NUMERICAL SIMULATION OF MUD FLOW GENERATED IN ATSUMA, HOKKAIDO, JAPAN

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1. INTRODUCTION

On September 6, 2018, "Hokkaido Eastern Iburi Earthquake" (magnitude 6.7) occurred at a depth of about 35 km in the central eastern Hokkaido Iburi district. The damage caused by sediment disaster to humans is enormous. As a countermeasure, we developed a numerical simulation model of sediment disaster. By using numerical simulation, damage from sediment disaster can be predicted, and simulation results are very useful for people evacuation.

The basic formulas used in the current numerical simulation model of debris flow and mud flow do not consider the external force due to earthquake. So, considers the difference in flow characteristics due to the different mudflow locations by comparing the simulation results of the mudflow generated in Takaoka area, and Yoshino area of Atsuma. In addition, considers the effect of earthquake on the flow characteristics of mudflow by numerical simulation of mudflow considering acceleration due to earthquake.

2. NUMERICAL SIMULATION MODEL

In this study, except for the momentum conservation equations, the basic equations used in the analysis are the same as the two-dimensional mudflow analysis model of Takebayashi and Fujita (2020). The equation of motion of the mudflow considering the seismic acceleration is described as follows in general coordinate system. (Only flowing direction.)

$$\frac{\partial}{\partial t}\left(\frac{hU}{J}\right)+\frac{\partial}{\partial \xi}\left(U\frac{hU}{J}\right)+\frac{\partial}{\partial \eta}\left(V\frac{hU}{J}\right)-\frac{hu}{J}\left(U\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial x}\right)+V\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial x}\right)\right)-\frac{hv}{J}\left(U\frac{\partial}{\partial \xi}\left(\frac{\partial \xi}{\partial y}\right)+V\frac{\partial}{\partial \eta}\left(\frac{\partial \xi}{\partial y}\right)\right)$$

$$=-(g-a_z)h\left(\frac{1}{J}\left(\left(\frac{\partial \xi}{\partial x}\right)^2+\left(\frac{\partial \xi}{\partial y}\right)^2\right)\frac{\partial z_b}{\partial \xi}+\frac{1}{J}\left(\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial z_b}{\partial \eta}\right)+a_\xi\frac{h}{J}\cos\theta$$

$$-\frac{1}{\rho_m}\left(\frac{1}{J}\left(\left(\frac{\partial \xi}{\partial x}\right)^2+\left(\frac{\partial \xi}{\partial y}\right)^2\right)\frac{\partial P}{\partial \xi}+\frac{1}{J}\left(\frac{\partial \xi}{\partial x}\frac{\partial \eta}{\partial x}+\frac{\partial \xi}{\partial y}\frac{\partial \eta}{\partial y}\right)\frac{\partial P}{\partial \eta}\right)-\frac{\tau_{b\xi}}{\rho_m J}$$

Fig. 1 shows the shape and depth of the slope failure used for the numerical simulation of the Yoshino and Takaoka area. Background image is quoted from GSI. The depth of the slope failure was determined based on the difference between the DSM measured by drone and the DEM measured by GSI before the disaster.

Fig. 2 shows the temporal changes in seismic acceleration observed by the Japan Meteorological Agency in Sikanuma, Atsuma. In this analysis, it is assumed that the slope failure occurs when the seismic acceleration is near the maximum, so occur the slope failure at 8.5 seconds in Fig. 2.

The analysis was performed under 3 conditions. Cases 1 and 2 are Yoshino area and Case 3 is Takaoka area. Case 1 is an analysis taking into account the earthquake. Case 2 does not consider the earthquake.

