Analysis of PVC Foam and Carbon Nanofiber Syntactic Foam

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Innovation in Micro and Nano Composites

NYU-poly
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NATIONAL SCIENCE FOUNDATION

Objective

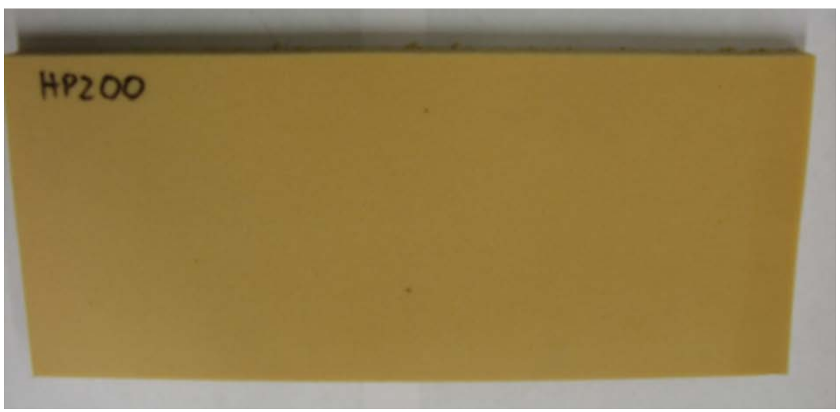
- Study, analyze and compare:
  - **PVC foams**
  - **Syntactic foams with 1% Carbon nanofiber**

- Test all materials using *both* static and dynamic tests

- Compare the **yield strength**, **plateau strength**, and **elastic modulus** across each foam type and experiment type.

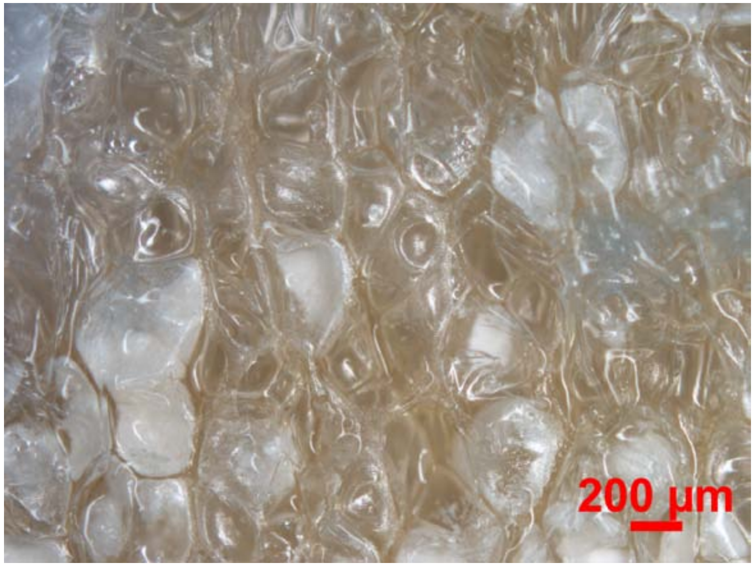
- To convey test methods, instrumentations, and protocols for analysis

Testing and Comparing Two Foam Types

PVC Foam	**1% CNF Syntactic Foam**
	

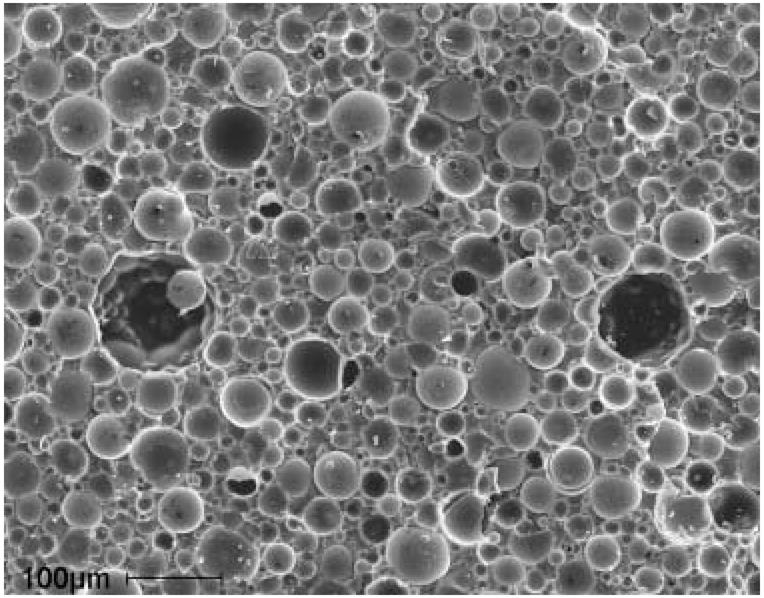
PVC Foam

- Lightweight
- Chemically-resistant; easy to clean
- Does not absorb water
- Can be stapled and screwed into; ideal for marine upholstery and structural applications
- Forms, cuts and glues easily
- Excellent insulator
- Weathers well

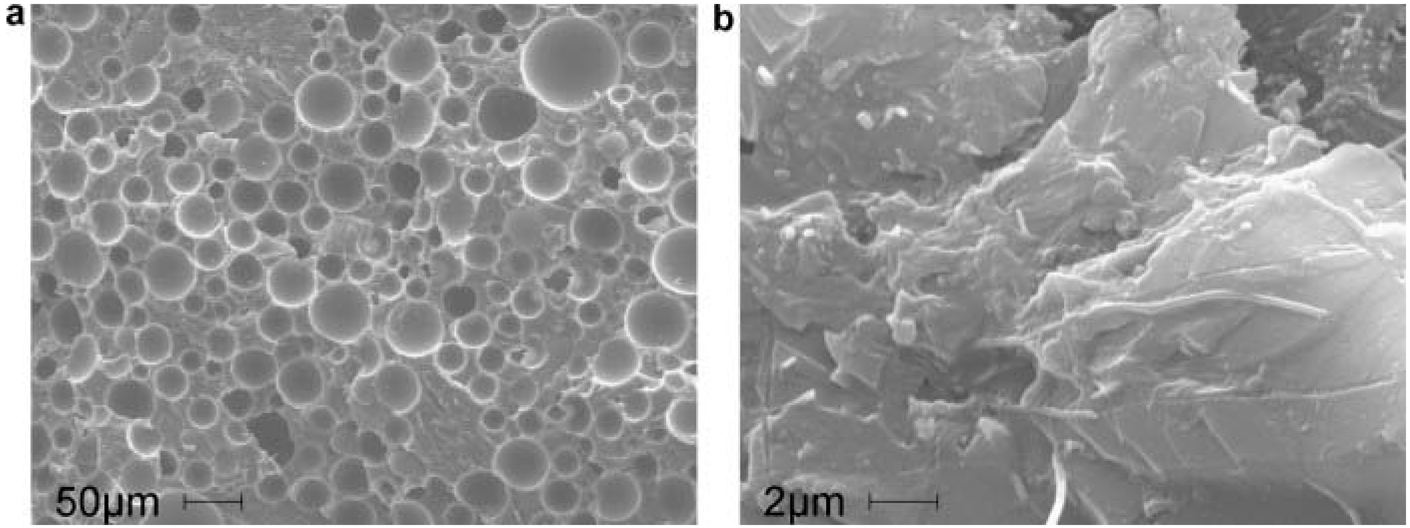


Syntactic Foam

- Porous composite materials
- Hollow glass microballoons mixed with a hardening agent
- High elastic modulus, strength, and energy absorption
- Low moisture absorption
- Strength, lightweight, and energy absorption lead syntactic foams to applications in aerospace and marine vehicles

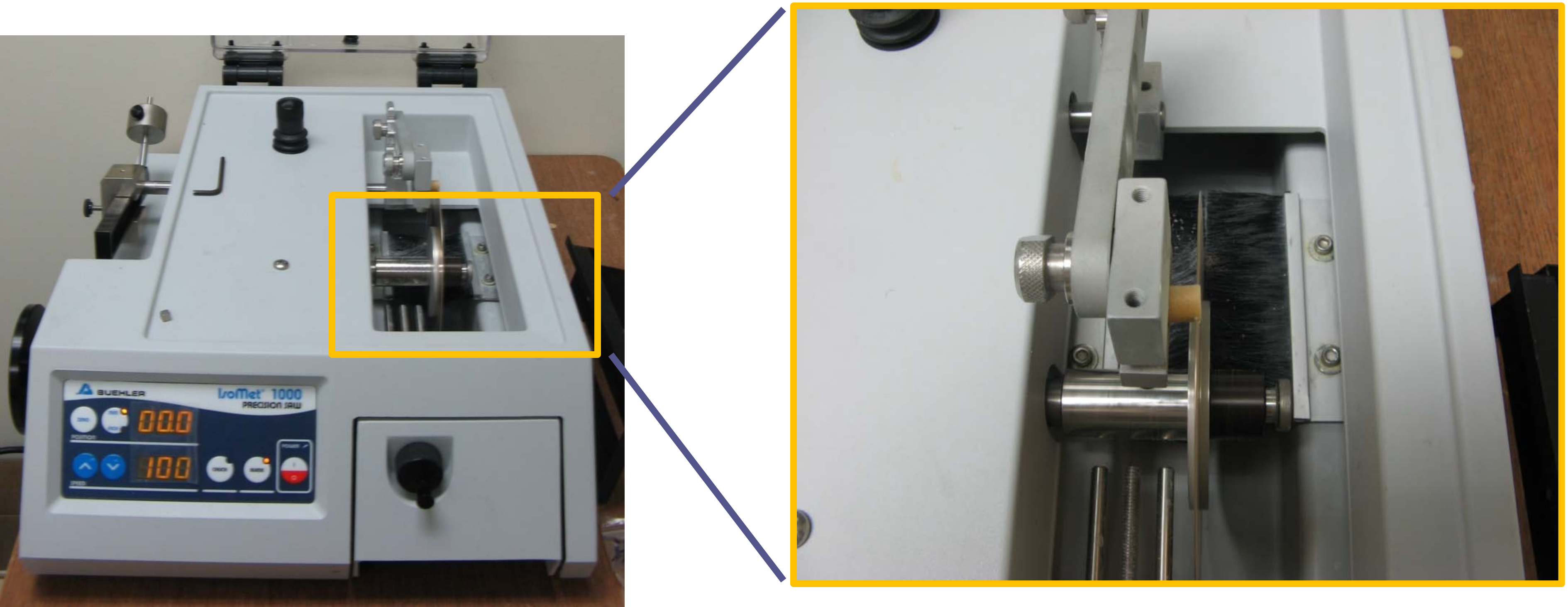


1% Carbon Nanofiber Syntactic Foam



- For this study, carbon nanofibers (CNF) were added to the syntactic foam mixture during production
- CNFs have high strength and modulus
- This study will analyze whether the addition of CNFs will improve the strength of syntactic foams

Specimen Preparation



Test Specimens

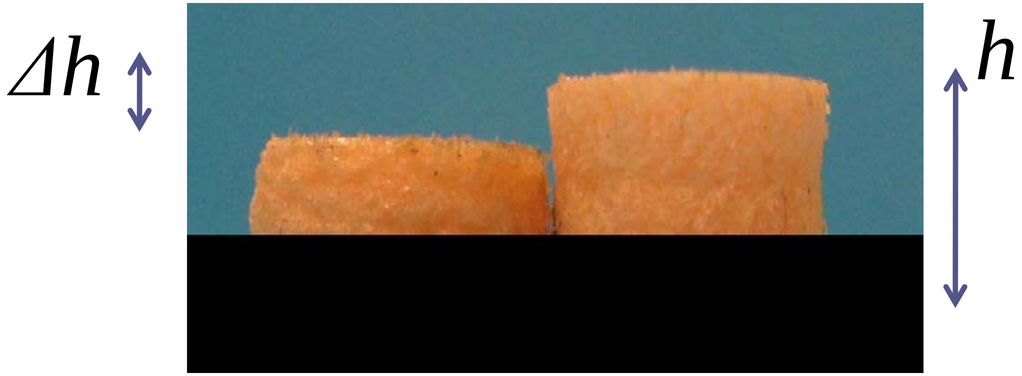
PVC Foam

Carbon Nanofiber Syntactic Foam

Strain and Strain Rate

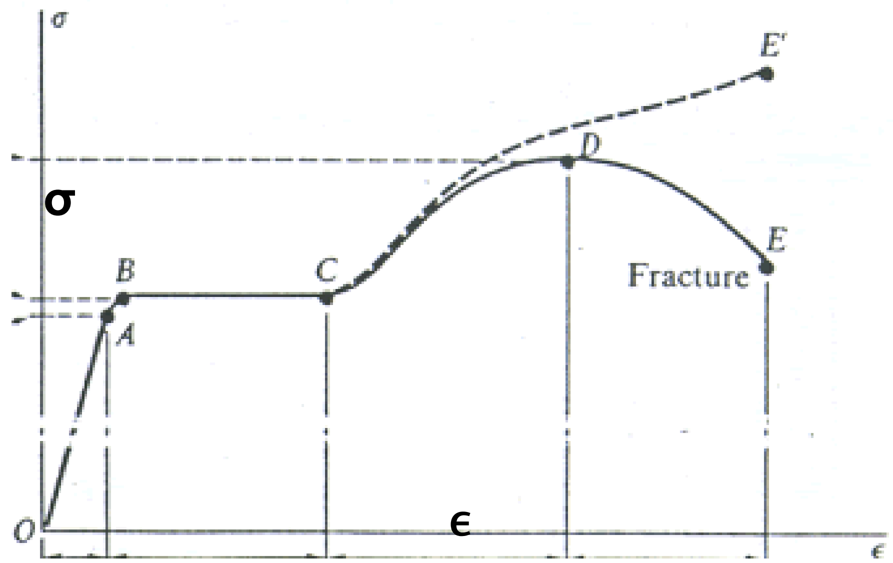
- **Strain** is defined as the ratio of change in the length of a mechanical test sample
- **Strain rate (/s)** is defined as the rate of change of strain with respect to time, ***t***.

