New Approaches for the Analysis of Loess Slope Stability

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INTRODUCTION

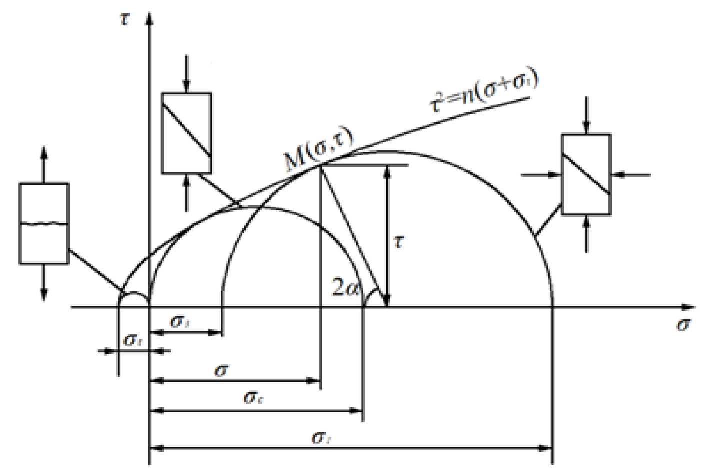
Currently, the method of limit-equilibrium is being used for the analysis of slope stability. To satisfy the equations of equilibrium, the conditions of yield and stress boundary by ignoring the deformation of soil, the yield criterion and the associated plastic flow rule should be met otherwise accuracy cannot be guaranteed. In the recent past, the theory of limit analysis has widely been used in the analysis of slope stability because it provides the accurate solutions of upper-bound and lower-bound.

QUADRATIC-PARABOLIC FAILURE CRITERION

$$\tau^2 = n(\sigma + \sigma_t)$$

$$\frac{1}{2}(\sigma_1 - \sigma_3) = \frac{\tau}{\sin 2\alpha}$$

$$\frac{1}{2}(\sigma_1 + \sigma_3) = \sigma + \tau \cot 2\alpha$$

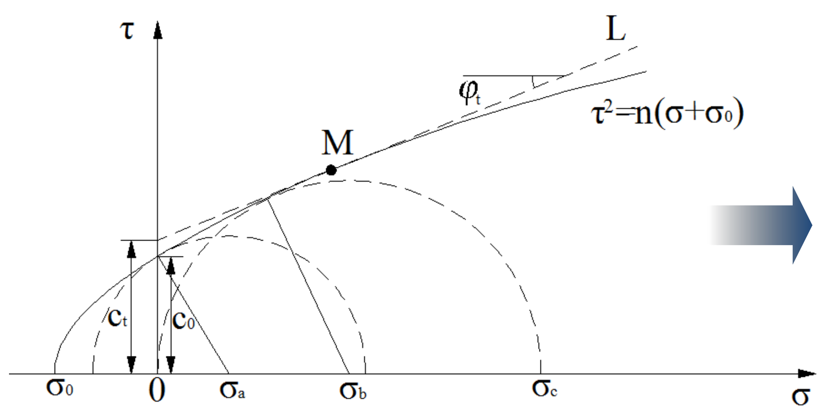


(1) the gradient of curve decreases with the increase of stress, and (2) the friction angle becomes smaller as it is concerned with the nature of undisturbed loess itself.

UPPER-BOUND SOLUTION OF PLASTIC-LIMIT ANALYSIS

When objects in plastic-limit state, assumes stress field and admissible velocity field respectively to that of equilibrium-stress field and compatible-velocity field for the virtual-work principle, then virtual-work principle can mathematically be expressed as follows:

$$\int_V \sigma_{ij} \dot{\varepsilon}_{ij} dV = m^* \left(\int_V F v_i \, dV + \int_A T v_i \, dS \right)$$



$$c_t = \frac{n}{4\tan\varphi_t} + \tan\varphi_t \sigma_t \qquad (\sqrt{n\sigma_t}, +\infty)$$

$$\tan\varphi_t = \frac{d\tau}{d\sigma} = \frac{n}{2\sqrt{n(\sigma+\sigma_t)}} \qquad (0, n/2\sqrt{n\sigma_t})$$

