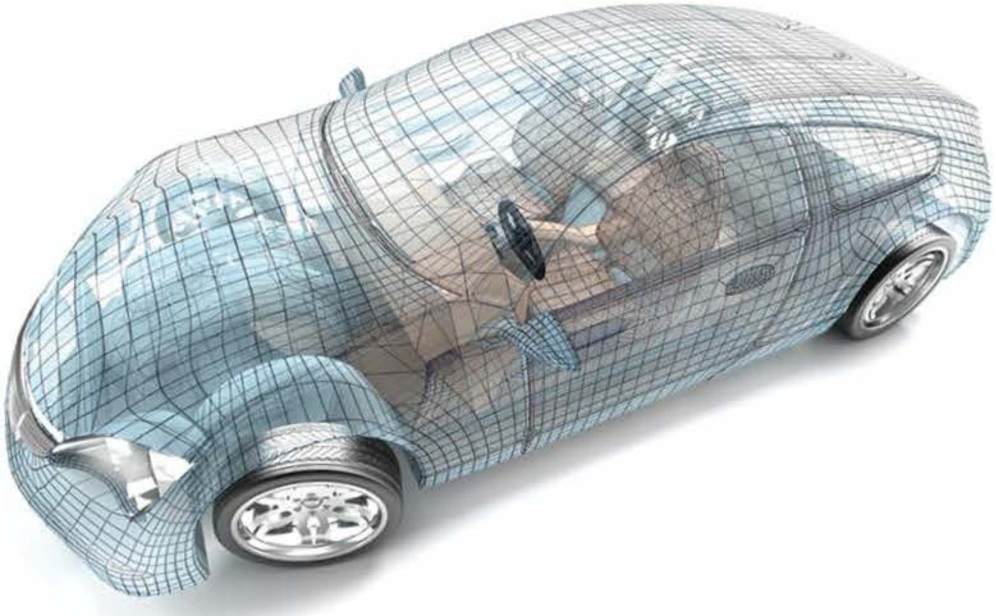
TCC 2020

THERMOPLASTIC
COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



Novel Approach to Thermoplastic Composite Production Enables Localized Design Optimization

Presented By: Chris Oberste, Ph.D.
Founder and CEO
WEAV3D

ABOUT WEAV3D

WEAV3D Inc. develops revolutionary fiber-reinforced plastic manufacturing processes and processing equipment.

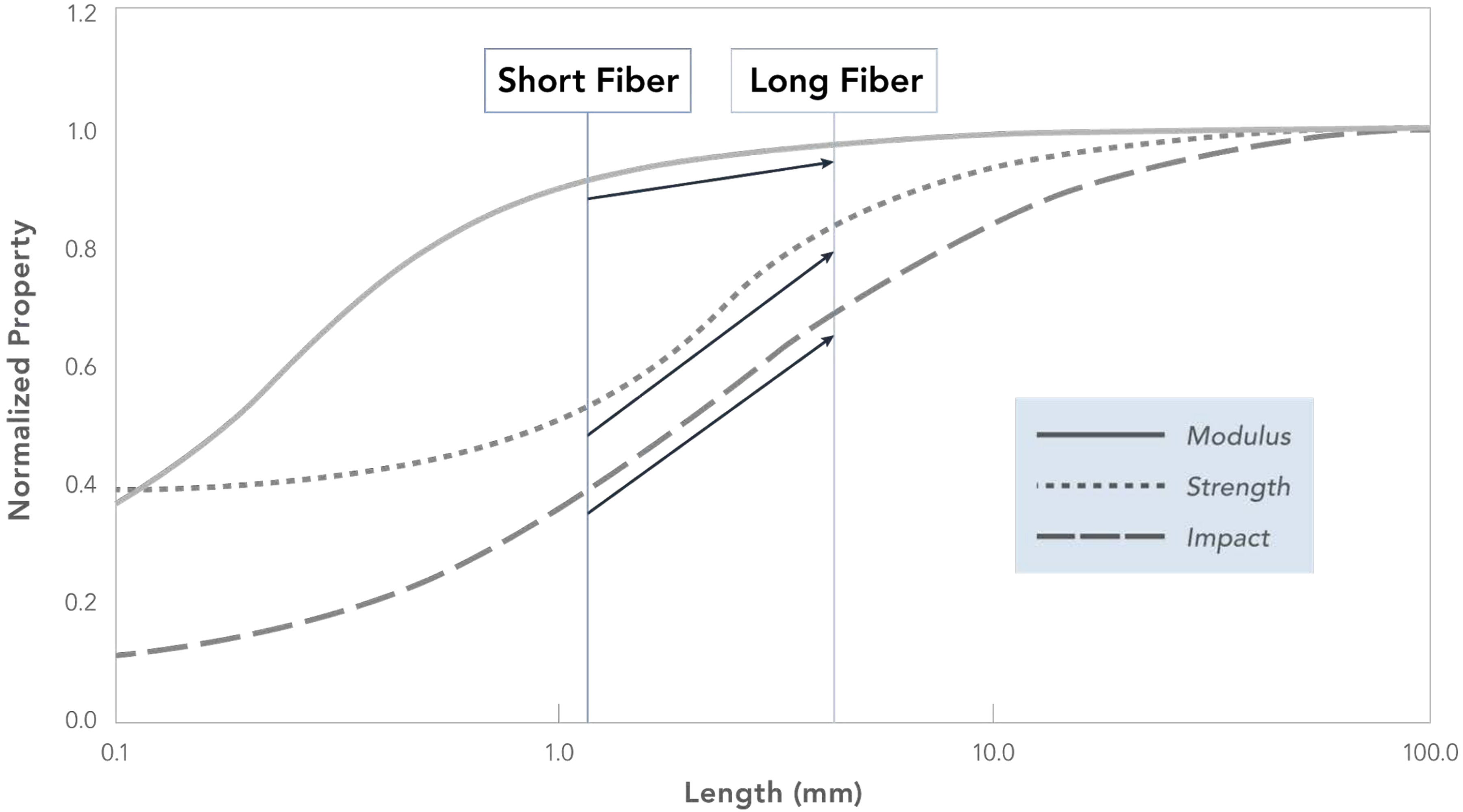
- Patent-pending technology produces low-density, continuous-fiber-reinforced lattice structures
- Continuous manufacturing process reduces cost and enables high-volume production
- Ideal approach for optimizing structural plastics design for automotive, aerospace, construction and other uses

LITERATURE REVIEW

J.L. Thomason has published extensively on the topic of short and long glass-fiber-reinforced polypropylene and polyamide plastics.

