Industrial Advisory Board (IAB) Meeting

May 26, 2021

Timber Pile Splicing with FRP Composite Wraps

Hota GangaRao, PI

Need and Industrial Relevance

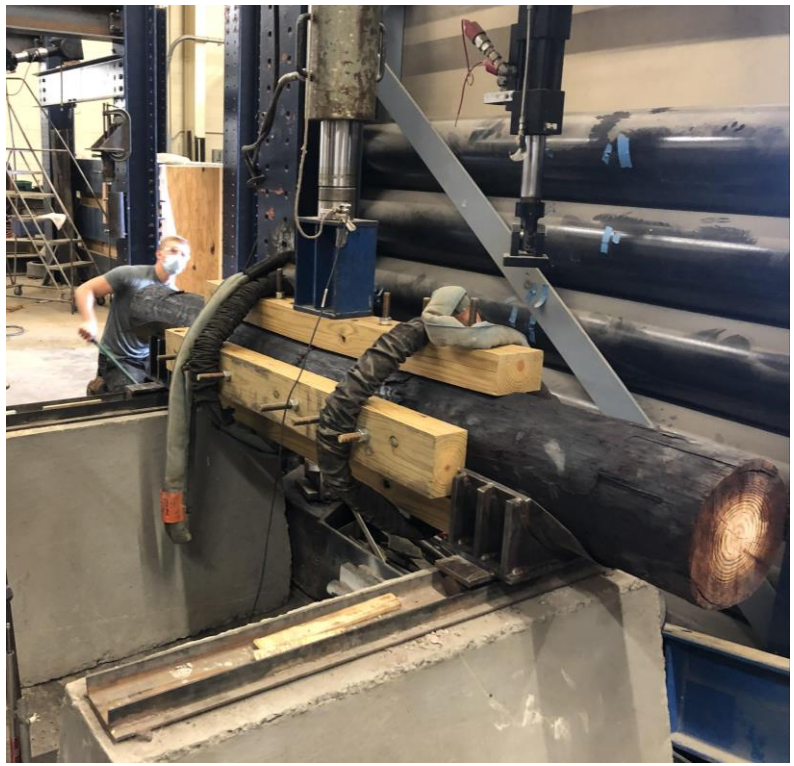
- Sponsored by Louisiana Transportation Research Center (LTRC)
- Develop guidelines and procedures for installation and design of FRP composite wraps for timber piles

State of the Art both in Industry and Academia

- Behavior of FRP wrapped piles through laboratory and field evaluations
- Limited focus on development of guidelines for installation and design

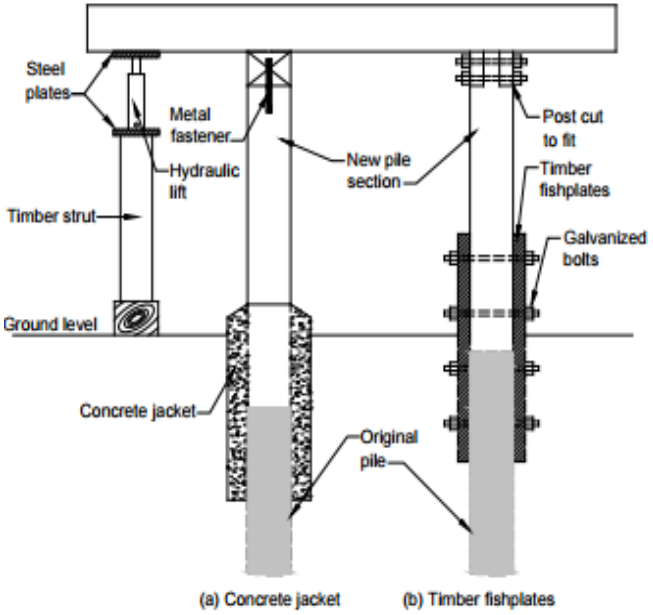
Project Goals

- Evaluate critical failure modes of timber piles repaired with FRP wrap splicing
- Evaluate strengths of various splicing methods
- Develop design and installation guidelines based on experimental results and field experience



Objectives

- COMPLETE: Evaluate the strength of legacy splices
- COMPLETE: Develop a new splice using FRP wraps and evaluate strength
- ONGOING: Develop design equations to determine capacity of FRP splicing
- PLANNED: Develop simplified design and installation guidelines based on experimental results



Approach (Research Methods)

Legacy Splice

- Three types of traditional splicing methods, wood, steel, and c-channel.
- Piles are cut in half and reassembled using plates and bolts.
- Each Pile uses four plates of the selected material and secured with a total of twelve bolts.

