Macro-scale Materials Characterization for Hard and Soft materials

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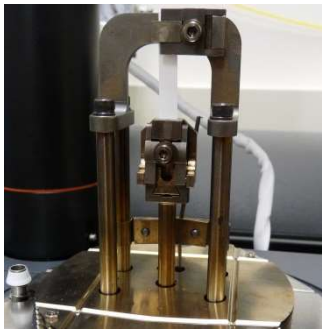
Length Scales of Mechanical Testing at MRL

Atomic Force Microscopy
Kathy Walsh
Tutorial 4 (1100)

AMTEL testing

Nanomechanical Characterization
Kathy Walsh
Tutorial 6 (1530)

Characterization of Soft Materials and Polymers
Roddel Remy
Tutorial 10 (4 June 1030)

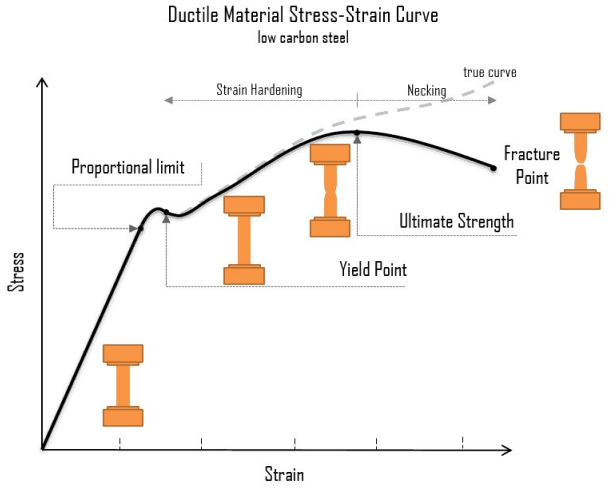


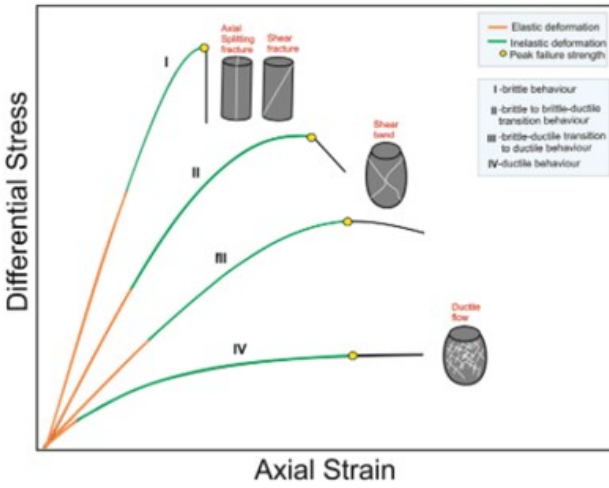
10^{-12} m 10^{-9} m 10^{-6} m 10^{-3} m 10^{0} m

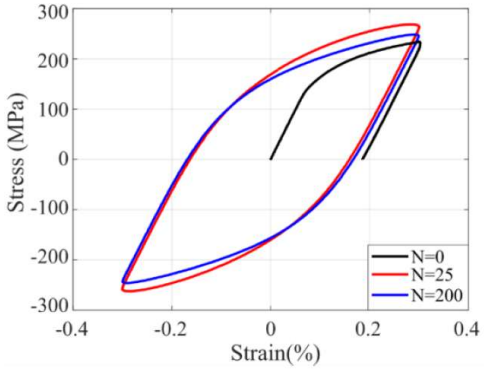
Goals of Mechanical Testing

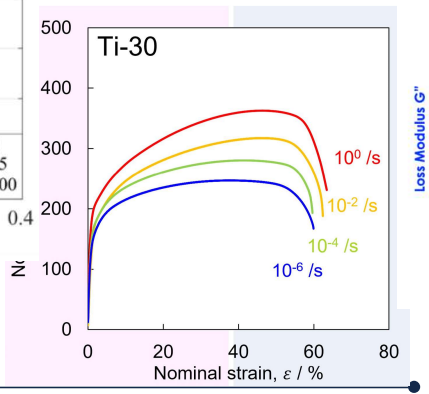
- Stress/Strain behavior
  - Material response (strain) to an external force (stress)

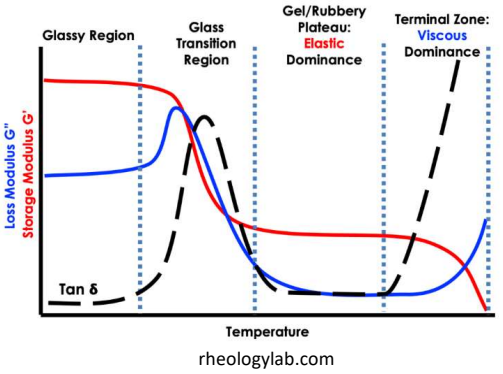
- Properties
  - Quasi-static
    - Elastic Modulus
    - Yield Strength
    - Ultimate Strength
    - …
  - Dynamic
    - Cyclic fatigue
    - Rate sensitivity
    - Viscoelastic properties
      - Storage modulus, loss modulus, tan delta
    - Crack growth
    - …











