Shear Propagation in Granular System

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Abstract**.** Shear propagation and formation of sheared region in a sand system are investigated by a simulation. Our experimental apparatus for sand system is one of the simplest sets in order to obtain shear pattern, called as linear split-bottom cell. In this paper we give an analysis based on simulation for the above-mentioned system. Although a sand particle has a variety of forms from sphere to needle in general, but here we assume an ensemble of the simplest shape such as cubes in a rectangular parallelpipe split into two halves. One of the halves is moved along the split quasi-statically**.** We obtain a pattern of shear region and various quantities obtained from our simulation are compared with experiments.

1. Introduction

Properties in sand system has recently been studied from elementary processes[1]-[3] and also actual applications to technological fields[4]. As is well-known, sand systems consist of sand particles. Generally, forms of sand particles diverge from sphere to needle. Ensemble of such particles forms an example of typical random system. When stress is given at a site, along a line, along a surface and/or to bulk body, propagation of stress and strain becomes very complicated. It is very important to investigate the quasi-static propagation of stress and strain in the sand system.

Therefore we built up an experimental apparatus to study how the shear propagates and is formed as simple as possible which is shown in Fig.1.

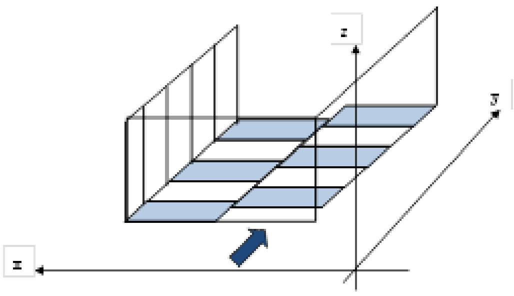

Fig.1 Experiment apparatus which is made of acrylic box with a split along the longest edge of the box. One side of the box is movable with a quasi-static velocity (blue stich arrow).

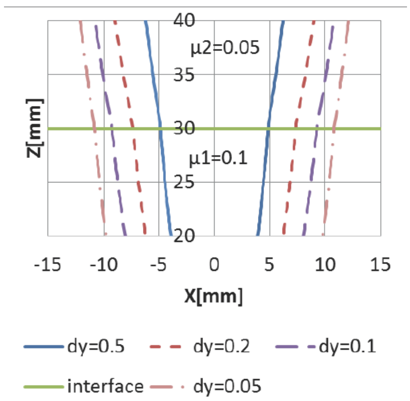

Fig.2 Shear lines across the horizontal interface of two sand layers with two different stickiness

In Fig.1, The right hand side of outer box can be moved quasi-statistically, where stress propagates from bottom to top. Although a sand particle has a variety of forms from sphere to needle in general, but here we assume an ensemble of the simplest shape such as cubes in a rectangular parallel pipe split into two halves. One of the halves is moved along the split quasi-statically shown in Fig.1. We obtain a pattern shown in Fig.2 and various quantities obtained from our simulation are compared with experiments. Figure 2 shows the boundary of shear region which across the horizontal interface of different kinds of sand in our numerical calculation. The longitudinal lines are shear lines which sliding distances from initial positions are 0.5 [mm], 0.2[mm], 0.1[mm] and 0.05[mm], respectively. But all incidence angles to the interface are so small that we can't confirm whether the refraction's law is followed Snell's law known for geometric optics [5].

We assume that sand particles are approximated by small cubes and our sand ensemble is regularly piled 340×680 cubes which approximates a random piling. When one side of the box is under the force which is shown an arrow in Fig.1, the sand particles at the bottom move together with the bottom plate and many particles at the top share the slip between the right and left half boxes. By assuming the friction force between two particles we have obtained the following equation.

$$\begin{gathered}\left[\mu_x\left(f(x,z)-f(x-1,z)\right)-d_{shr}\right]+\left[\mu_x\left(f(x,z)-f(x+1,z)\right)-d_{shr}\right]\\+\left[\mu_z\left(f(x,z)-f(x,z+1)\right)\left(z_{top}-z\right)-d_{shr}\right]\\+\left[\mu_x\left(f(x,z)-f(x,z-1)\right)\left(z_{top}-z+1\right)-d_{shr}\right]=0\end{gathered}$$

Here, $f(x,z)$ is displacement of a particle at x and z and $\boldsymbol{\mu_x}\left(\boldsymbol{f(x,z)}-\boldsymbol{f(x-1,z)}\right)$ is friction between the particles at x, z and x-1, z, where $\boldsymbol{\mu_x}$ and $\boldsymbol{\mu_z}$ are the friction coefficient, as shown in Fig.3. $[G-d_{shr}]$ means $G-d_{shr}$ if $G-d_{shr}>0$, and 0 if $G-d_{shr}<0$. Once we know the numeric values of four neighbour sites of $f(x, z)$, we can obtain the value of $f(x, z)$ by using this equation.

2. Concluding remarks

Many scientists examined the shear pattern in the sand system by experiment or by numerical technique and here is the trial of simulation for the experiment. Some results of experiment are understood by the present simulation, but some are now going to be solved. The present calculation shows that the refraction's law of shear line obeys the refraction law like equipotential surface across the interface of different dielectric constants. The maximum slid line shows a complicated feature. We are now trying to investigate the model of various shape of grain.

References

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