$$\varepsilon = \frac{\Delta h}{h}$$



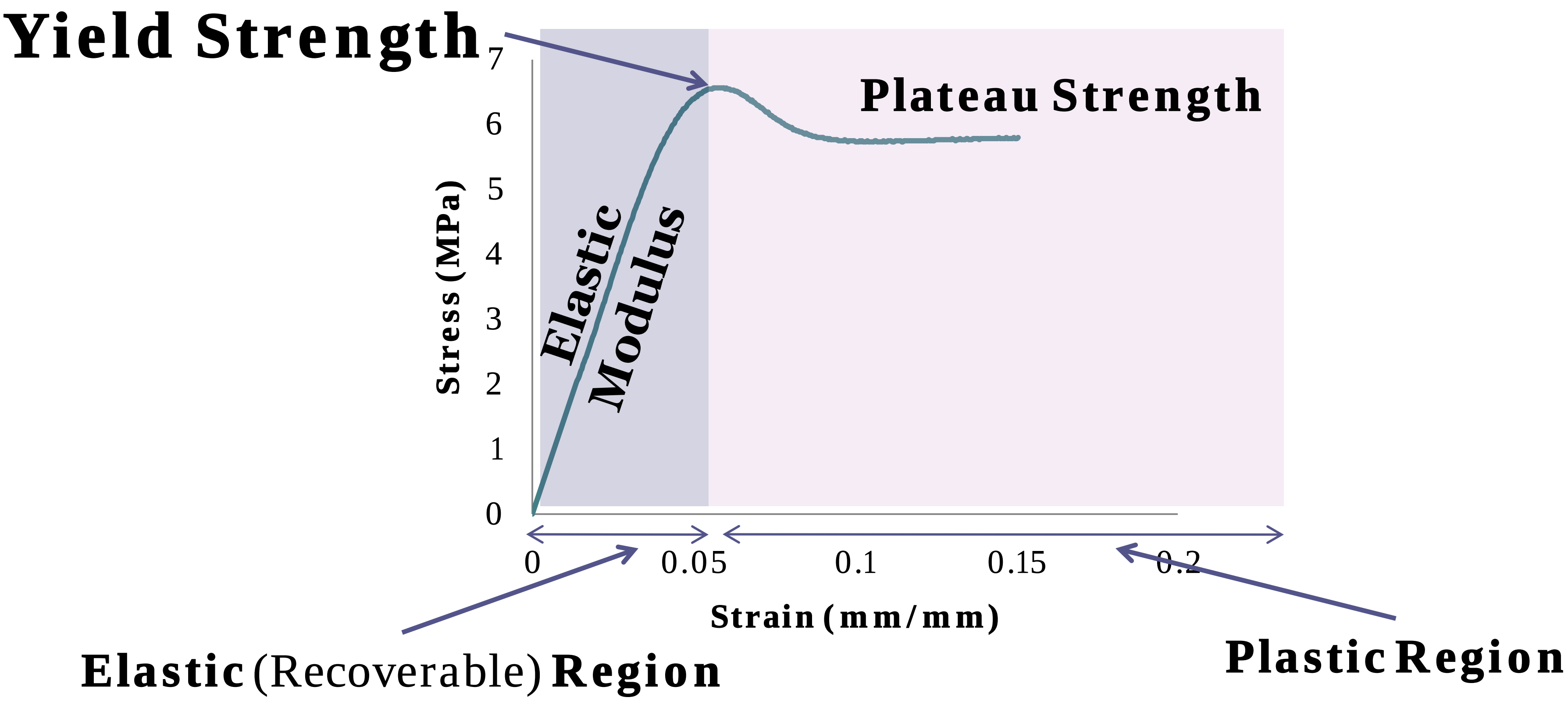
Modulus of Elasticity

- The ratio of stress to strain (the measure of resistance to elastic deformation).
- **Stress** is a measure of the average force per unit area.
- **E = Elastic Modulus = stress / strain**
- Units:
  - Elastic Modulus (Pa)
  - σ: Stress (Pa)
  - ϵ: Strain (mm / mm)



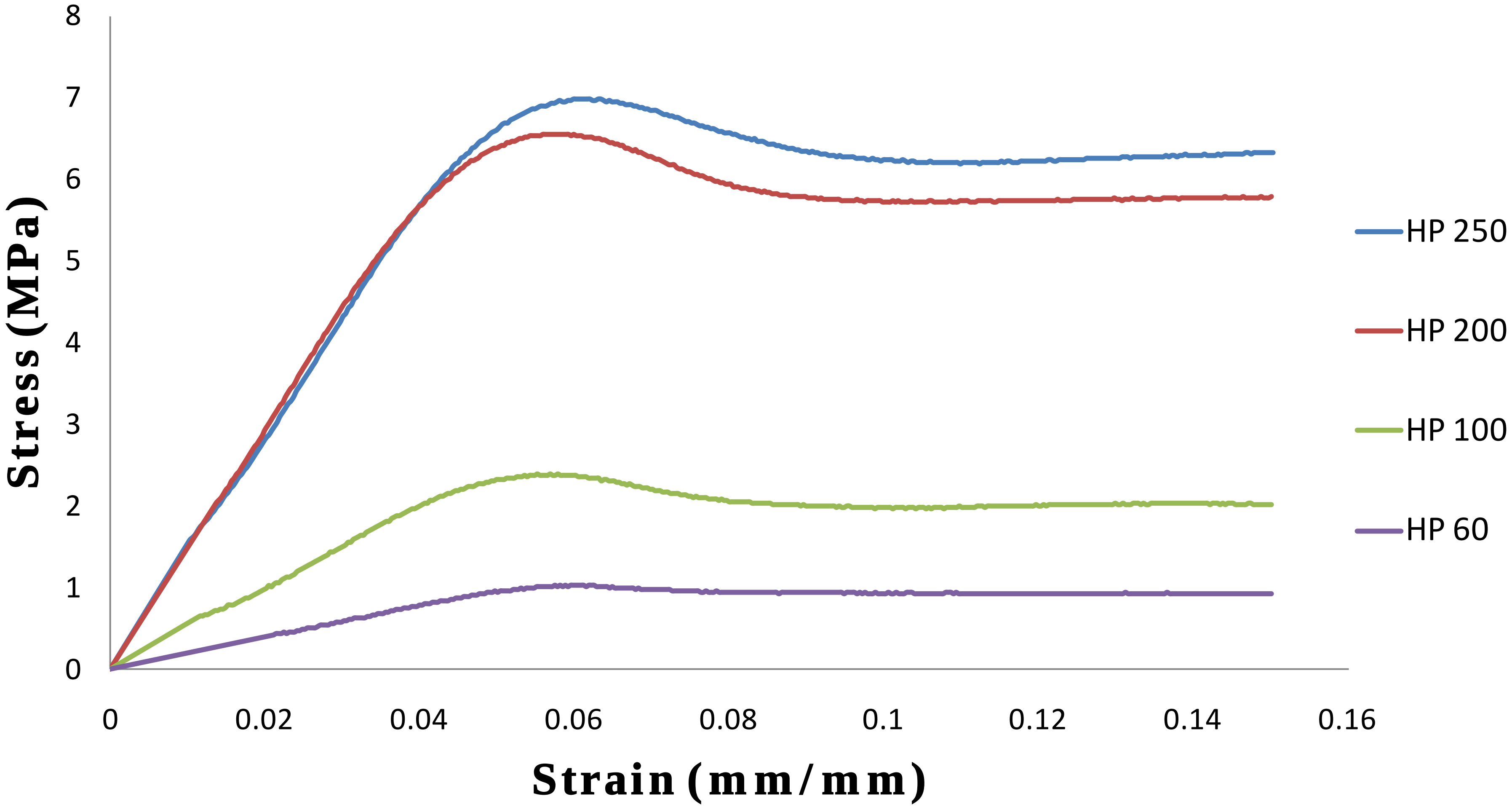
Yield Strength

- The stress at which material strain changes from elastic deformation to plastic deformation, causing it to deform permanently.

