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

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ABSTRACT

The failure mechanism of granular columns and the characteristics of this failure flows have been intersted in researching in recent years. In particular, the experiments in failure mechanism and failure flow of 2D granular column are not often 2D standard. Therefore, Cuong T. Nguyen et al. (2015) conducted research this problem based on 2D standard in the laboratory and developed a numerical computation model using SPH (Smooth Particles Hydrodynamics) method (Cuong T. Nguyen et al., 2017). This model has proven the reliability by verification of calculation and experimental results. In this paper, the developed numerical model is used to perform a series of numerical experiments that some are difficult or impossible to obtain accurate results by physical experiment model to re-examine the previously identified characteristics and find out the rules more general of this failure flow.

Keywords: Granular Flow, 2D Granular Column, Failure Mechanism, Numerical Experiment, Characteristics of Flow

1. INTRODUCTION

The failure mechanism of 2D granular columns have been researched for many years such as Balmforth et al. (2005), Lube et al. (2004,2005), Lajeusses et al. (2004.2005) and Trepanier et al. (2010), Bui H. H. (2007), … but most of the authors have used granular materials, not 2D materials as Grit, Fine glass, Coarse glass and Polystyrene, Fine quartz, Coarse quartz sand, Suga and Rice, glass beads, … Trepanier et al. (2010) used granular rods as granular materials to conduct 3D granular flow experiments and extract from cross sections and regard them as 2D numerical model results. Only Bui H.H. (2007) and Cuong T. Nguyen et al. (2013, 2015, 2017) can use 2D materials and conduct 2D standard experiments. The research results of Cuong T. Nguyen et al. (2015) with truly 2D have shown that there are differences than previous authors using 3D materials or conducting experiments are not truly 2D.

In this research, we used numerical computation program developed by Cuong T. Nguyen et al. (2017) based on solving the system of soil mechanics equations using Smoothed Particle Hydrodynamics Method (SPH) to perform a series of numerical experiments in failure mechanism of 2D granular columns. The numerical experiments simulation is less cost and time 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 Cuong T. Nguyen et al. (2015).

2. MATERIALS AND MODEL FOR EXPERIMENTS

2.1 Model of experiment

2.1.1 Setup for model of experiment

To research 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, the real experiment is setup the same model in right side of Figure 1.

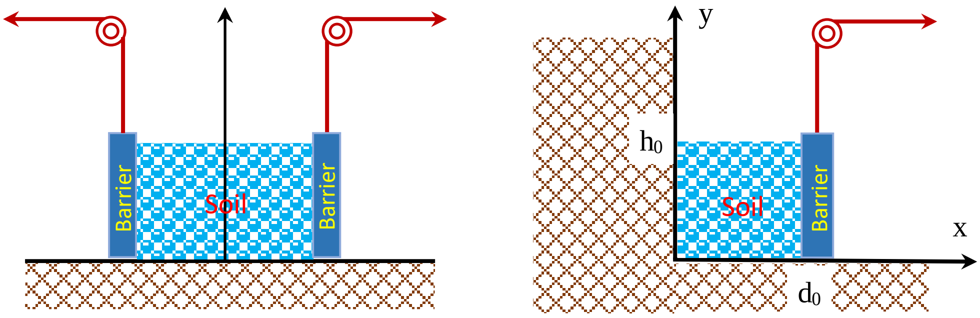

Figure 1. Experiment model

A series of physical experiment model (in the laboratory), barrier is used to keep stable granular column during the experimental model setup stage. Barrier wil be removed appropriately (Cuong T. Nguyen et al., 2017) 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 Cuong T. Nguyen et al. (2015). The results have been summarized inTable 1.

Table 1. Properties of soil

Name	Value	Unit
Density (ρ)	2074	(Kg/m3)
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 Numerical modeling

In this paper, the numerical experiments have been conducted by numerical computation model and developed before (Cuong T. Nguyen et al., 2017). This model use the mesh-free method Smoothed Particle Hydrodynamics (SPH) to solve the equations of soil mechanics. The Drucker-Prager is soil model used in this study.

