
Traveling Distance Analysis of Landslides in 2005's Kyushu Disaster Associated with its Application to the Land Use Restriction

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Abstract

To scrutinize the characteristic of the traveling distance of landslides “L”, the equivalent friction coefficients induced by earthquake “ $M_{fe}=H/L$ (H: traveling height)” and ones by heavy downpours “Mf” are analyzed. These equivalent friction coefficients are obtained from aero photo interpretations, topological analysis and field investigations. The equivalent friction coefficient of landslides induced by the earthquake M_{fe} is obviously bigger than ones induced by the rainfalls M_f . The result is very clear in the diagram of relation between the landslide volume V and M_f , M_{fe} following by multi discrimination analysis in which the discrimination rate is 100%. In a distinguish test of the average, the difference between them is also significant. The internal friction angle in dry condition obtained by shear tests with a sample of granite slope failures induced by the earthquake is two times larger than the one in saturated condition, whereas the average M_{fe} is almost three times larger than M_f . Therefore, under the condition of low soil moisture, traveling distance of landslides occurred in an earthquake could be shorter than the case expected with saturated condition in such as typhoons. Hence, it is important for the risk assessment to estimate the traveling distance under the condition of high soil moisture with heavy precipitation.

In the case of landslides induced by the earthquake, the Bayesian probability analysis of their slope gradients is also carried out. Consequently, followings are obtained.

- 1) The equivalent friction coefficient of landslides induced by the earthquake is obviously bigger than ones induced by the rainfalls. Therefore, the vulnerable areas of landslide that must be subjected to the warning regulation or legal restriction can be wider than estimated from the case of earthquake, at least, in Fukuoka district.
- 2) With the results in this study, we can evaluate the area range under the landslide risk, combining with the former study on the slope gradient by the author.

Keywords: landslide, equivalent friction coefficients, traveling distance, typhoon, earthquake

1. Introduction

Landslides are essential natural hazard in the mountainous areas. For landslide mitigation and land use restriction, it is important to detect their travel distances as well as to find out the susceptible slopes with appropriate indexes. To scrutinize the characteristic of the travel distance of landslides “L”, the equivalent friction coefficients of landslides induced by earthquake “ $M_{fe} = H/L$ (H: travel height, L: horizontal travel distance)” and ones by heavy downpours “Mf” are analyzed. These equivalent friction coefficients are obtained from aero photo interpretations, topological analysis and field investigations. The equivalent friction coefficient of landslides induced by the earthquake M_{fe} is obviously bigger than ones induced by the rainfalls M_f . The result is very clear in the diagram of relation between the landslide volume V and M_f , M_{fe} , following by multi discrimination analysis in which the discrimination rate is 100%. In a distinguish test of the average, the difference between them is also significant. The internal friction angle in dry condition obtained by shear tests with a sample of granite slope failures induced by the earthquake is two times larger than the one in saturated condition, whereas the average M_{fe} is almost three times larger than M_f . Therefore, under the condition of low soil moisture, travel distance of landslides occurred in an earthquake could be shorter than the case expected with saturated condition in such as typhoons. Hence, it is important for the risk assessment to estimate the travel distance under the condition of high soil moisture with heavy precipitation. Consequently, followings are obtained. 1) The vulnerable areas of landslide that must be subjected to the warning regulation or legal restriction can be wider than estimated from the case of earthquake at least in Fukuoka district. 2) With the results in this study, we can evaluate the area range under the landslide risk, combining with the former study on the slope gradient by the author.



Fig. 1. Location Map of the study area (Western Japan)

2. Methods and Fields

To analyze the characteristic of the travel distance “L” of landslides, the equivalent friction coefficient of landslides induced by Fukuoka earthquake 2005 “Mfe” are compared with ones by heavy downpours “Mf”.

Mf and Mfe is defined as H/L (H: travel height i.e. vertical distance between the crown of scarp and the toe of slide debris, L: travel distance, i.e., the horizontal distance between the crown of scarp and the toe of failure sedimentation). These equivalent friction coefficients are obtained with aero photo interpretations, topological analysis and field investigations of landslides occurred in duration of 2003–2005 in Oita, Miyazaki, and Kagoshima prefectures, Kyushu district (Fig.1, Photo 1–4). These data are submitted to the statistical analysis such as multi discrimination analysis (Anderson 1984) with landslide volume and the equivalent friction coefficients Mfe, Mf.