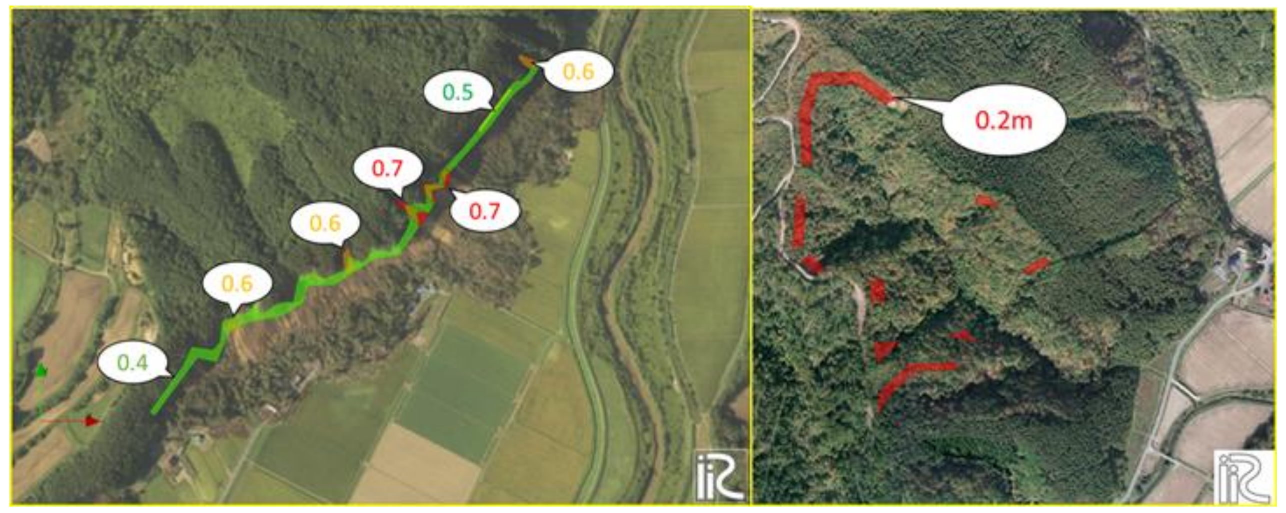


Fig. 1 Shape and depth of slope failure used in numerical simulation (unit: m)

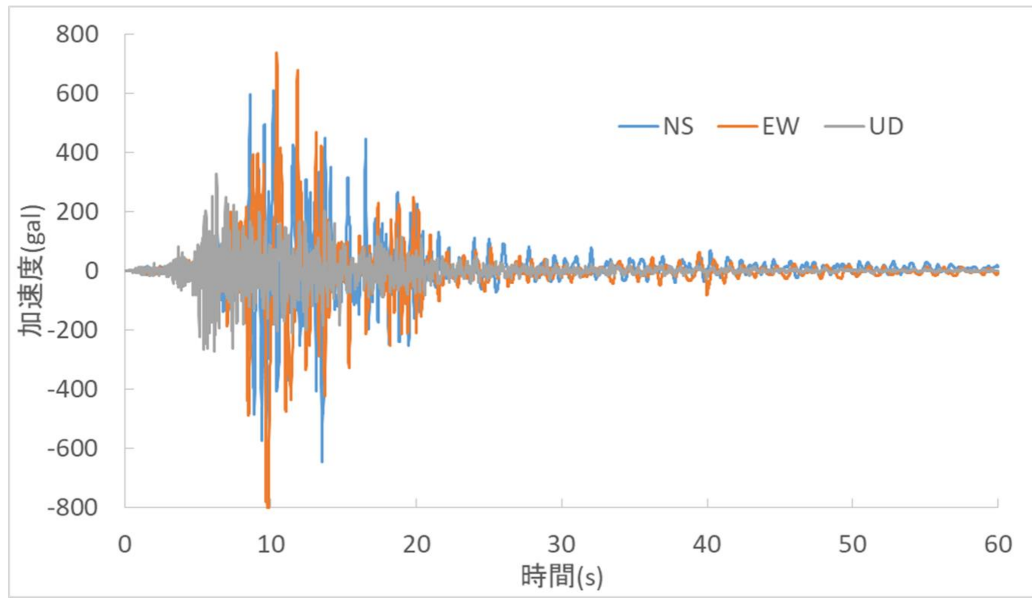
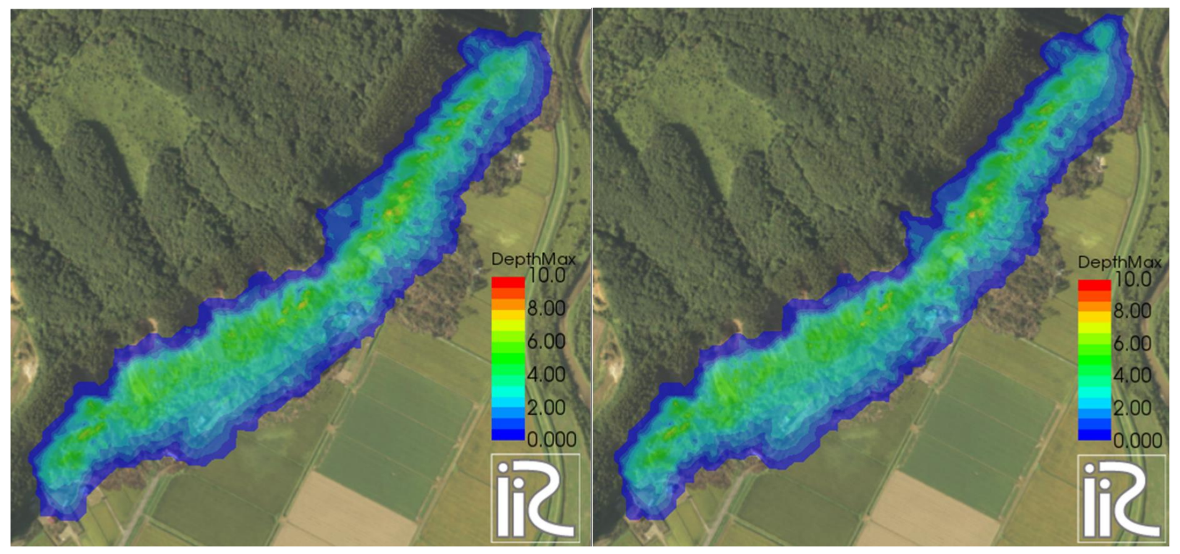


