

STUDYING ON FAILURE MECHANISM OF 2D GRANULAR COLUMNS: NUMERICAL RESULTS

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Abstract. The destruction of particle columns is more common in industry and in natural processes. Therefore, it is necessary to understand the mechanism and its destructive characteristics. Almost previous researchs on destruction mechanism and destructive flow of 2D particle column are, normally, not truly 2D experiments because: (1) the materials used in these experiments are not 2D; and (2) the experiments are performed in 3D then using the symmetry characteristic to extract the cross-sections. In this study, a series of numerical experiments which are difficult or impossible to obtain by physical experiments have been done by the numerical model using SPH (Smooth Particles Hydrodynamics). The numerical calculation results have been checked by physical test results and show a good fit. Numerical calculations showed the characteristics of the 2D particle column destruction process in detail. Moreover, the results of the calculations with the change of material properties have shown the regularity of the destruction. This is the basis for the search experience functions of the law of destruction of the particle column under the influence of gravity.

Keywords: granular flow, 2D Granular Column, failure mechanism, numerical experiment, characteristics of flow.

Classification numbers: 2.5.1, 3.4.3, 5.4.1.

1. INTRODUCTION

There have been many studies on destruction mechanism of 2D granular columns as Balmforth *et al.* [1], Lube *et al.* [2, 3], Lajeusses *et al.* [4, 5] and Trepanier *et al.* [6], Bui [7], ... but most of the authors have used not 2D granular materials as grit, fine glass, coarse glass and polystyrene, fine quartz, coarse quartz sand, sugar, and rice, glass beads, etc. Trepanier *et al.* used granular rods as granular materials to conduct 3D granular flow experiments and Tran took the result at the symmetric section through the center as a 2D numerical model results. Only Bui [7] and Nguyen *et al.* [8, 9, 10] used truly 2D materials and conducted 2D standard experiments.

Nguyen *et al.* [9] showed that there are differences between his results with those of previous authors.

In this research, we used numerical computational program developed by Nguyen *et al.* [10] based on solving the system of soil mechanics equations using Smoothed Particle Hydrodynamics Method (SPH) to perform a series of numerical experiments in destruction mechanism of 2D granular columns. The numerical experiments simulation is less cost and time consumable than physical experiment model (in the laboratory). Moreover, they can obtain accurate results in some cases that are difficult or impossible. The results will be used to consider experimental functions more comprehensively about the failure flow characteristics of 2D granular columns based on a series of physical experiment model by Nguyen *et al.* [8, 9].

2. MATERIALS AND MODEL FOR EXPERIMENTS

2.1. Model of experiment

2.1.1 Setup for model of experiment

To study the failure characteristics of 2D granular columns, the experimental model is shown in Figure 1. The left side of Figure 1 is the full design of the experimental model. However, owing to the symmetric properties, Laboratory experiments are carried out according to the model shown in right side of Figure 1.

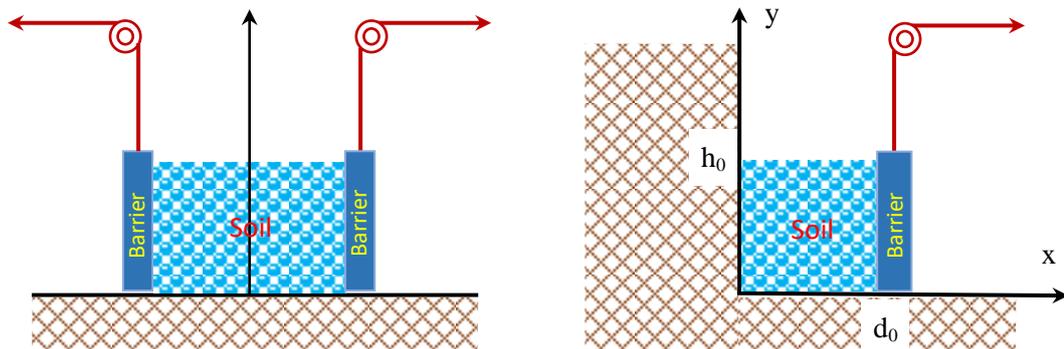


Figure 1. Model of experiment.

A series of physical experiment model (in the laboratory), barrier is used to keep stable granular column during the experimental model setup stage. Barrier will be removed appropriately [9] to minimize the influence on granular columns collapse process. The numerical experiments which don't have barrier, the initial setup for the granular column with initial column height h_0 and initial granular column width d_0 in Figure 1.

