Study of Granular Materials in Compression Using NRSF2

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1. Background and Motivation

- Granular material such as silica sand is a hydrostatic pressure dependent frictional material. The global stress-strain relation of silica is complex, and depends on initial state of the specimen and the loading history.
- This research aims to provide a fundamental understanding of macroscopic stress-strain relations to its microstructure, to study the magnitude of non-homogeneous and anisotropic strain distribution within a deforming assemblage of particles, and to develop an understanding of the meaning of terms "stress" and "strain" in particulate materials subjected to various types of loading conditions.

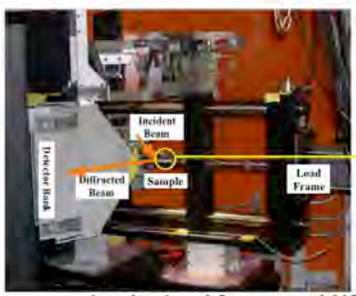
2. Experimental Details

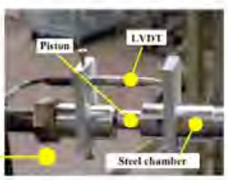
2.1 Materials

Unground silica (Ottawa and Q-Rok sand)

Type	Grain Shape	Mineral	Specific Gravity	% SiO_2	Mean grain size D_{50} (mm)
Ottawa	Round	Quartz	2.65	99	0.86
Q-Rok	Angular	Quartz	2.65	99.8	0.81

2.2 Testing set-up



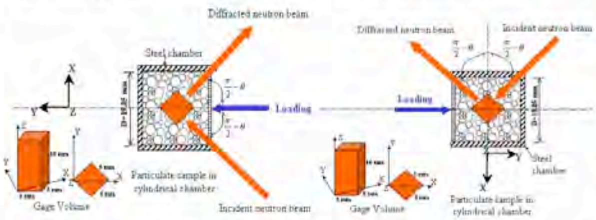


Close-up of the setup – LVDT, piston, and steel chamber holding the particulate materials

In-situ load frame and NSFR2

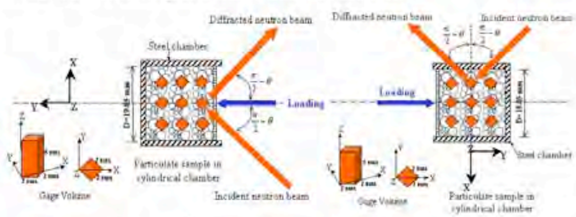
2.3 Measurement

- Continuous loading – Cylindrical sample with diameter 19 mm and height 19 mm; gage volume with incident slit 5×10 mm² and receiving slit 5 mm; axial displacement rate was 0.0004-0.0006 mm/sec; counting time was 60 sec per strain measurement.



Continuous Loading Measurement

- d-spacing mapping – Cylindrical sample with diameter 19 mm and height 19 mm; gage volume with incident slit 2×5 mm² and receiving slit 2 mm; axial displacement rate was 0.005 mm/sec; counting time was 40-70 min per strain measurement.

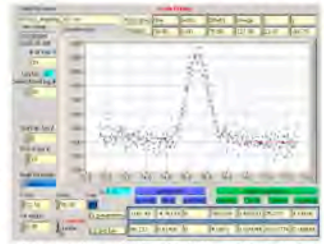


Local Strain Mapping Measurement

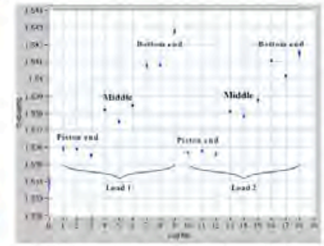
2.4 Monochromator and lattice plane selection

- Monochromater Si400 ($\lambda = 1.89$ Å)
- SiO_2 $(\bar{3}21)$ reflection at 2θ of 75.60°

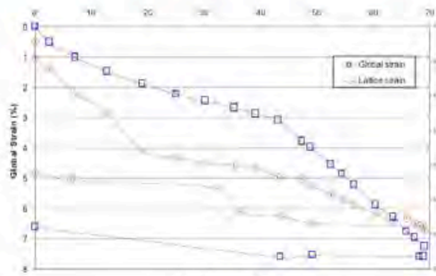
3. Experimental Results



Example of fitted diffraction data



Lattice spacing mapping data



Strain vs Stress

Global strain includes elastic strain in particles, slippage between particles, crushing and compaction of particles. Lattice strain indicates only elastic strain within particles.

4. Summary

- Methodology to study particulate materials using neutron diffraction is developed.
- Immediate applications to granular materials, powder metallurgy, and sintered ceramics.
- Elegant approach to obtain elastic strains locally and globally for an assemblage of particles under confined conditions is presented.
- Information useful for developing suitable elasto-plastic constitutive models of frictional materials.
- SNS-VULCAN can be used to reduce counting time and obtain multiple hkl data for strain mapping of particulate materials.

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