Fig. 2 Temporal variation of seismic acceleration observed at Sikanuma, Atsuma

4. DISCUSSION OF SIMULATION RESULTS

Fig. 3 shows the distribution of the maximum flow depth obtained by the simulation in the Yoshino area. As a result, in both cases, the mud flow reached the house in about 6 seconds and reached the maximum flow area in about 30 seconds. Therefore, it can be seen that the effect of the earthquake motion was very small.



(a) Case1 (b) Case2

Fig. 3 Distribution of the maximum depth of mudflow in Yoshino (unit: m)

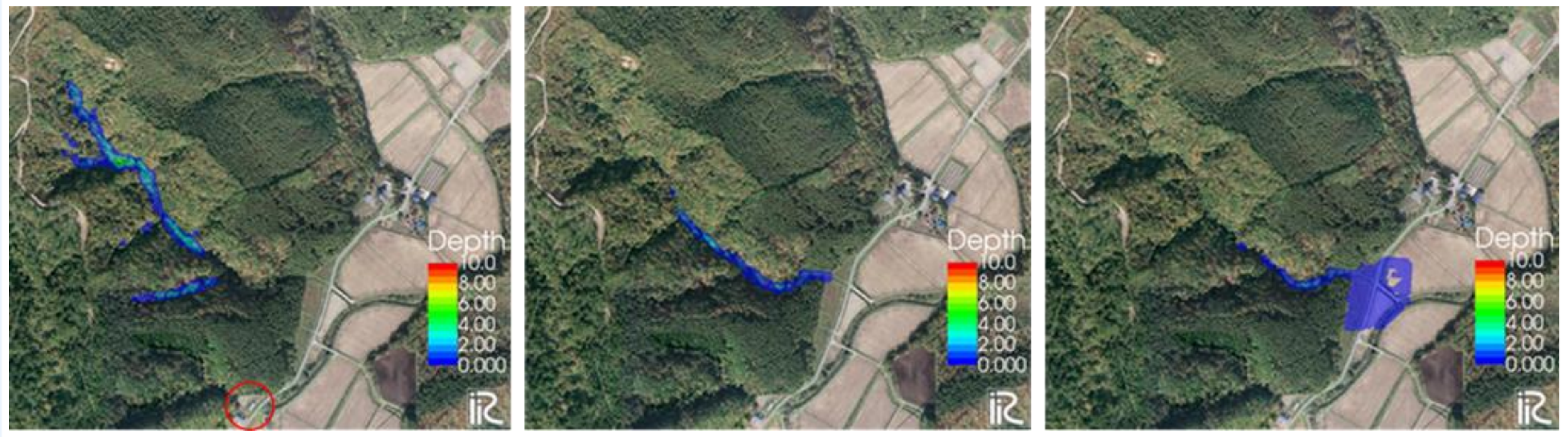
However, there were differences in the flow velocity vectors at each time. Fig. 4 shows the distribution of the velocity vector after 3 seconds. In Case1, the leftward vector component appears larger than in Case2. In other words, the dynamics of the instantaneous mudflow are affected by the earthquake, but finally, the effects of the earthquake in each direction cancel each other, and the effect of the earthquake is extremely small.

(a) Case1 (b) Case2

Fig. 4 Distribution of velocity vector after 3 seconds (unit: m/s)

Fig. 5 shows the temporal change in the depth of the mudflow in Case 4. As shown in the figure, it can be seen that the mudflows generated from each tributary merge and flow down the main river slowly. The time to reach the farmland is 150 seconds, and the flow velocity at the time of farmland flooding is 3 m/s, which is very slow compared to the Yoshino.

the time required for the mudflow to reach the mountain stream exit is much longer than Case1,2 , so it is possible to start evacuation after the earthquake occurs.



(a) After 30s (b) After 150s (c) After 200s

Fig. 5 Temporal change of mud flow depth in Takaoka area in numerical simulation (unit: m)

5. CONCLUSIONS

・it was more effective to consider different disaster prevention measures and evacuation methods for parallel slopes and valley topography even in the same Atsuma.

・In addition, the velocity vector of mud flow considering the effect of acceleration due to the Hokkaido Eastern Iburi Earthquake showed a difference in velocity vector, but no difference in the flow range.

REFERENCES

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