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Ram resistance of a seasonal snowcover

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सार — इस शोधपत्र में प्रत्यानयन गुणांक के आधार पर हिमाच्छादन का रैम प्रतिरोधक मालूम करने के लिए एक संशोधित सूत्र प्रतिपादित किया गया है। हिमधाव के पूर्वानुमान में इसका प्रचालन विषयक महत्व है ।

ABSTRACT. In this paper a modified formula has been derived for working out Ram resistance of snowcover considering coefficient of restitution. It has an operational value in avalanche forecasting.

1. Introduction

Snow, which comprises of ice crystals, air, water vapours and impurities, may avalanche due to structural weakness of the snowcover resting on a slope. Weakness may develop due to over burden or metamorphic processes. Identification of the weakness, thus developed, is of concern to an avalanche forecaster besides mountaineers, skiers and back country travellers. Appropriate assessment of the weakness and hence the stability of the snowpack requires continuous monitoring of numerous snow and meteorological parameters, which may not always be feasible.

For quick assessment of snowpack stability, an index of relative strength called Ram resistance (R) (defined as the resistance offered by snow to penetration of metal cone when rammed with known force) was evolved by Perla (1976). The equation used for the computation of Ram resistance assumes that the coefficient of restitution is 1.0 (collision between the guide rod & shaft is perfectly elastic) and the total energy produced by the impact of the hammer is transferred to the tip of the cone. The aforesaid assumptions remain fairly valid for R values upto 20 kg, beyond which the difference is found to be alarming.

In order to improve upon the equation, Gubler (1974) considered the effect of partial restitution and derived the expression for mean Ram resistance (R) and concluded that the energy transfer would improve by 30-60% if the shaft and the guide rod were made integral. This paper suggests yet another expression taking partial restitution into account but without catering for the energy losses between the guide rod and the shaft subsequent to the impact.

2. Measurement of Ram resistance

Ram penetrometer consists of an aluminium tube (generally one metre long) with a conical tip at one side. Through a thin guide rod a hammer weighing one or two kg is dropped from a known height. The energy of hammer blow causes penetration of the rod into the cover.

Let the weight of the hammer and tube with guide rod be m_1 and m_2 kg respectively; height of the fall of hammer be h cm, the depth of penetration in n strokes be $\triangle$ (cm) (Fig. 1), then the Ram resistance of the layer (R) in kg is :

$$R = \frac{m_1 n h}{\triangle} + m_1 + m_2 \qquad (1)$$

This is the equation which is being used in practice for operational evaluation of snow resistance and hence the stability indices of snowcover in India, Switzerland and many other countries (Upadhyay *et al.* 1977).

The derivation of Eqn. (1) assumes, the following approximation :

(*i*) The coefficient of restitution = 1.

(*ii*) All the energy produced by the impact of hammer including potential energy of the system is transferred to the tip of the cone.

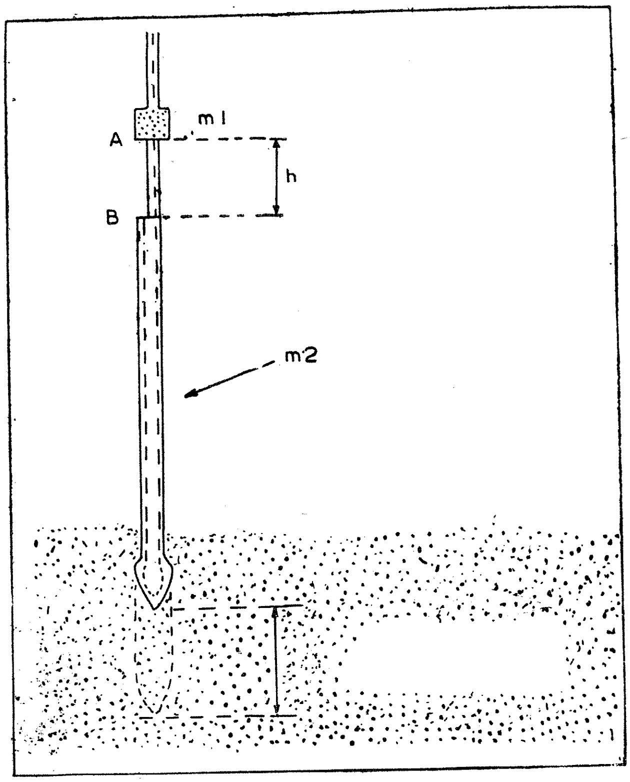

Fig. 1. Measurement of R by Ram penetrometer

Besides, if free penetration of the penetrometer tube, be △ then the resistance of this layer should be $\leqslant m_2$ whereas Eqn. (1) shows that $R=m_2$.

3. Modified expression

Writing down the equation of motion based on the laws of conservation of momentum for direct impact between hammer and tube, we obtain:

$$v_2 - v_1 = e(u_1 - u_2) \tag{2}$$

and

$$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2 \tag{3}$$

where, u_1, u_2 are velocities of hammer and tube before impact,

v_1, v_2 are velocities of hammer and tube after impact,

e is coefficient of restitution and

m_1, m_2 are masses of hammer and that of the tube *plus* guide rod respectively.