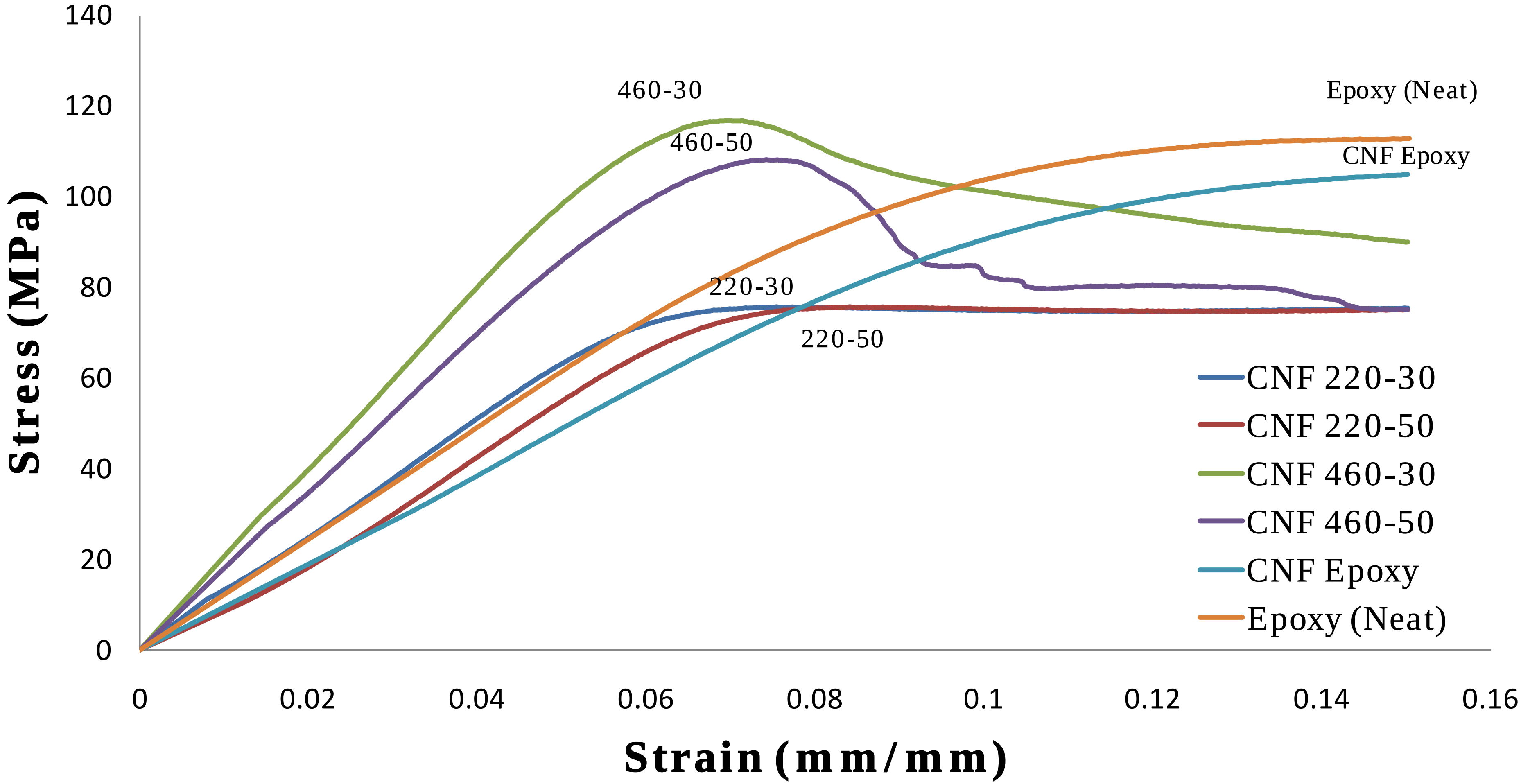


Quasi-Static Compression Testing

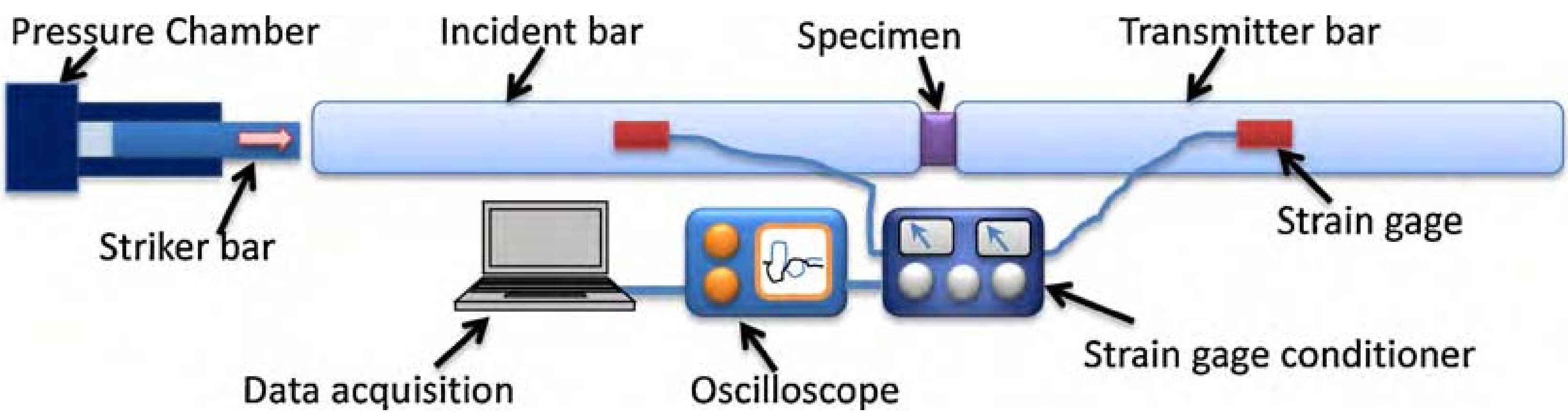
PVC Foam Quasi-Static Comparison



CNF Syntactic Foam Quasi-Static Comparison



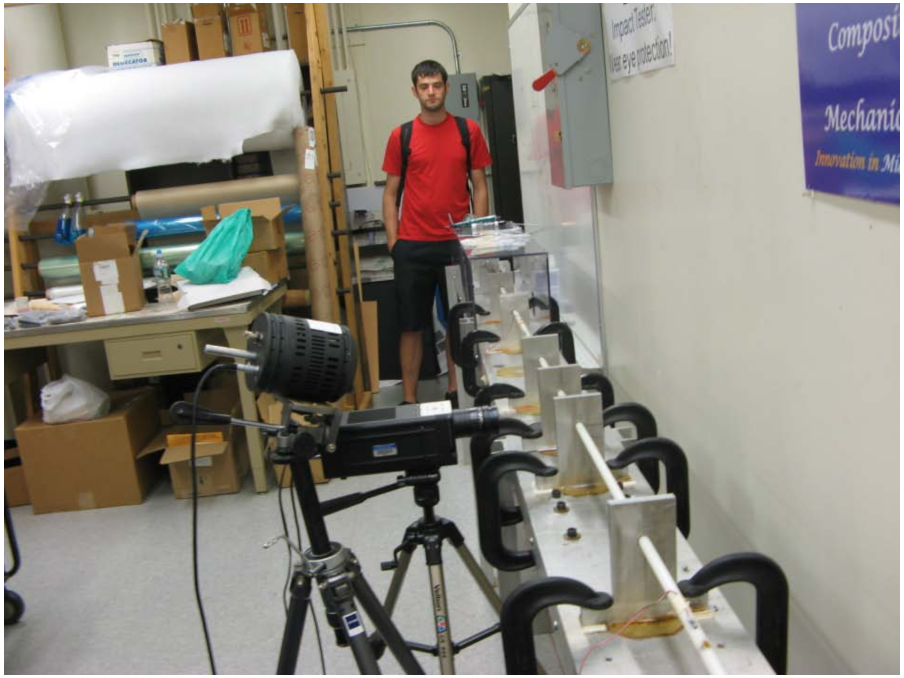
The split-Hopkinson Pressure Bar (SHPB) apparatus used in ***high strain rate*** testing of materials.

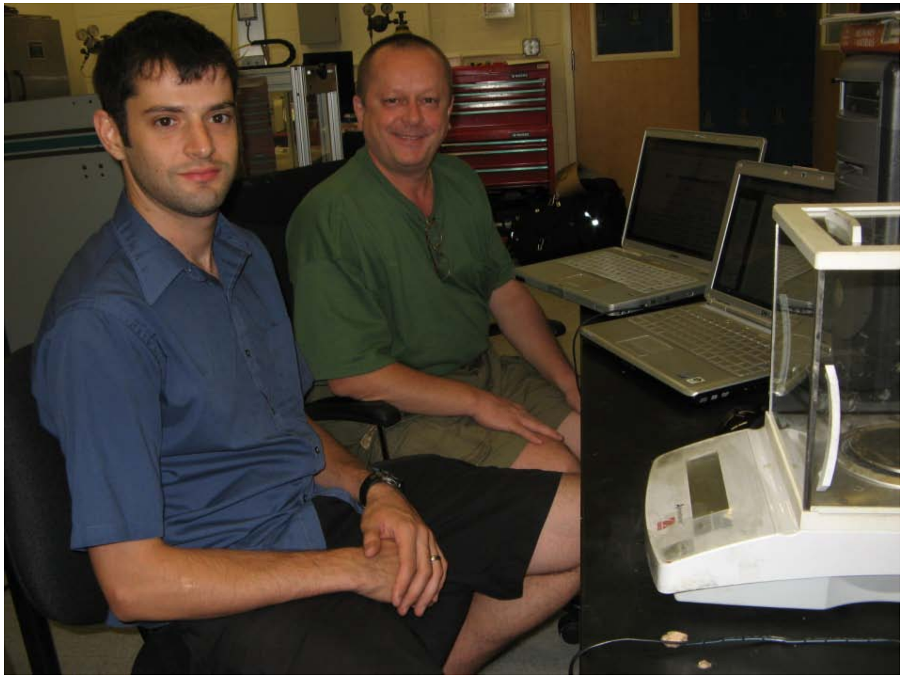


SHPB capable of testing materials in high stress at extremely higher strain rates

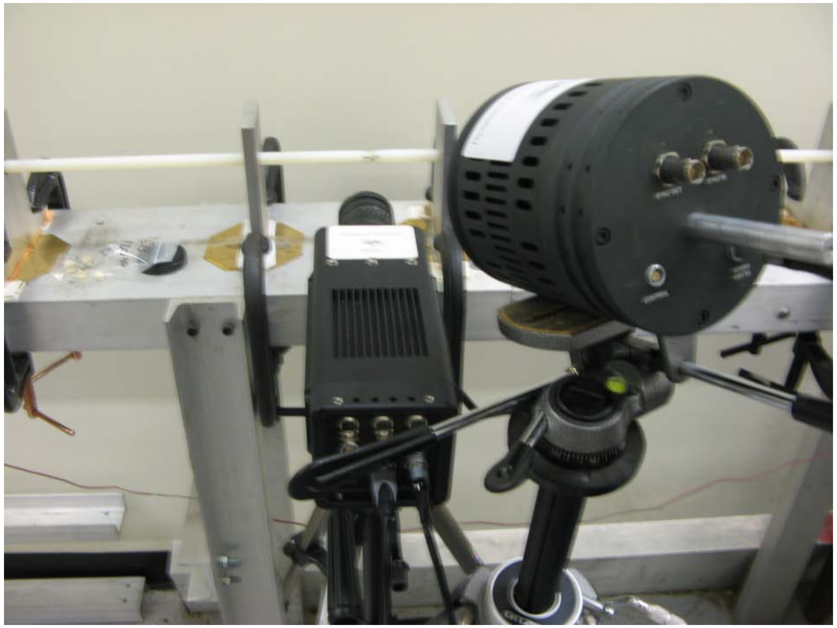
- The split-Hopkinson pressure bar is capable of achieving the highest uniform uniaxial stress loading of a specimen in compression at nominally constant strain rates of the order of 10^3 /s

