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LUNAR REGOLITH DENSIFICATION

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Core tube samples of the lunar regolith obtained during the Apollo missions showed a rapid increase in the density of the regolith with depth. Various hypotheses have been proposed for the possible cause of this phenomenon, including the densification of the loose regolith material by repeated shaking from the seismic tremors which have been found to occur at regular monthly intervals when the moon and earth are closest to one another. A testbed has been designed to study regolith densification. This testbed uses Minnesota Lunar Simulant (MLS) to conduct shaking experiments in the geotechnical centrifuge with an inflight shake table system. By reproducing realistic in-situ regolith properties, the experiment also serves to test penetrator concepts.

The shake table system has been designed and used for simulation experiments to study effects of earthquakes on terrestrial soil structures. It is mounted on a 15 g-ton geotechnical centrifuge in which the self-weight induced stresses are replicated by testing an n-th scale model in a gravity field which is n times larger than Earth's gravity. A similar concept applies when dealing with lunar prototypes, where the gravity ratio required for proper simulation of lunar gravity effects is that between the centrifugal acceleration and the lunar gravity.

Records of lunar seismic tremors, or moonquakes, have been obtained from Dr. Nakamura of the University of Texas for use in this study. Dr. Nakamura has been involved with lunar seismic studies for many years. While these records are being prepared for use as the input

data to drive the shake table system, records from the El Centro earthquake of 1940 are being used to perform preliminary tests, using a soil container which was previously used for earthquake studies. This container has a laminar construction, with the layers free to slide on each other, so that the soil motion during the simulated earthquake will not be constrained by the otherwise rigid boundaries.

The soil model is prepared by pluviating the MLS from a hopper into the laminar container to a depth of 6 in. The container is mounted on the shake table and the centrifuge is operated to generate an acceleration of 10 times Earth's gravity or 60 times the lunar gravity, thus simulating a lunar regolith thickness of 30 ft. The shake table is then operated using the scaled "moonquake" as the input motion. One or more model moonquakes are used in each experiment, after which the soil is analyzed for its density profile with depth. This is accomplished by removing from the soil bed a column of soil contained within a thin rubber sleeve which has been previously embedded vertically in the soil during pluviating. This column of soil is transferred to a gamma ray device, in which the gamma ray transmission transversely through the soil is measured and compared with standard calibration samples. In this manner, the density profile can be determined.

Preliminary results to date are encouraging, and the Center plans to study the effects of duration of shaking, intensity of the shaking motion and the frequency of the motion.

