Small flume experiment on the formation of landslide dam

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Introduction

Severe rainfall brought by Typhoon Talas in 2011 catastrophically damaged Kii Peninsula including Mie, Nara, and Wakayama Prefectures. The heavy rainfall induced many sediment-related disasters in Mie, Nara, and Wakayama Prefectures, including 33 deep-seated landslides, 30 rock falls, and 21 stream blockages, with total sediment amount of approximately 100 million m^3 (MLIT, 2011; MLIT, 2013). The collapsed material of landslide mainly mobilized as 2 type of movement; flows downstream as debris flow or blocking the stream channel as landslide dam. By data analysis of deep-seated landslides in Kii Peninsula caused by typhoon in 2011, we found that landslide dam were likely to form in catchments of streams with gradient <10° and inflow angle >60°, while debris flow were likely in catchments of streams with gradient >10° and inflow angle <60°. Experimental research is essential to improve and confirm this result.

Experimental research on landslide dam failure has been largely conducted (e.g. Singh and Scarlatos, 1988; Yan et al., 2009; Zhou et al., 2013; Cao et al., 2011). However, experiment on the formation of landslide dam by deep-seated landslide collapsed material is still lacking. Thus, we conducted small flume experiment to separate the phenomena of mobilization and deposition of materials.

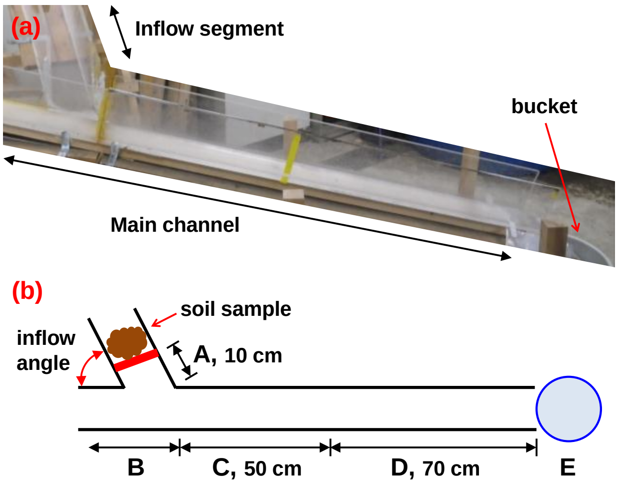

Fig. 1 Small flume instrument

Method

We developed a small flume consisted by a main channel and an inflow segment (**Fig. 1a**). Both segments have 10 cm width and 15 cm height by acrylic material. Length and gradient of main channel is 130 cm and 10°, respectively. A bucket was placed at the end the flume for capturing transported soil sample. The gradient of the inflow segment was 45°. We placed soil sample as sediment dam in 10 cm upstream from the confluence. Experiment was applied for two different inflow angles by 60° and 30°. After the experimental flushing, percentages of soil deposition were measured in 5 sections (**Fig. 1b**). We used soil samples 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. We used 5 classes of water content 0%, 10%, 20%, 60%, and 100% for examining the possibility of landslide dam formation in various water contents.

Result and Discussion

Percentage of soil deposition and pattern of collapsed material movement were influenced by water content. In water content of 0% and 10%, soil samples were mostly deposited in the section B (the confluence between inflow and stream segment) for more than 50% with no deposition on section E (**Fig. 2**). But in water content 20% to 100%, the soil flowed further to lower sections. The higher the water contents the more soil deposition percentage in lower sections. Nigoridani soil samples have liquid limit of 19.5% checked by fall cone tests and plastic limit of 13.6%. The larger the gap between liquid limit and plastic limit, the more water must be incorporated into the soil to achieve flow (Fleming et al., 1989). In presence of excess water above the liquid limit, soil behaved as liquid material and mobilizes as debris flow (Das, 2014, Fleming et al., 1989). Judging by the soil deposition percentage at each section, boundary between landslide dam and debris flow might be decided as follows: if the soil deposition in section B is ≥40% then it can be judged as landslide dam, otherwise it can be judged as debris flow. The comparison of soil deposition at section B to section E (**Fig. 4**) shows strong result with R^2 >0.8, as well as the student t-test result (p-value <0.05). Thus the distinction between landslide dam and debris flow based on the deposition in section B is adequate.

The possibility of collapsed material from deep-seated landslide to form landslide dam depends on the topographic factors that involve the interaction between river and slope dynamics (Dal Sasso et al., 2014; Stefanelli et al., 2015). The inflow angle of flume setup was modified to confirm its influence to formation of landslide dam. Generally, by changing inflow angle from 60° to 30°, the soil deposited more on lower sections (**Fig. 2** and **Fig. 3**). On water content 0% and 10%, smaller inflow angle reduced the soil deposition in section B to under 50%. On