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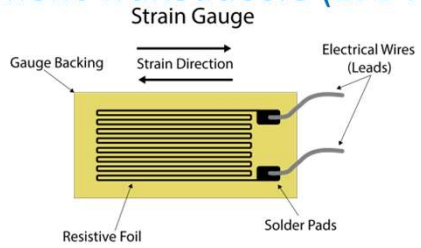
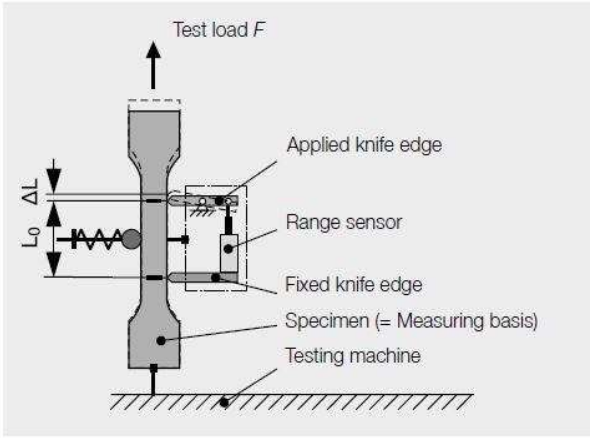
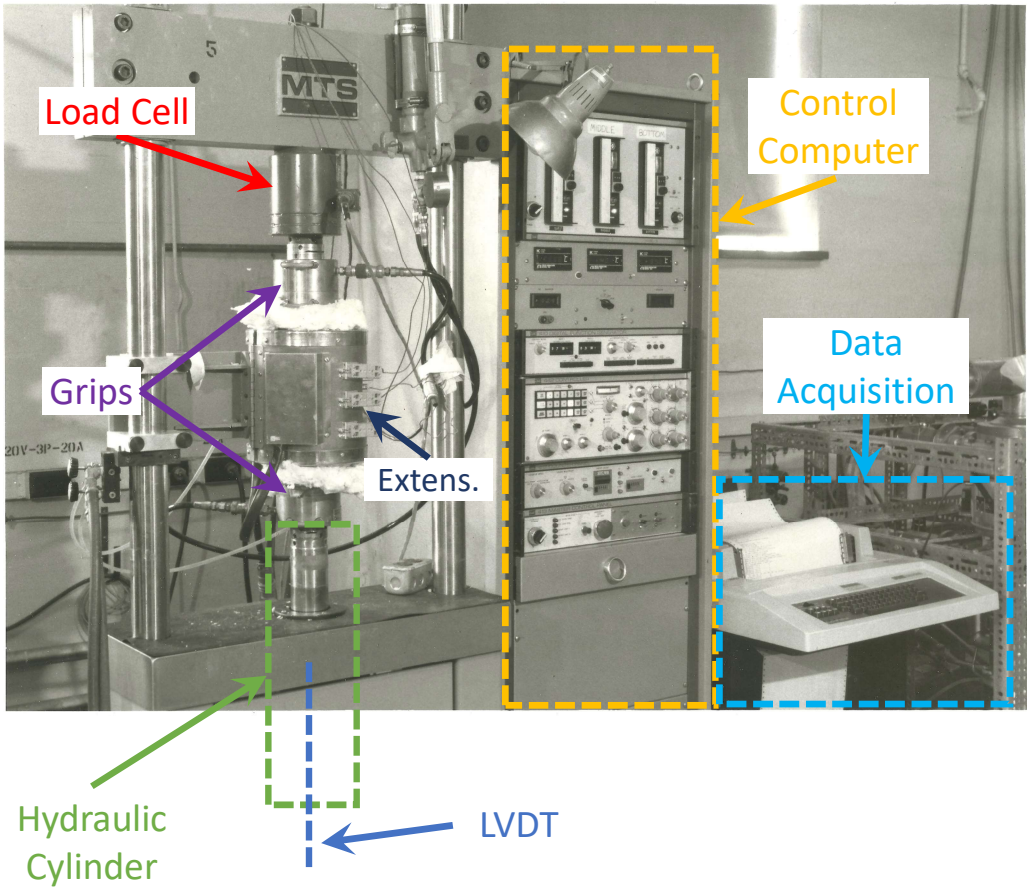
Traditional Test Instrumentation

- Components
  - Load Cells
  - Hydraulic Cylinder
  - Linearly Var. Displacement Transducers (LVDT)
  - Extensometers
  - Strain gauges
  - Control Computer
  - Data Acquisition

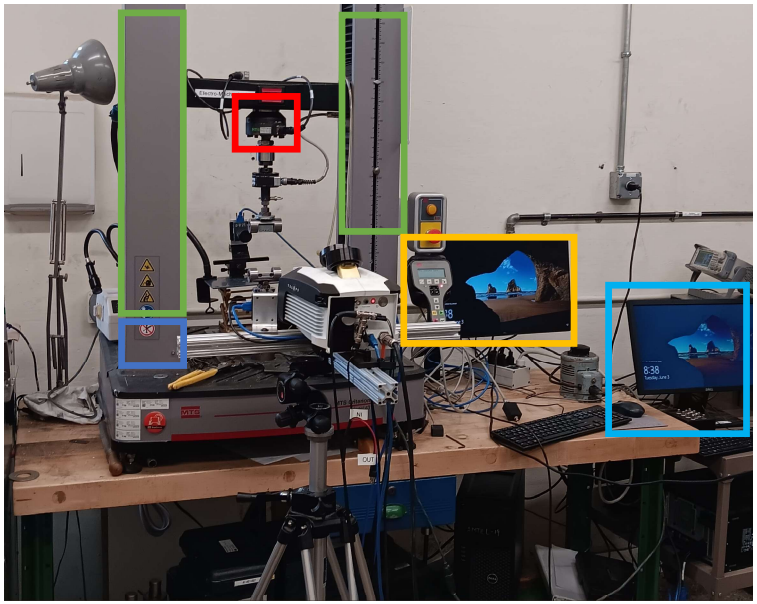


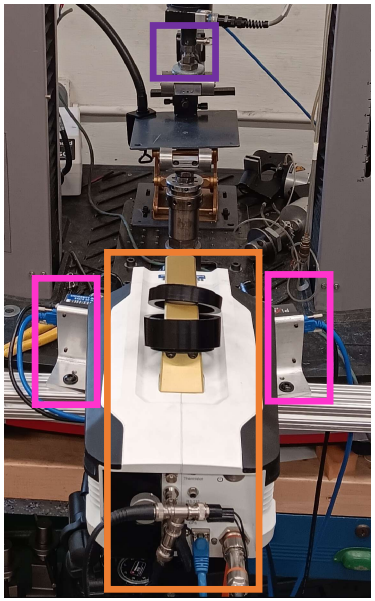


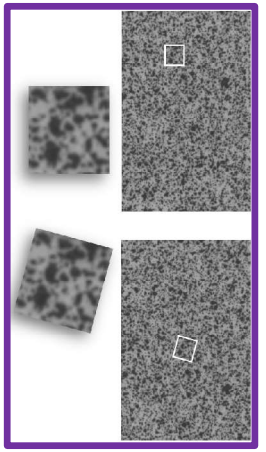


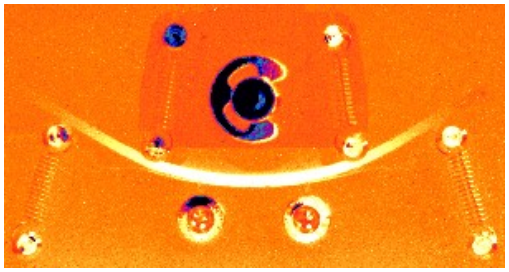
Modern Test Instrumentation

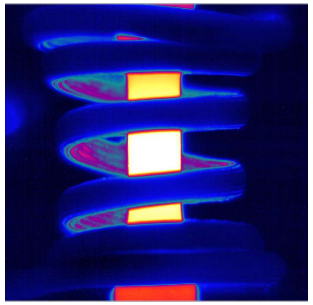
- Components
  - Load Cells
  - Screw Drive
  - Calibrated Servo
  - Extensometers
  - Strain gauges
  - Control Computer
  - Data Acquisition
  - Optical Strain
    - Point tracking
    - **Digital Image Correlation**
      - **2D and Stereo**
  - **Thermography**

