EVALUATING DEGREE OF MIXTURE OF SOIL PARTICLES USING DEM ANALYSIS

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1. INTRODUCTION:

Soil mechanics, sometimes, deals with the mixing of soil such as in deep mixing of soil and mixing of soil in tunnel boring machines, i.e., EPB shield machine. It is important to estimate the extent of mixing of the soil to confirm the required performance of such phenomenon. The extent of mixing in deep mixing of materials is usually estimated by measuring the permeability or unconfined compression strength of the material at different curing periods (Bruce et al., 2013). Another index to assess the quality of mixing is blade rotation number (Yoshizawa et al., 1996).

This study intends to define a parameter for calculating the degree of mixture of soils mixed by the rotary action of two stirring rods in a cylindrical soil specimen using discrete element method (DEM).

2. METHODOLOGY:

2.1. Material and Specimen Preparation:

The DEM simulations were carried out using a modified version of LAMMPS (Large-scale Atomic/Molecular Massively Parallel Simulator; Plimpton 1995). 165,919 spherical particles having elastic modulus of 71.6 GPa, particle density of 2650 kg/m^3 and size ranging from 2 to 2.2 mm were generated. These particles were pluviated inside a box from a height exceeding 100 cm. A cylindrical region (dia. = 30 cm, thickness = 2 cm) was created inside the box and extra particles were removed around this region. After this, two stirring rods were provided by deleting particles in two given regions as shown in Fig. 1. The material was mixed by rotating these rods at 100 RPM.

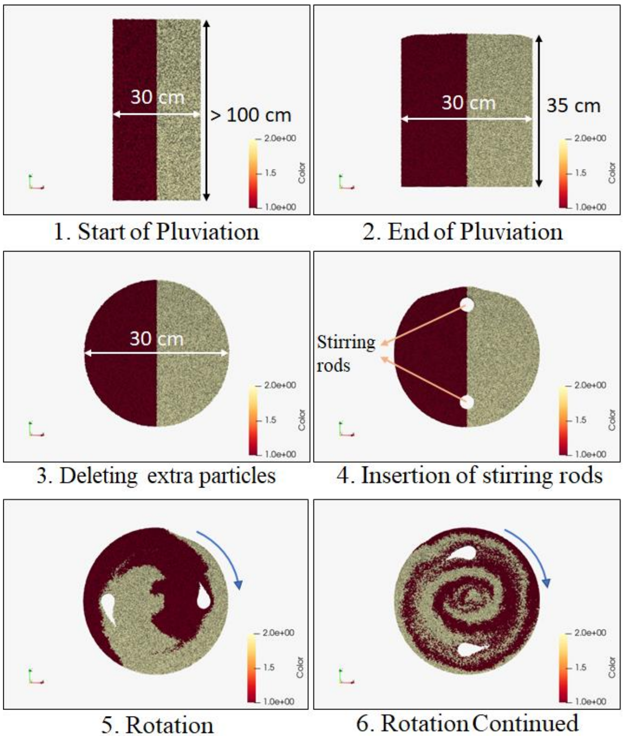

Fig. 1: *Simulation steps.*

2.2. Calculation of degree of mixture:

For the calculation of degree of mixture, d_m, the particles in specimen are divided into the two regions based on the initial coordinate as shown by different colors in Fig. 2. The specimen is divided into one hundred equal sized grids spread all over the specimen.

For each grid, the degree of mixture, d_m, is defined as one minus the difference in the number of two types of particles divided by the total number of particles in that grid expressed as percentage.

$$d_m = \left(1 - \frac{|n_1 - n_2|}{n_1 + n_2}\right) * 100 \qquad \text{(Eq. 1)}$$

Here, n_1 and n_2 are number of type 1 and type 2 particles.

Eq. (1) implies that for each rotation in any grid, if the number of both types of particles are equal, the degree of mixture is highest (i.e., 100%). If there are no particles in any grid, that grid is omitted from the calculations. Example of grid number 72 is provided in Fig. 3(a).

