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Static Analysis and Pseudostatic Slope Stability

Meftah Ali

***Abstract*—**This article aims to analyze the static stability and pseudostatic slope by using different methods such as: Bishop method, Junbu, Ordinary, Morgenstern-price and GLE. The two dimensional modeling of slope stability under various loading as: the earthquake effect, the water level and road mobile charges. The results show that the slope is stable in the static case without water, but in other cases, the slope lost its stability and give unstable. The calculation of safety factor is to evaluate the stability of the slope using the limit equilibrium method despite the difference between the results obtained by these methods that do not rely on the same assumptions. In the end, the results of this study illuminate well the influence of the action of water, moving loads and the earthquake on the stability of the slope.

***Keywords*—**Slope stability, pseudo static, safety factor, limit equilibrium.

I. Introduction

THIS work deals with the static analysis and pseudo static stability of a slope located near the RN 90, in the town of Mazouna (wilaya of Relizane- Algeria) [1]. The movements of land are frequent phenomena on the slopes, which occurs either slowly or quickly, which affects all or only some particular portions, depending on the geotechnical parameters, geological, climatic and morphological conditions. Many other factors, and the interrelationships involved, and that the phenomenon are complex and can take many forms. Landslides land has forms that depend on solid configuration, and soil properties. They are characterized by lateral translation of a certain mass of materials at a distinctly individual fracture surface without significant internal deformation, and usually occur in unconsolidated material. The comprehensive evaluation of slope stability requires information on the geological, hydrogeological, geotechnical and topographical, these features are needed to perform and interpret the different results of slope stability analysis [2].

II. Different Methods of Calculated

These include for example, the various assumptions [3]:

A. Assumptions on Interslice Efforts

Fellenius (Swedish) method: assumes the circular slip line and totally neglects the interslice efforts [4].

$$F_s = \frac{1}{\sum_{1}^{n} w_i \sin\alpha_i} \left[\sum_{1}^{n} (w_i \cos\alpha_i - u_i) \tan\varphi'_i + c'_i \frac{b_i}{\cos\alpha_i} \right] \quad (1)$$

Bishop generalized method: assumes that the slip line is circular and that the equilibrium of horizontal and vertical forces. It is a relationship between the horizontal and vertical components of interslice efforts [3].

$$\sum_{i=1}^{n} (\mathrm{Vi} - \mathrm{Vi}+1) \left[\frac{\sin\alpha\ \mathrm{i} - \frac{\tan\varphi\ \mathrm{i}}{F_S}\cos\alpha\ \mathrm{i}}{\cos\alpha\ \mathrm{i} + \frac{\tan\varphi\ \mathrm{i}}{F_S}\sin\alpha\ \mathrm{i}} \right] = \sum_{i=1}^{n} \left((\mathrm{Wi} - \frac{\mathrm{Cibi}}{F_S} \mathrm{tg}\alpha\ \mathrm{i}) \left[\frac{\sin\alpha\ \mathrm{i} - \frac{\tan\varphi \mathrm{i}}{F_S}\cos\alpha\ \mathrm{i}}{\cos\alpha\ \mathrm{i} + \frac{\tan\varphi \mathrm{i}}{F_S}\sin\alpha\ \mathrm{i}} \right] - \frac{\mathrm{Cibi}}{F_S} \right) \quad (2)$$

Bishop simplified method: it was assumed that the sum of the vertical forces in a single tranche is zero; this condition makes the application easier [3].

$$F_S = \frac{1}{\sum_{i=1}^{n} w_i \sin\alpha_i} \left[\sum_{i=1}^{n} \left[c_i \cdot \frac{b_i}{\cos\alpha_i} + \tan\varphi_i \left[\frac{W_i - \frac{c_i b_i}{Fs} \tan\alpha_i}{m_\alpha} \right] \right] \right] \quad (3)$$

B. Assumptions on the Thrust Line

Janbu Method proposes to consider the strength and equilibrium point of a typical vertical zone, and also assumes that the slip line in the vicinity of the lower third of the slice height [5].

$$F_S = \frac{\sum_{i=1}^{n} b_i . s_i \frac{1}{\cos^2\alpha_i}}{\sum_{i=1}^{n} (w_i + \Delta v_i) \tan\alpha_i} \quad (4)$$

$$\text{avec: } s_i = \frac{c'_i + (\frac{w_i + \Delta v_i}{b_i} - u_i) \tan\varphi'_i}{1 + \frac{tg\alpha_i . \tan\varphi'_i}{F_S}}$$

Janbu Simplified Method: In this method, Junbu offers a simplified formula in which it totally ignores interslice efforts, and introduced an empirical correction factor depends on the ratio between the depth and length of the mass swiped [5].