Split Hopkinson Pressure Bar Setup and Data Acquisition

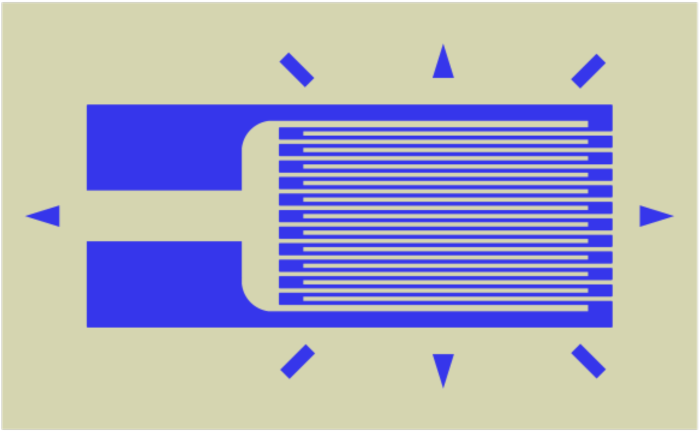


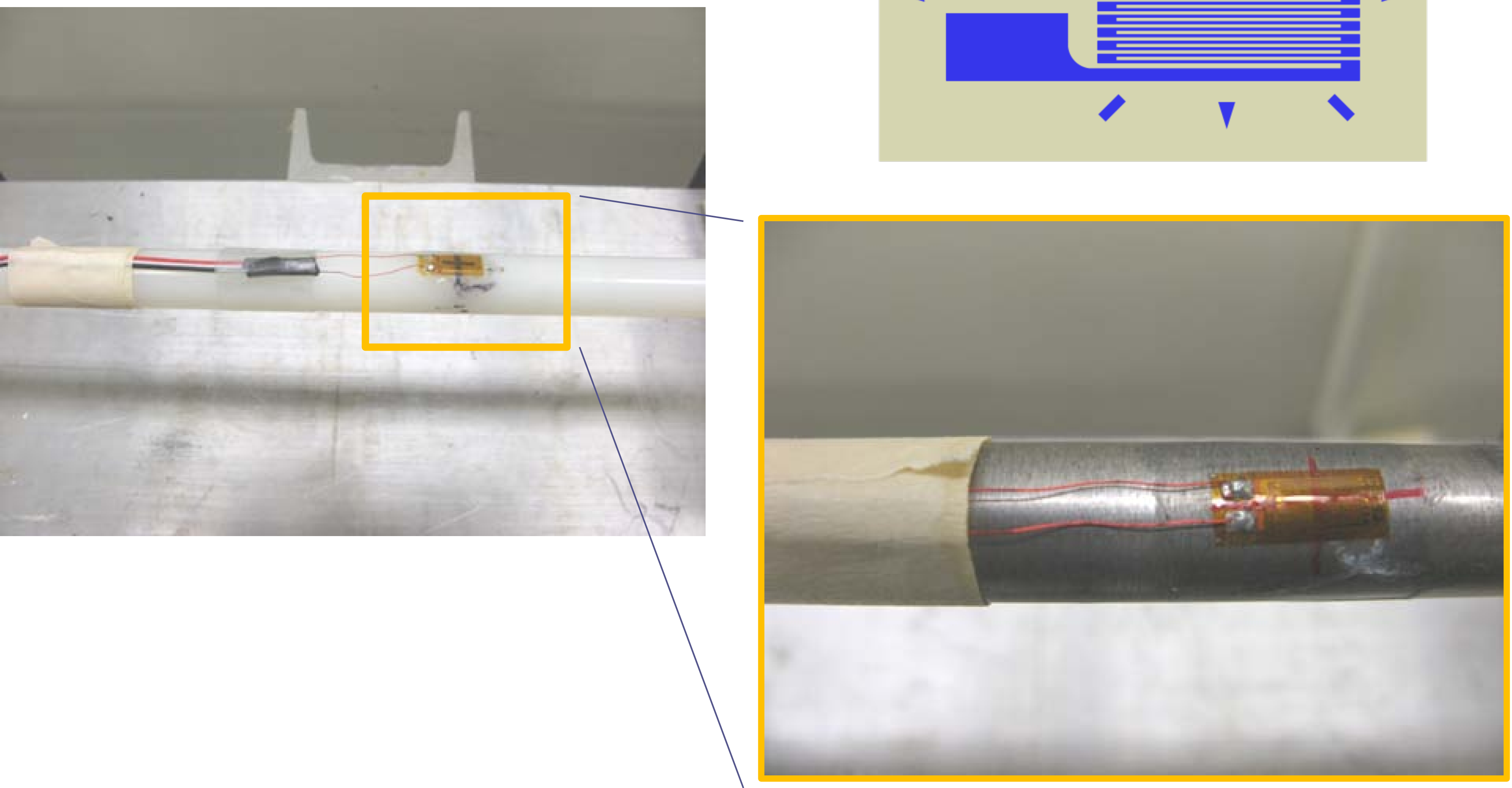


High Speed Image Acquisition System



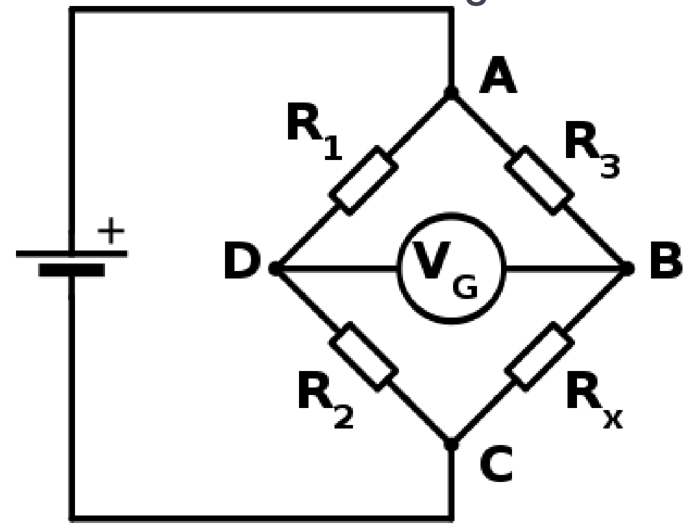
Strain Gauge





Strain Gauge

Wheatstone Bridge



Gauge Factor:

$$GF = \frac{\Delta R / R_G}{\epsilon}$$

- ΔR is the change in resistance due to strain.
- R_G is the resistance of the undeformed gauge.
- ϵ is strain.

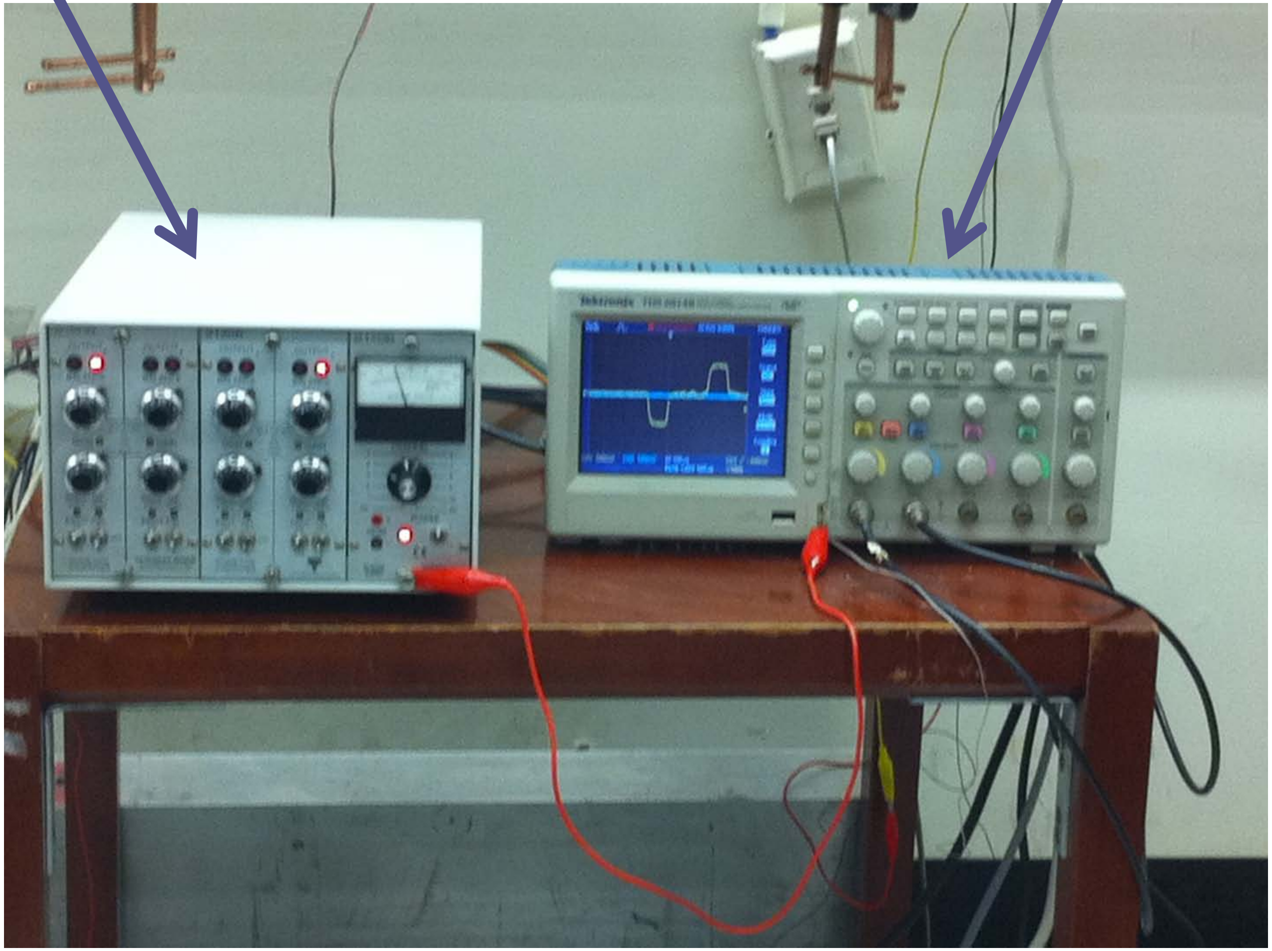
Output (v) from the bridge:

$$v = \frac{BV \cdot GF \cdot \epsilon}{4}$$

- BV is the bridge excitation voltage.