Completed Steel Plate Splice

FRP Splice

- Unidirectional Glass/Epoxy composite used (provided by SIKA).
- Piles are cut in half and reassembled using FRP wrapping with the hand-layup application method.
- Three layers of fabric used for each pile

Completed FRP Splice

Approach (Research Methods) Cont'd

Shear Testing

- C-Channel splicing was strongest, wood plate splicing was weakest in shear stress capacity

Axial Testing

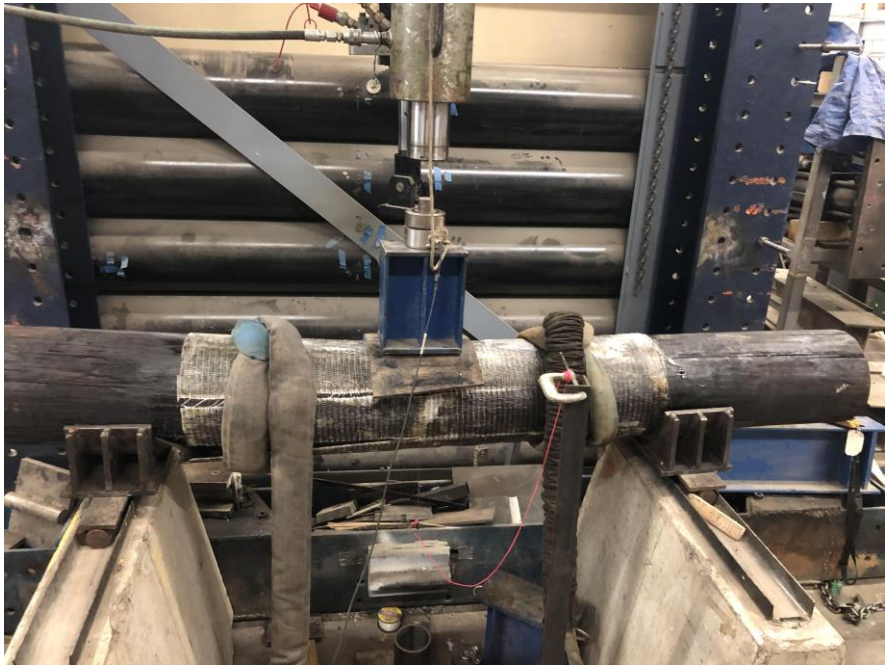
- FRP wrap splicing was strongest, flat steel plate splicing was weakest in axial stress capacity

4-Point Bending Testing

- Wooden plate splicing was strongest, FRP wrap splicing was weakest in bending stress capacity

Summary

- C-Channel strongest overall of traditional methods
- FRP splice can be improved by adding additional reinforcement in the hoop direction



Shear Test on FRP Spliced Pile (typical failure mode)

Approach (Research Methods) Cont'd

Improved FRP Splice Design

- To improve shear and bending capacity three additional layers of fabric were added to reinforce the hoop direction for a total of six layers
- Shear stress capacity improved by roughly 50% (strongest of all splicing mechanisms in shear)
- Bending Stress capacity improved by roughly 35%

Improved FRP Splice Bending Test

Outcome/Deliverables

- Training course on utilization of guidelines with field training
- Capacity of splices under axial, flexural, and shear loads
- Development of new splice using FRP

Impact

Simplified guidelines and established material properties will allow designers and field teams a much needed level of comfort when rehabilitating timber piles with FRP composite wraps

Testing of splices will provide solid data on their performance under axial, flexural, and shear loads

Project Duration & Proposed Budget

Sponsor	Duration	Budget		Total, $	Progress Status
		Spent, $	Remaining, $		
LTRC	**2015.11-2020.12**	**233,069**	**0**	**233,069**	**Concluded**

