Calibration of Model Parameters in 2D DEM for Soil-Grouser Sytem

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ABSTRACT: *For interaction studies in terramechanics, it has become popular to apply the Discrete Element Method (DEM) because of its capability in modeling local shear lines or large displacement of soil under various running gears. Through the development of in-house 2D DEM program for soil-grouser system, we conducted a reference experiment where quasi-2D condition was assumed. Since the contact mechanics in the program is modeled by a linear contact model where a spring and a damper are connected in parallel, the necessary parameters that should be calibrated are spring constant, coefficient of friction, and coefficient of rolling friction if the critical damping condition is assumed. The soil model in the experiment is made of aluminum cylinder. Density of model soil element and radius are common between DEM and the experiment. As for calibration process, the image-based procedure was applied to determine the coefficient of friction by using the angle of slope formed after the movement of grouser. Moreover, the coefficient of rolling friction was subsequently adjusted following the decision of the coefficient of friction. The normal spring constant was decided from the trial-and-error approach, the order of which was learned from the previous reports on DEM application in terramechanics.*

Purpose of Study

- to upgrade previously developed 2D DEM code for soil-grouser interaction analysis by comparing with the result of simple 2D experiments
- to investigate the effects of height and thickness of grouser on gross traction in relation with the soil behaviour and with partial gross traction on grouser surfaces

Experimental device

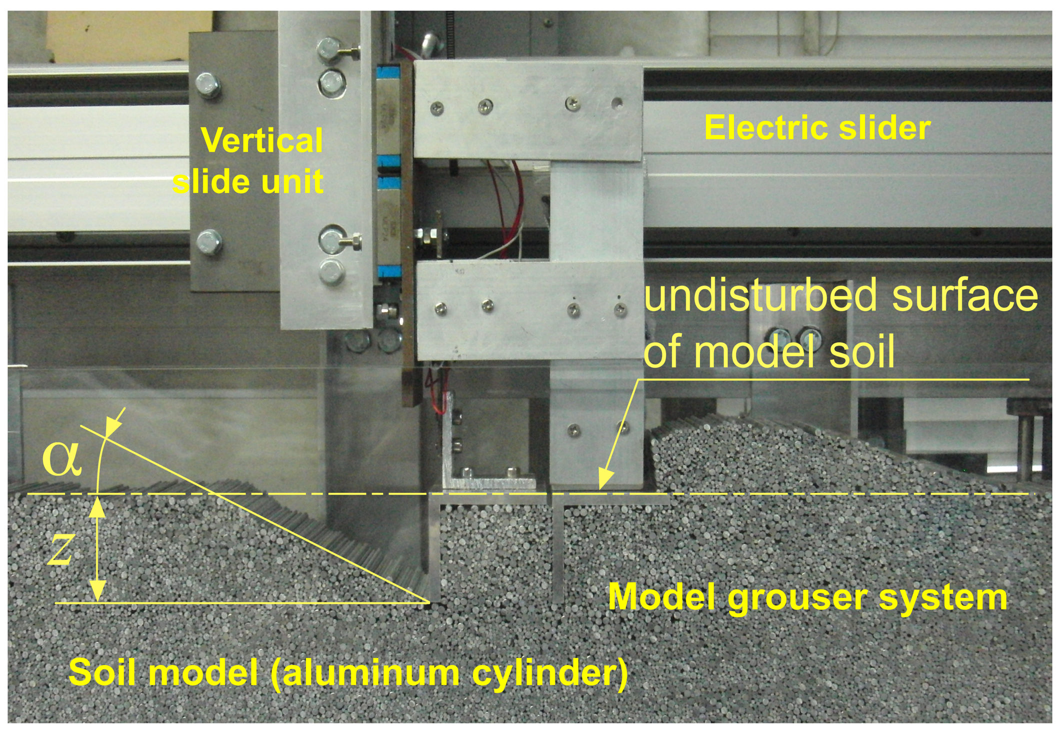

Figure 1. Experimental system using 2D soil model.

