Analysis of a Structure on the Moon

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Abstract
As technology quickly advances, a future in space is not hard to image. Building a future for the human civilization in space will require the construction of various structures. In order to do so the procedure of structure design must change as it will be located in a new atmosphere. Many of the environments in space are hazardous and different from that of Earth. The most familiar atmosphere to explore with in space is that of the Moon. The purpose of this research is to explore the design parameters that would need to be changed when designing a structure on the Moon. Using a single span bridge structure, different conditions were explored. This research underlines the findings and possible suggestions for constructing on the Moon.

Background

This research was composed of two major parts. The first part consisted of researching the differences between the Earth and Moon and determining whether it could possibly have an effect on the design of the structure. The second part consisted of learning a structure analysis program and using it to analyze the structure based on the parameters determined from part one of the research.

Earth vs. Moon

The Earth and Moon have many differences. These are gravity, geology, erosion, collision, vacuum effects, solar winds, seismic occurrences and temperature differences. Each of these differences were carefully analyzed to determine whether or not they would affect the design of the structure.

Figure 1- Image of Earth and Moon for comparison.

First, a difference in gravity was determined. The Earth has a gravity of 9.81 m/s^2 while the Moon has 1/6 of that amount, which is 1.66 m/s^2 [4]. This variance would obviously affect the structure design by decreasing the load. The geological differences between the Earth and Moon consisted mainly of their surfaces. The Earth has bodies of water, plate tectonics and an atmosphere, all creating a livable surface. On the other hand, the Moon's surface is heavily craters. The surface is dry and contains nonorganic material [4]. The Earth experiences erosion while the Moon does not. For this particular research, the effects of this difference were not looked into much as the research is more on the structure being built. In order to focus more on the geology it would require a geotechnical perspective. In comparison to the Earth the Moon experiences constant collisions from meteors flying through space. This could potentially cause damage to the structure, however designing for collisions is never really possible since it is an extreme case. Since the Moon has not atmosphere, its daily temperature changes are large. In sunlight the temperature can reach 253 °F while temperatures in times of darkness can drop to -243 °F [5]. This temperature variance would definitely affect the design of the structure. Solar winds, seismic activities and vacuum effects were also analyzed but determined to be irrelevant to the design of the structure [7].

After careful analysis it was determined that the parameter that affected the structure the most was that of temperature difference the Moon experiences. It was then decided that the focus of the analysis would be on the effect that temperature would have on the structure. This is because metal typically shrinks in low temperature and elongates in high temperatures. This variance in temperature can result in huge stress change daily.

Sample Structure

For this research a simple span bridge structure was chosen due to its simplicity and popularity [1]. The structure was composed of 4 structural steel girders, with a yield strength of 50ksi. The first and last girders are placed at a distance of 3 feet from each end. Each girder in placed at a distance of 12 feet from each other. The bridge is 164 feet long and 42 feet long. The support conditions were made fixed because both end fixed generates less moment and stress in the middle of the structure. Figure 2 seen below displays the structure in further detail.

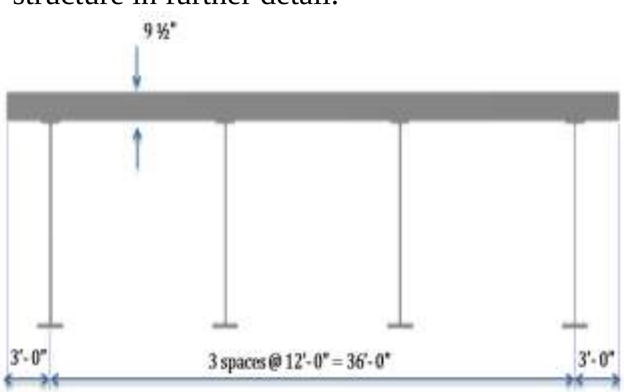


Figure 2 - Simple Span Bridge

Computer Modeling

The analysis of this research required the use of a structural analysis program called ANSYS. ANSYS is a computer aided structural software that was made available at the University of New Haven. This software has the capability of delivering high-quality reliable structural simulation results [3]. Part of the research process consisted of gaining familiarity with this program. Figure 3, located below, shows the model created for the simple span bridge.

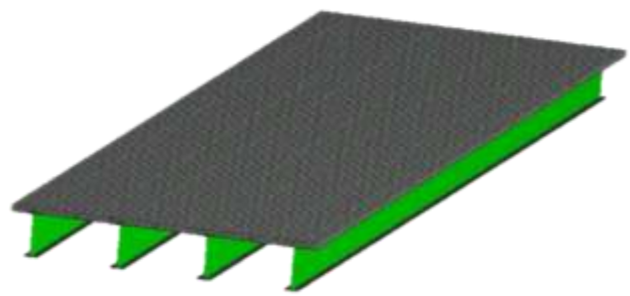


Figure 3- Computer Model of Simple Span Bridge

Load Cases and Application

The load cases needed for this research consisted of the self-weight of the structure, the temperature variance and a traffic load design. Each of these cases were applied to both the Earth and the Moon to determine the differences between each.