The model has been adjusted and verified by Cuong T. Nguyen et al., (2017). The calculation results of the model are quiet consistent with the experimental results. To test this model against, we compared the calculation results with the experimental results in the failure 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 ($a = h_0/d_0 < 0.65$)

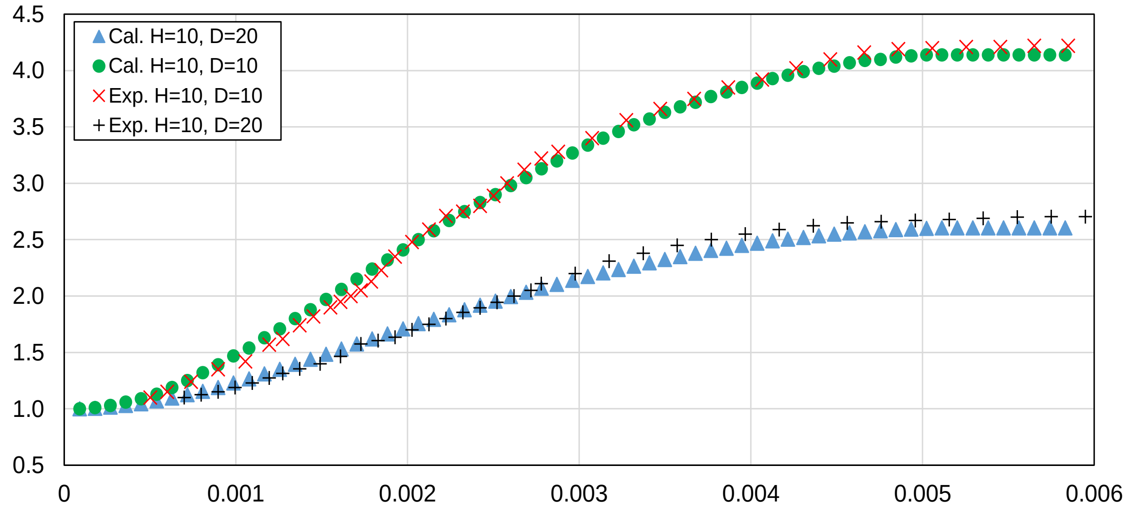

Figure 2. Testing result of numerical computation model

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

3. RESULTS AND DISCUSSION

3.1. Conduct experiments

The research group conducted 221 experiments 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 maxium 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, analyzed based on factors and shown in Figure 3, Figure 4 và Figure 5.

3.2. Discussion on the results

221 numerical experiments were conducted in total and each of the experimental result was verified by physical experiment model in the laboratory then compare with experimental functions shown on the basis of a series of experimental data by Cuong T. Nguyen et al. (2015).

The numerical experiment results are used and checked again experimental formulas that our research group shown before and found them appropriately. As shown below:

- There are two failure mechanisms observed as shown by Cuong T. Nguyen et al. (2015) with ratio $a = h_0/d_0$: $a > 0.65$ or $a < 0.65$.
- 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:

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

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

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

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 Cuong T. Nguyen et al. (2015).

