Reinforcement of Cellulose Nonwovens with Thermoplastic Lattices

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IACMI Member Meeting 2025

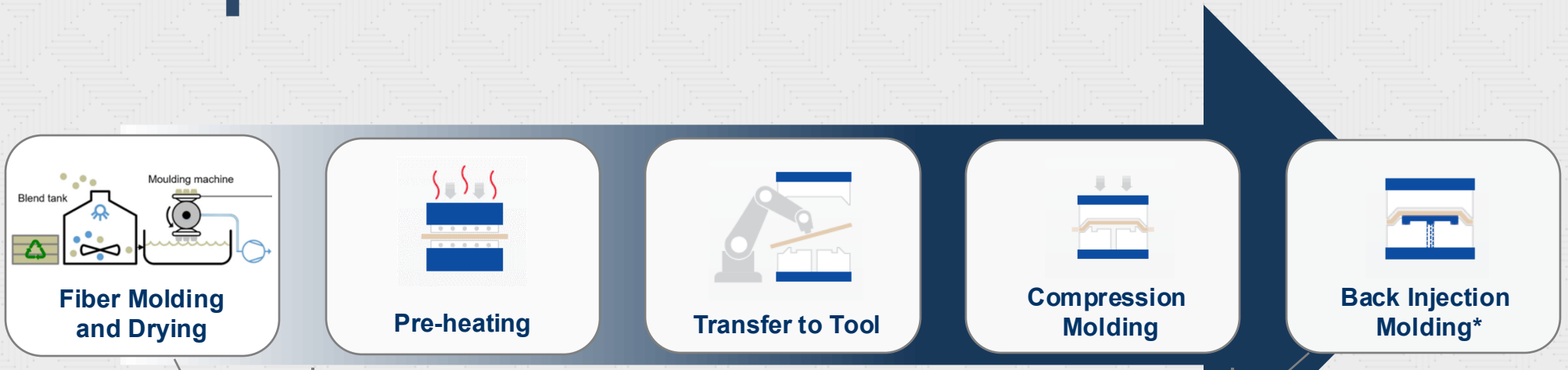
Dayton, OH

June 25, 2025

Outline

- Background
- Project Objectives
- Panel Forming and Characterization
- Lab Scale Forming Trials
- Forming and Validation of Full-Scale Demonstrator
- Summary of Results

Paper Composites – Benefits and Limitations

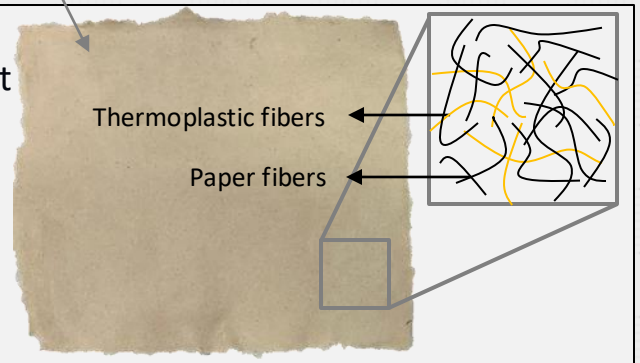


Benefits

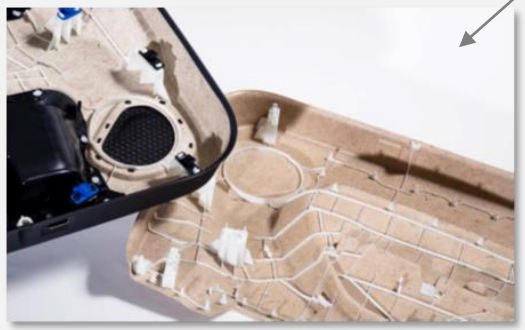
- Established molding equipment
- Robust supply chains

Limitations

- Short fiber lengths
- Low melt shear strength
- Low gsm / sheet



Hybrid paper composite sheets



Back injection molded interior panels

Opportunities

- Parts can be back injection molded
- Natural fiber composites are fully recyclable
- Can combine recycled pulp and recycled plastic
- Lattices can improve molding of complex geometries from flat sheets

Paper composites are a cost-efficient alternative to nonwoven NFPP

Why WEAV3D Composite Lattice?