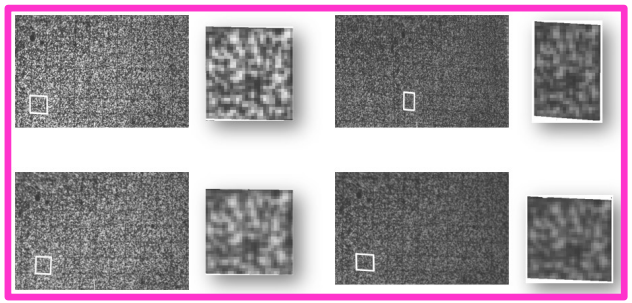




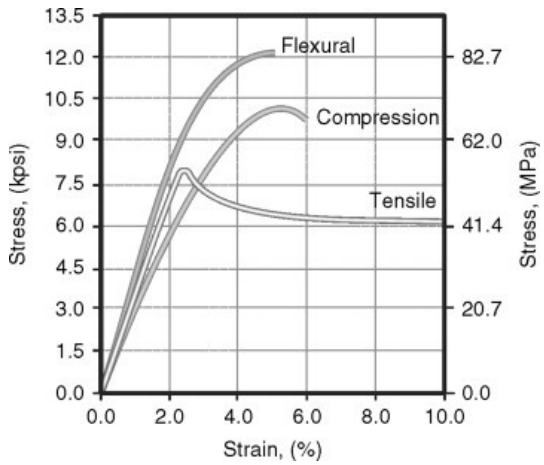


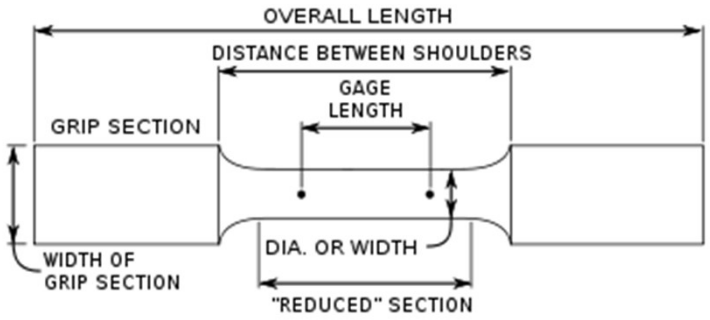




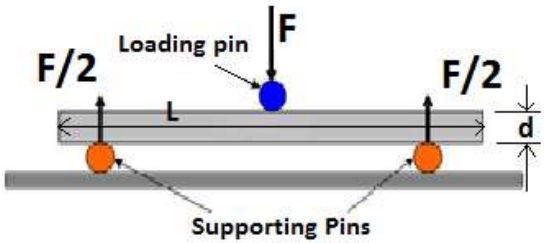


Types of Tests





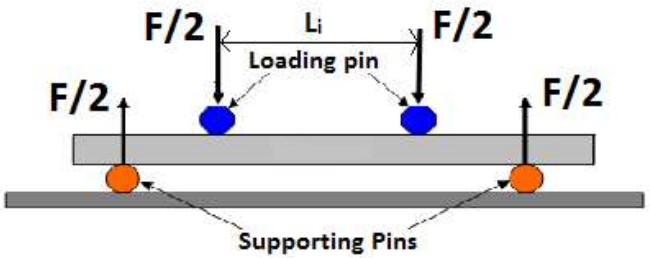
3-point Flexure test



F = Force
b = width of the specimen
L = length
d = thickness

$$\sigma = \frac{3FL}{2bd^2}$$

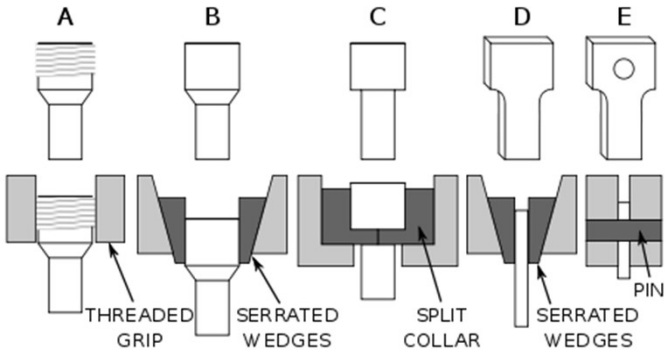
4-point flexure test

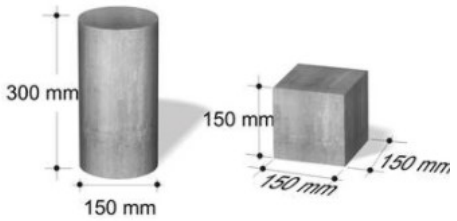


If $L_i = 1/3\ L$ $\quad \sigma = \frac{FL}{bd^2}$

If $L_i = 1/2\ L$ $\quad \sigma = \frac{3FL}{4bd^2}$

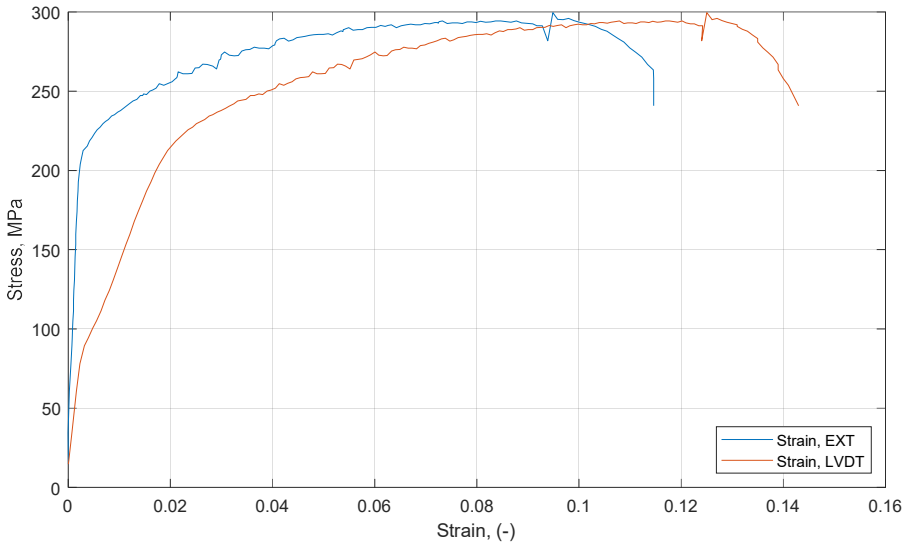
If $L_i = L_i$ $\quad \sigma = \frac{3F(L-L_i)}{2bd^2}$

