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Compaction Behavior of Surrogate Degraded Emplaced Waste

Sandia National Laboratories

Geoscience Research and Applications Group

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Outline

- ***Background and Motivation***
- ***Material and Sample Preparation***
- ***Experimental Methods***
- ***Test Equipment***
- ***Test Methods and Data Reduction***
- ***Results and Analysis***

The Waste Isolation Pilot Plant (WIPP)

- **Permanent disposal of defense transuranic waste**
- **Permian Salado Formation**
  - Underground at 2150 ft
  - CH waste is emplaced in Panels
  - RH-TRU waste is emplaced in boreholes drilled into the walls of Panels
  - MgO engineered barrier material
- **Experimental work focuses on room closure modeling**
  - End state degraded waste (as in at the end of 10,000 yrs)

Material Preparation

- Two unique recipes; 50% and 100% degraded waste states
- Percentage of degradation indicates the anticipated amount of iron degraded by weight
- Generally all materials were hand prepared so that pieces were 6-8 mm and/or passed 9.5 mm sieve
- Iron oxide was crushed and passed 1 mm sieve

Mass (kg) and percent by weight of materials in test specimens				
Material	Case 1 (50% degraded)		Case 2 (100% degraded)	
Iron, not corroded	1.9	18.3%	0	0.0%
Corroded iron and other metals	4.6	44.4%	7.3	67.0%
Glass	1.0	9.6%	1.0	9.2%
Cellulosics + plastics + rubber	0.7	6.8%	0	0.0%
Solidification cements	1.2	11.6%	1.2	11.0%
Soil	0.5	4.8%	0.5	4.6%
MgO backfill	0	0.0%	0	0.0%
Salt precipitate, corrosion-induced	0.47	4.5%	0.90	8.3%
Salt precipitate, MgO-induced	0	0.0%	0	0.0%
Total batch size	10.37	100.0%	10.9	100.0%

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Sample Preparation

- Cylindrical shaped samples
- Materials were hand mixed in a bowl
- Brine was used to completely saturate the sample

Hydrostatic Tests – Pre-test Specimen Assembly

- ‘Volume standard’ used for repeatable starting sample volume
- Because of expected large deformations, a gum rubber jacket with 1/8” wall thickness was used

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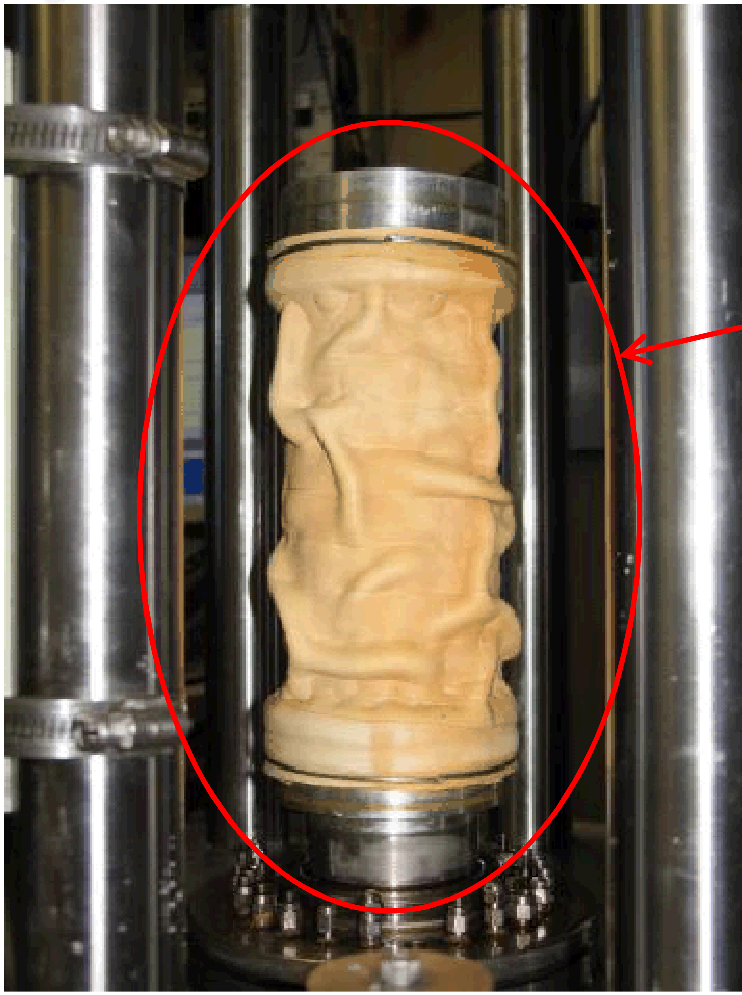
Triaxial Tests – Pre-test Specimen Assembly



- Initially tried reusing samples from hydrostatic tests
- Irregular deformation of material from hydrostatic testing resulted in need for alternate method to create a ‘testable’ sample

