# Study on Collapsed Soil Movement by Flume Experiments and Application of Distinct Element Method Corresponding to Fluidized Conditions

Yoshiiku Musashi[1], Takahisa Mizuyama[2], Miho Yamasaki[3]

## 1. INTRODUCTION

The investigation on actual disastrous slope failure showed that the collapsed soil mass was not completely fluidized and partly keeping original shape in many cases.

In most of the past studies on the movement of collapsed soil, completely fluidized soil was subjected to clarify process of enlarging travel distance and forecast disastrous area. However, it is also necessary to discuss movement of collapsed soil stopping before fluidizing, and design efficient countermeasure adapted to individual conditions of collapsed soil movement.

In order to discuss fluidized condition of collapsed soil, flume experiments were conducted in this study, changing flume gradient and water content of the soil. Numerical simulation of the experiment results were also conducted by using two-dimensional Distinct Element Method (DEM), and methods of applying the DEM to several fluidized conditions were discussed.

## 2. FLUME EXPERIMENTS ON FLUIDIZED CONDITION OF COLLAPSED SOIL

Experiments were conducted on the specimen soil flowing down from the box settled at the upside end of the flume with different gradient (35°, 40°, 45°) and different water content (dry, partially saturated with about 35% water of total weight, fully saturated). Dry and partially saturated soil were settled with its surface parallel to flume bed, however, fully saturated soil was settled with its surface horizontal because of liquid condition of the soil in the box.

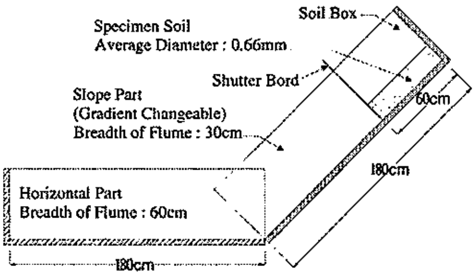


**Fig.1** Experimental Equipment

3 types of fluidized condition were observed in the experiments as shown in Fig.2 and Table 1. Dry soil was fluidized completely. And the cases using the flume with 45° gradient resulted in all of the soil moved, while the soils were partially left in the box keeping the original shape in the cases of 35° and 40° with the partially saturated and fully saturated soil. Volume of the soil keeping the original shape was largest in the cases of partially saturated soil. Therefore, collapsed soil tends to be fluidized on the steeper slope, and not to be fluidized under the partially saturated condition.

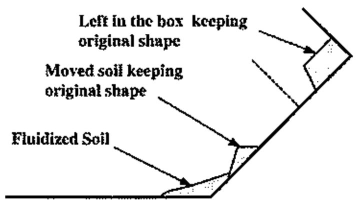


**Fig.2** Types of Fluidized Condition

**Table 1** Fluidized Condition Observed in Experiments

| Flume Gradient | Water Content Condition | Fluidized Soil | Moved Soil Keeping Shape | Left in the Box |
|---|---|---|---|---|
| 35° | Dry | 100% | None | None |
| | Partially saturated | 5% | 2% | 93% |
| | Fully saturated | 32% | 68% | None |
| 40° | Dry | 100% | None | None |
| | Partially saturated | 7% | 16% | 77% |
| | Fully saturated | 39% | 23% | 38% |
| 45° | Dry | 100% | None | None |
| | Partially saturated | 100% | None | None |
| | Fully saturated | 25% | 75% | None |

[1] Yachiyo Engineering Co., Ltd. Water Resources Department, Tokyo, 161-8575, Japan (phone: +81-(0)3-5906 -0771, fax:+81-(0)3-5906-0809, e-mail:musashi@yachiyo-eng.co.jp)

[2] Kyoto University, Division of Forest &Biomass Science, Graduate School of Agricultural Science, Kyoto, 606 -8502 (phone:+81-(0)75-753-6091, fax: +81-(0)75-753-6088, e-mail:mizuyama@kais.kyoto-u.ac.jp)

[3] Kyoto University, Division of Forest &Biomass Science, Graduate School of Agricultural Science Kyoto, 606 -8502 (phone:+81-(0)75-753-6091, fax: +81-(0)75-753-6088, e-mail:myama@kais.kyoto-u.ac.jp)

## 3. NUMERICAL SIMULATION CORRESPONDING TO FLUIDIZED CONDITION

Numerical simulation of the experiment was conducted by using two-dimensional DEM model.

Fig.3 shows experiment and calculation result of shape change using dry soil on the slope gradient of 45°. As the first step, simulation of the dry soil movement using elements of single circular particles resulted in excess traveling reach and flat deposition because of too small rolling friction. Then, the model was added with rolling friction by mixing element of rigidly combined particles. After that the simulation came to be fit for the experimental results.

Fig.4 shows experiment and calculation result of shape change using saturated soil on the slope gradient of 45°. General DEM model which transmits force through rebounding spring and viscous dashpot between the elements cannot express phenomena of incompletely fluidized soil partly keeping the original shape observed on the experiment. The original shape of soil could be kept by the adhesion of soil particles. Then, Extended DEM (EDEM) model, which was introduced pore-spring that transmits tensile force between elements in addition to rebounding spring (Fig.5), was applied and can explain the movement keeping the original shape.

