EVOLUTION OF SAMPLE TUBE PREPARATION TECHNIQUES FOR PLANETARY DRILL TESTING

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Introduction

- Electric Vehicle Controllers (EVC) and the Northern Centre for Advanced Technology (NORCAT) have created two generations of Lunar Highland Simulant
- Simulant preparation techniques and equipment resulted from drilling activities in support of Regolith and Environment Science and Oxygen and Lunar Volatiles Extraction (RESOLVE)
- The purpose of defining the compaction process was to minimize the effect of density on drill testing
  - This allowed other variables including drill bit geometry, auger, RPM, and thrust to be evaluated independent of density
- Density of Highland Regolith falls within a range of 1.40 to 2.29 g/cm^3 (p484 Lunar Source Book)

ASTM Standards

ASTM Compaction Standards have been developed for use in civil engineering

Standard Proctor Test ASTM D698

Modified Proctor Test ASTM D1557

Both standards influenced the vessel designs and compaction techniques developed for drill testing

CHENOBI Simulant

- Standard Proctor Density Test
  - Maximum Dry Density: 1.85 g/cm^3
  - Optimum Moisture Content: 11.6%

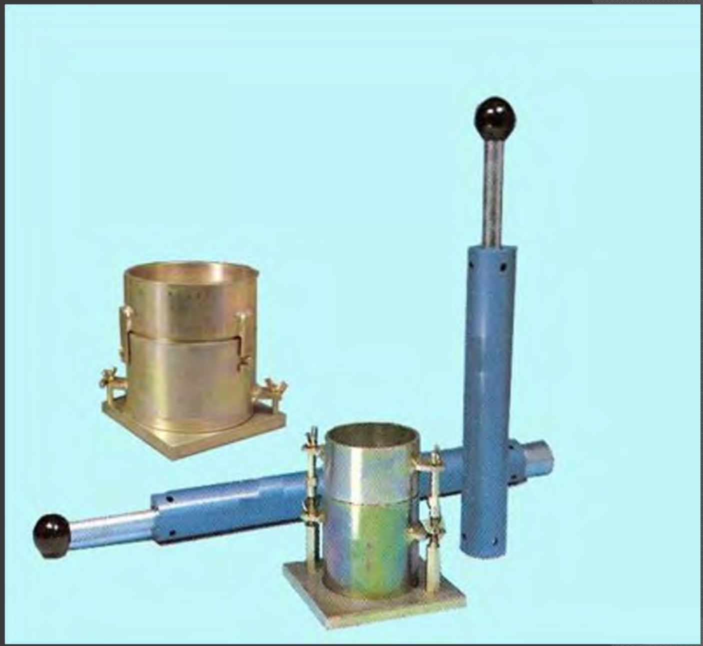
- This test was performed in a certified geotechnical lab using CHENOBI simulant

Modified Proctor Vessel

- 152.4 mm (ID) stainless steel mold
- 115.5 mm height mold
- 5 layers – 25 blows/layer
- 50.8 mm diameter circular face
- 4.53 kg hammer
- 457 mm drop height
- Removable upper ring

- Density is calculated based on the relationship between vessel volume and the weight of the compacted material

