CNCs for Foam Stability in Cellular Concrete

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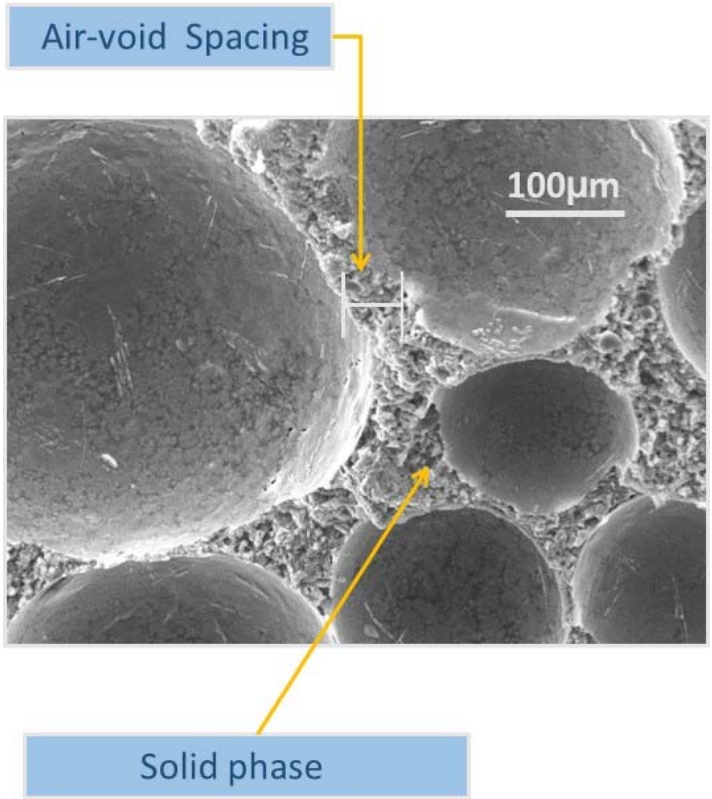
TAPPI

Cellular Concrete: A Brief Introduction

- Concrete Containing >20% Air
  - Density = 300 to 1500 kg/m^3

- Non-Structural Usage:
  - Thermal Insulation
  - Sound Insulation
  - Shock Absorption

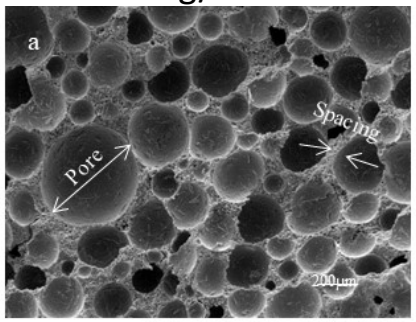


Cell Size and the Air-Void Network

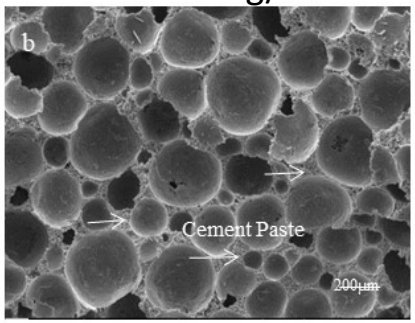
- Mechanical Properties:
  Open Cell vs. Closed Cell
- Thermal Conductivity:
  Mean Cell Size
- Sound Absorption:
  Tortuosity

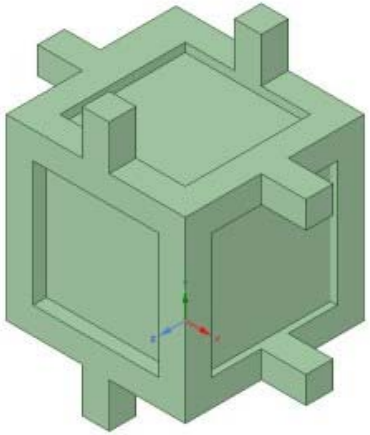
(Mostly Closed Cell)

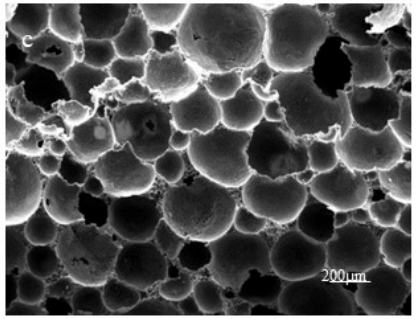
1000 kg/m^3



600 kg/m^3







300 kg/m^3

(Open Cell)

Over-Arching Objectives

- Stabilize the Foam Bubble Network
- Control Bubble Size for Optimal Performance
- Allow Use of Portland Cement Alternatives

Objectives of THIS Report

- Prepare Cellular Concrete
  - Portland Cement
  - Wood Ash for Partial Substitution of Cement
  - Alkali-Activated Fly Ash (Completely Replace Cement)

- Measure Physical & Mechanical Properties
  - Thermal Conductivity
  - Noise Reduction Coefficient

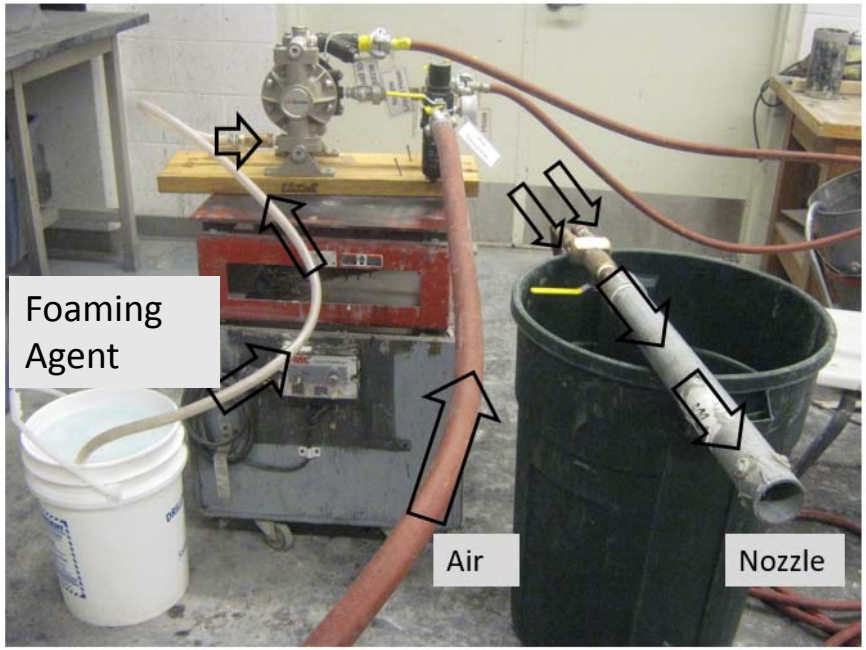
- Characterize the CNC modified Cellular Structure

Mixture Details

- Target cast density 1000–1400 kg/m^3
- Two Sets of Binders:
  - Class C Fly Ash + Alkali Activation
  - 80% Portland Cement + 20% Wood Ash
- Curing at 21°C with 100% relative humidity

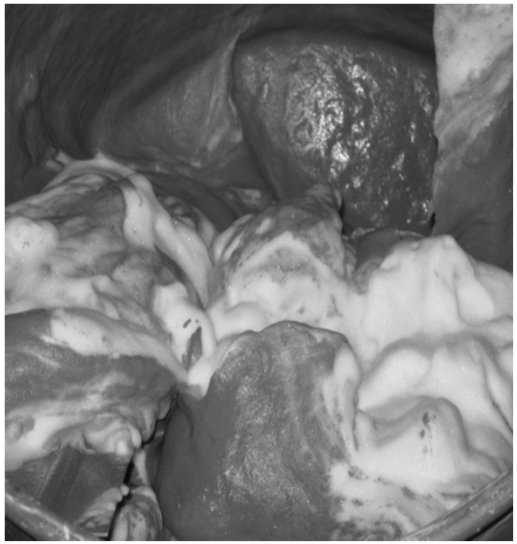
Series 1: Protein-Based Conventional Foaming Agent
Series 2: CNC-Based Foaming Agent

