

The use of Solar Heating and Heat Cured Polymers for Lunar Surface Stabilization

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Dust and surface stabilization

- Dust ejecta during lunar launch/landing can affect visibility, erode nearby coated surfaces and get into mechanical assemblies of in-place infrastructure
- Dust mitigation will be necessary for certain areas of the lunar habitat
- Surface stabilization can be used for roads, launch pads and other dust free areas



Surveyor

- Apollo 12 LM landed 163m from the Surveyor 3 craft
- NASA-SP-284: Analysis of Surveyor 3 material and photographs returned by Apollo 12 – found “sandblasting” with shadows showing that the blast came from the LM



Overview

- Compare and test potential stabilization methods
 - Polymer palliatives
 - Solar
 - Microwave
- Evaluation Criteria
 - Mass
 - Power
 - Ease of use
 - Time
- Physical and engineering properties

Polymer Palliatives

- Technology successfully used in military applications for helicopter pads and roads
- Polymer is sprayed with water as the solvent
- Technology required very little development



Rhinosnot.com

Polymer Palliatives

■ Advantages

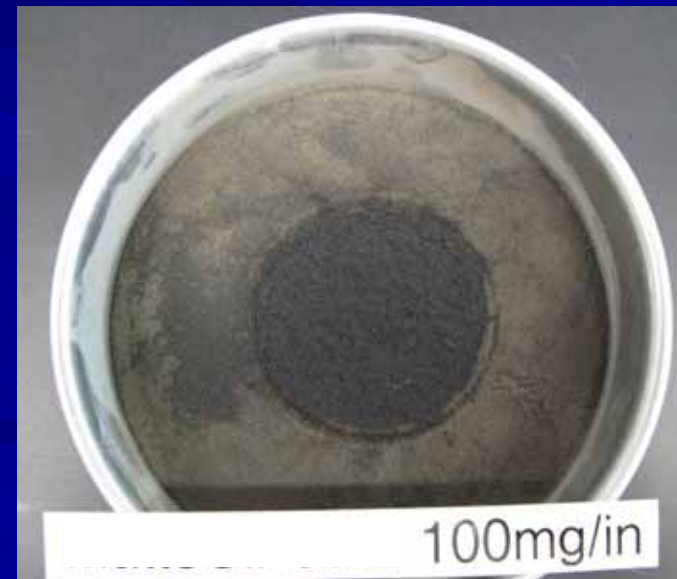
- Ease of use: heat, UV or ambient curing
- Many commercially available products (solvent free solids or liquids) with different desirable properties: High temperature resistance, abrasion resistance, flexibility

■ Disadvantages

- Mass
- Consumable

Polymer Palliatives

- Evaluated 4 commercially available powders and 1 developed at KSC
 - Abrasion, UV resistance, high temperature resistance
- Demonstrated stabilization in the lab and in the field using our solar concentrator
- Investigated different spreading ratios, mixing ratios and application methods
- Polymers do not begin thermal degradation until 260 – 290 C
- Coverage rates ranged from 0.08 to 0.31 kg/m²