Project Name: Timber Pile Rehab with FRP Composite Wraps
Project Number: WVU 5

Center for Integration of Composites into Infrastructure

Industrial Advisory Board (IAB) Meeting

May 26, 2021

Development of Sheet Pile Wall Test Procedure

Josh Wilt and Hota GangaRao, PI

Need and Industrial Relevance

- Sponsored by Creative Pultrusions and US Army Corp of Engineers (potential)
- No standardized test method exists to determine the moment capacity of FRP sheet piles

State of the Art both in Industry and Academia

- For the same section, different FRP manufacturers report vastly different moment capacities
  - Non-homogenous nature of FRP makes scale-up of coupon tests questionable
- WVU tested sheet pile in the field

Project Goals

- Develop a standardized test method to arrive at the moment capacity of FRP sheet piles
  - Test should be easily replicated at independent labs to arrive at the same data
- Determine the moment capacity of several different shapes from various manufacturers
- Incorporate the test method and data into design guides

Approach (Research Methods)

- 4 sections of 8 inch deep sheet pile were joined together to form a 6 foot wide wall
- Testing mold constructed from concrete used to restrain the pile at the bottom
- Elastomeric padding applied to the face of concrete to simulate properties of soil

Approach (Research Methods)

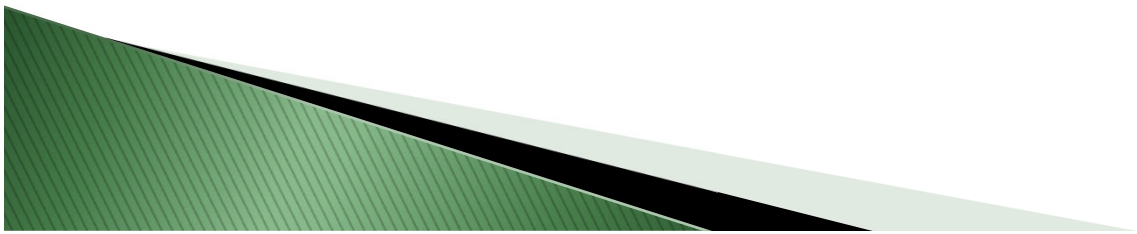
- The concrete mold used to restrain the pile faced issues resulting from a large amount of bending moment generated by applied load
- Metal plates fabricated to clamp the mold with the pile inserted together
- Steel channel placed on top of concrete to prevent uplift

Approach (Research Methods)

- Replication of tests needed to verify data
- Analysis of strain data is showing relatively high modulus of material when compared with theoretical results, concrete mold may still be affecting the modulus
- Further optimization needed

Outcome/Deliverables

- Standardized test method
- Moment capacities of various sheet piles



Impact

Standardized test method will allow for end users to compare different products with a high confidence in the reported values

Design guides can be revised to better incorporate FRP sheet pile, opening up markets and providing durability to end users.

Project Duration & Proposed Budget

Sponsor	Duration	Budget		Total, $	Progress Status
		Spent, $	Remaining, $		
Creative Pultrusions	**2019.8-2021.6**	**74,434**	**45,566**	**120,000**	**Ongoing**

Project Name: Development of Sheet Pile Test Procedure

Project Number: WVU-6

L.I.F.E.

Center for Integration of Composites into Infrastructure

Industrial Advisory Board (IAB) Meeting

May 26, 2021

Rheology of Polymer Melts with and without Chopped Carbon Fiber

Ray Liang, Rakesh K. Gupta and Hota GangaRao

(Content is under Industry Member's review)

Center for Integration of Composites into Infrastructure

Industrial Advisory Board (IAB) Meeting

May 26, 2021

Thermomechanical Response of FRP Composite Jacketing for Tank Cars under Impact and Fire

Andrew Kenney

Hota GangaRao, PI

Need and Industrial Relevance

Sponsored by: US DOT PHMSA (Pipeline and Hazardous Materials Safety Administration)

