DIFFERENCES OF PHYSICAL PROPERTIES BETWEEN TEPHRA AND TUFF BRECCIA-ANDESITE ON SLIDING LAYER AND SURROUNDING LAYERS OF LANDSLIDES

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1. INTRODUCTION

Landslides frequently occurred in Kyushu area caused by heavy rainfall. The physical properties of sliding layer and surrounding layers on tephra and tuff breccia-andesite in landslide have not been observed. Istiyanti et al.[1)] explained that the characteristics of sliding layer and surrounding layers on tephra materials on Aso volcanic mountains. Heavy rainfall on July 2012 triggered numerous landslides throughout the month in Aso volcanic mountain area. The sliding layers on tephra had the highest plasticity index and fine fraction content[1)]. Furthermore, the low average soil hardness indicated the location of the sliding layer in tephra materials[1)].

Rainfall induced landslides also frequently occurred on the area that consist of tuff breccia-andesite. On July 2017, heavy rainfall triggered several landslides in Fukuoka and Oita Prefecture. Many landslides occurred in the area consist of tuff breccia-andesite. Therefore, this research aimed to compare the characteristics on sliding layer and surrounding layers between tephra and tuff breccia-andesite of landslides caused by heavy rainfall.

More than 50% of fine fraction content were contained on the sliding layer[2)]. Moreover, the origin of a soil cohesion can be reflected by particle size distribution. Using the Atterberg limits, we can also classify the cohesion of soils, identification, description, and basis for preliminary assessment of their mechanical properties[3)].

2. RESEARCH AREA

Four locations of the landslide were selected as the research area (**Fig. 1**), two landslides were located at Aso volcanic mountains area and the other landslides were located at Oita prefecture. Landslides on Aso volcanic mountains area were located at Takadake area which occurred on July 12th, 2012 when a cumulative rainfall of 508 mm[4)] triggered numerous landslides throughout the month. The landslides called Takadake 1 and Takadake 2 in this study which had the distance between these landslides around 600 m. Takadake 1 is located at 32° 53' 54.06" N, 131° 7' 33.47" E with landslide dimensions of 34 m in length and 10 m in width. Furthermore, Takadake 2 is located at 32° 54' 7.81" N, 131° 7' 17.77" E with landslide dimensions of 18 m in length and 39 m in width. These shallow landslides occurred on sediment covered slopes consisting of alternating layers of tephra and "kuroboku" (humus andosols)[5)]. The soil materials in the Takadake area consist of tephra layers formed by volcanic activities.

The other landslides were called Ohtsuru and Ono landslides which had the distance between these landslides around 3,300 m. Heavy rainfall on July 5th, 2017 triggered several landslides in Fukuoka and

Oita Prefecture. The total rainfall on that day was 336 mm[4] and induced landslide at Ohtsuru. The next day after heavy rainfall on July 6th, 2017, Ono landslide was occurred and total rainfall was 66.5 mm[4]. Ohtsuru landslide is located nearby Yanase, Hita City at 33° 23’ 6.16” N, 130° 54’ 0.53” E. Furthermore, Ono landslide is located nearby Ono river, Hita City in Joguyama Mountain (645 m), 33° 23’ 23.53” N, 130° 56’ 7.25” E. That landslides consist of two types of soil material; tuff breccia and andesite.

3. RESEARCH METHODS

The methods in this study were field observation and laboratory tests. Soil stratigraphic analysis and soil hardness measurements were observed on the field. The stratigraphy analyses in each landslide were observed by scraping the surface to expose the soil layers. Afterwards, characteristics of soil layers were identified, such as depth and soil hardness value of soil layers. The soil hardness value was measured using the Yamanaka-type soil hardness meter. In this study, the soil hardness values on each sub-layer at Takadake 1, Ohtsuru, and Ono and on several sub-layers at Takadake 2 were measured. Unfortunately, because of the condition in the field, the depth of soil layers on Ono landslide were not able to be identified.