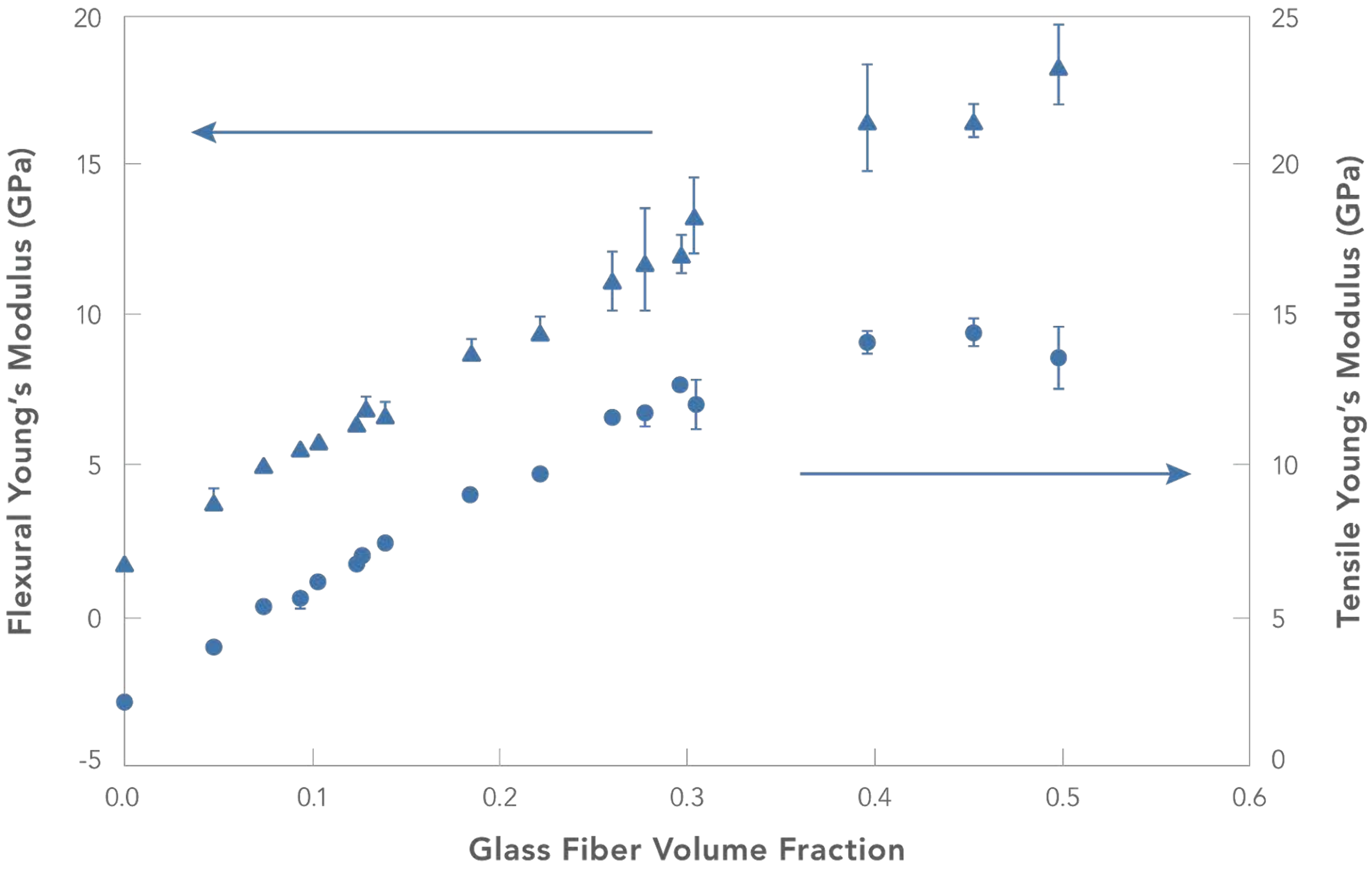
- Focused on the effects of fiber length and fiber volume fraction on the tensile modulus, tensile strength and impact resistance of these materials
- Key findings include:
  - The critical fiber lengths for tensile strength, tensile modulus and impact resistance differ significantly
  - Fiber volume fraction is linearly correlated to stiffness
  - Fiber volume fraction is quadratically correlated to strength and toughness

FIBER LENGTH SCALE EFFECTS



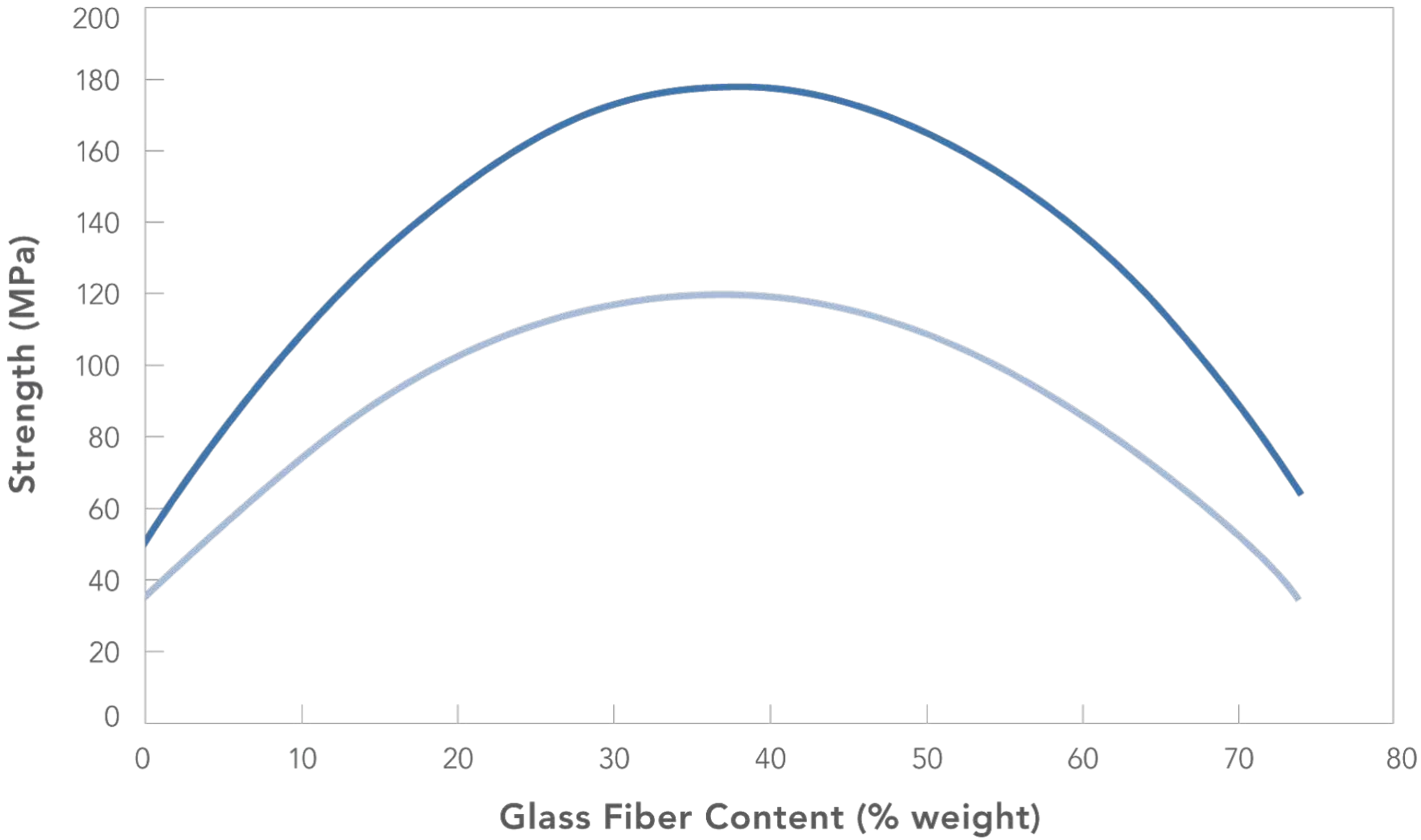
Effect of fiber length on mechanical properties, normalized against continuous-fiber properties. Original figure modified to label short and long-fiber length scales. (Thomason, 2002)