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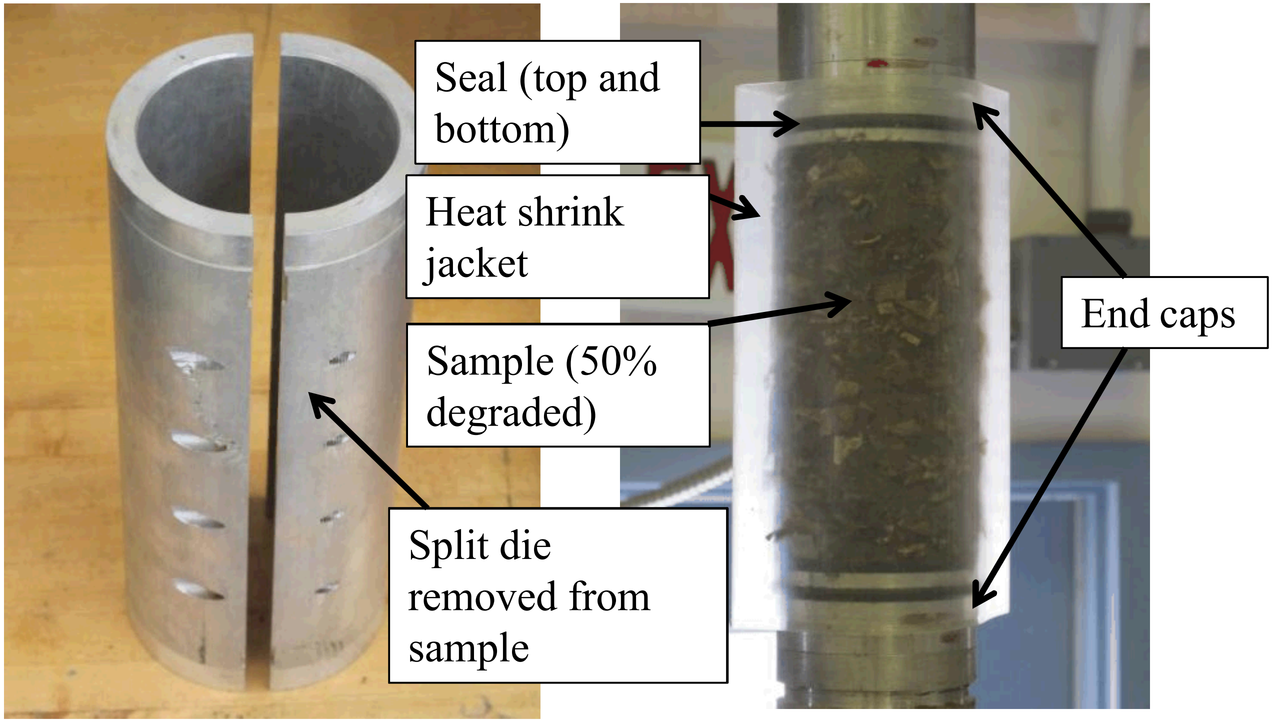
Triaxial Tests – Pre-test Specimen Assembly

- Material compacted axially in a die to 80% of planned confining pressure



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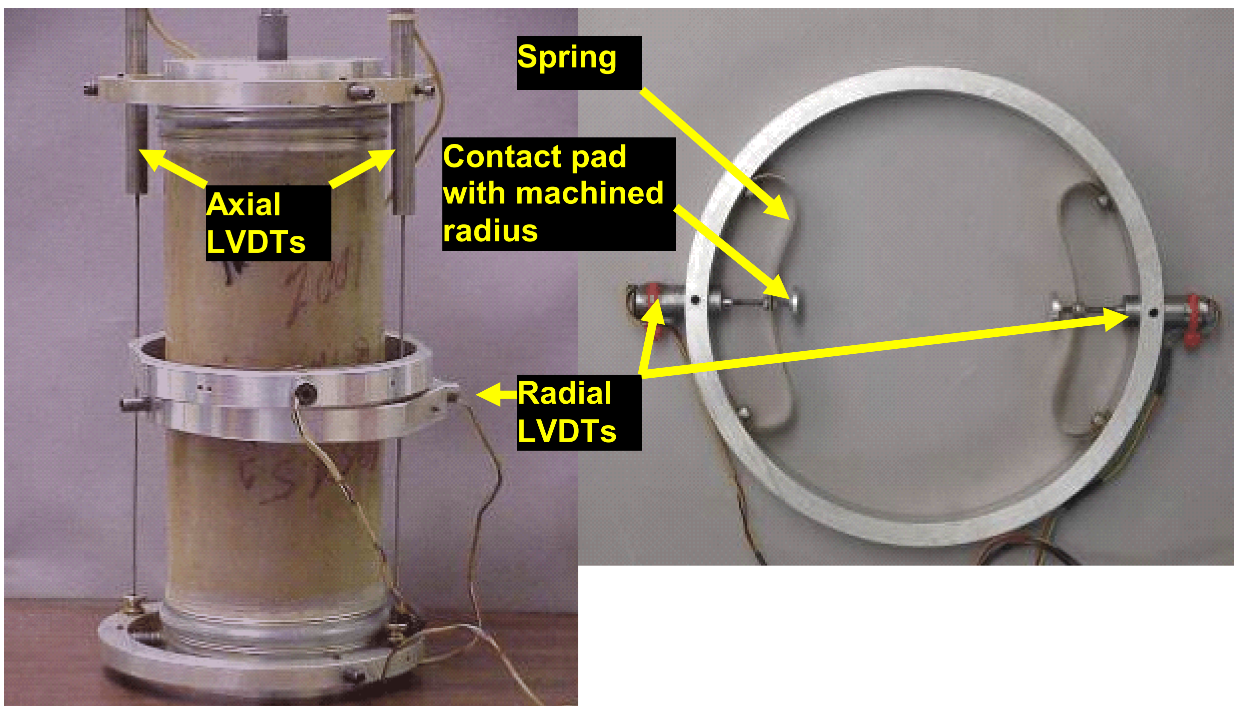
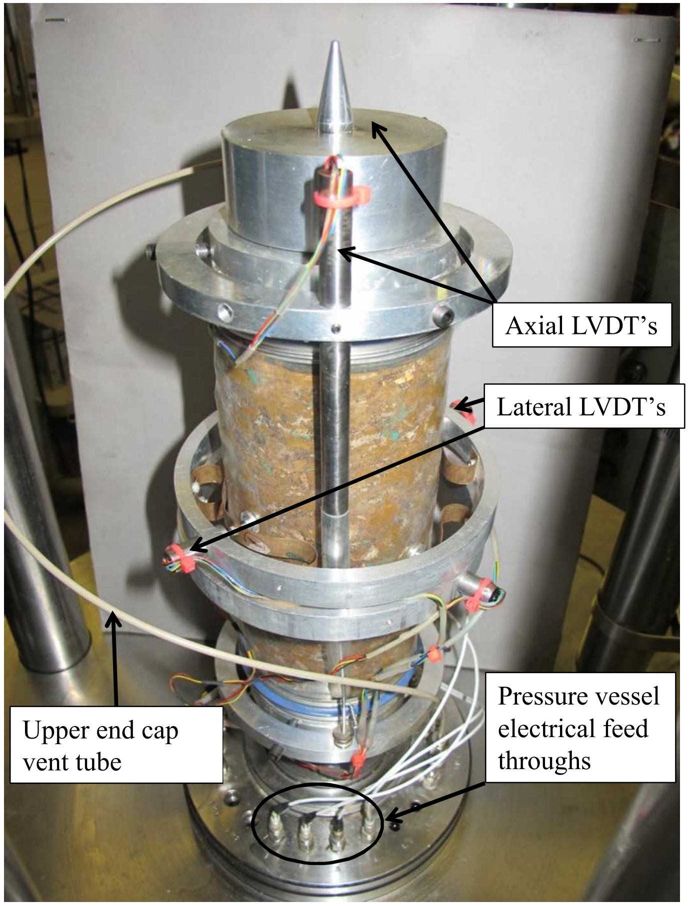
Triaxial Tests – Pre-test Specimen Assembly (cont.)

