COMPUTING THE BREAK POINT OF SNOW SLIDE

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1. Introduction

Snow stabilization fence is one of the main means for preventing snowslide. The design of snow fences and space between them are usually determined according to experience, so there must be a big variation and the design is often not perfect. This paper, based on the adhesive and plastic property of snow, using the material dynamics theory, tried to set up a computational model at the breaking critical point of the on slopes, and modified this model according to the author many years experience on snowslide treatment.

2. Computing Model

Snow can be treated as a kind of adhesive and plastic material. Suppose the falling of snow forms an arc shape, and its bottom is tangent to the slope, as shown in Figure 1, snow slide along arc BAC, according to the computing scheme of adhesive material when losing stable mode, when snow slides, its weight and the shearing force along the arc shall form a equilibrium force system.

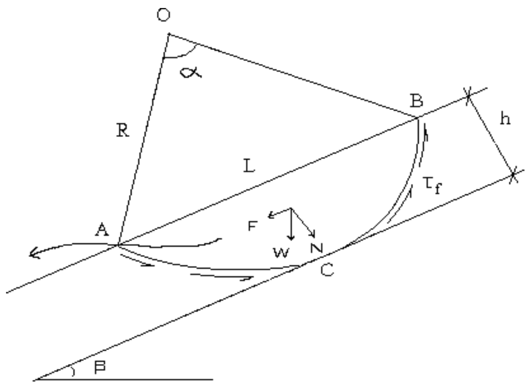

Figure 1 Snow sliding model

2.1 Weight of snow and its components

Snow weight：

$$W=\int_o^a\int_{R-h}^R \gamma r dr d\theta=\frac{\gamma\alpha}{2}r^2\Big|_{R-h}^{R}=\frac{\alpha\gamma}{2}\left[R^2-(R-h)^2\right]\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

Gravity center of snow body:

$$S_r=\int_o^a\int_{R-h}^R r r dr d\theta=\frac{\alpha}{3}\left[R^3-(R-h)^3\right]\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(a)$$

$$S_r=\int_o^a\int_{R-h}^R r r dr d\theta=\frac{\alpha}{3}\left[R^3-(R-h)^3\right]\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(b)$$

and the coordinates:

$$r_c = \frac{S_r}{S} = \frac{2}{3}\left[\frac{R^3-(R-h)^3}{R^2-(R-h)^2}\right]$$

$$r_\theta = \frac{S_\theta}{S} = \frac{\alpha}{2}$$

Components of weight force:

Along slope:

$$F = W\sin\beta = \frac{\alpha\gamma}{2}\left[R^2-(R-h)^2\right]\sin\beta \cdots\cdots(3)$$

Along slope norm:

$$N = W\cos\beta = \frac{\alpha\gamma}{2}\left[R^2-(R-h)^2\right]\cos\beta \cdots\cdots(4)$$

2.2 Shearing force on arc surface

According to Moor-Kuer theory:

$$\tau_f = \sigma tg\phi + C \cdots\cdots(5)$$

Φ——snow friction angle

C——snow adhesive force

Here:

$$\sigma = \frac{N}{AB} = \frac{\alpha\gamma}{2}\left[R^2-(R-h)^2\right]\cos\beta/2\sqrt{R^2-(R-h)^2} = \frac{\alpha\gamma}{4}\cos\beta\sqrt{R^2-(R-h)^2} \cdots\cdots(c)$$

put it into （5）:

$$\tau_f = \frac{\alpha\gamma}{4}tg\phi\cos\beta\sqrt{R^2-(R-h)^2} + c \cdots\cdots(6)$$

2.3 Equilibrium condition

Computing the moment to point O, then we have equilibrium equations:

$$F\gamma_c - R^2\alpha\tau_f = 0 \cdots\cdots(7)$$

$$F\gamma_c - \int_b^a \tau_f RRd\theta = 0$$

Put (6)、（3） into (7), we have:

$$\frac{\gamma}{3}\sin\beta\left[R^3-(R-h)^3\right] - R^2\left[\frac{\alpha\gamma}{4}tg\phi\cos\beta\sqrt{R^2-(R-h)^2} + c\right] = 0 \cdots\cdots(8)$$

