Recently, many scientists have developed a technique for predicting maximum avalanche run-out distance (Lied and Bakkehåi, 1980; Bakkehåi et al., 1983; Martinelli, 1986; McClung and Lied, 1987).

The objective of this study also is to know the run-out distance of a long-running avalanche which caused heavy damage in Japan. The relations among the total volume (V) of snow broken in a rupture zone, the vertical avalanche fall height (H), the total horizontal distance (L) and the altitude (h) of the start point of the avalanche were investigated using the records of recent avalanche disasters which occurred in Japan, including several big-scale avalanches. The equivalent coefficient of friction (μ) is defined as (Izumi, 1985; Glenne, 1986),

$$\mu = H / L = \tan \alpha$$

(1)

where $H$, $L$, and $\alpha$ are shown in Fig. 1.

Fig. 1 Schematic diagram of avalanche geometry.

a: avalanche starting point
b: end of the debris
C: avalanche path
L: horizontal reach

I. Associate Professor, Research Institute for Hazards in Snowy Areas, Niigata University, Niigata, Japan 950-21.
Figure 1 shows the schematic diagram of avalanche geometry. In the figure, the angle $\Theta$ is defined by sighting from the extreme point reached by avalanches in the past (extreme run-out position) to the starting point and $\alpha$ is the angle defined by sighting between the position $b'$ and the starting point. In Fig. 1, $b'$ is defined as the point at the same elevation as $b$ for which the distance $0-b'$ is the same as the true horizontal reach ($L$). The true horizontal reach ($L$) is that defined by projection of the path onto the plane defined by $0-b-b'$. The excessive travel distance ($L_e$) also can be defined as the horizontal distance of the front of the avalanche beyond the distance one expects from a frictional slide down with a coefficient of kinetic friction of $\tan 32^\circ$, namely,

$$L_e = L - H / \tan 32^\circ \tag{2}$$

where the angle $32^\circ$ is the experimental result from Endo and Akitaya (1974).

Figure 2 shows the relation between the equivalent coefficient of friction and snow volume broken. In the figure, $\triangle$, $\bigcirc$ and $\bullet$ are the surface avalanche of dry snow, full-depth avalanche of dry snow, and full-depth avalanche of wet snow respectively, and the arrow in the figure was put on the avalanche which went down naturally without encountering structures. The value of $\mu$ decreases with increasing the snow volume broken. From the figure it seems that a big avalanche travels a longer distance.

![Graph showing the relation between equivalent coefficient of friction and snow volume broken.](image)

**Fig. 2** Variation in equivalent coefficient of friction ($\mu$) with avalanche volume ($V$).

The big scale avalanches greater than $1 \times 10^3$ in the volume of snow were slab avalanches of dry snow and had smaller equivalent coefficient of friction than any other avalanches.
Figure 3 illustrates the relation between the excessive horizontal distance and the snow volume broken. The excessive travel distance was minor or negligible for full-depth avalanches with less than about $3 \times 10^3 \text{m}^3$ in the volume. The excessive travel distance of the slab avalanche of dry snow increased with increasing the snow volume broken.

The excessive distance also increased linearly with increasing the altitude of the avalanche starting point. The minimum value of the angle of elevation of the avalanche from the outer end of debris to the avalanche starting point fitted to the criterion angle $18^\circ$ empirically obtained in Japan (Takahashi, 1960).

![Diagram showing the variation in excessive horizontal distance (Le) with avalanche volume (V).](image)

**Fig. 3.** Variation in excessive horizontal distance (Le) with avalanche volume (V).
REFERENCES


