Environmental Effects on Lunar Base Designs

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Many plans for the construction of Lunar Bases have been made but not all the environmental conditions have been examined. This presentation recollects many different ideas of Lunar Bases that have been proposed and original suggestions on ways to improve them. In addition, it relates the structural concepts of lunar bases with the difficulties it must overcome because of the environmental effects.
II. Introduction

- Lunar Bases have been on the minds of scientists, and others for over 40 years.

- The purpose for a lunar base changed from a military facility to a laboratory to study the lunar geology, to a larger plan to explore our neighbor planets.

- The models have changed and improved over time.
Main Purposes for Colonizing and Industrialization of the Moon:

- To utilize Lunar Resources of energy (He-3)
- Establish a permanent man presence on the Moon.
- To perform scientific research and experimentation.
III. Environmental Forces
### Wide Temperature Swings

- Temperatures drop below 100 k before the next dawn. Extreme temperatures from -260° F to 212° F.

- Transition from day and night occur 14.7 Earth days at the equator which is more noticeable because of lack of atmosphere.

- Different sections of a structure (lunar base) might have huge differences in temperature.
Difference in Temperatures

Sunlight hitting this side of the moon creating extremely high temperatures.

Side of the Moon in darkness with low temperatures.
Planetary Radiation

- Radiation like: Ultraviolet, atomic oxygen, solar flares, galactic cosmic rays, and others hit the surface continuously.

- Average Solar Radiation is 1,400 w/m^2

- Effects on metallic components will be small but glass and polymer components will be affected after long time exposure.
Infrared Radiation on the Moon
Atmospheric Pressure

- Near absolute vacuum, $10^{-12}$ torr.

- Benign environment for most materials which are not chemically or molecularly stable.

- In lunar structures internal pressure is dominant and must be maintained at 15 psi.

- Effects might include: out gassing for exposed steels; effects of high vacuum on alloys, and advanced material; and increased evaporation of lubricants and volatiles.
Dust

- Make up most of the lunar surface.
- Clings rapidly, and sticks to everything
- Has the capability to electro statically charge up to heights of one meter, making it more difficult for the construction of lunar bases.
- Easily disturbed and put into suspension.
Gravity

- 1/6 of Earth’s gravity.

- A structure in the Moon would have 6 times more strength and bearing capacity than on Earth.

- Dead and Live loads include: gravity, human locomotion, light machinery, and structural weight.
Atmosphere

- Moon has a thin, or one can say no atmosphere at all.

- No magnetic field.

- No protection from radiation, and especially meteorites which impact at full velocities.

- However, because of lack of atmosphere, there is no natural corrosion or drainage.
Meteorites

- Biggest threat on the Moon.
- Bombard the lunar surface constantly.
- Tiny meteorites, micrometeorites, might strike up to 25 kilometers per second creating craters 10 to 20 times larger than the impacting objects.
- Resistant structures are necessary.
Lunar Craters
Produced by meteorites

Lunar South Pole

Lunar North Pole
IV. Lunar Concepts

- Inflatable
- Rigid and Erectable
- Cement, Concrete and Lunar Materials
- Lava Tubes
Inflatable Structures

- First proposed by Vanderbilt, Criswell and Sadeh (1990).
- Basic idea of a modular “tuft pillow”.
- Consists of quilted inflatable pressurized structures with the use of fiber composites.
- Shielding is provided by regolith.
- Less cost and rapid construction.
- Needs complementary structure for support.
The Torus-Dome Inflatable

Concept and picture courtesy P. Chow
Box Shaped Inflatable

Inflatable structure. [p. 353 Vanderbilt, Criswell, Sadeh in Johnson & Wetzel 1988]

Concept and picture courtesy M. Criswell
Erectable Structures

- Consists of rigid modules and buildings covered in regolith for protection against radiation.

- 3 types: Rigid Structures, Non-Rigid Expandable, and Combined Rigid and Non-Rigid Expandable.

- 2 classifications: Low arch and flat shield structure.
Inflatable Sphere/Structural cage Habitat

Concept and picture courtesy M. Roberts (NASA)
Self-Deploying Structure

Concept and picture courtesy
Y. Hijazi
Modular Approach

Concept and courtesy of M. Schroeder

Flat shield Structure, pressurized
Lin (1988) proposed that the Moon has the elements needed to make cement: Alumina, Calcium Oxide, and Silicate.