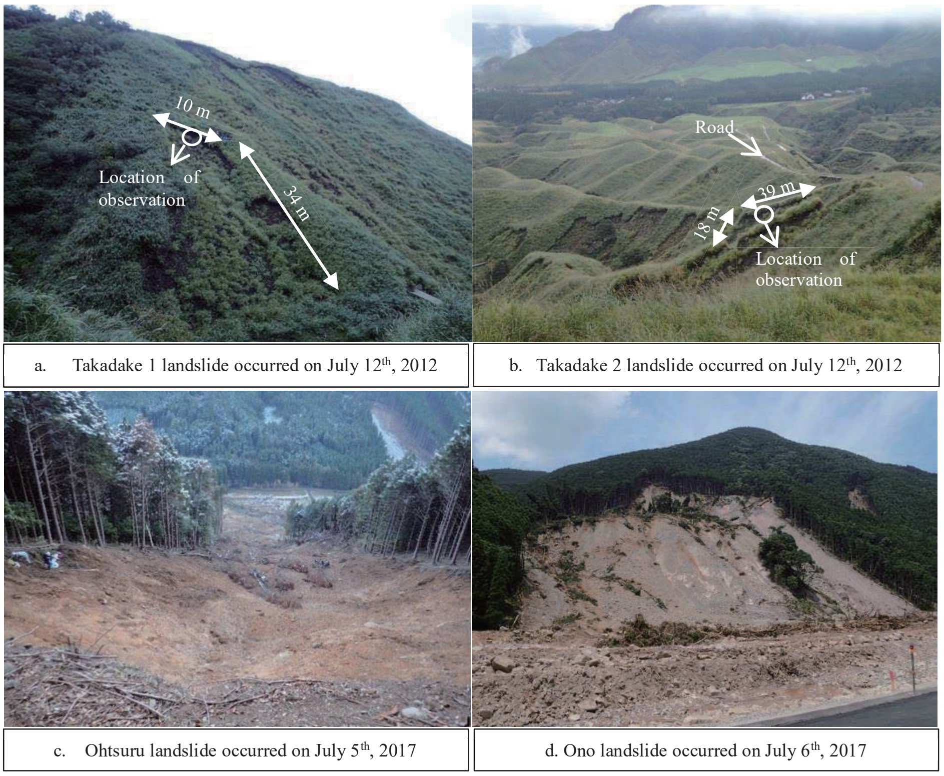
Disturbed samples were collected from the center of each soil layer to observe the characteristics of soil in laboratory tests using particle size distribution (JIS A1204, 2009 cited in JGS 2015)[6] and liquid limit and plastic limit tests (JIS A1205, 2009 cited in JGS 2015)[6]. The mass on disturbed samples for particle size distribution was 115 g and that for liquid limit and plastic limit tests were 230 g using sample less than 425 μm[6]. However, tuff breccia from Ohtsuru landslide was not able to be observed at particle size distribution because of the condition on material.

4. RESULTS AND DISCUSSIONS

(1) Soil hardness and soil stratigraphy

Kuroboku and scoria layers from Takadake 1 and Takadake 2 landslides will be observed in this study. Takadake 1 has two kuroboku layers with two scoria layers, which both layers are located on scoria layers (N1 kuroboku is located on the N2 scoria and N3-4 kuroboku is located on OJS scoria). Furthermore, Takadake 2 has three kuroboku layers with two scoria layers: N1 kuroboku and N2 kuroboku are located on the N2 scoria layer and N3-4 kuroboku is located on the OJS scoria layer. N3-4 kuroboku layer at Takadake landslides is divided into two sub-layers, N3-4 kuroboku upper part (N3-4 kuroboku (U)) and N3-4 kuroboku lower part (N3-4 kuroboku (L)).