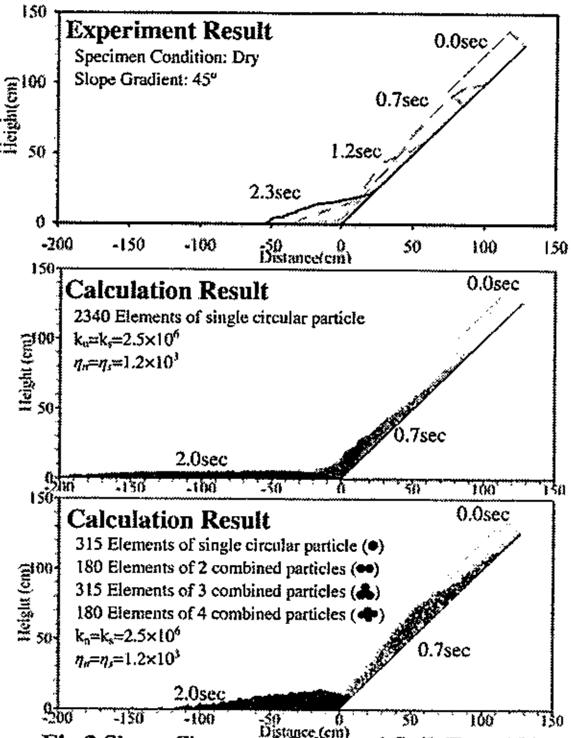

**Fig.3** Shape Change of Collapsed Soil (Dry, 45°)

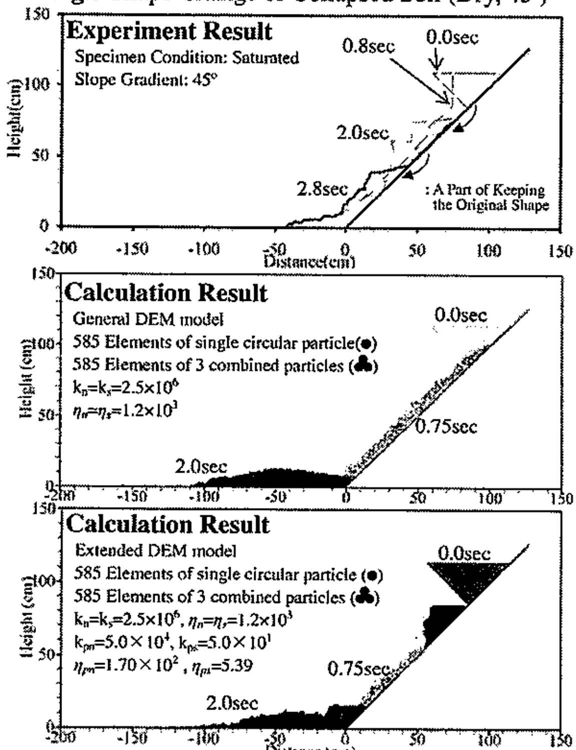

**Fig.4** Shape Change of Collapsed Soil (Saturated, 45°)

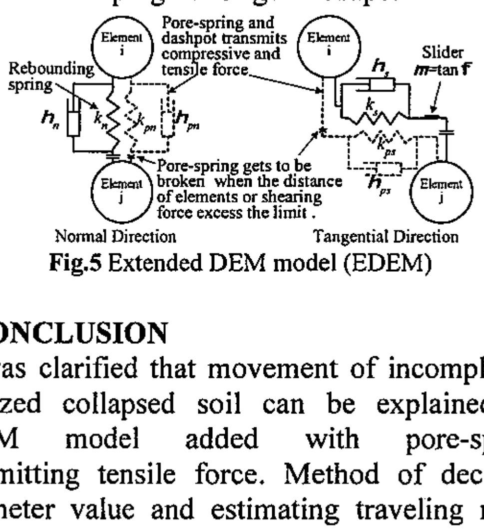

**Fig.5** Extended DEM model (EDEM)

## 4. CONCLUSION

It was clarified that movement of incompletely fluidized collapsed soil can be explained by EDEM model added with pore-spring transmitting tensile force. Method of deciding parameter value and estimating traveling reach and impact force corresponding to fluidized condition should be studied hereafter.

**KEY WORDS: landslide, slope failure, fluidization, collapsed soil movement, Distinct Element Method**

## REFERENCES

Musashi, Y., Mizuyama, T. (2009): Investigation on collapsed soil movement in disastrous slope failures, Journal of the Japan society of Erosion Control Engineering, Vol. 61, No.5, pp.31-36., Hakuno, M. (1993): Simulations of landslides, rock avalanches and debris flows by the extended distinct element method, Proceeding of the 25th Congress of IAHR, B, pp. 13-24