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Study on Sample Preparation Method of DEM

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Abstract. Three numerical sample preparation methods, namely, radius expand method, hierarchical compaction method and gravity descent method, were studied using discrete element method (DEM) to simulate the actual sample. The processes of these three methods were described in details and the differences of these three methods were discussed. The impacts of mechanical parameters in DEM model on the numerical results were analyzed.

Introduction

Since Cundall[1, 2] proposed discrete element method (DEM) suitable for rock mechanics and soil mechanics. When chosing the discrete element method for the numerical simulation, Jensen and other people [3] consider the size of generate sample necessary to try as close as possible of the size of the laboratory test, and the aspect ratio to be controlled at about 2.0 to 2.5. The initial porosity, which directly determines the initial density of the sample, will affect the mechanical properties of the sample. For the number of particles, Jian Zhou and other people [4, 5] discuss the changes in the number of particles on the impact of the sample macro mechanics.

In this paper, three numerical sample preparation methods, namely, radius expand method, hierarchical compaction method and gravity descent method, were studied using discrete element method (DEM) to simulate the actual sample. The processes of these three methods were described in details and the differences of these three methods were discussed. The impacts of mechanical parameters in DEM model on the numerical results were analyzed.

Different methods of sample preparation

Numerical preparation sand samples and laboratory preparation sand samples is similar, and both require a sample preparation tool. Sample preparation tool is constrained wall, and generate the required size model. But to generate sand samples, if not stable filled between the particles, it would be occurs substantial overlap, and the particles also does not appear stable filled in the high initial porosity. In order to generate a stable sand samples, we can use radius expand method, hierarchical compaction method and gravity descent method.

Radius expands method. In the process of the sand samples generation, when use the first radius expand method, first randomly generated a certain number of particles within the four walls, particle size is randomly uniformly distributed within the specified range, and fill the area of the walls by the radius of the expanding, and then meet the specified porosity. In the generate sample process, in order to allow the sample do not have a large contact force, and make the sample to reach equilibrium within a short time, often use radius expand method to generate the sample. When this method is used, the use of the particle size range of ($R_{\min}$, $R_{\max}$), the specified porosity of n and to determine the size of the sample (length h, width w). Generate the target sample is derived as follows:

First use the average radius to calculate the number of particles in the specified porosity n :

$$\overline{R} = \frac{R_{\min} + R_{\max}}{2} . \tag{1}$$

$$N = \frac{h \times w(1-n)}{\pi \overline{R}^2}. \tag{2}$$

Where $\overline{R}$ is the average particle radius, N is the total number of particles.

Because the sample is randomly generated, so afraid sometimes produce a large amount of overlap, we will set a radius expansion factor m, such as the first m is 1.6, and make particle size reduced to($\frac{R_{\min}}{m}, \frac{R_{\max}}{m}$), and then generate particles number is N, the porosity of this time is n_0. There is the relationship:

$$\frac{\sum R^2}{\sum R_0^{\ 2}} = \frac{1-n}{1-n_0}. \tag{3}$$

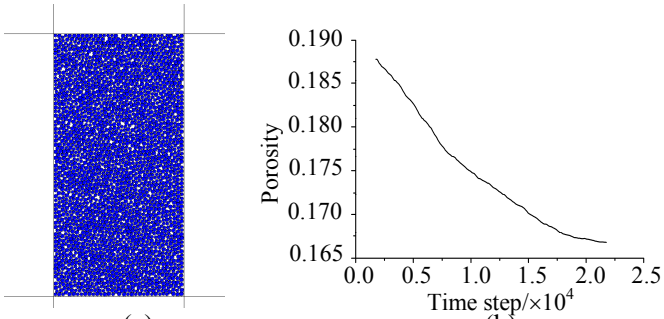
This will produce a new radius expansion factor m, and let this new m return to the beginning of the calculation, so the specified porosity of this time is n. There is the relationship:

$$m = \sqrt{\frac{1-n}{1-n_0}}. \tag{4}$$

Radius expand method to generate the parameters of the sand samples are shown in Table 1, Radius expand method generates sand samples and porosity changes shown in Figure 1.