PLASTIC LIMIT ANALYSIS OF THE LOESS SLOPE STABILITY

SLOPE WITH FISSURE-LINEAR CRACK SURFACE

The **weight of sliding mass** can be expressed as followed:

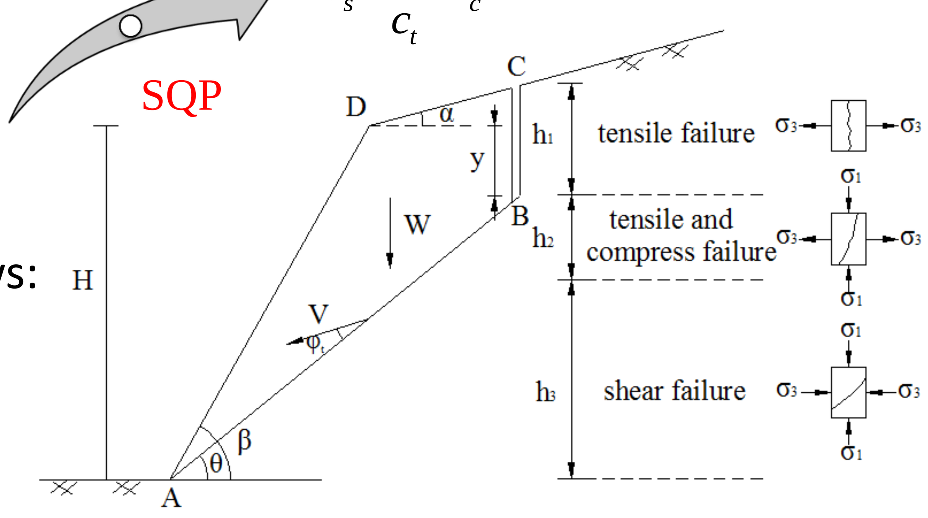
$$\dot{W}_{外} = W_{ABCD} V_{\perp} = W_{ABCD} V \sin(\theta - \varphi_t)$$

The **dissipation power** can mathematically be written as follows:

$$\dot{W}_{内} = c V_L L = \frac{c_t V \cos\varphi_t (H - y)}{\sin\theta}$$

SQP

$$N_s = \frac{\gamma}{c_t} H_c$$



$$H = \frac{(h_1 - y) h_1 \sin(\theta - \varphi_t) \sin\theta \tan\theta \gamma}{2c_t \cos\varphi_t \tan\alpha \tan\theta - \gamma y \sin\theta \sin(\theta - \varphi_t) \tan\alpha - \gamma(h_1 - y)\sin\theta \sin(\theta - \varphi_t)\tan\theta} + y$$

SLOPE WITH LOGARITHMIC SPIRAL CRACK SURFACE

The weight of sliding mass:

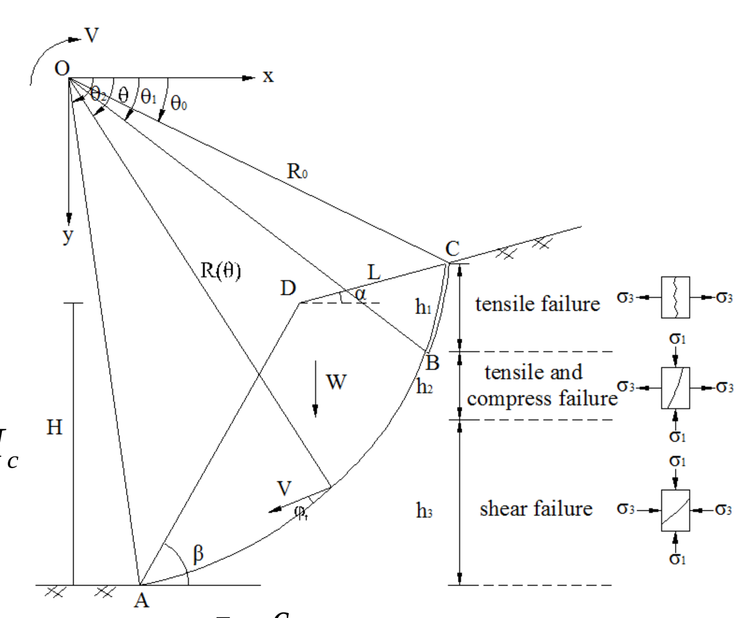
$$\dot{W}_1 - \dot{W}_2 - \dot{W}_3 = \gamma R_0 V (f_1 - f_2 - f_3)$$