- Heat shrink jacket used
- Radial deformation measurements made using two LVDT's mounted in a ring with two contact points



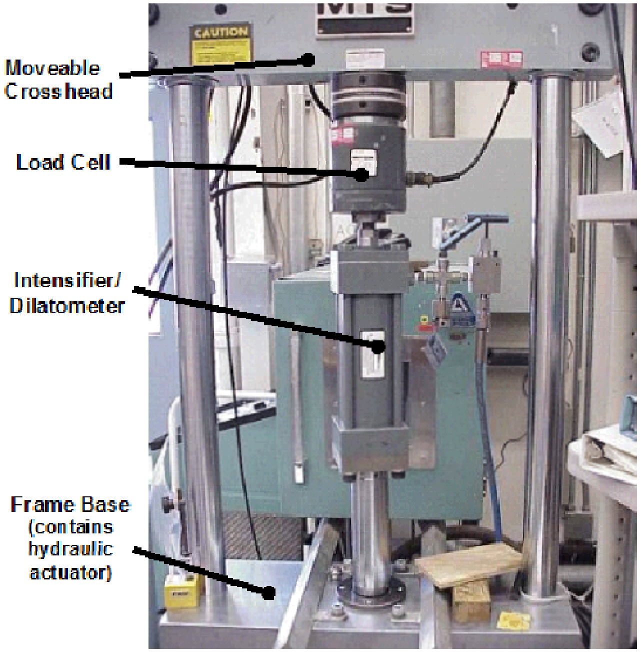
Triaxial Tests – Pre-test Specimen Assembly (cont.)

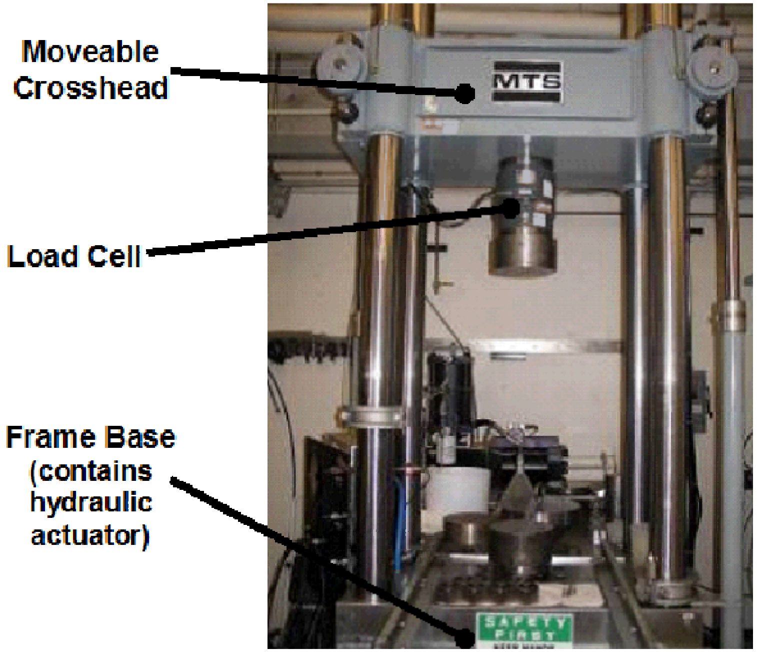
- Sample mounted in pressure vessel
- Electrical feed throughs used for LVDT's and internal load cell



Load Frames and Pressure Vessel

- Because of large sample deformations (~750 cc or 45% volume loss) two load frames were used
  - One load frame functioned solely as a dilatometer with ~700 cc capacity
  - Second load frame served as a reaction frame for the 100 MPa pressure vessel. A second dedicated dilatometer with ~300 cc capacity was used in tandem
  - Intensifier/dilatometers used to pressurize sample and to accurately measure fluid volume