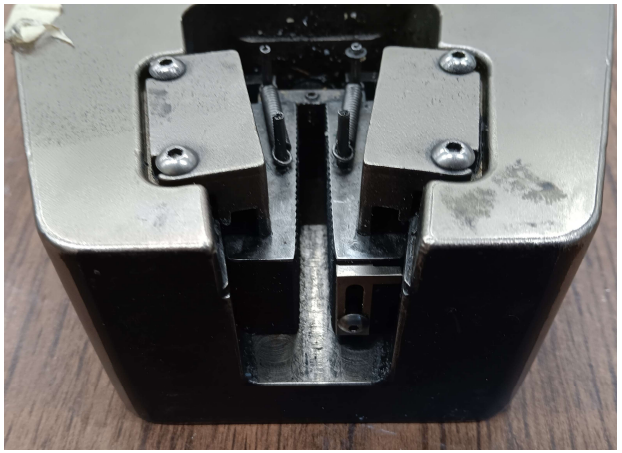


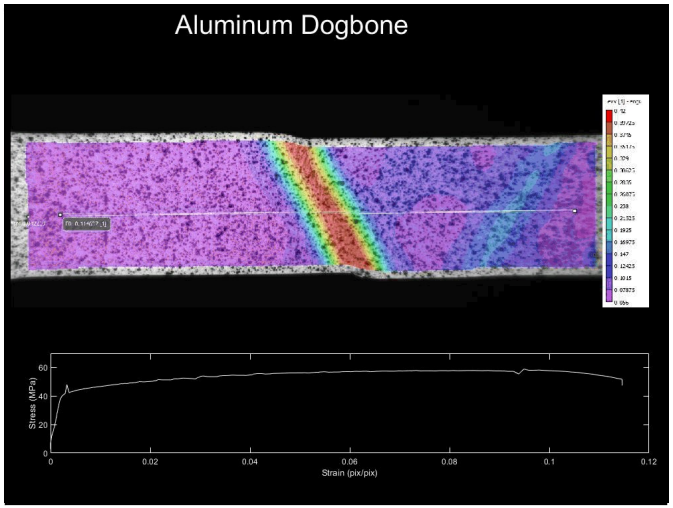


Tensile Test: Aluminum Example

- Test Equipment
  - 2D Digital Image Correlation
  - Electro-mechanical uniaxial machine (30kN max)
    - Mechanical Grips
- Test article
  - Cross section: 1 mm x 10 mm
  - Gage section: 40 mm

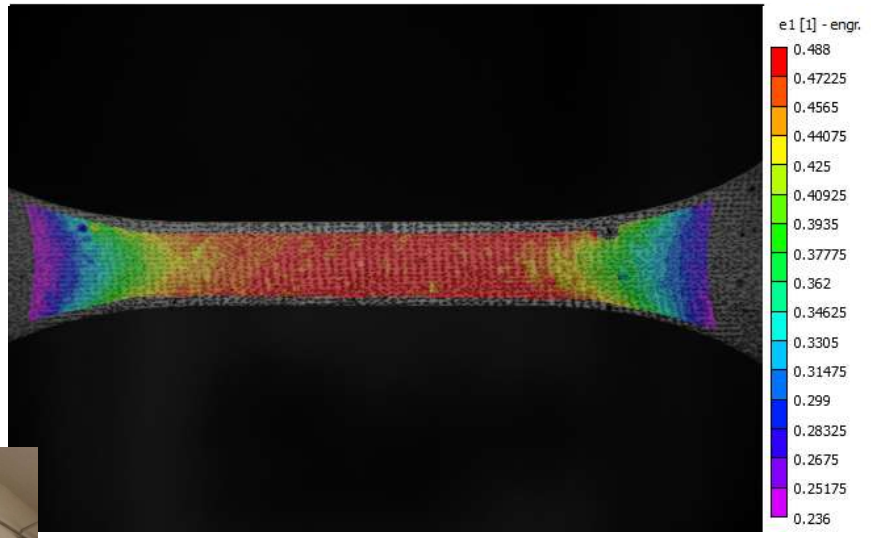


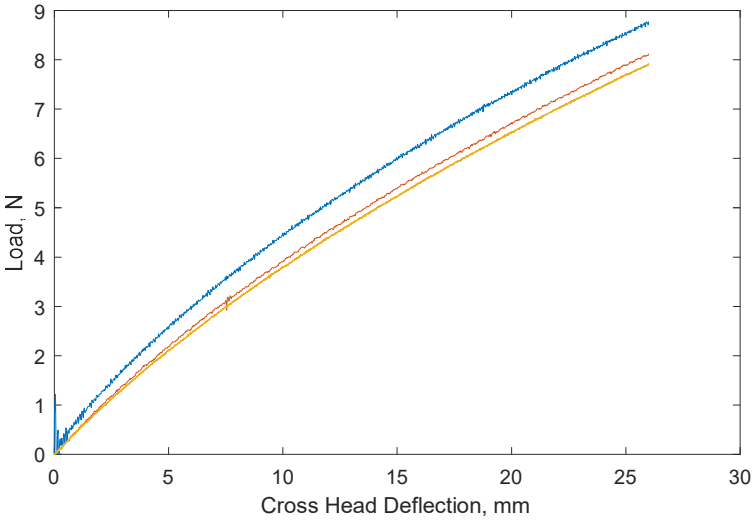


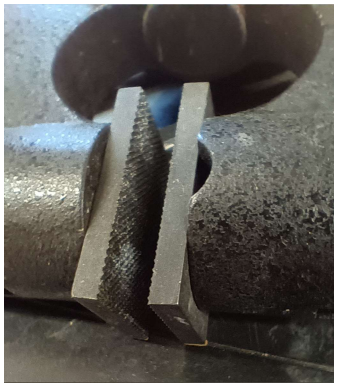


Tensile Test: Elastomer Example

- Test Equipment
  - 2D Digital Image Correlation
  - Electro-mechanical uniaxial machine (5kN max)
    - Pneumatic grips
- Test article
  - Cross section: 3 mm x 15 mm
  - Gage section: 40 mm