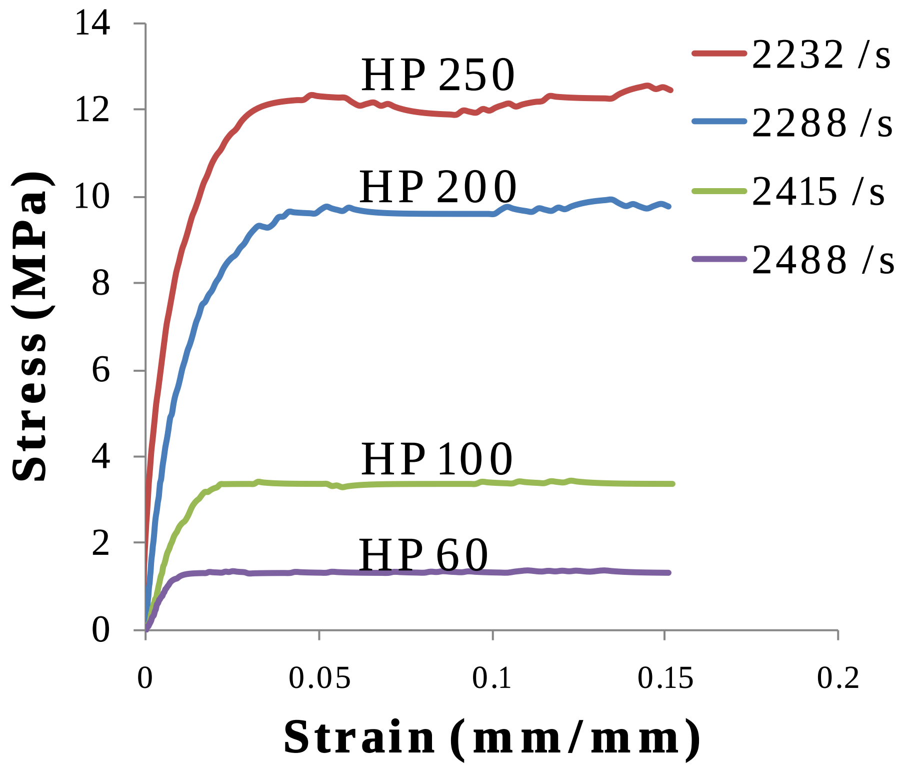
Amplifier

Oscilloscope

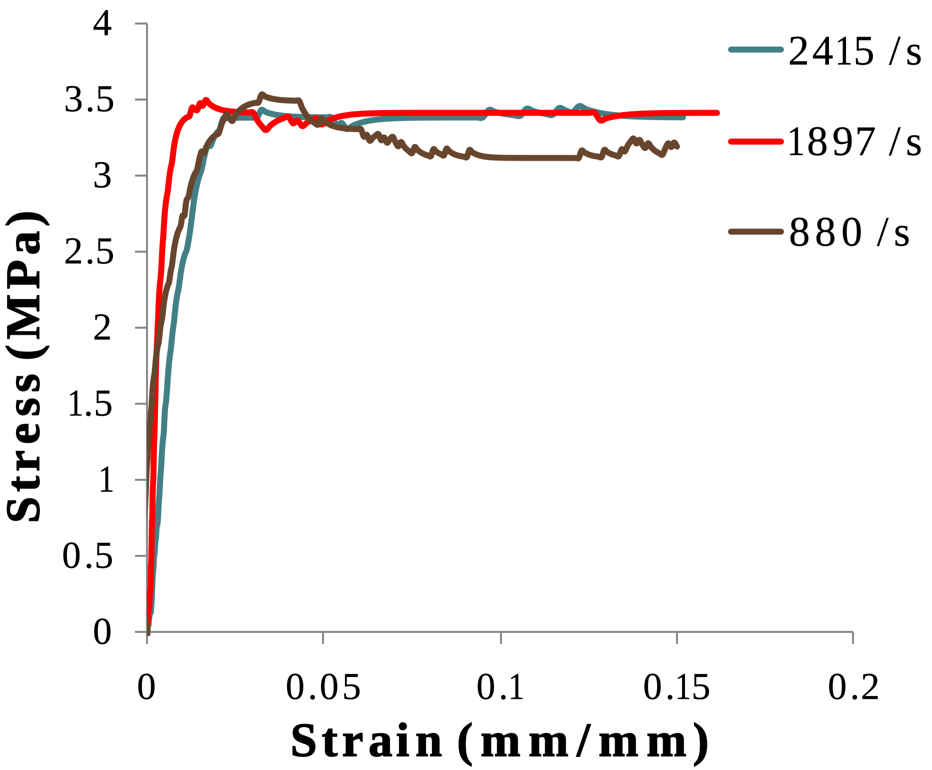


SHPB Dynamic PVC Foam Comparison

High Strain Rate, Varying PVC Foam Densities

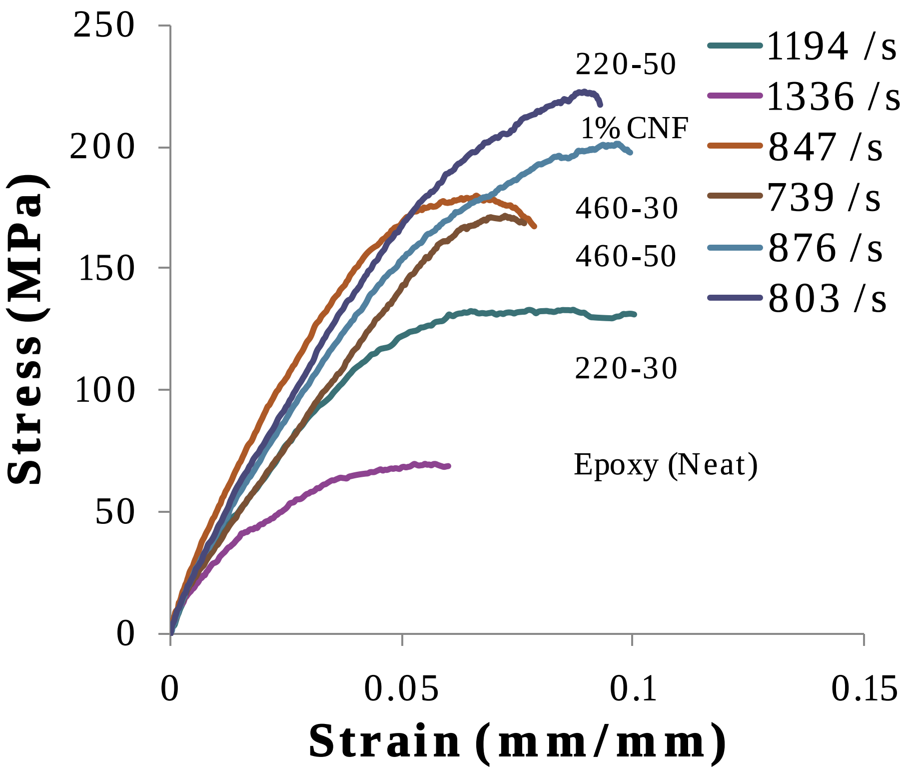


HP 100 PVC Foam at Varying Strain Rates

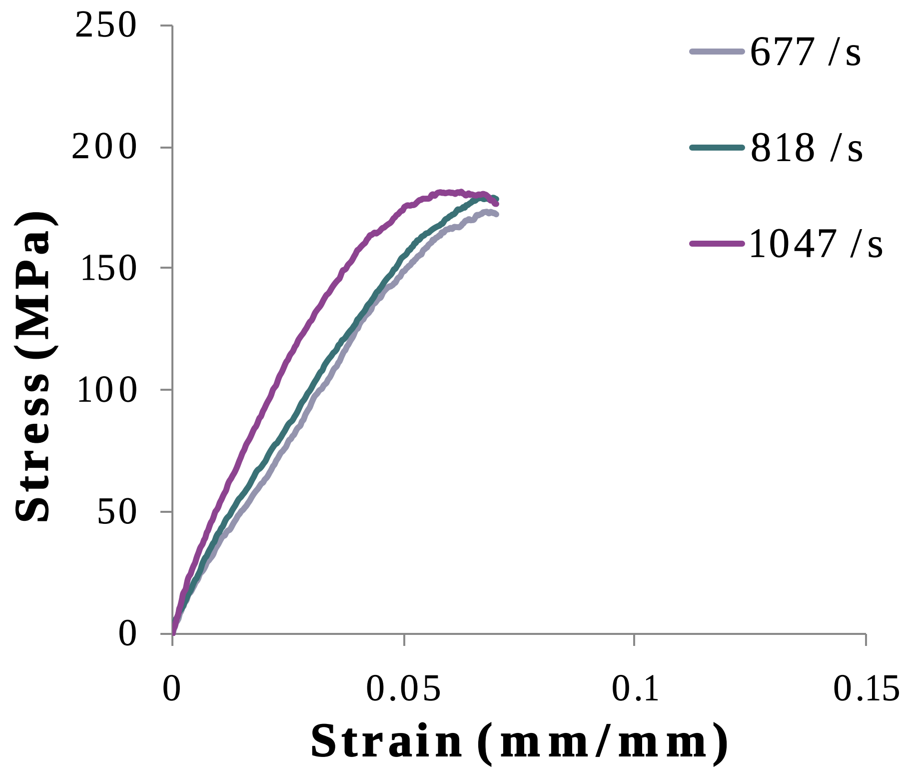


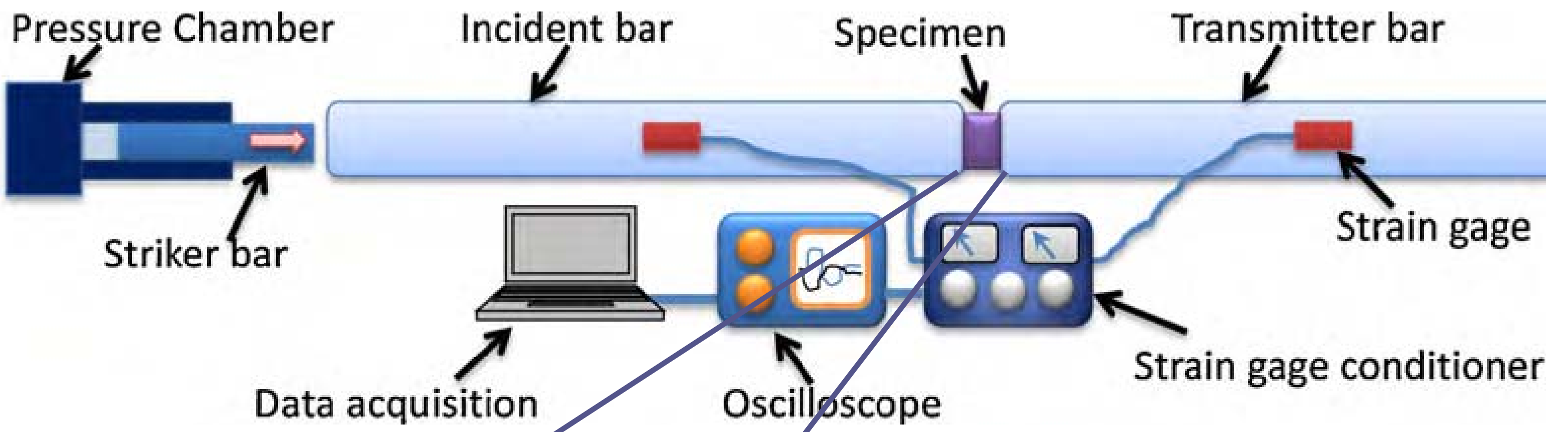
SHPB Dynamic CNF Foam Comparison

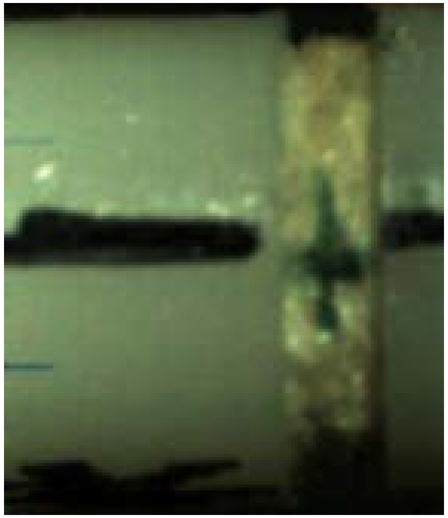
High Strain Rate, Varying CNF Foam

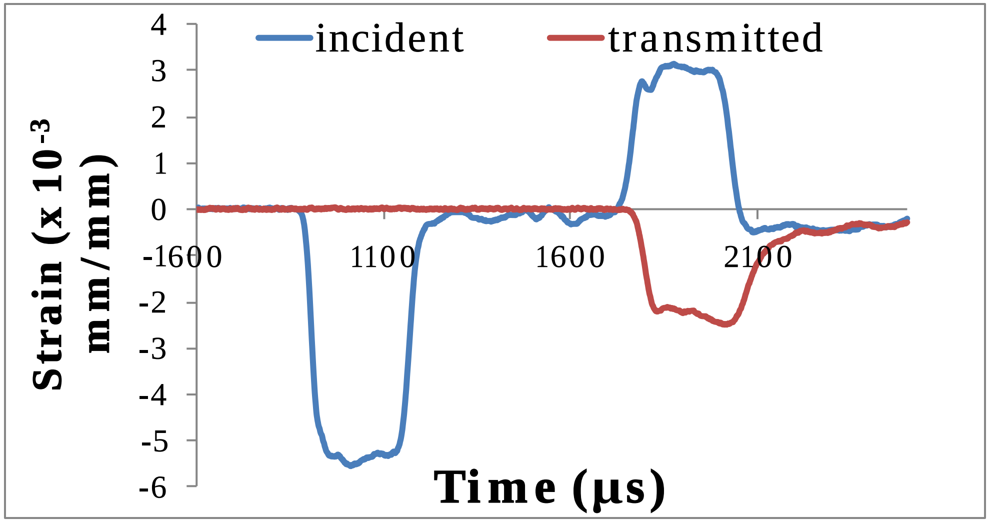


CNF460-30 Foam at Varying Strain Rates

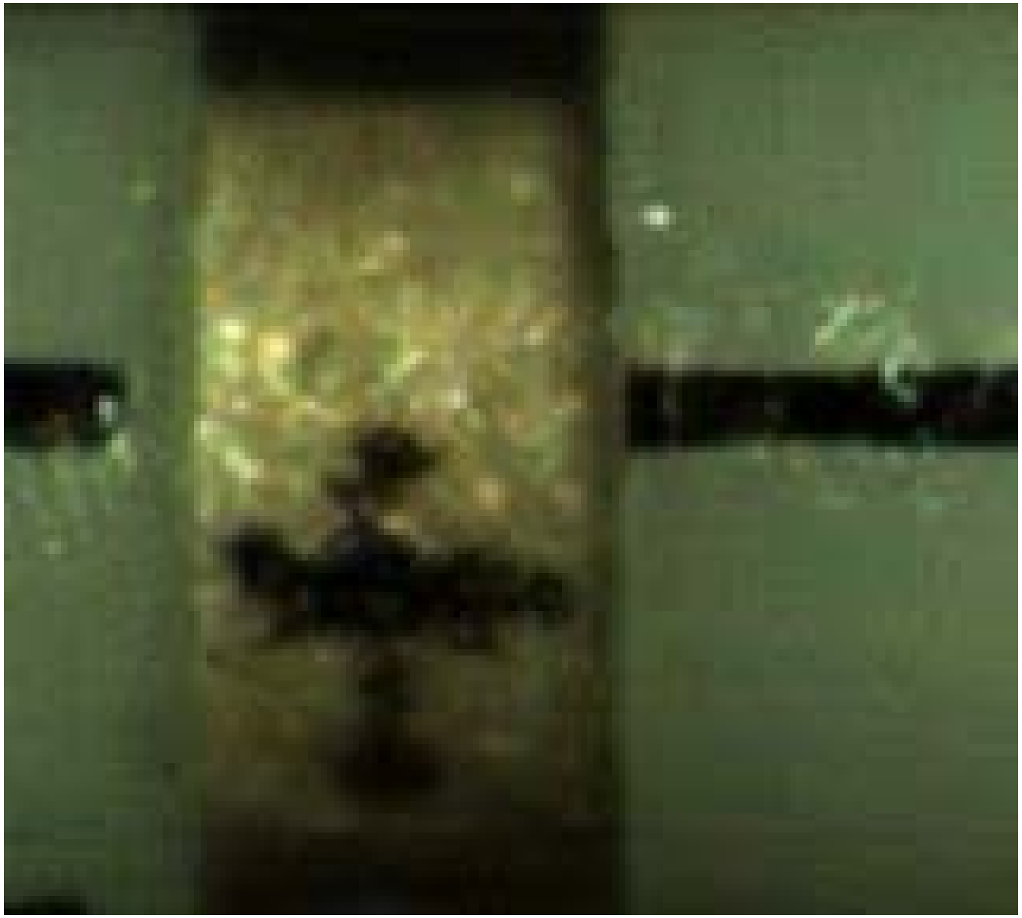



Pressure Chamber
Incident bar
Specimen
Transmitter bar
Striker bar
Strain gage
Data acquisition
Oscilloscope
Strain gage conditioner