The other 2 accessible materials needed to make concrete are:

- Water which could be made through hydrogen reduction.
- Aggregates which are obtained from the crushed soil.
Three-level concrete Lunar Base

a) Concrete Lunar Base

b) Elevation

c) Plan view

d) Cross section A-A

Concept and picture courtesy Lin (1985)
Hexagonal Concrete Lunar Structure

Concept and picture courtesy Robert L. Wright
Adobe

- Another concept suggested by Khalili (1988) to construct lunar bases.

- Adobe block will be made from unprocessed lunar soil and the fusion of lunar resources with solar heat.

- Adobe structures don’t have the ability to resist loading stresses that will occur due to internal pressurization.
Lava Tubes

- Structural idea suggested by Horz (1985) as the best lunar environment because of its properties as a natural cavern.

- Lava Tubes are created by flows of molten lava.

- Interior provides protection from radiation.
Inflatable structure within lava tube

Lava Tube with excavated features

Concept and courtesy of Robert L. Wright
Suggestions and Models
In this model I suggested there are many things that will contribute to maintain a lunar base working and safe which include: artificial gravity and atmosphere, protection from different types of radiation, and meteorites, etc. The shield protects from radiation, extreme temperatures and meteorites; while the “tent-like” structure backs it up just in case anything trespasses the shield; and it also serves as an artificial atmosphere which provides Earth-like gravity within the tent and all around the base.
Suggestion #2

Lunar Bases

The Moon

Transparent material that will surround the moon and protect it

Meteorite
This suggestion is just based on one idea. There would be a transparent material surrounding the Moon which will have special abilities that will enable it to resist all the environmental severities of the Moon. At the same time it will maintain within it a stable temperature, Earth’s gravity, and Internal Pressurization. In addition, it will protect the inhabitants from radiation, and most especially, meteorites. If any impurity reaches the artificial atmosphere, it will go through until a specific point and it will bounce off the “atmosphere”.
Steel as a Lunar Base Material

\[ \frac{\text{density}}{\text{volume}} = \frac{\text{mass}}{\text{volume}} \]

\[ \text{Volume} = \pi r_0^2 \ell \]
\[ V = \pi \cdot 2.5^2 \cdot 3 \text{ m} \]
\[ V = 58.9 \text{ m}^3 \]

\[ \text{Mass} = \frac{1.5 \cdot 10^6 \text{ g/m}^3 \cdot 58.9 \text{ m}^3}{8.84 \cdot 10^7 \text{ g}} \]

\[ F = \frac{m}{g} \]
\[ F = (8.84 \cdot 10^7) \cdot \frac{1}{6}(9.8 \text{ m/s}^2) \]
\[ F = 1.44 \cdot 10^8 \text{ Newtons} \]

\[ \sigma = \frac{F}{A} \]
\[ A = \pi (r_0^2 - r_i^2) \]
\[ A = \pi (2.5 \text{ m}^2 - 2.4 \text{ m}^2) \]
\[ A = \pi \cdot .49 \]
\[ A = 1.54 \]
\[
\sigma = \frac{F}{A}
\]
\[
\sigma = 1.44 \cdot 10^8 \text{ Newtons/}1.54 \text{ m}^2
\]
\[
\sigma = 9.37 \cdot 10^7 \text{ N/m}^2
\]

<table>
<thead>
<tr>
<th>Steel: E = 2.0 \cdot 10^{11} \cdot \text{N/m}^2</th>
<th>Yield Strength = 2.5 \cdot 10^8 \text{ N/m}^2 = \sigma_y</th>
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\[
\sigma = E \varepsilon
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9.37 \cdot 10^7 \text{ N/m}^2 = 2.0 \cdot 10^{11} \text{ N/m}^2 \varepsilon
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\varepsilon = 4.68 \cdot 10^{-4}
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F_y = 3.85 \cdot 10^8 \text{ Newtons}
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2.5 \cdot 10^8 \text{ N/m}^2 = 2.0 \cdot 10^{11} \text{ N/m}^2 \varepsilon
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\varepsilon = 1.25 \cdot 10^{-3}
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\Delta L = \varepsilon L
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\Delta L = (4.68 \cdot 10^{-4}) \cdot 8 \text{ m}
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\Delta L = 3.75 \cdot 10^{-3} \text{ m}
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\Delta L = L \cdot \varepsilon
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\Delta L = 1.25 \cdot 10^{-3} \cdot 8 \text{ m}
\]
\[
\Delta L = 0.01 \text{ m}
\]
V. Conclusion

For the construction and regulation of a Lunar Base, more studies and examinations are needed to improve all the existing concepts.

In my opinion, the best Lunar Base concept presented is the lava tube structures because less material and money is needed and it provides natural protection.

Shielding, internal pressurization, safety and reliability, resistance, loading, use of local materials and other aspects must be taken into account before the lunar base is created.
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