Meftah Ali is PhD student in Civil Engineering, Sidi Bel Abbés University, Algeria (e-mail: genietech2013@yahoo.fr).

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$$F_s = f\,\frac{\sum_{i=1}^{n} b_i . s_i \dfrac{1}{\cos^2 \alpha_i}}{\sum_{i=1}^{n} w_i \tan \alpha_i} \tag{5}$$

$$\text{avec: } s_i = \frac{c_i + (\dfrac{w_i}{b_i}) \tan \varphi_i}{1 + \dfrac{tg\,\alpha_i . \tan \varphi_i}{F_s}}$$

C. Assumptions on the Direction of Interslice Efforts

Spencer Method is based on the orientation of efforts interslice [6].

$$Q = \frac{C_i \dfrac{b_i}{F_s \cos \alpha_i} + \dfrac{\tan \varphi_i}{F_s} W_i \cos \alpha_i - W_i \sin \alpha_i}{\cos(\alpha_i - \theta_i) \left[1 + \dfrac{\tan \varphi_i}{F_s} \tan(\alpha_i - \theta_i) \right]} \tag{6}$$

Morgenstern and Price Method: This method assumes a function of interslice forces and inclination of interslice efforts can vary by an arbitrary function [7].

$$F_f = \frac{\sum\left[\left\{ c'l + \left(N - ul\right) \tan \varphi' \right\} \sec \alpha \right]}{\sum \left\{ W - \left(V_i - V_{i-1}\right) \right\} \tan \alpha + \sum \left(H_i - H_{i-1}\right)} \tag{7}$$

$$F_m = \frac{\sum \left(c'l + \left(N - ul\right) \tan \varphi' \right)}{\sum W \sin \alpha} \tag{8}$$

D. Assumptions on the Distribution of Stresses along Slides Online

Disturbance Method: The idea is to start with an approximate value of the normal force that is disturbed by multiplying it by a term P [3].

$$F_s = \frac{\sum_{i=1}^{n} ((N_i \tan \varphi_i + c_i \dfrac{b_i}{\cos \alpha_i}) \left[\left(x_i + x_{i+1}\right) \sin \alpha_i - (y_{Bi} + y_{Bi+1}) \cos \alpha_i \right]}{\sum_{i=1}^{n} 2x_{Gi}.W_i - N_i \left[\left(x_i + x_{i+1}\right) \cos \alpha_i + (y_{Bi} + y_{Bi+1}) \right] \sin \alpha_i} \tag{9}$$

Sarma Method: He proposes a horizontal acceleration factor (Ky) as a safety measures a two-dimensional slope [8].

$$\tau_{it} = \lambda f(x) \tau_i$$

Pseudo Static Stability Method: pseudostatic method evaluated the stability of a slope under earthquake. [9].

$$F_h = \frac{a_h w}{g} = k_h w \text{ et } F_v = \frac{a_v w}{g} = k_v w \tag{10}$$

Algerian Earthquake Regulations RPA99 Version 2003: considered in a calculation of seismic slope stability [10].

$k_h = 0.5A$ (%g), $k_v = \pm 0{,}3\, k_h$

$$Fs = \frac{\sum \dfrac{c'b + (w - ub)\tan \varphi'}{\dfrac{1 + \tan \alpha \tan \varphi'}{Fs} \cos \alpha}}{\sum w \left[\sin \alpha + k_h (\cos \alpha - \dfrac{Y_G - Y}{R}) + k_v \right]} \tag{11}$$

