Comparative Experimental Study of Terrestrial Compaction Methods on Lunar Regolith Simulant.

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Introduction: With the Artemis missions planning a sustained presence on the moon, the importance of various forms of infrastructure are an apparent need for supported long-term operation. Landing pads, habitats, power generation and ISRU plants, and roads will all benefit from surface preparation efforts, including compaction. Several methods are used for compaction terrestrially, however the effectiveness of each in a lunar environment is largely unstudied.

The Planetary Surface Technology Development Lab (PSTDL) at Michigan Technological University (MTU) conducted a comparative study on compaction effectiveness of lunar simulant between 3 simplified models of popular terrestrial compaction systems, namely a rolling vibratory compactor, a sheepsfoot compactor, and a plate compactor. These tests aim to quantify the difference in performance between the three compaction systems on lunar regolith under atmospheric conditions, and identify a model to further develop for testing in vacuum conditions.

Methods: This experiment compared the effectiveness of 3 different compaction systems, a plate compactor (PC), a sheepsfoot compactor (SC), and a rolling vibratory compactor (RVC). The tested systems were all designed to have approximately the same surface contact area, and weight; 450 cm^2 and 25 kg respectively. The PC and RVC also used the same vibratory motor to ensure consistent energy output. The assembled compaction systems can be found in Figure 1.

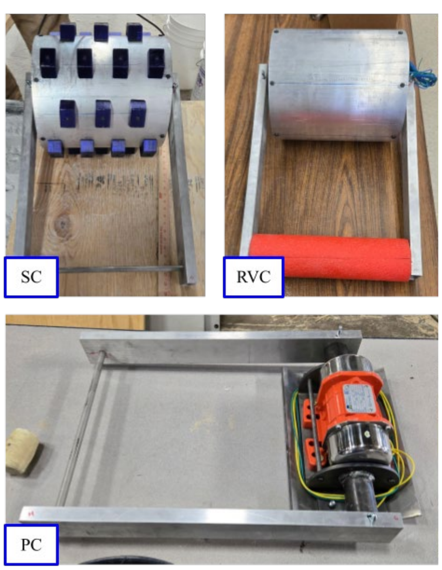

Figure 1: Assembled Compaction Systems

A total of 12 tests were conducted, 4 per system, in a 1.35 m x 1.02 m x 25.4 cm bed of regolith, allowing for 2 tests per bed (figure 2). The bed contained approximately 400 kg of MTU-LHT-1A, MTU's lunar highland regolith simulant [1]. Each test consisted of 2 minutes of continuous compaction. Standard penetration tests (SPT) [2] were used to qualify the compaction test results, with 7 tests before any compaction and 20 per test site after both tests had been completed, reading a total of 47 SPT tests per bed.

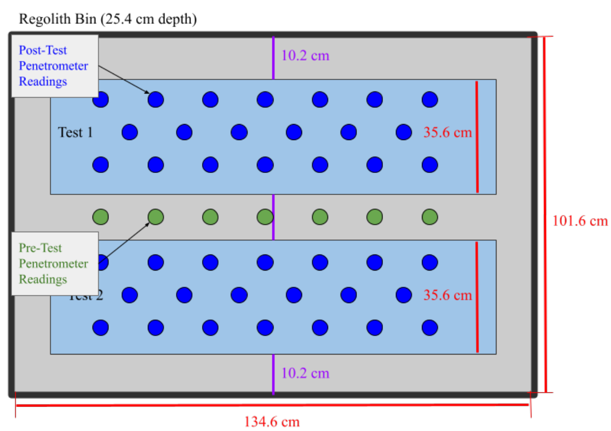

Figure 2: Test Bed, with Penetrometer Test Sites

Preliminary Results: Figure 3 shows a comparison of the test beds before and after compacting from each system, illustrating the surface finish with each system. The RVC and PC systems left very similar smooth surfaces with a slight bump in the locations where testing was concluded and the compactor was removed from the regolith. By comparison, the SC teeth left a very distinct and uneven surface pattern.

Figure 3: Compaction Test Surface Finishes

During testing, it was observed that the rolling systems had a tendency to push regolith up and over the sides of the bin during the forward and backward motion. The PC also caused some piling toward the extreme ends of its compaction tracks, but not nearly as much as the other two systems. The result was a shallow and compact area in the middle of the testing area, with deeper and less compact areas on either end. After each of the tests, measurements were taken from the top edge of the bed to the lowest point of the regolith in the middle of the trench, then subtracted from the initial height of regolith in the bed (22.86cm) to calculate the remaining depth of regolith in the bin. The average of these depths can be found in Table 1. This data shows that of the systems, the RVC had the lowest remaining depth of regolith which is consistent with the observations made during testing.

Table 11: Minimum Depth, Averaged per System

PC (cm)	SC (cm)	RVC (cm)
12.75	13.0	7.75

Figure 4 shows the average increase in pressure between pre and post-test compaction SPT measurements.

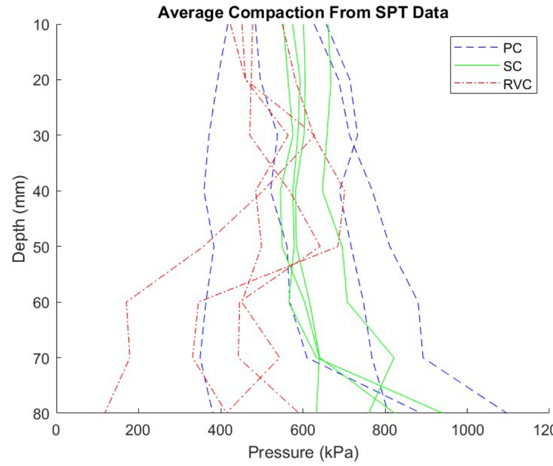

Figure 4: Average SPT Data from All Compaction Tests

While the SC and the RVC have similar patterns in the data, the PC measured pressures are less consistent. However, the PC was the first system tested, and the vibration was not consistently applied for the first two tests, represented by the leftmost of the PC tests. On this account the rightmost PC tests are taken to be more representative of the PC's performance.

The RVC was noted to have diminished insertion pressure past 50cm on the majority of tests. This indicates that the compaction achieved did not extend as deep into the regolith bed as the alternative systems.

Conclusions and Path Forward: Presently the testing conducted seems to indicate the vibratory plate compaction system was a more effective per weight than the other systems tested. Before finalizing conclusions, additional tests are planned to compare power usage per system. After selection, a new design iteration will focus on vacuum capability and more robust measurements to better inform site-preparation modeling and logistics planning.

References: [1] van Susante, P. and Carey, C. (2022) *Michigan Technological Universities' Lunar Highland Simulant MTU-LHT-1A, SRR XXII.* [2] Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, ASTM D1586/D1586M (2022).