GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE
The UNIVERSITY of OKLAHOMA

IMMERSE LAB

Investigating Freeze-Thaw Behavior of Nanomodified Fiber-Reinforced Polymers

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2021 REPORT CARD FOR AMERICA'S INFRASTRUCTURE ASCE
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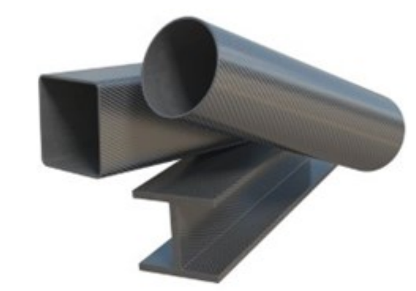
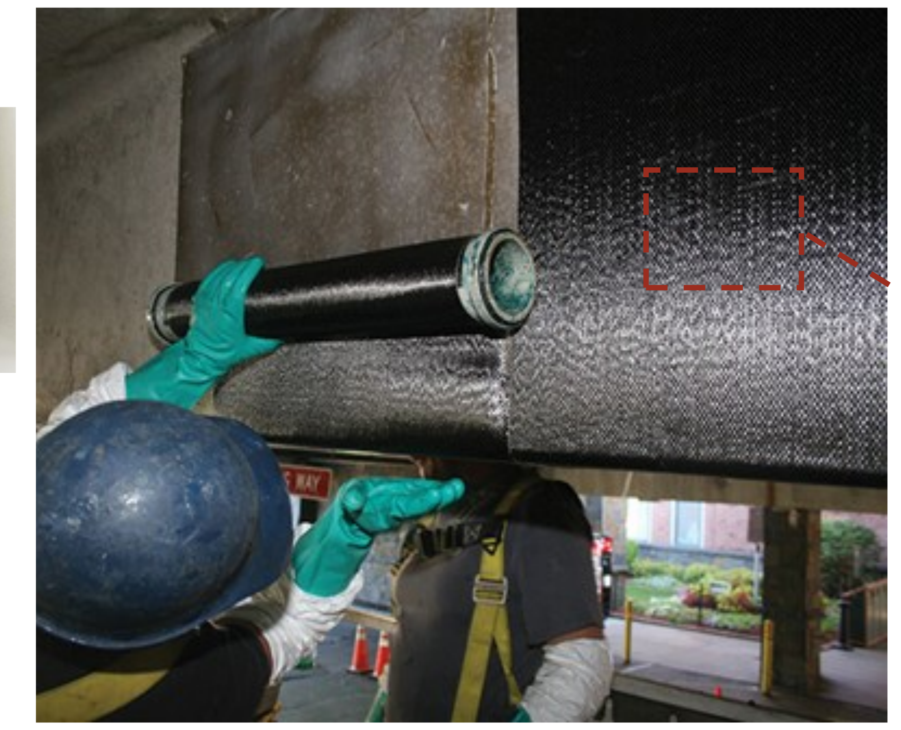
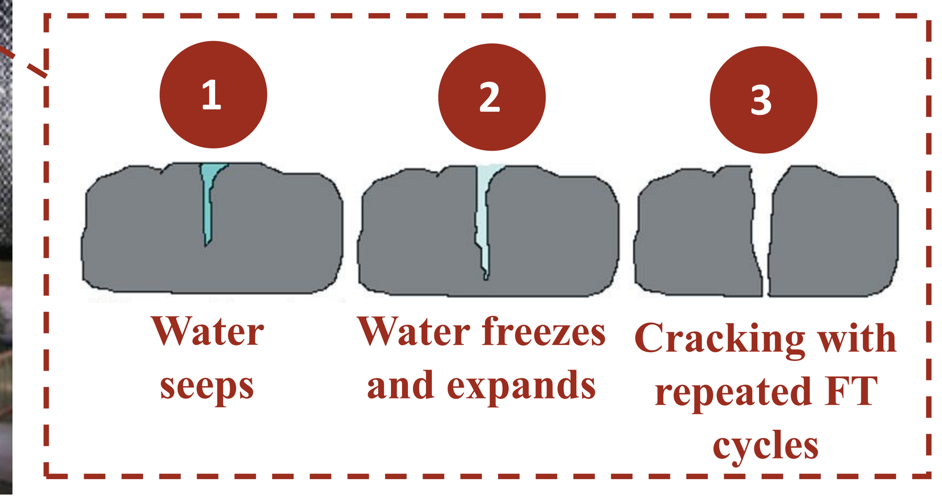
Why is our Infrastructure Failing?
- Deteriorating Materials
- Lack of Maintenance on Aging Structures