Table. 1 Radius expand method to generate the parameter of the sand samples

$h \times w$ /m	$R_{\max}$ /m	$R_{\min}$ /m	m	ρ_s /kg/m^3	k_n /N/m	K_s /N/m	k_w /N/m	f_c	n_0 /%
0.12×0.06	0.001	0.00075	1.6	2630	5×108	5×108	5×107	0.5	20



(a) (b)

Fig. 1 Radius expand method generates sand samples and porosity changes

Hierarchical compaction method. When use the second hierarchical compaction method to prepared sand samples, the first four walls contained volume is divided into several parts, and respectively use Radius expand method to compress. Use such a method to generate the sample will slightly be denser than radius expand method. Because when layered, each layer of particles reduced, and contact effect between the of the particles pass more easily, so the sample will slightly be dense. When use the hierarchical compaction method to prepared samples, we will be compress each layer and add a wall to avoid the particles of another layer spread to the layer, and wait until the layer of particles generated, then this wall delete, and then generate another layer. Wait until all particles generated, and then consolidated. So using the hierarchical compaction method to prepared sand samples, when every layer of particles generated, it will increase a wall, like this will increase the impact of the boundary conditions for the preparation of sand sample. Therefore, when using the hierarchical compaction method to prepared sand samples, it should not be divided up into many layers, that can avoid the impact of their boundary conditions.

Hierarchical compaction method generates sand samples and porosity changes shown in Figure 2. In the figure, the sample is divided into two layers to compress. The parameters of the sand samples are shown in Table 1

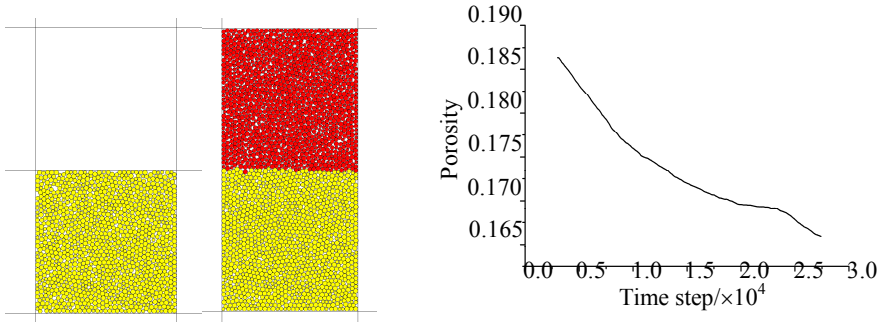


Fig. 2 Hierarchical compaction method generates sand samples and porosity changes

Gravity descent method. When use the gravity descent method to prepared sand samples, we specify the acceleration of gravity is 9.81m/s^2, the height of the falling is h_f, the initial fall particle number is N_0, the initial height of wall is 0.24m, first generated 3 walls, and randomly generated particles that we specify the radius. The maximum particle size R_{max} is 1mm, the minimum particle size R_{min} is 0.75mm, gradation uniformly distributed, the average particle size is 0.875mm, and let the particles fall into the range of wall, then through several debugging, cycle calculated to 1×10^6 step, then the sample reached equilibrium and removed the excess particles. We want to generate the initial sample of 0.12m×06m, so the end of the calculation we remove particles higher than 0.12m above, then the top wall plus up, and prepared out of the initial sample.

Gravity descent method generates sand samples and porosity changes shown in Figure 3. The parameters of the sand samples are shown in Table 2

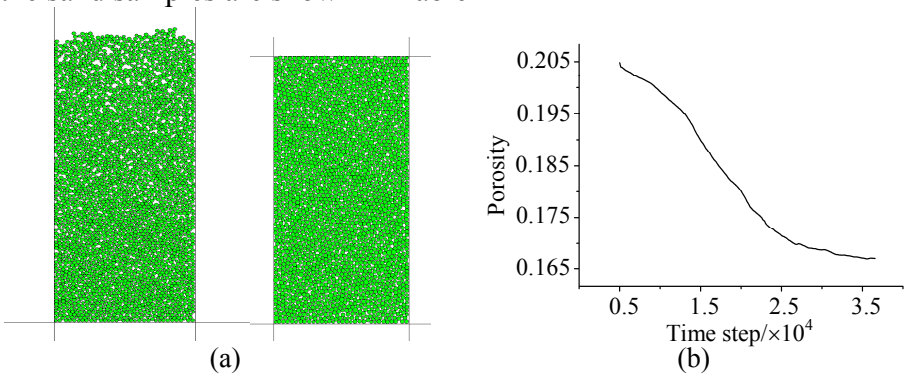


Fig. 3 Hierarchical compaction method generates sand samples and porosity changes

