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Simulation of element tests using Discrete Element Method

(Simulationen der Elementversuche unter Einsatz von Diskreten Elemente Methode)

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Introduction

Granular soils are composed of distinct particles which have different shapes, sizes and make displacements without any dependence on other particles. They can be described in the simplest form as a group of particles that interact together through contact laws.In order to investigate the micro-scale soil response, numerical simulations are a very useful tool for researchers.

The Discrete Element Method (DEM) is one of the leading approaches to deal with discontinuous simulations which for necessary due to the discontinuous nature of granular soils. The DEM is the numerical approach that enables us to get information about the global behavior from the individual particles and their interaction by using simple contact laws.

The aim of the study is to do simulations of element tests using the Discrete Element Method. With the scope of this work, the soil is investigated under drained triaxial and simple shear tests. For simulation purposes, open-source software YADE is used by using the Discrete Element Method.

Simulation of Tests

In this work, spheres are used to represent soil particles. Within a cuboidal cell, a granular assembly of spherical particles was generated by using the deposition of grains under gravity.The distribution of particle sizes is depicted in Figure 2.

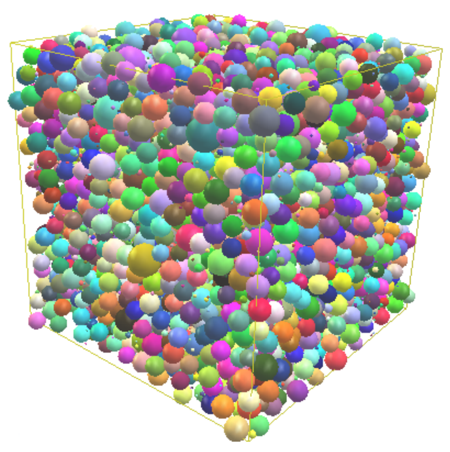

Fig. 1: Assembly of spheres

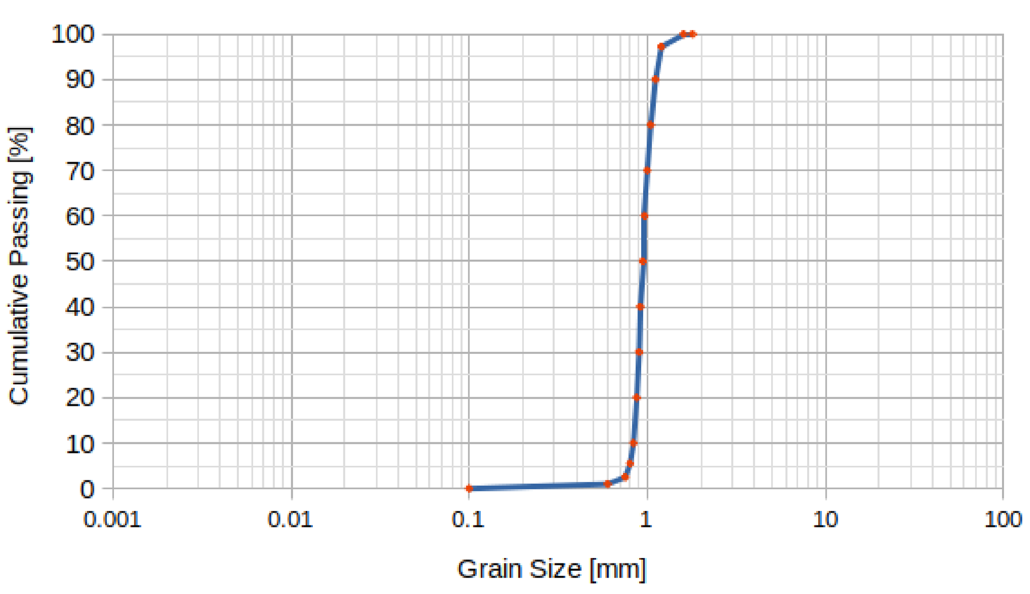

Fig. 2: Particle size distribution

The particle generation is carried out under the following parameters:

- Young' modulus = 25 MPa
- Friction angle (φ)= 30°
- Poisson ratio = 0.4
- Density = 2650 kg/m3

While all the simulations was carried out the numerical damping coefficient was taken as 0.2

The same size distribution and sphere properties were adopted for all simulations. Following the generation of the particles and decomposition under gravity, the system was compressed isotropically. With these conditions, a mean stress of $p_0' \approx 100$ kPa was set for the initial state.

Determination of the optimum number of particles

The determination of optimum number of particles is done by comparing the microscopic and macroscopic responses of soil from several drained triaxial test simulation results.