We Must Utilize:
- New Materials
- New Technologies

Fiber-Reinforced Polymers (FRP)
- High Corrosion Resistance
- High Strength-to-Weight Ratio
- High Impact Strength
- Long term Durability
- Unknown Freeze-Thaw Effects
- Low Shear Strength
- Linear Elastic to Failure
- Complex Failure Mechanisms

Durability Issues Due to Freeze-Thaw Cycles

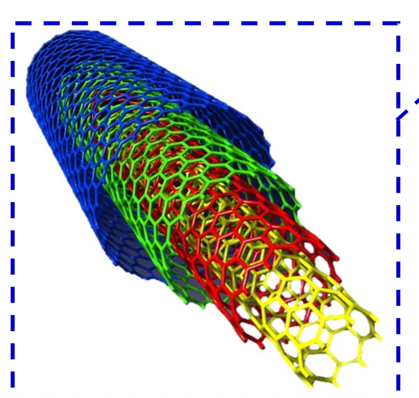


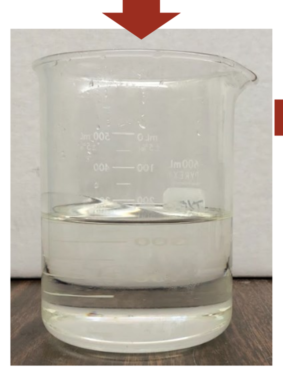
Research Goals
→ Understand possible microscopic debonding in fiber reinforced polymer matrix during freeze-thaw

→ Correlate mechanical changes of fiber reinforced polymers observed through tensile testing with nanotube content and number of freeze-thaw cycles

Methodology

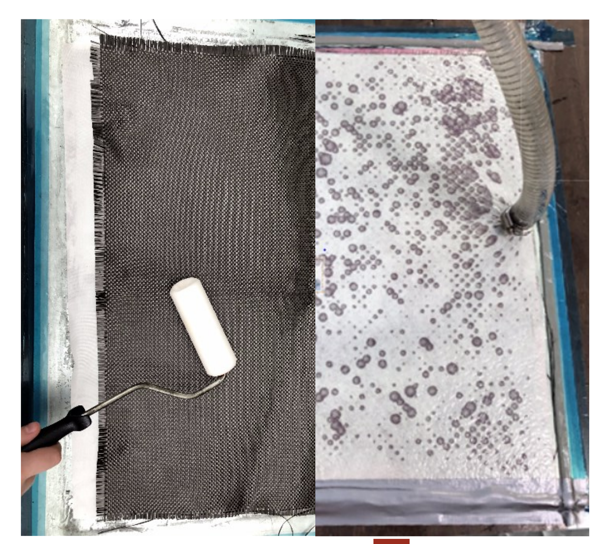
Multi-Walled Carbon Nanotubes (MWCNT)