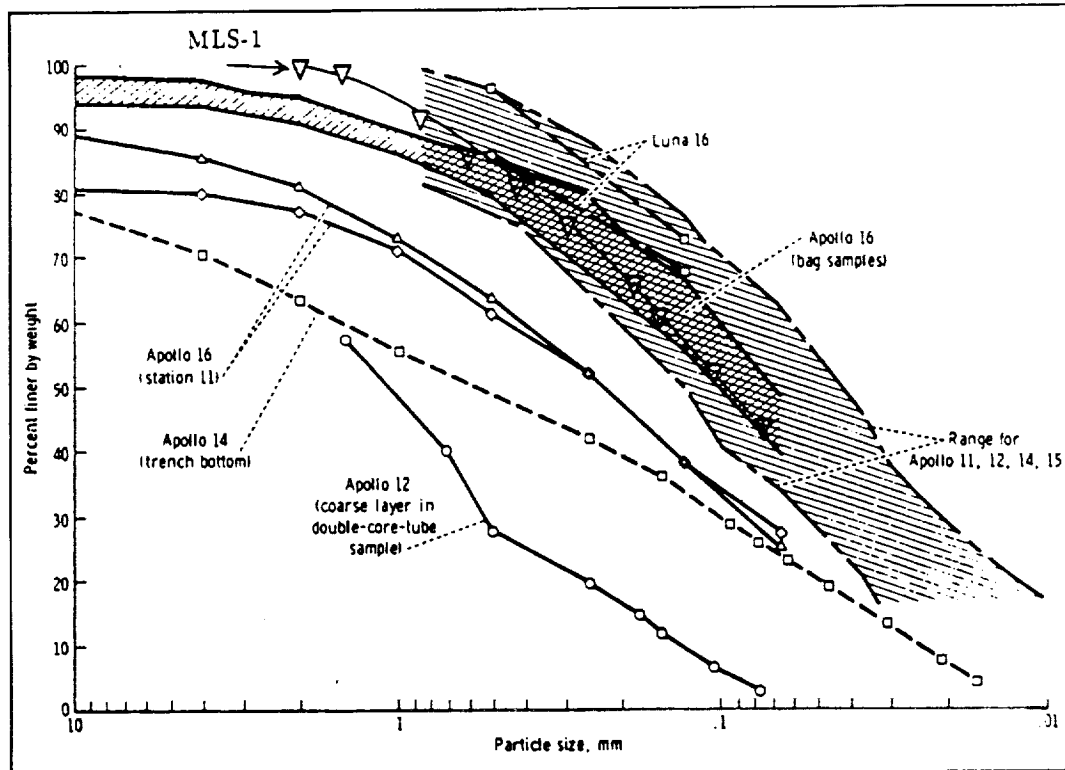


Fig 7.1 Grain size distribution curves for Apollo samples and recombined MSL-1

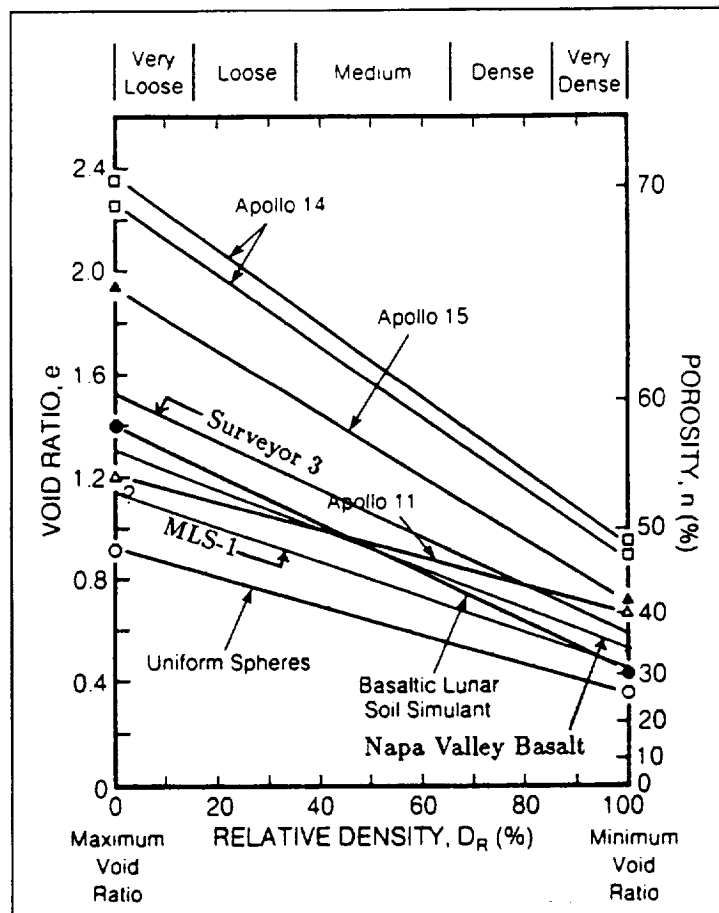