FIBER VOLUME FRACTION vs. MODULUS — LONG GLASS



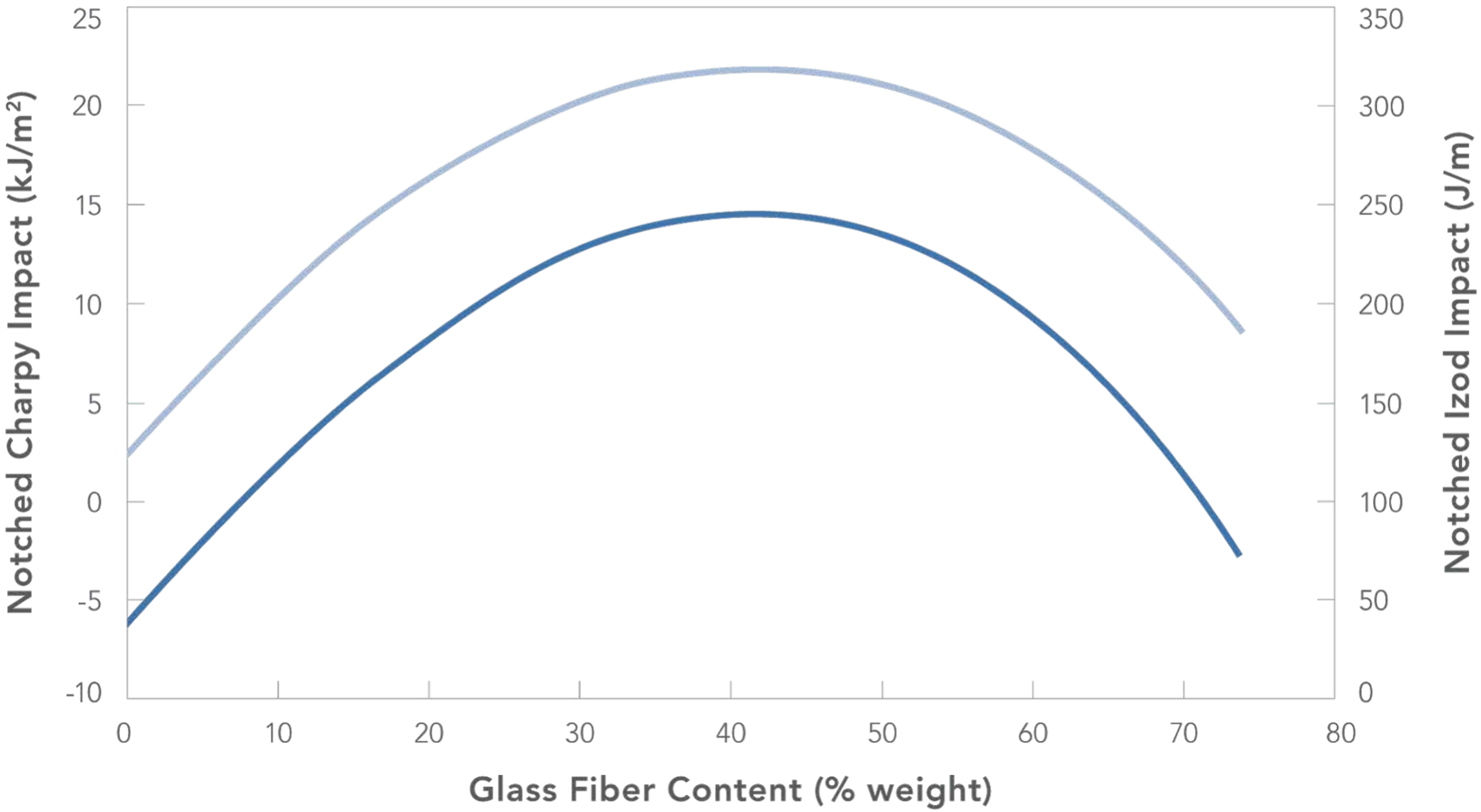
Plot of Young's modulus vs. fiber volume fraction. Values for flexural (triangle) and tensile (circle) modulus are offset to show deviation. (Thomason, 2005)

FIBER WEIGHT FRACTION vs. STRENGTH — LONG GLASS



A plot of tensile strength (light blue) and flexural strength (dark blue) vs. fiber weight fraction. (Thomason, 2005)

FIBER WEIGHT FRACTION vs. IMPACT — LONG GLASS



A plot of Charpy (light blue) and Izod (dark blue) impact resistance vs. fiber weight fraction. Charpy and Izod data is offset to more clearly show the data. (Thomason, 2005)

MICROMECHANICS THEORY — CONTRIBUTING FACTORS

Modulus - Load transfer and distribution between fiber and matrix

- Fiber alignment
- Fiber volume fraction
- Fiber modulus

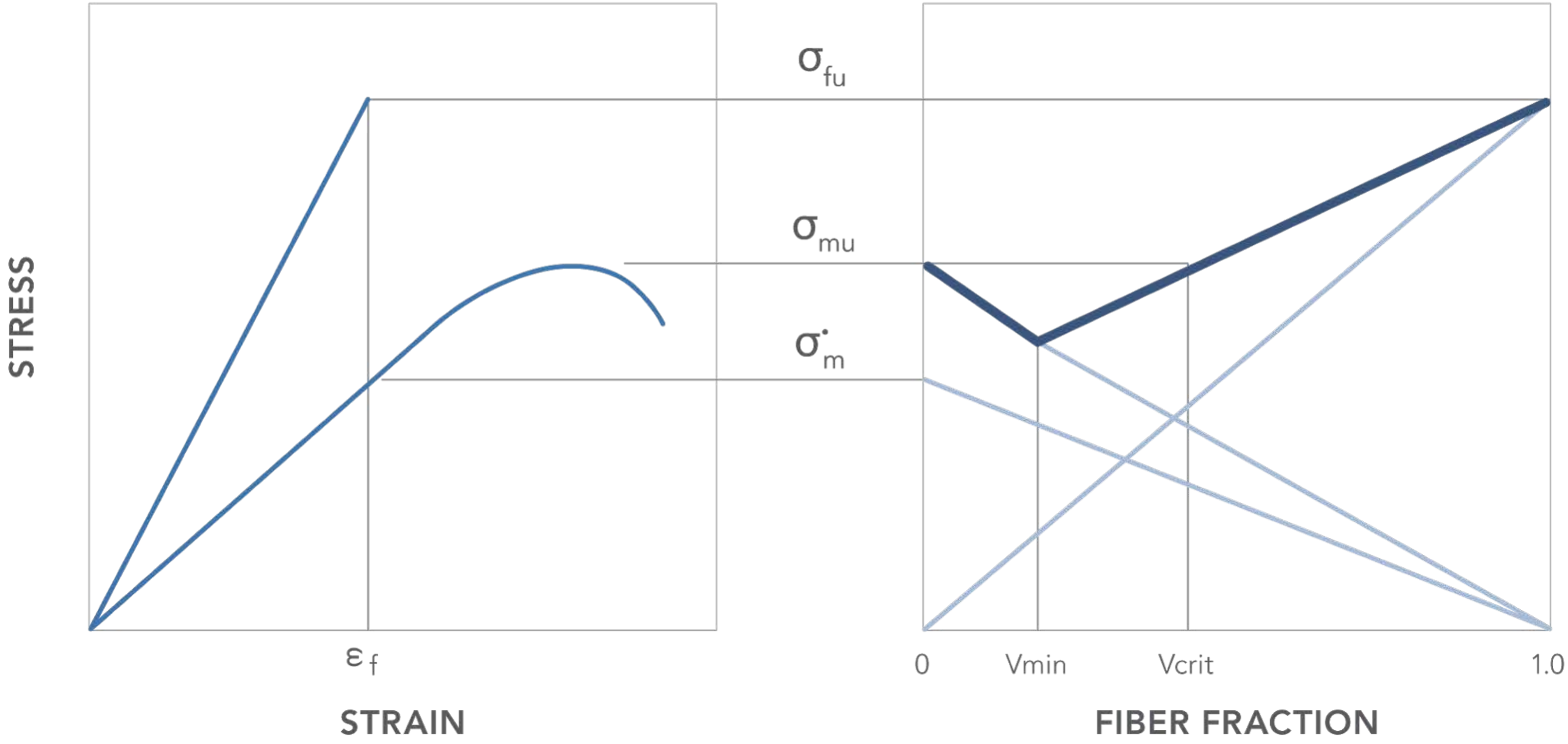
Strength - Failure mode (fiber, matrix, interface)