The values of soil hardness and soil stratigraphy are shown in **Fig. 2.** Dissimilarity in soil hardness is observed between kuroboku and scoria layers[1]. The soil hardness in Takadake 1 shows N2 scoria has the highest soil hardness value (average = 18.5 mm) and



a. Takadake 1 landslide occurred on July 12th, 2012

b. Takadake 2 landslide occurred on July 12th, 2012

c. Ohtsuru landslide occurred on July 5th, 2017

d. Ono landslide occurred on July 6th, 2017

Fig.1 Landslides in this study (Photos taken on October 2016 (Takadake landslides) and December 2017 (Ono and Ohtsuru)).

N3-4 kuroboku has the lowest soil hardness value (average = 14.5 mm)[1]. However, the soil hardness value in Takadake 2 shows OJS scoria has the highest value (average = 23.9 mm) and N3-4 kuroboku has the lowest value (average = 18.1 mm)[1]. The sliding layers from field observation in Takadake landslides were located at N3-4 kuroboku (L) which have the low average soil hardness.

Ohtsuru and Ono landslides consist of tuff breccia and andesite which erupted around the Neogene period (7 Ma to 1.7 Ma)[7]. The sliding layers from field observation in that landslides were located at the boundary layer between tuff breccia and the upper layer. The sliding layer in Ohtsuru landslide was located at the boundary between tuff breccia and weathered andesite, and in Ono landslide was located at the boundary between tuff breccia and weathered tuff breccia.

Highly weathered andesite, weathered andesite, and tuff breccia from Ohtsuru landslide were observed in this study. The soil hardness in Ohtsuru landslide shows tuff breccia has the highest soil hardness value[8] (average = 22.0 mm) and weathered andesite has the lowest soil hardness value (average = 12.7 mm). The sliding layer from field observation in Ohtsuru landslide was located at the boundary between tuff breccia and weathered andesite which have the obviously different of soil hardness between those layers.

The materials in Ono landslide are divided into three soil layers; weathered andesite, weathered tuff breccia, and tuff breccia layer. The soil hardness shows tuff breccia has the highest soil hardness value[8] (average = 31.1 mm) and weathered tuff breccia has the lowest soil hardness value (average = 20.7 mm). The sliding layer from field observation in Ono landslide was located at the boundary between tuff breccia and weathered tuff breccia which have the obviously different of soil hardness between those layers.