To simulate traffic load a design vehicle was chosen from the ASSHTO-approved live loading specifications. After looking through various types, the HL - 93 design vehicle was selected because it causes the highest moment to the structure [2]. The design vehicles serves to represent the rain load to help design traffic loads. Figure 4 and 5 seen below give a clear specification of the type of vehicle and its loads.

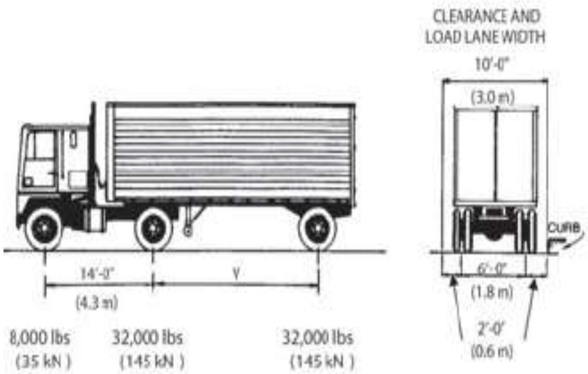


Figure 4 - HL 93 Design Vehicle Specification

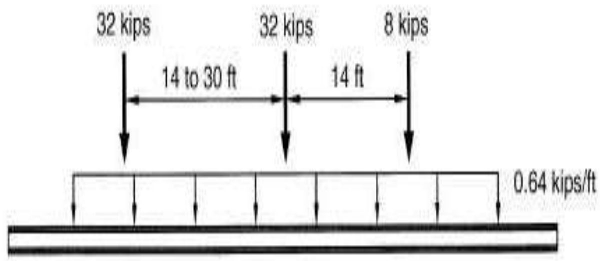


Figure 5 - HL 93 Design Vehicle Load Distribution with Rain Load

Figure 6 below shows an example of how exactly the loads were applied to the structure. The red arrow represents the HL 93 application. Calculations were made to determine the placement of the loads. The loads were applied on the first and second girder. Applications of the 2 other girders were not necessary since the structure is symmetrical.

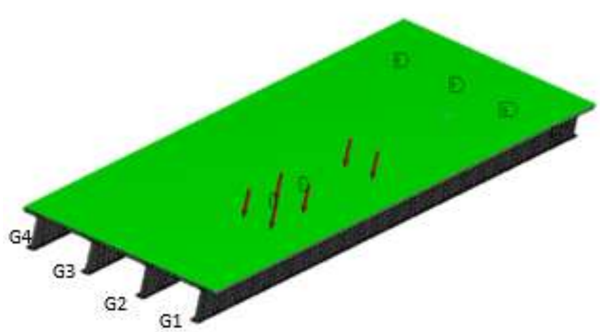
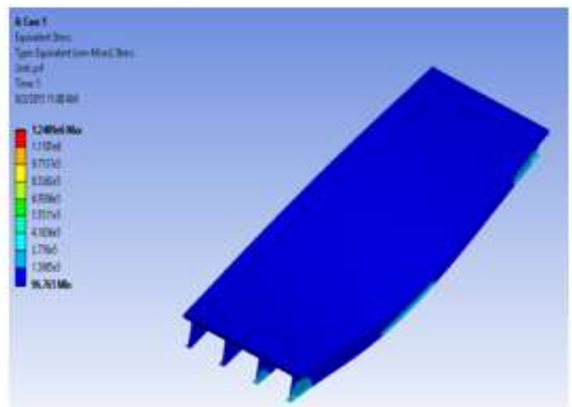


Figure 6 - Load Application on Simple Span Bridge

Results

The results were focused on equivalent stress, which represents all tri-axial stress [3]. The first set of results was based on the Earth with a load case application of self-weight and design vehicle. The results were that of a maximum stress of 1 ksi for Girder 1 and about 0.6 ksi for Girder 2. These results were determined to be acceptable for the material used which can hold 50 ksi stress.