- Drill testing was limited by vessel height



http://alatlaboratoriumsipil.wordpress.com/tag/compaction-test/

Proctor Vessels and Vertical Hammers

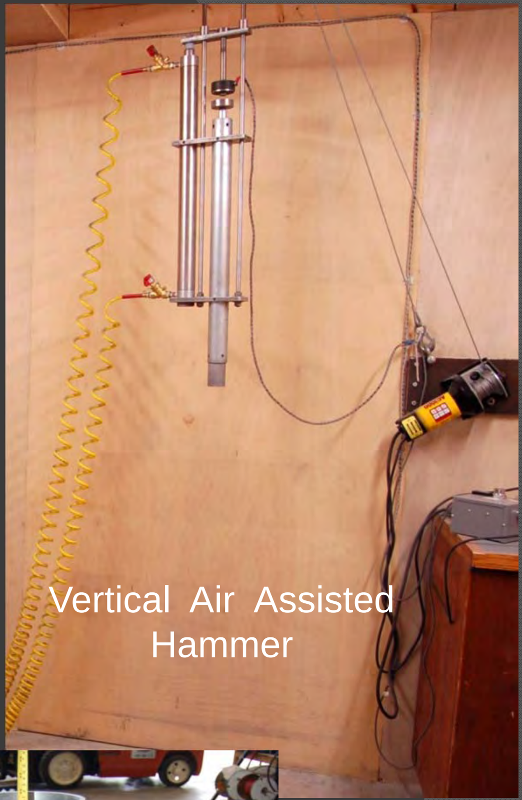
Stackable Modified Proctor Vessel

- RESOLVE drilling specifications called for sample recovery to a depth of 1 m

- **Challenge** - to increase vessel height while maintaining simulant density
- **Solution** – Stackable Modified Proctor Vessels allowed for maintaining the number of vertical dead hammer blows per layer

- The technique was altered to include an air assisted lift of the dead blow hammer – 1125 hammer lifts required

- The Stackable Modified Proctor Vessels allowed for the evaluation of drill bits and augers used to generate and transport cuttings from the drill bit/media interface



Vertical Air Assisted Hammer

Stackable Proctor Vessel

Stackable Modified Proctor Vessel Challenges

- Only one stackable unit available
  - Eliminated ability for simultaneous testing and sample preparation

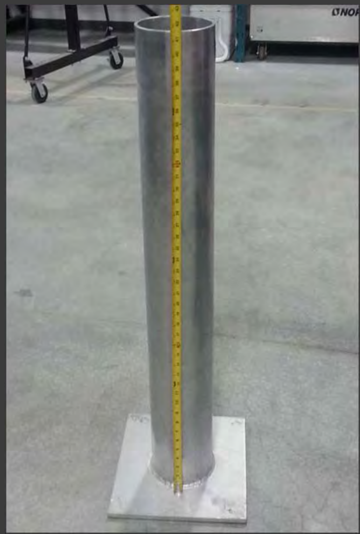
- Test Vessel Cost

- Excessive Preparation Time

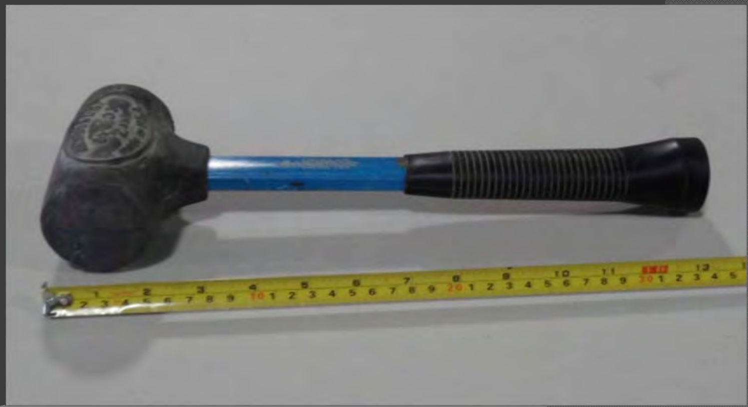
- Excessive Mass

105 cm Aluminum Test Vessel

- Manufactured from commercial, off the shelf components
- Reduced manufacturing cost
- Two units allowed for simultaneous use and preparation
- Leak-proof design
- Required adaptation of compaction techniques
  - Vertical dead blow hammer eliminated due to the increased height of test vessel
  - Manual hammer blows administered to the perimeter of the wall – 10 blows per layer
  - Density was replaced by mass due to the loss of the vertical drop technique



