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Physical Vulnerability Characteristics of Buildings by Numerical Simulation of Debris Flow

*Hyo-Sub Kang[1)], Ananta Man Singh Pradhan[1)], Barsha Pradhan[1)] and Yun-Tae Kim[2)]

[1), 2)] *Department of Ocean Engineering, Pukyong National University, Busan, Korea*
[2)] *yuntkim@pknu.ac.kr*

ABSTRACT

This study performed the back analysis using the FLO-2D model from a total of 4 cases of debris flow disasters occurred in between July and August, 2011. The appropriate input parameters were determined through the quantitative index analysis and survey data of debris flow affected area. Numerical analyses were carried out each study area, Disaster-induced factors(debris flow height, velocity and impact pressure) were calculated on the damage point of the building. Physical vulnerability functions of masonry buildings were obtained from the relationship of the degree of building damage and the physical characteristics of debris flow obtained through the numerical analysis.

1. INTRODUCTION

The continued increase in population and resulting demand for resources has given rise to pressures to settle in places where continuous land development processes become a risk. Human lives and structures located in debris flow-prone mountainous areas are commonly subject to debris flow hazards (Hu *et al*., 2012). In such areas, the development of appropriate hazard mitigation plans is an important aspect of public administration and civil protection (Zanchetta *et al*., 2004). Elements that are exposed to debris flow hazards include buildings, highways, railways, mines, and reservoirs. Compared with structural facilities such as railway bridges, common residential buildings are more easily damaged by debris flows. For this reason, it is important to analyze potential damage of residential buildings from debris flow hazards. A quantifiable integrated approach of hazard and risk management is becoming standard practice in risk reduction management (Fell and Hartford, 1997; Duzgun and Lacasse, 2005). Such quantitative assessment should include the expected losses as the product of the hazard with a given magnitude, the costs of the elements at risk, and the vulnerability (Uzielli *et al*., 2008). Physical vulnerability is a representation of the expected level of damage and is quantified on a scale of 0 (no loss or damage) to 1 (total destruction) (Fell *et al*., 2005). Thus, vulnerability assessment requires an understanding of the interaction between the hazard and the exposed element. This

[1)] Graduate Student
[2)] Professor

interaction can be expressed using damage or vulnerability curves (Quan Luna *et al*., 2011).

The main objective of this paper is to construct physical vulnerability characteristics of building structures in Korea to enable a quantitative assessment of debris flow risks. For this reason, performed the back analysis using the FLO-2D model from a total of 4 cases of debris flow disasters occurred in between July and August, 2011. Numerical analyses were carried out each study area, disaster-induced factors(debris flow height, velocity and impact pressure) were calculated on the damage the building. Physical vulnerability functions of masonry buildings were obtained from the relationship of the degree of building damage and the physical characteristics of debris flow obtained through the numerical analysis of debris flow. The proposed physical vulnerability functions could be used as a quantitative assessment of the structural resistance of building affected by a debris flow event, also it can be used urban debris flow vulnerability assessment.

2. CASE STUDY OF DEBRIS FLOW EVENTS

Fig. 1 shows aerial photographs of the study areas including the transportation zone, deposition zone and catchment area of each debris flow disaster. The characteristics of the damaged buildings for each debris flow disaster were also investigated. The degree of damage to the buildings was determined from a comprehensive analysis of field survey data, photographs, and reports from the scenes.

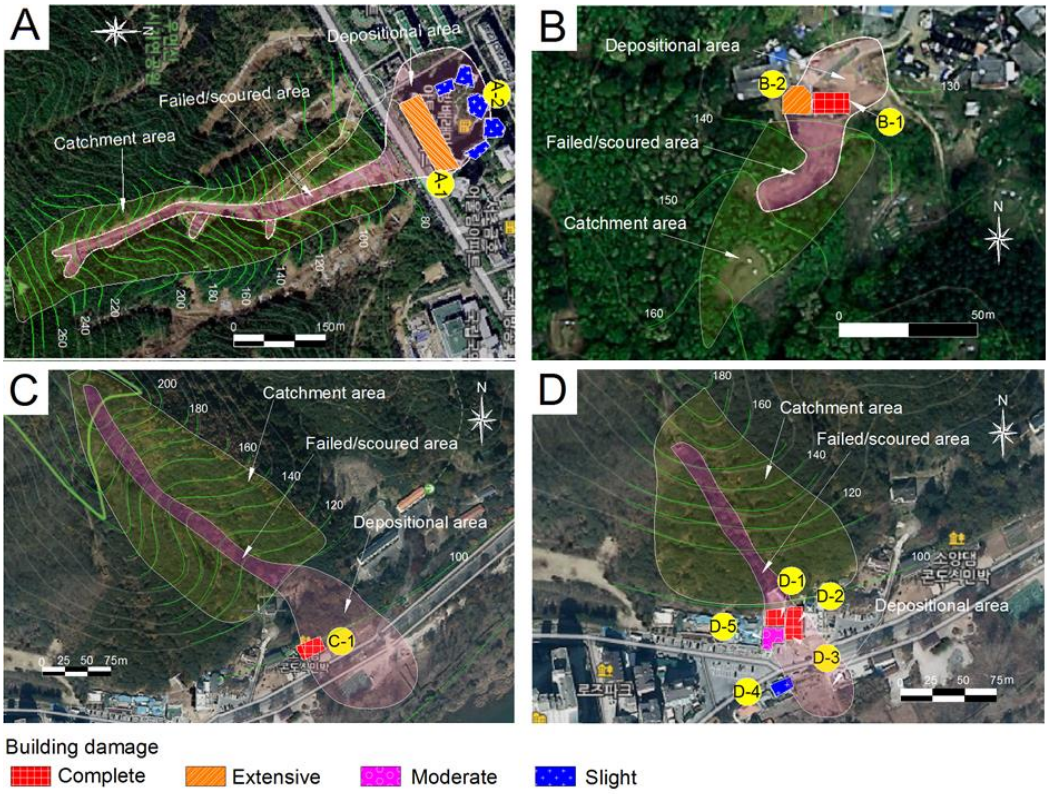
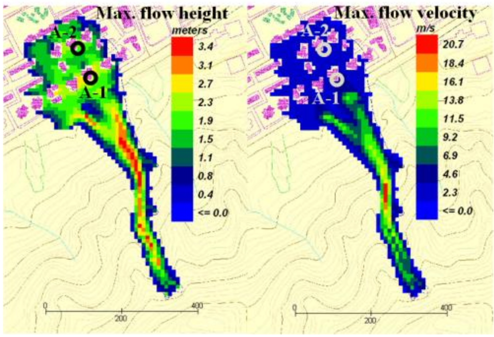


