Soil Creep Measurements in Khumbu*

Shuji Iwata**

Abstract

The rates of down-slope soil movement in two sites in Khumbu Himal were measured from November, 1974 to July, 1976. The average movements of pipes and painted stones were 0-0.4 cm/yr. at Lhajung (4420 m) and 0.2-0.5 cm/yr. at Kongma (5400 m). These low rates are due to the shortage of moisture content in the soil, dense vegetation, and non-frost-susceptible soil.

1. Introduction

Down-slope soil movement has been considered to be an important process for slope evolution in periglacial environments above timberline. In Khumbu Himal, Eastern Nepal, however, it is a question whether the soil movement connected with frost action is a major slope process or not, because only few sorted patterns exist (Iwata *et al.*, 1976). Therefore, measurements of actual down-slope soil movement were carried out at two experimental sites.

2. Experimental sites

The experimental sites were established on the slopes around the weather screens at Lhajung (4420 m) and Kongma (5400 m) (Fig. 1).

At Lhajung, measurements were carried out on four slopes of a gentle moraine ridge of the Thyangboche stage (Iwata, 1976). Soil and grass vegetation were well-developed and they showed no apparent difference by slope orientations. The inclination was steepest on the west-facing slope (27°) and most gentle on the south-facing slope (10°).

The experimental site at Kongma was located on the north and south slopes of the Lobuche stage moraine (Iwata, 1976). The moraine had fresh surface where soil was less developed and many stones were projected from the ground surface, covered with dwarf mat or cushion vegetation.

The existence of permafrost has not been confirmed yet in the Kongma valley, though Fujii

and Higuchi (1976) indicated the existence of permafrost above 4900 m to 5000 m in this region by ground temperature measurements.

3. Measurements of soil movement

Aluminium and steel pipes, 10 cm long and 0.7-0.9 cm in diameter, were inserted up to their tops in the ground at straight reference lines on experimental slopes. The reference lines were checked by a plumb and steel tape from fixed points which were chiseled on large and almost buried rocks. It seemed that these rocks used as fixed points were stable. In fact, they often served as dams for moving soil.

Twenty eight pipes were installed in 5 lines at Lhajung on November 16, 1974 and 16 pipes in 2 lines at Kongma on November 2, 1974. The north-facing slope at Kongma was covered by 5-10 cm of snow and the ground had frozen already at that time. At the Kongma site 40 stones with various sizes of 1-30 cm which were partially buried among the pipes on the lines were marked by painting.

The measurements were carried out at Lhajung on June 27, 1976 and at Kongma on July 3, 1976. The movements of pipes and painted stones were measured at a right angle to the reference line and parallel to the ground surface from the reference line. The accuracy of measurements is considered to be within ± 0.2 cm.

The results of measurements are shown in Table 1. The rates of movement were low, the maximum was only about 2 cm for 20 months and the average movements at Kongma were higher than those at Lhajung. Up-slope movements were observed at some pipes and stones, a phenomenon which was also reported by Washburn (1967) and Benedict

* *Glaciological Expedition of Nepal, Contribution No. 54*

** *Research student, Tokyo Metropolitan University, Setagaya-ku, Tokyo 158*

Fig. 1. Experimental sites and distribution of patterned ground.

A. experimental site at Lhajung. B. soil moisture measurements C. experimental site at Kongma. 1. reference line. 2. earth hummocks. 3. solifluction lobes. 4. sorted pattern. 5. moraine ridges. 6. rock wall. 7. pond. 8. talus.

Table 1. Surface movements in experimental sites.
(November, 1974 - July, 1976)

Site	Slope Orientation	Average Inclination/°	Marker	Movement/cm	
				average	range
Lhajung	N	13.5	8 pipes	0.7	0 —1.3
	E	19	4 pipes	0.1	—0.4—0.4
	S	10	9 pipes	0.4	0 —1.1
	W	27	7 pipes	0	—0.2—0.5
Kongma	N	14.5	8 pipes	0.4	0 —1.0
			13 stones	0.8	0 —3.0
	S	20.5	9 pipes	0.9	0 —1.0
			27 stones	0.7	—1.0—2.0

(1970). The relation between the movements and slope orientation was reverse in both sites; the higher rate of movement appeared on the north-facing slope at Lhajung and on the south-facing slope at Kongma. There was no apparent relation between slope inclination and the movements.

Since the period of measurement covered two winters, if the soil movements were mainly due to the frost action, the average rate of the annual movements was 0.04 cm/yr. at Lhajung and 0.2–0.5 cm/yr. at Kongma. The rates of soil movement at Lhajung (except for the north-facing slope) was

0–0.2 cm/yr. and were similar to the seasonal creep in temperate or semi-arid climates (Young, 1972). The rates of movement on the other slope (Kongma and the north-facing one at Lhajung) coincided with those of frost creep under periglacial environments (Rudberg, 1964; Washburn, 1967).