MWCNTs modify the bonds in FRPs

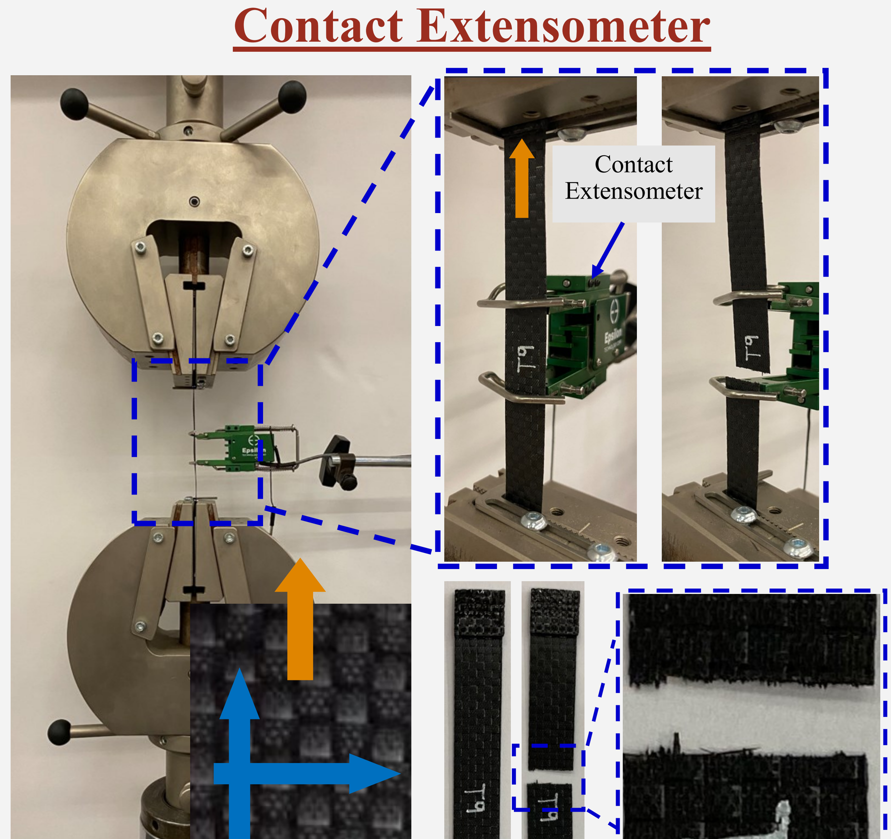
Ultrasonication


Mechanical Stirring


Vacuum-Assisted Hand Layup Technique


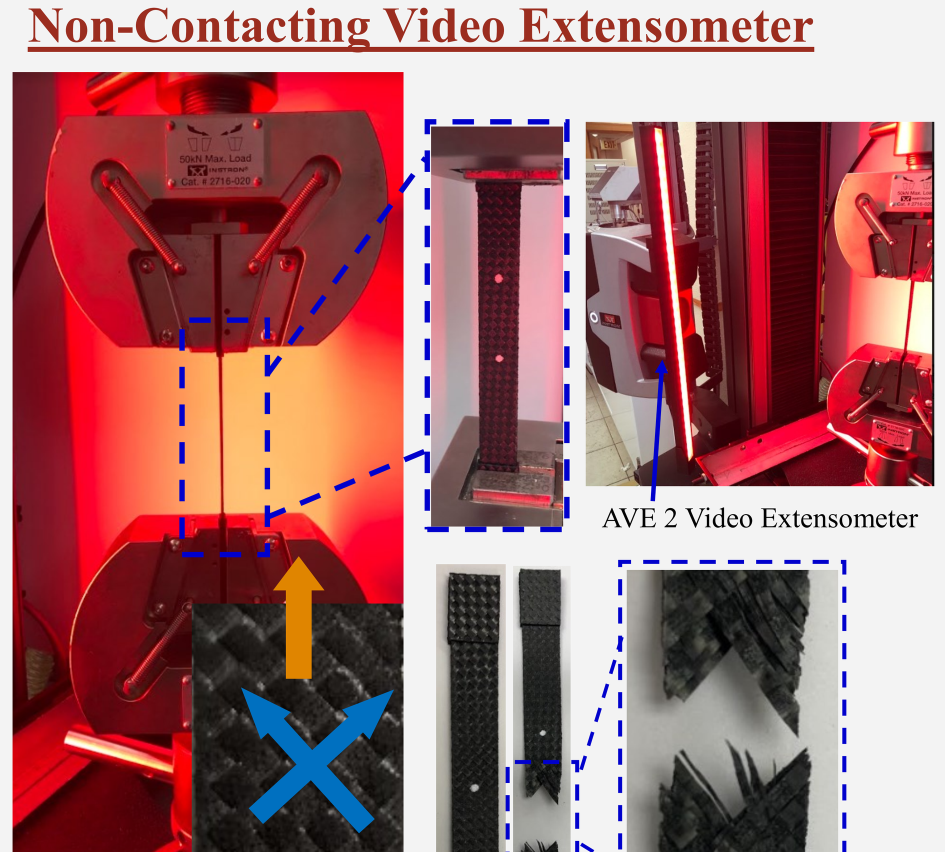
Freeze-Thaw Setup


Two Types of ASTM D3039 Tension Test