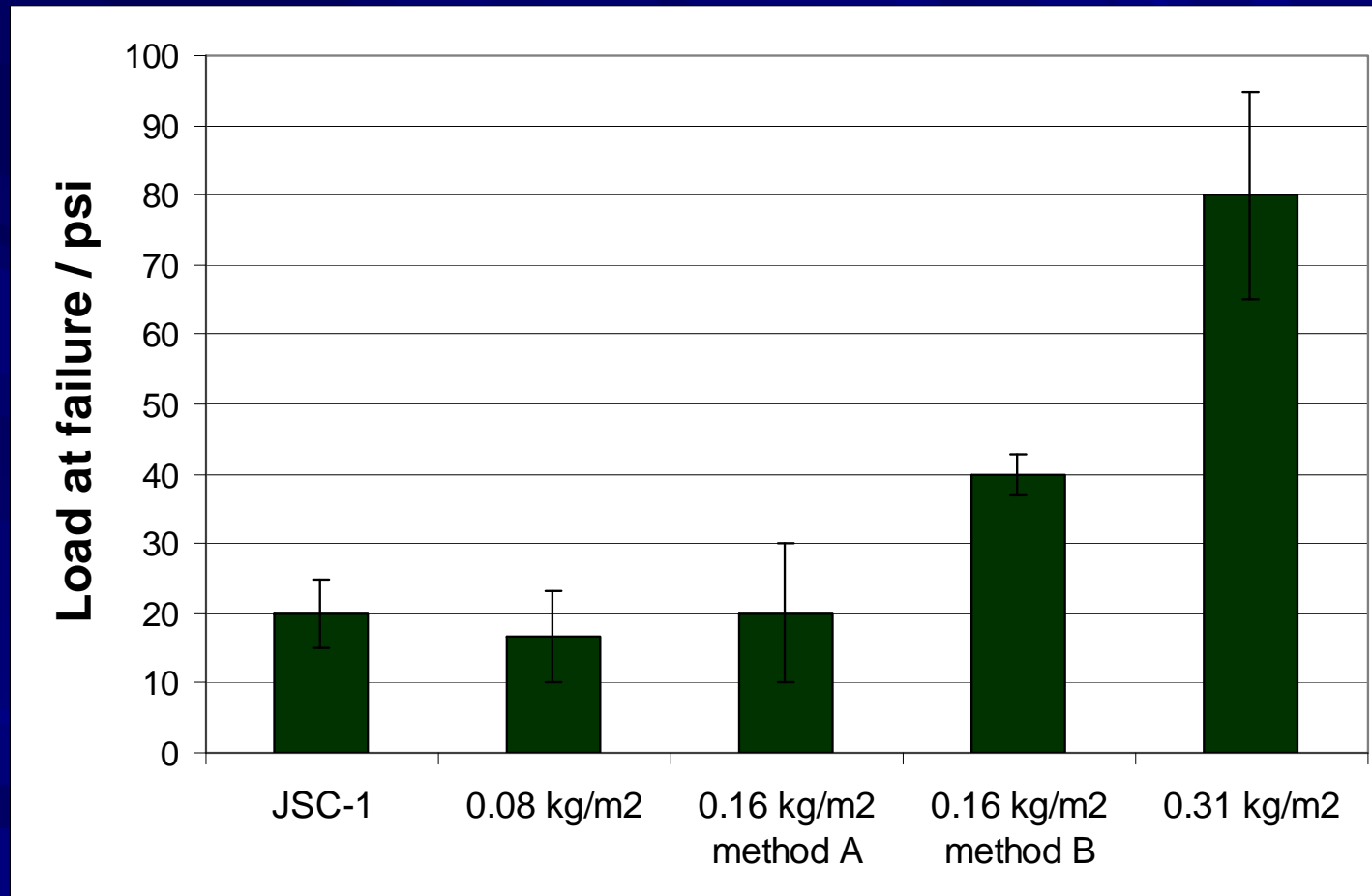


Load Bearing Strength

- Loads applied on different surface treatments were measured
- JSC-1A lunar simulant placed in a 6" diameter dish
- Surface treatment placed in center 3" diameter area
- Load is applied with a 0.75" diameter piston



