

Effect of existence of houses on inundation area of debris flow



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1. Introduction

In recent years, sediment disasters that houses are destroyed by debris flow are occurred frequently. In the future, it is expected that the number of occurrences of debris flow will increase due to the effects of global warming, in residential area, it is required to understand the flow characteristics of debris flow, and to take effective measures and evacuation based on it. In this study, focusing on the debris flow that occurred in Yagi 3 Chome, Asaminamiku, Hiroshima, Japan in 2014 (Figure 1) when some of the houses in the residential area were completely or half destroyed, two-dimensional debris flow numerical simulation considering the destruction process of houses is performed, and the effect of the existence of houses in the inundation area of debris flow is discussed.

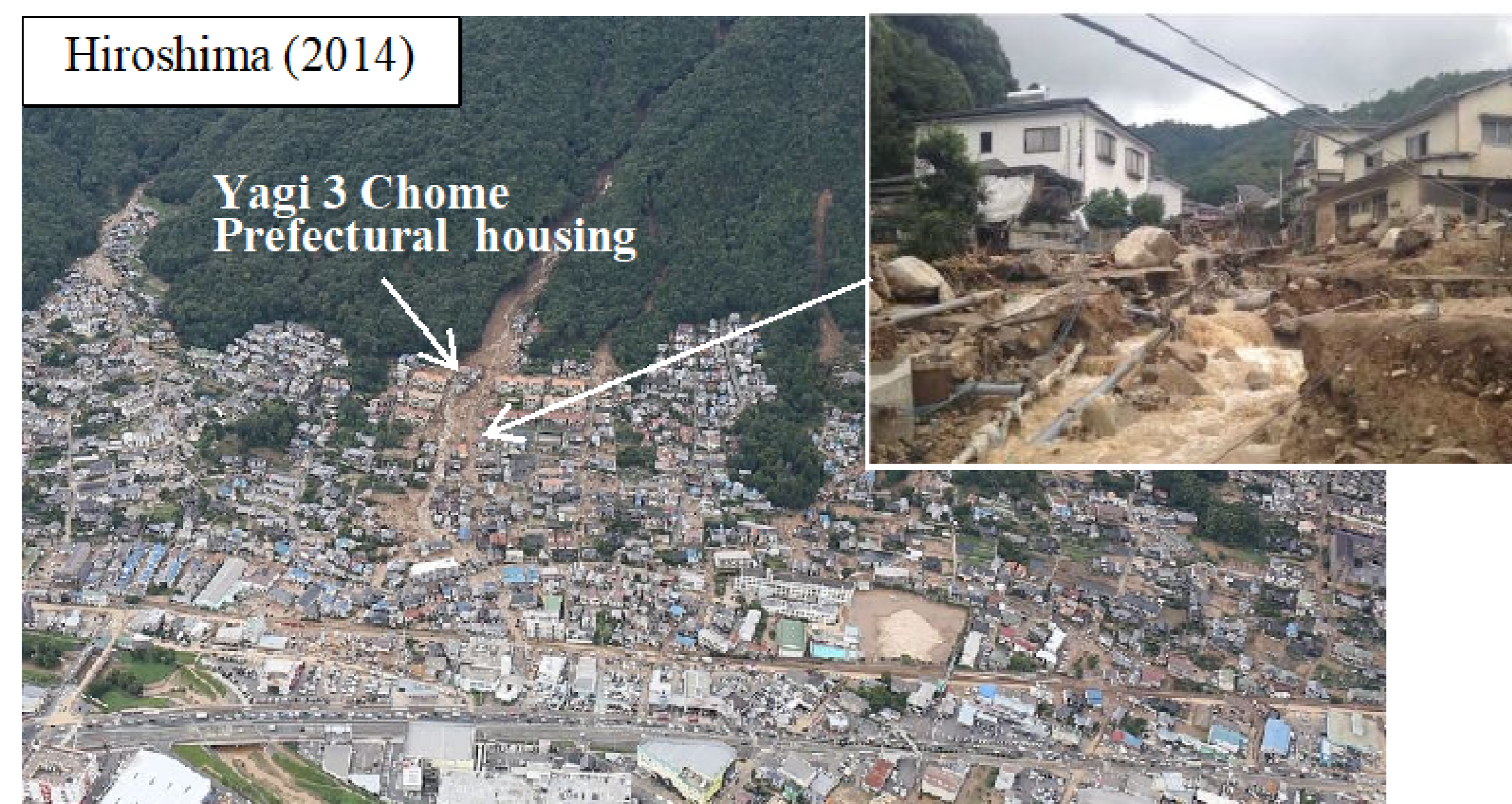


Figure 1. The debris flow that occurred in Hiroshima in 2014 (by MLIT)

2. Overview of numerical simulation

(1) Overview of the model

In this analysis, the constitutive equations of Egashira et al. (Egashira et al. 2004) and the two-dimensional debris flow analysis model (Takabayashi et al. 2020) considering the turbulent flow region over the laminar flow region are used.

The debris flow is generated by the slope failure. The development, transport and deposition processes are analyzed with the two-dimensional model. The shape of a house is represented by multiple analysis grids, and the stress acting on the house is determined by calculating the force acting on each analysis grid and is used to determine the destruction/non-destruction of the house. This is because many houses that were actually destroyed by debris flow were half destroyed, the house shape was easily changed, and the entire house did not behave like a single rigid body.