2.1.2 Soil model

The soil model used in these experiments is 2D soil model performed in physical experiments by Nguyen *et al.* [9]. The results have been summarized in Table 1.

Table 1. Properties of soil.

Name	Value	Unit
Density (ρ)	2074	(kg/m^3)
Friction angle (ϕ)	21.9	(deg)
Young's module (E)	5.84	(Mpa)
Poisson's ratio (ν)	0.3	
Dilatant angle (ψ)	0	(deg)
Cohesion (c)	0	(kPa)

2.2. Validation of developed numerical modeling

In this paper, the numerical experiments have been conducted by numerical computational model developed before [10]. The model has been adjusted and verified by Nguyen *et al.* [10]. The calculation results of the model are quiet consistent with the experimental results [9]. To test this model against, we compared our calculation results with the experimental results in the destruction process of granular column with two cases having different initial size:

- Case 1: $h_0 = 10$ and $d_0 = 10$ ($a = h_0/d_0 > 0.65$)
- Case 2: $h_0 = 10$ and $d_0 = 20$ ($a = h_0/d_0 < 0.65$)

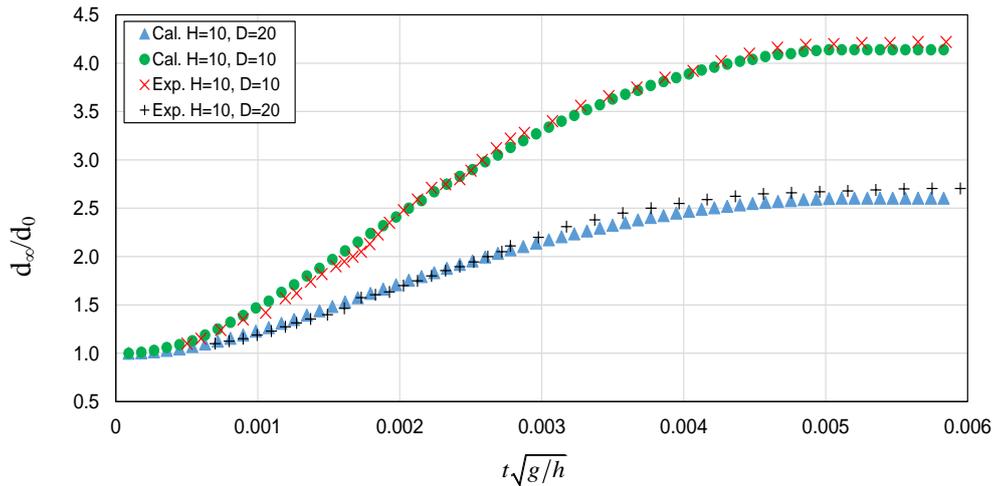


Figure 2. Testing result of numerical computation model.

The result being in Figure 2 shows that the numerical computation model in this research has been developed and used with high reliability.

3. NUMERICAL SIMULATION

3.1. Simulation scenarios

The research group conducted 221 calculation scenarios at different initial column heights h_0 (25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300). For each of the initial heights h_0 , the following granular column widths d_0 to ensure that their ratio $a = h_0/d_0$ varies each value of height h_0 .

- The height of granular column after the collapsing process h_∞ ,
- The maximum final run-out distance of granular flow d_∞ ,
- The width of range is not collapsed during failure process d_a .

The obtained results are synthesized and analyzed based on factors and shown in Figure 3, Figure 4 and Figure 5.

3.2. Result and discussion

221 calculation scenarios were conducted in total and some of them was verified by physical experiment model in the laboratory then compared with experimental functions shown on the basis of a series of experimental data by Nguyen *et al.* [9].

With the same properties of materials, the results of numerical calculations have shown a consistent with the experimental functions found from a limited number of physical experiments. As shown below:

- There are two failure mechanisms observed as shown by Nguyen *et al.* [9] with a as the ratio between the initial height and the initial width ($a = h_0 / d_0$): $a > 0.65$ or $a \leq 0.65$.
- In contrast, for $a > 0.65$, the relationships between the coefficient a and the ratios $(d_\infty - d_0)/d_0$, h_0/h_∞ and d_∞/d_0 were exponential in form and changes at $a = 1.5$, as shown in equations from 1 to 3 below:

$$\frac{d_\infty - d_0}{d_0} \approx \begin{cases} 3.25a^{0.96} & a < 1.5 \\ 3.80a^{0.73} & a > 1.5 \end{cases} \quad (1)$$

$$\frac{h_0}{h_\infty} \approx \begin{cases} 1.41a^{0.69} & a < 1.5 \\ 1.47a^{0.64} & a > 1.5 \end{cases} \quad (2)$$

$$\frac{d_\infty}{d_0} \approx \begin{cases} 4.27a^{0.73} & a < 1.5 \\ 4.66a^{0.65} & a > 1.5 \end{cases} \quad (3)$$

where: h_0 and d_0 are initial height and initial width; h_∞ and d_∞ are final height and maximum run-out distance.