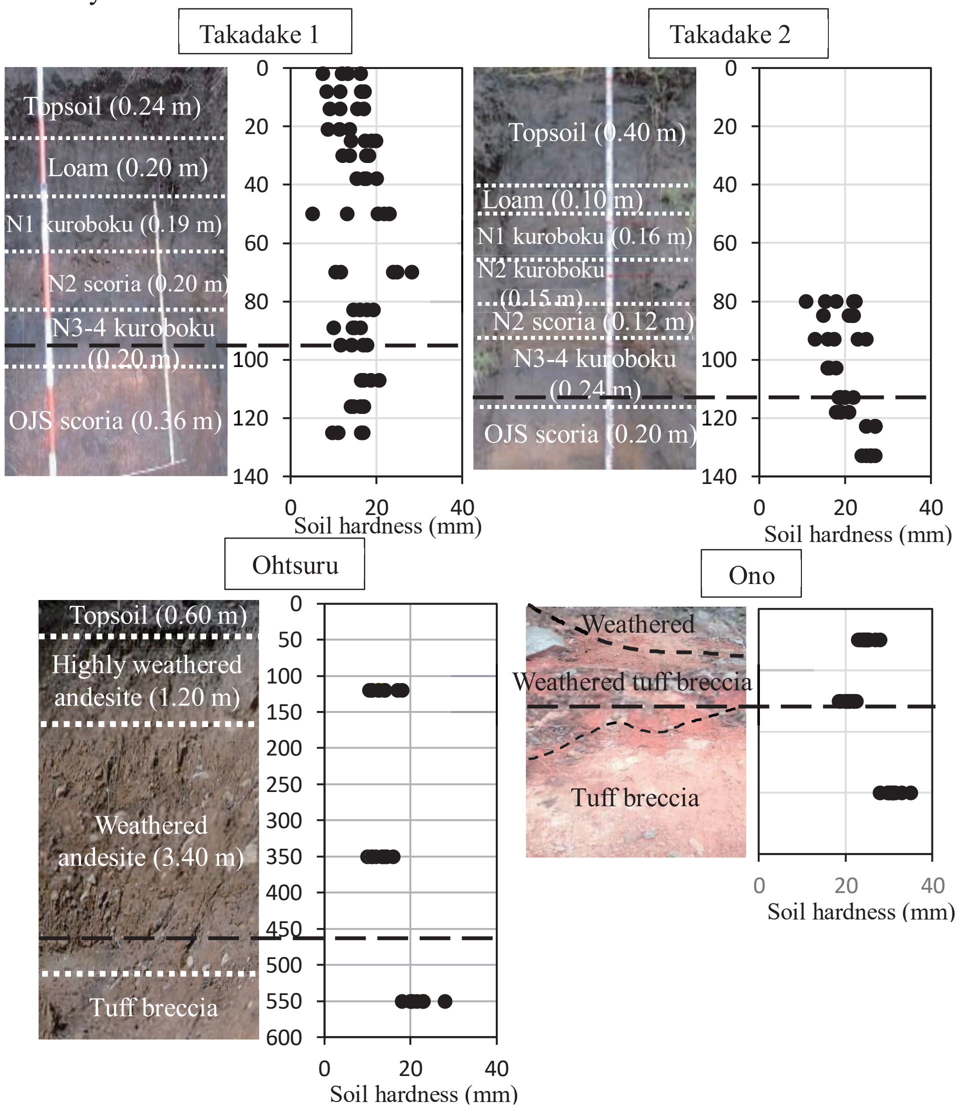


Fig.2 Soil stratigraphy on the field and soil hardness measurements values (y-axis is depth of soil layer (cm) and x-axis is soil hardness (mm)). Black dotted lines indicated location of sliding layer by field observation.

(2) Fine fraction content

Soil materials in this study consist of different types, such as tephra (kuroboku and scoria) in Takadake 1 and Takadake 2 landslides, and tuff breccia-andesite in Ohtsuru and Ono landslides. The particle size distribution shows generally the soil materials indicate poorly-graded soil (**Fig. 3**). The different curves on particle size distribution between tephra and tuff breccia-andesite materials have not been found.

The fine fraction content (less than 75 μm) (**Fig. 4**) shows the sliding layers on tephra materials have a higher fine fraction content than the other layers in each landslide, whereas the sliding layers in tuff breccia-andesite materials have a lower fine fraction content than the other layers in each landslide.

(3) Correlation between the sliding layers and soil materials

The liquid limit and plastic limit test results are plotted on a plasticity chart (**Fig. 5**) to classify the soil materials, which are separated between the sampling location denoted by different color, and sliding layers on each area denoted by the white circle with different color of outline and 'sliding layer'. The plotted data on kuroboku and OJS scoria layers are inorganic silts of high compressibility and organic clays[1]. The N2 scoria, however, are inorganic silts of medium compressibility and organic silts[1]. Furthermore, the plotted data on tuff breccia-andesite materials in Ohtsuru landslide are plotted at the same location with N2 scoria layers. The tuff breccia-andesite materials in Ono landslide are also plotted at the same location with kuroboku and OJS scoria layers.