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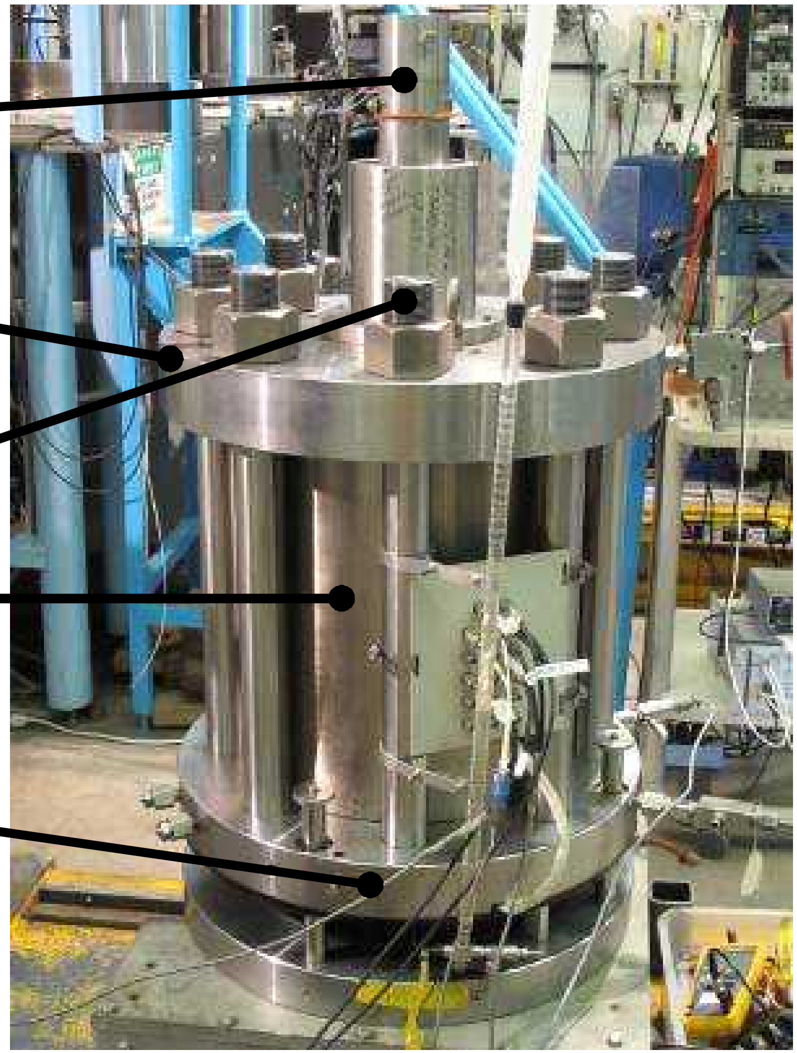
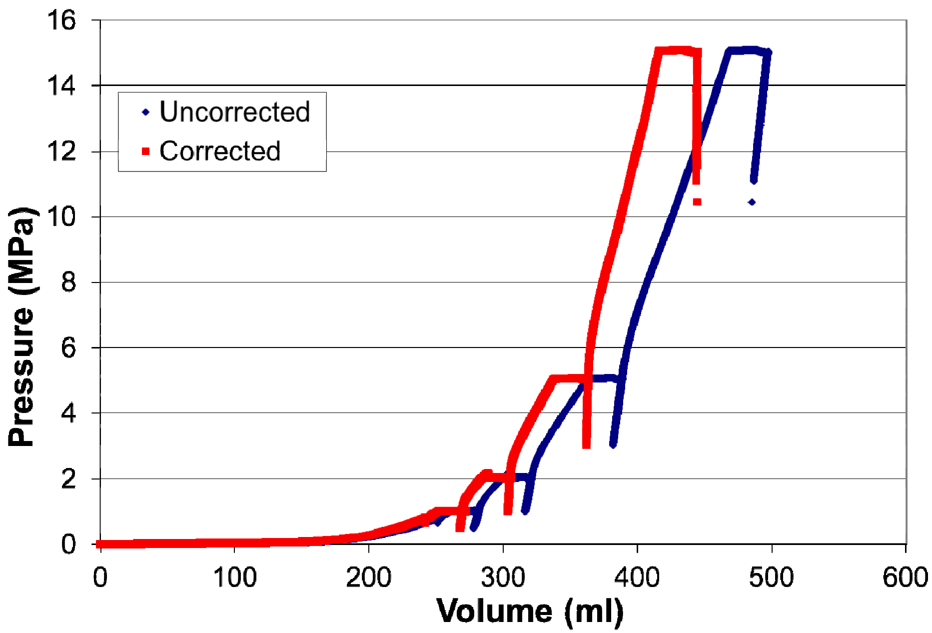
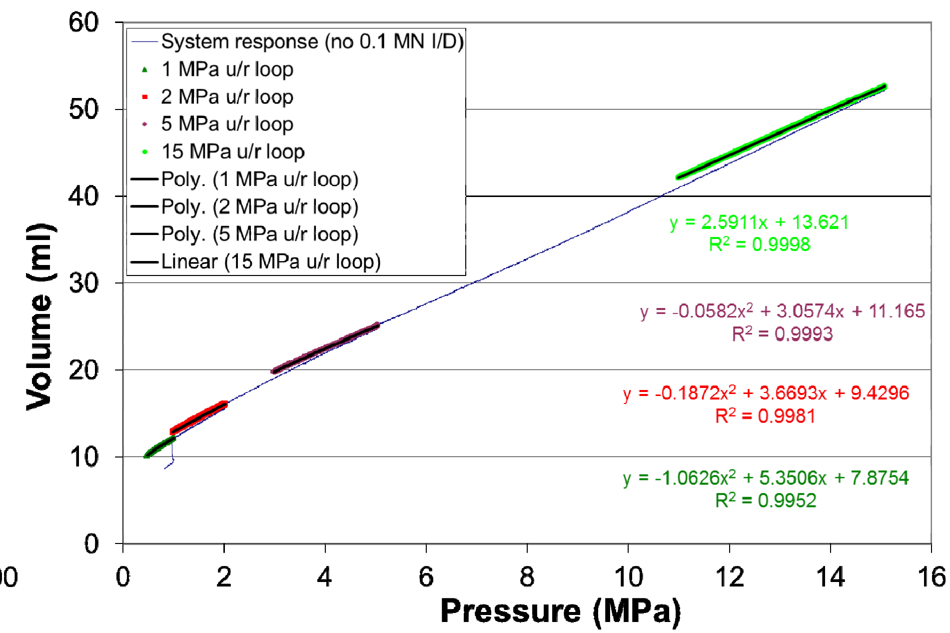
Pressure Vessel



Calibration of Hydrostatic Tests

- System response determined and subtracted from test data
- Accurate method: large sample deformation and relatively small system deformation





