Effect of Particle Properties on Soil Behaviour: 3D Numerical Modelling of Shearbox Test and Biaxial Test

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The aim of the project is to study the behaviour of granular material by numerical modelling of the micro-structure. The effect of the micro properties of a sample, (particle shape, particle size and interparticle friction angle), on its shear stress-strain behaviour, shear strength , and the micro-mechanisms controlling deformation have been investigated. The numerical sample replicated the true relative particle size distribution of medium sand.

The DEM (Distinct Element Method), first introduced by Peter Cundall, is a relatively new numerical method used in soil mechanics. Based on Newton's second law and Force-Displacement law, the DEM is considered to be good at describing the mechanical behaviour of discontinuous bodies, such as that which occurs between soil and the surface of structure.

As one of the implementations of DEM, PFC-3D (Particle Flow Code in 3D) models three dimensional assemblies of spherical particles rather than arbitrarily shaped particles because in many cases, this is accurate enough while the calculation is dramatically simplified. However, two or more balls can be bonded together to simulate the differently shaped particles if more sophisticated and realistic modelling is required.

The Numerical Modelling of Shear Box Test

In this study, the standard shearbox test commonly used to investigate the shear behaviour of soils has been modelled using PFC-3D. Each particle was formed by bonding two spheres together, as shown in Figure 1. The overall shape of the particle is determined by the ratio of radii of two spheres. The modelled sample of particles, 20mm thick, was placed inside a simulated split box of internal dimensions 60mm x 60mm.

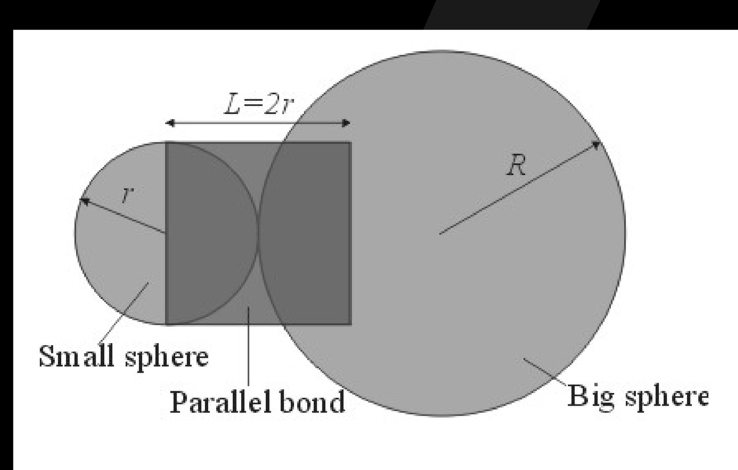


Figure 1

The vertical loading stress is applied through a platen simulated by two layers of spheres. Another platen is placed below the sample, and two horizontal wings are attached to the upper and lower halves of the box to prevent the particles from escaping while the sample is being sheared. The test was carried out by moving the lower half of the box and bottom platen horizontally while the upper half is kept stationary. A tested sample may contain up to fifty thousand particles.

