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Travel Length Analysis of Deep-seated Landslides' Collapsed Material in Kii Peninsula Caused by Typhoon Talas in 2011

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INTRODUCTION

Prediction of travel length or run-out of natural hazards is important for determining affected areas and flow intensity parameters, which are essential elements for producing hazard maps (Petrascheck & Kienholz 2003). Landslide travel distance prediction is a complicate issue because it is determined by the topograpichal factors, materials' properties (grain size distribution, water content, etc), mobile mechanics of collapsed material, confinement attribute of travel path, and so on (Guo et. al 2014).

There are many researchers studied travel length of collapsed material and its greatly influencing principal factors. Some of them used run-out distance as the indicator (Sorimachi 1977, Yoshimatsu 1990, Okubo et. al 1995), the other used equivalent friction angle (Moriwaki 1987, Iryo et. al 1992, Terada 1994, Yamada et. al 2000), whilst Ishikawa (1999) used travel ratio (run-out distance/relative height) as run-out distance indicator (Ishikawa n.d.).

Equivalent coefficient of friction (height difference/horizontal difference) is widely used as an indicator of run-out distance, and factors that generally influencing run-out distance are gradient of collapsed area, slope gradient, collapsed area's height, gradient of deposition area, material volume, confluence angle, and continuous rainfall (Ishikawa n.d.). This research aims to analyze the travel length of deep-seated landslides occurred in Kii Peninsula due to Typhoon Talas in 2011 based on its topographical characteristics by examine the coefficient of friction, and obtains the correlation of topographical characteristics to the travel length of collapsed material.

METHODOLOGY

The research area was in Kii Peninsula, mostly in Nara Prefecture and some in Wakayama Prefecture which was severely damaged by Typhoon Talas in 2011. Aerial photographs (ortho data) of research area after the typhoon used in the research were obtained from Ministry of Land, Infrastructure and Transport, Kinki Regional and Development Bureau with 1:200,000 scales taken on 13 September 2011. Furthermore, Digital Elevation Model (DEM) data was obtained from Geospatial Information Authority of Japan (GSI) with 1:25,000 scales.

DEM data were elaborated to contour map, slope map, slope aspect, and stream order. Whilst aerial photographs were analyzed in order to obtain the deep-seated landslides. Coefficient of friction and topographical characteristics of deep-seated landslides (including landslide width, landslide length, landslide area inclination, stream order, distance to stream, slope height, watershed area, upstream watershed area, stream inclination, and confluence angle) were obtained by combining result from aerial photographs analysis and maps elaborated from DEM data. Correlation of topographical characteristics to formation of coefficient of friction was obtained by multiple regression analysis.

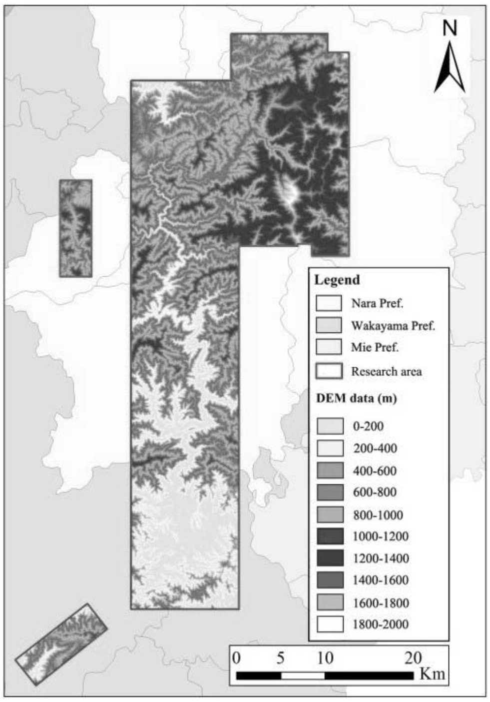

Figure 1. Research area in Kii Peninsula

RESULT AND DISCUSSION

There were 33 deep-seated landslide found by analyzing aerial photographs of research area, including 21 landslide dams, 10 debris flows, and 2 material depositions on relatively wide stream. There were 3 types of landslide dam found, namely long-term landslide dam, temporary landslide dam, and landslide dam inside reservoir.

Coefficient of friction for debris flow is measured from the top of the landslide area to the end of spreading (fanning) of landslide material, or at the end of material deposition at river curve in case spreading or fanning of landslide material could not be found. Whilst for landslide dam, coefficient of friction is measured from the top of landslide area to the end of main body of landslide material deposition. Material flows after collapse of landslide dam is not considered in this research.