On tephra materials, plasticity chart shows the range of plasticity index and liquid limit are higher at kuroboku layers than scoria layers. Furthermore, the tuff breccia-andesite materials plotted at the inside of scoria group. The sliding layers on tephra materials have the highest plasticity index and liquid limit on each landslide. The plasticity index and liquid limit are lower at sliding layers on tuff breccia-andesite

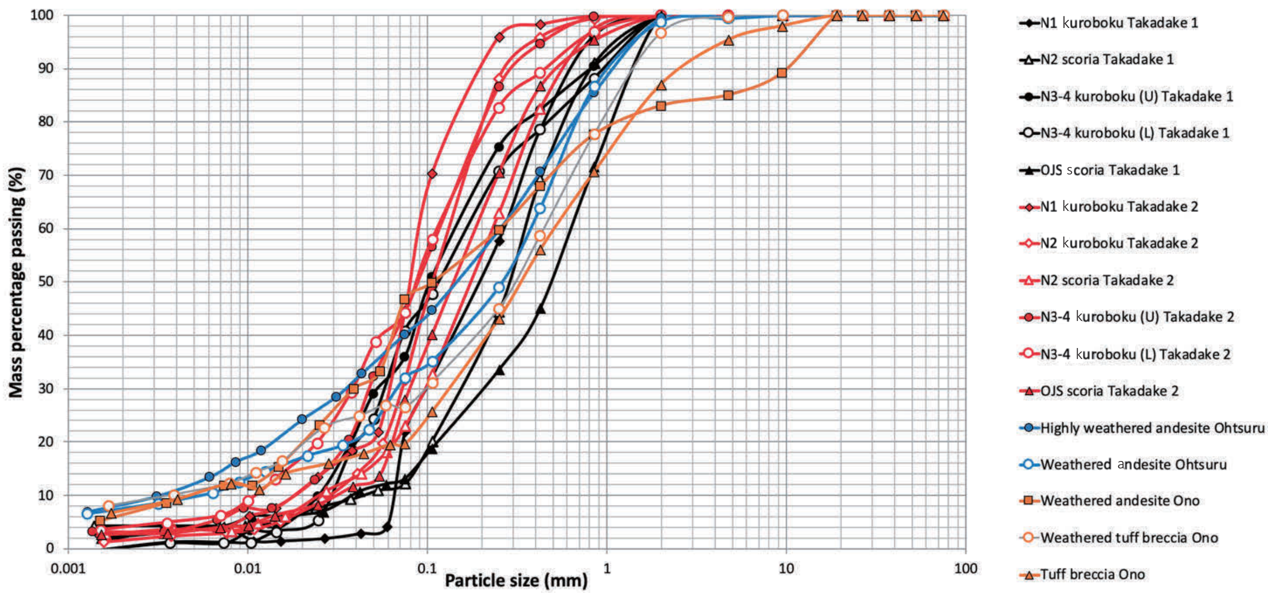


Fig.3 Particle size distribution curves of all soil layers on landslides.

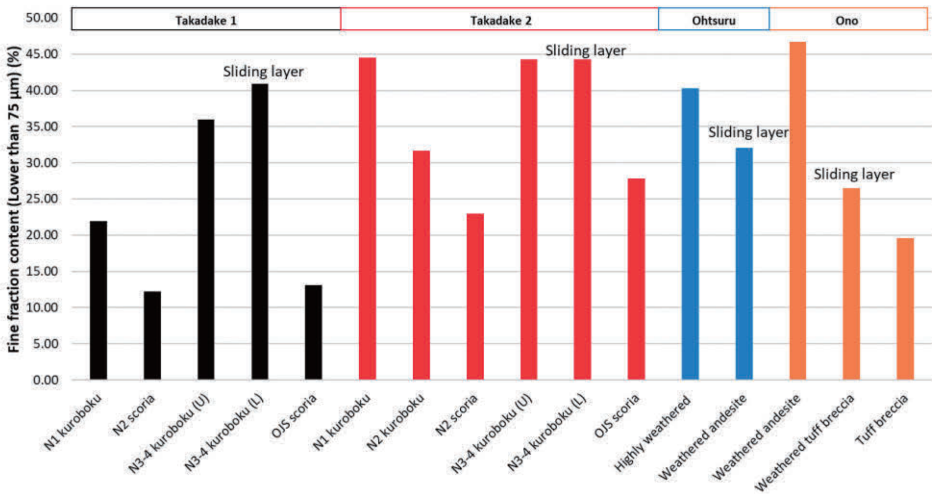


Fig.4 Fine fraction content of soil layers on landslides.

rather than sliding layers on tephra materials.