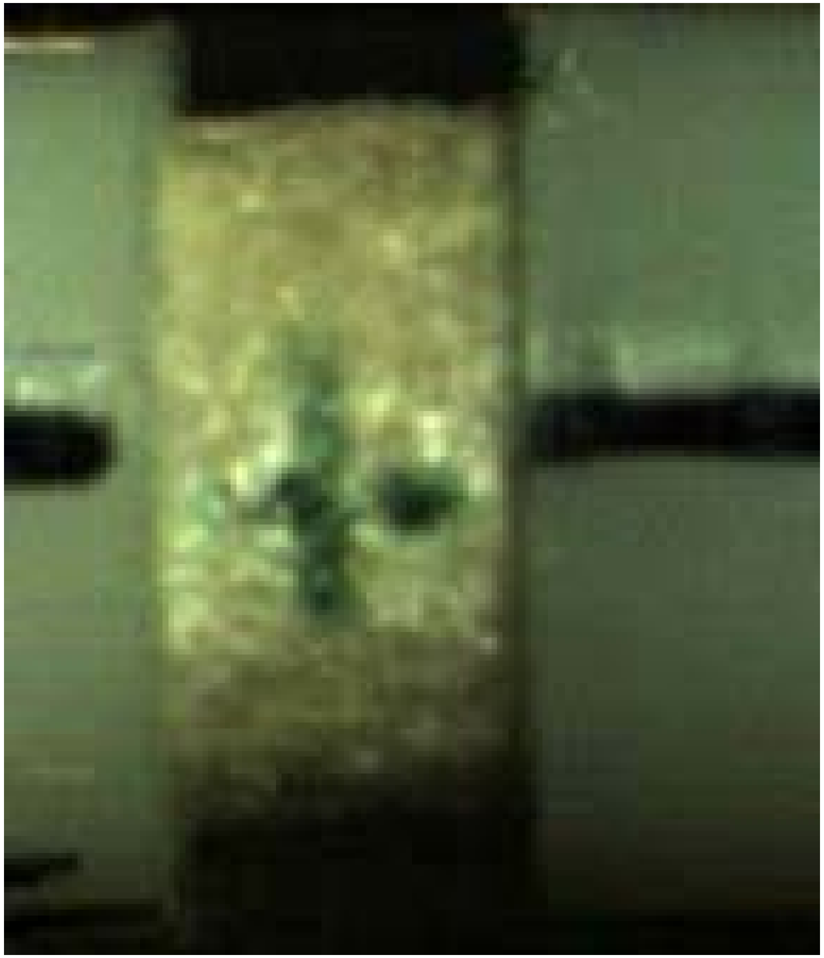



incident
transmitted
Strain (x 10^{-3} mm/mm)
Time (μs)
4
3
2
1
0
-1
-2
-3
-4
-5
-6
600
1100
1600
2100

HP 250, 400 psi, strain rate: 2184 /s

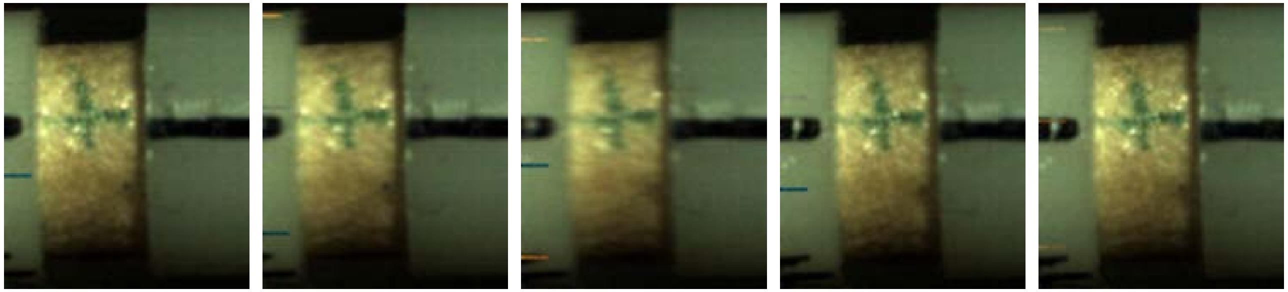


HP 100, 400 psi, strain rate: 2415 /s

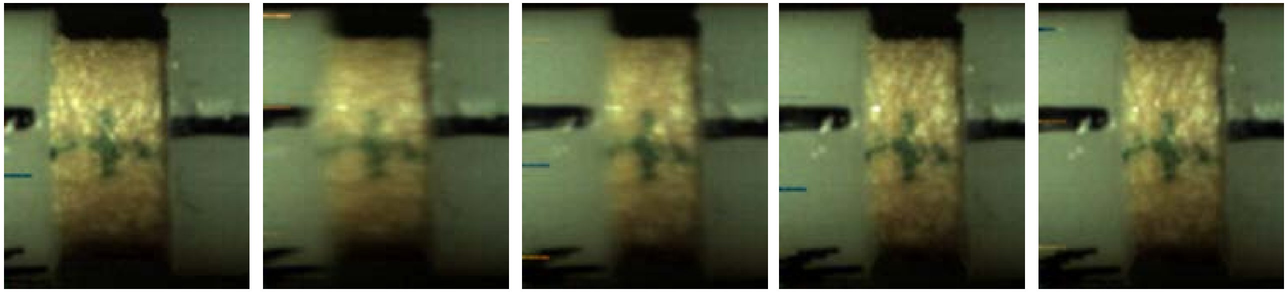


HP 200 PVC Foam

(6269 fps)



(100 psi)



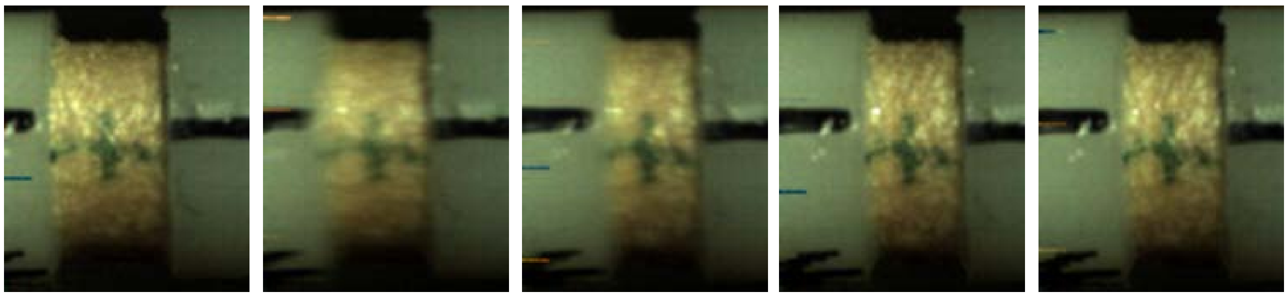
(250 psi)

(400 psi)