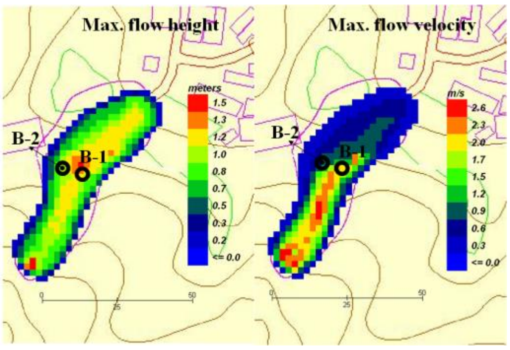
Fig. 1 Case studies of debris flow: (A) Seoul, (B) Yongin, (C) and (D) Chuncheon

3. NUMERICAL SIMULATION OF DEBRIS FLOW

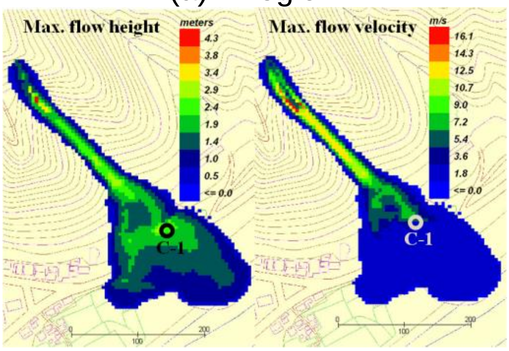
The FLO-2D model is a two-dimensional flood routing model that can simulate flows over complex topographies and roughness on urbanized alluvial fans. Hyper-concentrated sediment flows, such as mudflows and the transition from water flows to fully developed mud and debris flows, can be simulated as well. Figure 2 shows the maximum flow heights and maximum velocities modelled by the FLO-2D model. Based on simulation results, maximum flow height and velocity of debris flow were extracted at the corresponding pixel positions of the respective building.



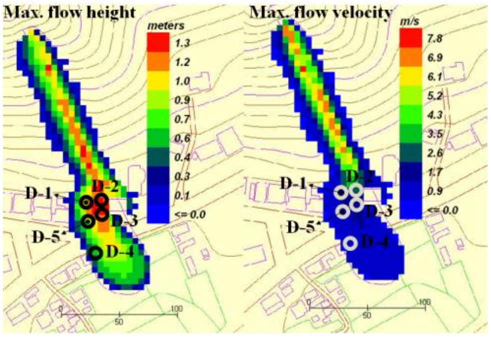
(a) A region



(b) B region



(c) C region

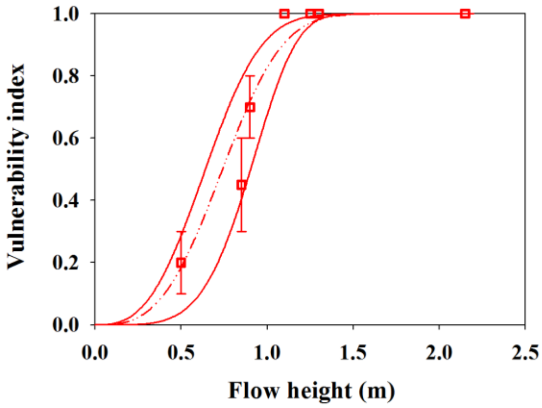


(d) D region

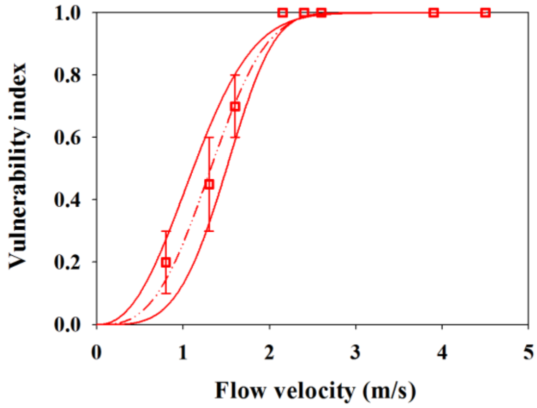
Fig. 2 Simulated results of maximum flow height and velocity each region

