第 III 部門

Influence of dropping height on the angle of repose of gravitating loose sand on an arbitrary plane

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1. Introduction

If sand is continuously and slowly added onto an arbitrary base, it will reach a steady state where the additional sand on the pile will fall off. Granular materials such as sand forms a pile on the base, and it has slopes bounded by the angle of repose. In this situation, the surface of the sandpile does not change and the angle of the sandpile is constant. The purpose of this study is to observe the shape of the sandpile which is formed on the base with various shapes [2]. In addition, the height from which the sand is dropped is changed to observe whether the formation of the sandpile is influenced by the dropping height [1, 4] . The angle of repose is measured to study the differences between each case in the experiment.

2. Apparatus and Methodology

As preliminary tests, the sand deposition methods and the types of sand were investigated to find which methodology is suitable for the experiment. Two types of sand, Silica sand No.6 and Silica sand No.8 were used for comparison. Regarding the deposition methods, the surfaces of the sandpile built by a funnel and a sieve were compared. The funnel had the sweep rate of 10 cm/s and the flow rates for Silica sand No.6 and No.8 were 1.62 kg/s and 1.54 kg/s, respectively. The sieve was set at 109.1 mm above the upper surface of the acrylic plate. Silica sand No.6 has friction angle of $\phi = 33.2°$, the minimum and maximum dry densities are ρ_{dmin} = 1.241g/cm^3, ρ_{dmax}=1.556 g/cm^3 while Silica sand No.8 has $\phi = 35.0°$, ρ_{dmin}= 1.153 g/cm^3 and ρ_{dmax}=1.554 g/cm^3 [3]. As a result, the surface of the sandpile was smoother when the sieve for the dropping methodology and Silica sand No.6 were used. Therefore, Silica sand No.6 with the sieve method was chosen for the further experiment.

Eight different shapes of acrylic plates were put on the table to pour the sand on. Various shapes of the acrylic plates were used to search whether there is any difference between the angle of repose measured at different positions on the complex shaped base. Basically, the acrylic plates were placed directly on the table, but when the acrylic plate was too small, the size of table was reduced by using a piece of wood. When a steady state was reached, the angle of repose was measured by a digital protractor. For each acrylic plate, we set several fixed points to measure the angle of repose. After the measurement of angle of repose, the dropping height of the sand was changed by moving the stepladder. The dropping height for higher cases was 342 mm measured from the upper surface of the acrylic plate to the sieve. Since we narrowed the stepladder and placed the sieve on the different step for lower cases, the dropping height for lower cases are slightly different, e.g. 116, 117, 115, 111, 118, 121 and 118 mm for Cases 1 to 8, respectively.

3. Results

According to the angle measurement at different positions of curvature of the plane in Case 4, the angle of repose at concave was larger than that at convex. The lateral pressure at convex might cause larger angles of repose.

The relationship between the average angle of repose and the dropping height is shown in Figure 1. We obtained larger angles of repose for a lower dropping height in all cases except for Case 6. It is considered that when the dropping height is high, the potential energy of the particles is larger, causing the destruction of the surface which had already formed. We can see that the angle of repose was closer to the friction angle when a dropping height is lower in all cases except for Case 6 and 8. The standard deviation of the angle of repose was obtained in each case, and the relationship with the dropping height was shown in Figure 2. Comparing the standard deviation from the two different heights, the standard deviation was smaller in lower dropping heights except Case 6.

4. Discussion and Conclusion

In this study, the experiment was conducted to observe the shape of the sandpile and the angle of repose. The angle of repose measured from the experiment was used to investigate the relationship with the dropping heights. For the dropping height, the angle of repose was basically larger in cases with a lower dropping height. This result can be observed from the shape of the sandpile, whose slope is steep at a lower dropping height and gentle at a higher dropping height. In addition, the relationship between the angle of repose and friction angle was investigated, and the angle of repose was closer to friction angle with a higher dropping height in most cases.

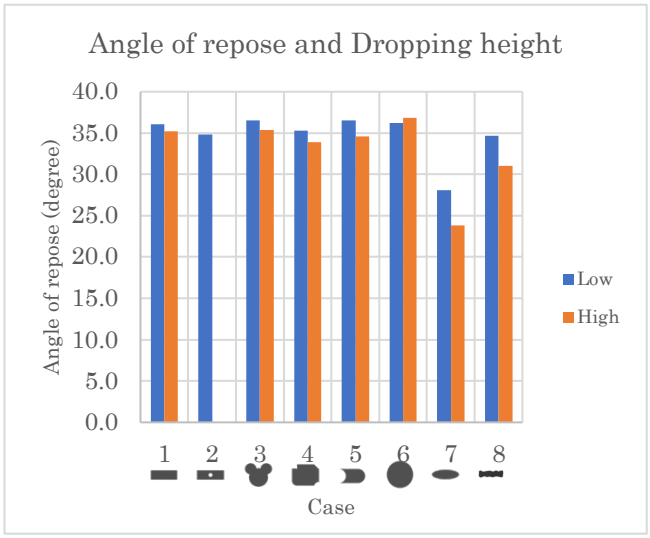

Figure 1: Average angle of repose for each case under two different dropping heights

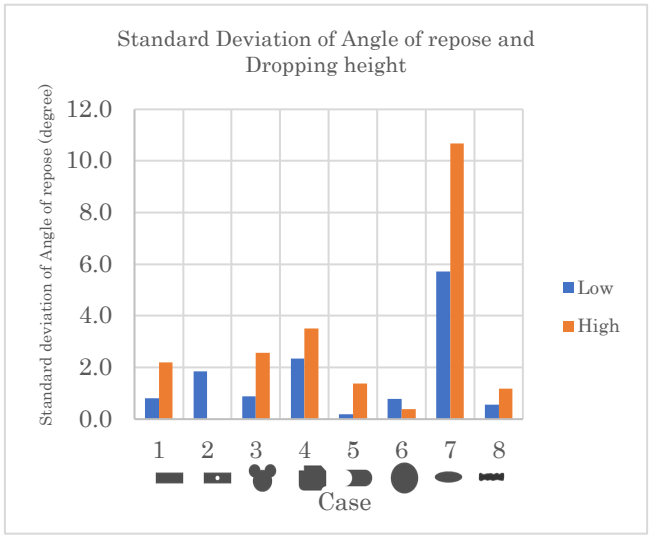

Figure 2: Standard deviation of angle of repose for each case under different dropping heights

7. References

[1] Pauli, N. S., Gioian, G. (2007). The topography of steady sandpiles on arbitrary domains. Proc. R. Soc. A (2007) 463, 1247–1258.

[2] Khosravi, M.H., Pipatpongsa, T., Takemura, J. (2013) Experimental Analysis of Earth Pressure against Rigid Retaining Walls under Translation Mode. Géotechnique 63.12, 1020-028.

[3] Fang, K. (2019) Progression and onset of undercut slope failure observed by surface velocity in physical models subjected to arch action, Department of Urban Management, Kyoto University, Doctor thesis, 2019

[4] Pipatpongsa, T., Heng, S., Iizuka, A., Ohta, H. (2010). Statics of loose triangular embankment under Nadai's sand hill analogy. Journal of the Mechanics and Physics of Solids 58 (2010) 1506–1523.

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