The stress F_{hx} per unit width of the flow direction, acting on the analysis grid of the house, is evaluated by the sum of the static pressure due to debris flow and the fluid force by kinetic energy acting on the house as follows.

$$F_{hx} = \frac{1}{2} \rho_m g h^2 \cos \theta + \rho_m h u^2$$

ρ_m : the density of mixture of water and sediment, g : the gravity acceleration,
 h : the flow depth, θ : the bed slope, u : the depth integrated flow velocity.

The house destruction critical stress per unit width seems to vary depending on the house structure. In this analysis, 800 kN/m was applied to all wooden houses as the house destruction critical stress per unit width.

(2) Analysis condition

The analysis grid is 2 m square grid. Three types of analysis conditions were used (Table 1). The destruction of houses was assumed to occur only in wooden houses, and not in RC structure houses. A house is represented by multiple analysis grids, and only the part exceeding the destruction critical is determined to be destroyed. Therefore, the half or partially destroyed house can be evaluated.

Table 1. Analysis conditions

Case No.	Contents
Case1	Considering destruction of houses
Case2	Treating houses as impervious non-destructive structures
Case3	Disregarding the existence of the houses

3. Result and discussion

Figure 2 shows the horizontal distribution of the amount of change in ground height in the residential area after the debris flow obtained in Case 1, which was superimposed on the photograph after the disaster. The portions shown in blue in the figure 2 are the portions where houses are determined to have been destroyed. In the house area A located directly downstream of the mountain stream exit, the analysis results show that all houses were completely destroyed. In the house area B located further downstream, some houses were completely destroyed, and others were half destroyed. In the house area C located further downstream, no house was determined to be completely destroyed, but some houses were partially destroyed. Therefore, we can see that the calculated results match the photograph after the disaster.

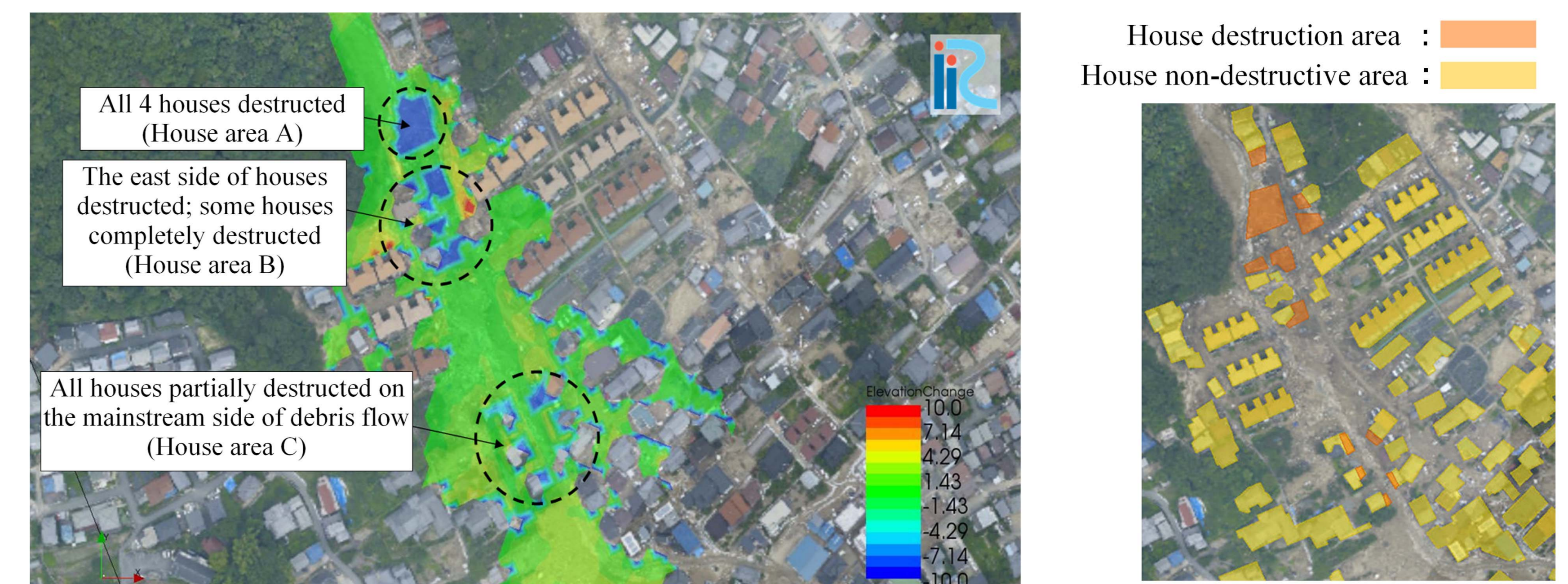


Figure 2. Reproduction of house destruction (Case 1)

4. Conclusions

In this study, focusing on the debris flow that occurred in Yagi 3 Chome, Asaminamiku, Hiroshima in 2014 when some of the houses in the residential area were completely or half destroyed, two-dimensional debris flow numerical simulation considering the destruction process of houses was performed, and the effect of the existence of houses on the inundation area of debris flow was examined. As a result, this numerical simulation model seems to be able to reproduce the state of complete or half destruction of houses relatively well, and to some extent to be able to evaluate the possibility of complete or half destruction of houses due to debris flow.

References

- Egashira, S., Itoh, T. (2004). Numerical Simulation of Debris Flow. *Journal of Japan Society of Computational Fluid Dynamics*, Vol.12-2, pp. 33-43. (in Japanese)
 Takebayashi H., Fujita, M. (2020). Numerical Simulation of a Debris Flow on the Basis of a Two-Dimensional Continuum Body Model. *Geosciences*, 10, 45.