すべり面土のせん断強度特性に基づく亀の瀬地すべりの地質的特徴についての一考
Discussion of Geology of Slip Surface Soil of Kamenose Landslide through Shear Strength Parameters of Remoulded Specimens

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Introduction

In 1996, Terzaghi *et al* discussed shales, stiff clays and pure minerals based on the fully softened and residual shear strength results of remoulded samples in laboratory tests and gave different ranges of fully softened and residual shear strength values expected for soils belonging to those geologies. This paper attempts to broadly interpret the geological features of Kamenose landslide slip surface soil based on its mineralogy and the test results of its fully-softened and residual shear strengths in comparison with the published results for clays and shales by Terzaghi *et al* (1996).

Materials and Methods

Soil samples passing through 425 μm sieve were used to prepare the remoulded specimens for the shear tests. A ring shear apparatus (Gibo 1994) with outside and inside diameters of 10 cm and 6 cm, respectively, was used to measure shear strength under constant effective normal stress. Specimens were sheared using shear speeds of 0.01 mm/min during the stage of fully softened shear and then during the stage of residual shear. The two stages of shear were punctuated by a faster shear speed of 0.5 mm/min to achieve larger displacements with the most economical time duration.

Results & Discussion

Geologically, the Kamenose area is composed of Tertiary volcanic rocks and sedimentary rocks on top of a base of granitic rocks. The Kamenose landslide activity is believed to be caused by heavy and thick lava flow from Dorokoro volcano riding up onto a weak layer of strata that has altered and become clayey. Its slip surface soil has been found to consist of highly argillized clay layers. On the sampled cores, the slip surface has been sandwiched between strongly argillized upper layer of gravel and a lower layer of sandy tuff (Egashira & Gibo 1991). Its mineralogy is dominated by smectite (77%) with quartz (14%) and slight amounts of feldspar and Mica (3% and 4%, respectively) in the <425 μm fraction (Table 1). The presence of a high smectite content is a common geological feature in slip surfaces of landslides in tuff or tuffaceous material associated with volcanic activity, which are subjected to increased and repeated sliding (Shuzui 2001). Smectite is a group of clay minerals that includes dioctahedral montmorillonite and trioctahedral saponite. The high smectite content in the Kamenose samples may also be due to the increased bicarbonate ion concentration in the groundwater in close proximity of the slip surface in the Toghe bloc of the slide (Yoshioka & Okuda 1972), as it seems to promote the formation of smectite from other minerals (Shuzui 2001). In this discussion, the fully softened friction angle of intact clay is considered as equal to the peak friction angle (Φ_{sf}) of a composition normally consolidated from a slurry as described by Terzaghi *et al* (1996). The variation of fully softened friction coefficients of the samples is shown in fig.1. It is evident from fig.1 that, with the increase of effective normal stress from 50 kPa to 400 kPa, the fully softened friction coefficient tends to decrease. This behaviour can be expected from geologies that are similar in mineral composition to that of the Kamenose slip surface samples, taking into account of the existence of high smectite content in them. At the lowest effective normal stress of 50 kPa, the particle arrangement could be visualized as a more random marix with a mix of face-to-face and edge-to-face particle interactions. As the effective normal stress increases through 100 kPa and 200 kPa up to 400 kPa, the edge-to-face interactions are reduced, while the face-to-face interaction of smectite particles

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dominates the matrix. At large shear displacements, the high content of smectite in the test samples promoted better orientation of platy particles along the shear plane that it produced polished and striated slickensides on the shear surface. The platyness of smectite particles, which promoted a high degree of face-to-face orientation and reduced interparticle friction, resulted as expected in very low residual friction angles that are as low as 8º. Terzaghi *et al* (1996) concluded that a relationship between fully softened strength (Φ_{sf}) and residual strength (Φ_r) should exist because both depend on the fundamental variables of particle size and platyness (fig. 2). In fig. 2, they suggested that the lower limit is defined by sodium montmorillonite with 1-mm-thick filmy particles, where the predominant particle orientation is face-to-face for both highly oriented and random geological fabrics and the Φ_{sf}-Φ_r is very small and close to each other. The other extreme is represented by non-platy particles such as quartz. Terzaghi *et al* concluded that the drained shear strength difference between Φ_{sf} and Φ_r is maximum at intermediate composition and this intermediate compositions correspond to clays and shales with values of Φ_r in the range of 8º to 12º and the values for Φ_{sf}-Φ_r in the range of 10º to 20º. The Φ_r values for the Kamenose samples in the present study ranged from 7º to 11.5º and the difference Φ_{sf}-Φ_r ranged from 8.4º to 19.6º (Fig. 2) agreeing very closely with the results published by Terzaghi *et al*.

Table 1. Mineralogy of Kamenose sample

Mineral	%
Smectite	77
Mica	2
Kaolinite	1
Quartz	14
Feldspar	3
Others	3

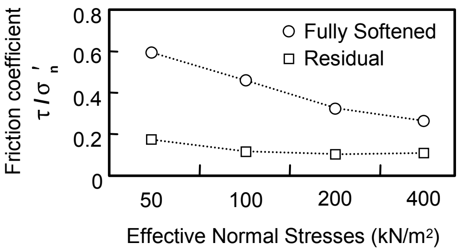

Fig. 1. Variation of fully softened and residual friction coefficients with effective normal stress of Kamenose sample

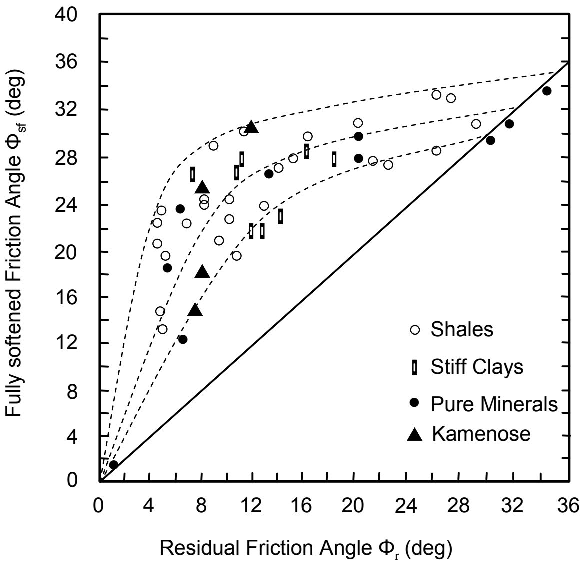

Fig. 2. Φ and Φ_r of Kamenose sample. Adapted and modified after Terzaghi, Peck & Mesri (1996)

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