Polymers: Load Bearing Strength

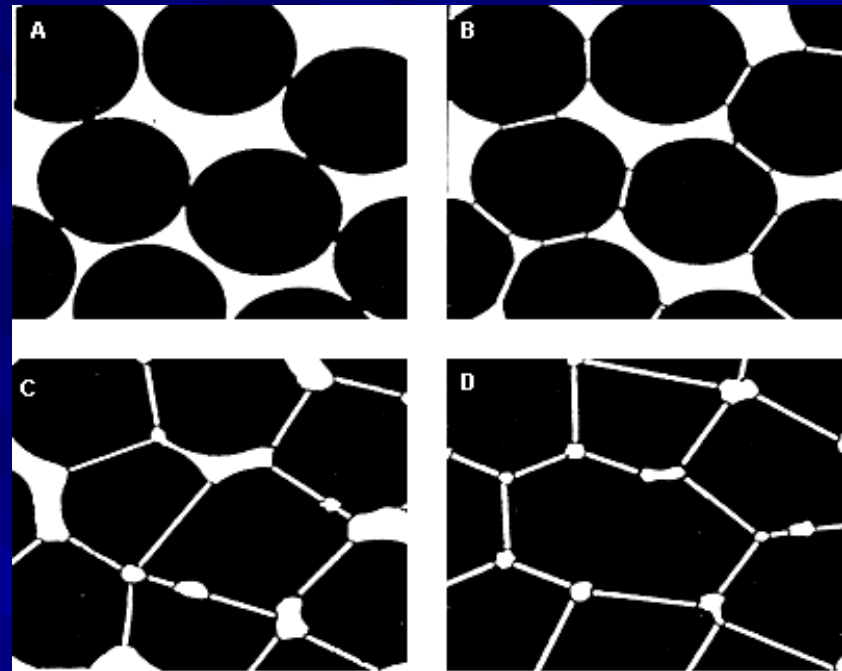


Polymers: Future Work

- Continue to work on spread rates and application methods
- Apply to larger areas
- Investigate thermal cycling and application under vacuum

Sintering

- Sintering is a method for making solid objects from a powder by heating the material (below its melting point) until its particles adhere to each other
- Particle size, density and packing of regolith are ideal for sintering
- Use *in situ* materials; need heat source



- A. Loose powder (start of bond growth).
- B. Initial stage (the pore volume shrinks).
- C. Intermediate stage (grain boundaries form at the contacts).
- D. Final stage (pores become smoother).

How long does it take?

100 m² area to a depth of 2.5 cm

Heating Method	Efficiency	Time in Days
1 m ² solar concentrator	100%	27
1 kW microwave	100%	35

- 2.5 m³ of regolith requires 3×10^9 J to heat 1000K assuming a regolith density of 1.5g/cm³; regolith heat capacity of 0.8 J/(g K)
- Assumes all energy is converted to heat
 - It will take longer: losses in solar concentrator, electrical to microwave conversion, coupling to regolith etc...

Microwave sintering

- Technology has been proposed for sintering a surface (Taylor et. al.)
- Most materials absorb microwave energy to some degree, especially at higher temperatures
- Lunar regolith is a great microwave absorber

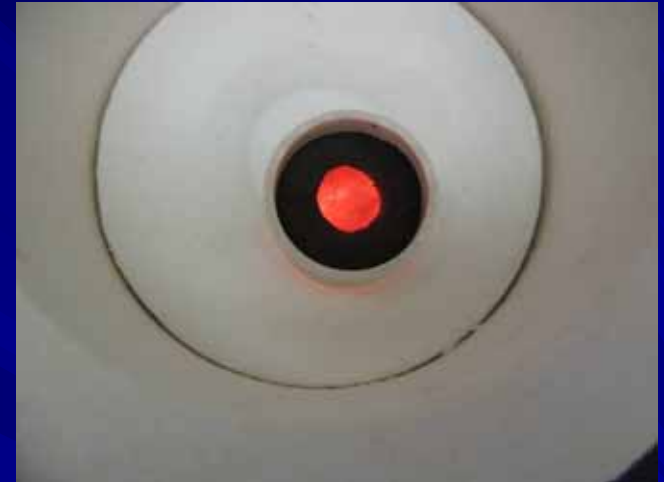
Microwave Sintering

■ Advantages:

- Much more efficient than electrical heating
- Moderate Mass
- Inexpensive technology
- Heats the bulk of material

■ Disadvantages

- Power consumption (1 – 10 kW?)
- Magnetron requires cooling
- Thermal runaway can lead to inconsistent results
- Energy might penetrate deeper than needed



Solar Concentrator



- Sunlight gives 1.3 kW/m² of energy
- Solar heating used for cooking, water purification and other uses



Solar Concentrator

■ Advantages

- No power
- Lightweight
- Inexpensive

■ Disadvantages

- Direct heating only heats the surface
- Uneven heating can cause problems
- Must follow the sun