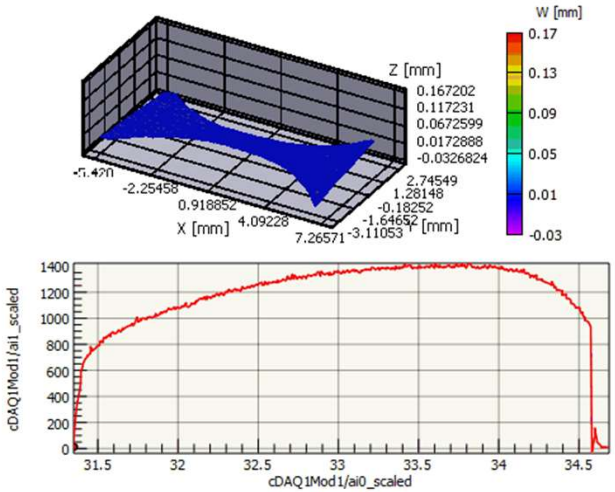




Hard Materials under Tensile Loading

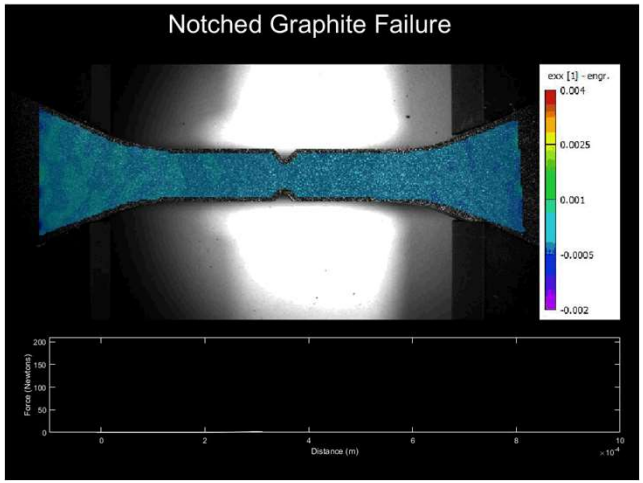
Plasticity Model Calibration

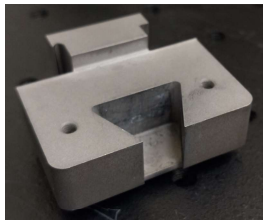
- Prof: John Lambros, PhD
- Student: Samuel Fayad
- Project: Measure high resolution full-field elastoplastic deformation as input for FEM
- Test Equipment
  - 3D Digital Image Correlation
  - Servo-Hydraulic uniaxial machine



Failure in Graphite

- Prof: Francesco Panerai, PhD
- Student: Henry Varona
- Project: Characterize material properties and failure in graphite for applications in Hypersonics
- Test Equipment
  - 2D Digital Image Correlation
  - Electro-mechanical uniaxial machine



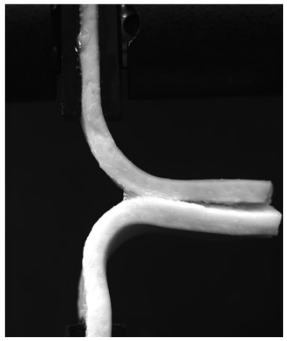


Soft Materials/Structures under Tensile Loading

Adhesion Measurements on Porcine Skin

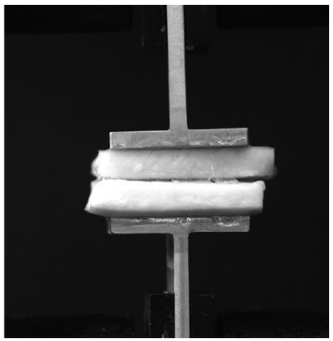
- Prof: **Hua Wang, PhD**
- Student: Joonsu Han
- Project: Analyze adhesion energy of bio-adhesive hydrogel on porcine skin
- Test Equipment
  - Electro-mechanical frame

T peel test (ASTM D1876)



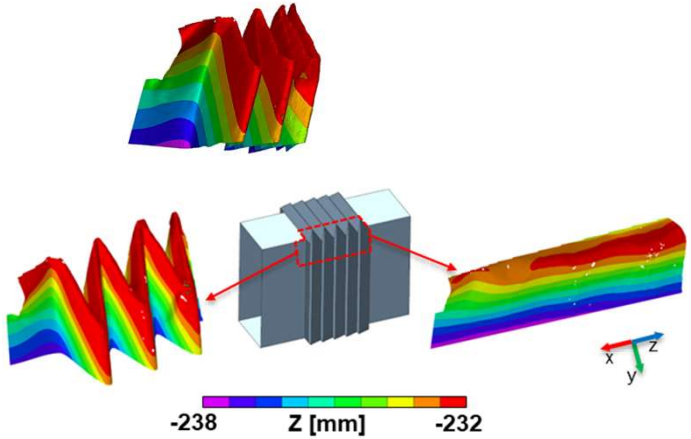
Lap-shear test (ASTM D5868)

Tensile test (ASTM D897)



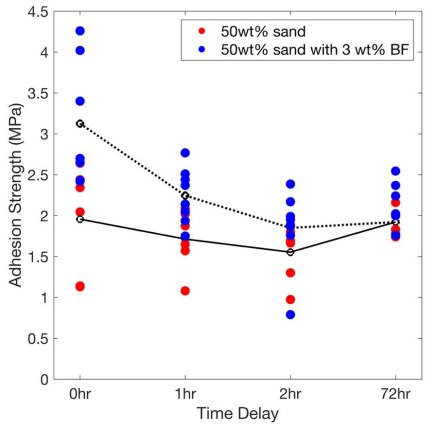
Mechanical Characterization of Origami Bellows