Using a cuboidal granular assembly with the previously described initial state, a triaxial DEM simulation was done for a triaxial drained test. The compaction phase is done after the defined isotropic pressure ($p_0' \approx 100$ kPa) and desired porosity value, which can also be seen in Table 1, is reached to be able to compare the results with the different number of particles.

Table 1: List of samples with cell dimensions and corresponding number of particles and void ratio

Sample	Cell Dimensions [mm]	Number of Particles	Void ratio (after compaction)
1	10x10x10	943	0.637162
2	12.5x12.5x12.5	1622	0.638740
3	15x15x15	2636	0.635170
4	17.5x17.5x17.5	4832	0.635945
5	20x20x20	6900	0.637110
6	22.5x22.5x22.5	9519	0.638999
7	25x25x25	11851	0.639235

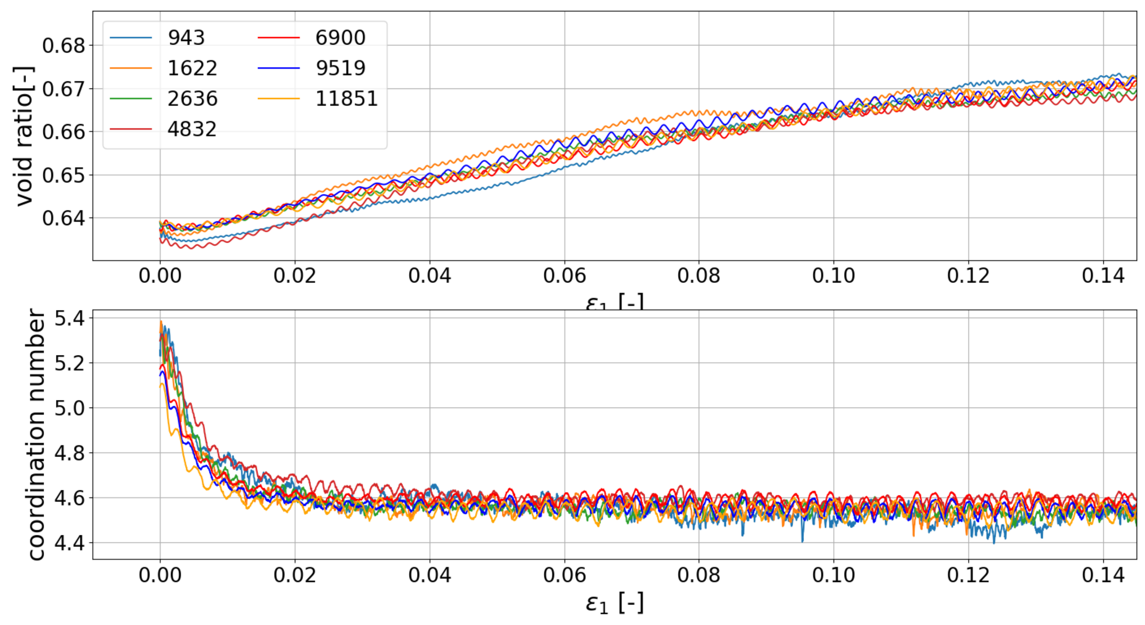

Fig. 3: Influence of the number of particles on coordination number and void ratio

Determination of the optimum number of particles is done based on coordination number and void ratio. In light of all simulations and soil responses, it can be concluded that the packing of 6900 particles is chosen to achieve stable macro and microscopic responses.

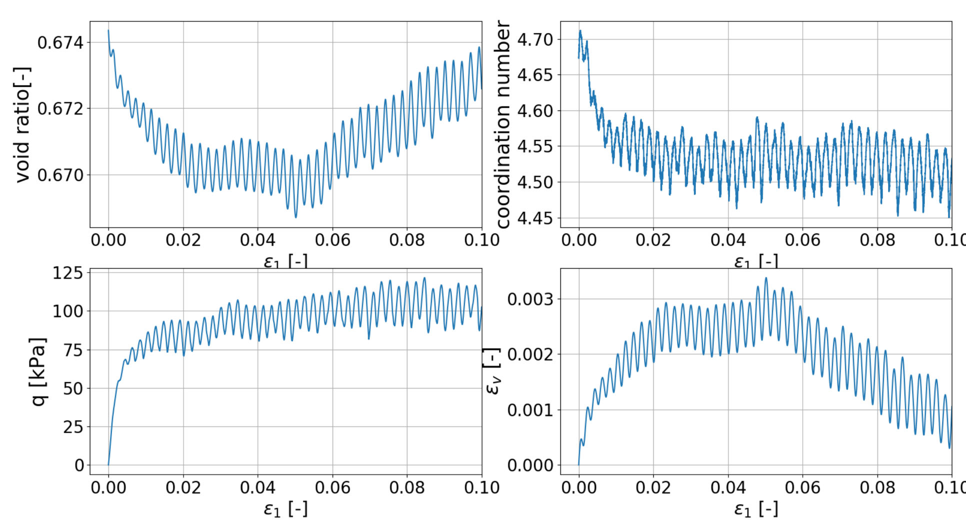

Fig. 4: Soil responses under drained triaxial test simulation with optimum number particle (initial void ratio 0.674)