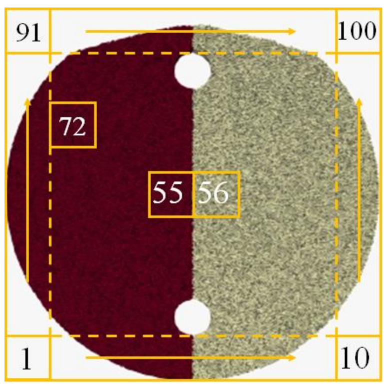

Fig. 2: *Specimen and grid system (not on scale).*

Keywords: DEM simulations, LAMMPS, Mixing of materials, Degree of mixture.
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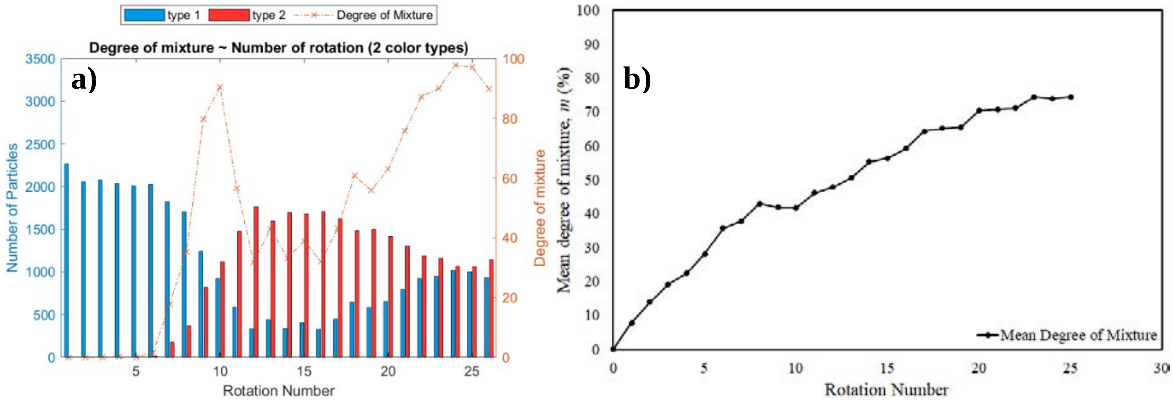

Fig. 3: a) *Number of two types of particles and variation of degree of mixture for grid 72*
b) *Mean degree of mixture at each rotation.*

In this study, the rods are given twenty-five rotations. The mean degree of mixture, m, is calculated for each rotation by calculating the mean of d_m of all the grids at the given rotation number using the following equation:

$$m = \frac{\Sigma(d_m\ for\ all\ grids)}{Total\ number\ of\ grids} \qquad \text{(Eq. 2)}$$

The mean degree of mixture, m, for the simulated specimen at each rotation is given in Fig. 3(b).

Fig. 4 illustrates the mixed condition of the specimen along with the color code exhibiting the distribution of degree of mixture around the specimen after 25 rotations.

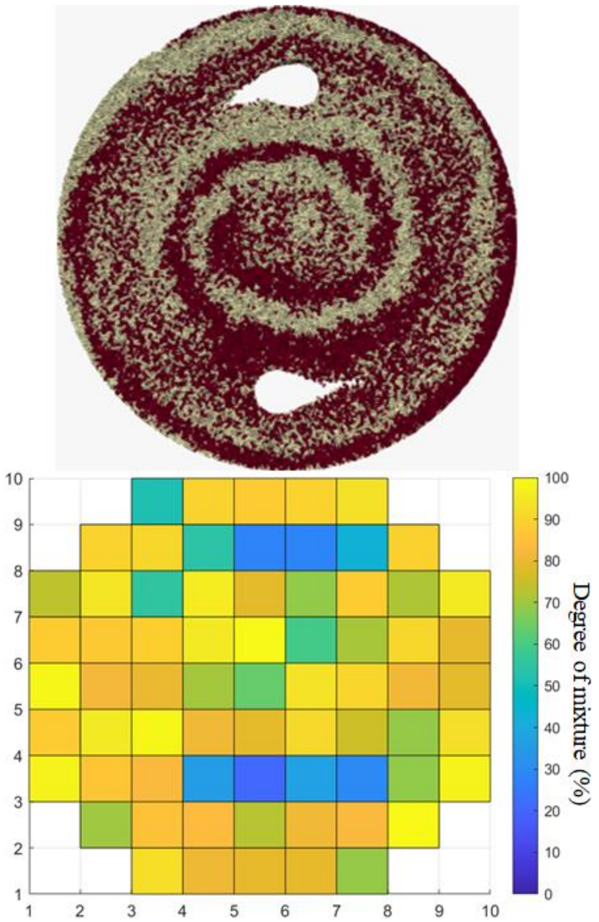

Fig. 4: *Mixed condition and spatial distribution of d_m after 25 rotations.*

3. CONCLUSION:

A new parameter for the calculation of degree of mixture has been defined. The results show that the parameter performs well for each grid at given number of rotations. It illustrates that as the number of rotations increase up to 25, the mean degree of mixture also increases.

4. REFERENCES:

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