Note: I/D = Intensifier/Dilatometer, u/r = unload/reload loop

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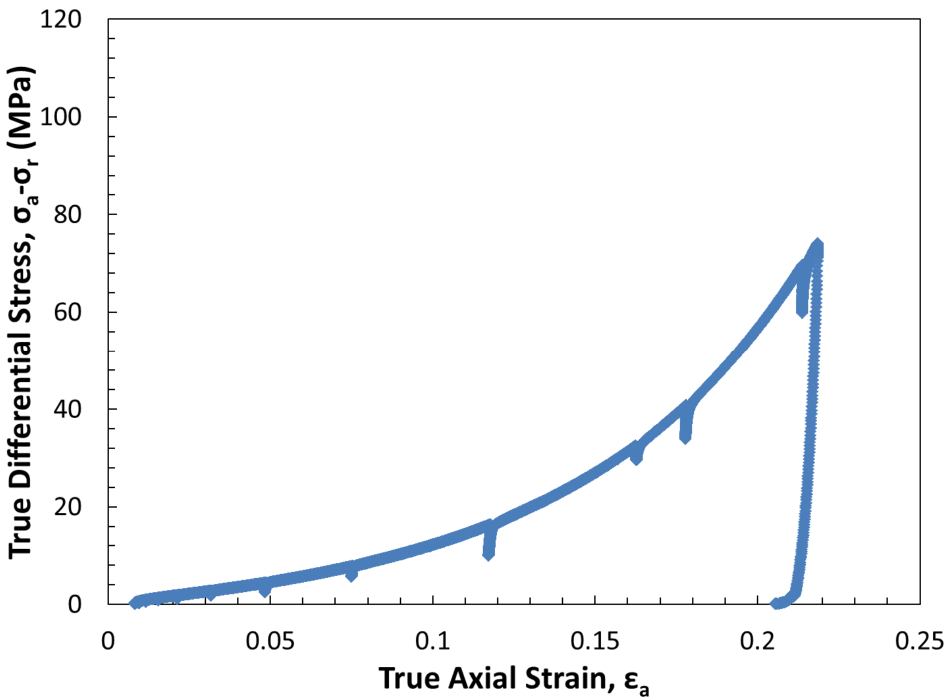
Triaxial and Uniaxial Strain Tests

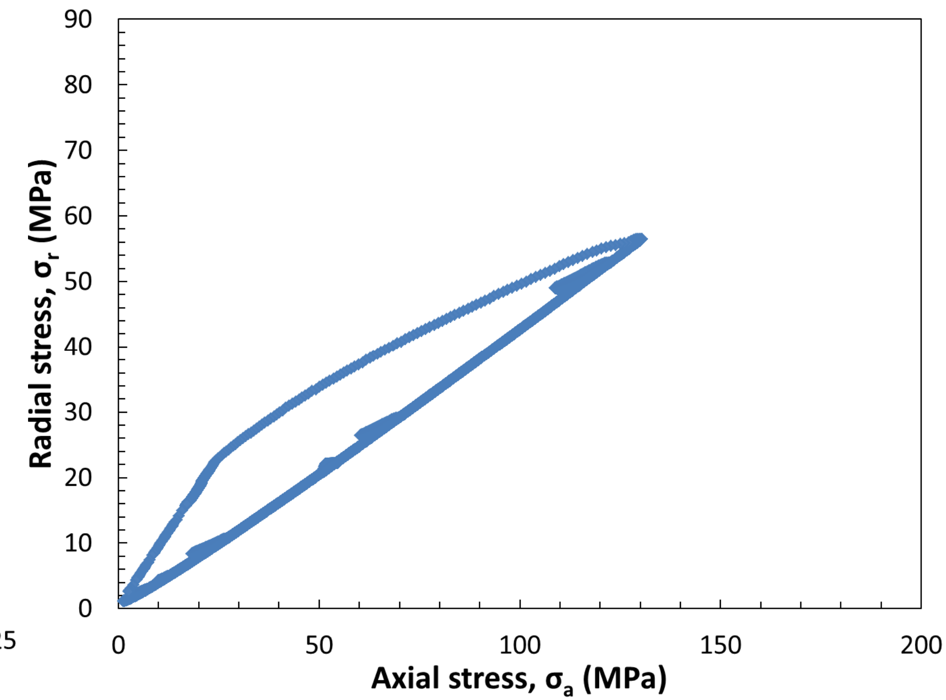
- **Unload/reload loops performed to determine elastic component of plastic/elastic deformation**
- **Confining pressure held at σ_r=constant and axially deformed to axial strain of ~20%**
- **Sample barreling was found giving $\nu > 0.5$**
- **Uniaxial strain tests run using σ_r control to maintain zero lateral strain condition**
- **Young's modulus and Poisson's ratio determined from:**

[illegible]

[illegible]