TUNEABLE

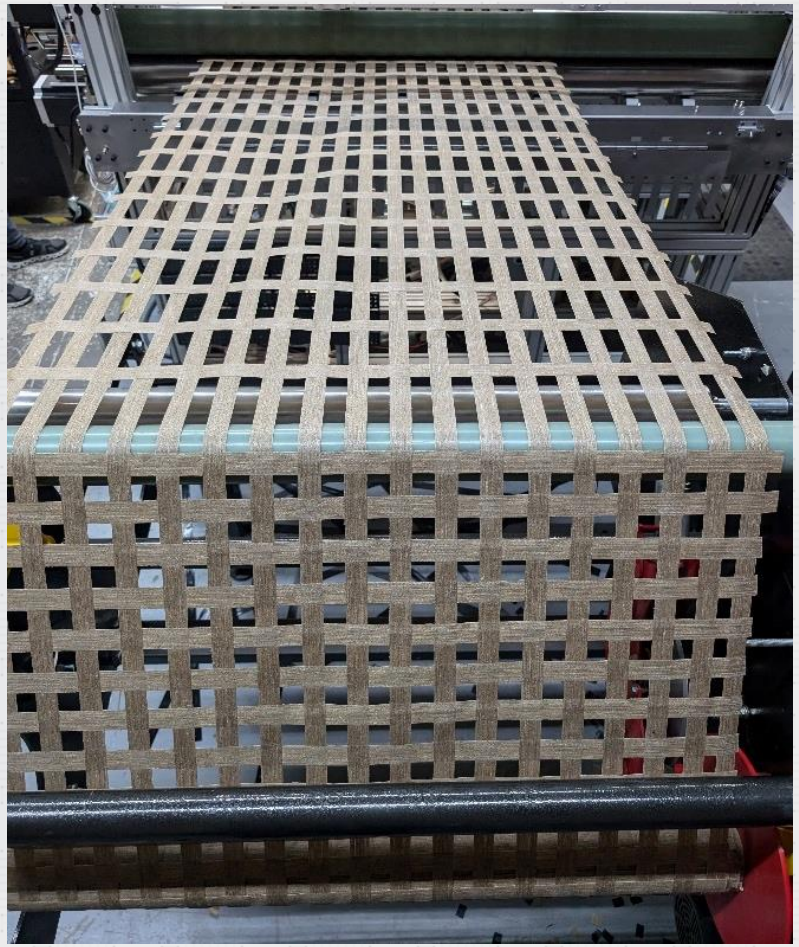
- Locally optimized lattice density
- UD tapes control strain during forming and increase melt strength

COST-EFFECTIVE

- Automated continuous process
- Co-formable with paper composite in single step

COMPATIBLE

- Sheet or roll format
- NFPP tape option available for monomaterial solution



Strategic use of UD tapes in lattice provides a cost-effective and adaptable solution

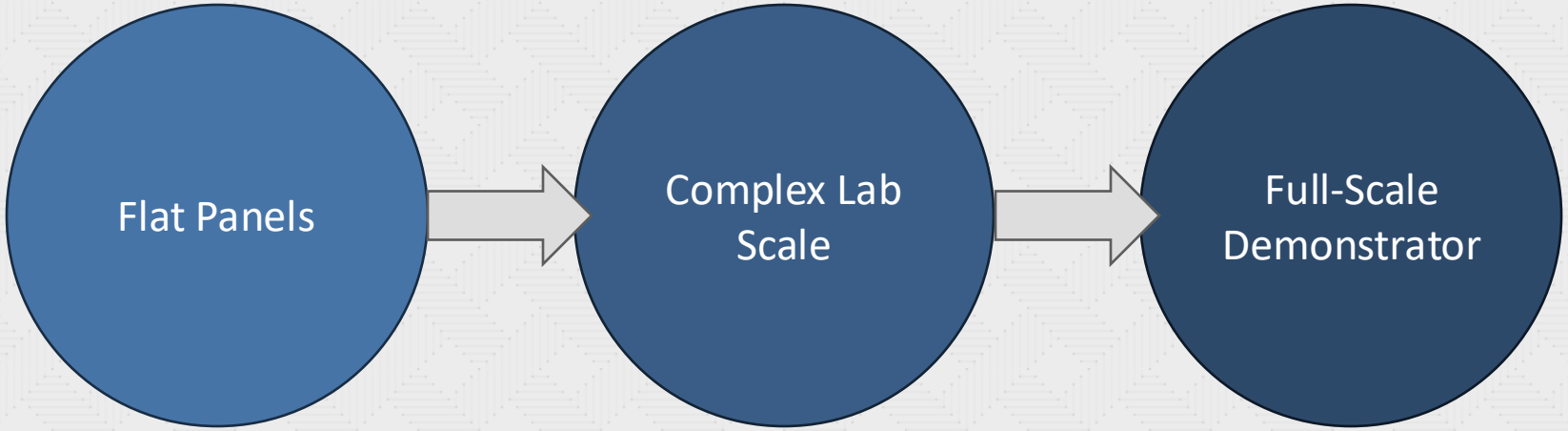
Project Objectives

Full Scale Part Forming Goals

1. Eliminate thru-thickness tearing of paper composite in deep draw/complex parts
2. Identify tool and process changes needed to convert from nonwoven NFPP to paper composite