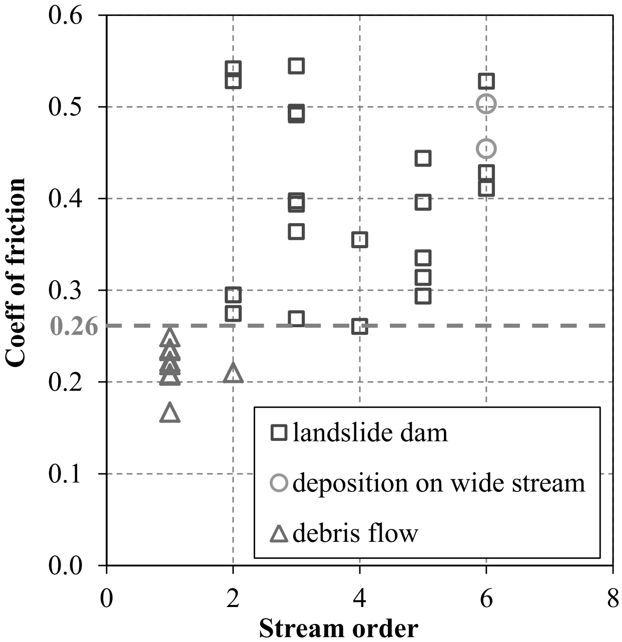

Figure 1. Stream order and coefficient of friction

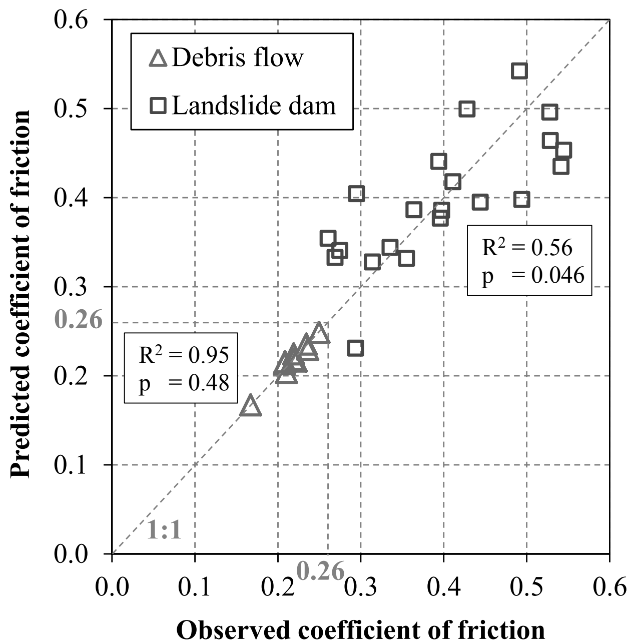

Figure 2. Coefficient of friction of landslide dam and debris flow

$$y = 0.0003d + 0.006i_1 + 0.009i_2 + 0.0003l - 0.0003w + 2.6\times10^{-6}ws_2 + 0.083 \quad \text{for landslide dams} \quad (1)$$

$$y = 0.008c + 0.001d + 0.001h + 0.01i_1 - 0.01i_2 + 0.0004l - 0.002w - 0.004ws_2 - 0.3 \quad \text{for debris flows} \quad (2)$$

The results as shown in Figure 1, implies that coefficient of friction is mostly less than 0.26 for debris flow and more than 0.26 for landslide dam. Coefficient of friction represents run-out distance and degree of fluidization of collapsed material. Smaller equivalent coefficient of friction means that the landslide material flows to downstream and inundated farther from the landslide area, while bigger equivalent coefficient of friction means that the landslide material flows not so far and might deposited near the landslide area. Stream order represent the location of deep-seated landslide occurrence, larger stream order implies larger upstream watershed area, larger amount of flood discharge and gentler stream inclination. Collapsed material of deep-seated landslide in 2nd to 6th stream order tends to deposit as landslide dam due to gentle stream inclination.

Formation of coefficient of friction were analyzed by regression analysis on topographical characteristics of deep-seated landslides, namely landslide width, landslide length, landslide area inclination, stream order, distance to stream, slope height, watershed area, upstream watershed area, stream inclination, and confluence angle. The equations above of coefficient of friction (y) formation were obtained, where c: confluence angle, d: distance to stream, h: slope height, i_1: landslide area inclination, i_2: stream inclination, l: landslide length, w: landslide width, and ws_2: upstream watershed area.

The results show that important factors for coefficient of friction formation of landslide dams are landslide length, landslide area inclination, and distance to stream. While important factors for debris flow's coefficient of friction formation are landslide area inclination and upstream watershed area. Figure 2 shows the relationship between coefficient of friction calculated by equation (1) and (2), and the coefficient of friction observed by this analysis. The calculated coefficient of friction approximately agrees with the observed one in this figure.

CONCLUSION

There were 33 deep-seated landslide found, including 21 landslide dams, 10 debris flows, and 2 material depositions on relatively wide stream. Landslide dam likely to have coefficient of friction more than 0.26, whilst debris flow likely to have coefficient of friction more than 0.26. The formation of coefficient of friction is influenced by the topographical characteristics of landslide area.

Keywords: travel length, collapsed material, deep-seated landslide, kii peninsula, typhoon talas

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