On-Axis Contact Extensometer


Direction of Loading Aligns with one of the Directions of Fiber

Failed specimen after tension test shows fiber failure

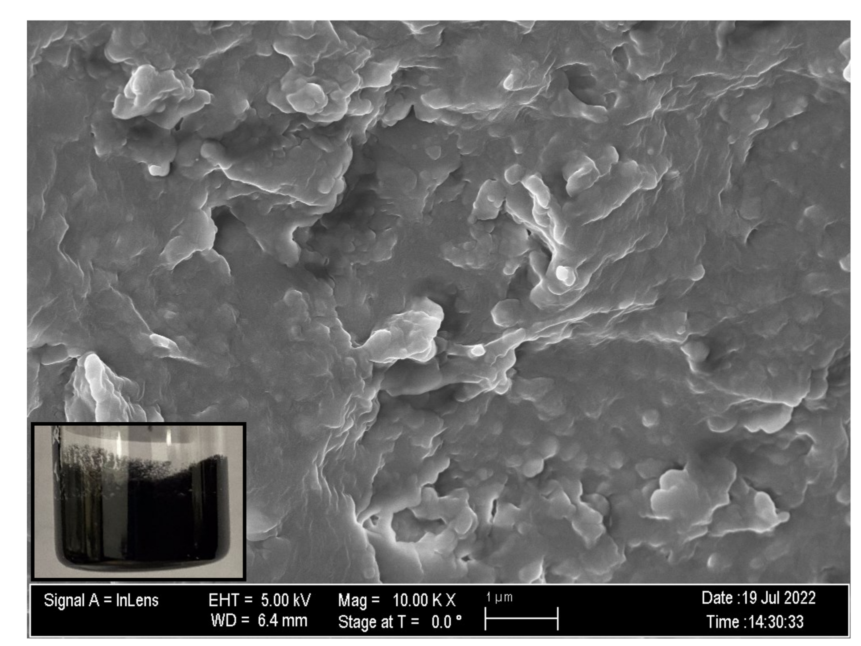
Off-Axis Non-Contacting Video Extensometer