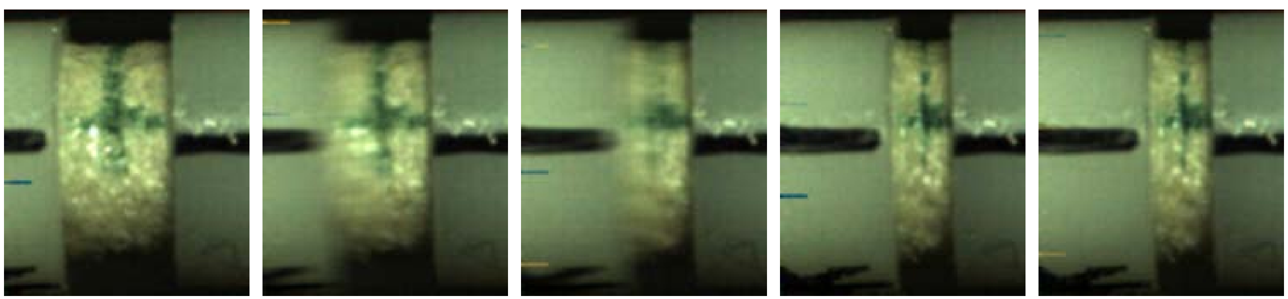
HP 200 vs. HP 60 PVC Foam

250 pounds per square inch

6269 frames per second



HP 200



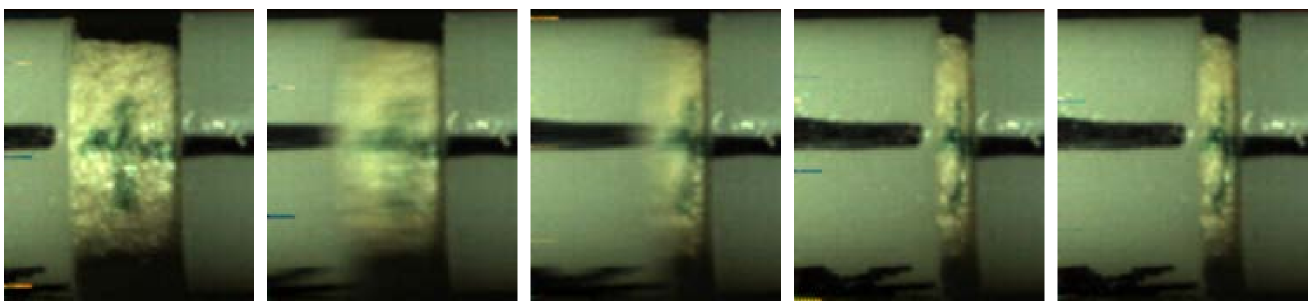
HP 60

HP 200 vs. HP 60 PVC Foam

400 pounds per square inch

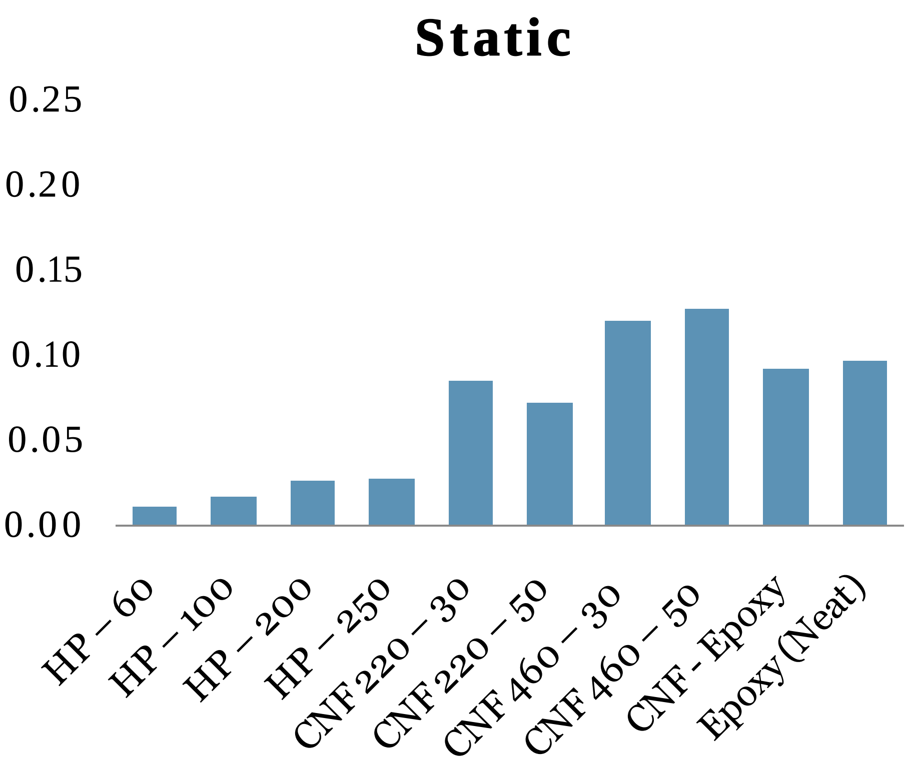
6269 frames per second

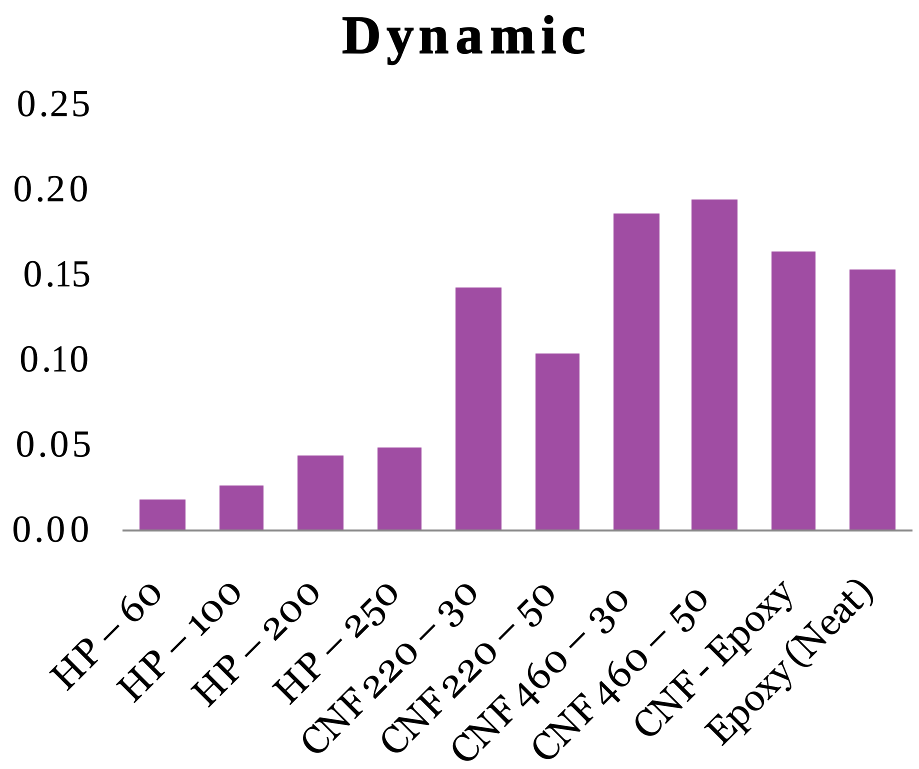
HP 200



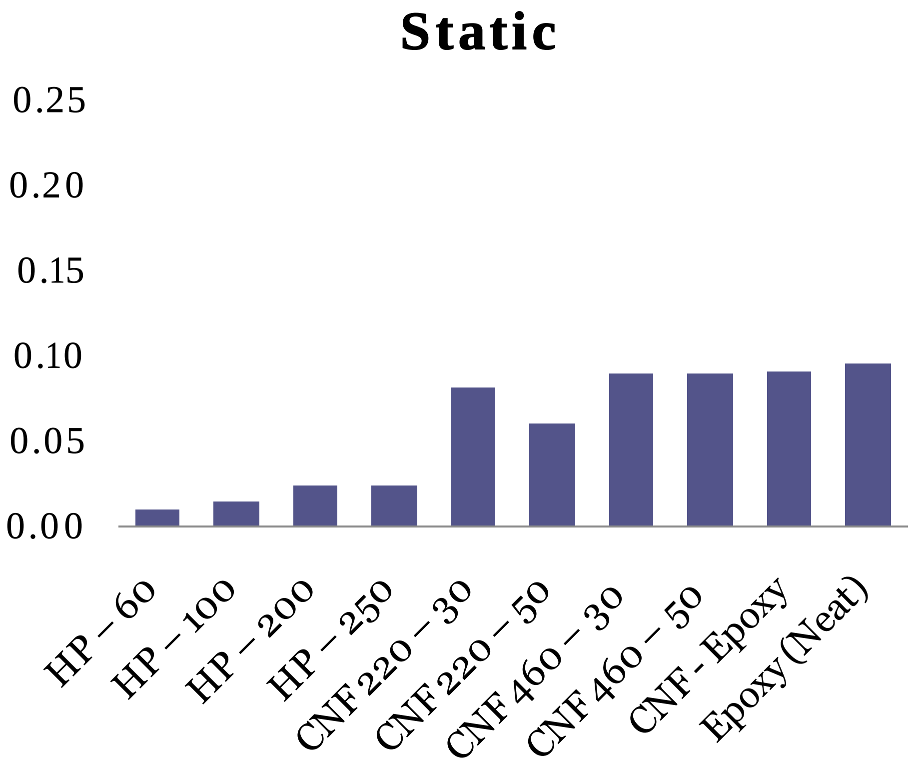
HP 60

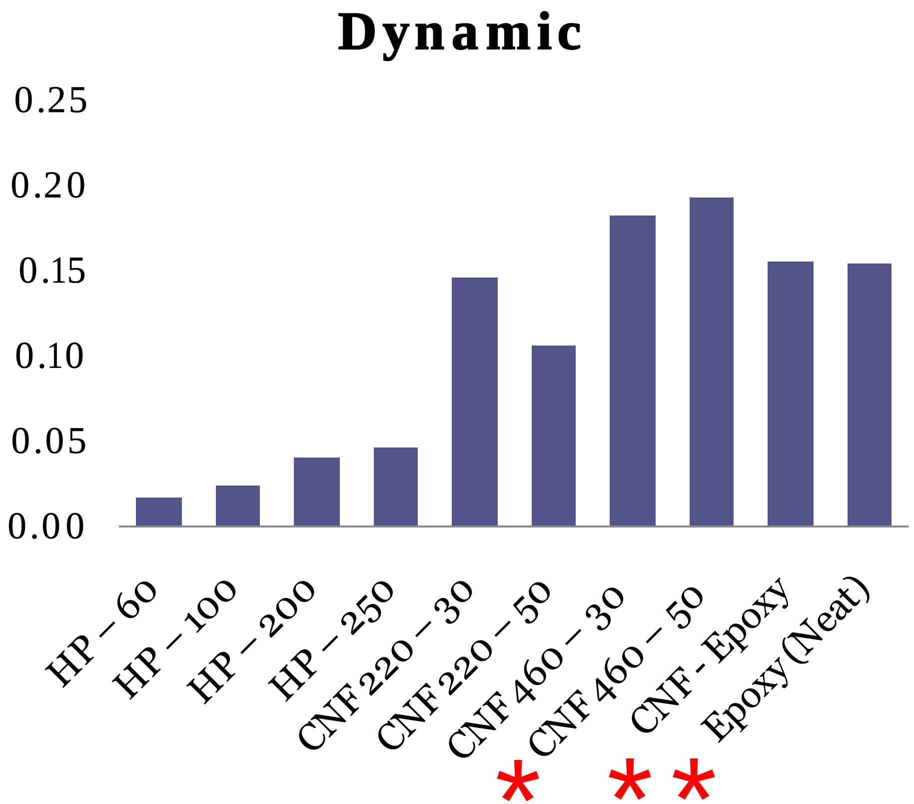
Yield Strength/Density (MPa/kg/m³)



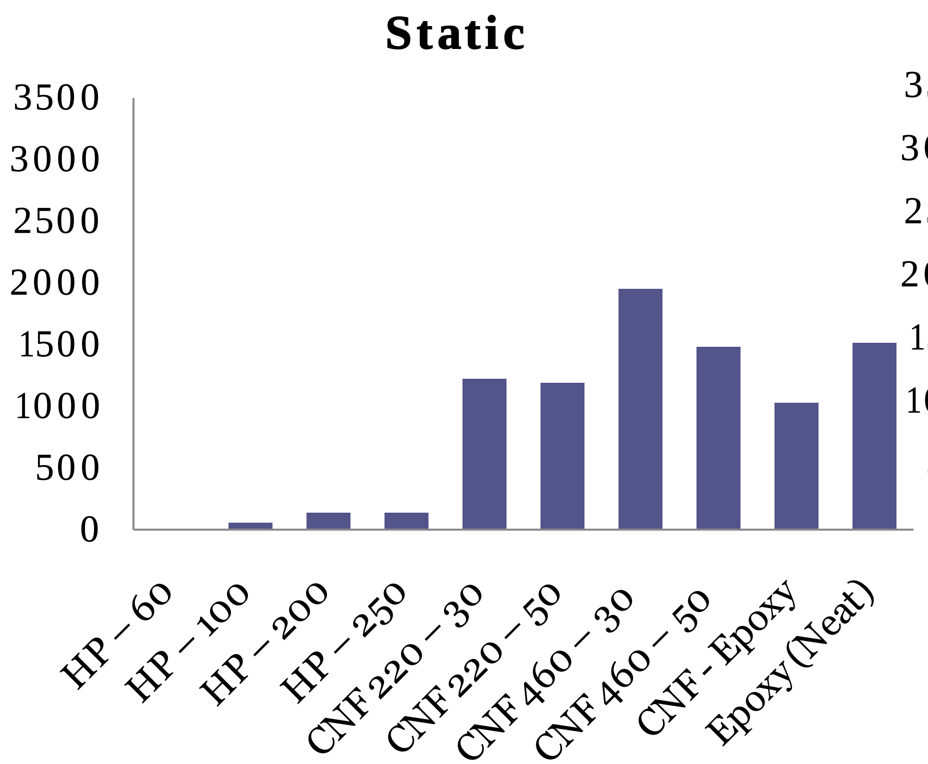


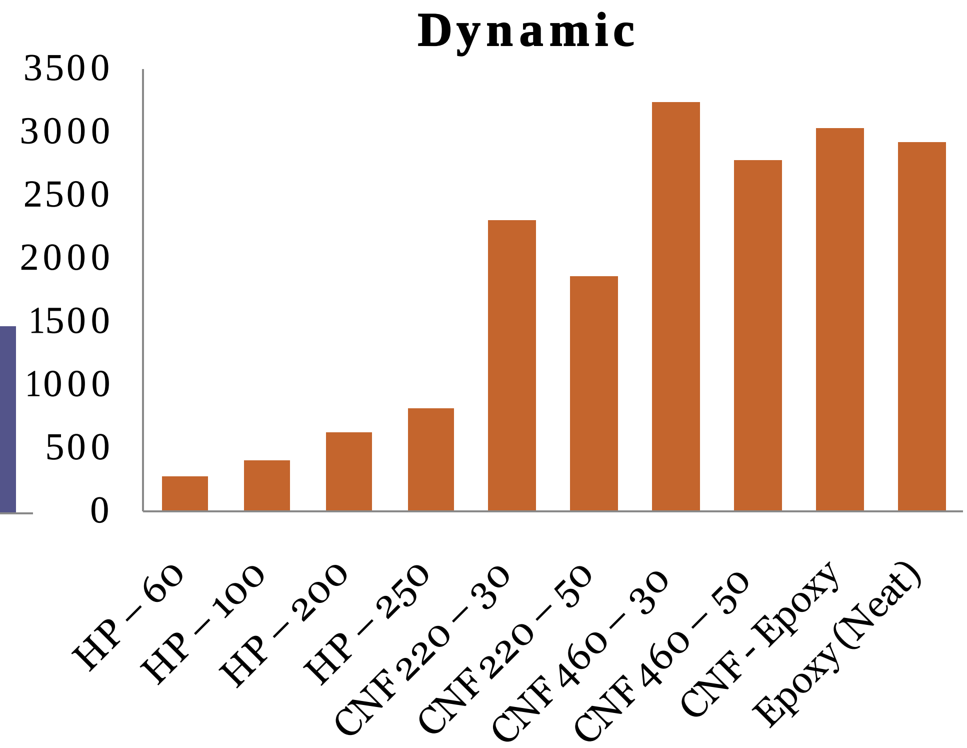
Plateau Strength/Density (MPa/kg/m³)