Sample Uniaxial Strain Test Results





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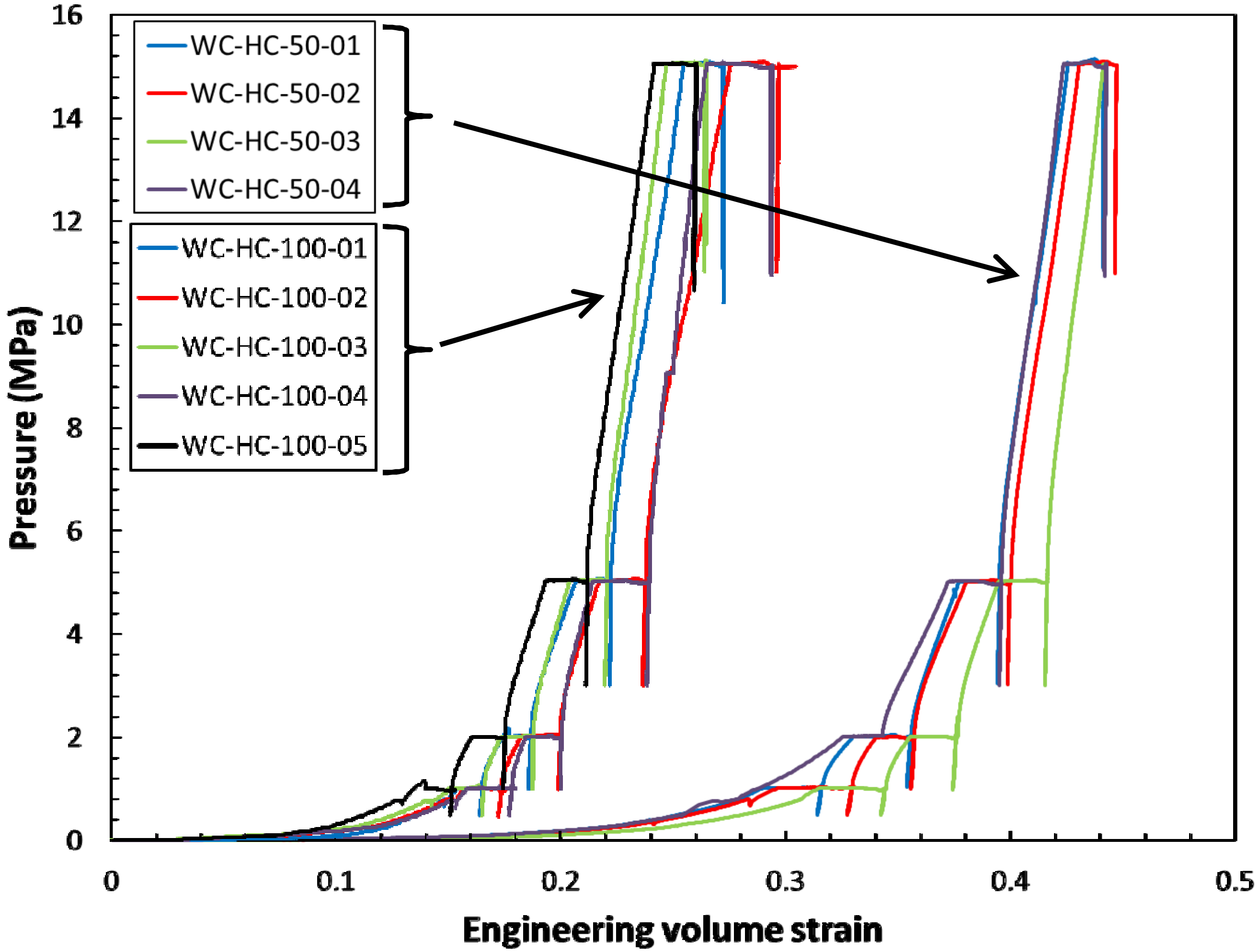
Hydrostatic Test Samples

Hydrostatic Tests – Pressure versus Volumetric Strain



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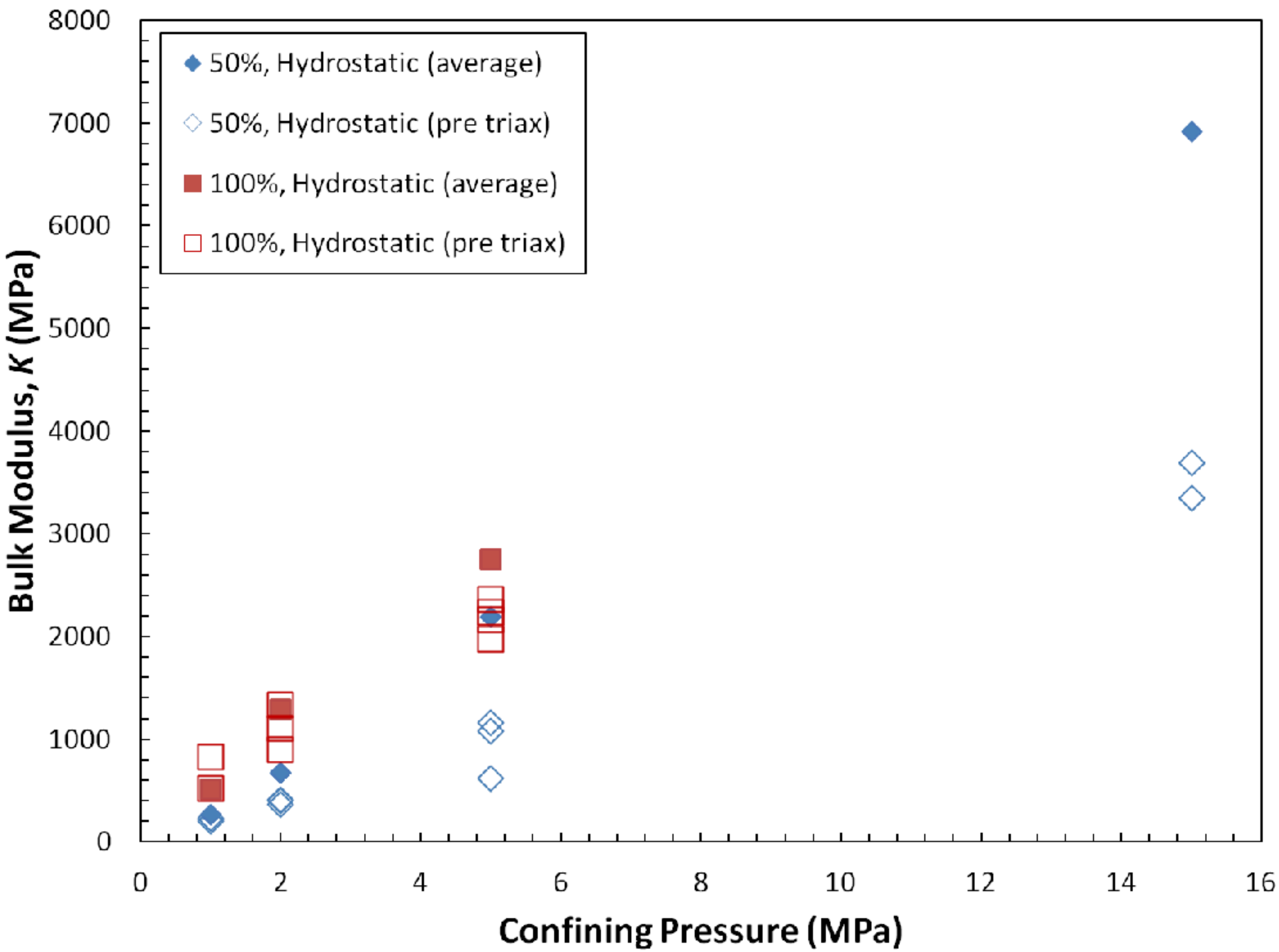
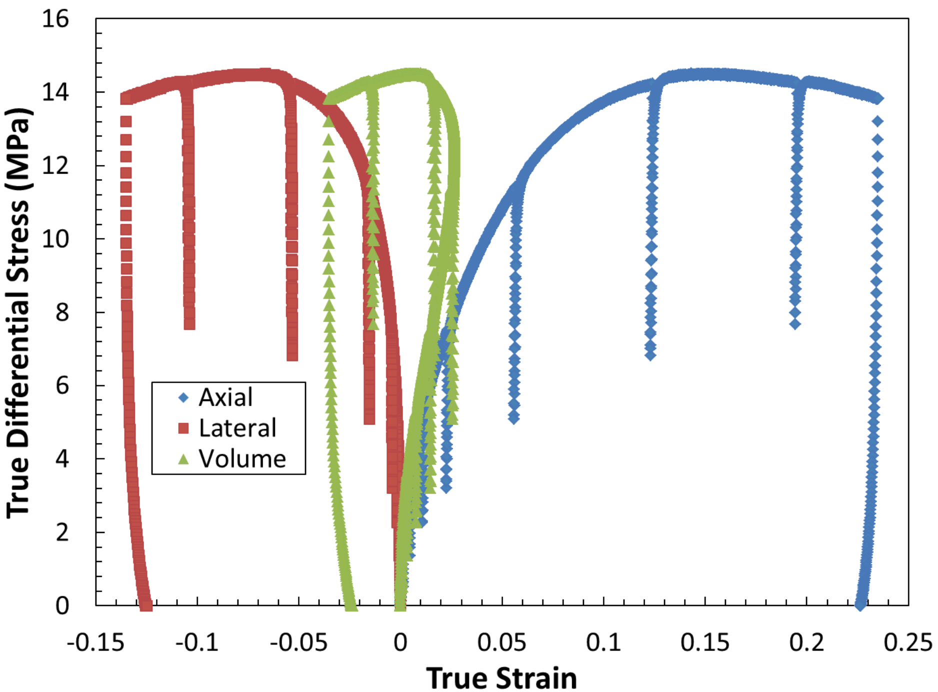
Bulk Moduli –
Hydrostatic and Triaxial Tests

