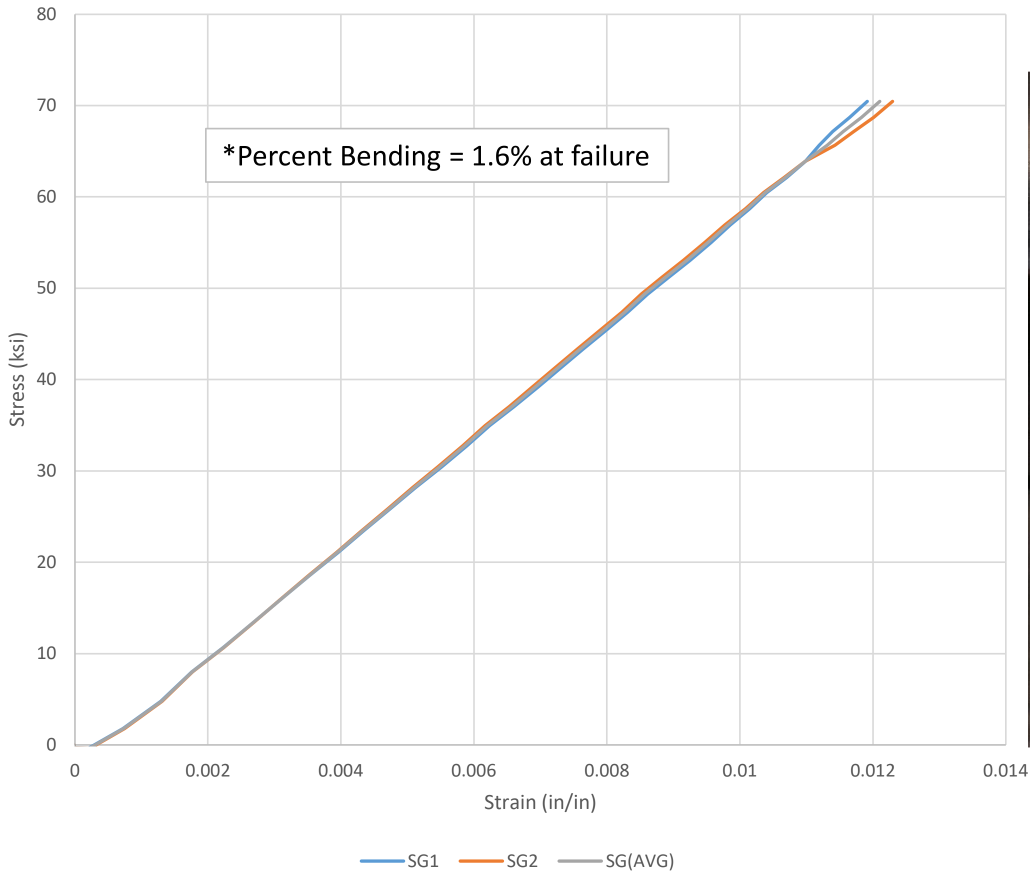


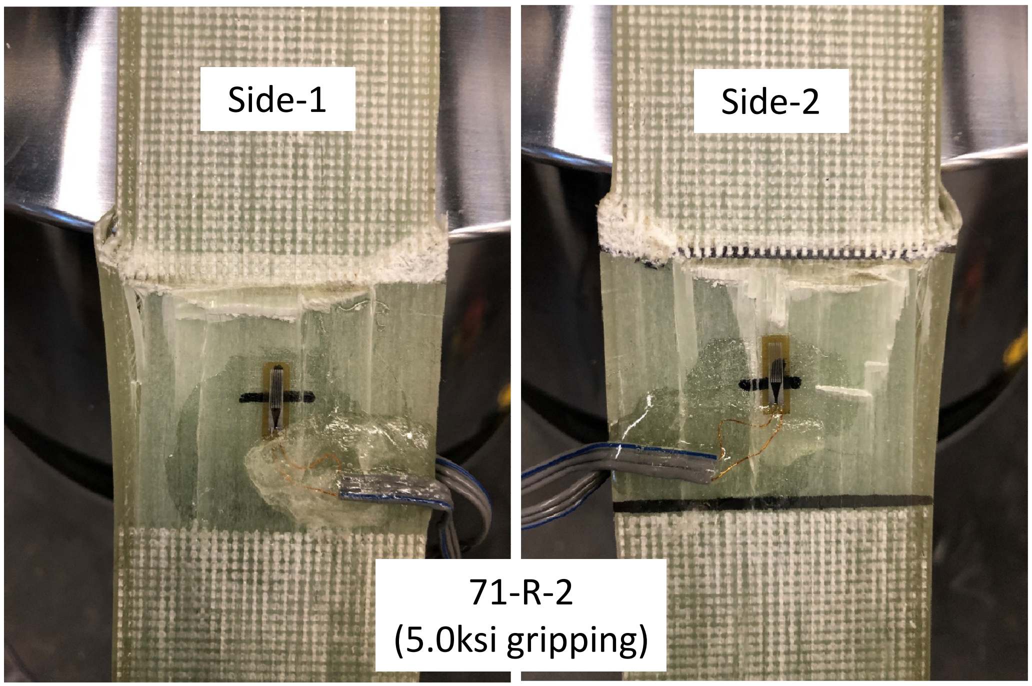


*ASTM 2584 - Standard Test Method for Ignition Loss of Cured Reinforced Resins

*ASTM 3171 - Standard Test Methods for Constituent Content of Composite Materials