- Critical length
- Interfacial adhesion
- Fiber distribution/wetting

Toughness - Fracture mechanics (propagation, deflection, arrest)

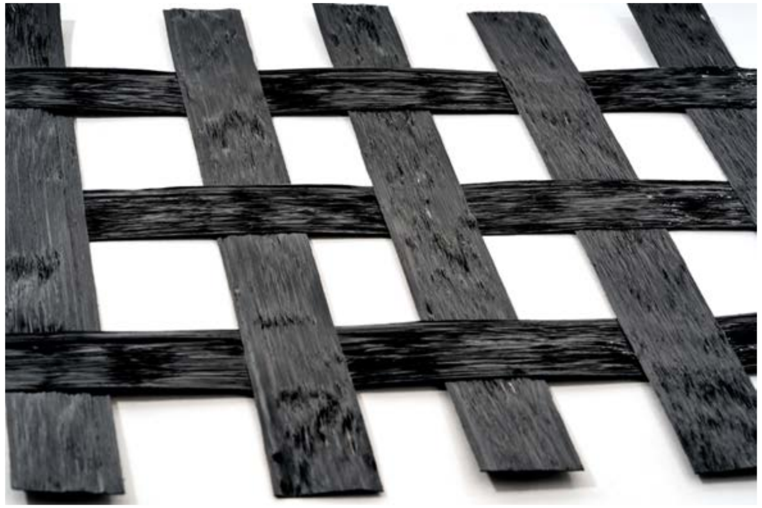
- Reinforcement-induced stress concentrations
- Fiber volume fraction driven ductile-brittle transition
- Crack deflection length

DUCTILE-BRITTLE RELATIONSHIP — CONTINUOUS FIBERS

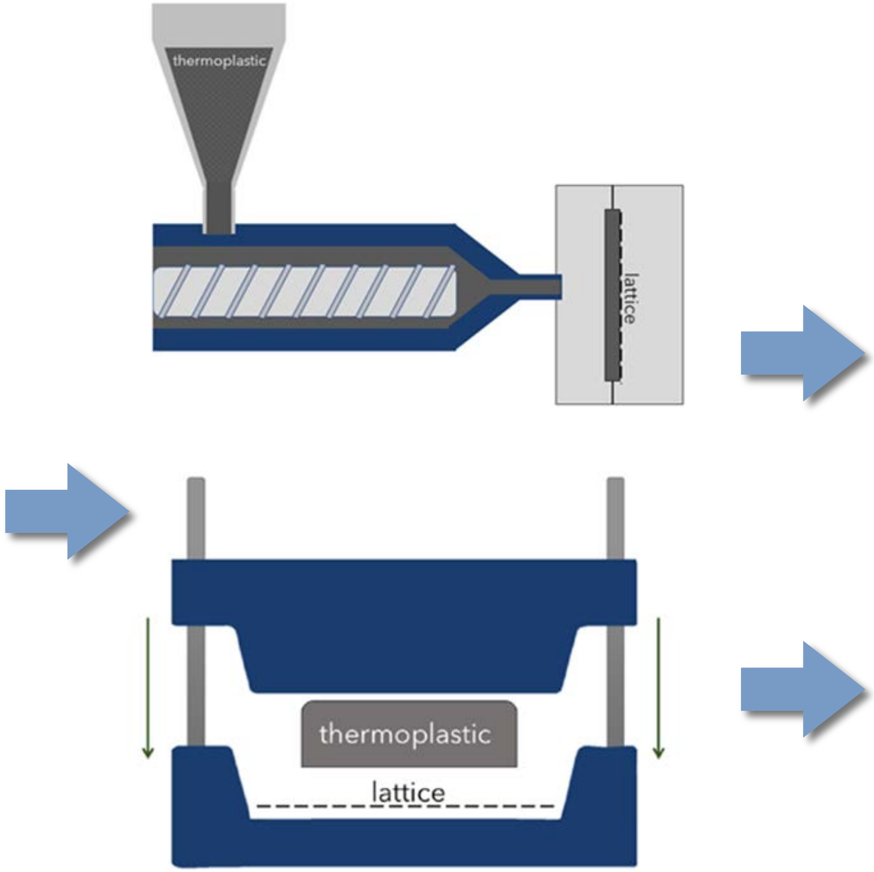


(Left) Stress-strain curve for reinforcement fiber and plastic matrix. (Right) Relationship between fiber volume fraction (Vf) and strength of CFRP, developed from figure on the left.