Experimental Goals

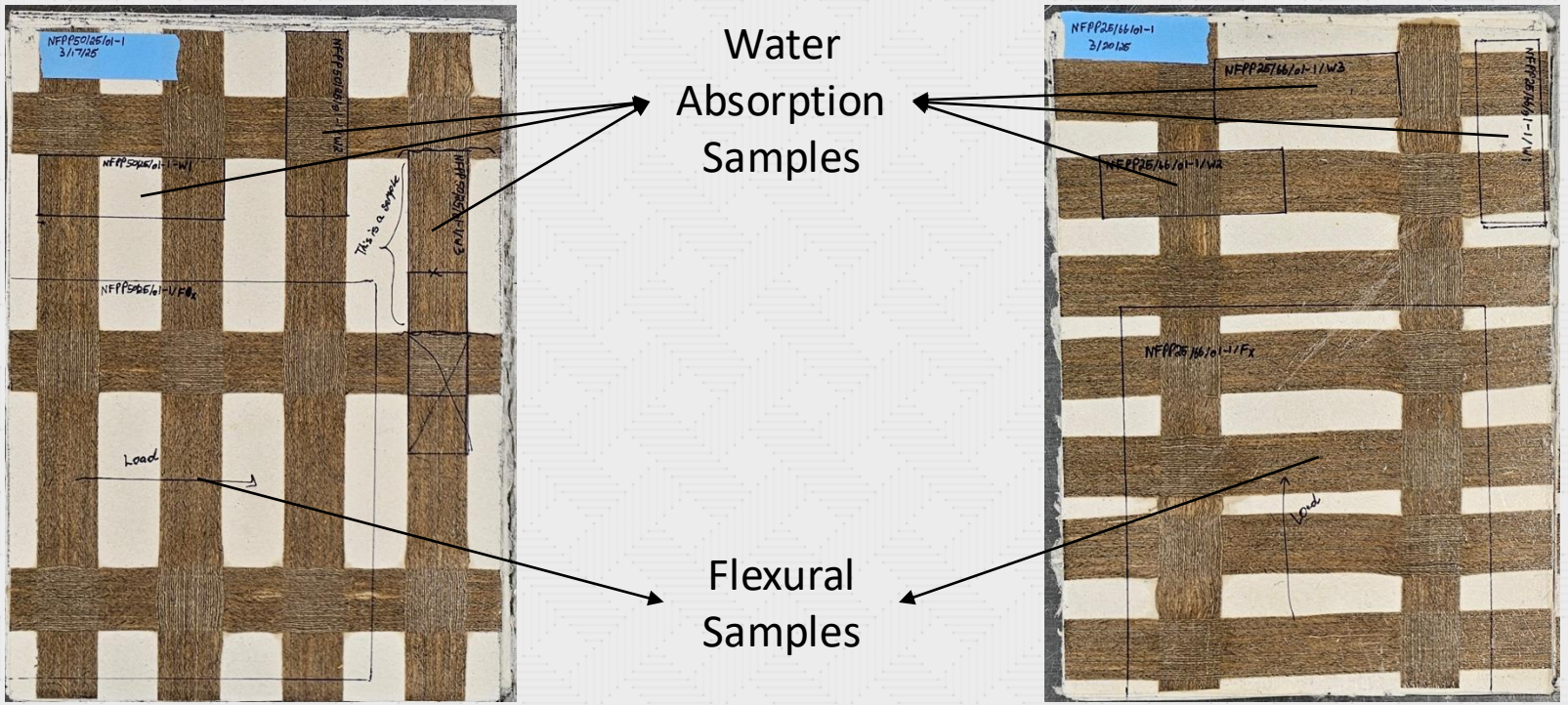
1. Characterize effect of lattice on flexural properties vs. baseline
2. Characterize water uptake of lattice reinforced panels vs. baseline



Flat Panel Forming and Characterization

Experimental Approach

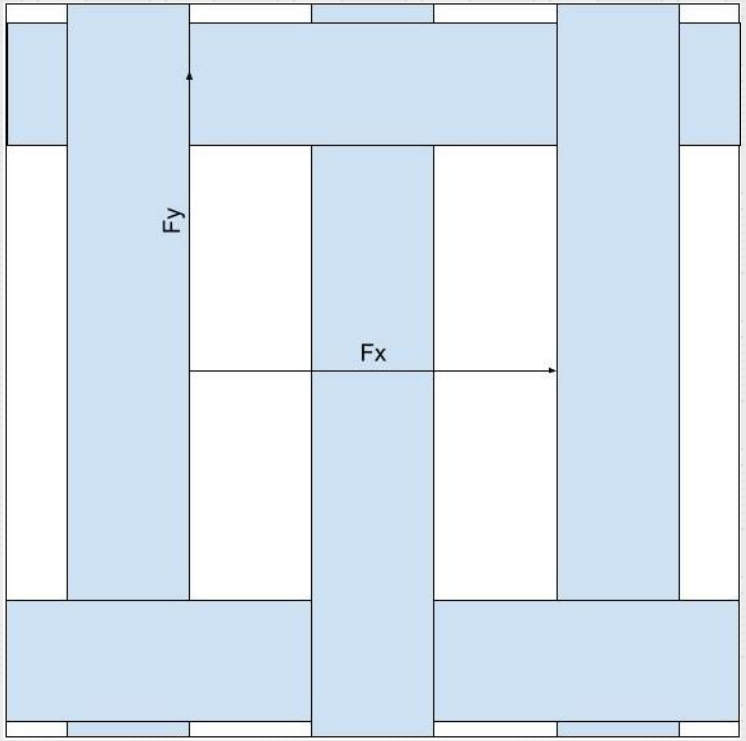
- 10 203.2 x 279.4 mm sheets of 60:40 (paper:PP) and 1 tape were compression molded at 190 °C for 5 minutes under 1.38 MPa then cooled under pressure
- 1 flexural sample was cut from each panel with dimensions 152.4 x 165.1 mm
- 3 water absorption samples were cut from each panel with dimensions 25.4 x 76.2 mm