Along slope direction, the equilibrium condition $\Sigma F_{AB} = 0$

That is：

$$\frac{\alpha\gamma}{2}\left[R^2-(R-h)^2\right]\sin\beta - 2\sqrt{R^2-(R-h)^2}\,\tau_f = 0 \cdots\cdots(9)$$

Solve the equation, we have:

$$a = \frac{4C}{\sqrt{R^2-(R-h)^2}\,(\sin\beta - tg\phi\cos\beta)\gamma} \cdots\cdots(10)$$

From (8), we have:

$$\left[1-\frac{4C}{\sqrt{R^2-(r-H)^2}(\sin\beta-tg\phi\cos\beta)\gamma}\right]\cdots\cdots\cdots\cdots(11)$$

And

$$R=\frac{1\pm\sqrt{1-\frac{4}{3}e}}{2e}h\cdots\cdots\cdots\cdots(12)$$

Here:

$$e=1-\frac{C}{(\sin\beta-tg\phi\cos\beta)\gamma h}\cdots\cdots\cdots\cdots(13)$$

From R, according to the geometric relation,

$$L=2\sqrt{R^2-(R-h)^2}\cdots\cdots\cdots\cdots(14)$$

β ——grade； γ ——volume weight（g/cm^3）；

Φ ——inner friction angle; C——snow adhesity（g/cm^2）；

h—— snow thickness （cm）

Modify（14）by temperature, we get the snow break length:

$$L=2K\sqrt{R^2-(R-h)^2}\cdots\cdots\cdots\cdots(15)$$

K——Temperature index 1.85--2.35。

Equation (15) can be used to compute the space of snow fences and snow walls. It shall be noted that the formula is sensitive to the parameters. The parameters in above formula come from actual observation and former experience in snow disaster prevention constructions.

3. Comparison of Space Calculation

In our country and Jpan, when computing the space of snow stabilization constructions, the formula originated from Swiss Snowslide Prevention Institute is used:

$$L=2\frac{2tg\beta}{tg\beta-tg\varphi}H$$

Here

L—Space between constructions（m）；

β —Slope grade;

H—Thickness of snow cover（m）；

tgΦ —Friction index between the slope and snow 0.5--0.7。

This formula is from experience, it comes from regression of data of experiment constructions. Same as the formula in this paper, this formula is also very sensitive to parameters. Table 3-1 shows the comparison data result from these two formula. The result of the experience formula is evidently irrational between 35° ～40° when different parameters are used.

Table 3－1 Space Computing Comparison

Formula / Grade	$L = 2K\sqrt{R^2 - (R-h)^2}$			$L = 2\dfrac{2tg\beta}{tg\beta - tg\varphi}H$			Comment
	K=1.85	K=2.00	K=2.45	tgΦ=0.5	tgΦ=0.6	tgΦ=0.7	R=0.23 (g/cm^3) H=166cm
30°	25.3			24.8			
35°	13.4	14.5	17.7	11.6	23.2	11.2	
40°	9.1	9.9	12.1	8.2	11.7	20.0	
45°	7.3	7.9	9.7	6.6	8.3	11.1	C=6.5 (g/cm^3)
50°	6.2	6.7	8.2	5.7	6.7	8.0	
55°	5.2	5.7	6.9	5.1	5.7	6.5	

Along National Highway G312 at Guozigou, the average grade of No.1 red-soil slope was 35° , the calculated spaces were 13-16m, the average grade of No.4,5 slopes was 38° , the calculated spaces were 10-14m.

The verification computation according to the grade, ground roughness, snow thickness and density of snowslide profile affirmed the correctness of this model. Also this model is more practical than foreign computing methods both in the preciseness and computational scope, and providing precise computational basis for the snow stabilization project by using snow fences.

The formula suggested here has considered the physic dynamic properties of snow, and the computing result is reasonable. The experience formula mainly considered the friction index, slope grade and snow thickness, its computing results vary great at different conditions.

This model was used in the design of the Guozigou snowslide treatment construction along National Road No. 312.