AVE 2 Video Extensometer

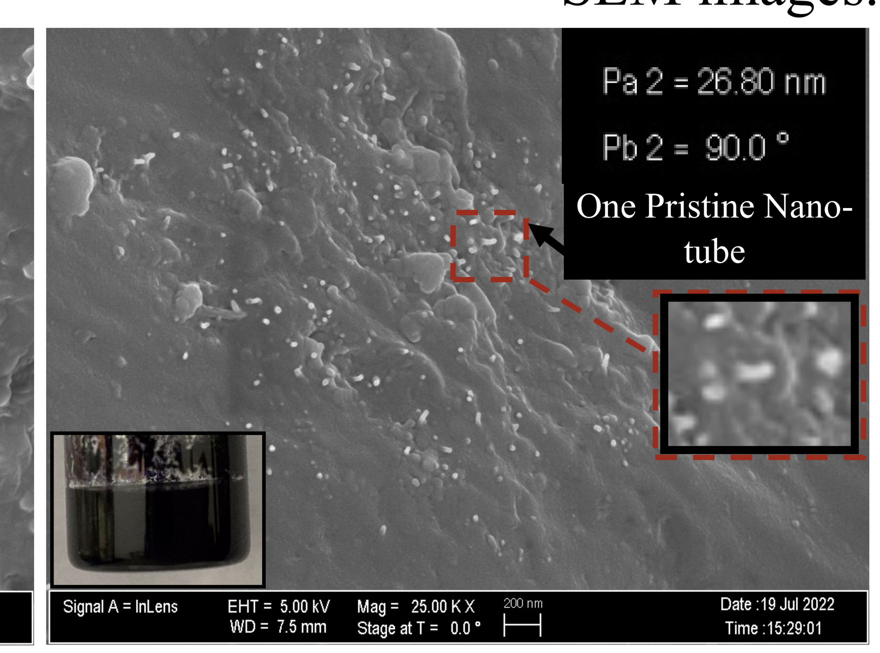
Direction of Loading is 45° from the Direction of Fibers

Failed specimen after tension test shows matrix failure

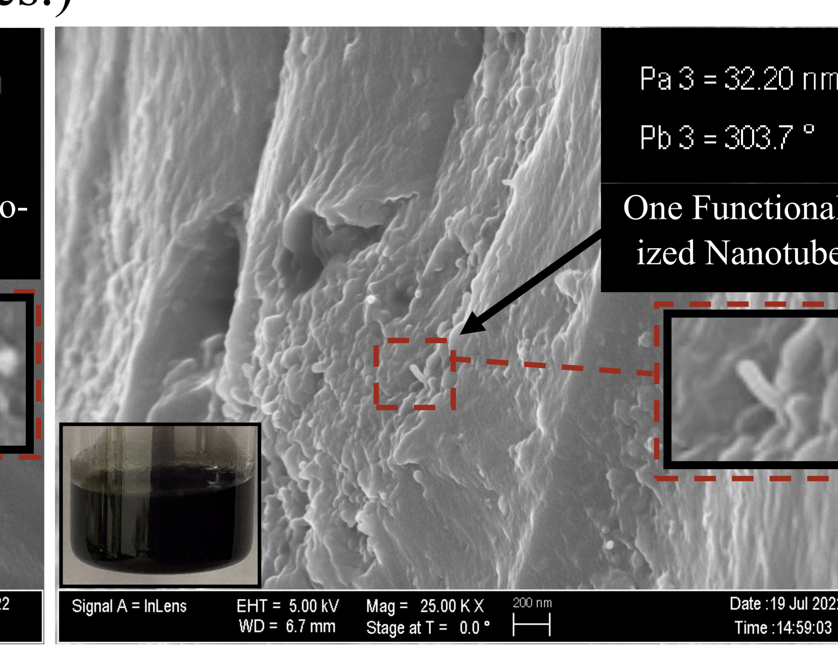
Results
Through SEM imaging shown below, there was apparent dispersion and visible MWCNTs show regular spacing without clumping.

Through visual observation of unhardened matrix samples, no apparent segregation of MWCNT and epoxy was visible after 3 months. (Shown in bottom left corner of corresponding SEM images.)