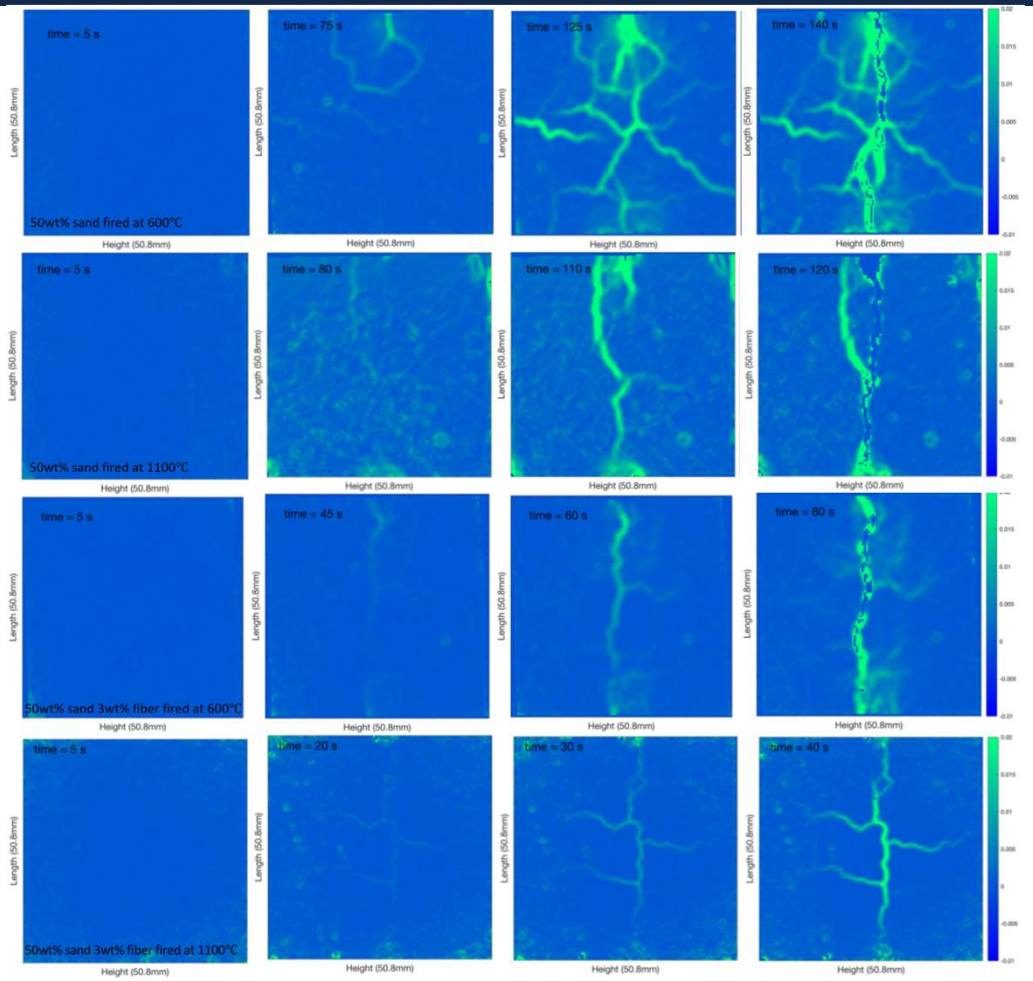
- Prof: **Xin Ning, Ph.D.**
- Student: Nikhil Ashok
- Project: Foldable, Deployable, and Shape-Reconfigurable Origami Electromagnetic Waveguides
- Test Equipment
  - Electromechanical universal testing machine in uniaxial tension
  - Digital Image Correlation
    - 3D – Two cameras – Coordinate map



Splitting of Geopolymer

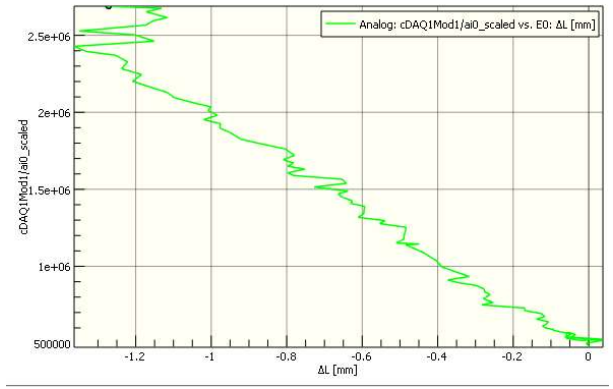
- Prof: **Waltraud M. Kriven, PhD**
- Student: Ally Brandvold
- Project: Investigation of adhesion strength between 3D printed layers of chopped basalt fiber-reinforced geopolymer, via tensile splitting
- Test Equipment
  - Universal mechanical testing instrument (Alliance RT/30)
  - Digital Image Correlation
    - 2D – single camera – Von mises strain map

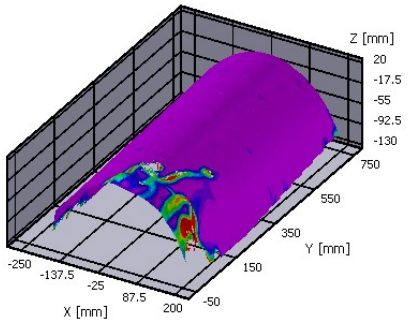


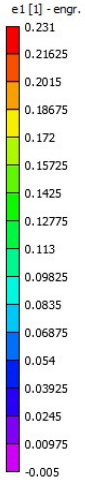


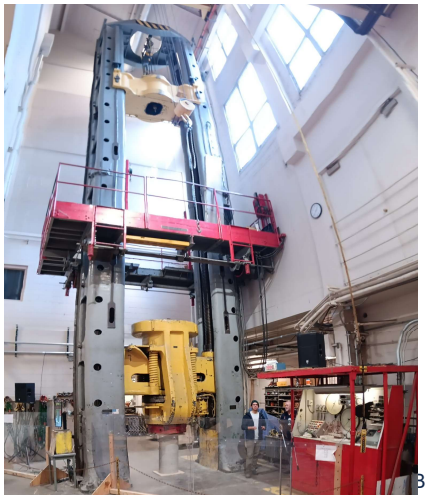
Large Scale Compression

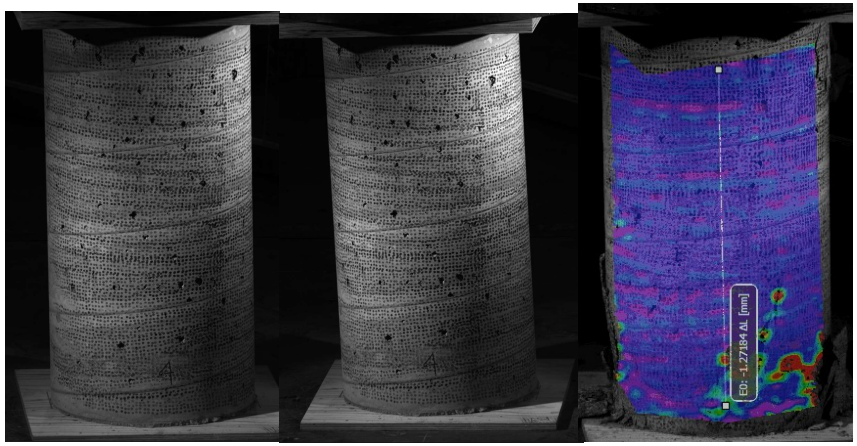
- Test Equipment
  - Engineering Open House Demonstration
  - Stereo Digital Image Correlation
  - Servo-hydraulic uniaxial machine (13MN max)
    - Compression Platons
- Test article
  - Cross section: 600 mm diameter
  - Height: 1 m
- Test Results
  - Max deflection: 1.27 mm
  - Max load: 12MN