Table. 2 Gravity descent methods to generate the parameter of the sand samples

$h\times w$ /m	R_{max} /m	R_{min} /m	h_f /m	ρ_s /kg/m^3	k_n /N/m	K_s /N/m	k_w /N/m	f_c	N_0
0.12×0.06	0.001	0.00075	1	2630	5×108	5×108	5×107	0.5	3000

Analysis of influencing factors

The discrete element method to simulate the actual sample, the mechanical properties of the soil particles, in the choice of constitutive model parameters we used to be our numerical simulation influential. we mainly change the parameters to prepare sand samples, and study the influence parameters have on the process of generating sand samples.

At first, friction coefficient is set to be 0.1, 0.25 and 0.5,respectively and the other parameters used to generate the initial sample are shown in Table 1. And then the specimens are consolidating in the confining pressure of 100kpa to be test specimens. The porosity of samples shows in Figure 4 (a). We

keep the minimum radius of particles R_{min} = 0.00075 unchanged and change the particle diameter ratio of the particles during the process of generating the samples. The particles maximum radius R_{max} is set to be 0.00075,0.001 and 0.0015, respectively and the particle size ratio R_{max}/R_{min} of 1,1.33and 2. The other parameters used to generate the initial sample are shown in table 1. And then the specimens are consolidating in the confining pressure of 100kpa to be test specimens. The porosity of sand samples shows in Figure 4 (b). In order to discuss the effect of confining pressure on the sample preparation, confining pressure is set to be 100kpa 150kpa and 200kpa respectively. Then we generate the samples under these confining pressures. The other parameters used to generate the initial sample are shown in table 1. The porosity of sand samples shows in Figure 4 (c).

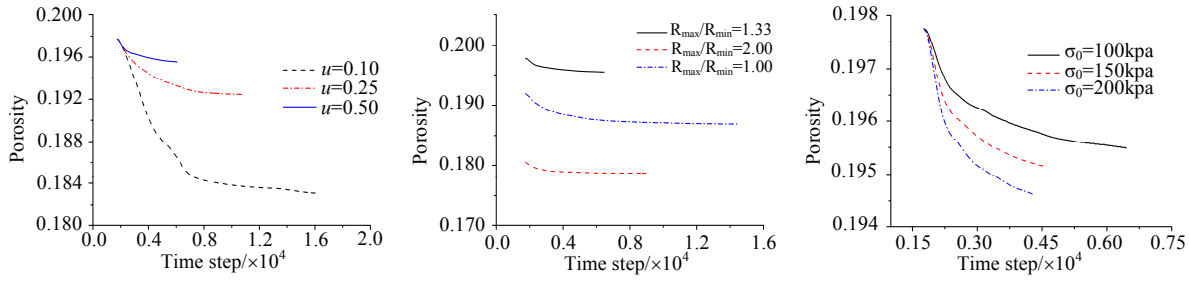


Fig. 4 The impact of different parameters on the sample porosity

Figure 4 (a), Figure 4 (b) and Figure 4 (c) reflects how the the coefficient friction, particle size ratio R_{max}/R_{min} and confining pressure affect the sample. By studying rules of the parameters how to affect samples to determine the influence of the density of the initial specimen, and the initial sample density will affect the future mechanics of the test specimen.

Conclusion

Three numerical sample preparation methods, namely, radius expand method were studied using discrete element method (DEM) to simulate the actual sample. The processes of these three methods were described in details and the differences of these three methods were discussed. The impacts of mechanical parameters in DEM model on the numerical results were analyzed. These three methods have their advantages and disadvantages. Different parameters will affect the porosity of the sand samples, and porosity determines the initial sample density, and will affect the mechanical properties of the sample as a results.

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