3rd IMA Conference on Dense Granular Flows

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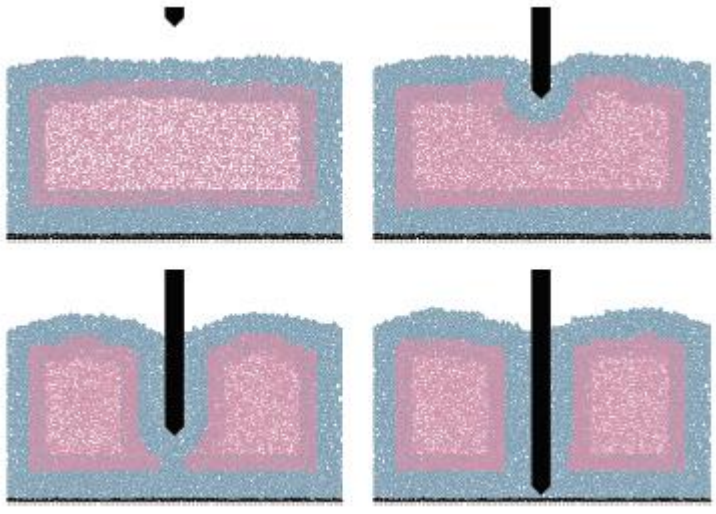
The 3rd Conference on Dense Granular Flows was organised by the Institute of Mathematics and its Applications (IMA) on 1-4 July 2019 at the Centre for Mathematical Sciences of the University of Cambridge, United Kingdom.

Over 70 delegates from research institutes and laboratories around the world joined the conference. Most were applied mathematicians and physicists. The conference was divided into four themes, viz. grains and fluids, segregation and avalanches, rheology, and granular physics. A selection of notable presentations and discussion with delegates is outlined below, with potential applications in civil engineering highlighted.

Prof Ken Kamrin of the Massachusetts Institute of Technology delivered the one of the keynote addresses, entitled “Extended continuum methods for dry and wet granular flow modelling”. He first introduced the material point method (MPM), a simple mesh-free continuum method for modelling granular flow which is able to capture basic behaviours. This model is good for predicting intruder dynamics near a free surface such as projectile impact and locomotion. It explains the resistive force theory of granulate intrusion, examples include bullets being fired into sand and the behaviour including rolling and slipping of a wheel on sand. MPM is not able to model discrete particle behaviours such as granular particles bouncing or being pushed out of the surface of the soil mass. For more complex behaviour of flow dynamics, discrete element method (DEM) is normally employed which requires significantly greater computing power and time. To improve the modelling performance, a hybrid numerical method is proposed. The material inside a granular mass is modelled as a continuum using MPM while the material close to the problem boundaries is modelled as discrete elements. The continuum

