Penetration Tests in a Mold on Regolith Quasi-Analogues at Different Relative Densities

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Outline

- Introduction
- Materials tested
- Equipment
- Selected results
- Summary and future work
Introduction

Robotic Exploration of Extreme Environments
Funded by the Helmholtz Association
5 years project
16 institutions from Space and Marine Research
Lunar soil simulant developed in the lab

Vrettos, 2012
Test Materials

Grain Size Distribution Curves

Comparison with common terrestrial materials

(a) filter dust  
(b) MMS-dust  
(c) MSS-D  
(d) quarry fines  
(e) sand WF34  
(f) MMS-sand  
(g) grey sand  
(h) glass beads  
(i) glass splinter
Test Materials

Grain Size Distribution Curves

Comparison among extra-terrestrial soil simulates

(a) filter dust
(b) MMS-dust
(c) MSS-D
(d) quarry fines
(e) sand WF34
(f) MSS-sand
(g) grey sand
(h) glass beads
(i) glass splinter

- JSC 1A Mars
- JSC 1A Lunar
- Syar fine
- Seramis
Test Materials

Properties of the materials tested

- glass splinter
- glass beads
- MMS-sand
- sand WF34
- MMS-dust
- MSS-D
- JSC 1A – Mars
- JSC1A - Lunar
- quarry fines
- filter dust
- Syar
- M-sand

Void ratio difference ($e_{\text{max}} - e_{\text{min}}$) vs Specific gravity $\rho_s$
Test Materials

Hygroscopicity

Influence on shear strength with increasing moisture content
Test Materials

Triaxial Tests
Test Materials

Triaxial Tests - Selected Results

Syar sand; dry & wet ($w = 4.8\%$)
Penetration Tests

**Equipment**

1.2 mm/min

∅ 10 mm

$D_r = \frac{e_{\text{max}} - e}{e_{\text{max}} - e_{\text{min}}}$

71 – 150 – 290 mm

112 – 125 – 200 mm
Penetration Tests

Selected Results – loose state

- Quarry fines
- MSS-D
- MMS dust
- Filter dust

- Glass splinter
- Glass beads
- Grey sand
- MMS sand
- Sand WF34

Force [N] vs. Depth [mm] for different materials in the loose state.
Penetration Tests

Selected Results – medium-dense state
Penetration Tests

Selected Results – dense state and different molds
Penetration Tests

Selected Results – different molds

Sand - WF34
Penetration Tests

Selected Results – rupture mechanism

(a) general shear
(b) local shear
(c) punching shear
Penetration Tests

Selected Results – rupture mechanism

\[ \alpha = 45^\circ - \varphi/2 \]
\[ \beta = 90^\circ + \varphi \]
\[ \psi = 45^\circ + \varphi/2 \]

(I) – (III) Rankine zones

Influence \( R \)
Penetration Tests

Selected Results – peak

Quarry fines, $D_r = 0.5$

$\sigma_1 - \sigma_3$

$\sigma_1 - \sigma_3 = f(D_r \ldots)$
Penetration Tests

Selected Results – ambient pressure $p_a$

- $p_a = 100$ kPa
- $p_a = 2.1$ kPa

Notice: Vrettos (2012)
Penetration Tests

Numerical Investigation – Preliminary findings
Summary

- Penetration Tests carried out in two classes of soil: (i) fine-grained dust and dust-like material (ii) sandy material
- Main trends expected to prevail when $D_r$ of the material is varied
- Index of Compressibility can help, whereas use of the grain size distribution curve as a prediction tool within each subgroup is not appropriate
- The effects of the rigid base and rigid walls have also been identified from the response
- Future work will include investigations with respect to particle shape
- Numerical investigation

Thank you for attention.