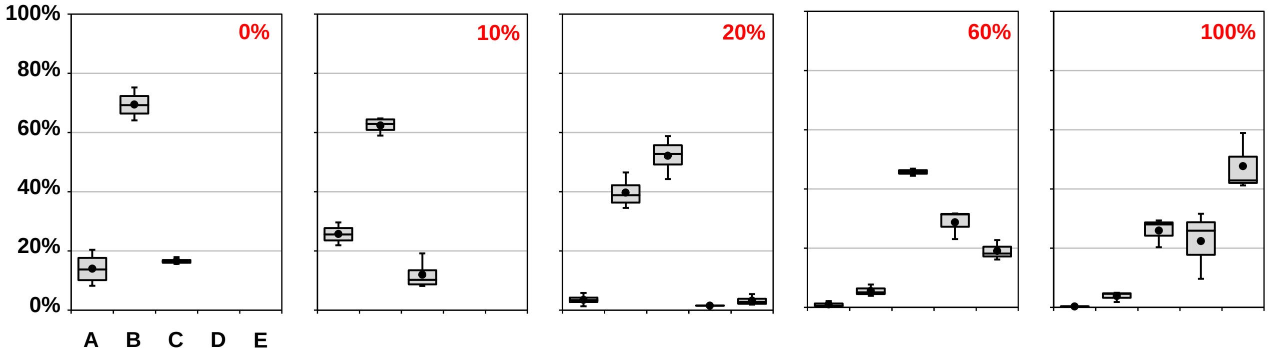

Fig. 2 Percentage of soil deposition for inflow angle 60°

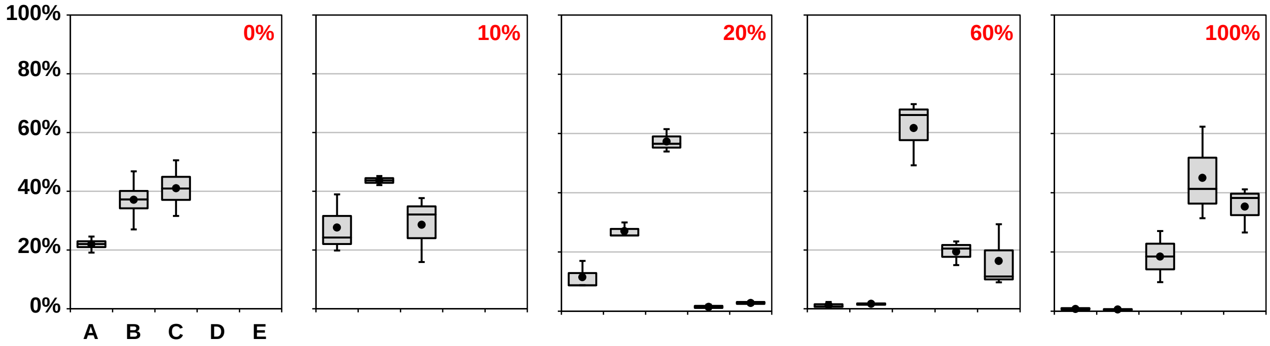

Fig. 3 Percentage of soil deposition for inflow angle 30°

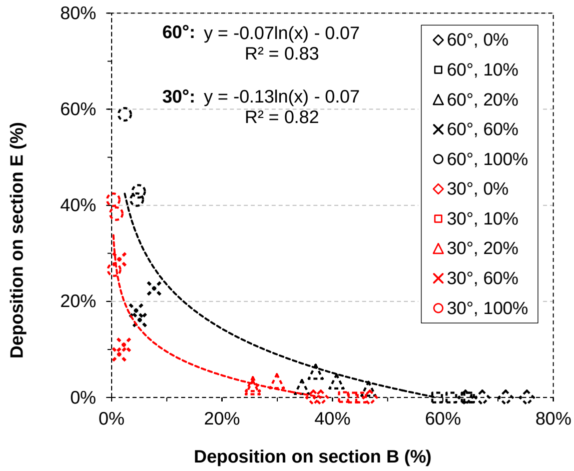

Fig. 4 Comparison of soil deposition at section B and E

water content 20% to 100%, smaller inflow angle generated smaller soil deposition on section A and B, and more on section C, D, and E.

On large inflow angle, the collision of soil sample and the stream segment expended a large amount of energy. The movement of overflowed collapsed material thereafter was stopped due to large energy loss upon the collision, and thus formed landslide dam. Meanwhile, small inflow angle generated soil sample to flow easily into the stream segment and caused the collapsed material to cost small amount of energy at the collision with opposite flume. The modification of inflow angle influenced the deposition in section B significantly, checked by student t-test with p-value <0.05. Landslide collapsed material would easily mobilize as debris flow on stream steeper than 10-20° (Hungr et al., 2014). Modification of stream segment inclination and comparison with soil samples from other site should be conducted in further experiment. So that the boundary between landslide dam and debris flow formation would be more apparent.

Conclusion

Result of the experiment confirmed that landslide dam formed in inflow angle 60° for water content less than the liquid limit. However, landslide dam was also found in inflow angle 30° with the same water content. We think that the fluidization of deep-seated landslide collapsed material is strongly influenced by grain size and water. Soil samples with different grain size will generate different result. The model experiment indicates the trends of phenomena and general properties. Modification of main channel gradient will be conducted in further experiments.

Reference

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