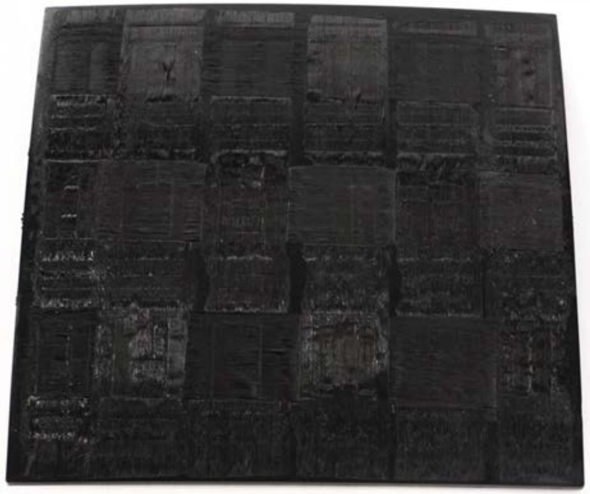
Rebar for Plastics™



COMPOSITE LATTICE



INJECTION/COMPRESSION MOLDING OR THERMOFORMING



LIGHTWEIGHT STRUCTURAL COMPOSITE PART

Rebar for Plastics™

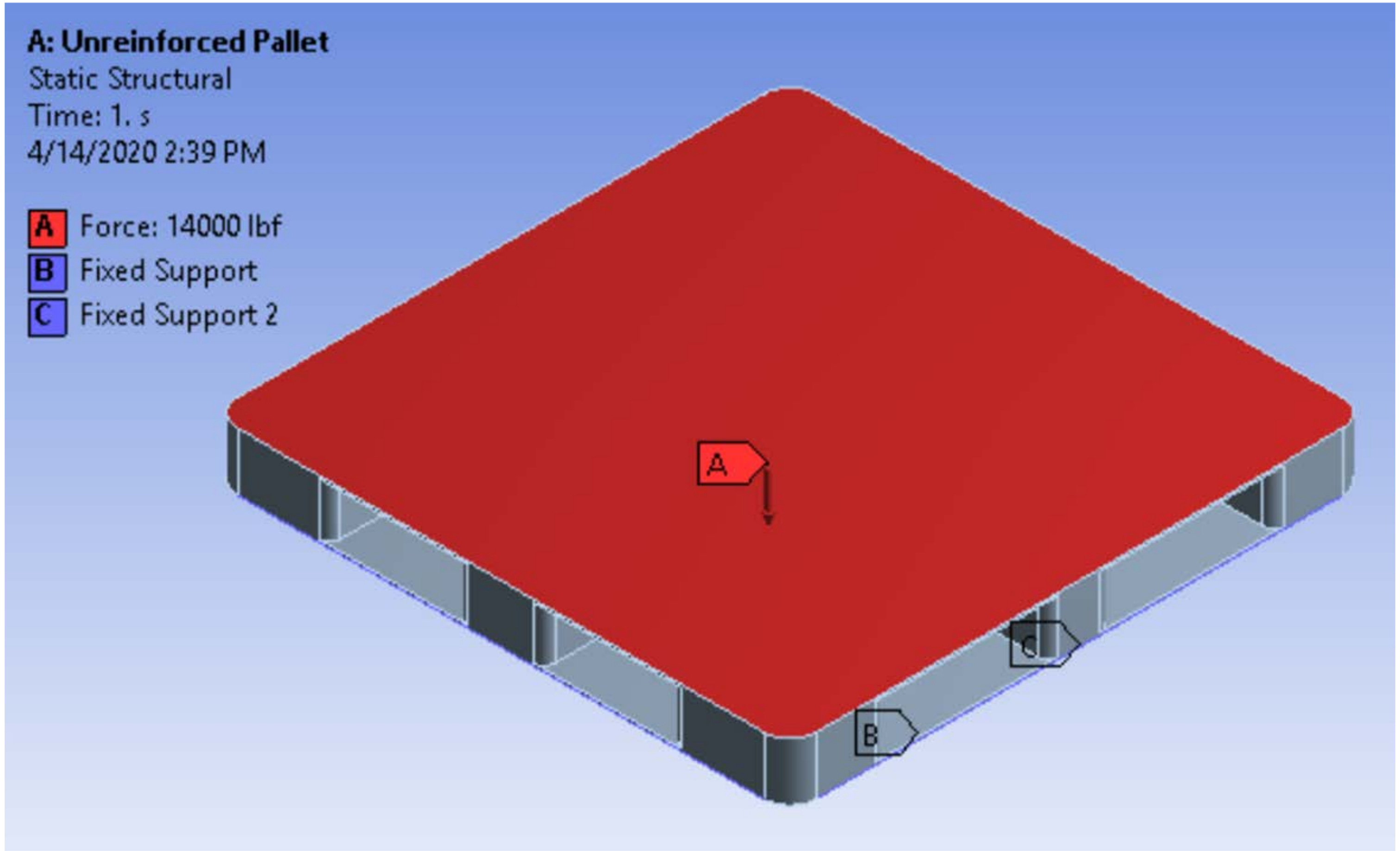
- Combination of:
  - Continuous fiber-reinforced tapes
  - Overmolded fiber-reinforced thermoplastic
- Independent tuning of:
  - Stiffness
  - Strength
  - Toughness
- Localized performance and cost optimization

CASE STUDY

POLYPROPYLENE PALLET

CASE STUDY — PALLET SETUP

Finite element analysis of 14,000 lb load over top surface of long fiber-reinforced polypropylene pallet



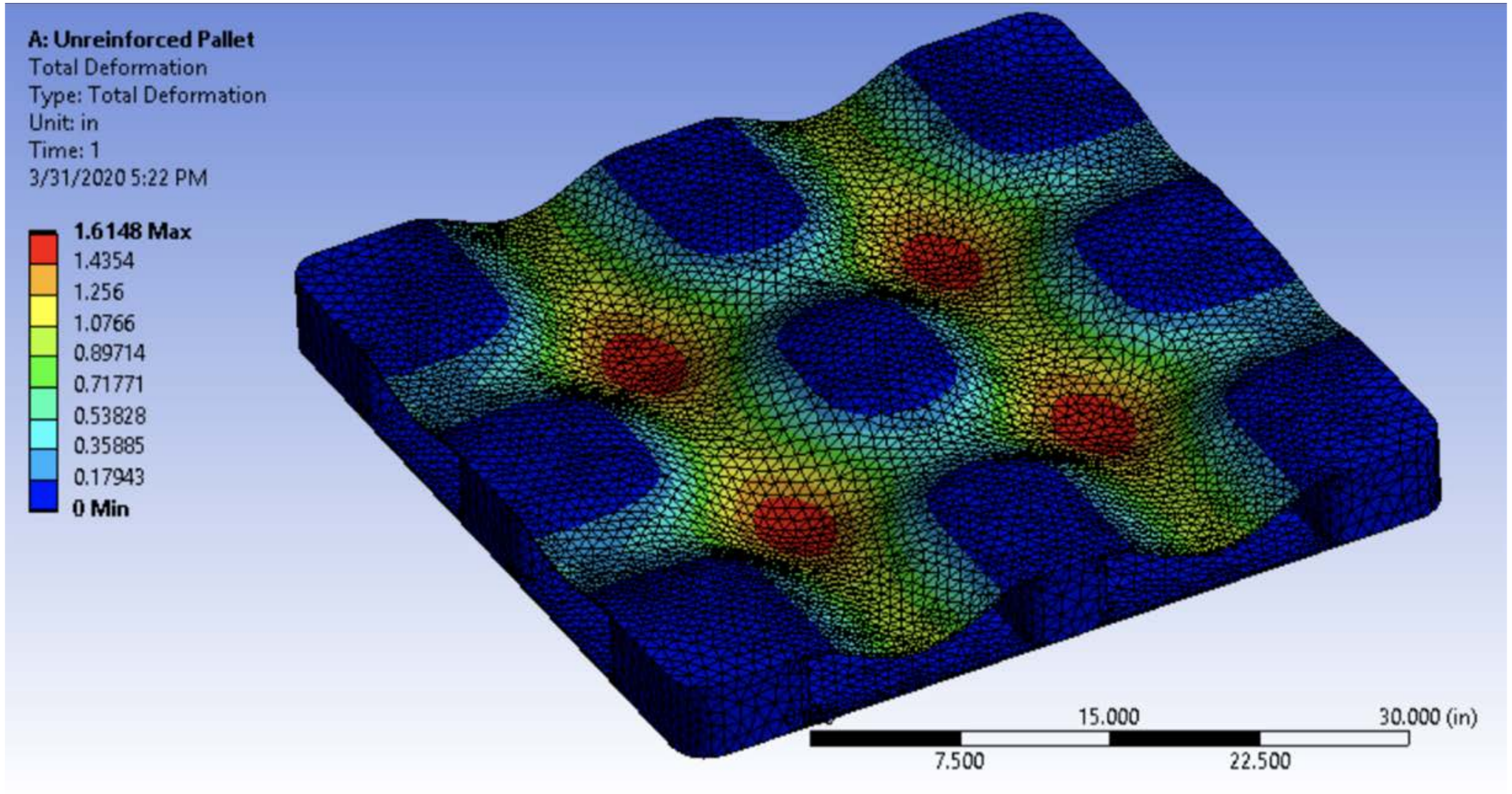
A: Unreinforced Pallet
Static Structural
Time: 1. s
4/14/2020 2:39 PM