The landslides induced by heavy rainfalls adopted here were triggered by the precipitation intensities of more than 90mm/hr (landslides in 2003) with Baiu stationary front, or under more than 1000mm total rain with a typhoon (landslides in 2005). On the other hand, the Fukuoka earthquake in 2005 shook the urban area of the millions resident (Fig.1) with the Magnitude $M_{jma} = 7.0$, Moment magnitude $M_w = 6.4 \sim 6.6$ and maximum seismic acceleration of 489gal or more. The casualties were up to more than 1000 and it caused serious damages in many buildings and houses along the Hakata bay (Photo.4). This earthquake also triggered some landslides.

In the vicinity of some landslides, the soil moisture content was observed, whereas the soil strength characteristics such as the difference of internal friction angle between dry and saturated condition are examined by shear tests in some landslide slopes.

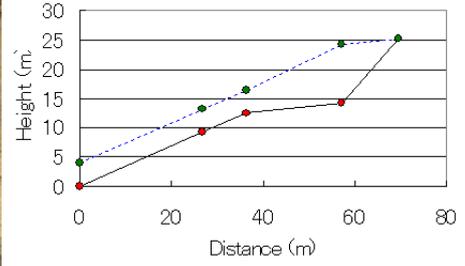
3. Results

Since generally Mf has relation to the landslide mass volume “V” (Voight et al. 1985), the results are shown in the diagram of relation between V and the equivalent friction coefficients Mf, Mfe (Fig.2).

The effect of geology on Mf and Mfe is also examined in Fig.4.

The equivalent friction coefficients “Mfe” of landslides occurred by the Fukuoka earthquake are obviously bigger than ones (Mf) induced by the rainfalls (Fig.2, Fig.4). Hence, the travel distance of landslides induced by rainfalls is definitely longer than Fukuoka earthquake’s case that took place in rather dry season with slightly dry soil condition.

Concerning of geological condition, Pumice or Pyroclastic Flow Sediments tend to have rather small Mf, i.e. longer travel distance than other cases (Fig.4).



The main lateral section

Photo. 1. A landslide in Takeda, Oita in 2005 (Dotted line: estimated original surface, Solid line: slip surface)



Photo. 2. A landslide in Kokonoe, Oita in 2005



Photo. 3. Landslides in Tano, Miyazaki in 2005



Photo. 4. Landslides induced by the Fukuoka earthquake on March 20, 2005

Multi discrimination analysis

Elucidating and evaluating the difference between water induced landslides and earthquake induced ones by multi discrimination analysis (Anderson 1984 etc.) with their volumes V and M_f using the data in Fig.1 (M_f Fuku and M_f rain), the discrimination rate is 100%, and Mahalanobis' squared distance (Anderson 1984) is quite big such as 102.2 (Fig.3).

This result implies they are well discriminated concerning with V and M_f .

The distinguish test of M_f average

Deriving from T-test (Anderson 1984 etc.) that is a statistical average discrimination test of M_f and M_f e, the difference between average values is also significant with the 5% risk level.

With these statistical analyses, it is obvious that the landslides triggered by the Fukuoka earthquake have shorter travel distance than the water induced ones.

The difference of internal friction angle of soil between dry and saturated condition

The internal friction angle in dry condition obtained by shear tests with a sample of granite slope failures induced by the earthquake is two times larger than the one in saturated condition, whereas the average M_f e is almost three times larger than M_f . Therefore, under the condition of low soil moisture, travel distance of landslides occurred in an earthquake could be shorter than the case expected with saturated condition in such as typhoons. Hence, it is important for the risk assessment to estimate the travel distance under the condition of high soil moisture with heavy precipitation.

4. Conclusion — Its application to the risk management

Consequently, followings are obtained.