4. Soil temperature

According to the report of the soil temperature in Khumbu (Fujii and Higuchi, 1976), the duration of below-zero temperature at 20 cm depth in the winter of 1973–1974 was 120 days at Lhajung. The

Fig. 2. Soil temperatures at Lhajung and Kongma. Daily maximum and minimum temperature at a depth of 10 cm.

soil temperature at Kongma was intermittently recorded for a total of eleven weeks from July until November, 1974. A part of the data obtained at Kongma is shown in Fig. 2 compared with those at Lhajung. The soil temperature at Kongma was about 6°C lower than Lhajung and had the same tendency of annual variation as that at Lhajung. It is estimated from the reduced ground temperature curve at Lhajung (Fujii and Higuchi, 1976, Fig. 1) that the duration of below-zero temperature at 20 cm depth was about 180 days at Kongma.

The number of days during which the soil temperature at a depth of 10 cm fluctuated between plus and minus was only 7 days at Lhajung where the soil temperature fell suddenly in October and November. While the minimum soil temperature at a depth of 10 cm at Kongma fell below 0°C at the beginning of September, the maximum temperature fell below 0°C in the middle of November; therefore the soil temperature fluctuated between plus and minus for a long duration. Freezing and/or thawing may occur at Kongma on about 120 days in a year.

As mentioned above, the soil temperature conditions at both sites are sufficient for soil frost but the numbers of freeze-thaw days are very different.

5. Soil moisture and frost heaving

Measurements of soil moisture contents were

Fig. 3. Soil moisture contents at Lhajung.

carried out near the experimental site at Lhajung (Fig. 1). Samples of soil were weighed, dried in desiccators until constant weights were achieved and then reweighed. The moisture contents were not high even during the Monsoon and became extremely low in November (Fig. 3). Although on February 17, 1975 the ground was covered by 2-3 cm thick snow, the moisture contents were not high, 10% at 1-10 cm depth and 11% at 5-15 cm depth.

A frost-heave frame was placed at the Lhajung experimental site in October, 1974, but it recorded heavings of only few millimeters until February, 1975. The pipes for measurement of soil movement at Lhajung had not been heaved from their original positions in November, 1974 when the measurements were made in July, 1976.

Measurements of soil moisture content were not carried out at Kongma. The vertical displacements of the pipes for 20 months at Kongma were 0.5-1 cm on the south-facing slope and 0.5-2 cm on the north-facing slopes.

6. Conclusion

There are many factors which control rates of soil movement, such as soil temperature, rates of penetration of the freezing plane, moisture content, slope inclination, vegetation and so on. These are interrelated and it is difficult to isolate the effect of any single factor, but soil moisture is considered to be the most important (Washburn, 1967; Price, 1973).

It seems that the cause of the low rate of soil movement at Lhajung is due to the low soil moisture in autumn when the soil begins to freeze. The highest rate of movement at Lhajung was observed only on the north-facing slope where high soil moisture content occurred due to long-lasting snow. This conclusion is supported by the distribution of patterned ground which is restricted only at the place of high soil moisture conditions such as in shallow hollows and on north-facing slopes (Fig. 1),

Because the soil temperature at Kongma reached below 0°C in September while the ground received considerable rain from the Monsoon, the ground could freeze. It is considered that the cause of the low movement rates at Kongma are due to the mat and cushion vegetation and the non-matured stone-rich soil.

As the rate of solifluction summarized by Washburn (1967) and Benedict (1970) in the arctic and alpine regions range between 3 and 6 cm/yr., the rates of soil movement observed are less than that of solifluction. The results indicate that solifluction is a minor process for slope evolution at both experimental sites. In fact, there occur only few solifluction features around the experimental sites. Many vegetated lobes, however, were observed on slopes in the areas around the Dzonglha Khalka and the Khumbu Glacier (Glacier EC 200) and in the upper part of the Imja basin. Because some vegetated lobes were apparently formed by solifluction, it is difficult to conclude that the solifluction process is unimportant in the whole area of the Khumbu Himal.

References

- Benedict, J.B. (1970): Downslope soil movement in a Colorado Alpine Region: Rates, processes, and climatic significance. *Arc. Alp. Res.*, **2**, 165-226.
- Fujii, Y. and Higuchi, K. (1976): Ground temperature and its relation to permafrost occurrence in the Khumbu Region and Hidden Valley. *Seppyo*, **38**, special issue, 125-128.
- Iwata, S. (1976): Late Pleistocene and Holocene moraines in the Sagarmatha region, Khumbu Himal. *Seppyo*, **38**, special issue, 109-114.
- Iwata, S., Fujii, Y. and Higuchi, K. (1976): Nepal Himalaya no Kohzohdo (Patterned ground in the Nepal Himalayas). *J. Geogr.*, **85**, 143-161.
- Price, L.W. (1973): Rates of mass wasting in the Ruby Range, Yukon Territory. *Permafrost*, North American Contribution, National Academy of Science. 235-245.
- Rudberg, S. (1964): Slow mass movement processes and slope development in the Nowa Storfjäll area, Southern Swedish Lappland. *Zeit. Geomor. N.F. Supplementband*, **5**, 192-203.
- Washburn, A.L. (1967): Instrumental observations of mass-wasting in the Mesters Vig district, north-east Greenland. *Meddr. Grønland*, 166 (4), 267pp.
- Young, A. (1972): *Slopes*. Longman, London and New York, 288pp.