The fine fraction content (less than 75 μm) and plasticity index values also plotted on the plasticity index and fine fraction content chart (**Fig. 6**). That chart shows dissimilarity between the kuroboku and the scoria layers[1)]. Scoria layers show low fine fraction content and plasticity index values and kuroboku layers show high fine fraction content and plasticity index values[1)]. Moreover, the plasticity index and fine fraction content are lower at sliding layers on tuff breccia-andesite rather than sliding layers on tephra materials.

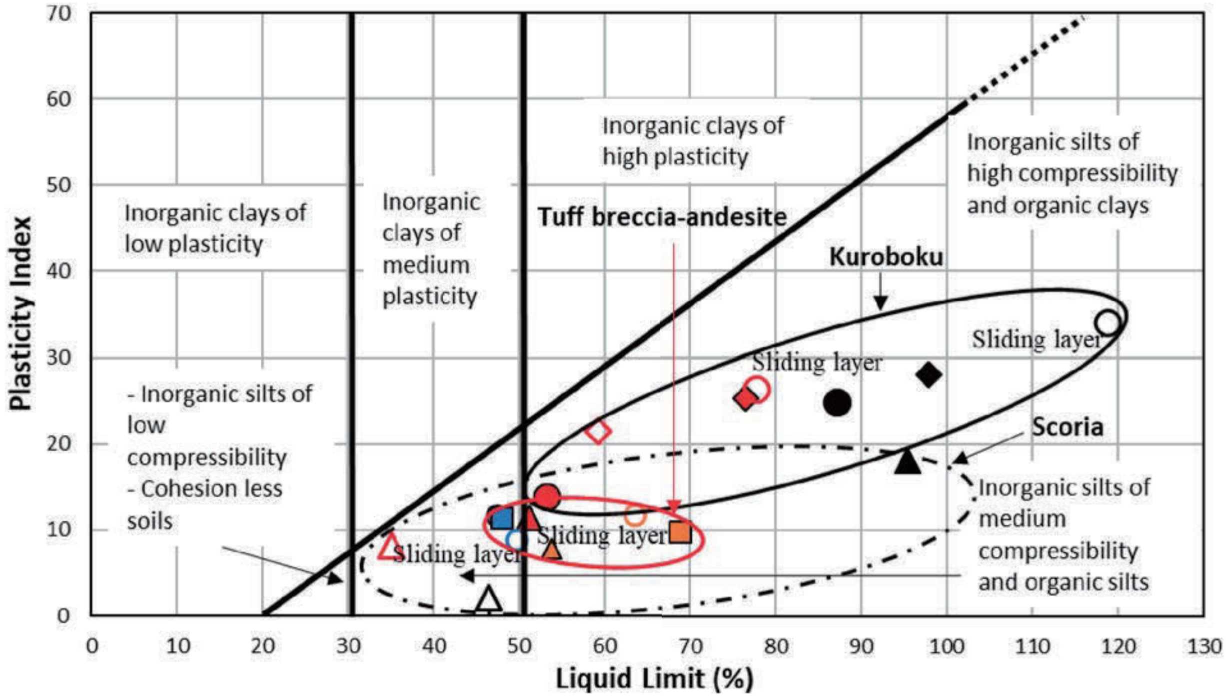


Fig.5 Plots of plasticity index and liquid limit of soil materials on the plasticity chart.