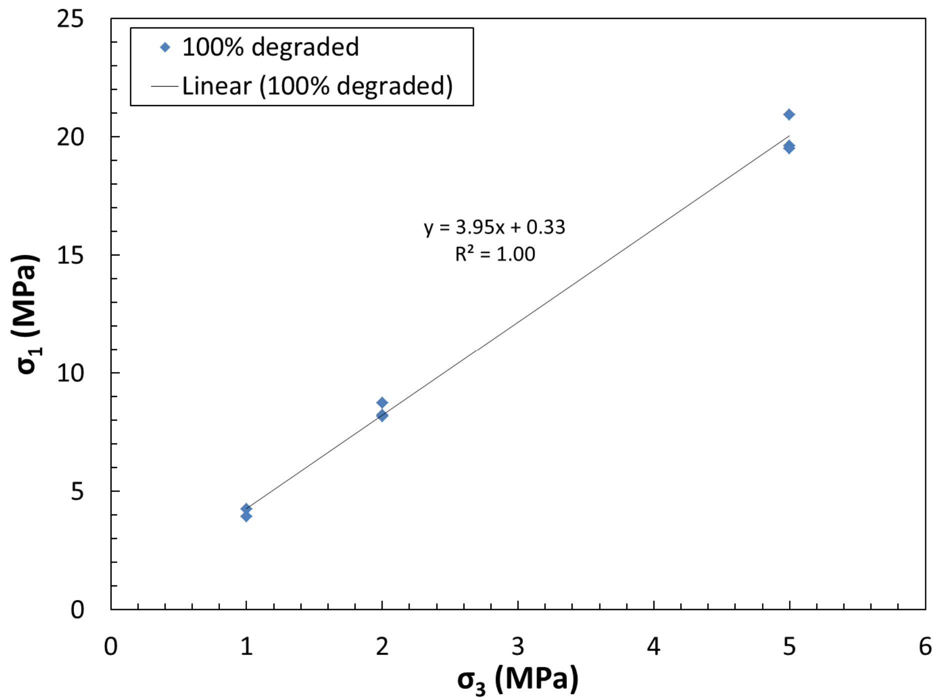


Peak Stress Behavior – 100% Degraded Waste

Peak stress observed for 100% degraded triaxial tests.



Mohr-Coulomb failure envelope developed



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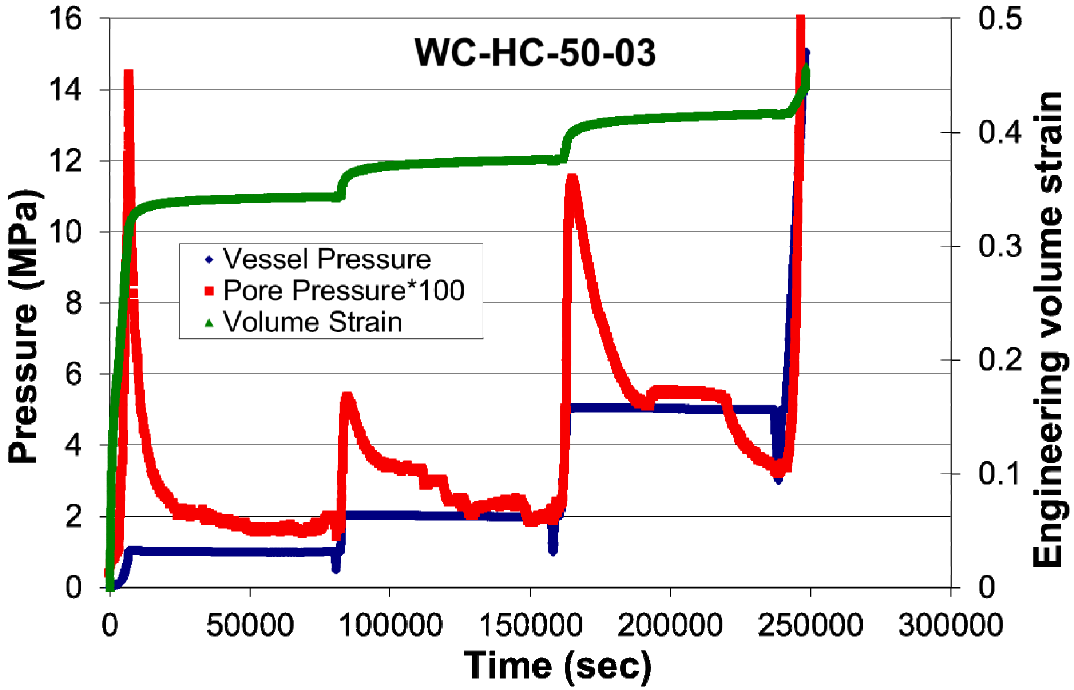
Creep in Hydrostatic Tests