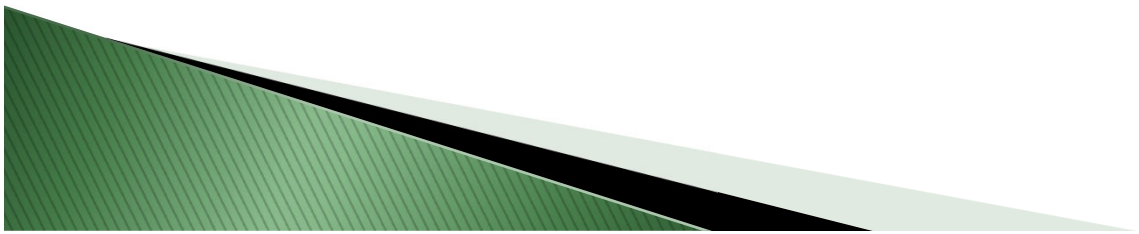
- Tens of thousands of rail tank cars (e.g., DOT-111, CPC-1232, DOT-117R, and DOT-117) fail during derailments causing env hazardous while hauling flammable hazardous materials (HM)
- In May 2015, to enhance the safety of transportation of flammable liquids by train, US DOT released final rules for both the new & old cars.
- FRP composites offer a better retrofit alternative than using thicker metal shells and other protection system which add to weight and cost.

State of the Art both in Industry and Academia

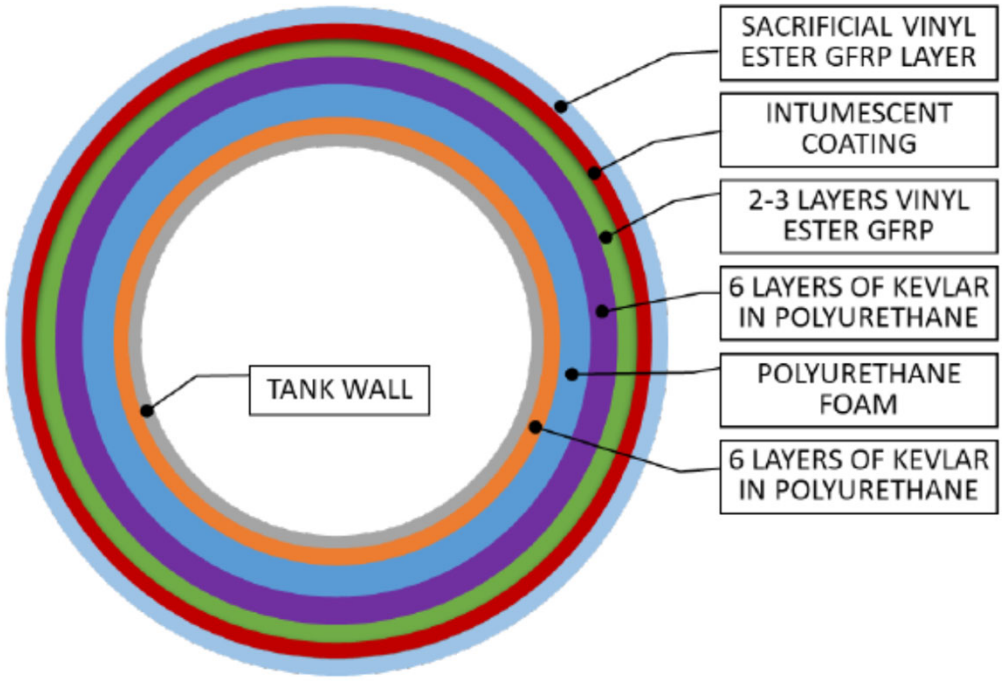
- Currently tank cars made of steel, retrofitting with thicker shell adds to the weight resulting in reduced shipping capacity and increased cost of shipping.
- Multifunctional FRP composite jacket will provide better performance in terms of high strength and stiffness, better puncture resistance, and excellent energy absorption under the impact, in addition to providing longer survival time under fire.
- WVU has significant experience in manufacturing and testing such multifunctional FRP composite structures with desirable mechanical and fire resistance properties.