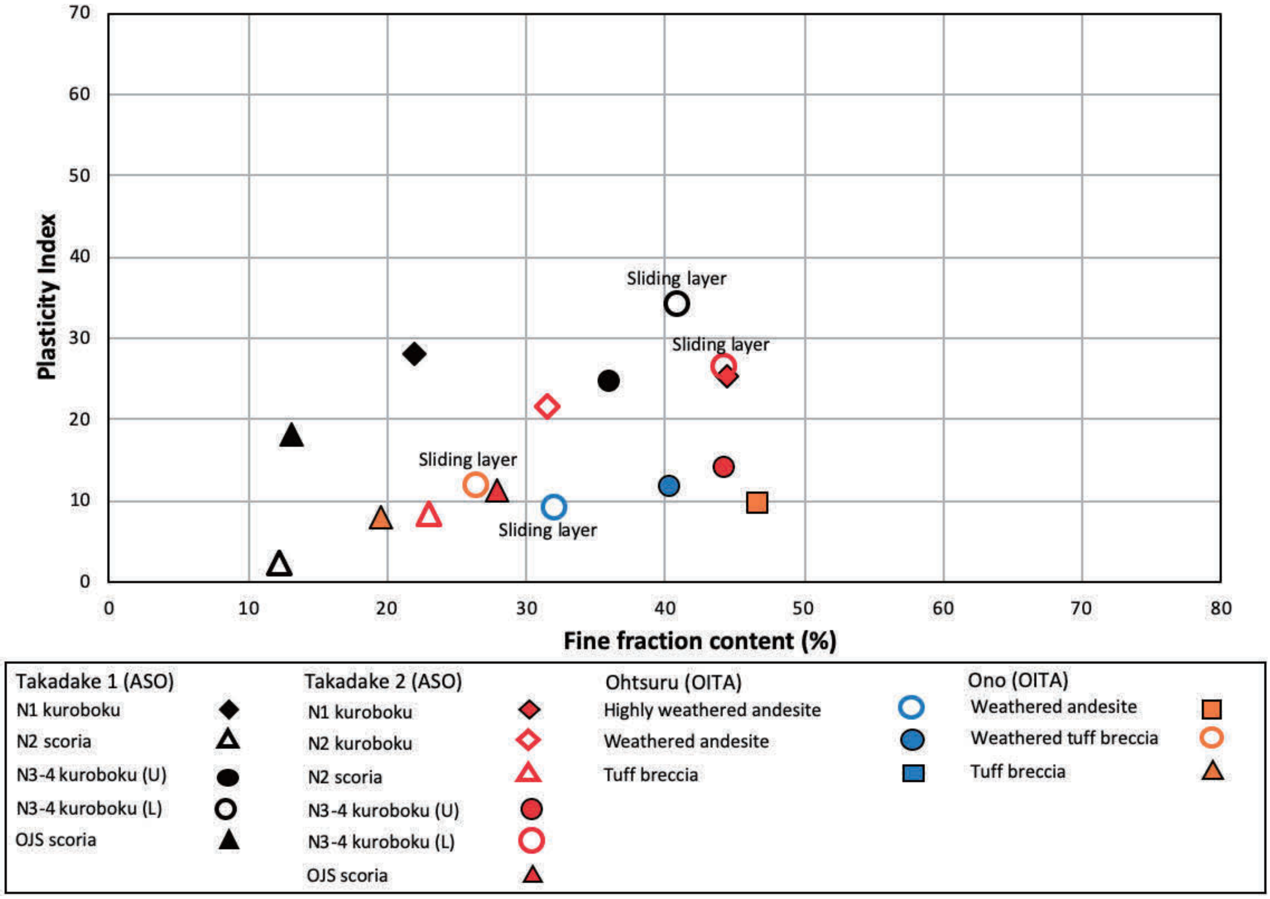


Fig.6 Fine fraction content (%)-plasticity index chart of soil materials on landslides.

5. CONCLUSIONS

This research aimed to compare the characteristics on sliding layer and surrounding layers between tephra and tuff breccia-andesite of landslides caused by heavy rainfall. Four locations of the landslide were selected as the research area. Two landslides were located at Aso volcanic mountains area which consist of tephra layers formed by volcanic activities and the other landslides were located at Oita prefecture which consist of tuff breccia-andesite materials.