Nomenclature

Flexural Samples

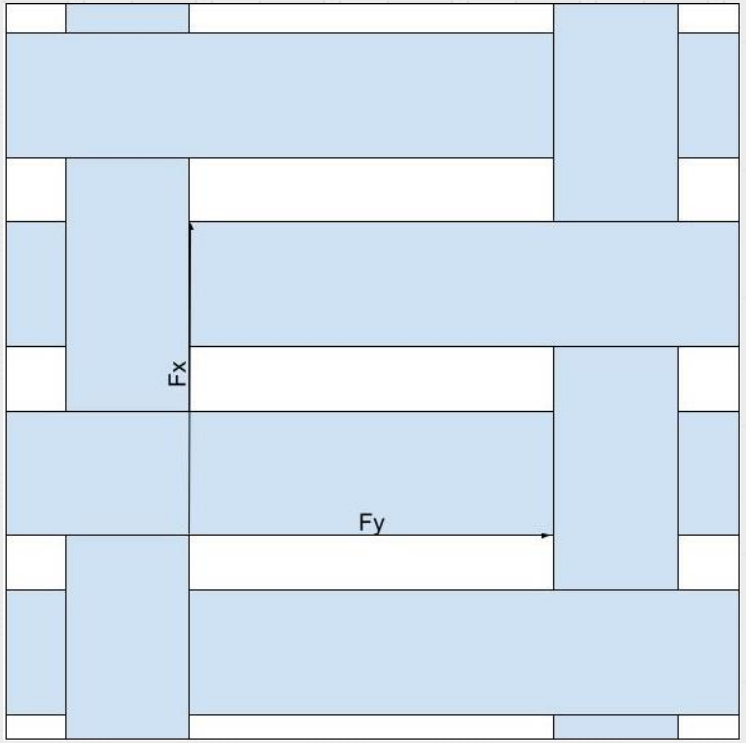
50/25 (Warp/Weft)



- Fx and Fy refers to the direction that the load is applied.

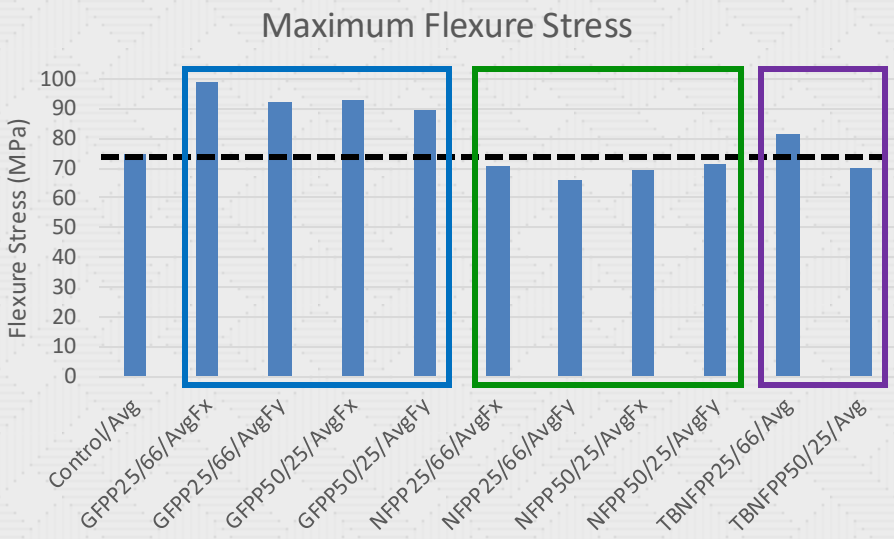
- W1: white area refers to no tape
- W2: center represents area where tapes overlap
- W3: only tape

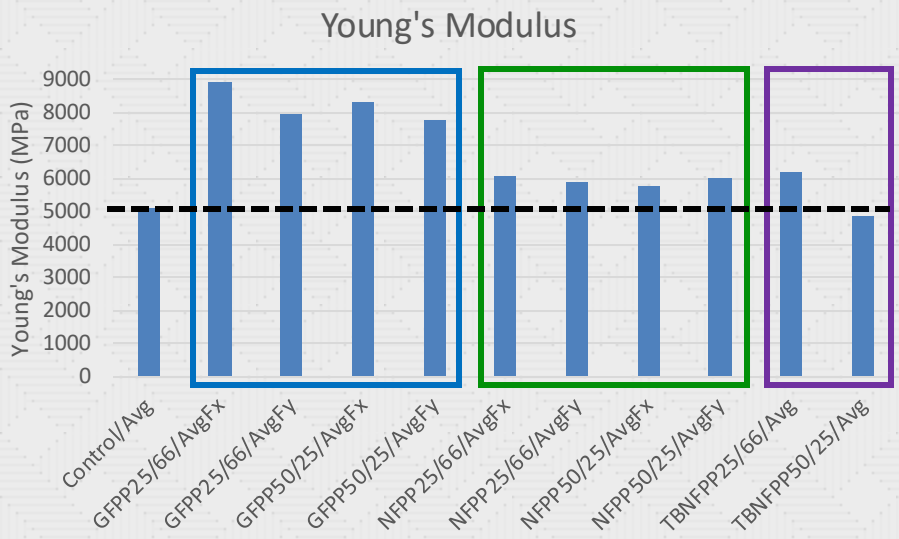
25/66 (Warp/Weft)