III. Modeling of the Slope by Classics Methods

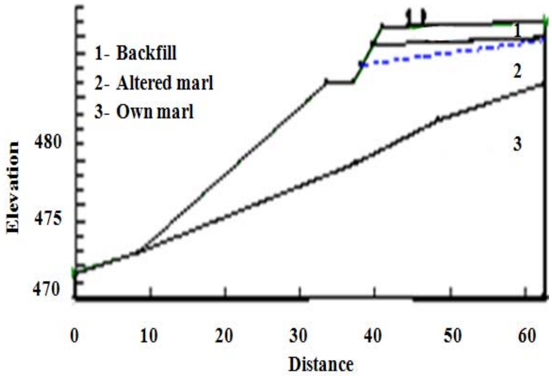

Fig. 1 General configuration of the analyzed slope

IV. The Geotechnical Characteristics of Soil

TABLE I
THE GEOTECHNICAL CHARACTERISTICS OF SOIL

The layers	γ_h (Kn/ m³)	Cu (Kpa)	φ
The backfill layer	19	20	15 °
The altered marl layer	18	13	17 °
The own marl layer	21	146	14 °
Stop (gabion)	21	10	35

V. Results and Discussion

A. Calculations of Static Stability

TABLE II
SAFETY FACTORS CALCULATED ACCORDING TO FIG. 1 (K = 0)

Condition	Method	Fs circular failure	Fs Non-circular failure
without water	Bishop	1.34	1.65
	Janbu	1.10	1.30
	Ordinary	1.21	1.32
	Morgenstern-Price	1.20	1.21
	Spencer	1.25	1.41
	GLE	1.15	1.21
With water	Bishop	1.28	1.58
	Janbu	1.10	1.21
	Ordinary	1.15	1.23
	Morgenstern-Price	1.05	1.13
	Spencer	1.18	1.30
	GLE	1.07	1.01

Table II shows the results obtained in the analysis of static stability, we can notice that for conditions (with water and without water), safety factors are greater than 1 therefore theoretically the slope is stable. These results tell us a stability of the slope. Good agreement was observed between the different results obtained in this analysis.

B. Calculation of the Pseudostatic Stability

TABLE III
RESULTS OF CALCULATIONS OF THE PSEUDOSTATIC STABILITY BY BISHOP METHOD FOR A CIRCULAR FAILURE SURFACE

Kh	Fs
0	1.34
0.10	1.09
0.14	1.00
0.20	0.91
0.30	0.78
0.40	0.68
0.50	0.60

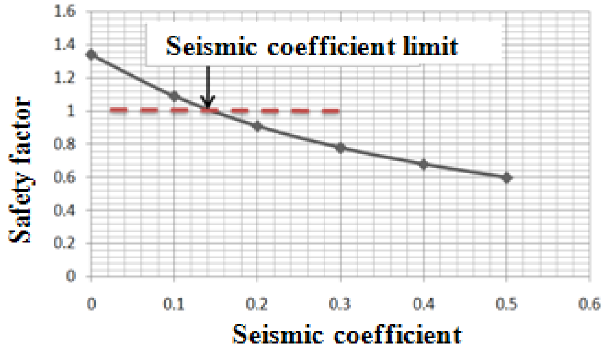

Fig. 2 Results of calculations of the pseudostatic stability by bishop method for a circular failure surface

Based on the above analysis of the pseudostatic stability and circular fracture surfaces calculated by the method of Bishop, it was found that the seismic coefficient Kh limit is of the order of 0.14, higher than this value seismic coefficients have a safety factor of less than 1 (Table II , Fig. 2).

TABLE IV
RESULTS OF THE ANALYZES OF THE PSEUDOSTATIC STABILITY IN NON-CIRCULAR FAILURE SURFACE BY BISHOP METHOD

Kh	Fs
0	1.65
0.1	1.37
0.2	1.14
0.29	1.00
0.3	0.98
0.4	0.86
0.5	0.76

Analyses of the pseudostatic stabilities carried out at the previous slope confirm seismic instability of this slope for non-circular failure surfaces calculated by the method of Bishop, it was found that the seismic coefficient Kh limit is of the order of 0.29, the safety factor Fs is less than 1 (Table III, Fig. 3).