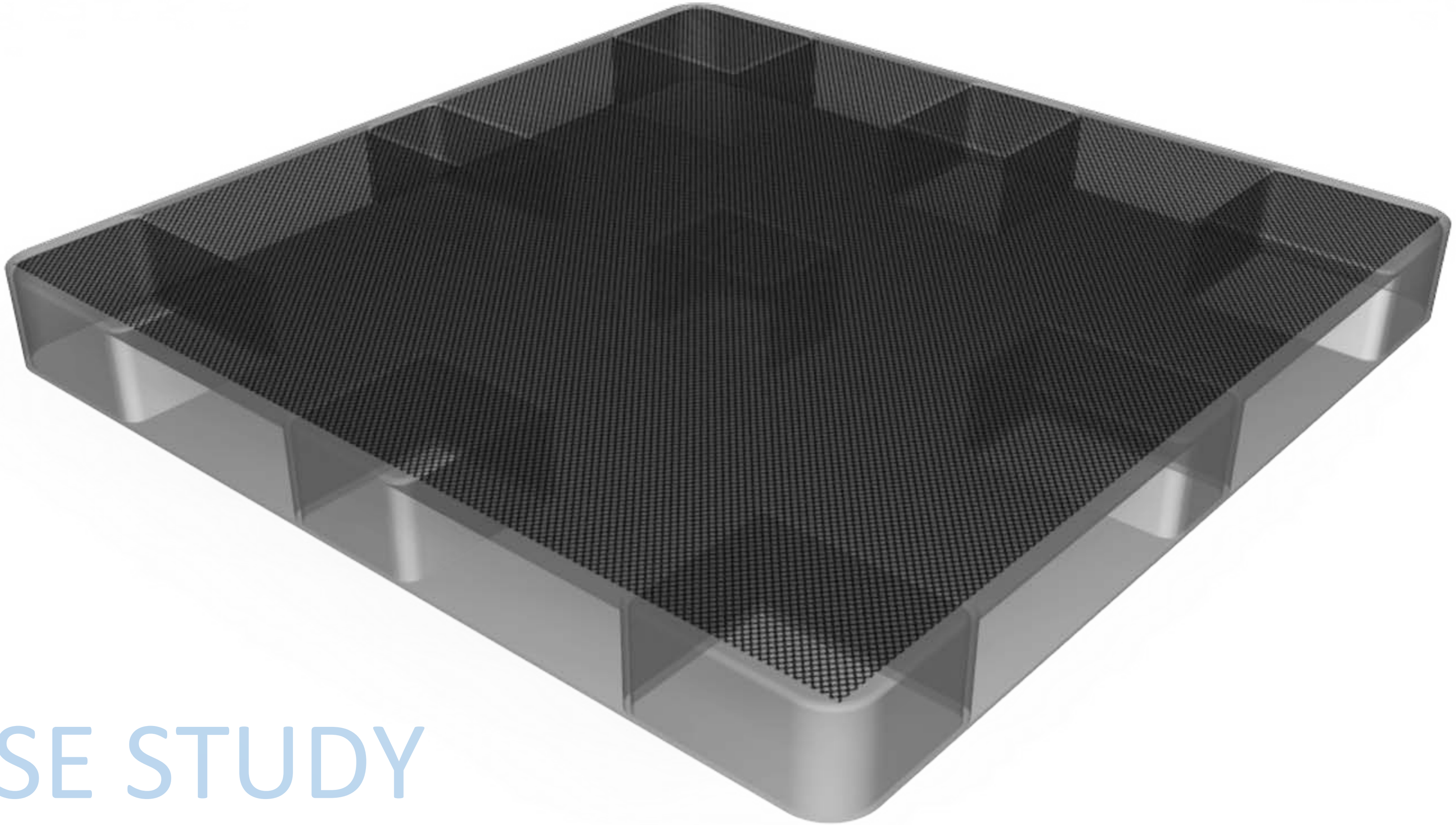
A Force: 14000 lbf
B Fixed Support
C Fixed Support 2

CASE STUDY — LONG FIBER-REINFORCED PLASTIC BASELINE

Baseline case using generic model, adjusted for realistic wall thickness and internal structure

- Long Glass PP (Vf = 16%)
- 4.9 GPa isotropic modulus
- Maximum deflection of 40.64 mm
- Mass = 16.9 kg