4. PHYSICAL VULNERABILITY CURVES

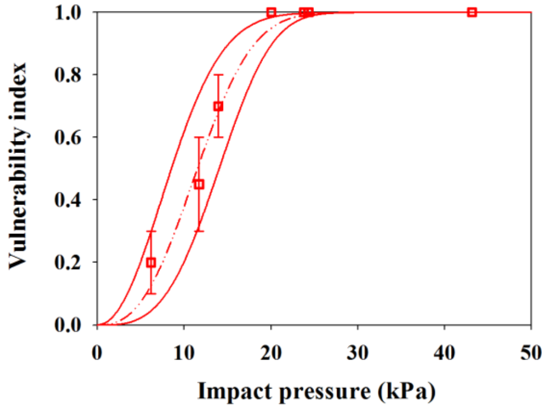
Nonlinear regression analysis was carried out to relate the vulnerability to the intensity of the debris flows using an analytic expression. To nonlinear regression analysis, a sigmoid function having an "S" shape was used. This function is an asymptote from a small value close to zero to a certain finite value. Physical vulnerability functions of masonry buildings were obtained from the relationship of the degree of building damage and the physical characteristics of debris flow obtained through the numerical analysis of debris flow. Three different empirical vulnerability curves were obtained, which were function of debris flow height (see Fig 3(a)), flow velocity (see Fig. 3(b)) and impact pressure (see Fig. 3(c)).



(a) Debris flow height



(b) Debris flow velocity



(c) Debris flow impact pressure

Fig. 3 Debris flow vulnerability curves

5. CONCLUSIONS

The physical characteristics of debris flows were evaluated by the numerical analysis from 4 debris flow disasters that occurred in July and August, 2011. A total of 10 damaged buildings were investigated in detail to determine the characteristics and patterns of the damage to buildings resulting from debris flows. Three different vulnerability curves were obtained as functions of the debris flow depth, flow velocity and impact pressure. Most of the masonry buildings were completely destroyed or seriously damaged, which is attributed to a greater vulnerability of brick buildings to lateral loads. With the masonry buildings, complete destruction occurred with impact pressures greater than 20 kPa. The impact pressure of debris flow corresponding to slight damage to an RC building resulted in complete destruction of masonry buildings. The vulnerability curves of the masonry buildings increased with increasing flow depth, flow velocity, and impact pressure. These physical vulnerability curves can be used to estimate the structural resistance of buildings in response to debris flow events.

ACKNOWLEDGMENT

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REFERENCES

Duzgun, H. S. B. and Lacasse, S. (2005), "Vulnerability and acceptable risk in integrated risk assessment framework, in: Landslide risk management," edited by: Hungr, O., Fell, R., Couture, R., and Eberhardt, E., Balkema, Rotterdam, 505–515.

Fell, R. and Hartford, D. (1997), "Landslide risk management, in: Landslide risk assessment," edited by: Cruden, D. and Fell, R., Balkema, Rotterdam, 51–109.

Fell, R., Ho, K.K.S., Lacasse, S., and Leroi, E. (2005), "A Framework for Landslide Risk Assessment and Management. *in: Landslide Risk Management,"* Edited by: Hungr, O., Fell, R., Couture, R., and Eberhardt, E., Taylor & Francis, London, 533-541.

Hu, K.H., Cui, P., and Zhang, J.Q. (2012), “Characteristics of Damage to Buildings by Debris Flows on 7 August 2010 in Zhouqu, Western China,” *Nat. Hazards Earth Syst. Sci.*, 12, 2209-2217.

Uzielli, M., Nadim, F., Lacasse, S., and Kaynia, A.M. (2008), "A Conceptual Framework for Quantitative Estimation of Physical Vulnerability to Landslides," *Eng. Geol.*, 102(3–4), 251-256.

Quan Luna, B., Blahut, J., van Westen, C.J., Sterlacchini, S., van Asch, T.W.J., and Akbas, S.O. (2011), "The Application of Numerical Debris Flow Modelling for the Generation of Physical Vulnerability Curves," *Nat. Hazards Earth Syst. Sci.*, 11, 2047-2060.

Zanchetta, G., Sulpizio, R., Pareschi, M.T., Leoni, F.M., and Santacroce, R. (2004), "Characteristics of May 5–6, 1998 Volcaniclastic Debris-flows in the Sarno Area of Campania, Southern Italy: Relationships to Structural Damage and Hazard Zonation," *J. Volcanol. Geoth. Res.*, 133, 377–393.