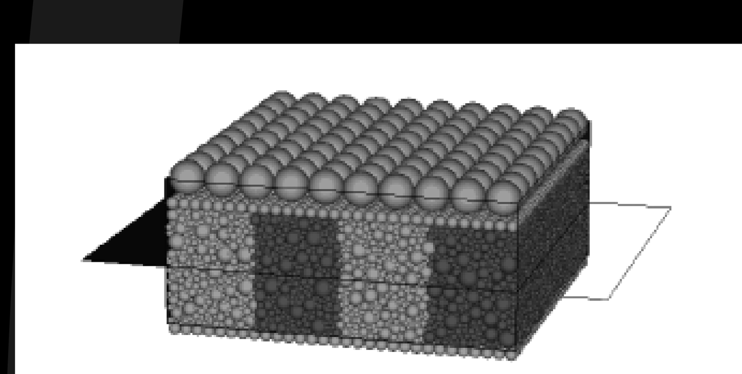


Figure 2

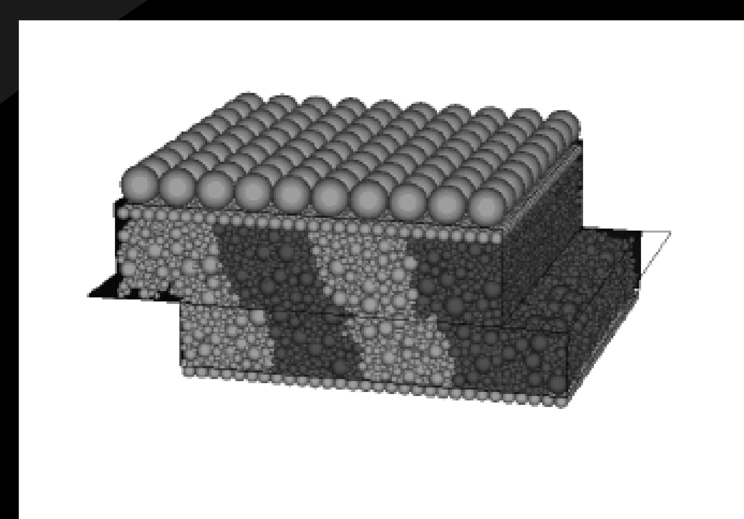


Figure 3

Figure 3 is the sample after being sheared and Figure 4 shows the stress ratio (shear stress to normal effective stress) and volumetric dilation observed during the test.

The shear strength and stress-strain behaviour are examined with different particle shapes, different particle sizes and different interparticle friction values.

The main conclusions are:

- The normal effective stress had very little effect on the mobilized friction angle.
- Particle shape plays an important role in the movement of the particles.
- The sample thickness to typical particle ratio is also important. However, the test results differ less when the particles are smaller than a certain size.

The particle friction angle contributes significantly to the shear strength as the sample starts to dilate.