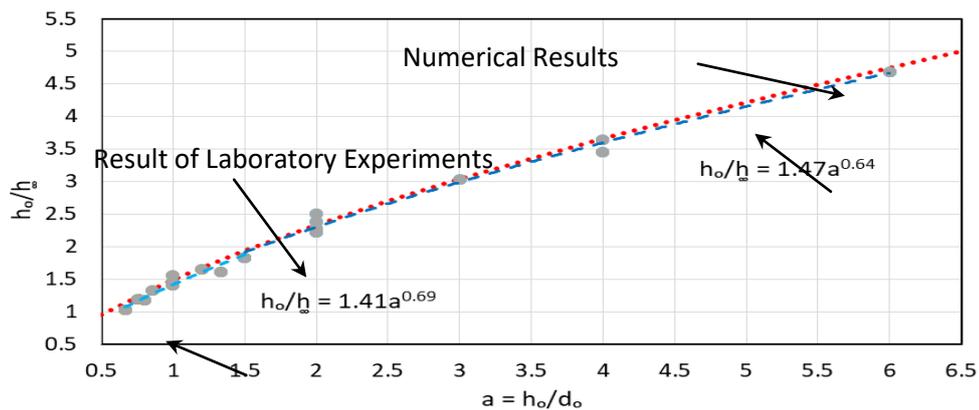


Figure 3. Relation between the coefficient h_0/h_∞ and the coefficient a compiled from the numerical results.

In Figures from 3 to 5 shown with $a < 1.5$ there are many results from physical experiment, but $a > 1.5$ the number of physical experiments is very seldom because they are difficult or impossible. Accordingly, in this paper, we will focus on using numerical experiment results to verify again experimental functions with $a > 1.5$ by Nguyen *et al.* [9].

From the figures, we can realize that the results of numerical experiment with $a > 1.5$ are a series of values creating a smooth curve between laboratory experiments' values. These results are quiet consistent with the values of experimental functions as $h_0/h_\infty = 1.47a^{0.64}$ in Figure 3, $d_\infty/d_0 = 4.66a^{0.65}$ in Figure 4 và $(d_\infty - d_0)/d_0 = 3.80a^{0.73}$ in Figure 5.

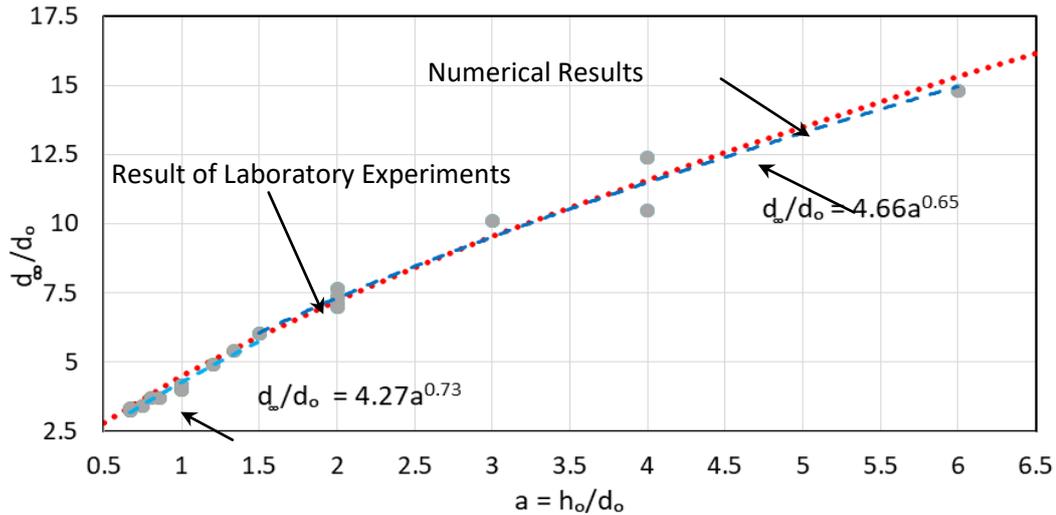


Figure 4. Relation between the coefficient $(d_\infty - d_0)/d_0$ and the coefficient a compiled from the numerical results.