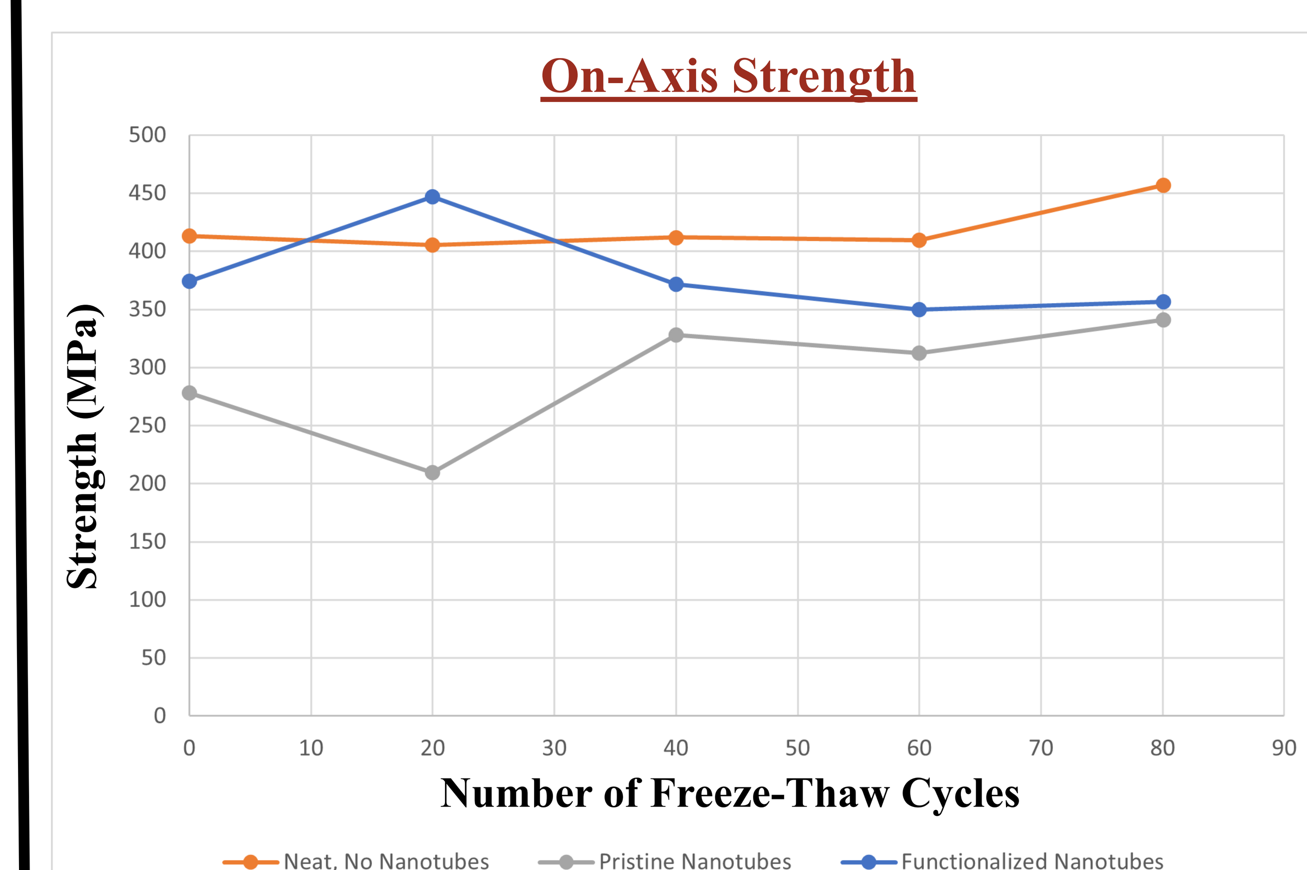

Neat Epoxy, No Nanotubes



Epoxy with 1% wt of Pristine Nanotubes



Epoxy with 0.5% wt of COOH Nanotubes



Conclusions
- Strength increase exhibited in on-axis loading (in the fiber-dominant direction) may be attributed more to the fibers than the nanomodified matrix.
- Testing with off-axis loading will likely reveal matrix dominant behavior. Mechanical properties are expected to change throughout freeze-thaw cycles more visibly.
- With little change in strength for on-axis loading specimens after 80 freeze-thaw cycles, testing matrix will be increased to include up to 250 cycles for off-axis specimens.
- When modifying polymer matrix with MWCNTs, SEM imaging showed good dispersion for all carbon nanotubes.

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