Preformed Foam



Specimen Preparation

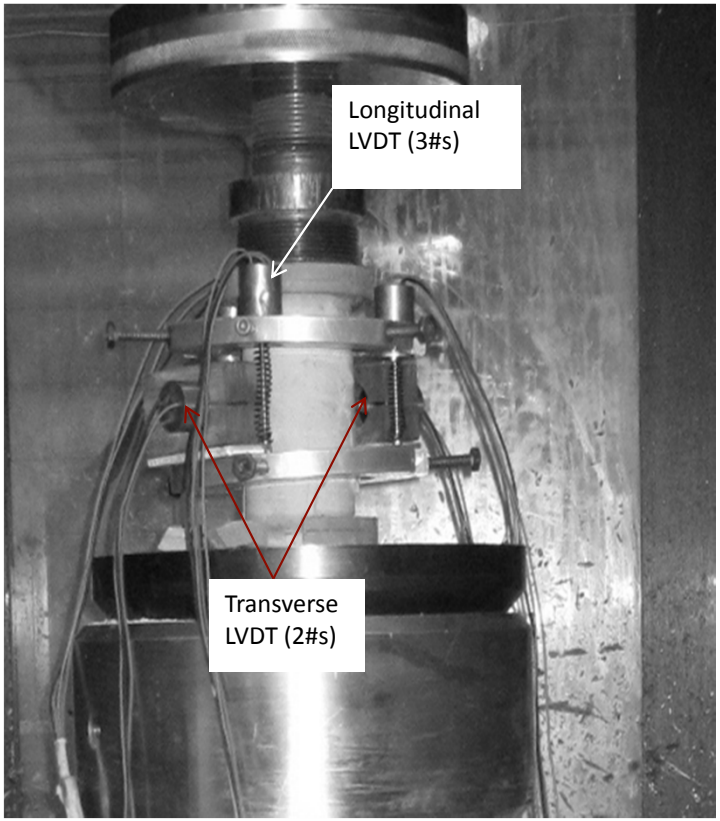
Paste



Paste +
Preformed Foam

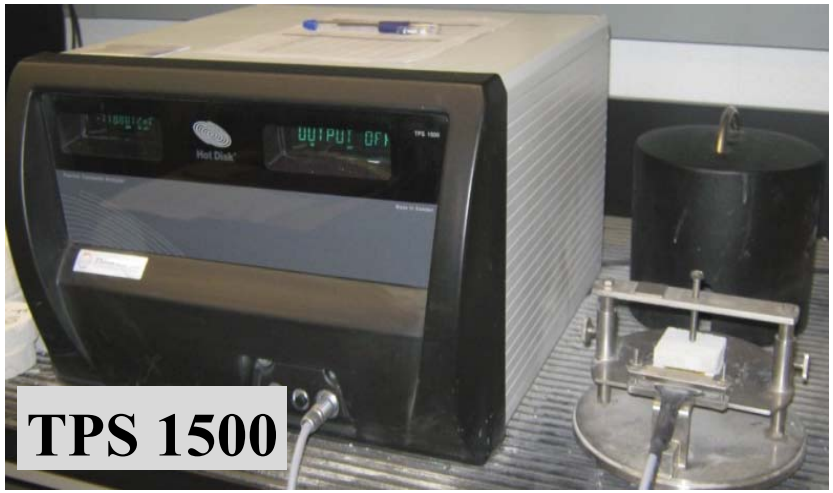
Cellular Concrete
Specimens

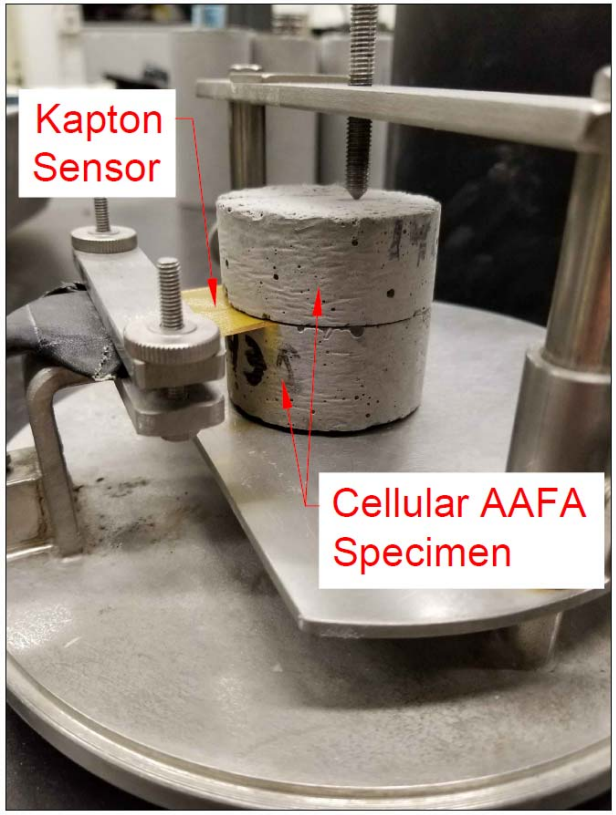
Experimental Setup: Compression Test



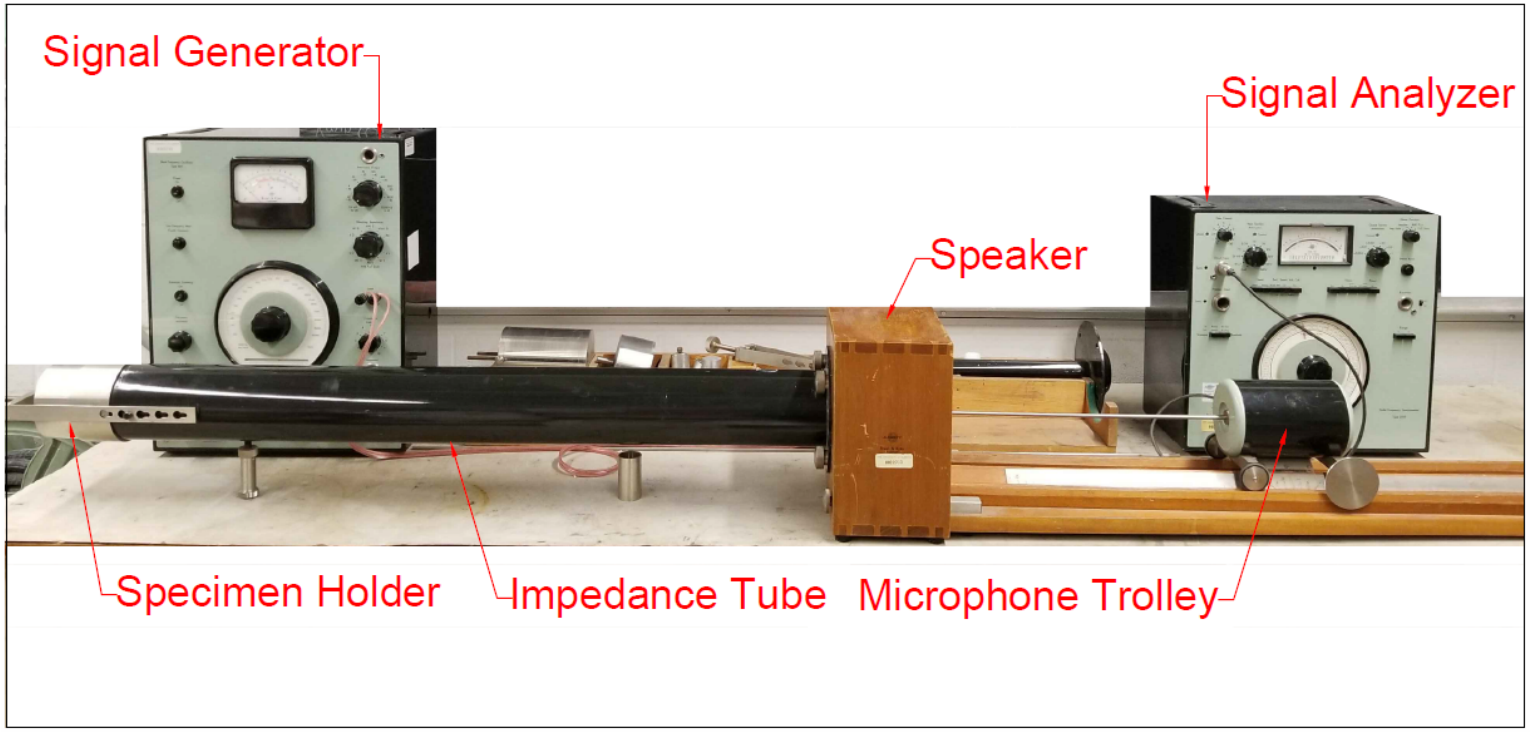
$$f_{foam} = \left(\frac{\rho_{foam}}{\rho_{solid}}\right)^{3/2}$$ for an OPEN Cell Foam