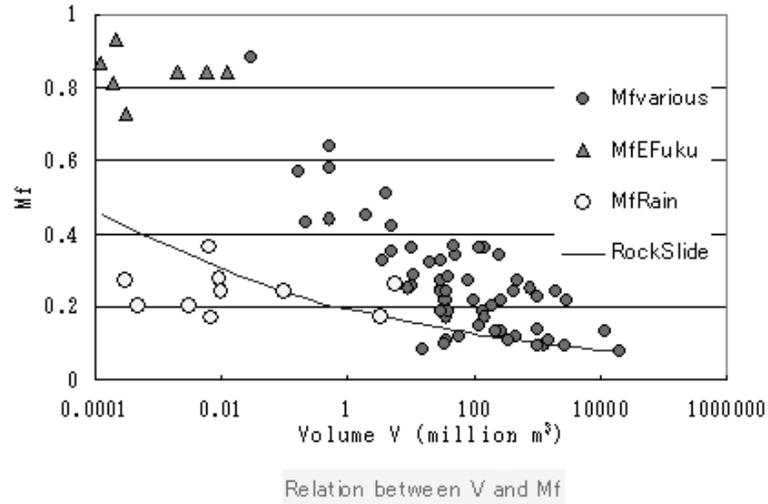


Fig. 2. Relation between volume V (million m^3) and the equivalent friction coefficient M_f : \circ : rain, \triangle : earthquake, \bullet : mixed (former studies), solid line: rock slides (Inokuchi 2006)

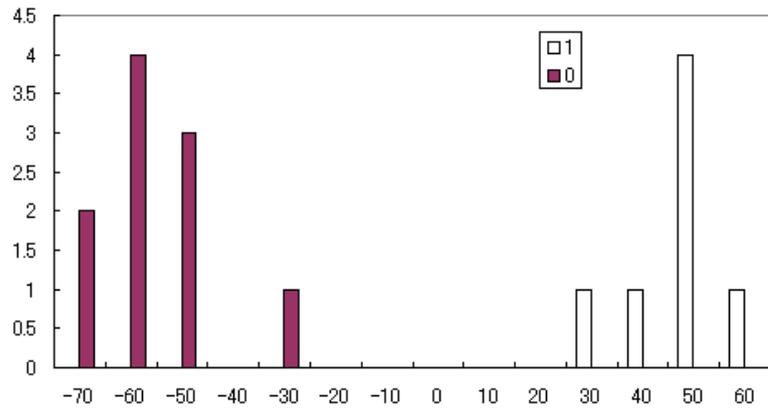


Fig. 3. Distribution of the discrimination scores in multi-discrimination analysis (Legend: 0= earthquake induced landslides in Fukuoka 2005, 1= water induced landslides in Kyushu)

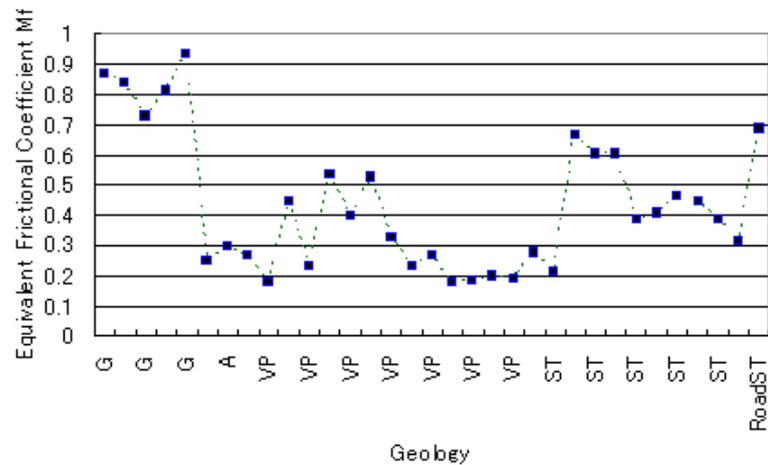


Fig. 4. Equivalent Frictional Coefficients of Landslides occurred in 2003–2005 (G: Granite, A: Andesite, VP: Pumice or Pyroclastic Flow Sediments, ST: Slates and tuff, the five from the left are data from ones induced by the earthquake)

- 1) At least, in a district of Japan, the vulnerable areas of landslide that must be subjected to the warning regulation or legal restriction can be wider (almost triple) than estimated from the case of earthquake, or the cases in former studies involving volcanic activity.
- 2) With the results in this study, we can evaluate the area range under the landslide risk, combining with the former study of the slope gradient (Kubota 1998) and so on.

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