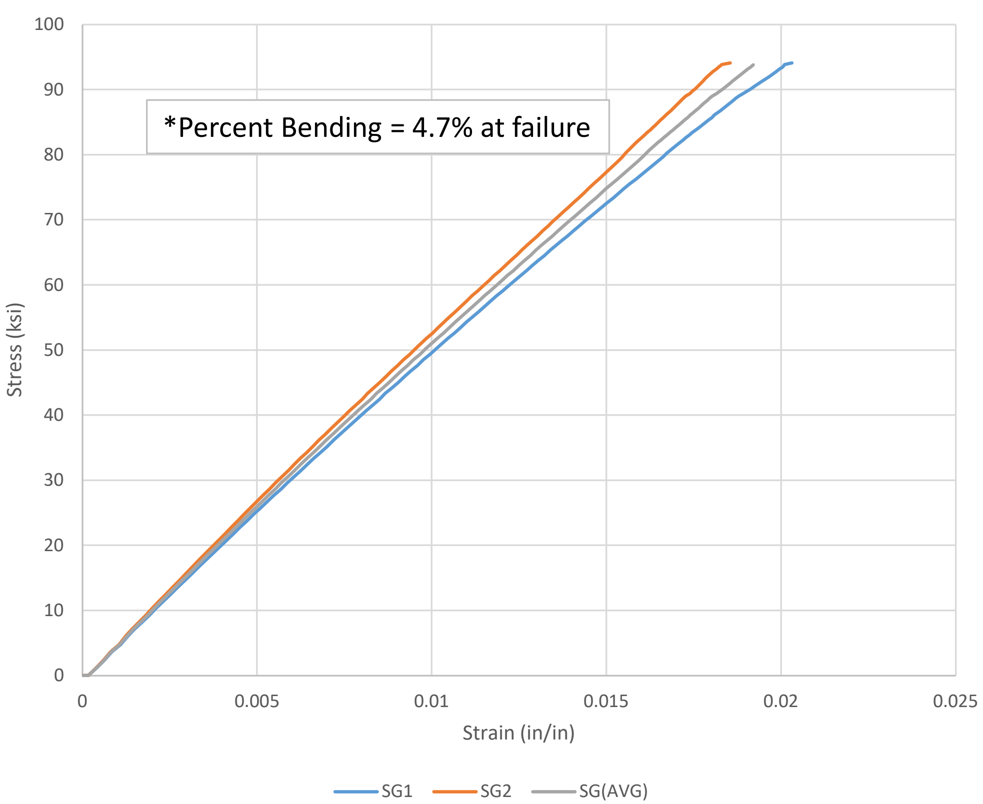
Compressive Testing





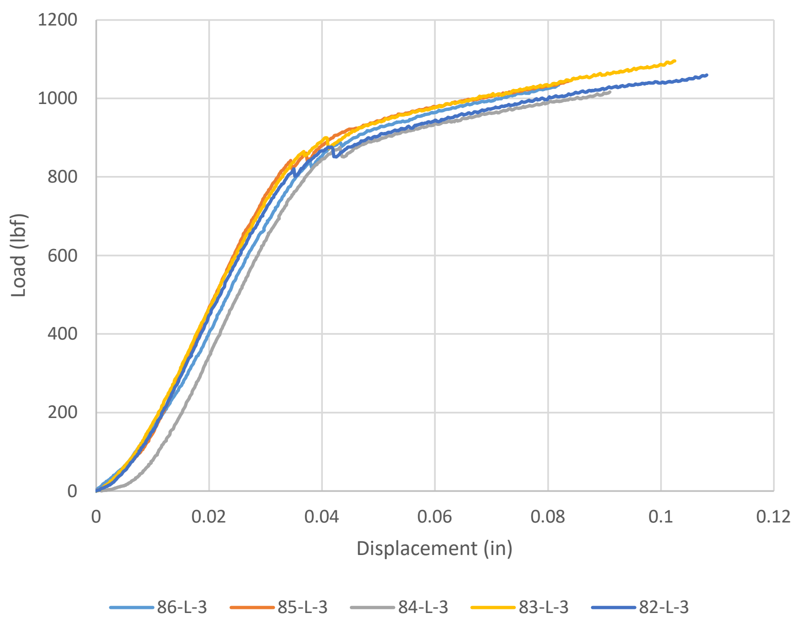
*Testing per ASTM D3410 - Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading

Tensile Testing

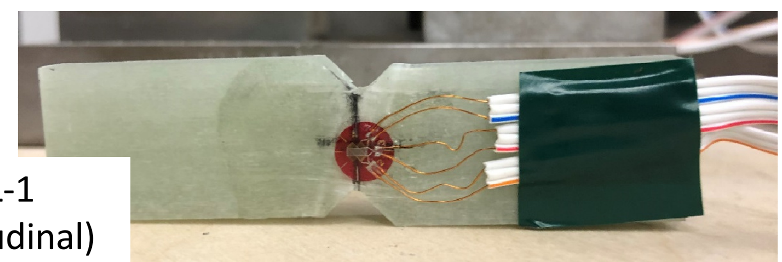


*Testing per ASTM D3039 - Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials

Shear Testing



*Testing per ASTM D5379 - Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

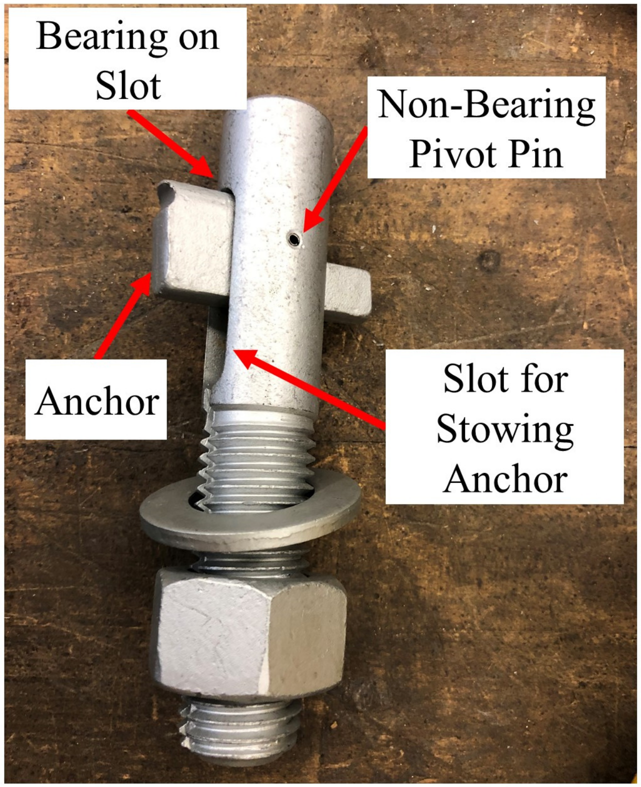


35-L-1
(Longitudinal)