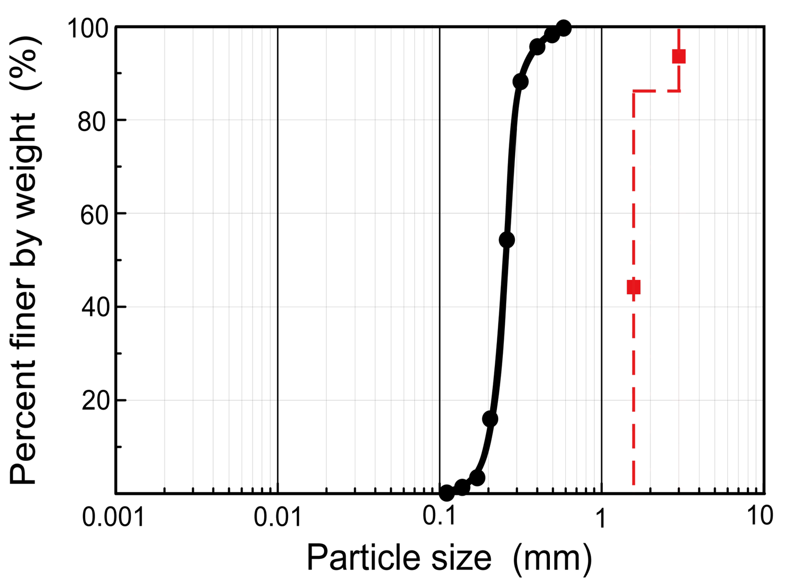

Figure 2. Particle distribution of model soil (red dashed line).

Discrete Element Method

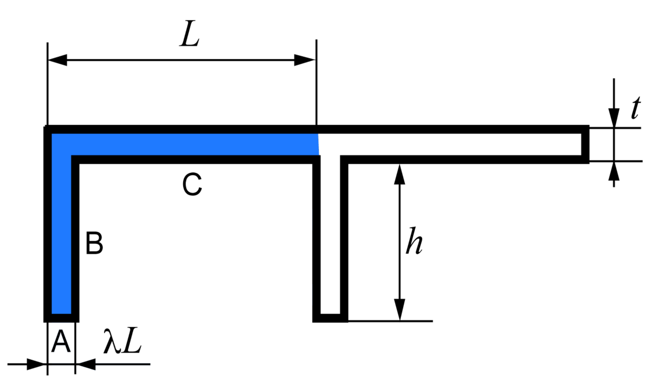

Figure 3. Model grouser system (target grouser is) in blue.

Table 1. Grouser parameters in experiments and in DEM.

Contact Weight, *W* (N)	7.84
Pitch of Grouser, *L* (cm)	5 (5.2**)
Grouser Height, *h* (cm)	0*,1, 2.5, 4, 5*, 6*
Thickness Ratio of Grouser, λ	0.1, 0.3, 0.5
Thickness of Top Plate, *t* (cm)	0.5 (5**)
Width of Grouser, b_g (cm)	5

NB) *Added in DEM; **In DEM only.

Table 2. DEM parameters.

Element diameter, *d* (mm)	1.6, 3.0 (16:3)
Initially-generated number of elements	26722
Elemental density (g/cm^3)	2.65
Normal spring constant, K_n (N/m)	50000
Tangential spring constant, K_t (N/m)	50000
Width of element, b_e (mm)	50
Friction coefficient for soil-soil, μ_p	0.2
Friction coefficient for soil-grouser, μ_g	0.2
Friction coefficient for soil-wall, μ_w	0.2
Coefficient of rolling friction, μ_r (m)	0.05
Time step, Δt (s)	0.000012
Velocity of grouser (m/s)	0.01

Results and discussion

Calibration Procedure:

a) Starting friction coefficients of μ_p, μ_g and μ_w are set from the angle of slope of a cavity, assuming the slope of this cavity seemingly forms intrinsic angle of slope and is regarded as "angle of repose" which may be defined by the inter-particle friction angle between soil models.

b) Subsequently, the friction coefficients μ_p, μ_g and μ_w are increased or decreased from the previous values, depending on the difference of the sinkage of grouser and the angle of slope of a cavity, using a tentative coefficient of rolling friction other than 0.0.

c) Then, the coefficient of rolling friction was adjusted so that the shape and angle of slope of a cavity becomes similar to the result of experiments while keeping the coefficient of friction μ_p, μ_g and μ_w constant.

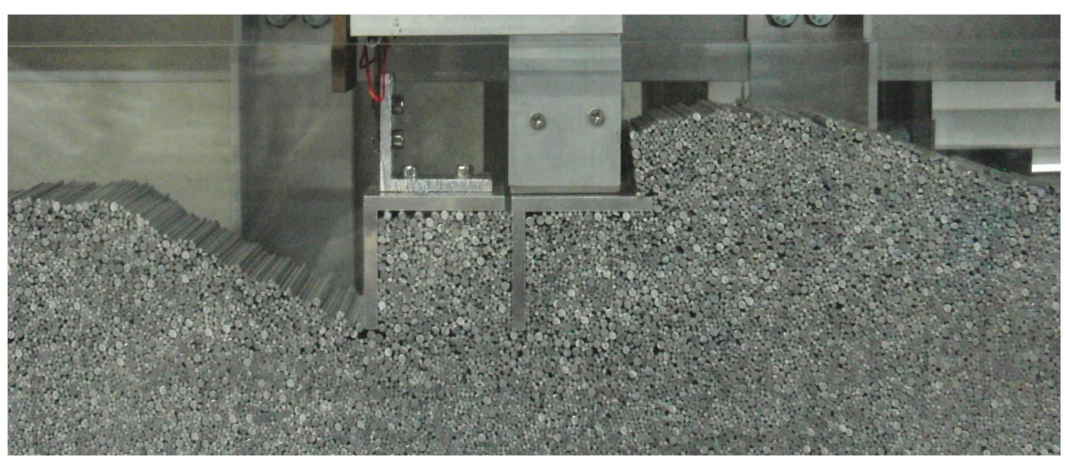

Figure 4. Behavior of model soil under a grouser in experiments (λ = 0.1, h = 4 cm).