Experimental Setup: Thermal Constants





Experimental Setup: Impedance Tube

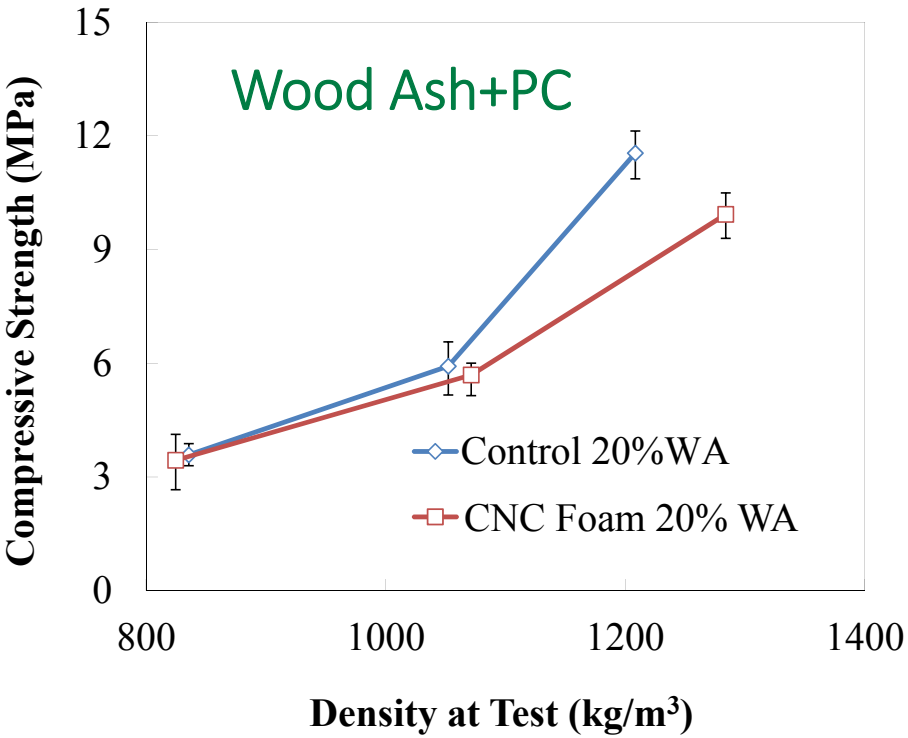


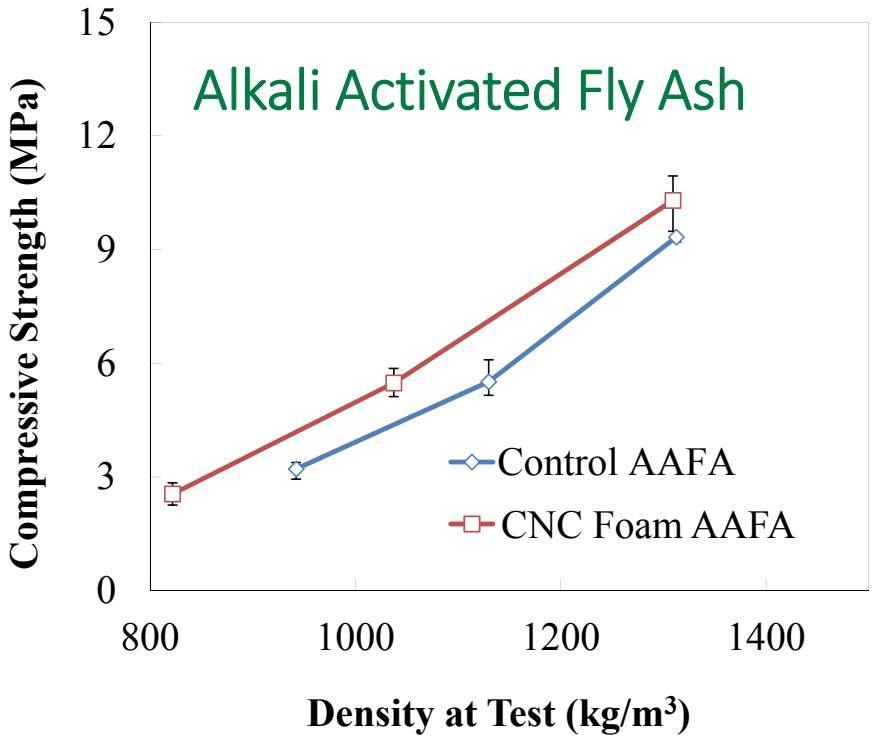
Effect of Foaming Agent

Control: Protein-Based Foam

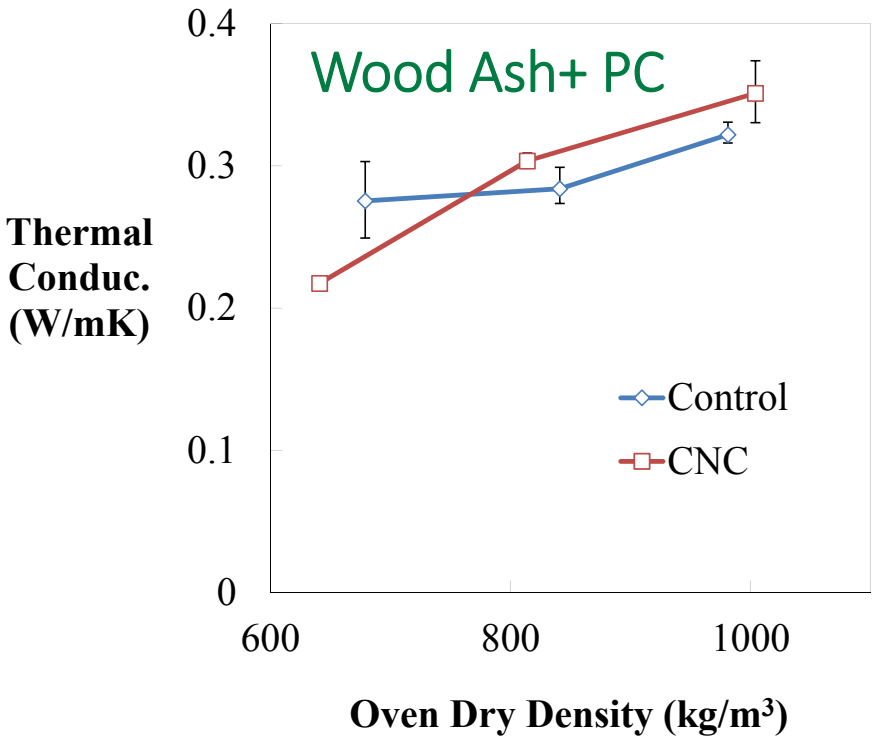
CNC Foam: CNC, MC, C-TAB

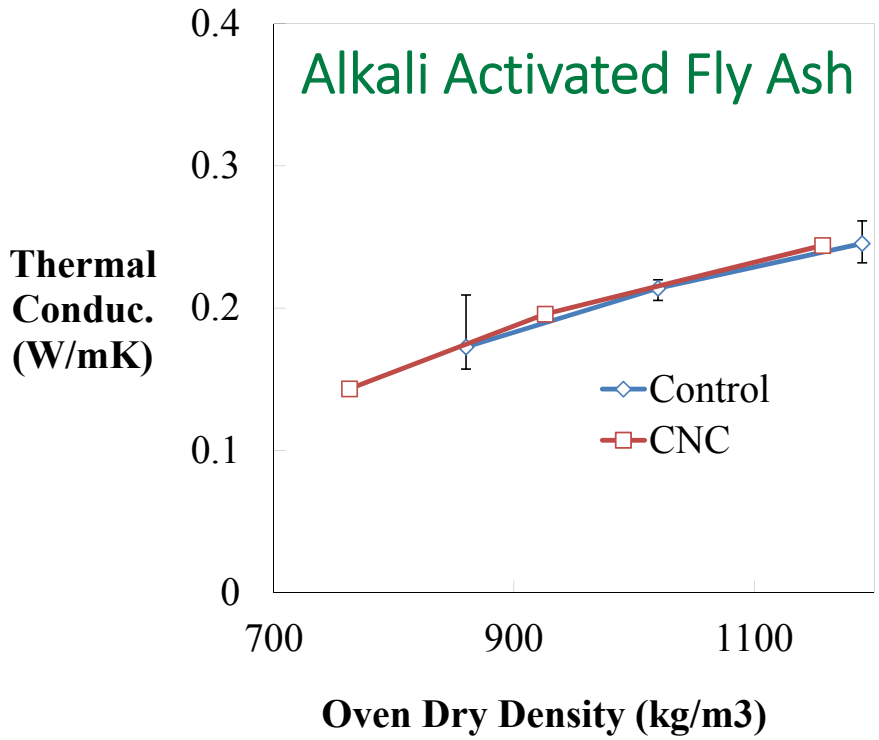
Compressive Strength



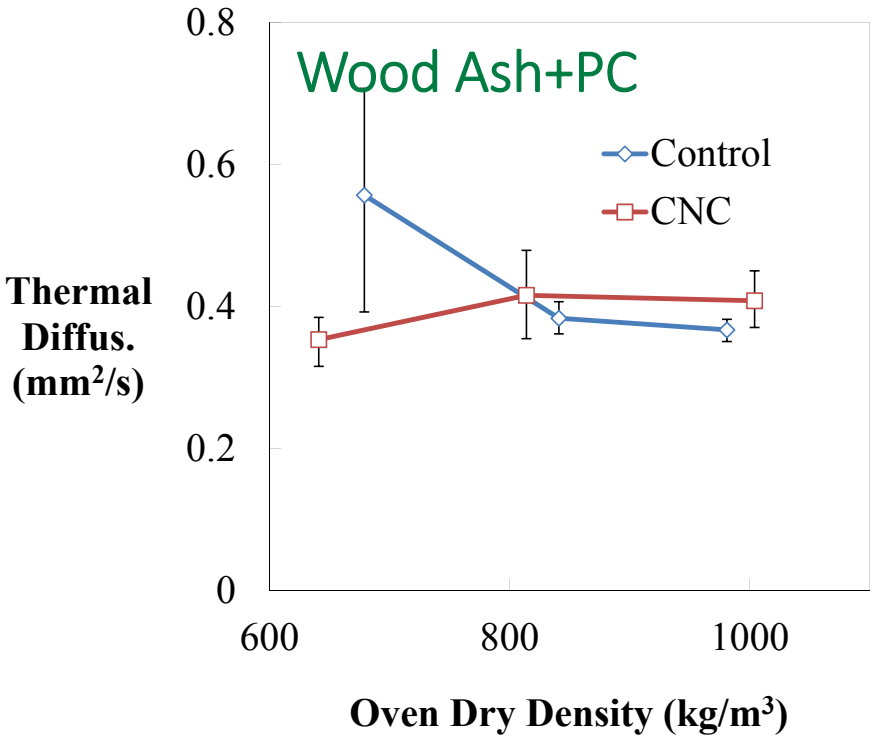


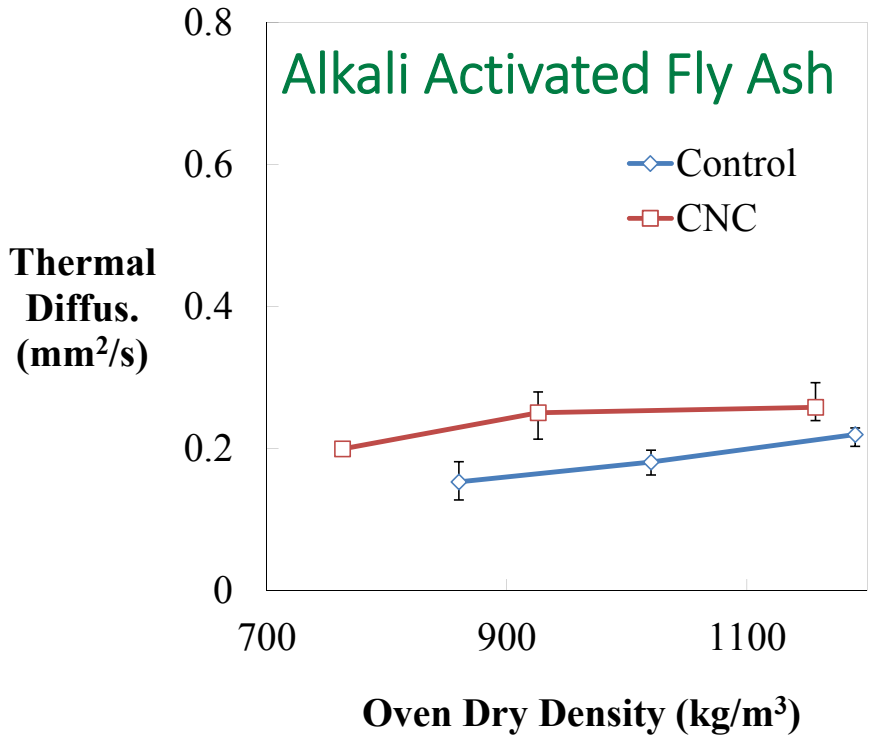
Thermal Conductivity



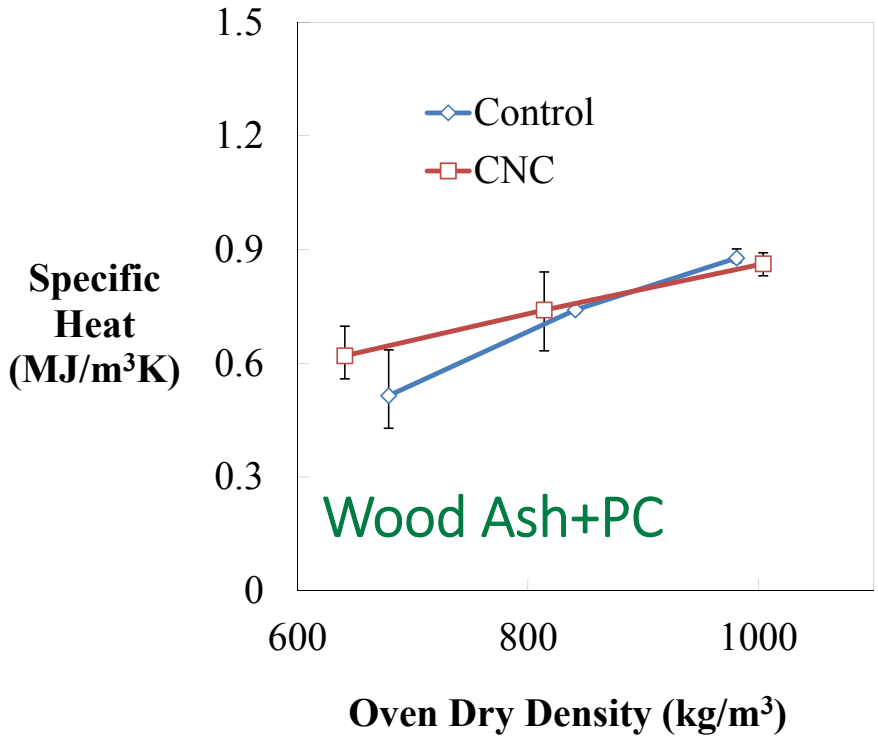