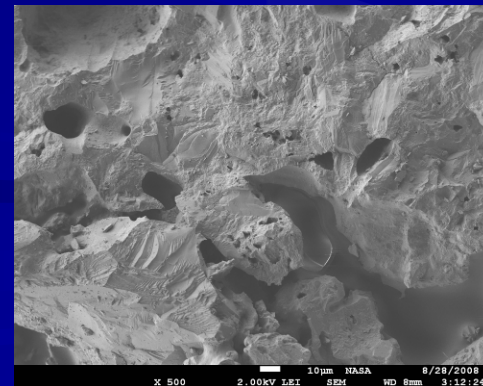
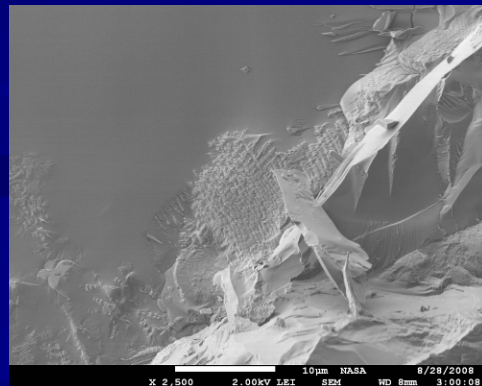
Solar Concentrator

- Rastering across a surface can produce cracking in between passes
- Staying on a sample can lead to both sintering and melting