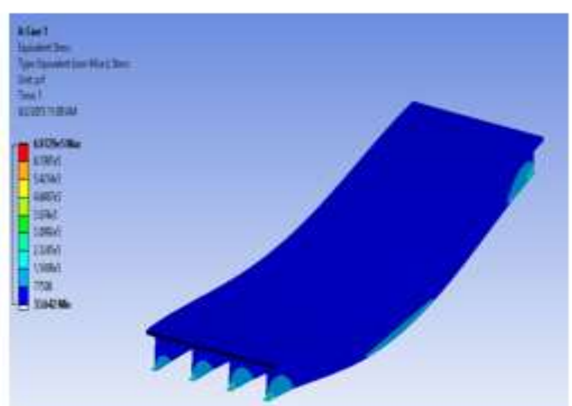
Girder 1



1 ksi

Figure 7 - Application of Self weight on the Earth

Girder 2

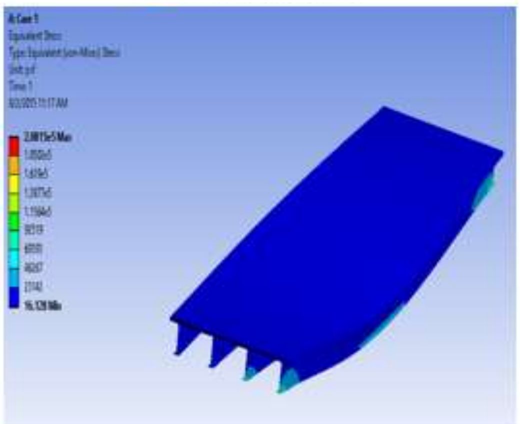


0.6 ksi

Figure 8 - Application of Self Weight on the Earth

The next set of results was based on the Moon with a load case application of only self weight. The results were that of a maximum stress of 0.2 ksi for Girder 1 and about 0.1 ksi for Girder 2, which in theory make sense because they are values that are 1/6 of that obtained on Earth. These results were determined to be acceptable for the structural steel.

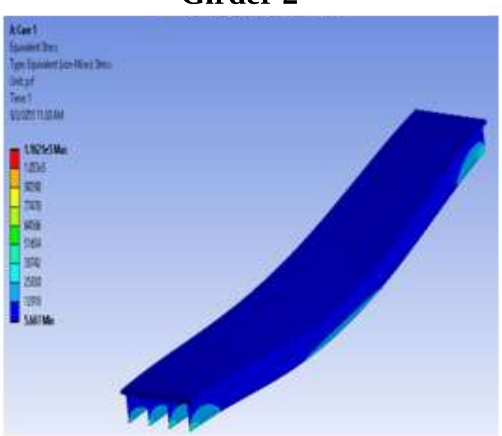
Girder 1



0.2 ksi

Figure 9 - Application of Self-Weight on the Moon

Girder 2

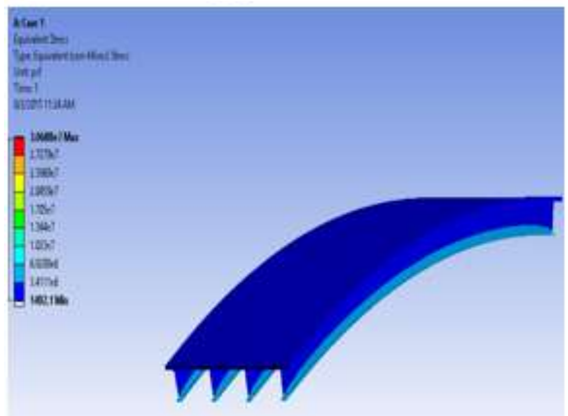


0.1 ksi

Figure 10 - Application of Self-Weight on the Moon

The results shown in Figures 11 and 12 was based on the temperature gradient of the Moon. The load case application was the temperature effect along with the self weight and traffic load. A temperature of 253 °F results in a stress of 35 ksi, and a temperature of -243 °F resulted in a stress of 60 ksi. Under these conditions the selected structural steel material would not be able to resist these loads.

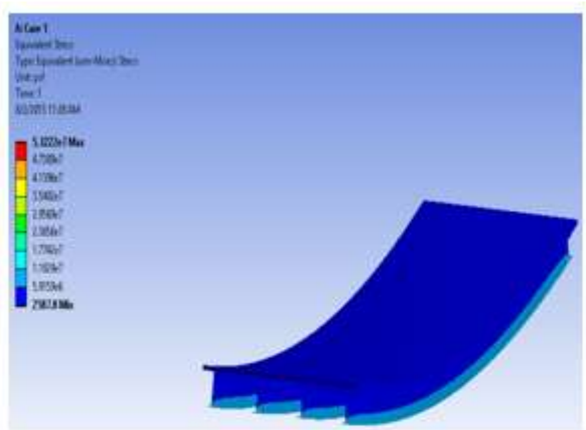
253 °F



35 ksi

Figure 11 - Temperature Variance Application on the Moon

-243 °F



60 ksi

Figure 12 - Temperature Variance Application on the Moon

Conclusion

After completing the research it was determined that the greatest effect when designing a structure on the moon is that of temperature. Using the temperature variance effect the structure was further analyzed. Upon the completion of the analysis it was determined that the maximum stress exceed its yield strength of the steel girder. Other materials were considered to determine if they would be able to withstand the design conditions. Such materials are that of aluminum and titanium, further analysis will determine if these material are suitable for a design on the moon. In addition, changing boundary conditions of the structure could help counteract the effects of such loads.

References

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Elvia Baca is currently a senior and will graduate in May 2016 with a B.S. degree in Civil Engineering along with a minor is Sustainability Studies. Elvia is originially from Elmsford, NY and hopes to pursue a Masters degree in Structural Engineering.