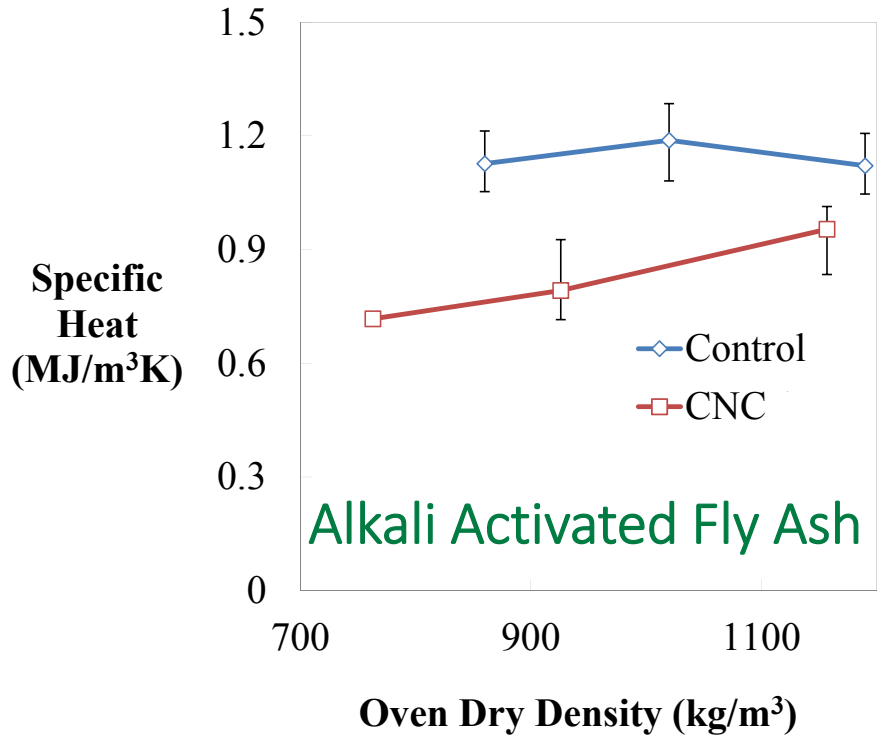
Thermal Diffusivity



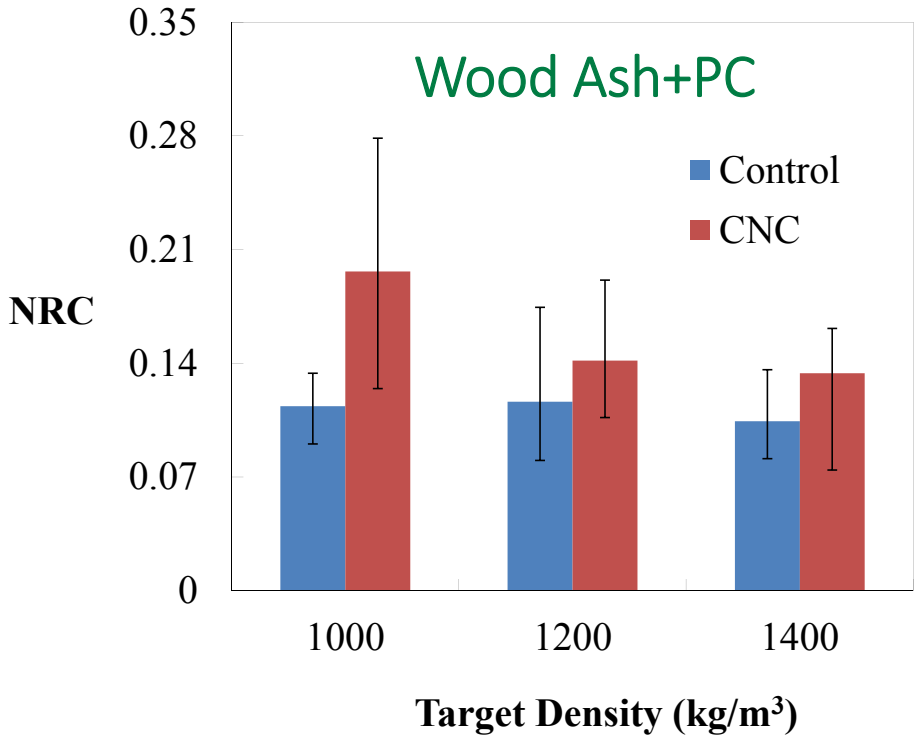


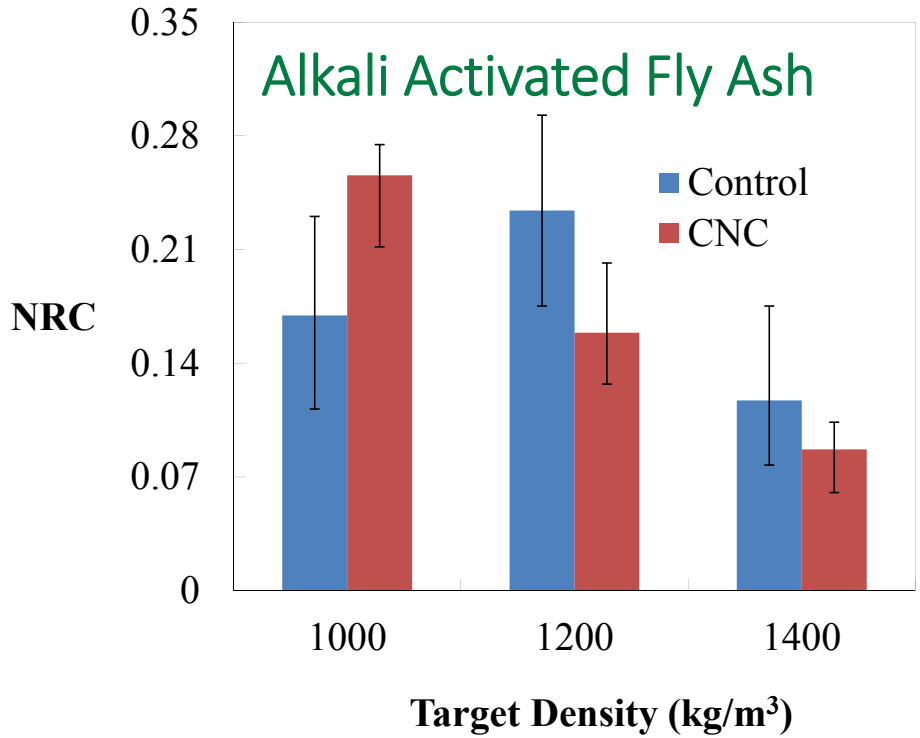
Specific Heat





Noise Reduction Coefficient





Macro-Properties: Summary

- The mixture of Wood ash+Portland Cement saw a reduction in compressive strength. Whereas Alkali Activated Fly Ash foam showed a slight increase in strength.
- CNC-based Wood Ash+PC foam composite had a slightly higher thermal conductivity.
- CNC-based Wood Ash+PC foam composite had higher NRC.

