CASE STUDY: HOLLOW CYLINDER TORSIONAL TESTING APPARATUS

USER: GRANULAR MECHANICS LABORATORY, DEPARTMENT OF CIVIL ENGINEERING, INDIAN INSTITUTE OF SCIENCE, BANGALORE, INDIA

The Indian Institute of Science (IISc) is India's premier institute for science and engineering research. Being one of the oldest research institutes in the country, it attracts top tier candidates.

The Department of Civil Engineering is 64 years old and has well known faculty in the areas of structural mechanics, geomechanics and hydrology. IISc has also been at the forefront of research in earthquake engineering, probabilistic mechanics and experimental soil mechanics. Extensive interdisciplinary research and consulting for various industries has prompted IISc to enhance its experimental infrastructure constantly.

THE PROBLEM

Assistant Professor Tejas Murthy's research team is interested in studying the complex behaviour of a wide range of geomaterials from soft rocks to sands at multiple length scales. The behaviour of a granular material is significantly affected by the particle morphology, packing of the ensemble, drainage conditions, cohesion between the grains, and stress conditions, including the direction and magnitude of principal stresses. We use a combination of image based measurements, physical modelling and elemental laboratory testing to gain a clear perspective of such complex material response. Accordingly, a large suite of constitutive models exist with different levels of complexity. However, a comprehensive understanding of material behaviour under controlled laboratory conditions is important before any prediction exercises may be begun.

Traditional triaxial, direct shear, and simple shear tests provide the mechanical response under limited boundary conditions. A suite of laboratory tests would be necessary in order to understand the mechanical behaviour of materials under a myriad of stress and boundary conditions. Some of these stress conditions may be captured using a hollow cylinder torsional testing apparatus. Additionally, the experimental data obtained from this apparatus can be used to calibrate existing constitutive models, and also provide a very firm basis for development of new ones.

THE SOLUTION

In order to understand these complex material systems under various stress conditions, a GDS HCA was procured. This choice was made based on the quality of the instrument, service (technical support) and prior experience of IISc in utilising GDS equipment. The hollow cylinder torsional apparatus (HCA) provides the user with the unique capability to independently control the magnitude and direction of the principal stresses by controlling the internal and

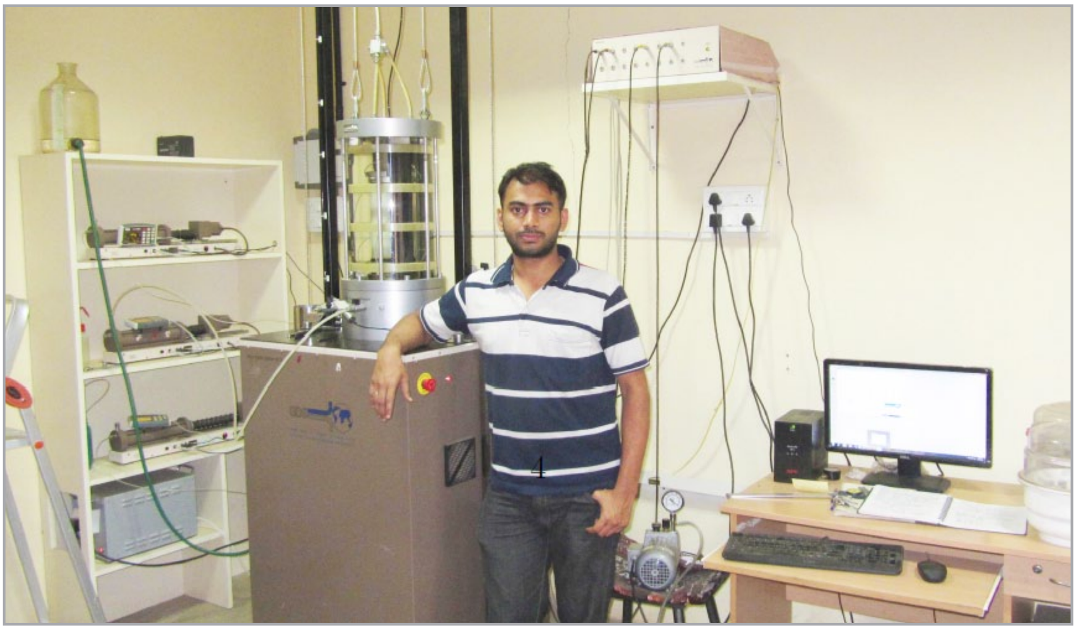

Fig 1. GDS HCA in the IISc Granular Mechanics Laboratory, with PhD candidate Ramesh Kannan.