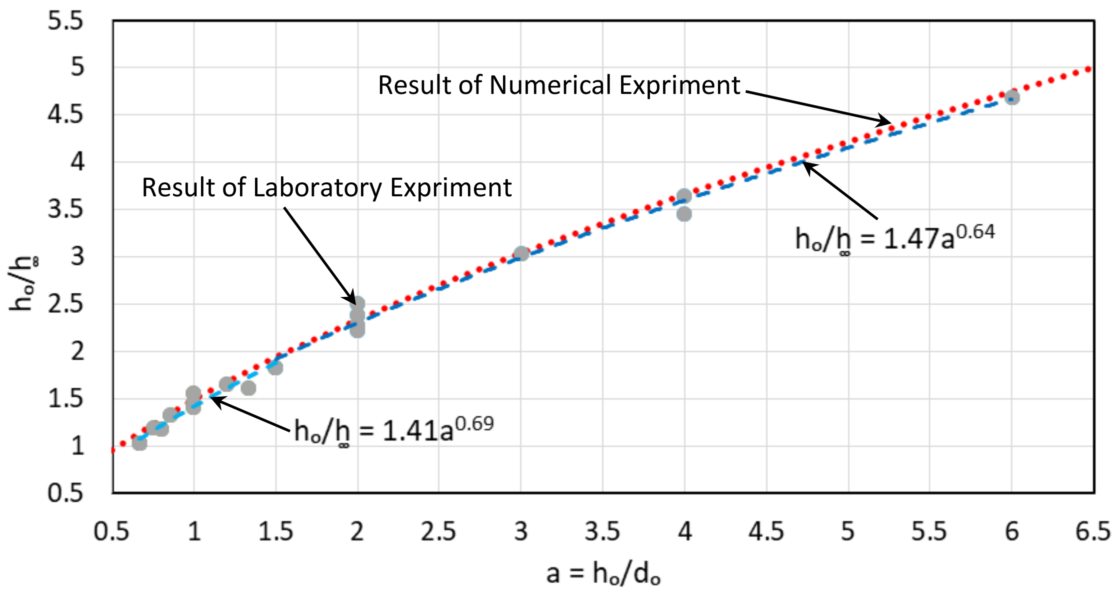

Figure 3. Relation between the coefficient h_0/h_∞ and the coefficient a compiled from the experiment results

From the figures, we can realized that the results of numerical experiment with a > 1.5 is a series of values creates 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 Fugure 5.

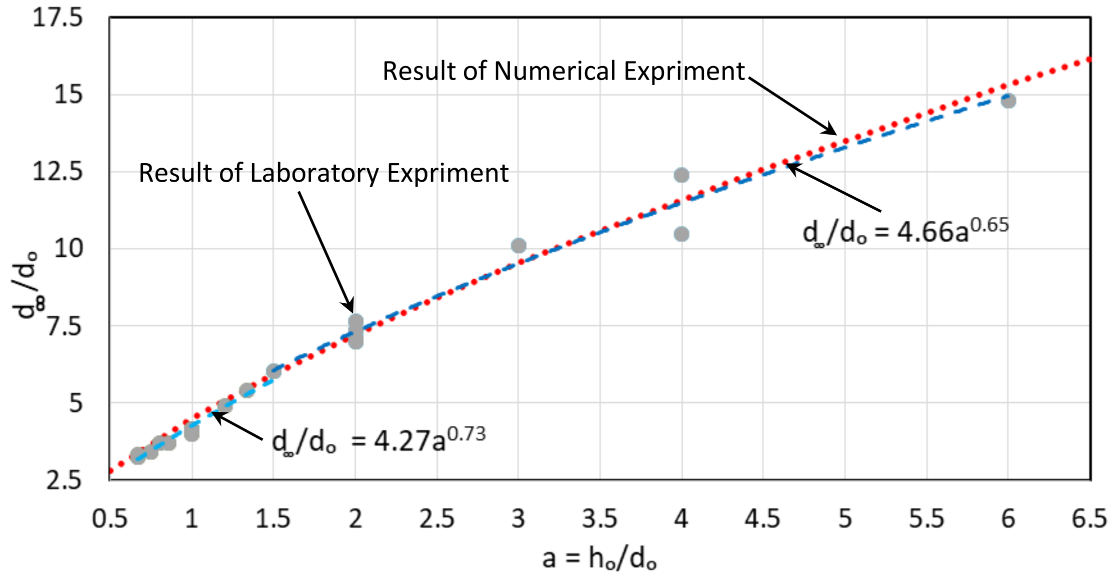

Figure 4. Relation between the coefficient $(d_\infty - d_0)/d_0$ and the coefficient a compiled from the experiment results

