Small Flume Experiment on Deep-seated Landslide Collapsed Material Movement

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INTRODUCTION

Collapsed material of deep-seated landslide mobilizes in two main types; debris flow and landslide dam. Debris flow is known as the mechanism of transporting sediment mass far downslope (Bathurst et al. 1997) and holds serious impact on human life and infrastructures since it moves rapidly, large in volume, destroys object without warning, and often occurs without warning (Nishiguchi et al. 2012; Highland et al. 1997). While landslide dam is defined as the natural blockage of river channels caused by landslide, having significant height, and potentially causing inundation of water behind it (Canuti et al. 1998; MLIT 2006). Landslide dam holds further threats than debris flow by causing flood in upstream area of dams, potential dam breaks due to overflowing of inundated water, and subsequence of debris flow threaten downstream area (e.g., Ermini and Casagli 2003; Inoue et al. 2012). The boundary of whether collapsed material of deep-seated landslide will mobilize as landslide dam or debris flow is not determined yet. By using deep-seated landslide collapsed material as soil sample, small flume experiment was conducted to analyze the mobilization and separate the phenomena of soil deposition.

METHOD

We developed a small flume consisted of a main channel and an inflow segment (**Fig. 1**). Both segments have 10 cm width and 15 cm height made of acrylic material. The gradient of the inflow segment was 45°. Gradient and length of the main channel is 10° and 130 cm, respectively. A bucket was placed at the end of the flume to capture transported soil sample. Soil sample was placed as sediment dam in 10 cm upstream from the confluence. Experiment was applied for three different inflow angles by 60°, 30°, and 0°. After the experimental flushing, percentages of soil deposition were measured in 5 sections (**Fig. 1**). The soil samples were collected from Nigoridani, Nara Prefecture where deep-seated landslide occurred in 2011 due to Typhoon Talas. D50 of the sampled soil was 5 to 6 mm. Seven classes of water content with 0%, 10%, 20%, 40%, 60%, 80%, and 100% were applied to examine the collapsed material movement in various water contents.

RESULT AND DISCUSSION

Sections B and E are considered important for evaluating formation of landslide dam or the movement of sediment to down streams. Section B was subjected to area in which soil collides with the opposite side of flume and landslide dam was possibly formed. Section E was assumed to be the area affected by sediment which mobilizes as debris flow. By variation of 0° and 30° inflow angle, the amount of soil deposition in section B did not change significantly ($p > 0.05$). Meanwhile, the soil deposition in 60° inflow angle showed significant change (**Fig. 2**). But compared to 0° and 30°, 60° inflow angle generated significantly distinct soil deposition on section B (**Fig. 2**). Based on 112 data of landslide dam from Ministry of Construction (1987) and Tabata, et al. (2002), the average percentage of landslide dam material volume is about 40% of the total collapsed material volume. Therefore we determined the boundary between landslide dam formation and transport as debris flow is soil deposition in section B ≥40%. The boundary based only on soil deposition on section B is adequate to determine landslide dam formation because soil deposition on section B has strong negative correlation ($p < 0.05$) to section E (**Fig. 3**).

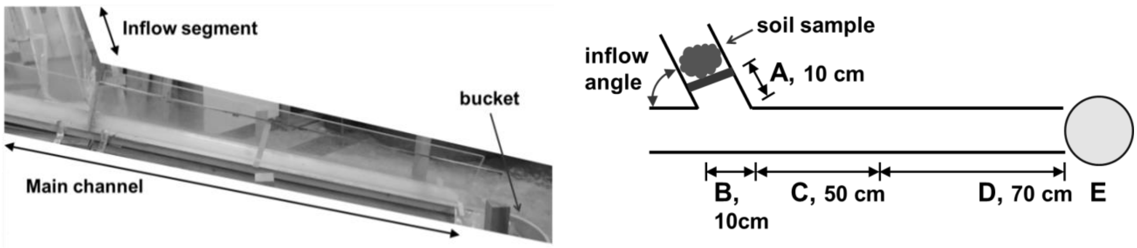

Fig. 1 Small flume instrument

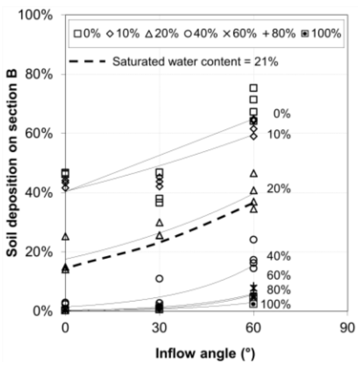

Fig. 2 Soil deposition on section B in various inflow angles

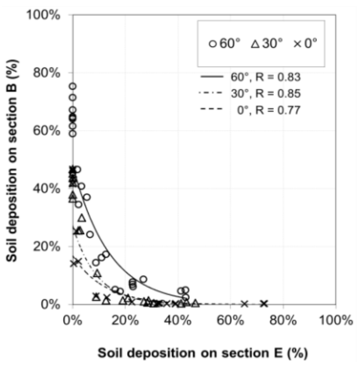

Fig. 3 Soil deposition on section B compared to section E

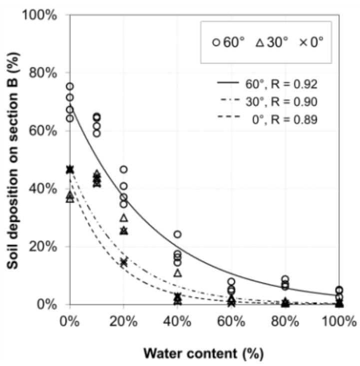

Fig. 4 Soil deposition on section B in various water contents

Heavy rainfall-induced deep-seated landslide generally occurs on soil's saturated water content. Saturated water content in Nigoridani soil sample is 21%, so DSL could possibly occur in this water content. By looking at the trend on 21% saturated water content and our determined boundary of 40% soil deposition in section B (**Fig. 2**), we found that deep-seated landslide could possibly form landslide dam on inflow angle >60°.Such finding was also confirmed by our previous research (Kharismalatri, et al., in press) that landslide dam by deep seated landslide occurred in inflow angle of >60° and stream gradient of <10°.Water content played an important role on soil deposition and collapsed material movement. Regardless the inflow angle, high water content generated less soil deposition in section B (**Fig. 4**). Debris flows are saturated with water and typically much more mobile than landslides of the same volume (Iverson, 1997; Legros, 2002). Presence of water is necessary to trigger deep-seated landslide and additional water can further be added by incorporation of saturated valley material or directly by mixing with water from a river (Legros, 2002). Therefore the condition of water content more than the saturated water content (= 21%) formed debris flow.

CONCLUSION

The findings of our experimental study agreed to our previous study based on field investigation and GIS analysis of deep seated landslides and dam formation in Kii Peninsula. Collapsed material formed landslide dam in large inflow angle with water content less than its saturated water content. Small inflow angle less than 60° has no significant impact on formation of landslide dam. The mobilization of collapsed material is also strongly influenced by water content. Combination of both laboratory and field investigation is essential for understanding the sediment transport and mechanisms of sediment dam formation by deep seated landslides.

Keywords: small flume, landslide dam, inflow angle, water content