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external cell pressures, axial load and torque. Complex stress paths, which are encountered in various boundary value problems, can be re-examined under controlled laboratory conditions to gain a unique perspective on the response of the material. Significant advances in understanding the anisotropy of granular materials has also been possible through these tests. Additionally, the IISc group has worked to understand microstructural features, such as particle shape and angularity, and how these affect the actual yield surface of a granular material through HCA tests.

Exploration of the state boundary loci, such as the critical state loci, not only in three dimensional principal stress space but also in the state space, has been possible through the HCA tests performed at IISc. Angular sand, spherical glass ballotini, and a wide range of particle morphologies were used as model materials for this study. The failure state is reached when the value of deviatoric stress peaks, while the critical state is defined when a constant specimen volumetric strain is observed. The critical state points are plotted in the principal stress space on an octahedral plane. These experimental results are used to calibrate some of the existing constitutive models and are a first step toward establishing models at multiple length scales.

THE RESULTS

An initial set of experiments was performed on an angular sand under drained conditions. The tests were performed at different b values (the intermediate principal stress ratio) varying from 0 to 1 at 0.2 intervals, with the principal stress inclination held at 0° throughout the tests. The results show that the peak value of deviatoric stress is almost constant with the variation of b from 0 to 0.5, after which it decreases. Since p' was also held constant, the variation of deviatoric stress represents the change in the critical state friction angle with varying b. Figure 2 displays a two dimensional representation of the three dimensional stress space, where the critical state points are plotted with the benchmarked Mohr coulomb and Lade's failure models in which the friction angle $\varphi = 34°$ and dimensionless constant $\eta = 48.3$ respectively.

A critical examination of the particle morphology and the macroscopic mechanical behaviour of these granular materials is currently being pursued. A combination of image analysis for shape description and the HCA tests for elemental mechanical response is underway. Extending the experiments to other complex materials under both static and cyclic loads is also envisaged in the near future. The hollow cylinder apparatus is an exceptional tool for use in understanding the behaviour of granular materials, and provides a very clear picture of the response of these materials under various boundary conditions. Observing interesting features of the material behaviour, such as non-coaxiality of stresses and strains, and descriptions of anisotropy at various stress and strain levels, is also possible here.

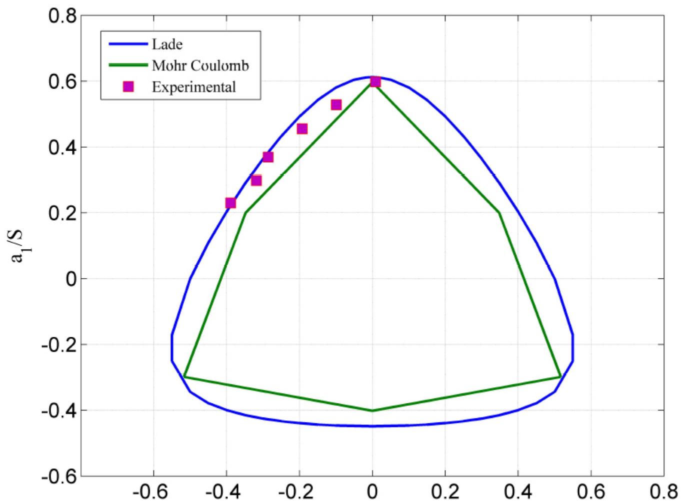

Fig 2. Model and experimental failure surfaces of sand.

TESTIMONIAL

'We are extremely happy with the GDS team for their involvement in every stage of the procurement and operation of the HCA. Special thanks to Dr Sean Rees (GDS Geotechnical Specialist) who has been very supportive. The accuracy of the results and performance of the hollow cylinder apparatus are satisfactory. Finally I would like to thank the IISc and Department of Science and Technology, Government of India, for their funding to procure the GDS HCA.' – Assistant Professor Tejas Murthy.