FAILURE PREDICTION MODEL OF A RUBBLE MOUND WEIR USING DISTINCT ELEMENT METHOD

SHIRO MAENO[1], KOHJI MICHIOKU[2] and EITO KASE[3]

[1] Associate Professor, Department of Environmental and Civil Engineering, Okayama University, 3-1-1 Tsushima-Naka, Okayama 700-8530, Japan.
(Tel: +086-251-8151, Fax: +086-251-8151, e-mail: maeno@cc.okayama-u.ac.jp)
[2] Professor, Department of Civil Engineering, Kobe University,
1-1 Rokkodai, Nada, Kobe 657-8501, Japan
(Tel: +078-803-6056, Fax: +078-803-6069, e-mail: michioku@kobe-u.ac.jp)
[3] Graduate student, Department of Environmental and Civil Engineering, Okayama University, 3-1-1 Tsushima-Naka, Okayama 700-8530, Japan.

Nature-friendly hydraulic structures such as a rubble mound weir have attracted attention in recent years. Therefore, it is important to establish a numerical model to predict a possible failure process. In this research the distinct element method, which is used for modeling the aggregate of discontinuous elements, is applied to model a failure process of the rubble mound weir.

To compare with the experimental results of author's former research work, the numerical model of the rubble mound weir as shown in Fig. 1, was applied. The scale of the model is about 1 to 10. Hydrodynamic forces acting on the rubble of the weir, such as: a drag force and a seepage force are required for the DEM calculation which was obtained by the flow analysis using VOF technique (see Fig. 2). Pressure gradient at the center of gravity of the particle is was used to calculate seepage forces which are obtained by multiplying pressure gradient by the volume of the particle.

Collapse of the rubble mound did not occur in Case1a, which agrees with the experimental result. Fig 3 shows the movement of particles in Case 1b. At first, the particles at the central part of the downstream slope move out from the mound. After that, the particles roll down along the slope and deposit around the downstream edge of the weir (0.1s - 0.4s).

The tendency of the movement of these particles clearly describes the initial failure process of the rubble mound weir (Maeno et. al. 2002).

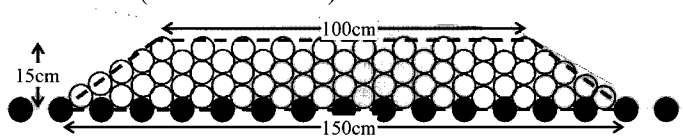

Fig. 1 Weir model

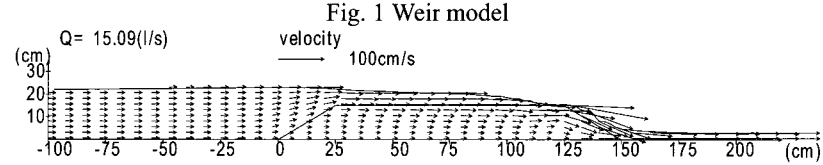

Fig. 2 Numerically obtained velocity distribution

Although the numerical results show that the area from where the first particle moved, another particle from the upper part falls into the vacated part, the experimental results show not all particles of the upper part fall down, due to the engagement between particles. The movement of particles ended in six seconds. The same tendency of the particles' movements was seen in Case 2.

In this study, the initial failure process of a rubble mound weir was studied using DEM in which the hydrodynamic force acting on the particles is obtained by porous flow analysis using VOF method. Obtained main results are as follows:

1) The numerical model using the DEM, in which the drag and seepage force are used as an enhancing factor to move the particle, can reproduce the initial failure process of the rubble mound weir.

2) Seepage force has a large effect on the movement of the particles from the down stream slope.

3) Effect of initial packing state creates the difference in the inter-particle contact angle, is an important factor on the failure process of the rubble mound weir.

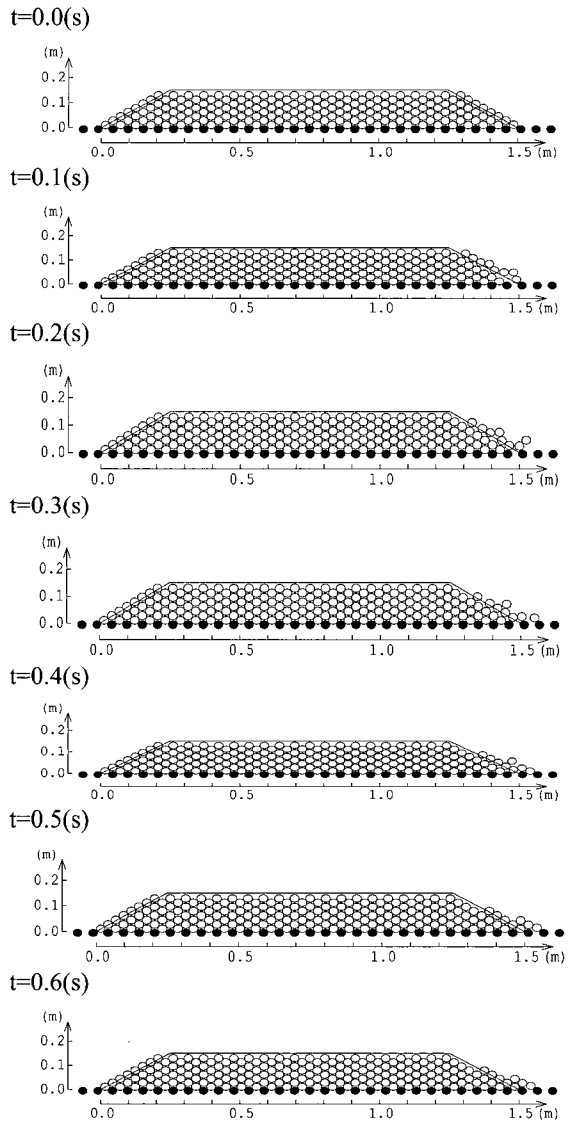

Fig 10 Failure process (Case 1b)

REFERENCES

Maeno, S., Michioku, K., Morinaga, S., & Ohnishi, T. 2002. Hydraulic characteristics of a rubble mound weir and its failure process, proc. of 5th ICHE Conference, Theme D.(CD-ROM)