A Closer Look at Air-void Characteristics

Foaming Agents (Surfactants)

Protein-based:

- Commercially available
- Protein-based
- Dilution – 3%

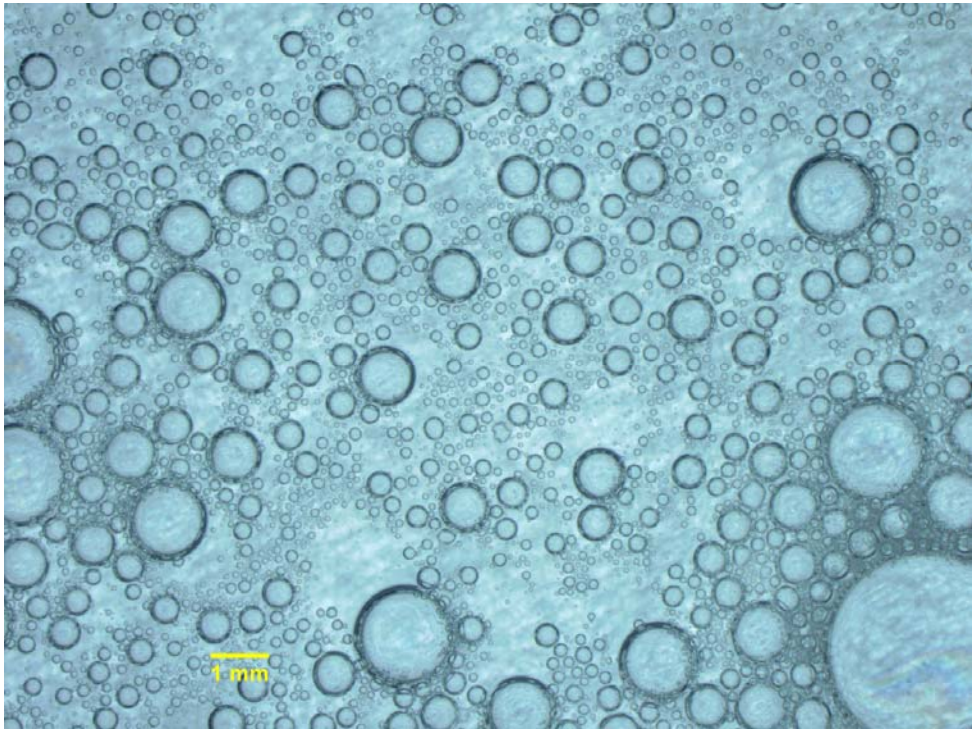
CNC-based:

- Cellulose nanocrystal - 1.7%
- Methyl cellulose - 0.05%
- C14-TAB - 0.0023% (tetradecyltrimethylammonium bromide)

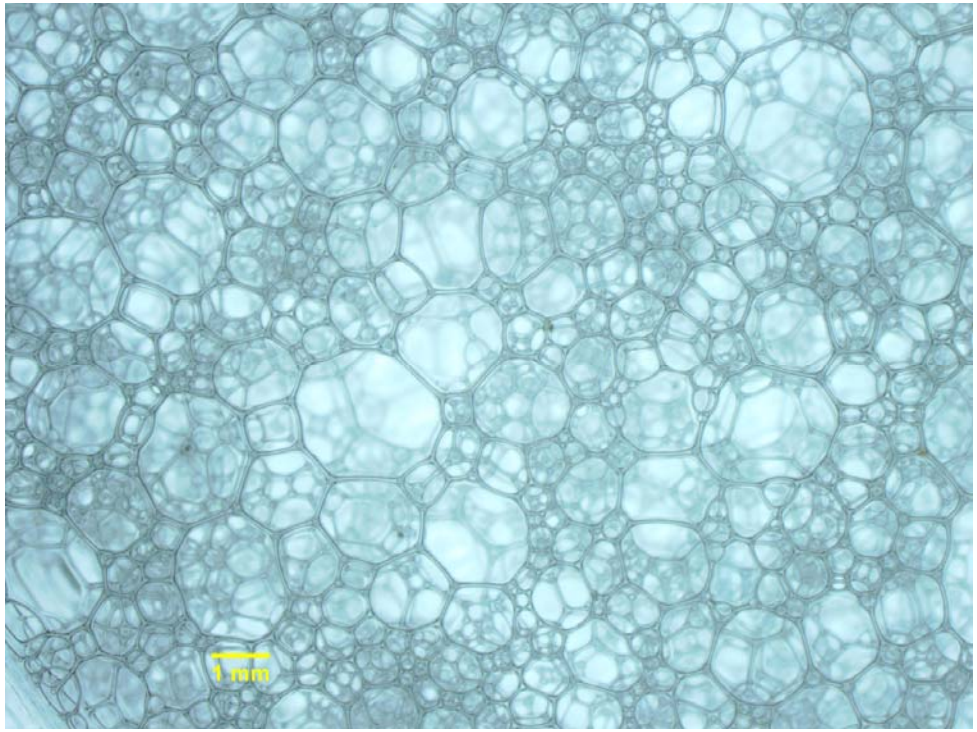
Foamed Concrete

- CSA General Use Portland cement (ASTM Type I)
- water/cement: 0.5
- Slurry density: 1795 kg/m^3
- Cast density (Foamed concrete): 1000 kg/m^3