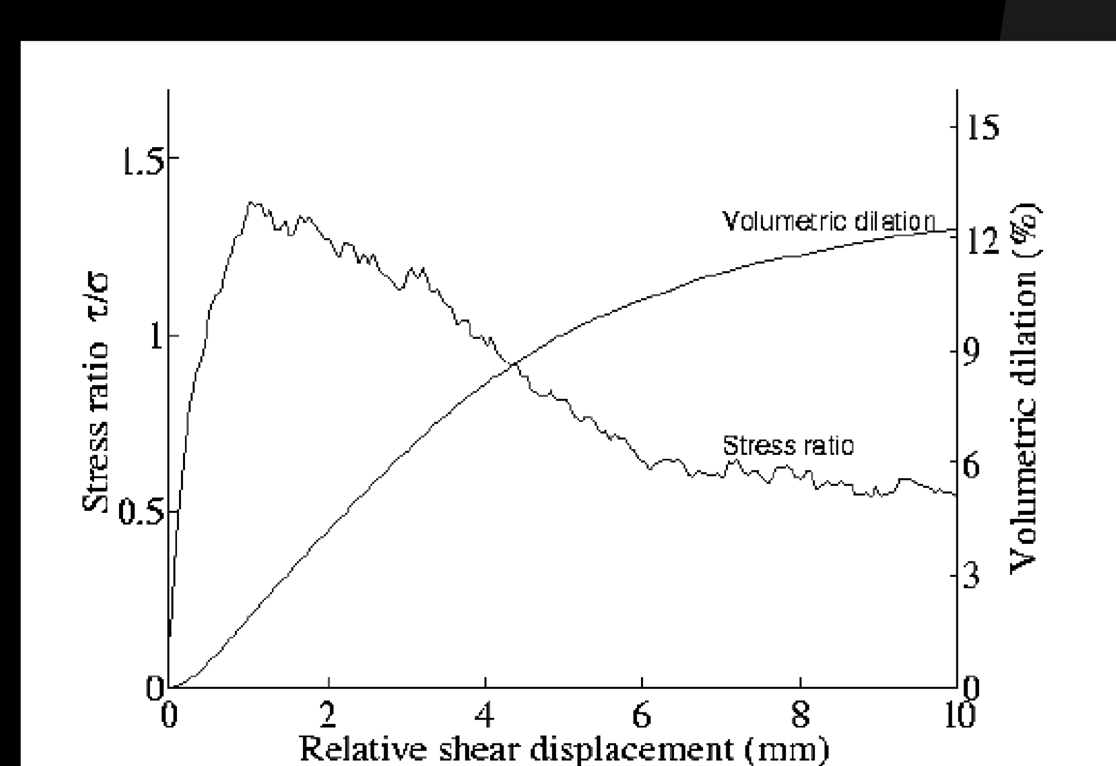


Figure 4

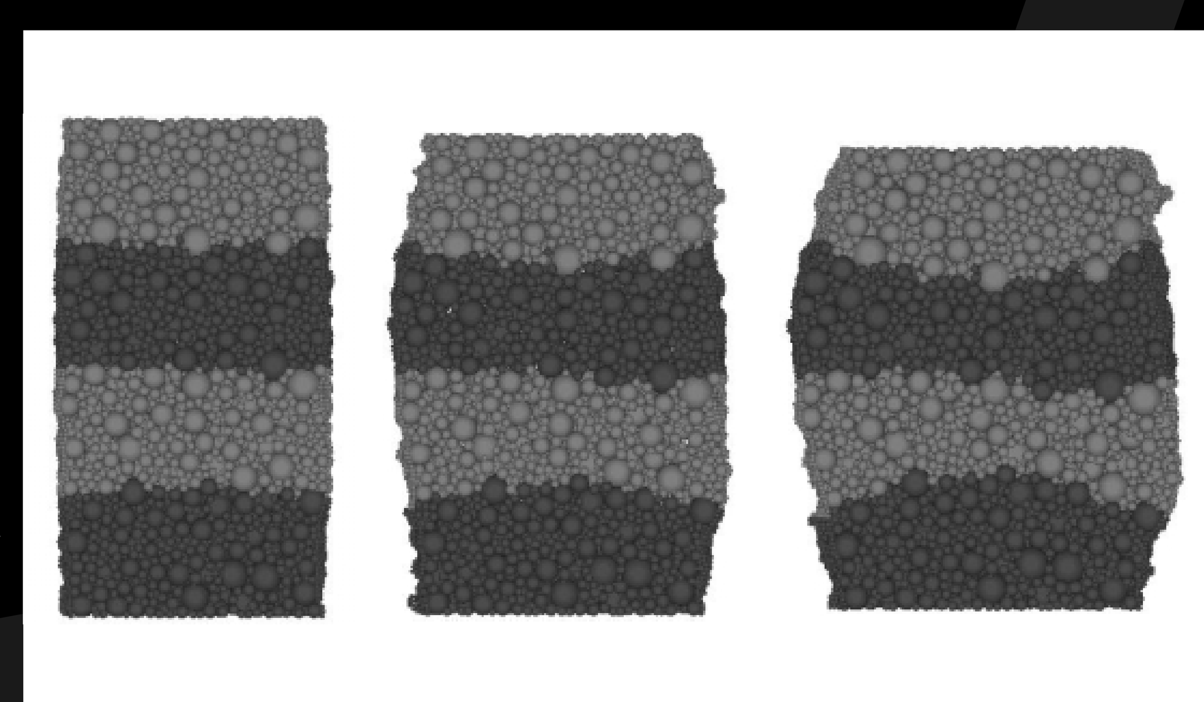
The Numerical Modelling of Biaxial Test

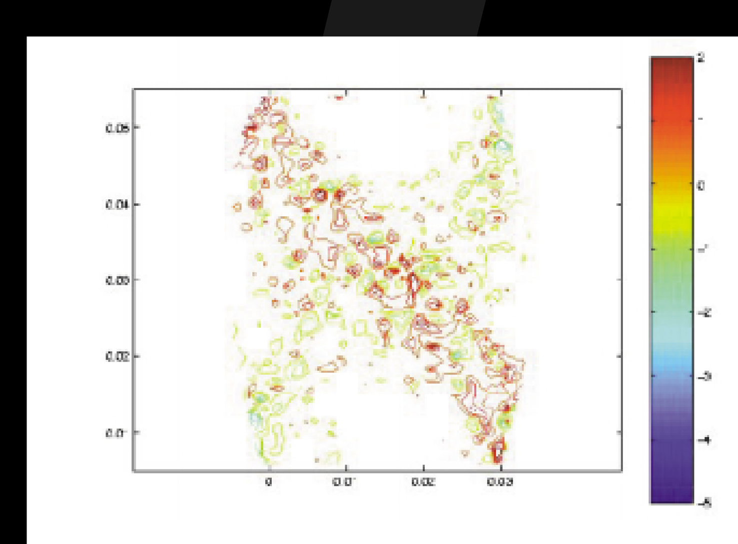
Particle size is potentially important in development of shear ruptures in soil, particularly when boundary displacements impose a discontinuity.

The previous shearbox test showed some evidence for this. The aim of this research is to investigate the factors controlling the development and propagation of shear bands and ruptures in particulate materials. Some initial studies have been carried out using a numerical biaxial test.

The test sample, with the dimensions of 30mm x 20mm x 60mm, is placed in a box consisting of four rigid walls.

The left and right side of the box are membranes simulated by a layer of softly bonded spheres. Each sphere in the membrane is subjected to the same force to provide a confining stress.





The first three pictures above show the sample after being compressed 2mm, 6mm and 10mm, respectively. The sample can be seen building up barrelling as the test being carried on. The particle rotation pattern is shown in the picture above. It is clear that the deformation is localized and concentrated in two narrow zones.

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