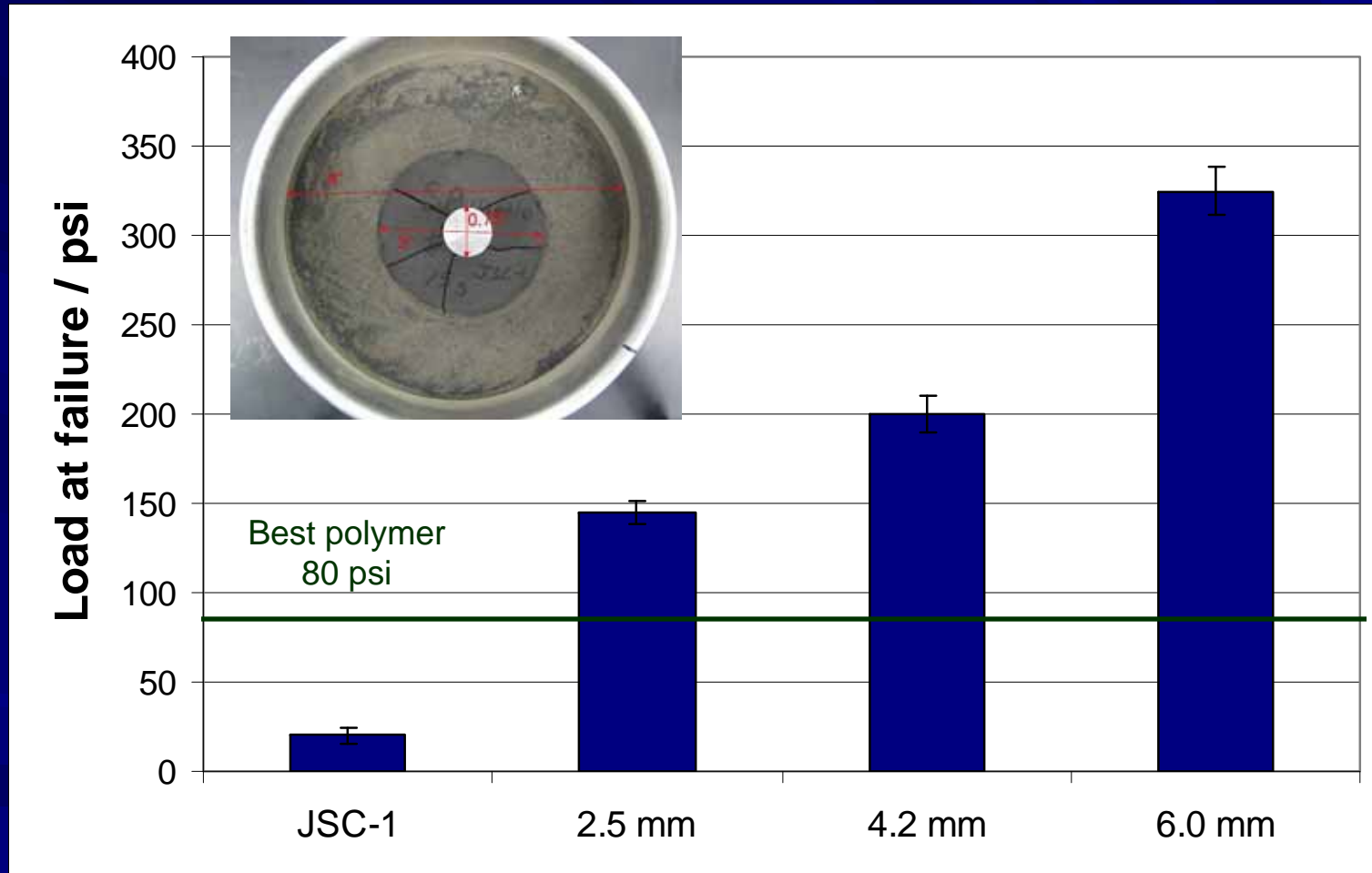


Solar Concentrator

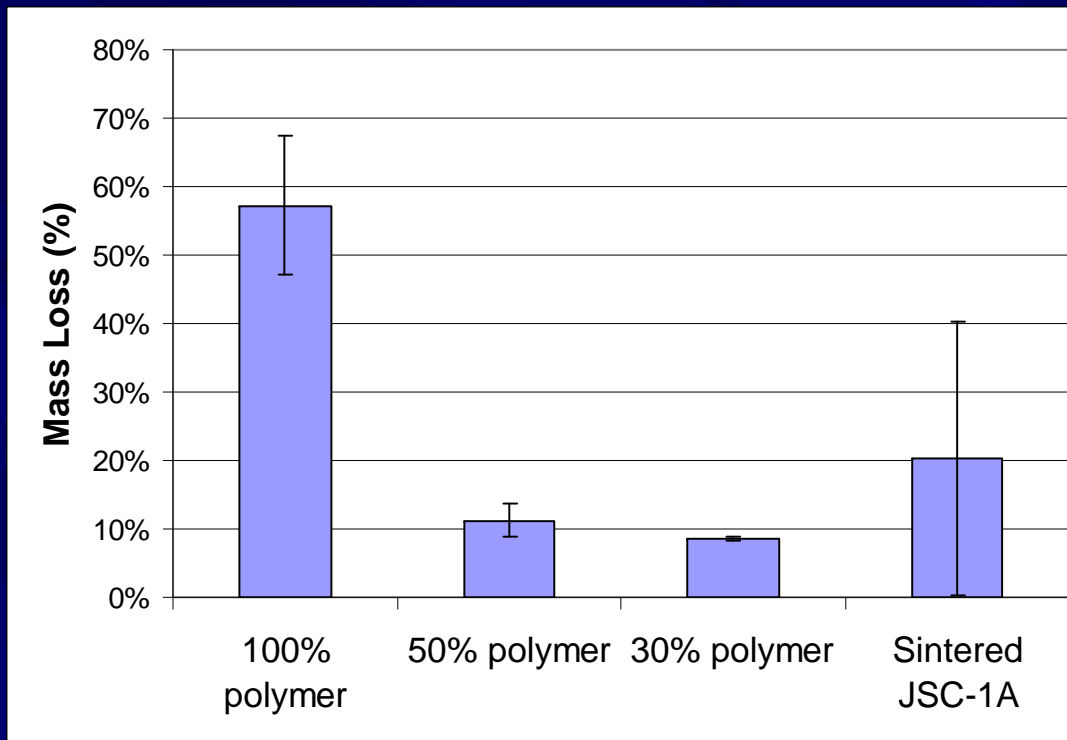
- You need good control to sinter, without melting
- Melted areas can be brittle; sintered areas might not have abrasion resistance



Sintered: Load Bearing Strength



Abrasive Blast Testing



- Test adapted from ASTM C704: Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature

Future Work

- Perform load testing on solar sintered samples, as was done for lab samples
- Abrasion testing (abrasive blast) to compare polymer, sintered, and melted specimens
- Thermal cycle testing
- Optimize...