Project Goals

- Manufacturing of Jacket Skins thru resin infusion
- Performance evaluation of Jackets Skins
- Finite Element Analysis of Jacket and substrate
- Curvilinear Jacket manufacturing & testing
- Finite Element Modeling of Puncture Test
- Testing after enhancing fire retardant Properties
- Cost Analysis



Approach (Research Methods)



Schematic of Configuration of Composite Layers for the Jacketed Tank

Multifunctional FRP Composite Protective Jacket

- ❑ Consisting of layers of:
  - Glass polymer composites
  - Fire resistance foam
  - Kevlar reinforced polyurethane
  - Intumescent coating
  - Sacrificial VE GFRP layer.

- ❑ To enhance
  - Puncture resistance
  - Fire resistance
  - Impact resistance

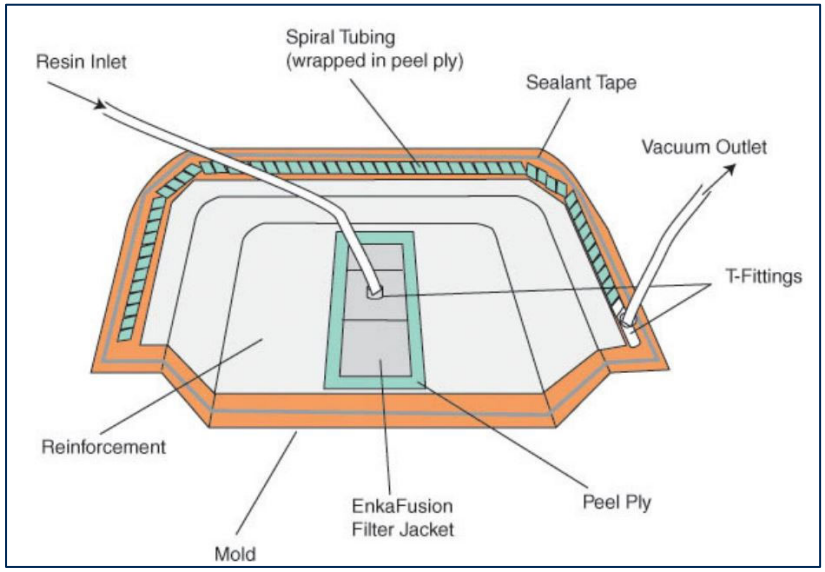
Infusion Process Developed for Multifunctional Jackets

Project Goals

- Create a multifunctional composite jacket for railroad tank cars
- Designed to allow for greater puncture and tear resistance during a derailment event
  - Made from a combination FRP and fire-resistant polyurethane foam

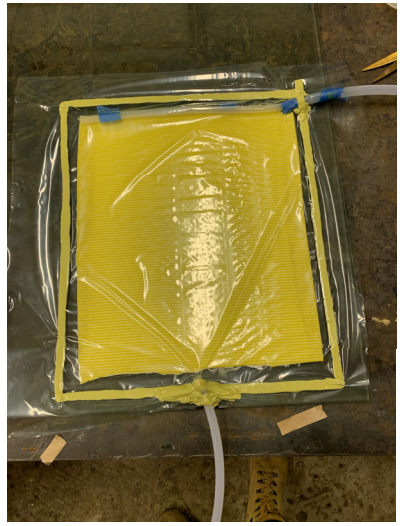
Creation of FRP Jackets

- To create the required high-strength FRP plate, vacuum infusion is used
- An infusion system allow for a more consistent sample for testing
  - Also provides smaller void ratio