- *Pore pressure measured on most hydrostatic samples.*
- *Creep observed*
  - *pore pressure redistribution likely*
  - *material creep possible*



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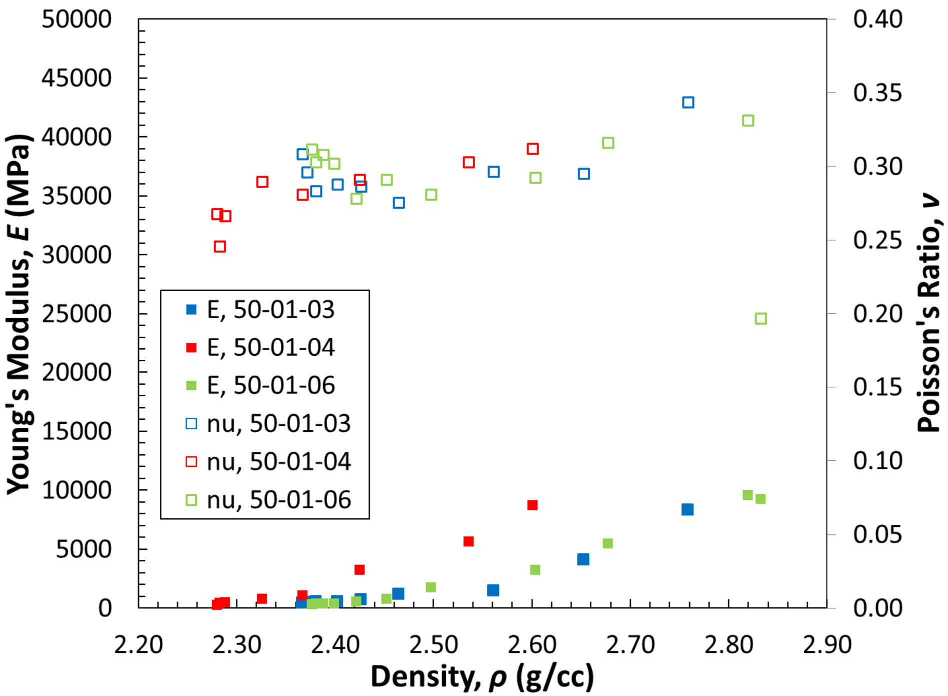
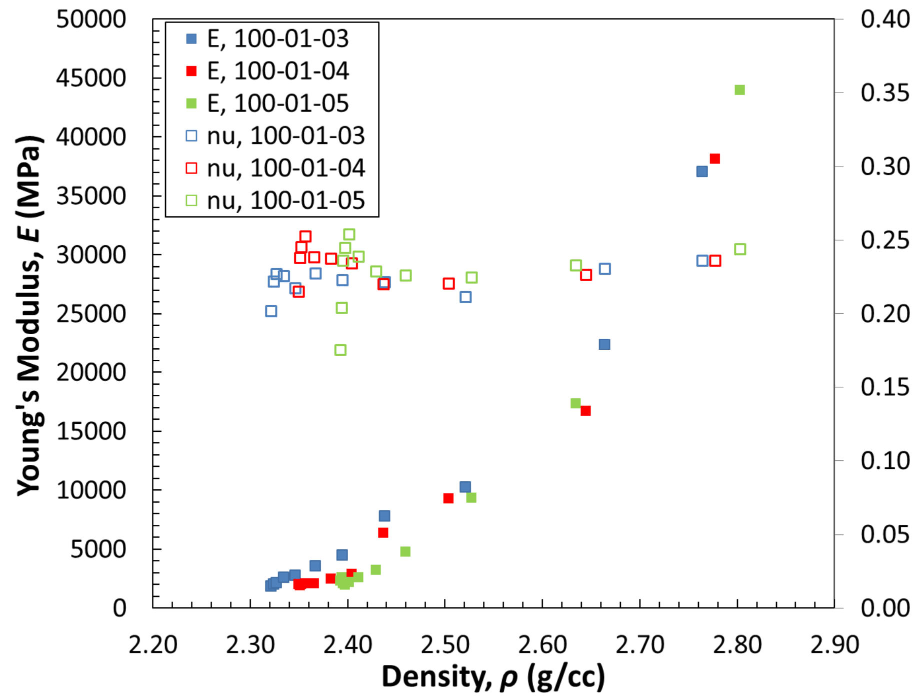
Young’s Modulus and Poisson’s Ratio

Young’s modulus and Poison’s ratio were determined as a function of density from Uniaxial Strain tests

50% Degraded



100% Degraded



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Summary

- *Test suite conducted that established the following for two surrogate material recipes (50% and 100% degraded):*

1) *Bulk modulus determined as a function of confining pressure*
2) *Young's modulus and Poisson's ratio determined as a function of density*
3) *Effect of pore pressure investigated*
4) *Mohr-Coulomb failure envelope developed from 100% degraded triaxial tests*

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