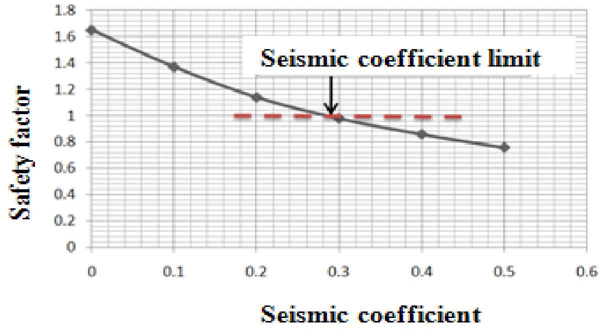

Fig. 3 Results of calculations of the pseudostatic stability by bishop method for a non-circular failure surface

TABLE V
ANALYSIS OF THE PSEUDOSTATIC STABILITY METHOD BY SARMA

Form of rupture	Coefficient IC horizontal	Safety factor
Circular failure	0.00	1.15 Static
	0.06	1.00 Critical
Non-circular failure	0.00	1.29 static
	0.13	1.00 Critical

The results obtained with the Sarma method contain a horizontal seismic coefficient of 0.06 for a safety factor Fs is equal to 1 in the case of a fracture surface circulaire.et a horizontal seismic coefficient equal to 0.13 for a safety factor Fs equal 1, Table V shows the results.

TABLE VI
ANALYSIS OF THE PSEUDOSTATIC STABILITY BY RPA99 MODIFIED IN 2003

Form of rupture	Horizontal Seismic Coefficient	Vertical Seismic Coefficient	Coefficient Security
Circular failure	0.13	+0.04	0.98
		-0.04	0.99

The analysis of the pseudostatic stability RPA99 changes in 2003 shows the seismic instability of the slope for horizontal seismic coefficient Kh= 0.13 and a vertical seismic coefficient Kv = ± 0.04. These results show that the influence of Kv is negligible.

VI. CONCLUSIONS

Analyses of slope stability based on simple static approaches (equilibrium calculation limits the method of slices). These approaches, although practices are not stringent since they do not take into account the seismic action on structures.

In the case of simple configurations, the use of equilibrium limit calculation methods based on the method of slices (Bishop method) is sufficient. While in the case of complex configuration, the use of sophisticated calculation tools such as finite element method is essential in terms both static and seismic.

Among the parameters influencing the safety factor, particularly note soil shear parameters (cohesion and angle of friction), but also the level of the groundwater may be present. Their knowledge is accurately known if we want to get results from significant and representative calculations of the state earthworks.

The theoretical application, as practical example, has shown that it is the combined action of several negative factors that is causing the loss. In addition to the seismic action, rupture often comes either from an increase in the stress associated with a change of the hydraulic characteristics, or a reduction of soil strength characteristics, or their combination.

References

[1] CTTP (juin 2007). "Étude de confortement du glissement sur R N 90 au pk 75+700" Rapport géotechnique final.

[2] Meftah, A. 2013. "L'utilisation de la méthode des éléments finis et les méthodes classiques pour l'analyse statique et pseudo statique de la stabilité des talus" mémoire de Magister, Université de Saida, Algérie, 2013, 127 p.

[3] Abdelkader, B. (2003). "Glissements de terrains" calcul de stabilité. OPU, 95p

[4] Fellenius, W. 1936. Calculation of the Stability of Earth Dams. Proceedings of the Second Congress of Large Dams, Vol. 4, pp. 445-463.

[5] Janbu, N. 1954. Applications of Composite Slip Surfaces for Stability Analysis. In Proceedings of the European Conference on the Stability of Earth Slopes, Stockholm, Vol. 3, pp. 39-43.

[6] Spencer, E. 1967. A Method of Analysis of Embankments assuming Parallel Interslice Forces. Geotechnique, Vol 17 (1), pp. 11-26.

[7] Morgenstern, N, R. and Price, V, E. 1965. The Analysis of the Stability of General Slip Surfaces. Geotechnique, Vol.15, pp. 79-93

[8] Sarma, S, K.1973. Stability Analysis of Embankments and Slopes. Geotechnique, Vol. 23 (3), pp. 423-433.

[9] Adriana, M, B. (2010). "Étude de la stabilité sismique de trois talus", Thèse de Doctorat, LAVAL, 2010, 205 p.

[10] RPA. 1999 (Version 2003). "Règles Parasismiques Algérienne ", 89 p.