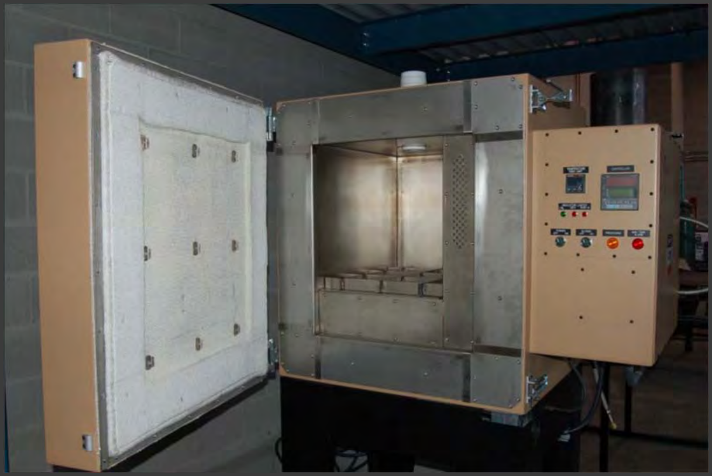
105 cm Aluminum Test Vessel



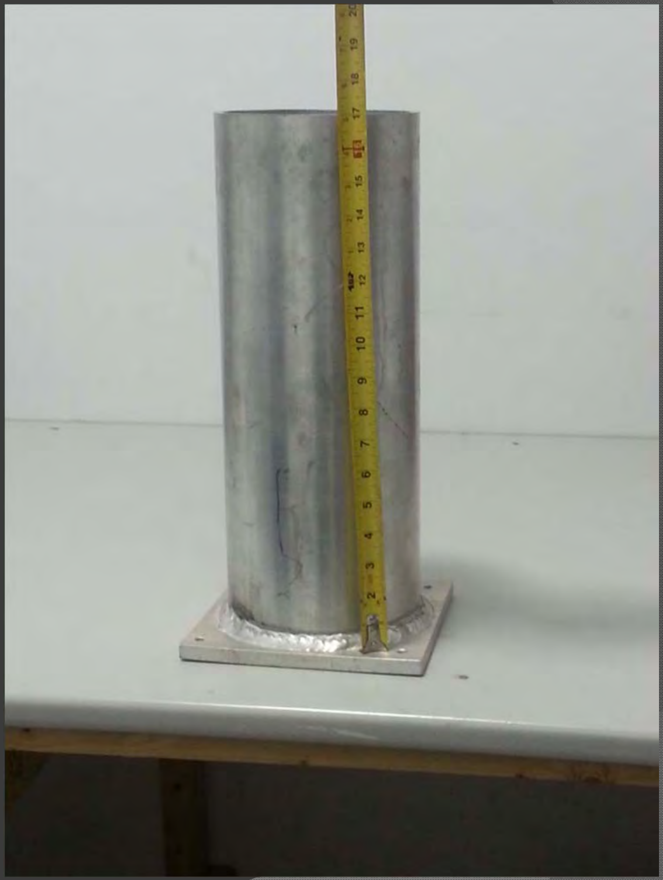
0.907 kg Dead Blow Hammer

43 cm Aluminum Test Vessel

- Specially built to fit within the NORCAT/Canadian Space Agency Cryo Temper Chamber
- Deeper than the Modified Proctor Vessel
  - 43 cm vs. 15.24 cm
- Leak-proof design
  - Seamless Weld at base plate