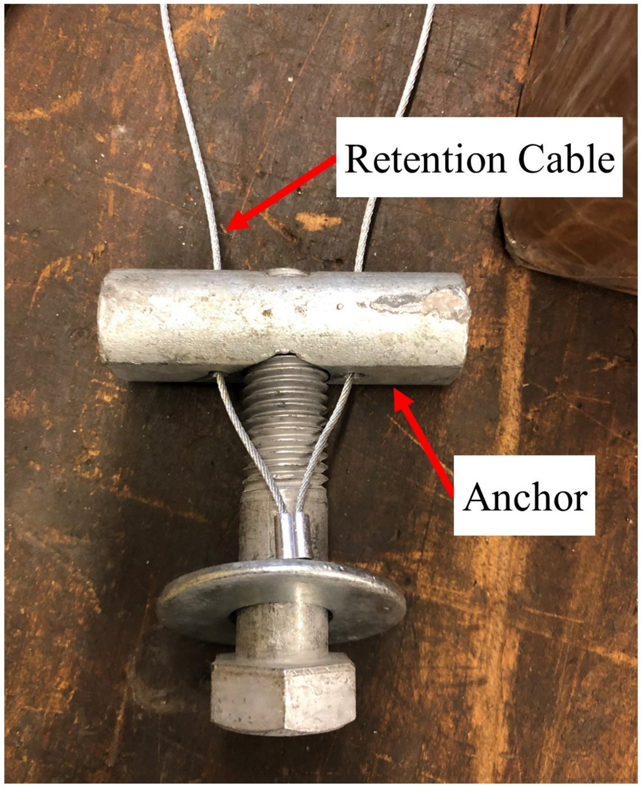
Bolt Testing

- Two blind bolt types; the **BlindBolt (24 mm)** and the **RS BlindNut (19.1 mm)**.
- For pin-bearing tests; **longitudinal (L)** and **transverse (T)** specimens were tested.
- Two spar cap thickness ranges were used;
    - **Thin** material *ranging from 25.4-35.6 mm* which is the material of the spar cap between 29-32 m from the root of GE37
    - **Thick** material *ranging from 40.6-55.9 mm* which is the material of the spar cap in the root-transition region of GE37.