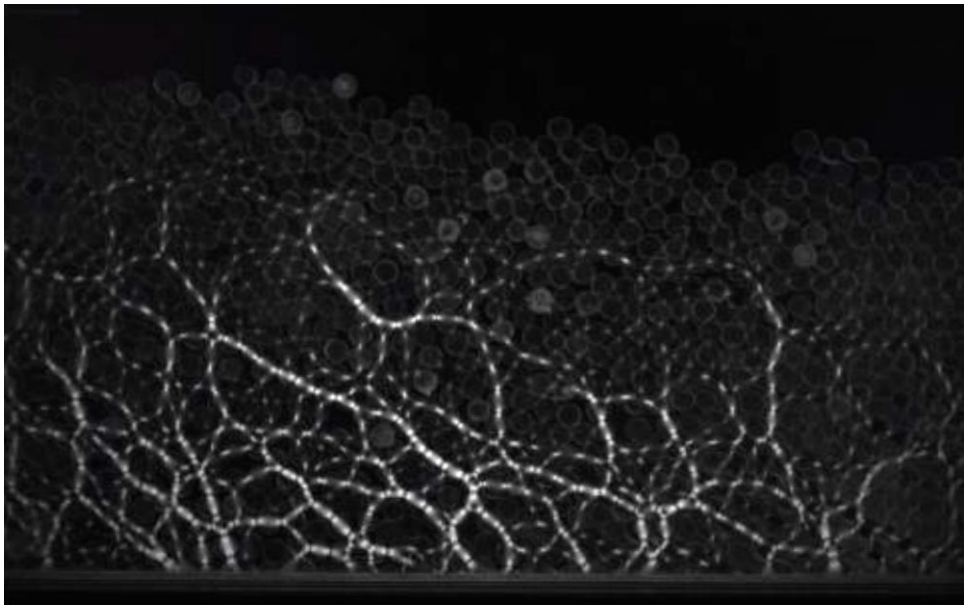
is modelled as an elastoplastic material with a Drucker-Prager plastic yield criterion. The interface between MPM and DEM regions is not fixed, but continuously updated by considering the so-called reconciliation zone, in which the discrete particles and continuum should move together and give the same velocity field. The hybrid approach is observed to give good agreement with pure DEM simulations. Numerical examples given include the collapse of a granular column, discharge of material form a 3D silo, and the insertion of a penetrometer into a bed of grains. From the examples given, it is expected that this modelling approach may potentially be used to study civil engineering applications including the pile-up mechanism of debris flow hitting a rigid barrier, pile driving etc.

Discharge from 3D silo showing continuum regime (pink) and DEM grains (blue), from Yue et al. (2018)



Insertion of cone penetrometer, from Yue et al. (2018)

An interesting presentation was given by PhD candidate Ms Amalia Thomas of the University of Cambridge on using photoelasticity to study granular flow. When a photoelastic material is placed between polarisers and subjected to stress, different regions of the material change the angle of polarisation of light based on the amount of stress (Daniels et al., 2017). This lets engineers and scientists visualise and predict the regions of high stresses. Before advances in the finite element method, photoelasticity was key for predicting regions of high tensile and compressive stresses for the manufacturing of mechanical parts. Force chains revealed from photoelasticity in a granular material enables the quantitative measurement of stresses and contact forces in the system. This technique allows the visualisation and quantification of the instantaneous forces transmitted between individual particles in a granular free-surface flow (Thomas, 2019).



Force chain from 2D avalanche of photoelastic discs, from Thomas (2019)

A large body of research work is devoted to the segregation of differently sized particles in a granular flow. I had a useful discussion with Dr Michele Larcher of the University of Trento, Italy, who was a civil engineer by training. In natural granular flows, he noted that reverse grading often occurs, in which higher concentrations of larger particles develop on top and in front of the flow (Larcher and Jenkins, 2015). This has obvious implications for the structural design of barrier systems. Particle segregation also affects parameters such as the flow depth and velocity, and the characteristics and consequence of impact forces on structures. While real world field experiments and back analysis are difficult, many researchers have tried to conduct physical experiments to study segregation, e.g. using binary mixtures of spheres which are different in size and mass. Using kinetic theory and mass, momentum and energy conservation equations, effects have been made to predict particle segregation in steady state as well as transient conditions, in both the depth (vertical) direction and the flow (longitudinal) directions. Comparison with results from DEM and physical experiments gives good agreements in general.

The quality of the research work presented at the conference was excellent. Many areas of applied research could find application in civil and geotechnical engineering, such as debris mobility analysis and design of defence structures against landslides. While outside my personal areas of professional practice, some research in granular flows such as bedload transport, segregation of particles, and erosion due to wind and water are highly relevant to civil engineering fields such as coastal engineering, port infrastructure, and river training.

After completing my overseas study in September 2019, I will return to Hong Kong to join a technical research and development division focusing on geotechnical safety and disaster preparedness. I look forward to consolidating my knowledge in this field.

ICE HKA's generous support for me to attend the conference is gratefully acknowledged. It is recommended that ICE continues to support members to take part in similar technical events of high repute internationally.

References

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