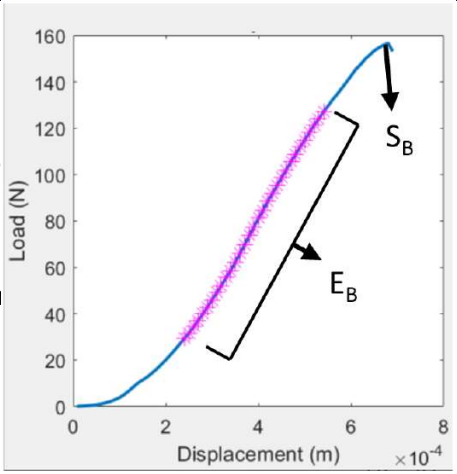


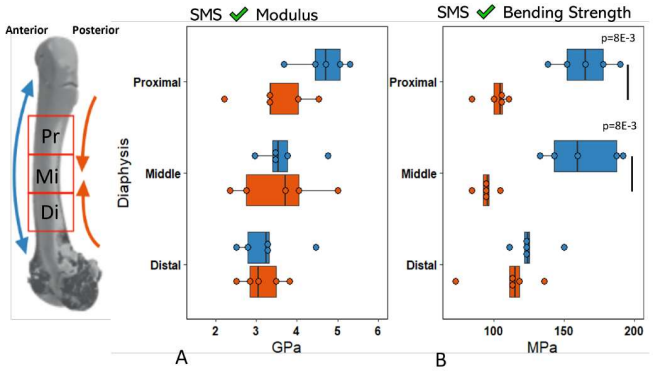


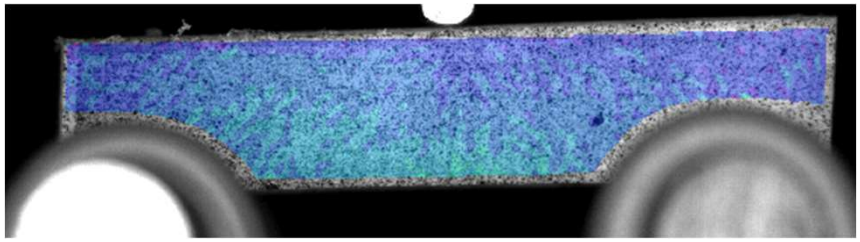


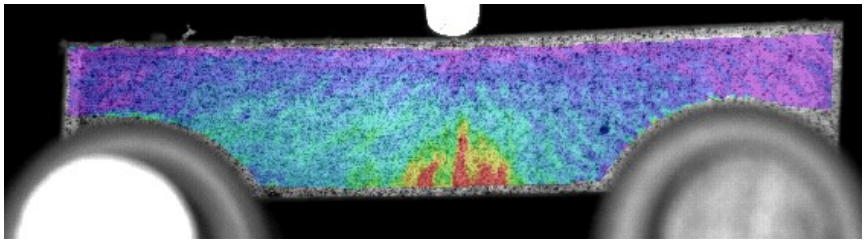
Bending of Sheep Bone

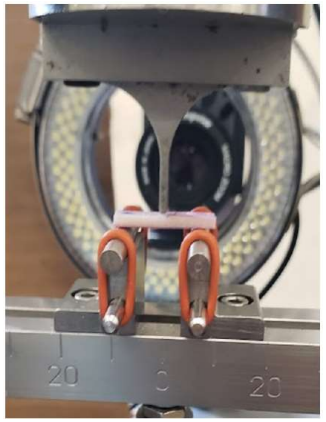
- Prof: Mariana E. Kersh, PhD
- Student: Sony Manandhar
- Project: Examining material properties of different s of sheep femurs
- Test Equipment
  - Electromechanical universal testing machine in Compression
  - Digital Image Correlation
    - 2D – single camera

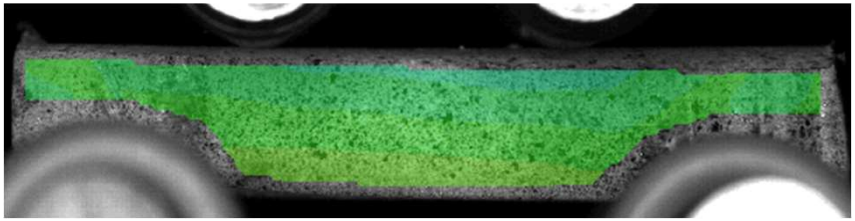


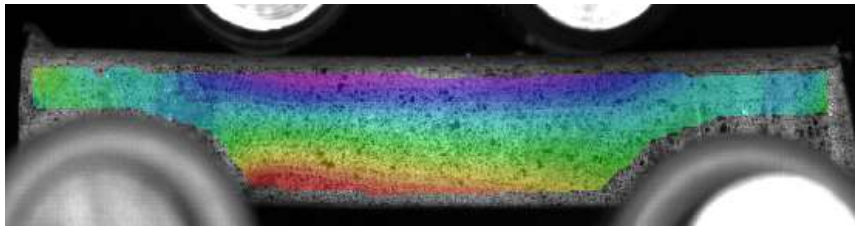






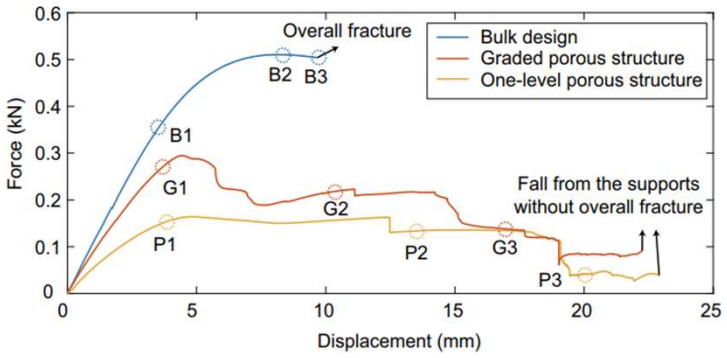


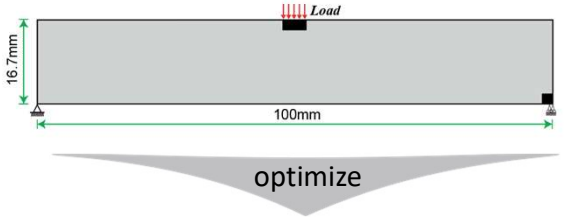




Bending of Graded Polymer Porous Structures

- Prof: **X. Shelly Zhang, PhD**
- Student: Zhi Zhao
- Project: Experimentally investigate the failure modes of topology-optimized graded porous structures, comparing them to bulk and one-level porous structures [1]
- Test Equipment
  - Electromechanical universal testing machine in 3 point bending