Blind Bolts Types

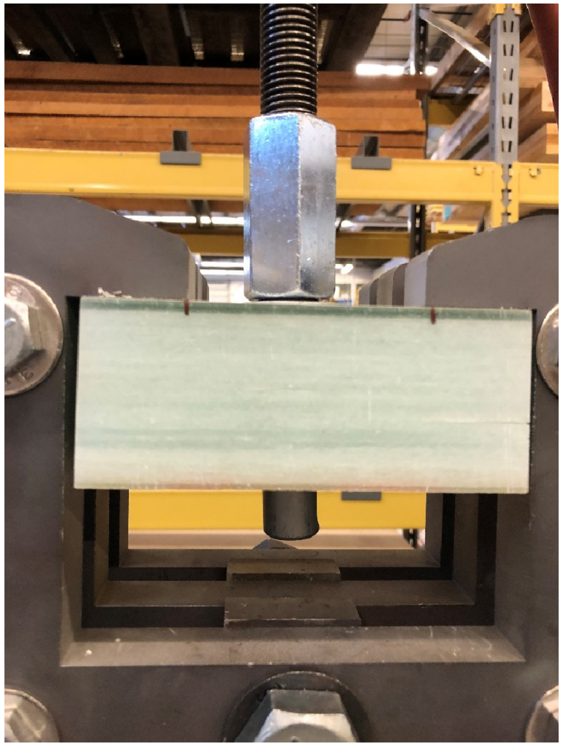


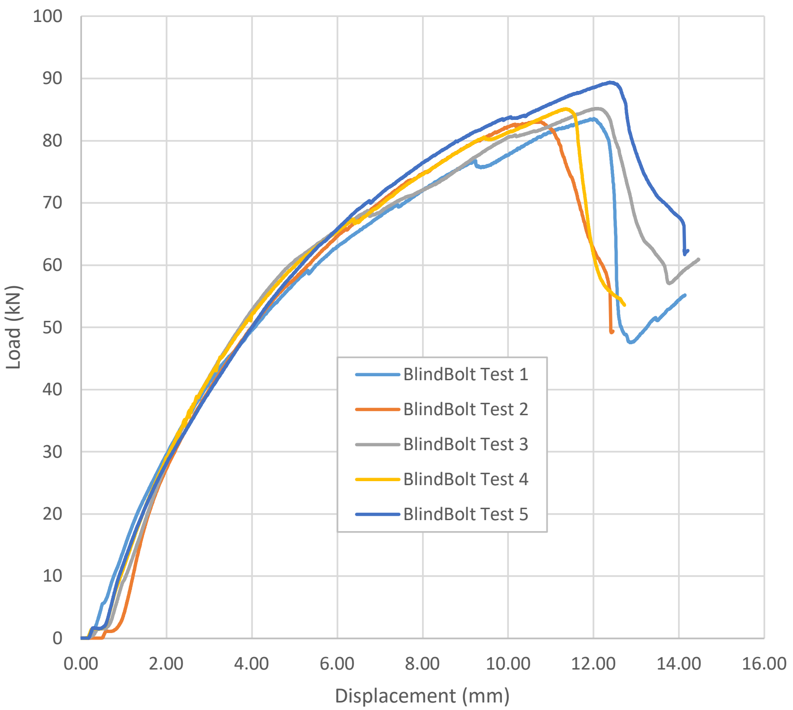
BlindBolt



RS BlindNut

Pull-Out Tests

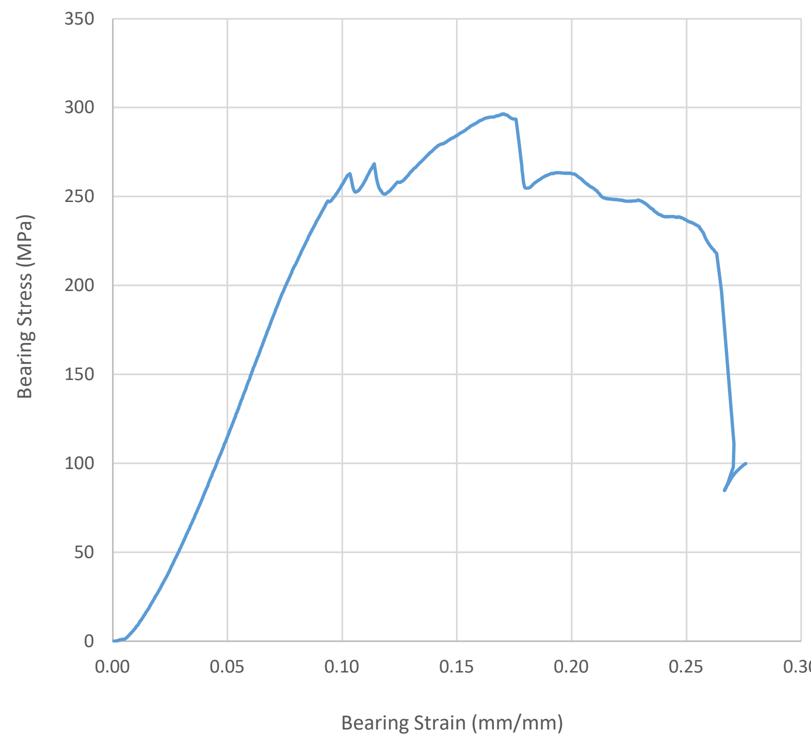




*25.4 mm = 1.0 in.

*Testing per ASTM D7332-Standard Test Method for Measuring the Fastener Pull-Through Resistance of a Fiber-Reinforced Polymer Matrix Composite

Pin-Bearing Tests



*25.4 mm = 1.0 in.

*Testing per ASTM D953-Standard Test Method for Pin-Bearing Strength of Plastics

As-Received Strength and Stiffness Compared to Data in the Literature for 100 kW Wind Blades

Property	Spar Cap of GE37 (V_f = 48-50%)	Sayer et al. (2013) (V_f = unknown) [a]	Ahmed et al. (2021) (V_f = 38-43%) [b]
Longitudinal Tensile Strength (MPa)	597	477	350
Longitudinal Compressive Strength (MPa)	504	447	225
Interlaminar Shear Strength (MPa)	55.0	32.3	-
Longitudinal Tensile Modulus (GPa)	36.8	26.7	15.6
Longitudinal Compressive Modulus (GPa)	42.7	26.2	-

[a] After Sayer, F., F. Bürkner, B. Buchholz, M. Strobel, A. M. van Wingerde, H-G. Busmann, and H. Seifert. "Influence of a wind turbine service life on the mechanical properties of the material and the blade." *Wind Energy* 16, no. 2 (2013): 163-174.

[b] After Ahmed, M. MZ, B. Alzahrani, N. Jouini, M. M. Hessien, and S. Ataya. "The Role of Orientation and Temperature on the Mechanical Properties of a 20 Years Old Wind Turbine Blade GFR Composite." *Polymers* 13, no. 7 (2021): 1144.

Conclusions

- This work presents results of tests of the GFRP material spar cap of a 1.5 MW decommissioned GE37 wind turbine blade for tensile, compressive, shear, bearing, and pull-through properties.

- Strength and stiffness properties of the GE37 after 11 years in a wind farm provide values which **outperform** the data published previously on 100 kW fatigued wind blades. More testing with age and capacity is still needed to judge strength and stiffness retention levels.

- Future work will focus on:
  - EXPERIMENTAL TESTING of other parts (shell, web) and other critical material properties (tension, shear, bending, …).
  - LARGE-SCALE PHYSICAL tests for potential reuse application(s).

Future Work

Prototype at DFL

Planned Four-Pole Configuration in a wind farm in Kansas