Load Evaluation of Debris Flow Agaisnt Steel Open Sabo Dam Using DEM

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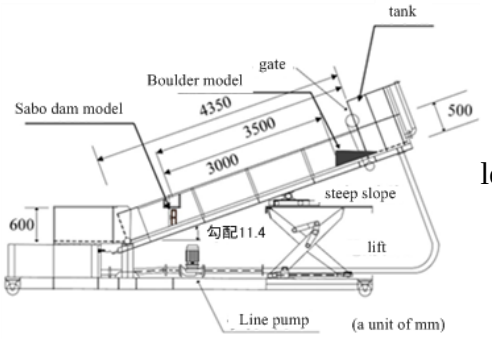
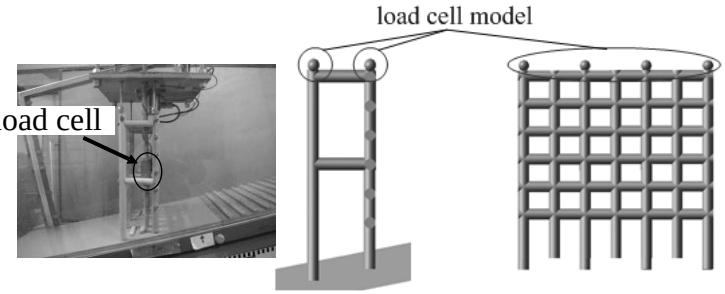
INTRODUCTION

When the debris flow attacks on a steel open Sabo dam, then the huge impact load occurs between boulders and the steel pipes. Therefore, it is very significant to evaluate the debris flow load of steel open Sabo dam from the design point of view. This paper presents experimental and computational approaches on debris flow load acting on the steel open Sabo dam. First, the debris flow experiment is carried out by using 1/40 scale flow channel, and the debris flow load is measured by using load cell. Second, the distinct element method (so-called DEM) is used to simulate the debris flow load of the model test. The computational results indicated good reproducibility of the test ones. The proposed debris flow load analysis will be useful for the safety assessment of steel open Sabo dam.



(a) Testing Flume



(b) Dam model

Fig. 1 Load measurement test

Fig. 2 Analytical dam model

LOAD MEASUREMENT TEST

Figure 1(a) shows the experimental model set-up with variable channel slope (θ), a length of 4.35 m, width of 0.3 m and height of 0.5 m. Water flow is made by using a line pump and a cistern. The flume inclination (channel slope) was fixed at θ=11.4 °. The initial position of water is 3.5 m far from the dam model. The potentiometer is set at the top of the steel open Sabo dam model to measure the impact load of debris flow. The diameters of grains are 30-40 mm (2.6 in the specific gravity) and the debris flow is made by rushing water in the boulder models.The steel open dam model with height of 260 mm, width of 270 mm and depth of 90mm, using wooden columns with diameter of 15mm is made as shown in **Figure 1(b)**, by using 1/40 scale of a real steel open Sabo dam. Moreover, the steel open dam model is hung from the measurement trestle to measure the debris flow load by using the load cell.

SIMULATION

Distinct Element Method (DEM)

The DEM normally uses spherical model, and initially involves a technique of the contact judgement between the elements. If the one element contacts with other element, a spring action is generated between the elements and finally, the equation of motion is solved based on the contact force.

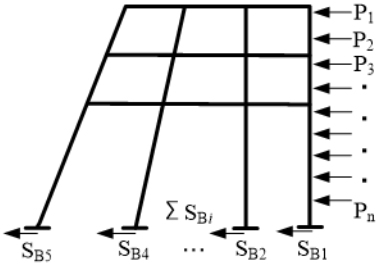


Fig. 3 Load evaluation

Analytical dam model and load evaluation

The analytical dam model is composed of cylindrical elements which are connected with springs between those elements, as shown in **Figure 2**. The load cell model is connected with springs between spherical model and connected to cylindrical model with springs, and the spring force is evaluated as debris flow load acting on whole structure as follows.

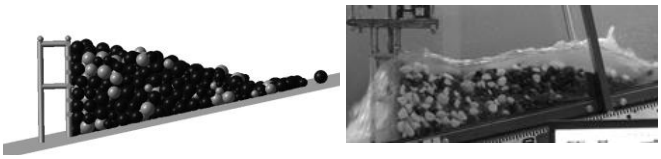
$$P_T = \sum_{i=1}^{n} P_i = \sum_{i=1}^{n} S_{Bi} \tag{1}$$

where P_T : the horizontal load acting overall structure, P_i : the contact force of boulder element i acting on each point to structure, S_{Bi} : the shearing force acting on the base element i of the dam, which corresponds to the value of load cell as shown in **Figure 2**, because the load was measured by load cell upside-down the dam.

Simulation and test results

Figure 4(a) shows the simulation result of debris flow movement, in which the gravels are filling up the front space of the dam. In comparison, **Figure 4(b)** shows the test result of debris flow movement. It is found that the movement of simulation shows in good agreement with the one of the test.

Figure 5 illustrates the time history of the debris flow load which is measured by load cell in the test, and also computed by Eq.(1) in the analysis. The debris flow load by the analysis is almost good agreement with one by the test result.



(a) Simulation (b) Test

Fig. 4 Debris flow movement

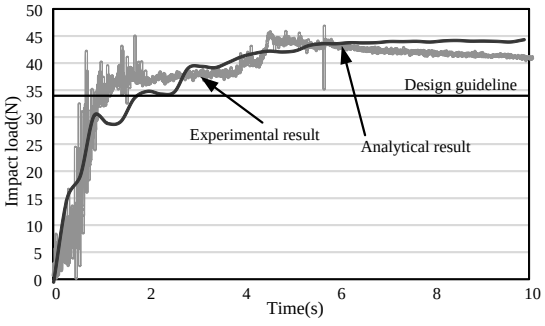


Fig. 5 Time history of impact load

CONCLUSIONS

It was confirmed that the proposed DEM can simulate well the debris flow load-time relation and the debris flow movement. This method will be applied to estimate the debris flow load acting on the actual steel open dam in the future.

Keyword: Impact load of debris flow, Load evaluation, Distinct Element Method