The dissipation power:

$$\int_{\theta_1}^{\theta_2} c_t (V\cos\varphi_t) \frac{R d\theta}{\cos\varphi_t} = \frac{c_t R_0^2 V}{2\tan\varphi} \left[e^{2(\theta_2 - \theta_1)\tan\varphi_t} - 1 \right]$$

SQP

$$N_s = \frac{\gamma}{c_t} H_c$$



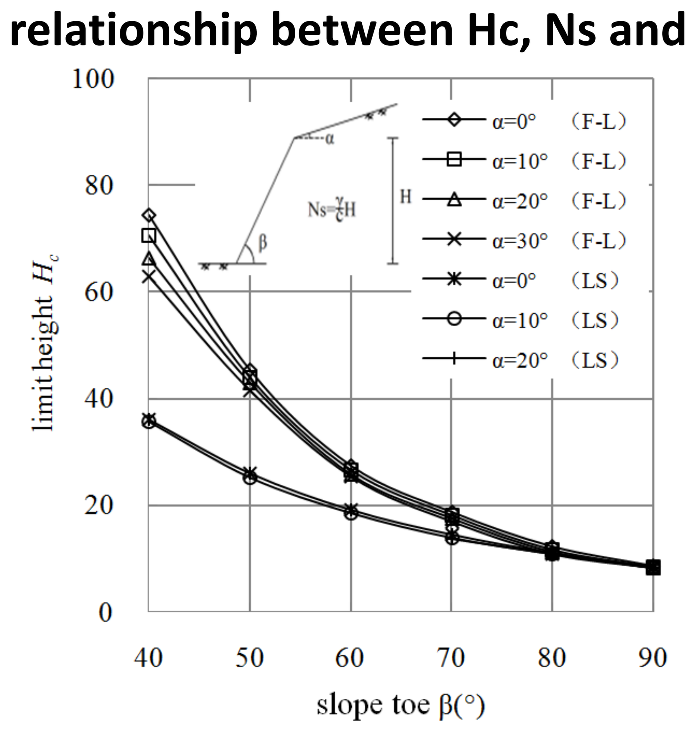
$$H = \frac{c_t}{\gamma} \frac{\sin\beta \left[e^{2(\theta_2 - \theta_1)\tan\varphi_t} - 1 \right]}{2\sin(\beta - \alpha)\tan\varphi_t (f_1 - f_2 - f_3)} \times \left[\sin(\theta_2 + \alpha) e^{(\theta_2 - \theta_0)\tan\varphi_t} - \sin(\theta_0 + \alpha) \right] = \frac{c_t}{\gamma} f(\theta_0, \theta_2, \tan\varphi_t)$$