Wet Foam: CNC vs Protein



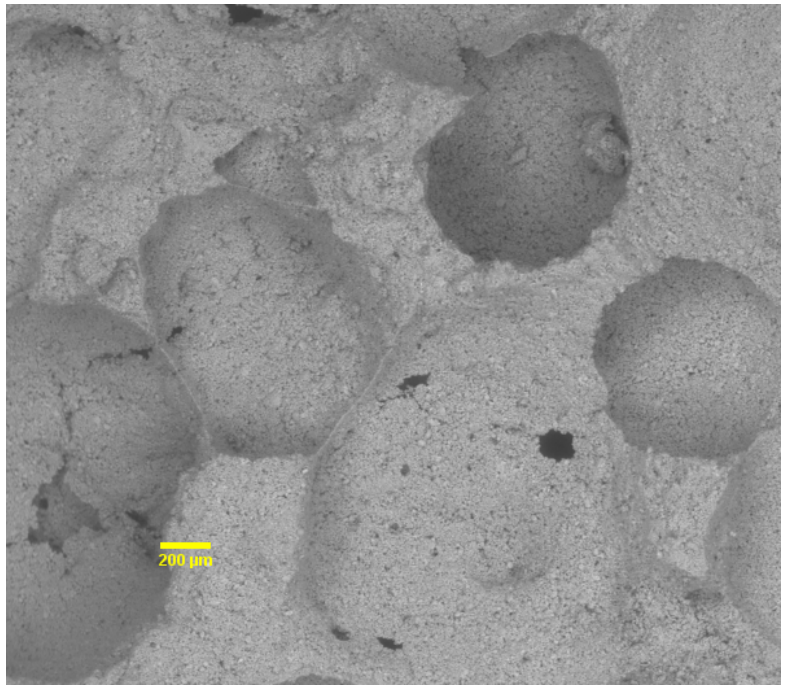
CNC-based foam



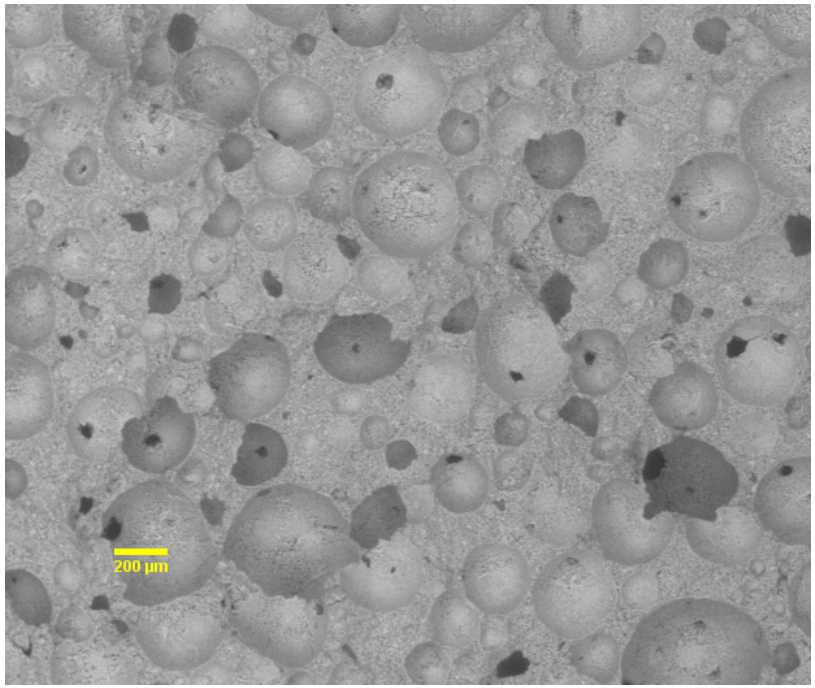
Protein-based foam

Light microscopy image

Foamed Concrete: CNC vs Protein



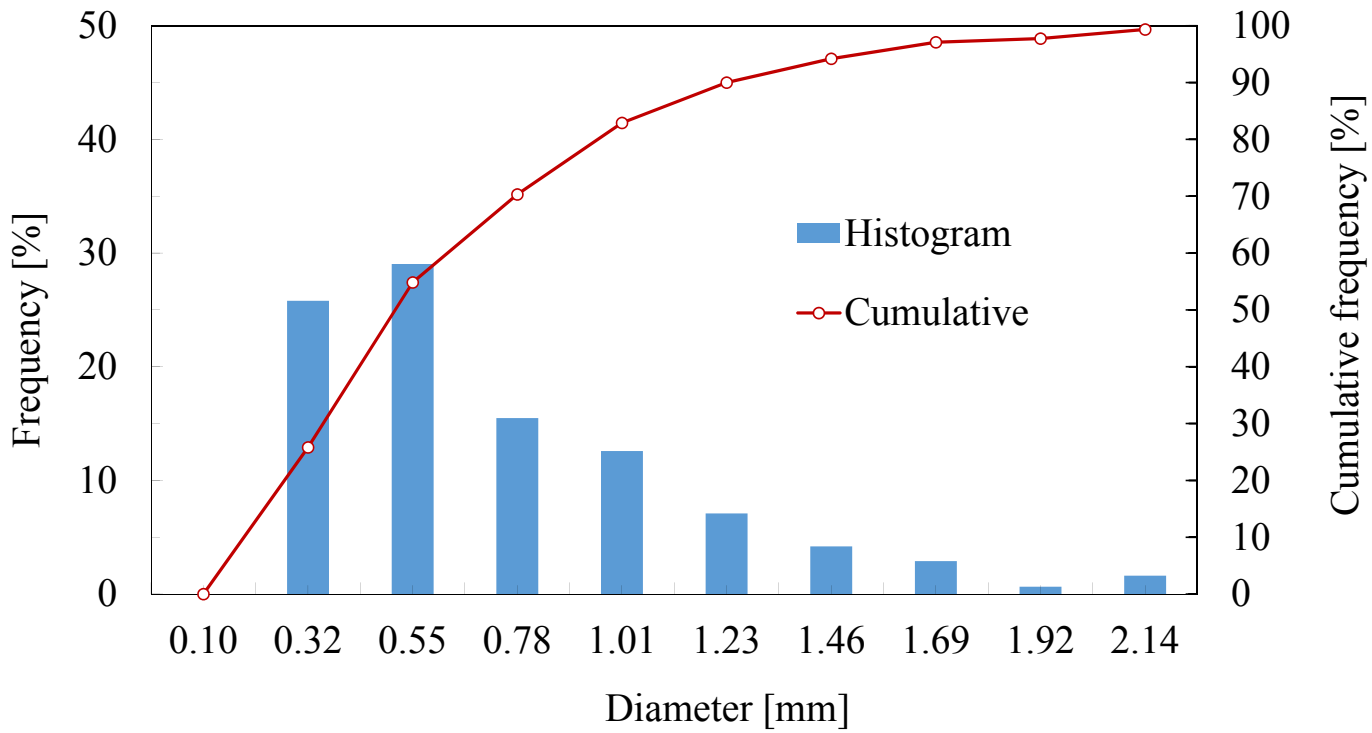
CNC-Cellular Concrete (1000 kg/m^3)



Protein-Cellular Concrete (1000 kg/m^3)