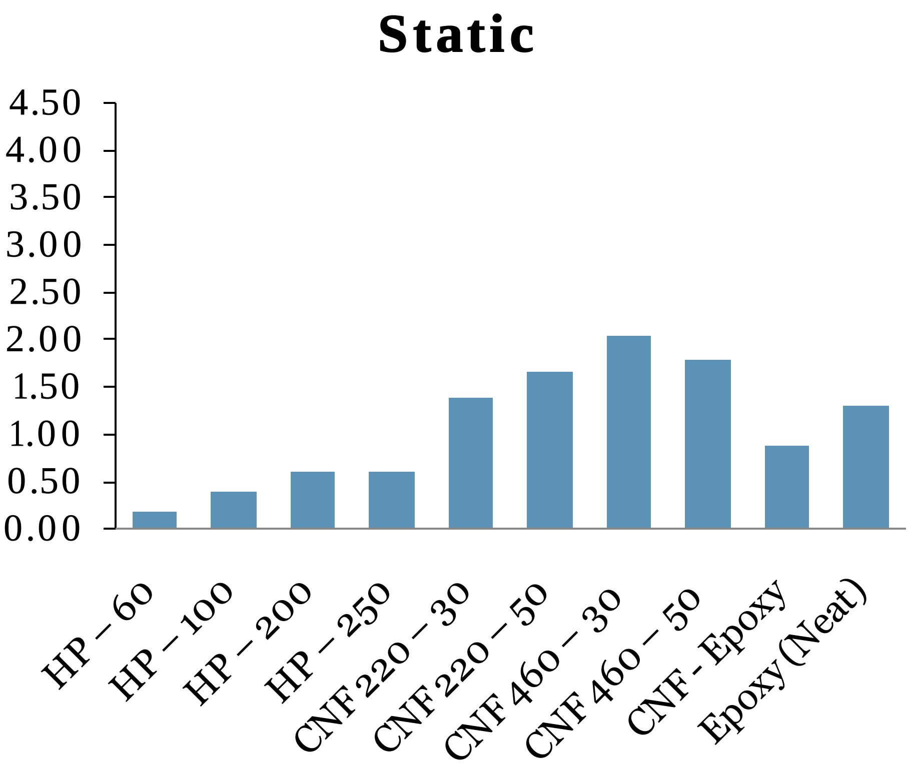


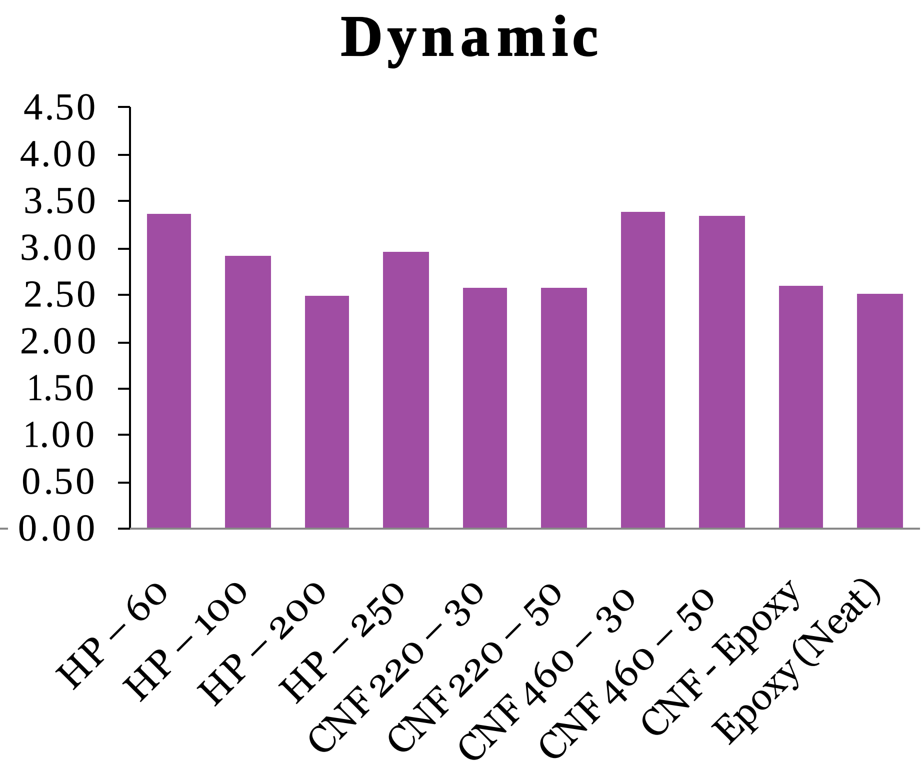
Elastic Modulus (MPa)





Elastic Modulus/Density (MPa/kg/m^3)





Results

- For **Static** Testing:
  - Specific Yield Strength (CNF 460-50)
  - Specific Plateau Strength (Epoxy-neat)
  - Specific *and* Absolute Elastic Modulus (CNF 460-30)
- Every value tested increased with density for PVC Foams
- Trend:
  - In all static tests, PVC foam was predictable in every category

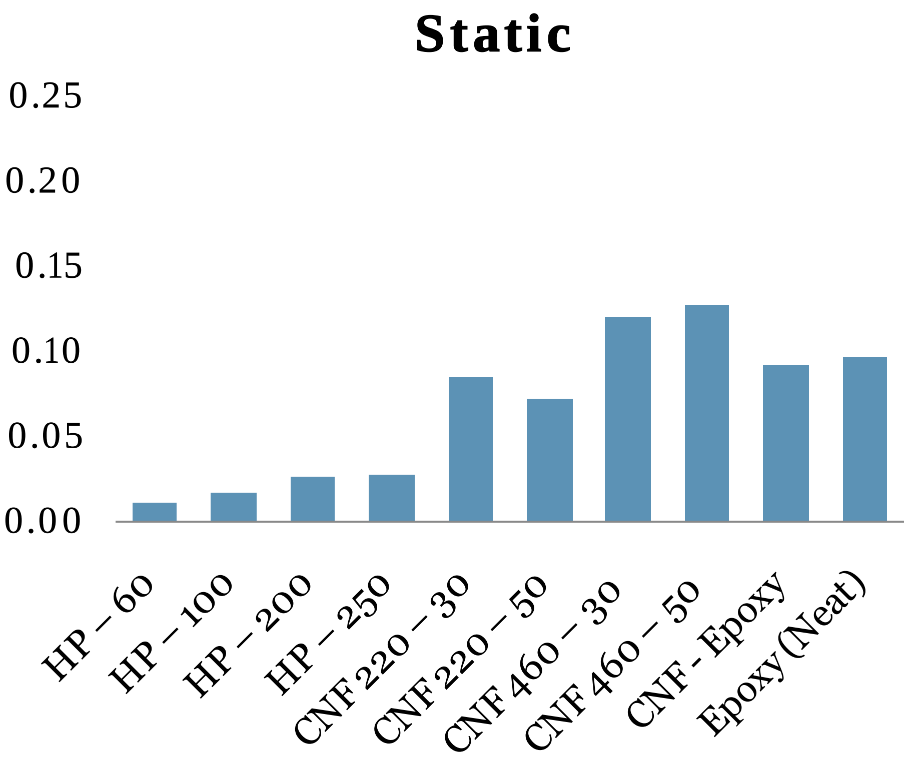
Results

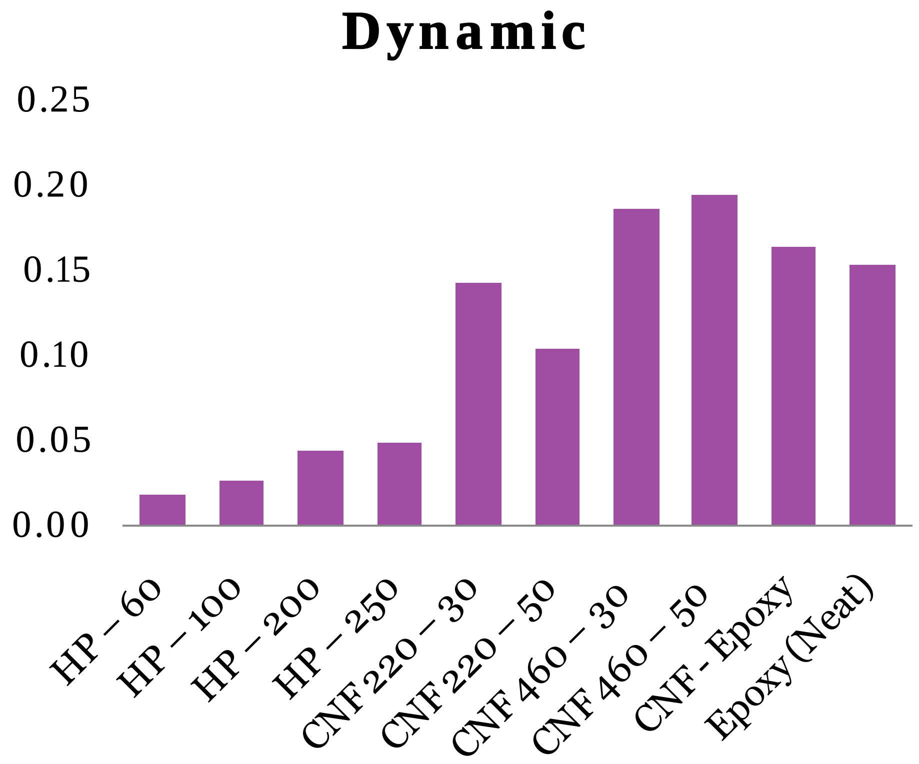
- For **Dynamic** Testing:
  - Specific Yield Strength (CNF 460-50)
  - Specific Plateau* Strength (CNF 460-50)
  - Elastic Modulus (E)
    - specific E: HP-60
    - absolute E: CNF 460-30

For Both Static and Dynamic Tests:

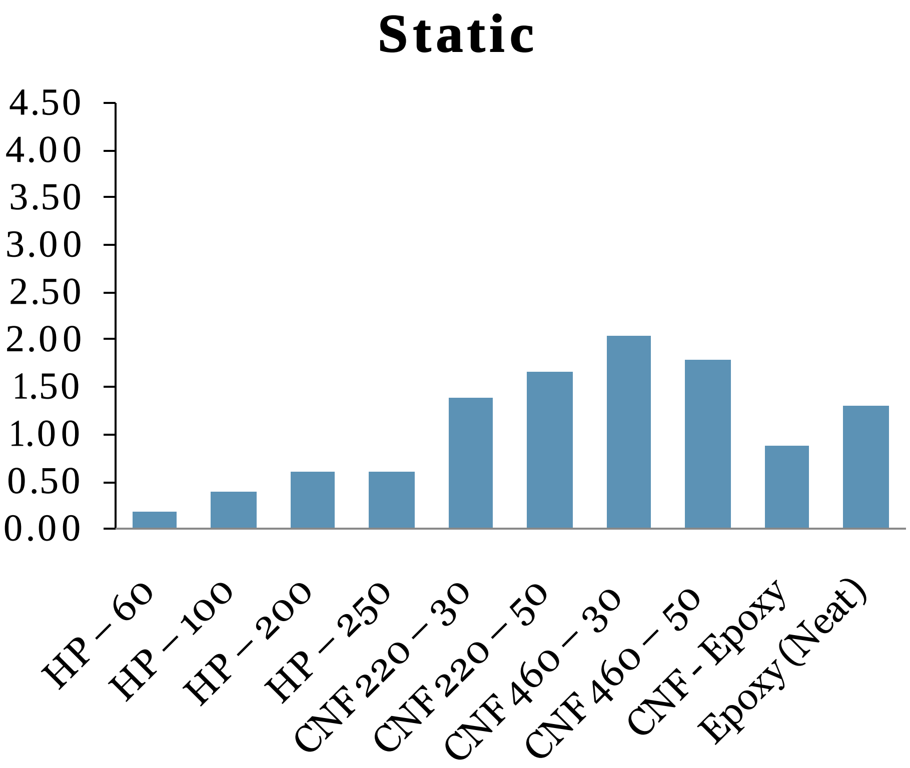
- Specific Yield Strength:
  - CNF 220-30 higher than CNF 220-50
  - CNF 460-50 higher than CNF 460-30
- Specific Elastic Modulus:
  - CNF 220-50 higher than CNF 220-30
  - CNF 460-30 higher than CNF 460-50
- PVC Foam predictable in every category except for *specific* modulus during dynamic SHPB tests

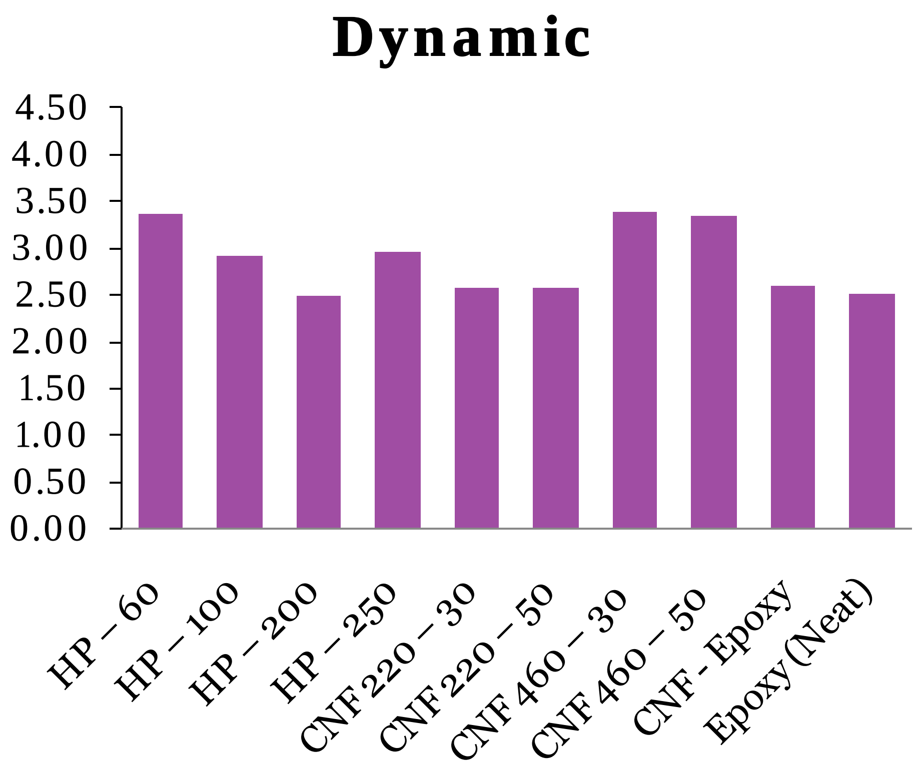
Yield Strength/Density (MPa/kg/m³)





Elastic Modulus/Density (MPa/kg/m³)





Improvements

- Tensile testing is recommended to gain a more complete understanding of the physical properties of PVC and CNF Syntactic Foams
- Repeat compression tests using more specimens per foam type
- Learning curve a factor in possible flaws in initial data acquisition

Acknowledgements

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