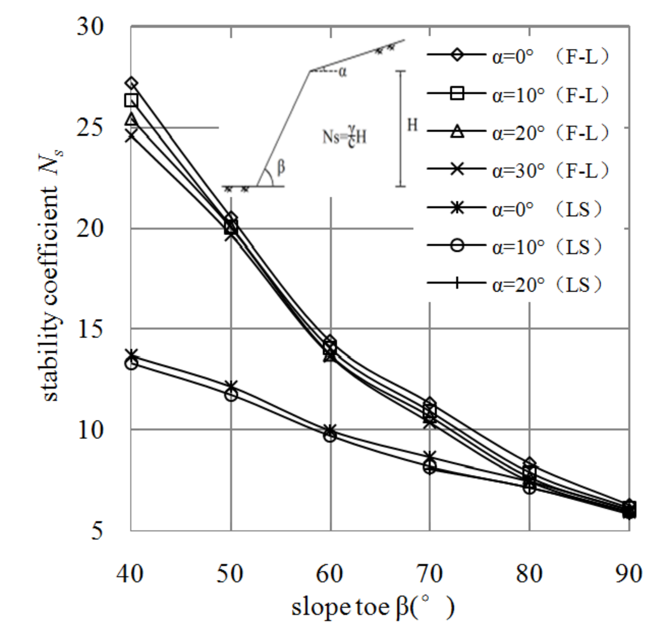
ANALYSIS OF EXAMPLES

The homogeneous loess slope of northern Shaanxi is taken as representative sample. It is rendered with the nonlinear quadratic-parabolic failure criterion; the basic parameters of which are shown in the follow Table.

Soil sample	Dry density g/cm³	Natural water content %	Specific gravity of soil G_s	Coefficient of earth pressure at rest K_0	Tensile strength σ_0/KPa	Physical and mechanical parameters n
Northern Shaanxi loess	1.22	18.5	2.72	0.33	8.74	38.24

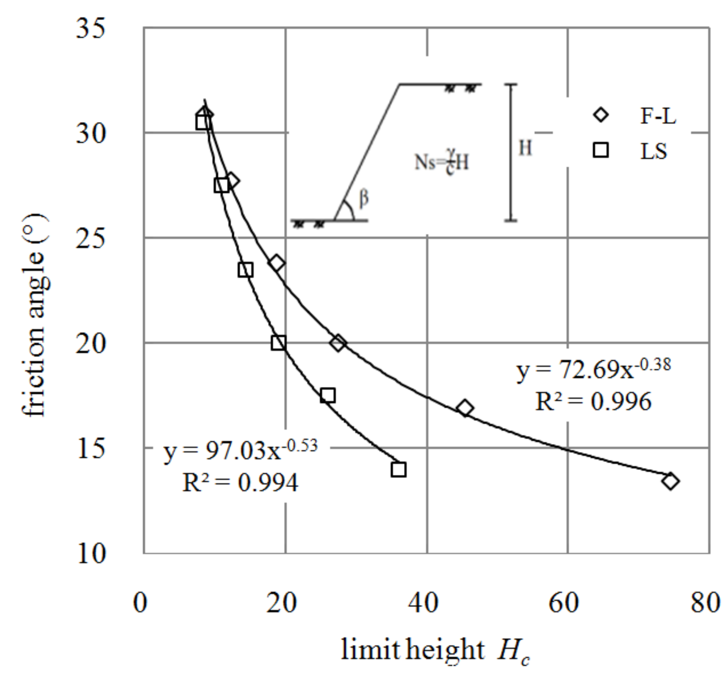
The relationship between Hc, Ns and toe slope





The relationship between Hc and Friction angle

The nonlinear value method reduces the error of constant value of the cohesion and the friction angle that has been mentioned by the traditional method as above, so that, the stability analysis can shows its worth as a practical approach.



CONCLUSIONS

The comparison of results between the plastic-limit analysis (under the two failure modes, i.e., fissure-linear and logarithmic spiral) and the limit equilibrium method is consistent and it shows that the plastic limit-analysis is more effective. Whereas, the difference of stability coefficient between the two failure modes is larger than anticipated, and, the mode of logarithmic-spiral failure takes a more conservative value as compared to the fissure-linear failure mode.

In the plastic-limit analysis, the slope toe has a great influence on the coefficient of slope stability and the limit height when it is compared with the influence of slope toe , which is small.

In this article, the nonlinear obtaining-value method that has been associated with the limit height of the slope, and, it reduces the error of constant value for cohesion and the friction angle under the traditional obtaining-value method, so that, the slope stability analysis can be considered as a practical-oriented approach.

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