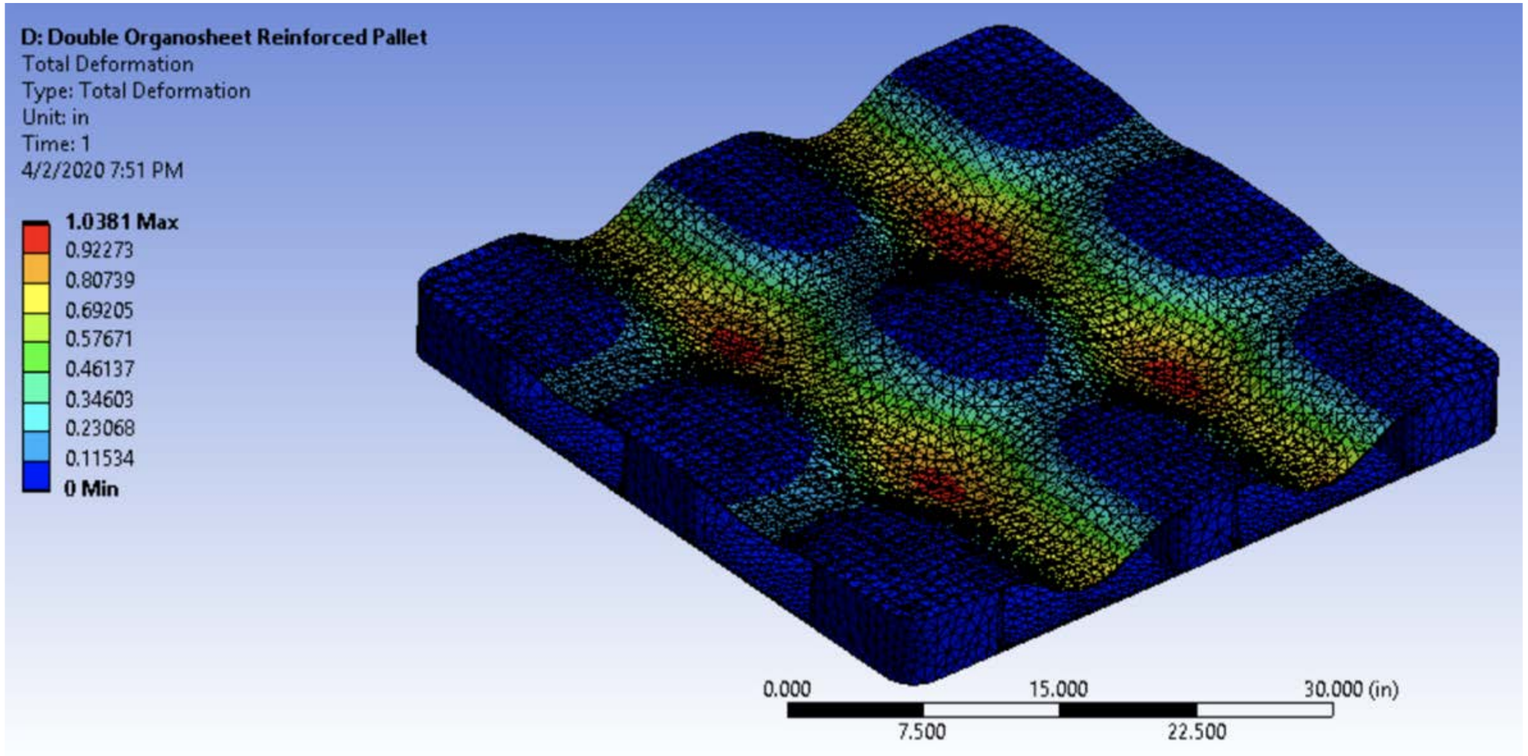
CASE STUDY

SHEET REINFORCEMENT

CASE STUDY — SHEET REINFORCEMENT

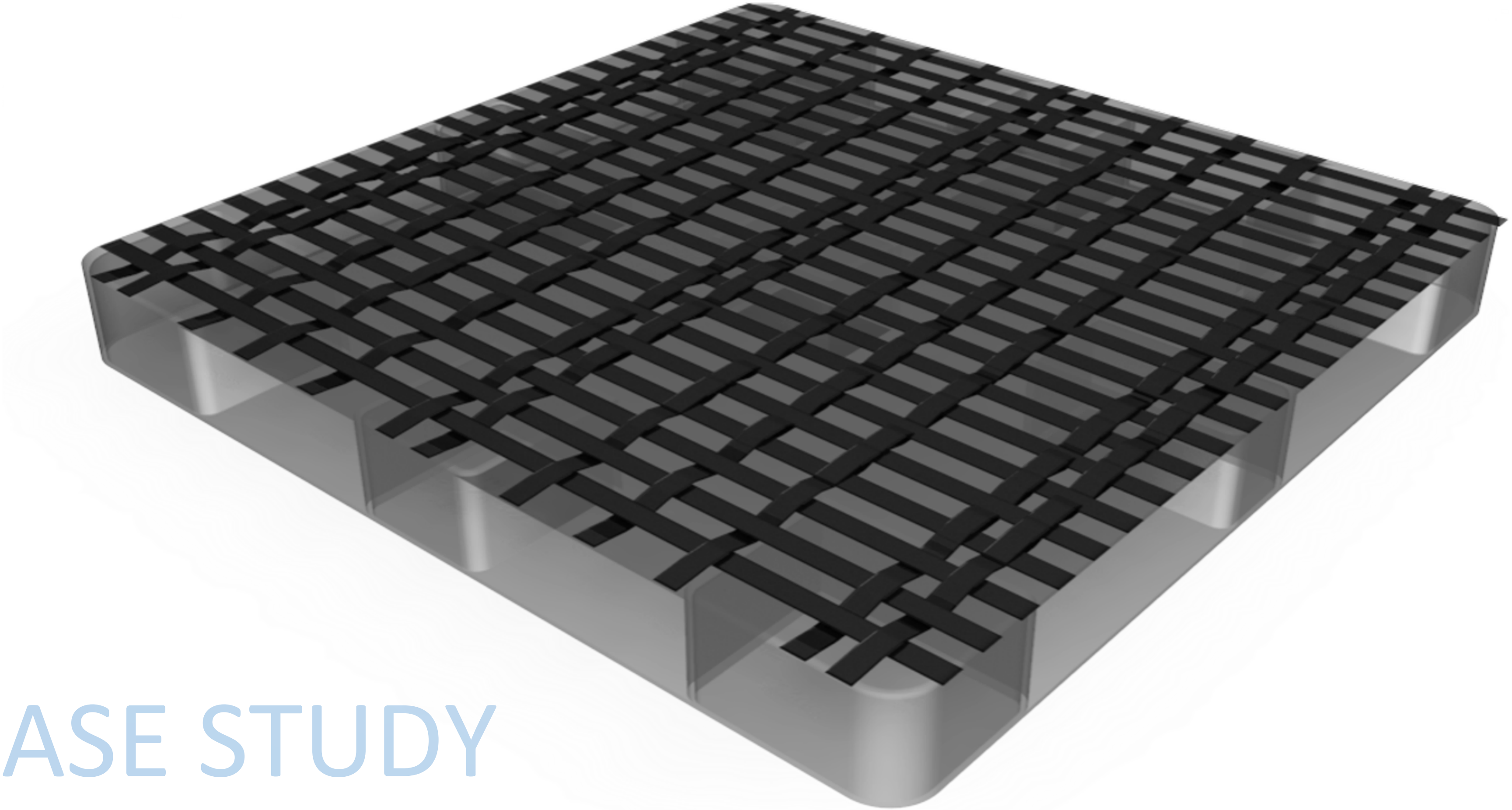
Simulate pallet under same load with organo sheet reinforcement laid evenly across top surface of pallet

- Glass/PP organo sheet (Vf = 47%)
- 20 GPa in-plane modulus (X-Y)
- Maximum deformation: 26.16 mm
    - 2-layer sheet
- Mass = 2 kg organo sheet + 15.5 kg plastic



D: Double Organosheet Reinforced Pallet
Total Deformation
Type: Total Deformation
Unit: in
Time: 1
4/2/2020 7:51 PM