The methods in this study were field observation and laboratory tests. Soil stratigraphic analysis and soil hardness measurements were observed on the field. Furthermore, the disturbed samples were collected from the center of each soil layers to observe the characteristics of soil in laboratory tests using particle size distribution and liquid limit and plastic limit tests.

The dissimilarity in soil hardness between kuroboku and scoria layers was found on tephra materials. Furthermore, the sliding layers from field observation in Takadake landslides were located at N3-4 kuroboku (L) which have the low average soil hardness. The sliding layer from field observation on the landslides which consist of tuff breccia-andesite materials were located at the boundary layer between tuff breccia and the upper layer. The sliding layer in Ohtsuru landslide was located at the boundary between tuff breccia and weathered andesite, and in Ono landslide was located at the boundary between tuff breccia and weathered tuff breccia. The obvious different soil hardness between those layers are shown; tuff breccia layers have the highest average soil hardness and the upper layers have the lowest average soil hardness.

For the particle size distribution, the same characteristic between tephra and tuff breccia-andesite materials were found. However, the sliding layers on tephra materials have a higher fine fraction content (less than 75 μm) than the other layers on each landslide.

The plasticity chart shows kuroboku and OJS scoria layers on tephra materials are inorganic silts of high compressibility and organic silts, and tuff breccia-andesite from Ono landslide also plotted at the same location as the kuroboku and OJS scoria layers. Furthermore, N2 scoria on tephra materials are inorganic silts of medium compressibility and organic silts, and tuff breccia-andesite from Ohtsuru landslide also plotted at the same location as the N2 scoria layers.

The range of plasticity index and liquid limit are higher at kuroboku layers rather than scoria layers at plasticity chart on tephra materials. The sliding layers on tephra materials have the highest plasticity index and liquid limit on each landslide. Furthermore, the tuff breccia-andesite materials plotted at the inside of scoria group. The plasticity index and liquid limit are lower at sliding layers on tuff breccia-andesite rather than sliding layers on tephra materials.

The plasticity index and fine fraction content chart shows dissimilarity between the kuroboku and the scoria layers. The sliding layers on tephra materials have higher plasticity index and fine fraction content than sliding layers on tuff breccia-andesite materials. According to these results, the tephra and tuff breccia-andesite materials on landslides caused by heavy rainfall have the different characteristics, especially the characteristics on sliding layers.

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REFERENCES

1) Istiyanti, M. L., Goto, S., Kimura, T., Sato, G., Hayashi, S., Wakai, A., Higaki, D.: Sliding layer estimation of shallow landslides on Aso volcanic mountains in Japan based on tephra layer-physical properties of soil, Geoenvironmental Disasters, 2020. (Accepted)

2) Kihira, K.: Physical and mechanical characteristics of the clay of sliding surfaces, Journal of Japan Landslide Society Vol.27(2), pp. 1-8, 1990.

3) Mitchell, J. K. and Soga, K.: Fundamentals of soil behavior, John, 3rd edition, pp. 85 and 95, John Wiley & Sons, Inc, 2005.

4) Japan Meteorological Agency: www.data.jma.go.jp/obd/stats/etrn/.

5) Sato, G., Goto, S., Kimura, T., Hayashi, S., Istiyanti, M. L., Komori, J.: Gravitational deformation as a precursor of shallow landslide within tephra-covered slope deposits in the Aso caldera, Japan, Journal of Japan Landslide Society, Vol.54(5), pp. 199-204, 2017.

6) The Japanese Geotechnical Society: Japanese Geotechnical Society Standards—Laboratory testing standards of geomaterials—, Vol. 1, 2015.

7) Geological Survey of Japan: https://gbank.gsj.jp/geonavi/geonavi.php.

8) Istiyanti, M.L. and Goto, S.: Physical and chemical of slip surface in landslides triggered by heavy rainfall at Hita, Oita, Japan, Proceeding of the 9th Symposium on Sediment-Related Disasters, pp. 67-71, 2018.

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