The use of Solar Heating and Heat Cured Polymers for Lunar Surface Stabilization. P. E. Hintze[1], J. P. Curran[2] and T. A. Back[2]. [1]NASA Corrosion Technology Laboratory, Mail Stop KT-E3, Kennedy Space Center, FL 32899 Paul.E.Hintze@nasa.gov, [2]ASRC Aerospace, Mail Stop ASRC-24, Kennedy Space Center, FL 32899, Jerome.Curran-1@ksc.nasa.gov, [2]ASRC Aerospace, Mail Stop ASRC-24, Kennedy Space Center, FL 32899 Teddy.Back-1@ksc.nasa.gov.

Introduction: Dust ejecta can affect visibility during a lunar landing, erode nearby coated surfaces and get into mechanical assemblies of in-place infrastructure. Regolith erosion was observed at many of the Apollo landing sites. This problem needs to be addressed at the beginning of the lunar base missions, as the amount of infrastructure susceptible to problems will increase with each landing. Protecting infrastructure from dust and debris is a crucial step in its long term functionality. A proposed way to mitigate these hazards is to build a lunar launch pad.

Other areas of a lunar habitat will also need surface stabilization methods to help mitigate dust hazards. Roads would prevent dust from being lifted during movement and dust free zones might be required for certain areas critical to crew safety or to critical science missions.

Work at NASA Kennedy Space Center (KSC) is investigating methods of stabilizing the lunar regolith including: sintering the regolith into a solid and using heat or UV cured polymers to stabilize the surface. Sintering, a method in which powders are heated until fusing into solids, has been proposed as one way of building a Lunar launch/landing pad. A solar concentrator has been built and used in the field to sinter JSC-1 Lunar stimulant. Polymer palliatives are used by the military to build helicopter landing pads and roads in dusty and sandy areas. Those polymers are dispersed in a solvent (water), making them unsuitable for lunar use. Commercially available, solvent free, polymer powders are being investigated to determine their viability to work in the same way as the solvent borne terrestrial analog.

This presentation will describe the ongoing work at KSC in this field. Results from field testing will be presented. Physical testing results, including compression and abrasion, of field and laboratory prepared samples will be presented.

Methods and results: A solar concentrator with a 1 m^2 collection area has been constructed for field testing at KSC, as shown in figure 1. The solar concentrator consists of a large lens mounted on a frame that allows the lens to move and follow the sun. The focal point of the lens is pointed downward to allow for rastering across a surface. The highest measured temperature created by the solar concentrator has been 1350°C. The solar concentrator easily achieves the temperatures needed to sinter or melt JSC-1 lunar simulant.

Initial experiments using the solar concentrator have focused on evaluating how thick a surface can be sintered and how best to sinter large areas. The first tests involved simply focusing the light on a bed of JSC-1. When this is done the top surface quickly melts at the focal point. Within two to three minutes, a combination of melting and sintering occurs to a depth of about 6 mm. Continued heating after this time does not increase the thickness of the sintered area at the same rate.

We are investigating the use of UV or heat cured polymers as additives or topcoats for the sintered product. The heat cured polymers are powders, that when heated, melt together and cure. We have been investigating products that are commercially available powder coatings used in various industries including high temperature applications. The powders do not contain or require a solvent, and can be applied by an electrostatic spray or simply by distributing over a surface. Abrasion testing is being performed on the powder coatings by themselves and in various mixes with JSC-1 ranging from 10 – 50% powder by weight. Testing is currently underway to identify the amount of polymer needed to cover an area, so that accurate masses can be calculated.

We have demonstrated that the polymer can be cured with the solar concentrator. Both 33% and 50% polymer:JSC-1 simulant mixes have been cured with the solar concentrator. A small area about 6 cm in diameter and 1 cm deep was solidified with the solar concentrator. This demonstration shows the ease in which the polymers can be used form a solid surface.

Figure 1: Solar concentrator used in sintering experiments at KSC.

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

Overview

- Compare and test potential stabilization methods
  - Polymer palliatives
  - Microwave
  - Solar
- 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

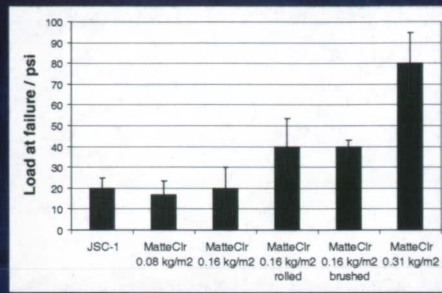
- Evaluated 4 commercially available powders and 1 developed at KSC
  - Abrasion, UV resistance, high temperature resistance
- Demonstrated stabilization in the lab and in the field using our solar concentrator
- Investigated different spreading ratios, mixing ratios and application methods
- Polymers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

MatteClr 30% 100mg/in

Load Bearing Strength

- Loads of 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

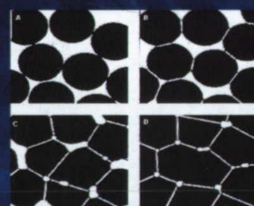


Polymers: Future Work

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

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).

Microwave sintering

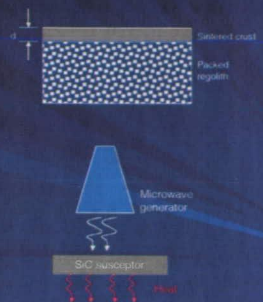
- Technology has been proposed for sintering a surface (Taylor et. al.) as well as other heating uses
- Most materials absorb microwave energy to some degree, especially at higher temperatures

Microwave Sintering

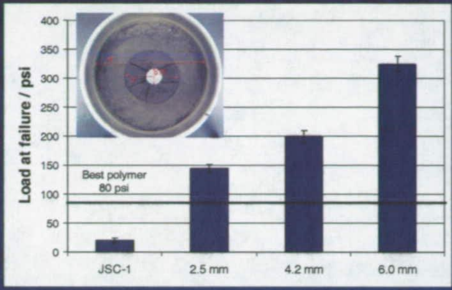
- Advantages:
  - Much more efficient than electrical heating
  - Moderate Mass
  - Inexpensive technology
  - Heats the bulk of material
- Disadvantages
  - Power consumption (1 – 10 kW?)
  - Magnetron requires cooling
  - Thermal runaway can lead to inconsistent results
  - Energy might penetrate deeper than needed

Microwave Sintering

- It would take a 1000W microwave 31 days to sinter a 100m^2 area to a depth of 2.5 cm assuming 100% efficiency (52 days assuming 60% efficiency)
- Microwaves would penetrate deep into the surface
- Susceptors can be used to localize heating



Sintered: Load Bearing Strength



Microwaves: Current Work

- Investigated the use of susceptors to localize heating
- Thermal runaway has caused problems

Solar Concentrator

- Sunlight gives 1.3 kW/m^2 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

- It would take 24 days to sinter a 100 m^2 area 2.5 cm deep with a 1m^2 collector assuming 100% efficiency (36 days with 67% efficiency)

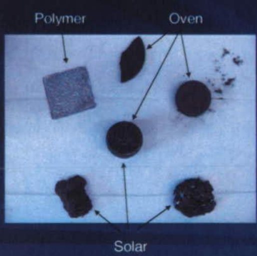
Solar Concentrator

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

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…

Samples



- Sintered samples made in the lab
- Sintered samples made with the solar concentrator
- Polymer samples