Trapping Mechanism of Debris Flow by Steel Open Dams

Nobutaka ISHIKAWA[1], Joji SHIMA[2], Tomoo MATSUBARA[3], Hiroshi TATESAWA[4], Toshiyuki HORIGUCHI[5] and Takahisa MIZUYAMA[6]

[1]Research Association for Steel Sabo Structures,Japan
[2] Sabo and Landslide Techical Center, Japan
[3] CTI Engineering, Co. Japan
[4] Bousai Consultant Co.,Ltd. Japan
[5] National Defense Academy, Japan
[6]Graduate School of Agriculture, Kyoto University, Japan
*Corresponding author. E-mail: cgishikawa@m4.dion.ne.jp

Fig.1 Rocks trapped by a steel open dam

INTRODUCTION

Rocks in the debris flow front were trapped by a steel open dam in Hokkaido, Japan as shown in Fig.1. This paper presents experimental and computational approaches to examine the trapping mechanism by a steel open dam. First, a model test was performed to examine the mechanism whereby gravel in the debris flow is trapped for the time history by using a flume. Second, a 3-D DEM was developed by assuming the gravel to be made up of spherical elements. Finally, the trapping process (riverbed height-time relation) and trapping ratio obtained by the 3-D DEM simulation were compared with those obtained by the model test.

HYDRODYNAMIC MODEL TEST

Hydrodynamic model tests were performed by using the channel with width of 20cm and a slope of 18° as shown in Fig.2. The debris flow model was provided as 7760 gravels with the diameter of larger than 1cm which are laid on the floor as a length of 1.85m and a height of 5.0cm.The steel open dam model was made by steel pipes of a diameter of 1.0cm, a height of 15cm and a pipe interval of 1.5cm which corresponds to 1.5 times of the maximum diameter of gravel (95% of gravel diameter distribution). The debris flow model was given from the upper-stream of 5m to the steel dam model at a rate of 3.0 liter per second.

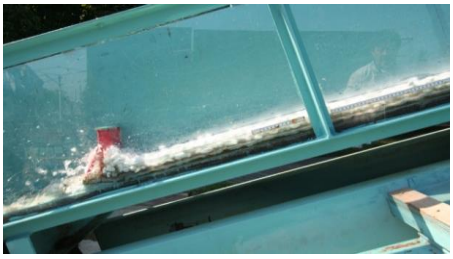

Fig.2 Hydrodynamic model test

Fig.3 Final trapping state (test)

TEST RESULTS

The final trapping state was found as shown in Fig. 3. Although the slit interval of the steel dam was 1.5 cm, gravels with a diameter larger than 1.0 cm were trapped by the steel open dam. This phenomenon may be a result of so-called "arch action." The trapping and outflow ratios of the gravels were 99.2% (7000/7760) and 0.8% (60/7760), respectively.

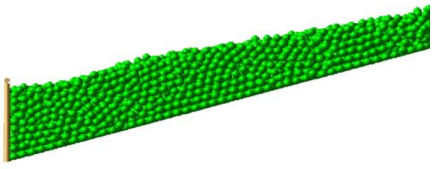

Fig.4 Trapping state of D=1.5cm (computed)

SIMULATION BY 3-D DEM

A 3-D DEM (Distinct Element Method) for the trapping simulation of debris flow was developed by expressing a riverbed as a plane element, a grid steel dam as a cylindrical elements and a gravel as a spherical element (Ishikawa, et al. 2004, Shibuya, et al. 2009).

The following input data was used; Contact spring constant of gravel : K_n=10^6N/m for the normal direction, K_s=1.5x10^5N/m for the tangential direction, h= 0.20 for the damping constant, tanφ= 0.404 for the friction coefficient. Computation time was 10 seconds and the computing interval time was 10^{-6}s. The flow volume is 3.0L/sec which corresponds to the flow velocity of 1.4m/sec and water depth of 1.07cm.

SIMULATION RESULTS

Figure 4 shows the computed trapping state of gravel diameter of 1.5cm which was relatively good agreement with the test result as shown in Fig.3.

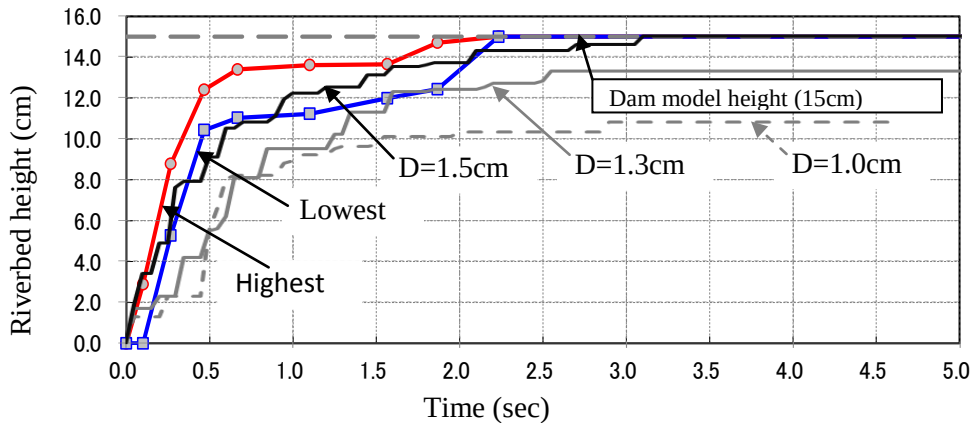

Fig.5 Riverbed height- time relation (test and computed)

The riverbed height–time relationships for D = 1.0, 1.3, and 1.5 cm were computed as shown in Fig.5, and were then compared with the test results. In Fig. 5, the lowest and highest heights of the entrapped gravel correspond to the lowest and highest levels of the captured gravel, respectively. As the diameter of the gravel increased, the computed riverbed height–time relationship approached the test results. The case of D = 1.5 cm was in good agreement with the test results. This was because the pieces of gravel used in the test were of uneven shape, even though the gravel has been passed through a 1.0-cm screen.

CONCLUSIONS

(1) The riverbed height–time relationship was measured by the test. This will provide the efficiency of the trapping performance of a steel open dam. (2)The riverbed height–time relationship and trapping ratio were computed by 3-D DEM and these results were very close to those of the test .

REFERENCES: Ishikawa,et.al (2004); Catch Effect of Debris flow for the Open Type Steel Check Dam by Physical and Numerical Modeling, Interpraevent 2004, Band 3,pp.153-163. Shibuya,et.al (2009); Trapping Simulation Analysis of Debris Flow with Drifting Trees by 3-D DEM , Proc. of Applied Mechanics, Vol. 12, pp.449-460.

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