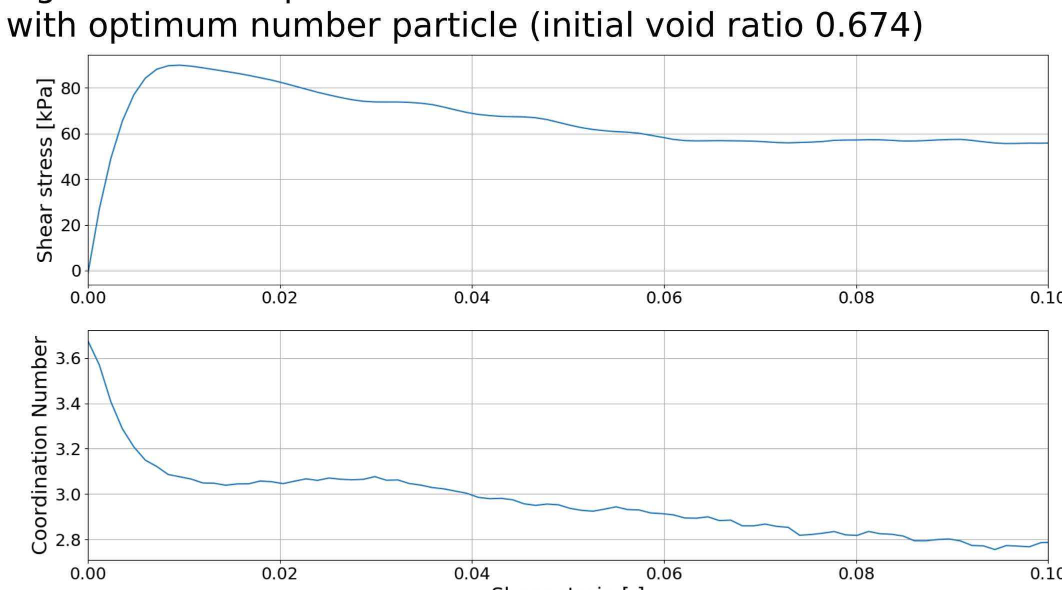

Fig. 5: Soil responses under simple shear test simulation with optimum number particle (initial void ratio is 0.91)

Force chain evolution

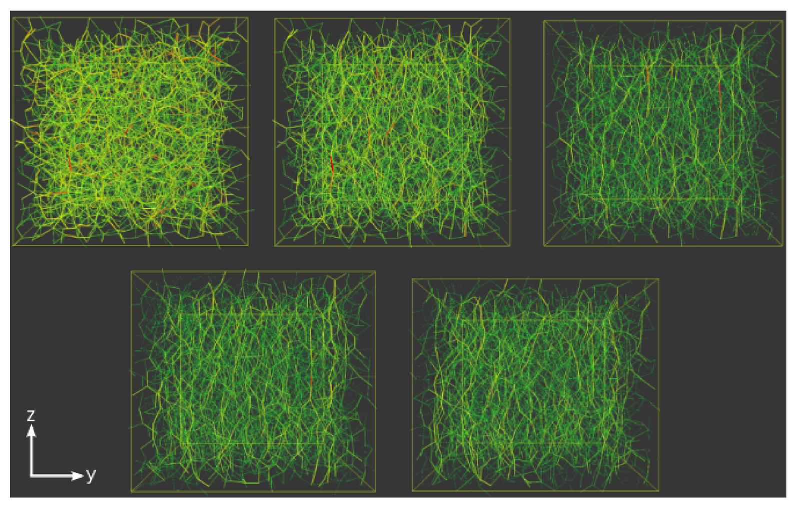

Fig. 6: The evaluation of force chains during triaxial test(initial void ratio 0.674)