Fig 7.2 Maximum and minimum void ratio for lunar soil and simulants

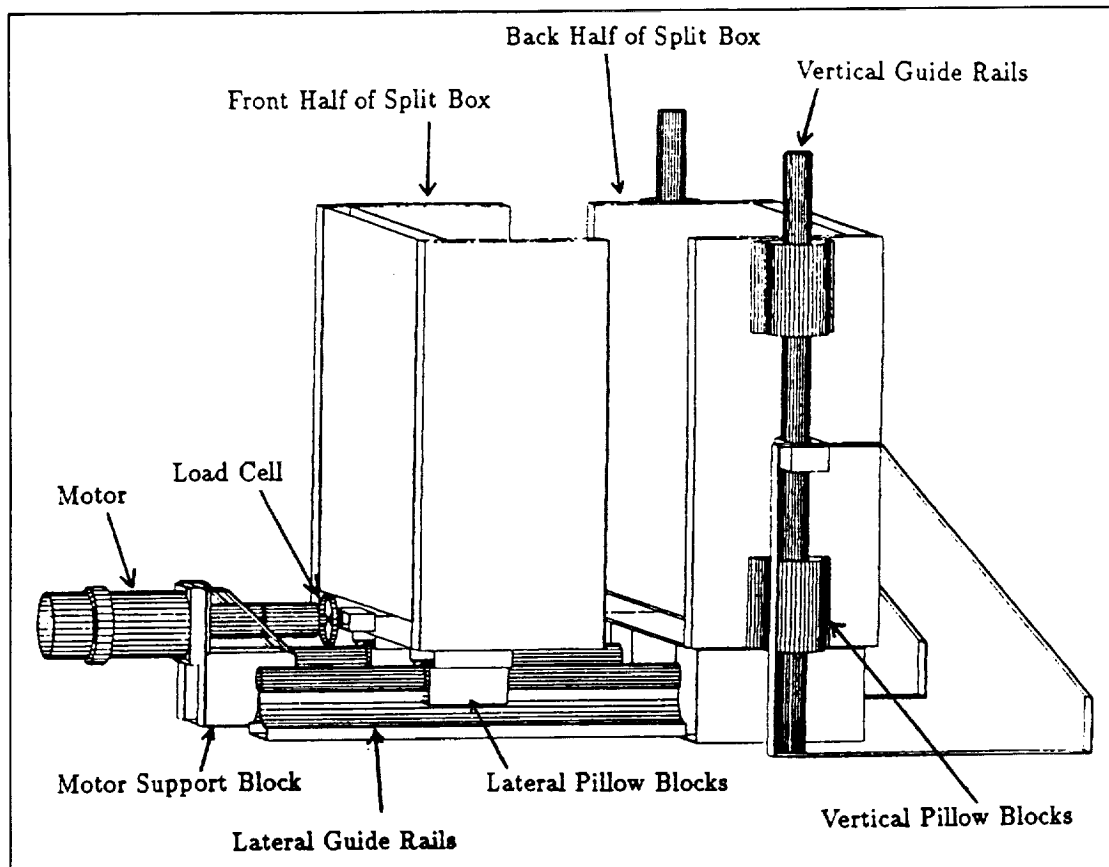


Fig 7.3 Direct tension device

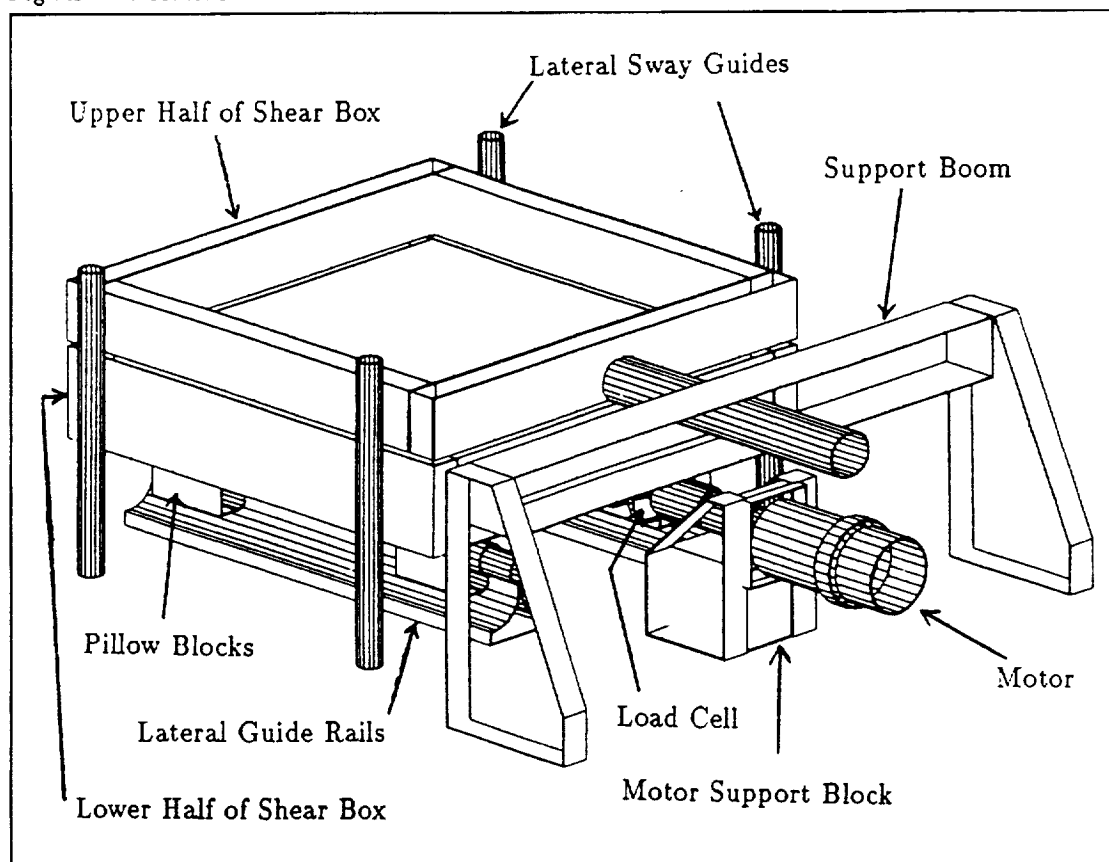


Fig 7.4 Direct shear device