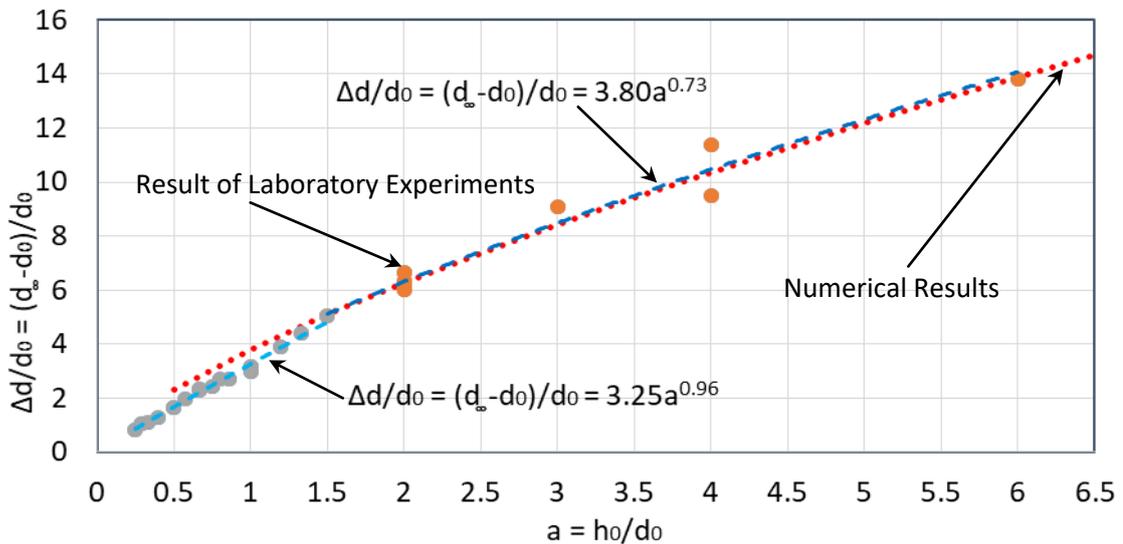


Figure 5. Relation between the coefficient d_∞/d_0 and the coefficient a compiled from the numerical results.

3.3. Change the properties of material

In this study, to better understand the destruction mechanism of 2D particle column. We have calculated many scenarios with different properties of materials. The results of numerical calculations show that when changing a property of a material, some characteristics of destruction [9] also change but still have a clear rule. Previous studies on the demolition characteristics of 2D granular columns by both physical experiment model [2,4,7,11,13,14] and numerical calculation [1,3,5,6,12,15,16] have not considered the change of material properties.

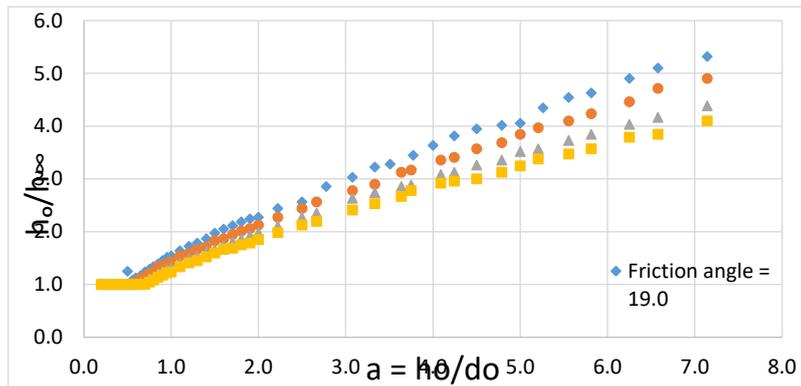


Figure 6. The calculation results of soil model with different internal friction angles.

Figure 6 showed the calculation results of granular materials have different internal friction angles. These results seem to have a rule indicates a certain relationship between the parameters.

4. CONCLUSIONS

The results of numerical calculation show a good agree with the results of physical experiment. This confirms the credibility of the developed numerical model. The results of numerical calculation are also quite consistent with the experimental functions. This shows the range of use of the empirical functions shown previously by us can be applied in a wider range.

Moreover, when the properties of material change, the numerical results in this study also show that some characteristics of the destruction process of 2D granular columns still follow a certain rule. This is the basis for putting the research results into practical applications.

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