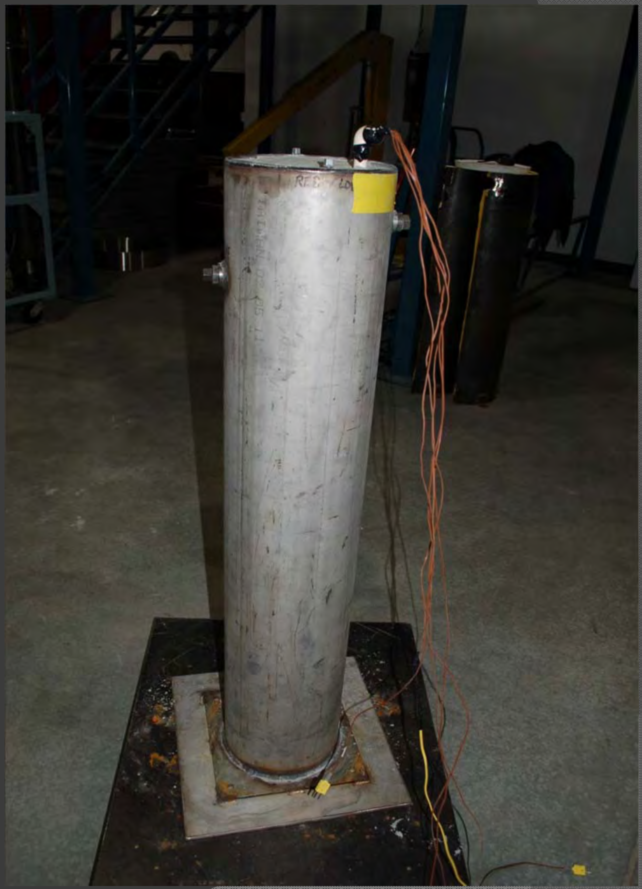
Cryo Temper Chamber



43 cm Aluminum Test Vessel

Cryo Test Vessel

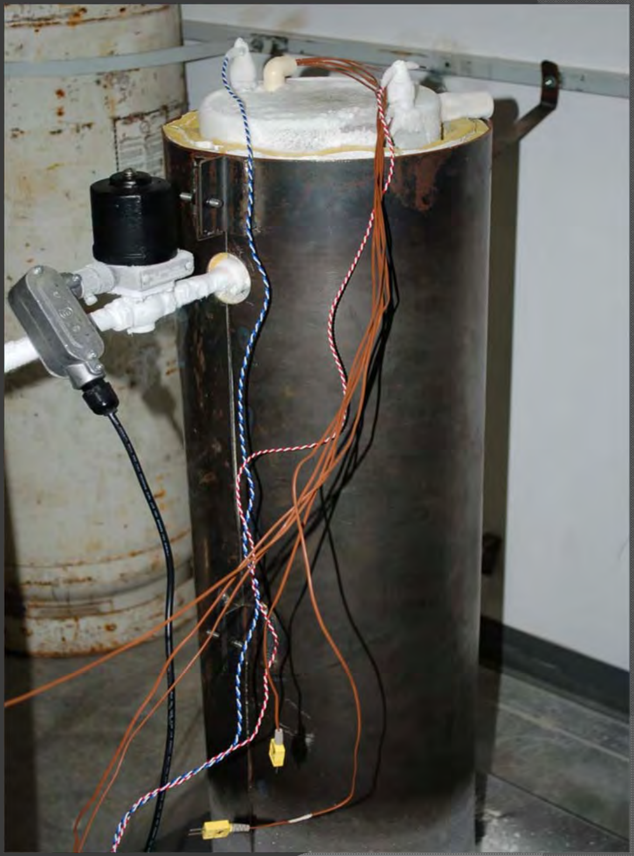
- Stainless steel, double wall construction
  - Top and bottom both sealed with leak-proof welds
- LN_2 is added through the outer wall via a solenoid valve
- Solenoid valve is monitored by liquid level sensors and controller
- Exhaust vent pipe and redundant pressure relief valve installed in the outer wall
- Thermocouples introduced at various depths in the simulant for temperature monitoring
- Insulated shroud protects operators from accidental contact with cooled vessel wall



Cryo Test Vessel

Cryo Test Vessel

- 1 m cryo test vessel required a new compaction method
  - Perimeter dead blows had little impact on compaction as the double wall construction dissipated the energy transfer
  - Compaction was achieved through the tamping of the simulant
- The same mass volume calculation as the 105 cm Aluminum Test Vessel was used



Cryo Test Vessel, Instrumented

Summary

- The Lunar Source Book indicated a density range of 1.40 to 2.29 g/cm^3 for Lunar Highland Regolith
- Standard and Modified Proctor Tests were utilized to verify that CHENOBI simulant could be compacted within this range
- Extrapolation of known density values allowed for larger test vessel design
- New techniques were developed to control moisture content and temperature
- Through the evolution of test vessel design and compaction methods, we were able to mitigate density as a variable in evaluating drill performance

Questions?