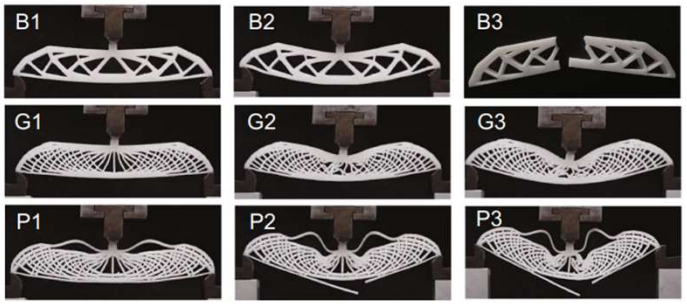


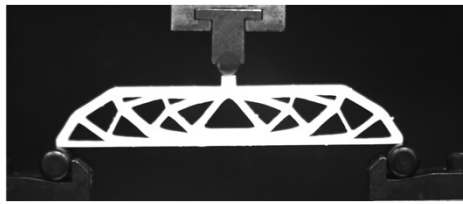


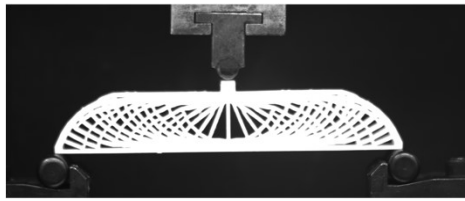
Bulk

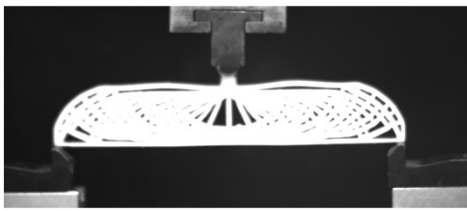
Graded porous

One-level porous



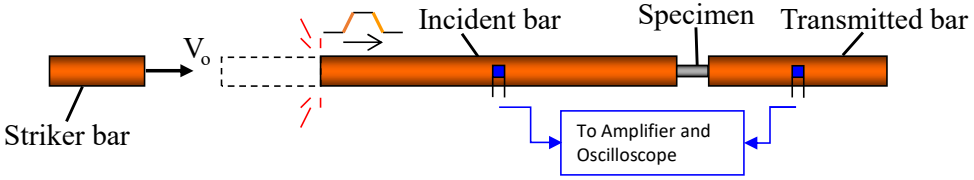


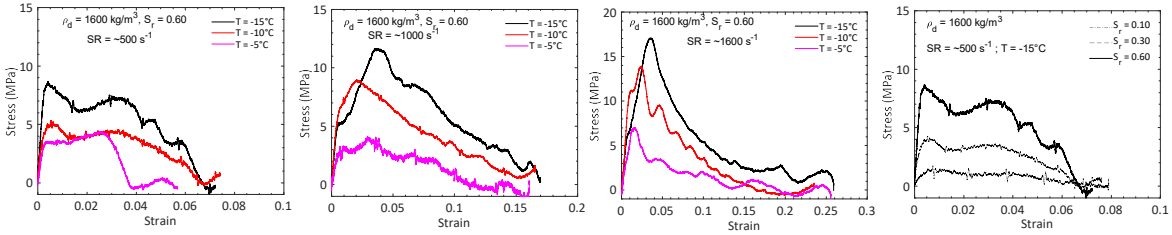


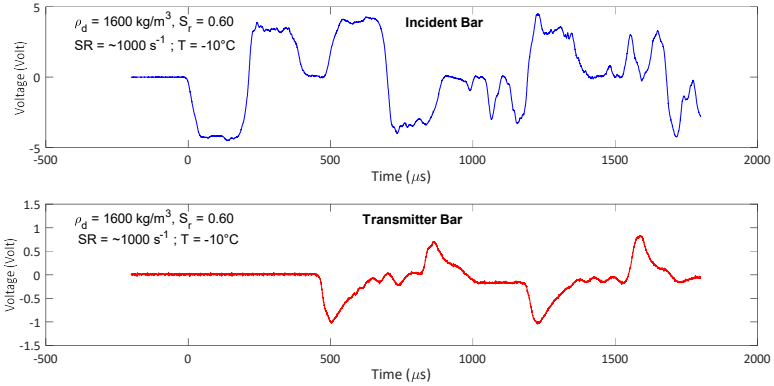


High Strain Rate – Split-Hopkinson Bar

- High strain rate material properties
  - Maximum rates
    - Electromechanical – 1 mm/s
    - Servo Hydraulic – 50-100 mm/s
    - SH Bar – 10^4 m/s

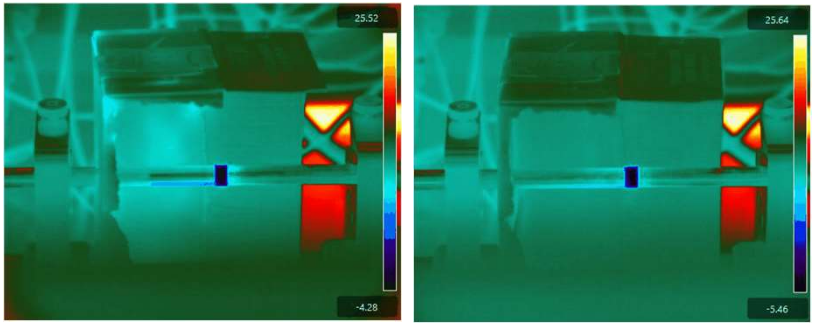


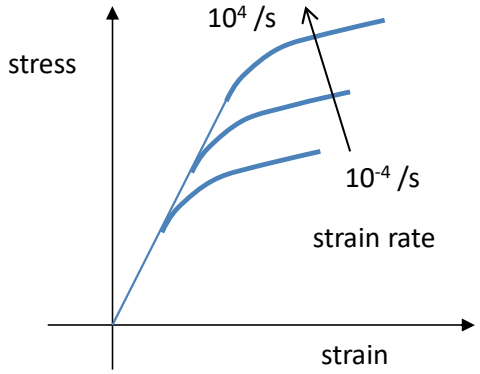




Stress vs Strain curves at different strain rates under various thermal conditions for frozen sand at specific initial degrees of saturation

Prof: Tugce Baser, PhD
Student: Cocou Davis





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