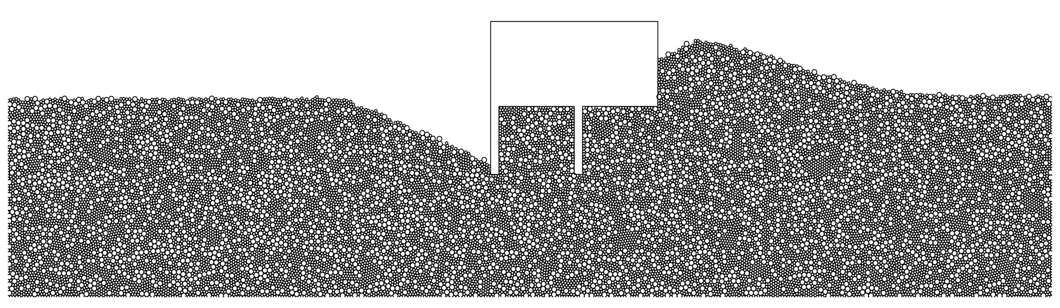

Figure 5. Behavior of model soil under a grouser in DEM (λ = 0.1, h = 4 cm).

Table 3. Sinkage of grouser

h [cm]	λ	z_e [mm]	z_d [mm]
1	0.1	23.6	18.1
1	0.3	20.0	19.3
1	0.5	19.4	17.3
2.5	0.1	31.1	30.3
2.5	0.3	29.8	28.6
2.5	0.5	22.5	23.9
4	0.1	44.3	43.7
4	0.3	37.5	40.0
4	0.5	32.5	28.6

Table 4. Angle of slope

h [cm]	λ	α_e [°]	α_d [°]
1	0.1	20	22
1	0.3	19	20
1	0.5	20	19
2.5	0.1	25	25
2.5	0.3	25	23
2.5	0.5	23	21
4	0.1	24	25
4	0.3	28	24
4	0.5	23	24

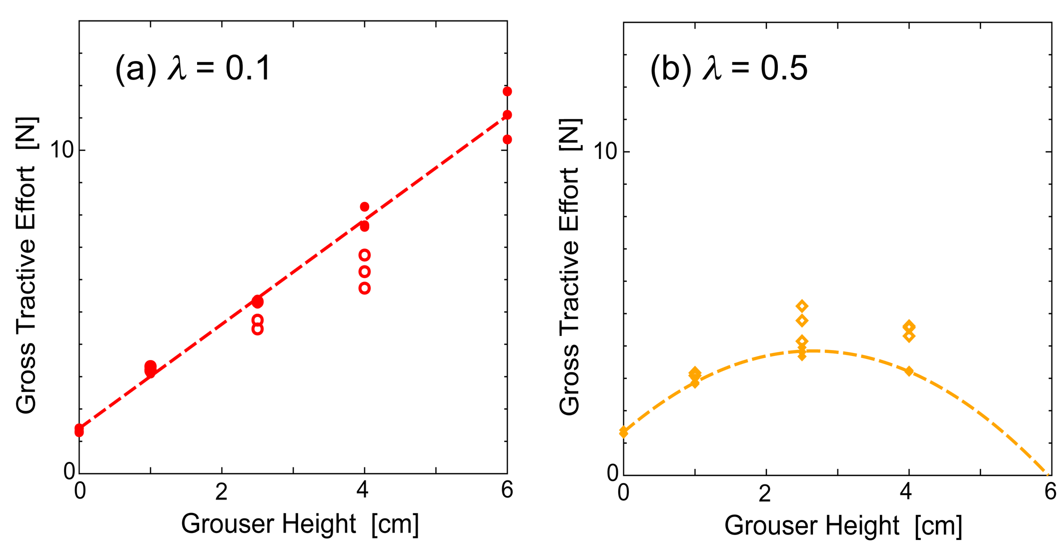

Figure 6. DEM result of gross tractive effort.

Concluding Remarks

- Two-dimensional DEM results confirmed larger gross traction for smaller thickness ratio of 0.1, which was observed in the 2D experimental results using artificial model soil.
- The effect of grouser height on gross tractive effort in case of λ = 0.1 should intensively be investigated in terms of the coefficient of rolling friction as well as the coefficient of friction between model soil elements to increase the accuracy of 2D DEM simulation of soil-grouser system.