1.0381 Max
0.92273
0.80739
0.69205
0.57671
0.46137
0.34603
0.23068
0.11534
0 Min

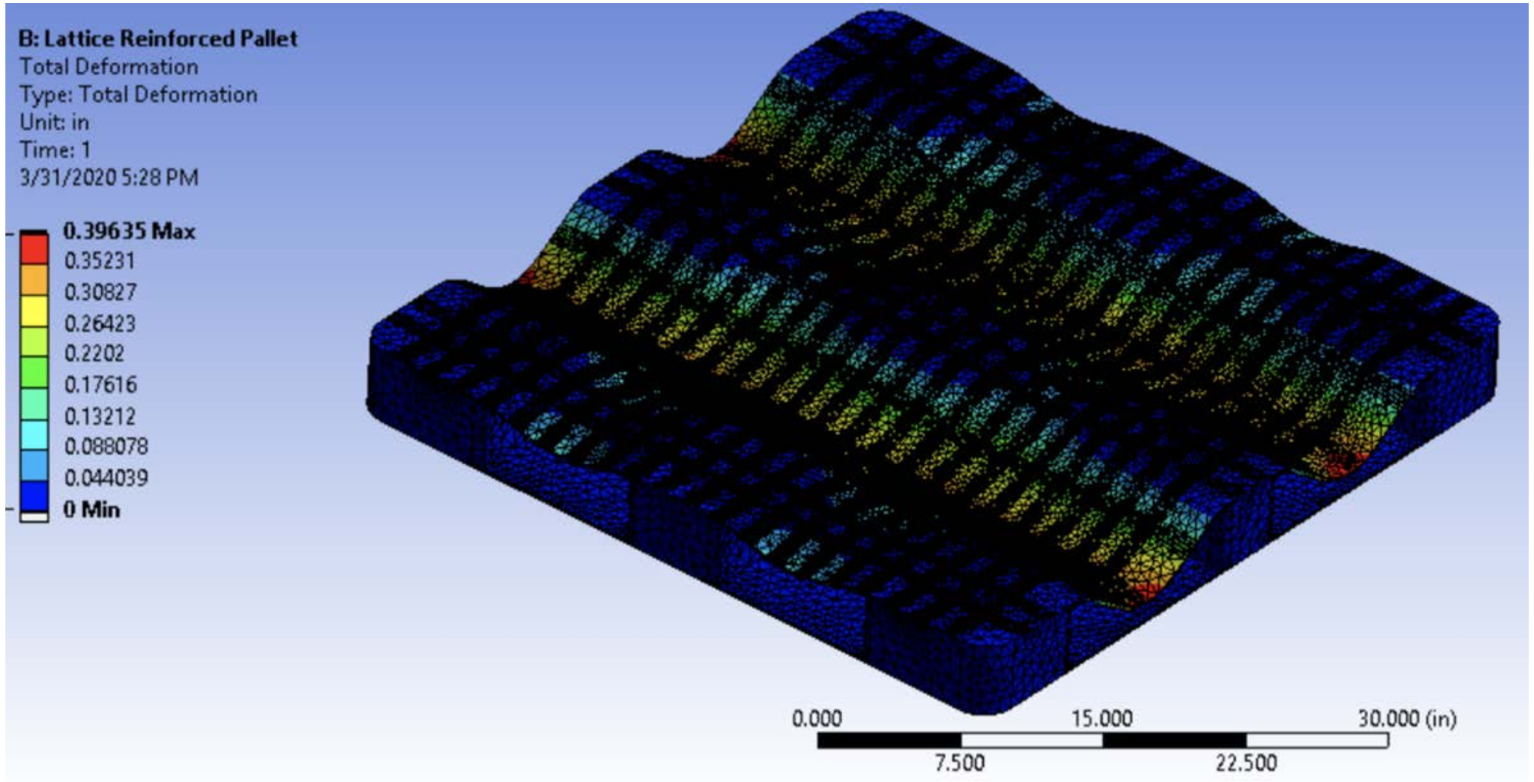


CASE STUDY

LATTICE REINFORCEMENT

Optimized design with lattice reinforcement

- Glass/PP UD Tape Lattice (Vf = 45%)
- Unidirectional tape modulus: 37 GPa
- Maximum deformation: 10.06 mm
  - 2-layer lattice configuration
- Mass = 0.73 kg lattice + 16.37 kg plastic



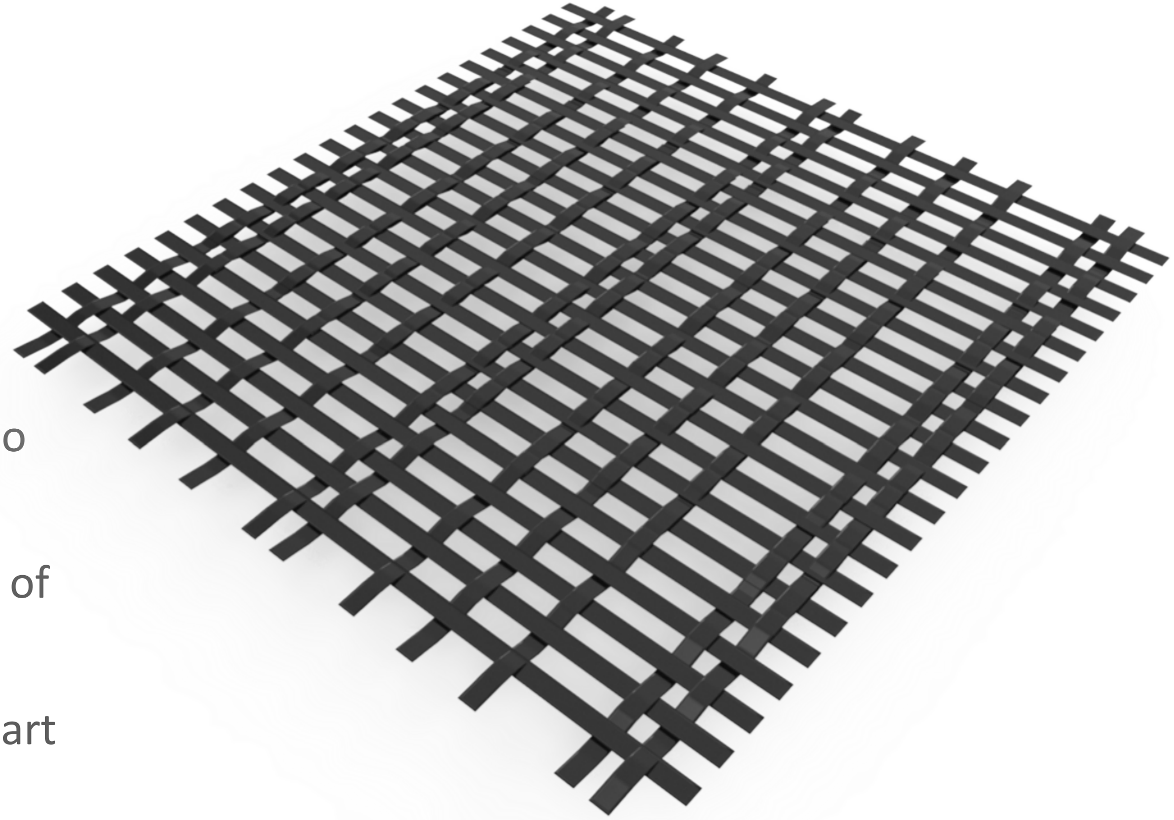
Results Comparison

	Long Glass Reinforced	Long Glass plus Organo Sheet	Long Glass plus Lattice
Max Deformation	40.64 mm	26.16 mm	10.06 mm
Deformation Change	-	-35.6%	-75.2%
Total Pallet Mass	16.9 kg	17.5 kg	17.1 kg
Mass Change	-	+3.6%	+1.2%
Total Material Cost	$35.49	$62.93	$42.37
Cost Change	-	+43.6%	+19.4%

Substantial stiffening can be achieved with controlled mass and cost change,
further optimization could reduce cost or mass by tuning max deformation

A true **Rebar for Plastics™** solution

- For non-aerospace applications, traditional composite laminates are overkill and not justifiable for the cost
- Laminate back-injection is a step in the right direction, but:
    - Relies on laminate for all mechanical properties, only using molded plastic to adjust section properties
    - Conventional laminates are expensive and unsuitable to high-volume mass production
- WEAV3D process enables low cost, high volume production of optimized lattices
    - Molded plastic remains the dominant material in the part
    - Use of continuous material is optimized to meet performance properties while minimizing cost and weight



Contact

WEAV3D Inc. is seeking partners interested in developing new product offerings for the automotive market using WEAV3D lattice preforms. For more information about partnering opportunities, please contact me at chris.oberste@weav3d.com.

www.**WEAV3D**.com