(An abstract to be submitted to the NASA Workshop on Granular Materials in Lunar and Martian Exploration to be held in NASA JFK Space Center, Orlando, Florida during February 2-3, 2005).

Mechanical and Structural Behavior of Granular Material Packed Beds for Space Life Support System Applications

by

Ramesh B. Malla[1] and Ganesh Anandakumar[2]

Department of Civil & Environmental Engineering
University of Connecticut
Storrs, CT 06269-2037, U.S.A.

Abstract

Long-term human mission to space, such as living in International Space Station (ISS), Lunar, and Martian bases, and travel to Mars, must make use of Advanced Life Support Systems (ALSS) to generate and recycle critical life supporting elements like oxygen and water. Oxygen Generation Assembly (OGA) and Water Processor Assembly (WPA), critical components of ALSS, make use of series of granular material packed beds for generation and recycling of oxygen and water. Several granular materials can be used for generation, recycling, processing and recovery of oxygen and water. For example, they may include soft bed media, e.g. ion exchange resins for oxygen generation assembly and hard bed media such as, activated alumina, magchem (Magnesium oxide) and activated carbon to remove organic species like ethanol, methanol, and urea from wastewater in Water recovery/processing assembly. These beds are generally packed using a plate-spring mechanism to provide sufficient compaction to the bed media throughout the course of operation. This paper presents results from an experimental study of a full-scale, 38.1 cm (15 inches) long and 3.7 cm (1.44 inches) diameter, activated alumina bed enclosed in a cylinder determining its force-displacement behavior, friction mobilizing force, and axial normal stress distribution under various axially applied loads and at different levels of packing. It is observed that force-displacement behavior is non-linear for low compaction level and becomes linear with increase in compaction of the bed media. Axial normal stress distribution along the length of the bed media decreased non-linearly with increase in depth from the loading end of the granular media. This paper also presents experimental results on the amount of particulates generated corresponding to various compaction levels. Particulates generated from each of the tests were measured using standard US sieves. It was found that the particulates and the overall displacement of the bed media increased with decrease in initial compaction of the bed media. This effect could be attributed to the greater tendency for inter-particle sliding/rubbing due to smaller internal friction angles, as seen from the shear tests, at lesser initial compacted levels. Upon unloading, it was observed that there was no change in displacement (especially rebounding) in the bed media. This effect could be attributed to the fact that the porous activated alumina particles fracture/break upon increase in applied load (during loading phase) and occupy void spaces in between the material grains; thereby leading to settling of the media. The load-displacement curve becomes more linear with increase in initial compaction of the bed media. It is concluded that compaction considerably affects the load-displacement behavior of the bed media. A series of tests were also conducted on the packed bed media to determine the force required to mobilize the friction between the bed media and the housing cylinder. The results from these tests showed the existence of significant friction between the bed media and the encasing stainless steel cylinder. Further, it was found that friction effects were more pronounced for media with higher initial compaction. Internal friction of the granular media was measured using direct shear apparatus. It was observed that the internal friction increased with increase in initial compaction of the bed media.

In this study, a computational model (CM) is also developed using finite element software ANSYS to verify experimental results obtained for the distribution of the axial normal stress and axial displacement along the length of the full-scale activated alumina bed media. In the computational model, the granular material is considered to have appropriate failure and frictional contact exists between the wall and the granular media. It is observed that the model predicts results closely with the experimental method. The computational results show that the axial normal stress distribution along the length of the activated alumina media decreases non-linearly from the loading end and is negligible beyond a certain depth. This can be attributed to the existence of friction between the walls and the media and that the friction takes up most of the applied load.

----

[1]Associate Professor, Department of Civil & Environmental Engineering, 261 Glenbrook Rd, Unit-2037, Storrs, CT 06269, U.S.A. Tel: (860) 4863683 Fax: (860) 486-2298; Email: mallar@engr.uconn.edu **(Corresponding Author).**

[2]Graduate Research Assistant, Department of Civil & Environmental Engineering, 261 Glenbrook Rd, Unit-2037, Storrs, CT-06269, U.S.A.; Email: anandg@engr.uconn.edu.