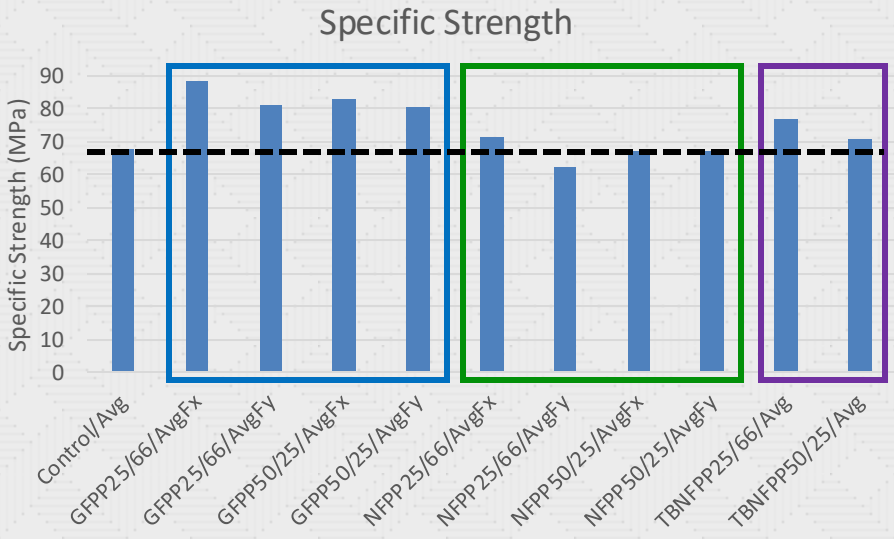


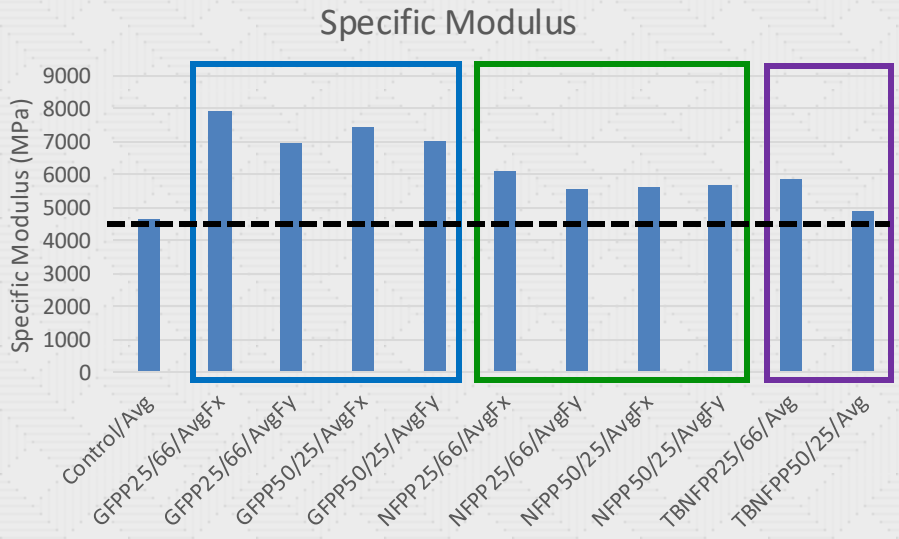
Water Absorption Samples

Natural and Glass Fiber Mechanical Data









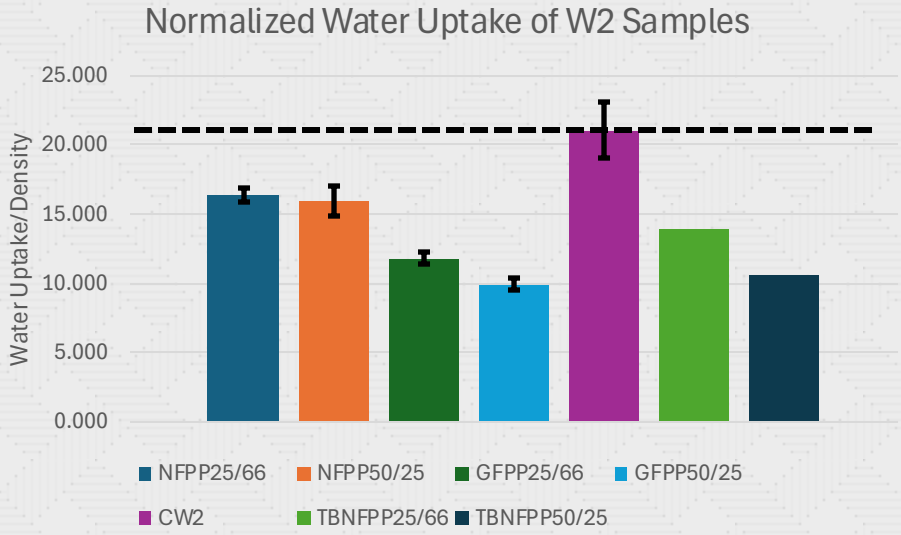
Key:

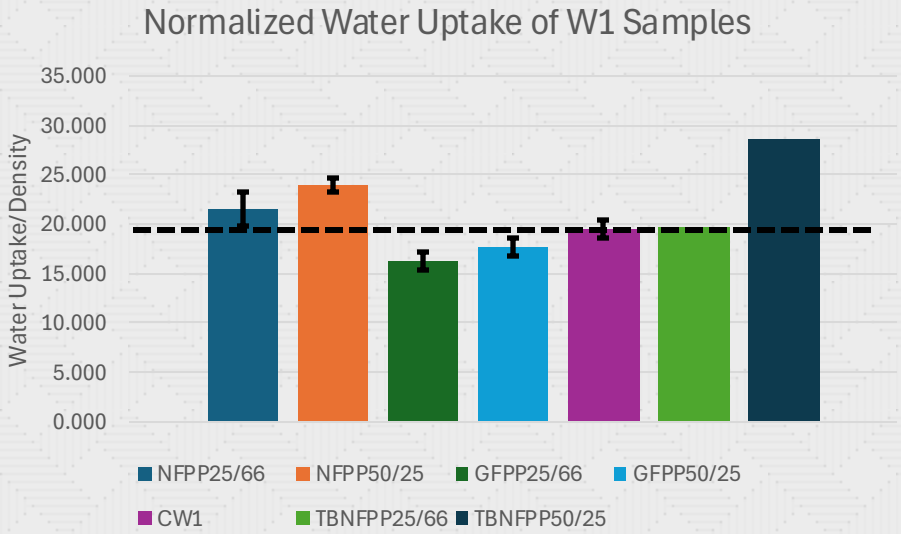
- GF – Glass Fiber (Blue)
- NF – Natural Fiber (Green)
- TB – Top & Bottom Reinforced (Purple)
- 50/25 & 25/66 – Warp/Weft
- Fx & Fy – load direction

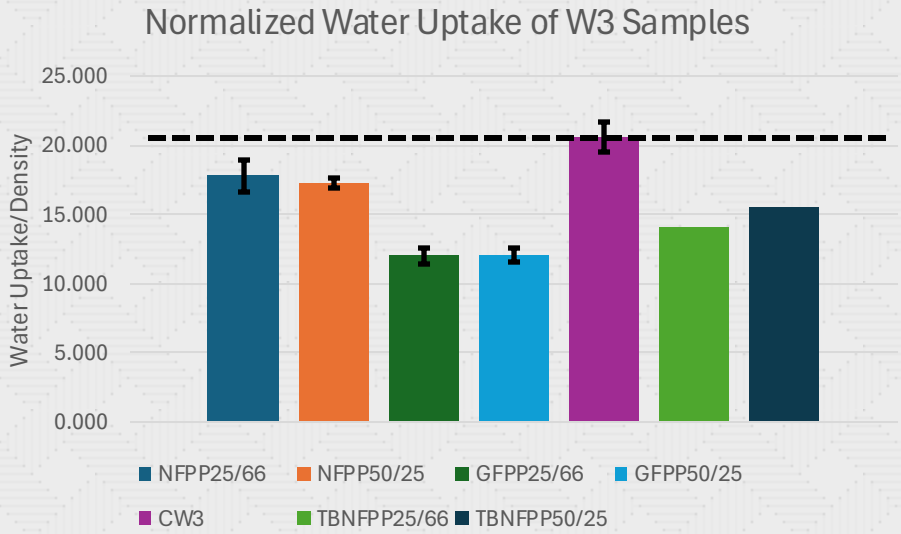
Average Water Absorption Data

Key:

- GF – Glass Fiber
- NF – Natural Fiber
- TB – Top & Bottom Reinforced
- 50/25 & 25/66 – Warp/Weft
- C – Control
- W# - Water absorption sample #





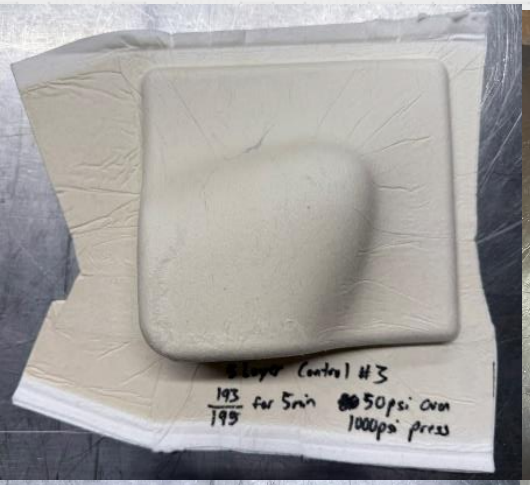


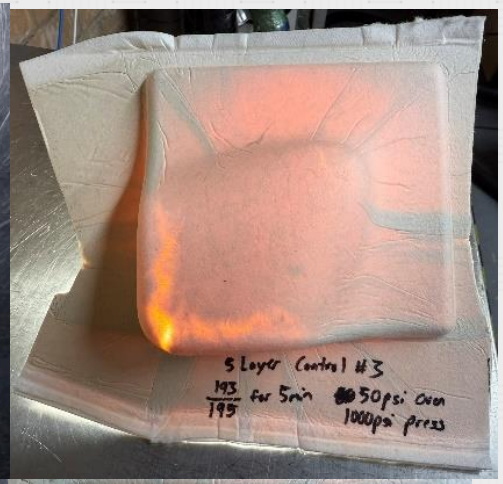
Lab Scale Forming

Experimental Approach

1. WEAV3D has a lab-scale thermocompression work cell, based around 25-ton carver press and contact oven with manual shuttle
2. Complex geometry tool (~6”x6”x2” cavity) with:
    1. 2” vertical draw corner
    2. Double curvature/bullet nose
    3. ½” step down on 3-sides
3. Control panels (no lattice) molded to establish tearing behavior and layer count limits of tool
4. GFPP and NFFP lattice reinforced panels molded with varying lattice spacing and lattice positioning to understand locality effects of tape position