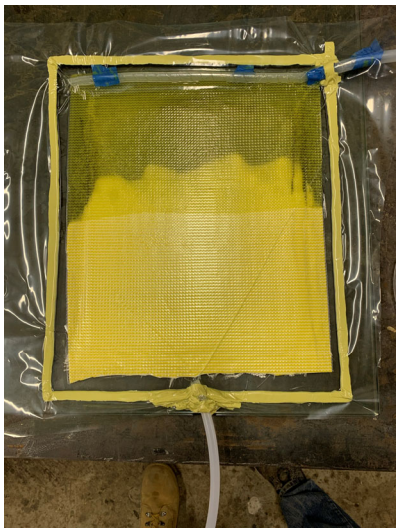
Research Methods

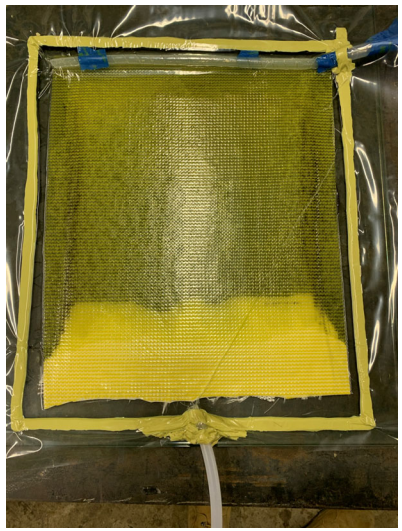
- The sheets of fabric are laid out on a glass plate
- An airtight seal is created around the sample
- Inlet and outlet resin tubes are added



Research Methods (cont.)

- As the vacuum is created, the resin is infused into the fiber layers
- The amount of time the infusion takes depends on the amount of layers



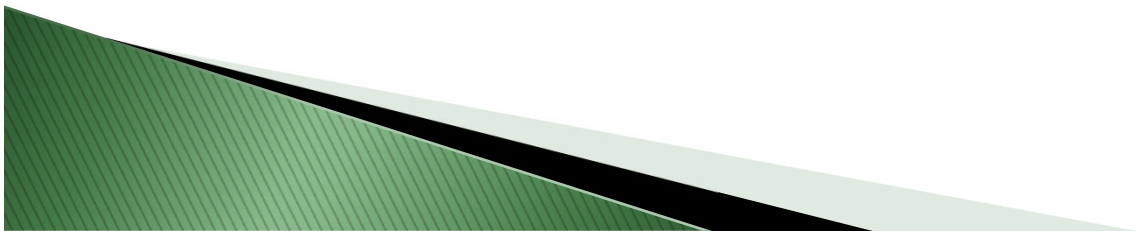


Research Methods (cont.)

- After the resin fully is fully infused, the plate is left to cure overnight
- After curing, the sample can then be evaluated for strength, stiffness, etc.

Future Work

- Further refine methods infusion methods
  - Increase infusion speed, reduce set up time, experiment with different resin mix ratios, etc.
- Experiment with different FRP configurations
  - Fiber orientation (0, 45, 90 or other angles)
  - Fabrics used (GFRP, Kevlar)
  - Number of sheets per sample



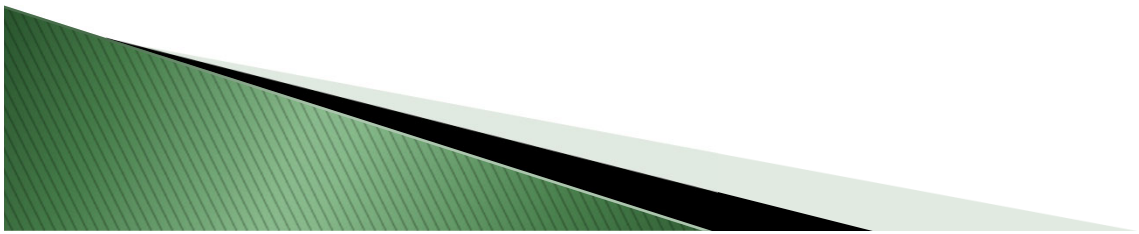
Impact

Successful completion of this research will provide a viable option of retrofitting old tank cars to bring them up to current safety standards.

- Minimal weight increase
- Lower retrofitting cost
- Enhanced mechanical performance and fire resistance in case of accident.

Project Duration & Proposed Budget

Sponsor	Duration	Budget		Total, $	Progress Status
		Spent, $	Remaining, $		
PHMSA	**2020.09-2023.09**	**65k**	**1,850,377.00**	**1,915,377.00**	**Ongoing**



Project Name: Thermomechanical Response of FRP Composite Jacketing for Tank Cars under Impact and Fire

Project Number: WVU 8

L.I.F.E

https://www.asme.org/topics-resources/content/preventing-railway-tank-disasters-with-composite-materials