In a free fall through height h, the velocity of hammer just before impact can be computed as :

$$u_1 = \sqrt{(2gh)} \tag{4}$$

and since the tube will be at rest,

$$u_2 = 0.$$

Applying the laws of conservation of energy and assuming that the entire energy produced by the impact is transferred to the tip of the cone, we may say that all the energy has been consumed in overcoming the resistance offered by the layer of the snow. Hence,

$$\text{Change in energy} = [\tfrac{1}{2}m_1v_1^2 + \tfrac{1}{2}m_2v_2^2 + (m_1+m_2)\Delta g] \tag{5}$$

$$\text{Work done in overcoming the resistance offered by snow layer} = R^*.\Delta g \tag{6}$$

where R^* is the average Ram hardness for the layer of thickness △.

Equating the two, we get:

$$\tfrac{1}{2}m_1v_1^2 + \tfrac{1}{2}m_2v_2^2 + (m_1 + m_2)\,\Delta g = R^*\Delta g \tag{7}$$

Substituting the values of u_1 and u_2 from Eqns. (4) and (5) in (2) and (3), we get

$$v_2 - v_1 = e\sqrt{(2gh)}$$

$$m_1v_2 + m_2v_2 = m_1\sqrt{(2gh)} \tag{8}$$

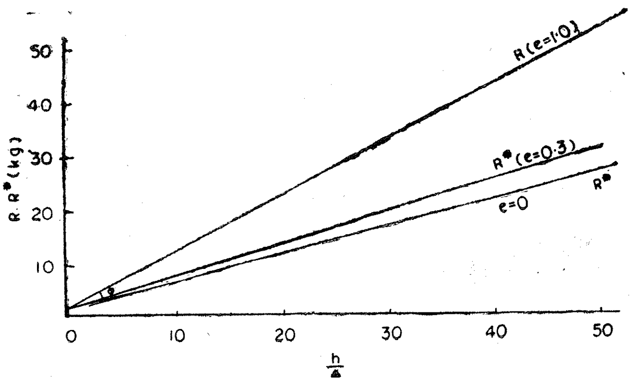

Fig. 2. Variation of R and R^* with $h/\triangle$

Solving aforesaid equations for v_1 and v_2 and substituting the same in Eqn. (7) we get after rearranging :

$$R^* = \frac{m_1 h}{\triangle(m_1+m_2)} (m_1 + e^2 m_2) + m_1 + m_2 \qquad (9)$$

4. Discussion

If $e=1$ the Eqn. (9) reduces to Eqn. (1) which is in operational use at present.

$$\text{Now,} \quad R - R^* = \frac{n h m_1 m_2}{\triangle(m_1+m_2)} (1-e^2) \qquad (10)$$

In practice, generally $m_1 = m_2 = 1$ kg; then

$$R - R^* = \frac{nh}{2\triangle} (1-e^2) \qquad (11)$$

This shows that (*i*) R is always greater than R^*, (*ii*) the difference, $R-R^*$, is inversely proportional to $\triangle$, the depth of penetration. Thus for harder snow, where $\triangle$ is less, the difference between resistance calculated from Eqn. (1) and (9) is highly significant.

Consider the following examples:

Example (a) : In soft snow, let
$n=1$, $h=10$ cm, $\triangle = 25$ cm, then
$R = 2.40$ kg
$R^* = 2.25$ kg if $e=0.5$
$= 2.20$ kg if $e=0.0$

Example (b) : In a very hard snow layer formed by wind crust or refrozen crust,
$n=1$, $h=20$, $\triangle = 0.5$ cm then
$R = 42.0$ kg
$R^* = 25.0$ kg for $e=0.5$
$= 20.0$ kg for $e=0.0$

Thus for softer or fresh snowcover, the Eqn. (1) may be used without much error, but for harder layers the differences are alarming. Fig. 2 shows the variation of R and R^* with $h/\triangle$. The lines are diverting apart towards higher values of $h/\triangle$, *i.e.*, for harder layers. Assume that $m_1 = m_2$; for 1 stroke the angle between R and R^* lines ($e=0.0$) is $\tan^{-1}(1/3)$, whereas the angle between $R^*(e=0.5)$ and R^* ($e=0.0$), line is only $\tan^{-1}$ (0.092).

However, while considering stability of snowcover from avalanche point of view the resistance beyond a Ram number of 20 to 25, it is not really pertinent as to how much more hard is the snow layer since a value around 20 would indicate that snow has hardened considerably.

The alloy or the metal used in Ram penetrometer may have a coefficient of restitution nearer to 0.0 than to 1.0. Even in case where actual value of e is not known it can obviously be seen that the use of Eqn. (9) for the computation of Ram resistance taking $e=0.5$ or 0.0 will be more appropriate than Eqn. (1).

5. Conclusion

Ram resistance given by Eqn. (1) or (9) does not describe compressible shear or tensile strengths of the cover. It is only an index, which suggests relative variations in strength from layer to layer. Eqn. (1) which gives more weightage to the stronger layer generally plays oversafe from avalanche forecasting point of view in assessing the weaknesses. This may affect the accuracy of forecasts by direct evidence.

Eqn. (9) suggests that computation of Ram resistance is not free from all approximations given earlier. It does presume that all the energy of the system is transferred to the tip of cone of the penetrometer, but it obviously gives better results than we get from Eqn. (1) and hence worth trying in operational use for studying the stability of snowcover.

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