Lunar Concrete
A Means to Reduce the Dust Hazard

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Lunar Concrete

- Use in situ resources to create a paved lunar playground
- Attainable achievement which greatly aids lunar exploration
- A flat, smooth lunar surface will...
  - Eliminate lunar topsoil
  - Aid landing operations
  - Aid surface operations
  - Increase geological data

- Production capability proven with Apollo samples
- Structural / construction constraints very flexible
- Able to be feasibly integrated with current architecture
Advantages of Concrete

- Economic
  - Less energy required for formation
- Compartmentalization
  - Can be molded into any shape
- Thermal strength
  - Can survive high and low temperatures
- Radiation shielding
  - Excellent barrier
- Abrasion resistant
  - Protects from micrometeorite debris
- Vacuum resistant
  - High environmental tolerability
Water vs. Sulfur?

- Concrete is...
  - Aggregate + Cement (15%) + Water (7%)
  - Aggregate + Sulfur (35%)

<table>
<thead>
<tr>
<th></th>
<th>Water based concrete</th>
<th>Sulfur based concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minerals</td>
<td>Ilmenite, Ice</td>
<td>Troilite, SO₂, H₂S</td>
</tr>
<tr>
<td>Supply</td>
<td>Medium- High</td>
<td>Low</td>
</tr>
<tr>
<td>Required</td>
<td>Low</td>
<td>Moderate- High</td>
</tr>
<tr>
<td>Outside Demand</td>
<td>Very High</td>
<td>Low</td>
</tr>
<tr>
<td>Architecture Integration</td>
<td>Easy</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

- Both designs could lead to spin-off technologies for Earth-based construction in dry regions
## Performance

<table>
<thead>
<tr>
<th></th>
<th>Using Lunar soil and alumina cement</th>
<th>Earth materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressive Strength</strong></td>
<td>10.9 ksi</td>
<td>7.96 ksi</td>
</tr>
<tr>
<td><strong>Static Modulus of Elasticity</strong></td>
<td>1100 ksi</td>
<td>1800 ksi</td>
</tr>
<tr>
<td><strong>Dynamic Modulus of Elasticity</strong></td>
<td>3120 ksi</td>
<td>2810 ksi</td>
</tr>
<tr>
<td><strong>Poisson’s ration at Peak Load</strong></td>
<td>0.39</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Modulus of Rupture</strong></td>
<td>1.21 ksi</td>
<td>1.24 ksi</td>
</tr>
<tr>
<td><strong>Coefficient of Thermal Expansion</strong></td>
<td>$2.9 \times 10^{-6} / ^\circ F$</td>
<td>$3.5 \times 10^{-6} / ^\circ F$</td>
</tr>
</tbody>
</table>

Data from Lin, Construction Technology Laboratories, 1986

- Lunar based concrete is comparable to Earth based concrete
  - True for water and sulfur mixtures
- More than adequate for paving
  - Reinforcing glass fibers may be required for large structures
Architecture Integration

- ISRU Rover Tools:
  - Excavator
  - Collector
  - Grinder
  - Filter
  - Processor
  - Separator
  - Storage
  - Ejector

- Additional tools for concrete capability:
  - Mixer
  - Layer / Sprayer
  - Curer
Research Pathway

- **PAST**
  - Apollo proved need for dust suppression
  - Post-Apollo proved concrete capability

- **PRESENT**
  - Applied concrete research
  - Integrate ISRU research
  - Increase geological data
  - Significantly aid Constellation

- **FUTURE**
  - Large playground
  - Launch pad barrier
  - Inflatable structure cover
  - Pressurized structure
  - Stepping stone to Mars
Challenges

- Adequate material availability?
- Appropriate processing method?
- Sufficient production rate?
- Enough operational payback?
- Amount of future infrastructure required?