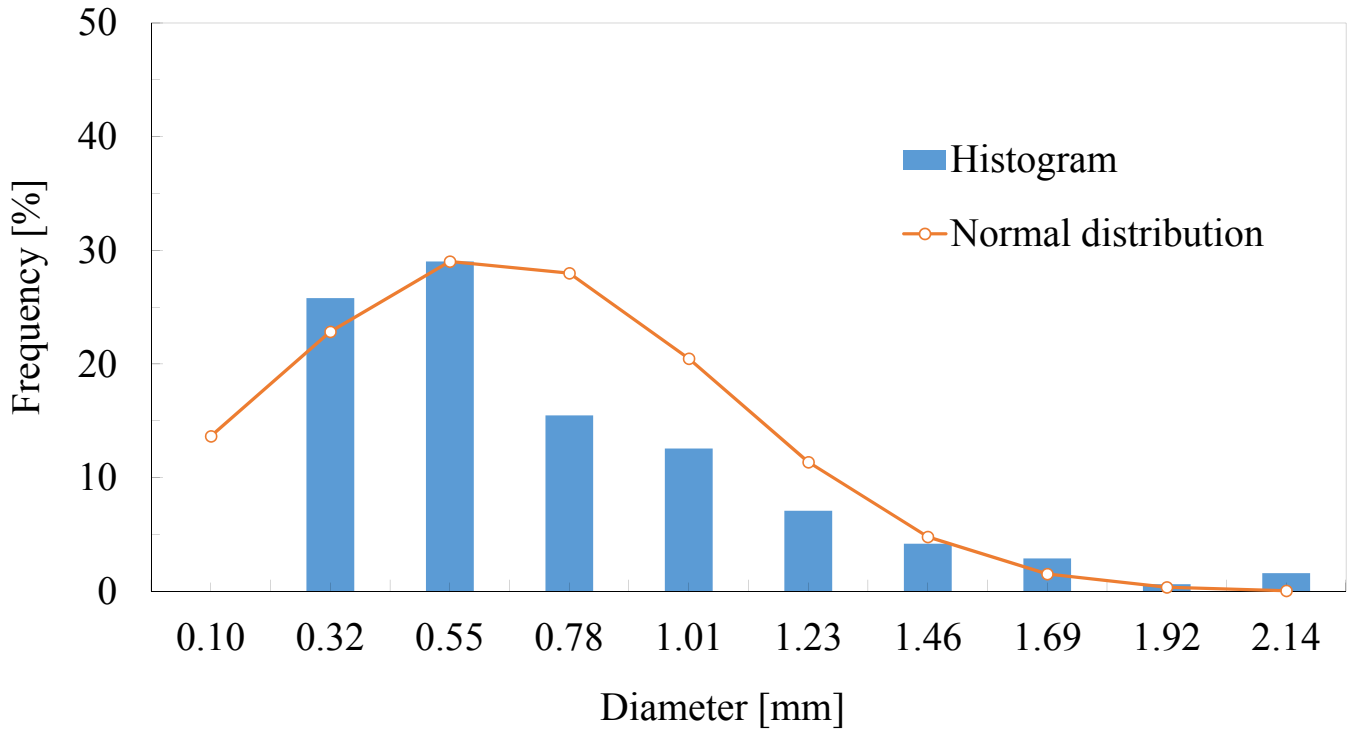
Scanning electron microscopy image

Void Size Distribution: Protein Foam

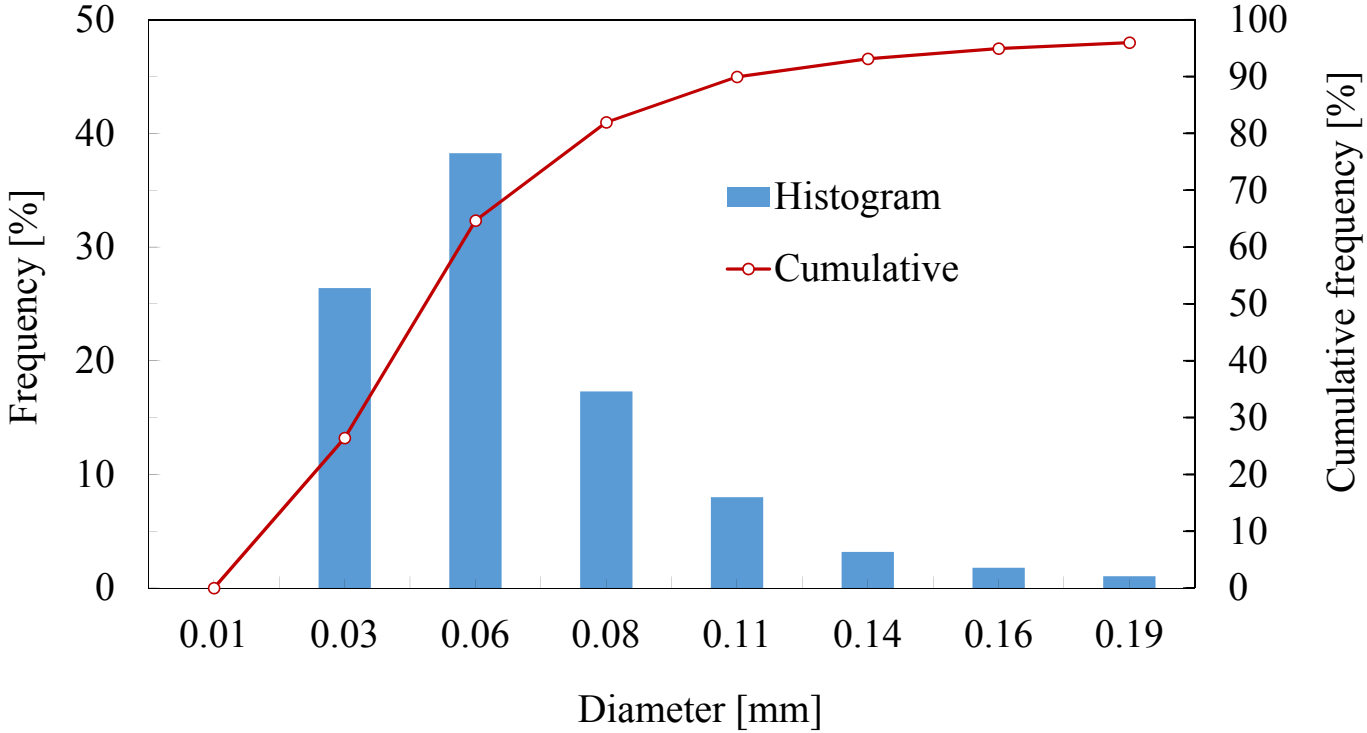


Mean (mm)	0.64
Median (mm)	0.50
Std. dev. (mm)	0.43

Void Size Distribution: Protein Foam …

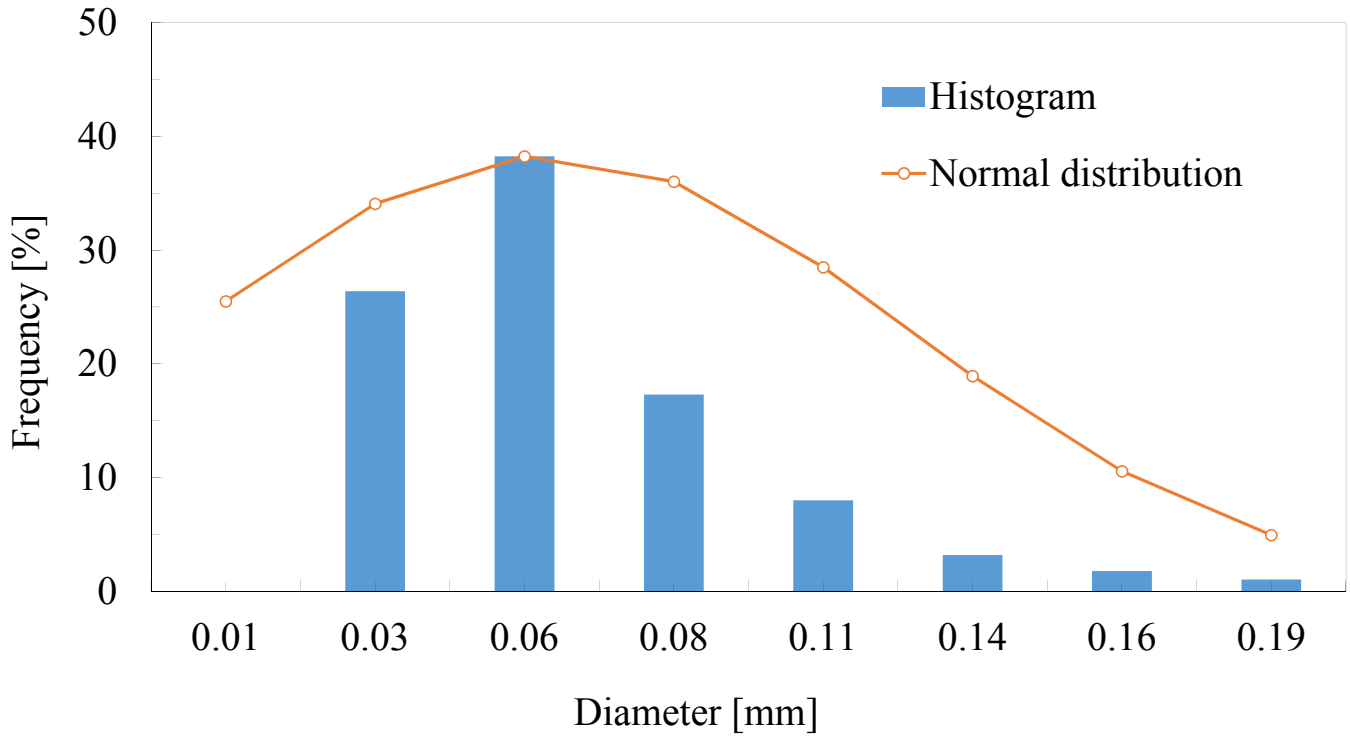


Void Size Distribution: CNC Foam

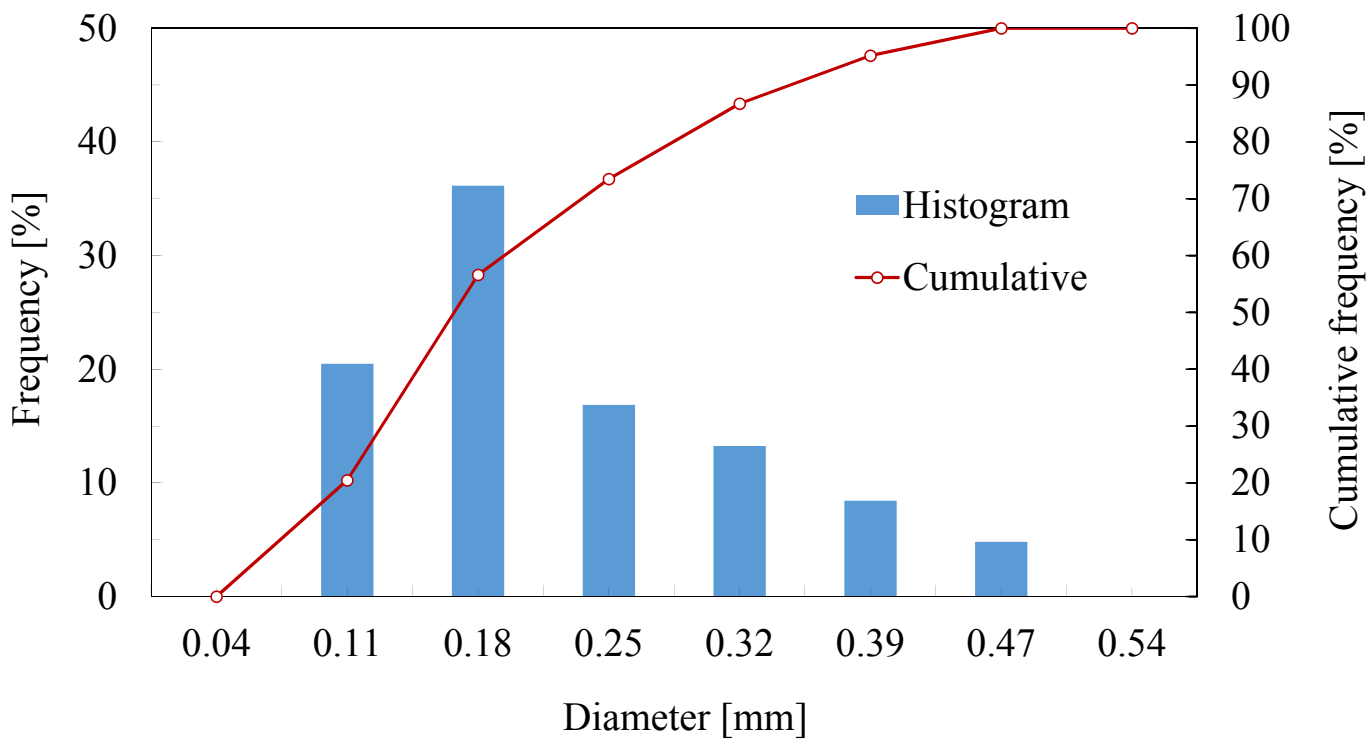


Mean (mm)	0.06
Median (mm)	0.04
Std. dev. (mm)	0.06

Void Size Distribution: CNC Foam …

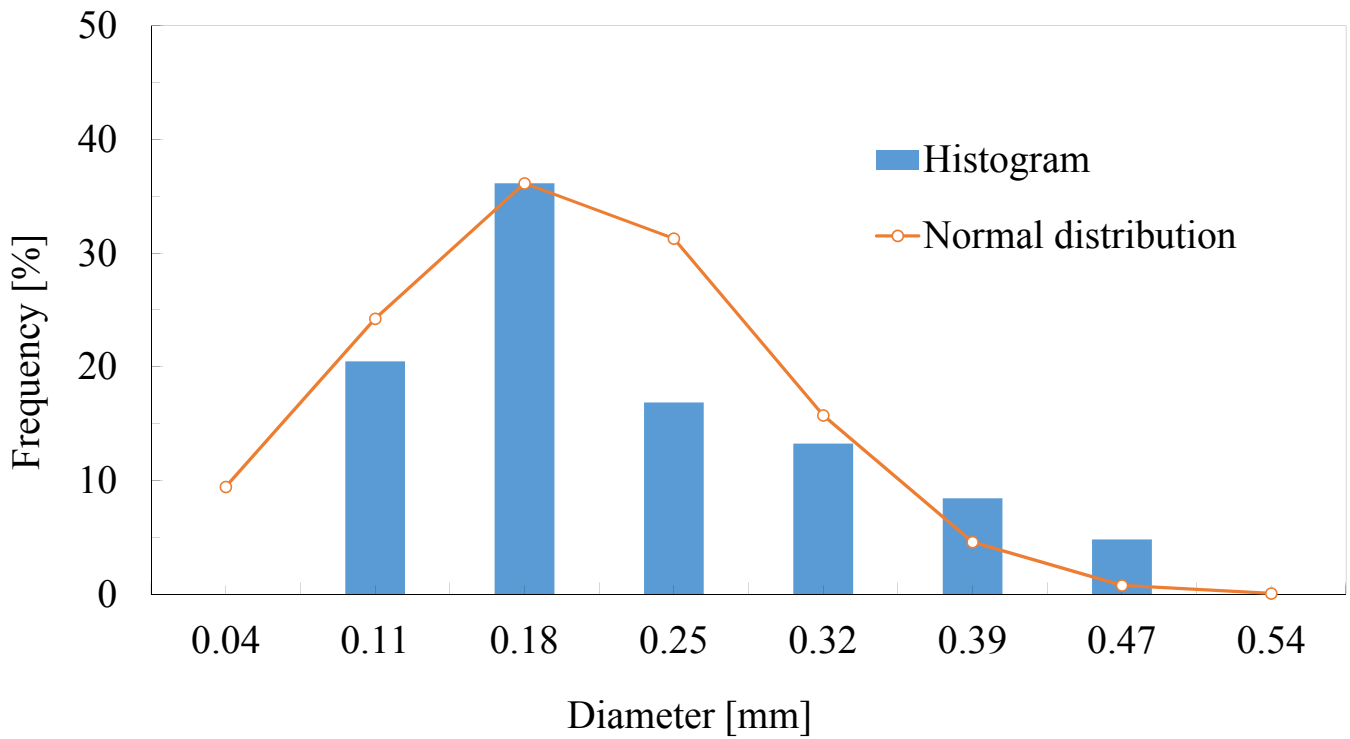


Void Size Distribution: Protein Foamed Concrete

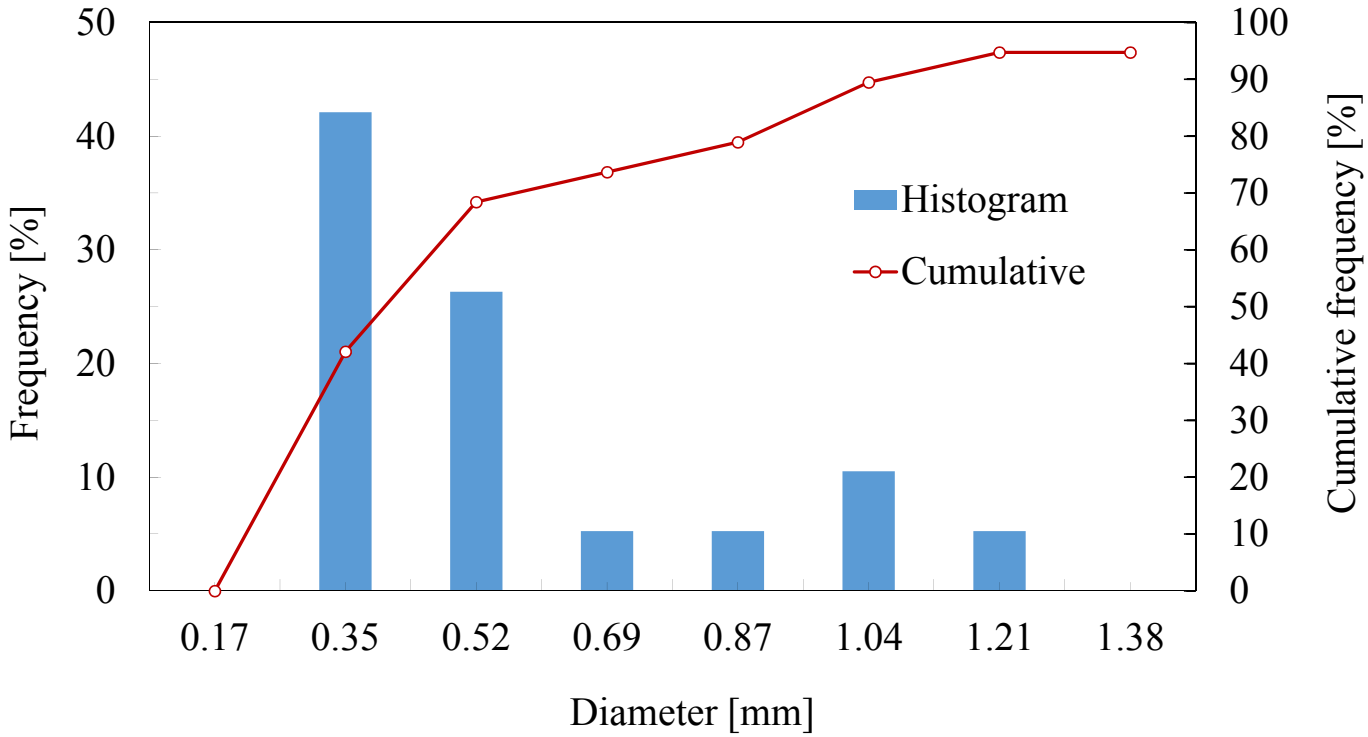


Mean (mm)	0.20
Median (mm)	0.17
Std. dev. (mm)	0.10

Void Size Distribution: Protein Foamed Concrete …

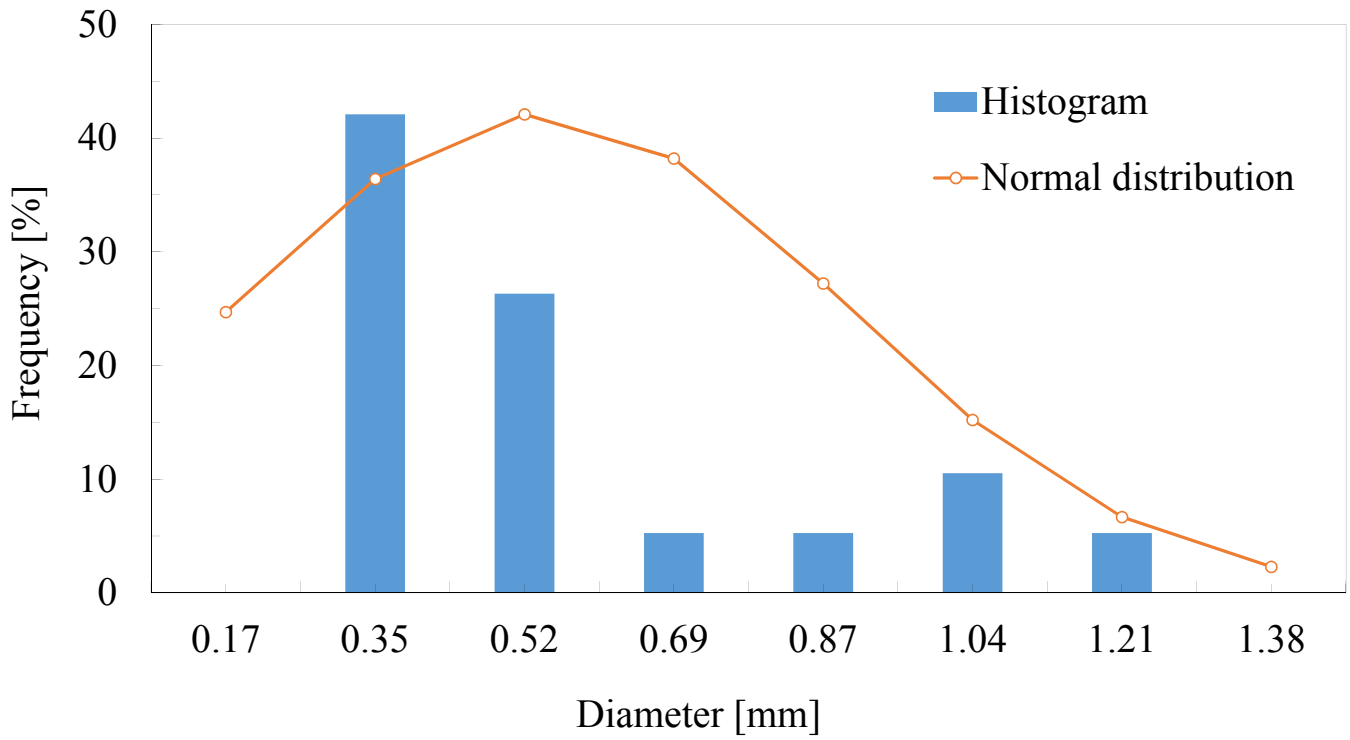


Void Size Distribution: CNC Foamed Concrete



Mean (mm)	0.54
Median (mm)	0.40
Std. dev. (mm)	0.35

Void Size Distribution: CNC Foamed Concrete …



Summary of Void Size Distribution

Protein-Based

Foam

Mean (mm)	0.64
Median (mm)	0.50
St. deviation (mm)	0.43

Polygonal

Foamed Concrete

Mean (mm)	0.20
Median (mm)	0.17
St. deviation (mm)	0.10

Open Cell

CNC-Based

Foam

Mean (mm)	0.06
Median (mm)	0.04
St. deviation (mm)	0.06

Circular

Foamed Concrete

Mean (mm)	0.54
Median (mm)	0.40
St. deviation (mm)	0.35

Closed Cell

Concluding Remarks…(1)

- CNC interferes with cement hydration process, but exact nature unclear;
- Portland cement-based composite performs better as thermal and acoustic insulation in the presence of CNC
- CNC foam renders a predominantly closed cell structure;
- Although smaller as foam bubbles, the CNC-based composite has relatively larger mean void size;

Concluding Remarks…(2)

- Cement hydration elevates temperature by 60 degrees C over ambient. How does this affect CNC? Foam Stabilization?
- CNC alone doesn't foam. Other supporting agents?
- Water drainage from the cell walls is arrested by CNC. How does pH inside cement-based systems affect the CNC-water interaction?

Acknowledgements

Personnel

- Ms. Brianna Jackson
- Ms. Miranda Annett

Partners

ALBERTA PACIFIC FOREST INDUSTRIES INC

HOKUETSU GROUP

NSERC CRSNG

LEHIGH HEIDELBERGCEMENT Group

Thank you

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