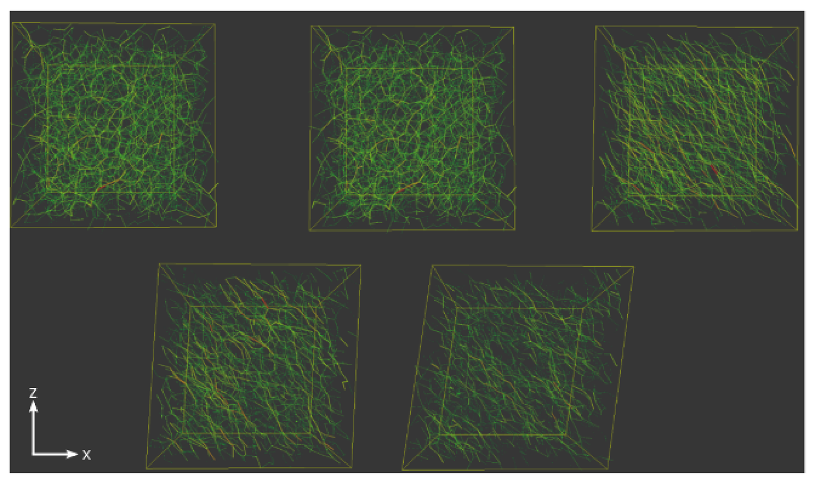

Fig. 7: The evaluation of force chains during simple shear test (initial void ratio 0.91)

Contact normal evolution

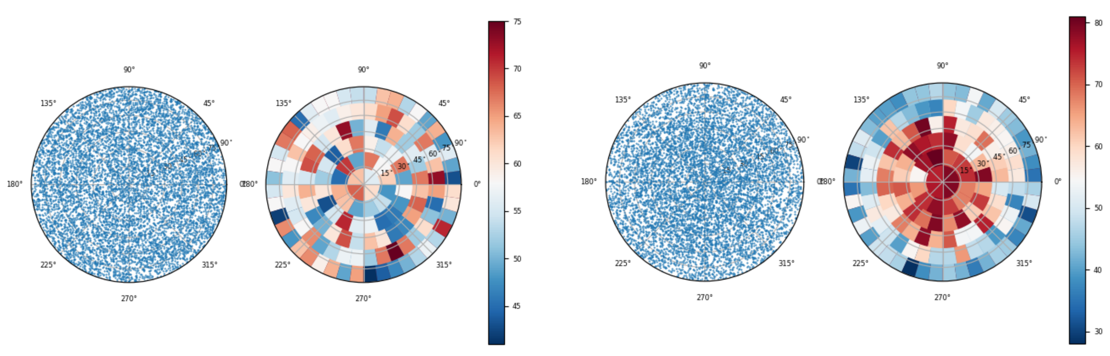

Fig. 8: Density and orientations of contact normal at initial and final state in drained triaxial test (initial void ratio 0.674)

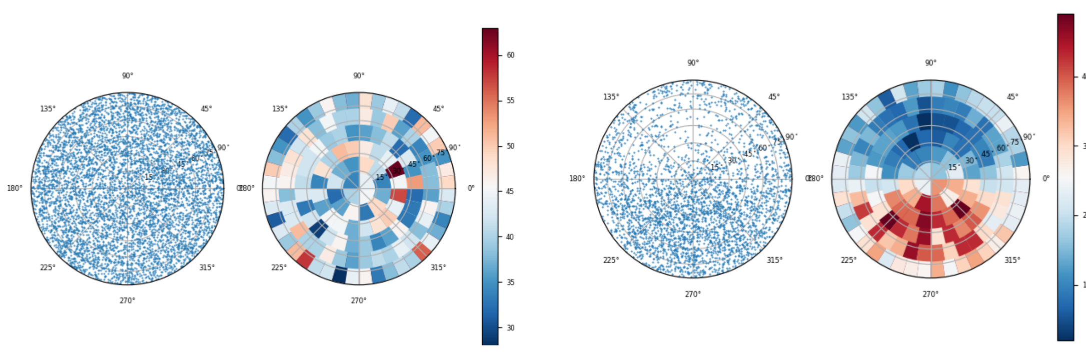

Fig. 9: Density and orientations of contact normal at initial and final state in drained triaxial test (initial void ratio 0.91)

Conclusion

The main object of the was to perform a simulation of element tests using Discrete Element Method. The study showed that DEM can be used successfully to capture soil behavior at grain scale.

In order to obtain converging results on macro- and micro-scale by comparing the void ratio and coordination number, it is necessary to generate particle assemblies that contain 6900 particles.

The evaluations proved that the force chains and contact normals are formed according to the loading direction. However, no pattern could be detected for grain rotations.

Project
Application-Oriented Research Project

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