
The Mechanism of Load Transfer in Granular Materials Utilizing Tactile Pressure Sensor Technology

Principal Investigator: Samuel G. Paikowsky

Graduate Research Assistant: Lawrence E. Rolwes (MSc)

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ABSTRACT

The mechanism of load transfer in particulate systems has significant implications in a wide range of fields including soil mechanics, storage and handling of bulks, manufacturing of powders (e.g. casting), and more. The load transfer in granular systems is highly influenced by the arching mechanism, which is related to the ability of discrete particles to interact in such a way as to redistribute forces, bridging over zones of less resistance/stiffness to those of greater resistance/stiffness. The ability to measure the stress distributions that result from arching is therefore paramount to the understanding of the mechanism, enabling the development of better design methods based on sound experimentation and analyses. Developments in grid based, tactile sensor technology has made it possible to measure normal stresses at a large number of points in close proximity. This technology allows for realistic normal stress distributions as opposed to those attained using the prevailing techniques of buried or surface-mounted pressure cells spaced at discrete intervals. Additionally, the ultra-thin construction and flexibility of the sensors overcomes the problems inherent with the stiffness variations introduced by load cells, and thus provide more accurate stress measurements.

The presented research employed tactile sensor technology to investigate two applications associated with arching of granular material: (1) the pressure dip beneath granular heaps, and (2) stresses on and around a model tunnel. The scope of the former application included: (i) multiple experiments that involved the measurement of the pressure distribution beneath conical piles of sand deposited from a fixed point source (axisymmetric conditions), and (ii) the design and construction of a trough-like apparatus which was employed to deposit long sand piles in order to investigate the resulting base pressure distribution under plane strain conditions. The scope of the latter application involved simulating the vertical movement of a buried structure under plane strain conditions with a trap door apparatus, and measuring the pressure distribution that resulted on and adjacent to the door under active conditions.

The tactile sensors provided excellent qualitative results, fully capturing the various pressure distributions that previously could not have been visualized. The quantitative measurements confirmed and expanded upon the results of past research, providing promising comparisons with the various analytical solutions employed to evaluate each problem. Past research has demonstrated the powerful ability of tactile sensors to provide quantitative results with accuracy comparable to common load cells. The current research expanded upon previous work and examined the performance of the devices in applications involving highly variable stresses of relatively small magnitudes. In summary, the results of the current work demonstrated the use of tactile pressure sensor technology as a powerful technique in examining the complex load transformation mechanism in granular materials.