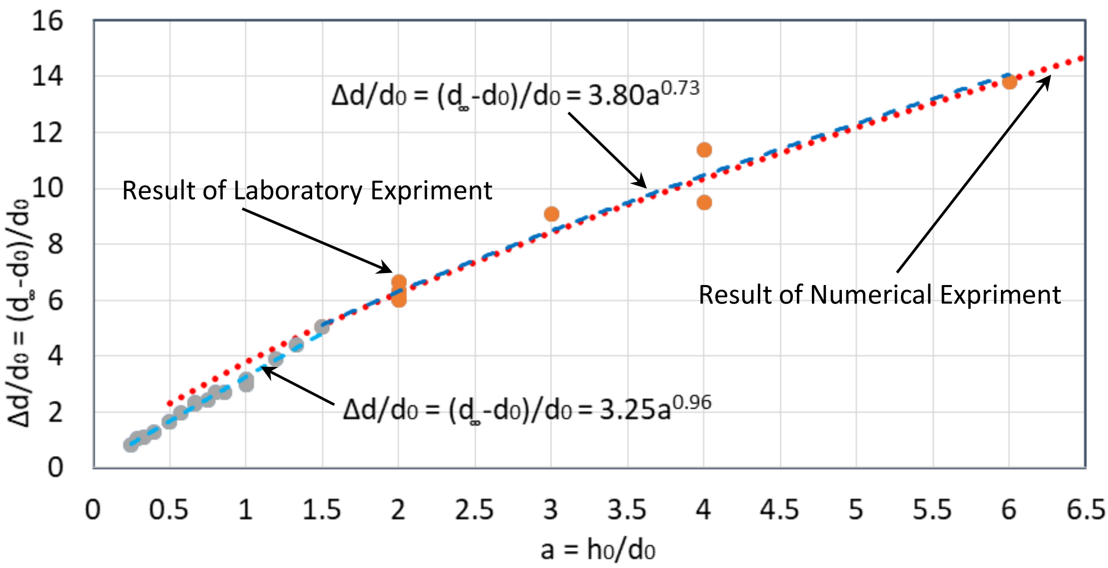

Figure 5. Relation between the coefficient d_∞/d_0 and the coefficient a compiled from the experimental results

3.3. Future work

Based on the achieved results in this study, the research group continue to study different materials and find out general experimental functions for soil model. These results will be really useful for the application results series of researches in the near future.

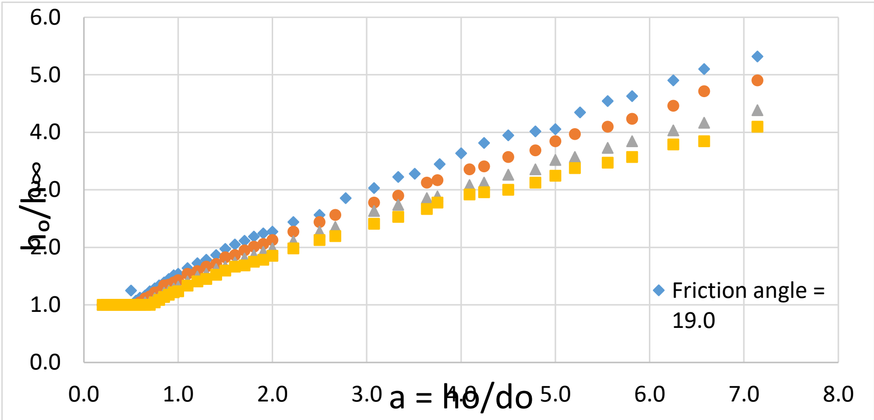

Figure 6. The calculation results of soil model with different internal friction angles

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

This research has confirmed more of the reliability we have previously found (Cuong T. Nguyen et al., 2015) on the failure characteristics of 2D granular columns based on the analysis of obtained results from experiments with more numbers and spread evenly at different initial values of granular column. The results of the numerical experiment series showed that the characteristic function of 2D granular columns failure mechanism found previously by (Cuong T. Nguyen et al., 2015) in both physical experiment models and nonphysical experiment models (some are difficult or impossible). Thus, the characteristics of flow we have shown (Cuong T. Nguyen et al., 2015) are suitable for all different initial parameters of 2D granular columns.

Finally, our paper is also a premise for futher research to determine the failure characteristics of 2D granular columns having different material properties. This is the basis for putting the research results into practical applications.

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