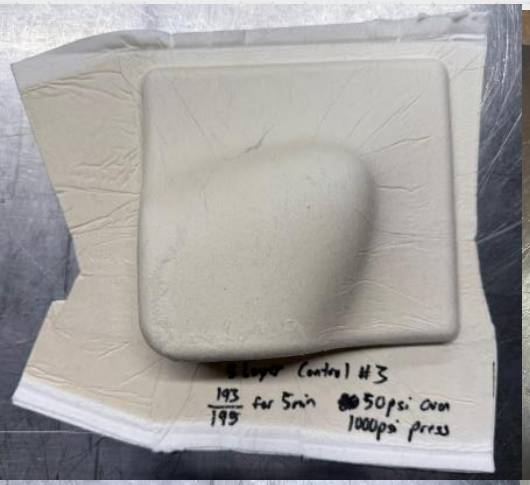
Complex Forming – GFPP 50-50

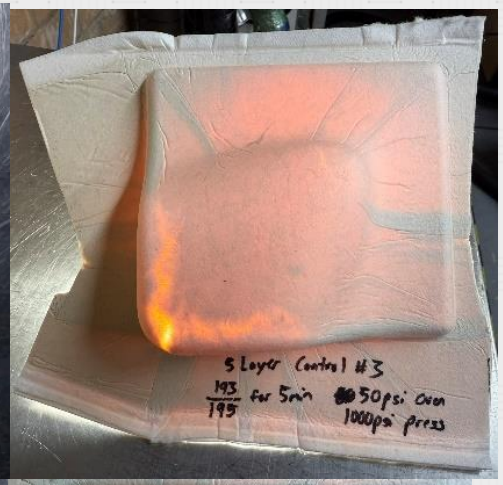




Control 5-Layer

Complex Forming – NFPP 50-50

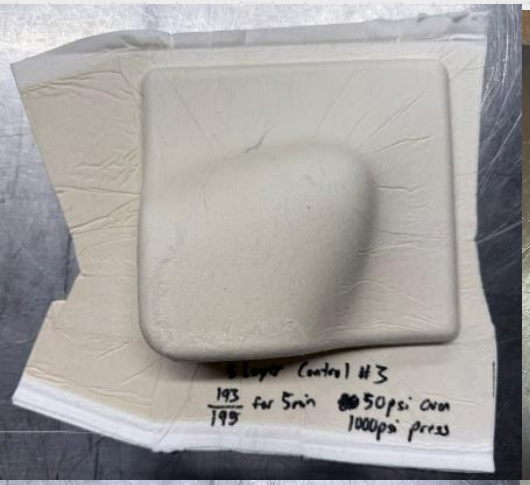


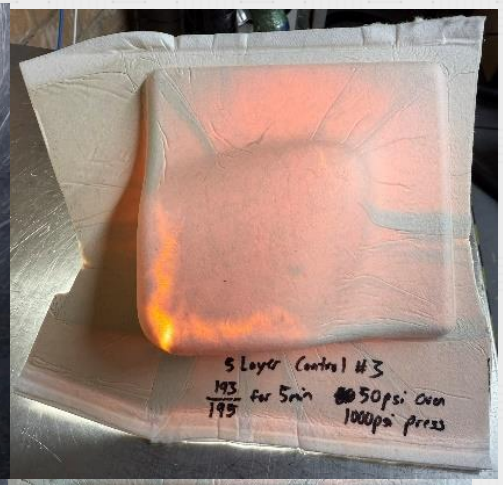


Control 5-Layer

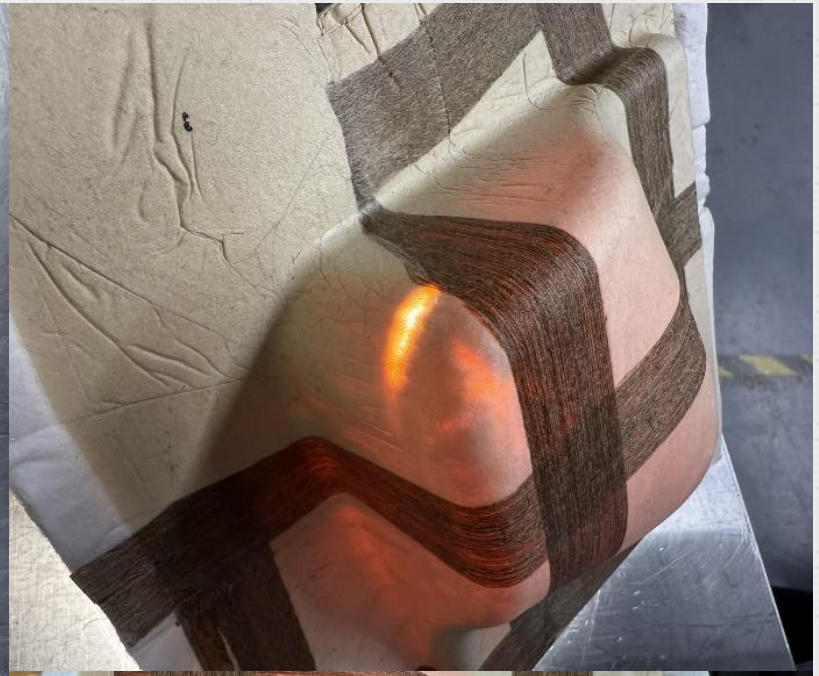
5-Layer

Complex Forming – NFPP 25-25

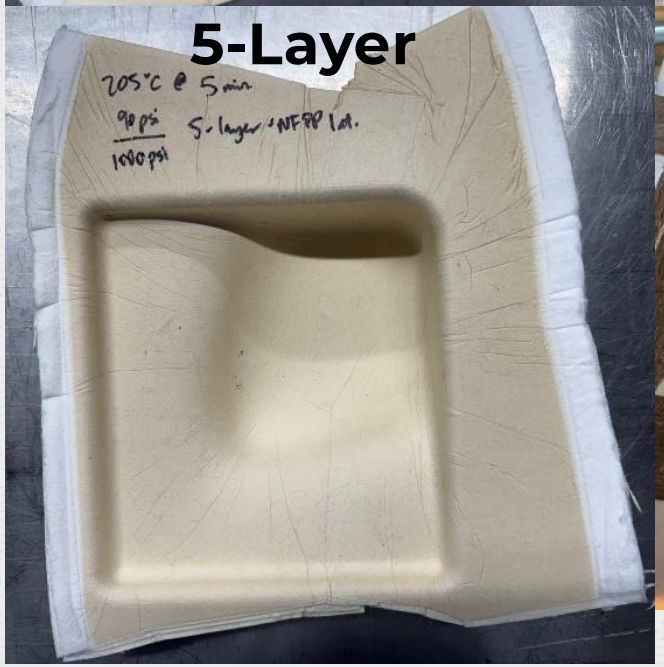


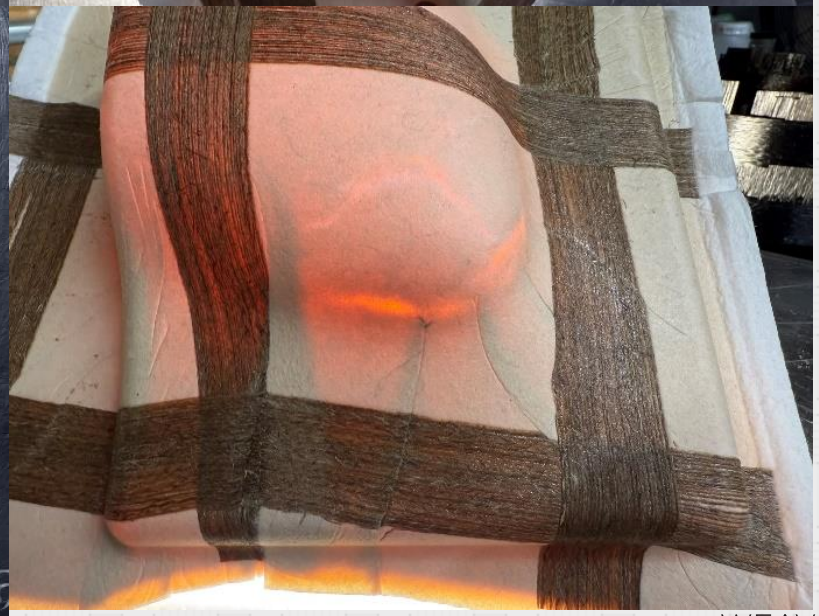


Control 5-Layer



5-Layer





Full-Scale Demonstrator

Forming Process

1. Molding trials conducted at Tier 1 facility in Spain
2. 16 pieces were produced:
    1. 3 control parts
    2. 10 NFPP lattice-reinforced parts
    3. 3 GFPP lattice-reinforced parts

THERMOPLASTIC PREPREG TAPE(S)

(Commercially Sourced)

WEAVE

Output lattice in sheet or roll format

TRIM

Tack and Co-Mold

THERMOCOMPRESSION MOLDING

In-Mold Shear Trim

LATTICE REINFORCED PAPER COMPOSITE PART

Comparison Against Control

Summary of Results

Full Scale Part Forming Goals

1. Lattice reinforcements successfully eliminated thru-tearing in paper composite
2. Lack of compressibility of paper composite requires tooling changes to accommodate wrinkle thickness along tool edge

Experimental Goals

1. NFPP lattices provide marginal improvements to specific strength and specific modulus, while GFPP lattices significantly improve both
2. Water uptake of lattice-reinforced panels is equivalent or better than control

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Detailed results will be presented at SPE ACCE and SPE TPO later this year