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Investigation of Building Loads Effect on the Stability of Slope

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***Abstract*—**In big cities, construction on sloping land (landslide) is becoming increasingly prevalent due to the unavailability of flat lands. This has created a major challenge for structural engineers with regard to structure design, due to the difficulties encountered during the implementation of projects, both for the structure and the soil. This paper analyses the effect of the number of floors of a building, founded on isolated footing on the stability of the slope using the computer code finite element PLAXIS 2D v. 8.2. The isolated footings of a building in this case were anchored in soil so that the levels of successive isolated footing realize a maximum slope of base of three for two heights, which connects the edges of the nearest footings, according to the Algerian building code DTR-BC 2.331: Shallow foundations. The results show that the embedment of the foundation into the soil reduces the value of the safety factor due to the change of the stress state of the soil by these foundations. The number of floors a building has also influences the safety factor. It has been noticed from this case of study that there is no risk of collapse of slopes for an inclination between 5° and 8°. In the case of slope inclination greater than 10° it has been noticed that the urbanization is prohibited.

***Keywords*—**Building, collapse, factor of safety, isolated footing, PLAXIS 2D, slope.

I. Introduction

CONSTRUCTION on sloping land is not subject to any regulations or recommendation in Algeria. However, the landslide is a widespread natural hazard in the world; the threat is similar to an earthquake. If there is a rapid movement of a large mass of earth, it can cause extensive damage to buildings, which exposes people to danger. Moreover, due to the rising rates of population growth in some cities in Algeria, there is a demand to construct buildings with multiple floors. Furthermore, construction on sloping land (landslide) is increasing considered, mainly due to a shortage of available flat lands for building. However, in recent years several studies have been made in this area.

Bearing capacity of shallow footing founded near slop crests under earthquake loading, using pseudo static limit equilibrium method has been studied by [1]-[4].

Some researchers like Paul et al. [5], have developed a procedure using Simplified Bishop's method to find the factor of safety against sliding failure of slope considering building loads. In the traditional analytic method, the building loads transferred to the slope at different levels from the buildings have not been considered while analyzing the stability of a slope.

Kourkoulis et al. [6] studied parametrically the effects of foundation type (isolated footing versus a rigid raft) on the position of sliding surface, and the combined effects of earthquake-triggered landslides and ground shaking on foundation-structure systems founded near slop (crests).

To study the influence of the number of floors of a building on the stability of the slope and to determine the factor of safety against sliding failure of the slope, PLAXIS 2D v. 8.2 software [8] was used. The buildings constructed on hill slope transfer loads on the sloping ground at different levels in the form of vertical, horizontal loads and bending moments, as shown in the Fig. 1, which further adds to the self weight of soil and may lead to sliding of slope. The finite element PLAXIS 2D v. 8.2 considers only vertical and horizontal loads. The successive isolated footing levels have been taken such as a maximum slope of two to three base/height connects the edges of the nearest footings, as according to the DTR-BC 2.331 [7]. The distance between the lower edges of the footing to the sloping ground surface is made greater than the minimum distance of 90 cm.

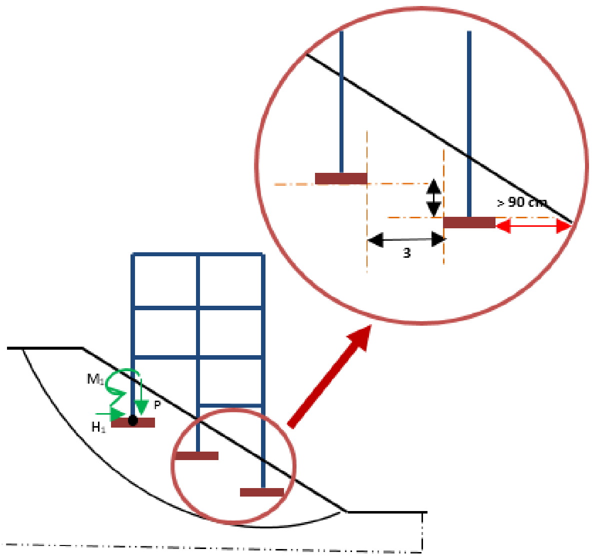

Fig. 1 Hill building configurations: Step back building

The PLAXIS program calculates a safety factor from the shear strength reductions method. In this approach, the strength parameters φ and c of the soil are reduced gradually

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until failure (slope unstable). The formula for the safety factor may be written as [8]:

$$F = \frac{\tan \varphi^{p\_cj}}{\tan \varphi^{d\_gis\ pc}} = \frac{c^{p\_cj}}{c^{d\_gis\ pc}} \quad (1)$$

Theoretically, the slope is stable if F > 1. The limit equilibrium (collapsing) is obtained when F = 1, this value indicates that a slope is on the boundary between stability and instability. If the value of the factor of safety is less than 1.0, the slope is unstable. However, because of the uncertainty of variables, the coefficient factor of safety obtained is not precise, and it is comprised between 1.25 and 2.00. This value should match the uncertainties of analysis, taking into account the following factors:

- Errors due to the accuracy of the methods of calculating stability.
- The experimental uncertainty of the determination of the physico-mechanical properties in the soil.
- The influence of dynamic loads caused by shaking such as: vehicles movement and earthquakes.

Recommended minimum values of factor of safety from Duncan and Wright [9] and U.S. Army Corps of Engineers' slope stability [10] are shown respectively in Fig. 2.

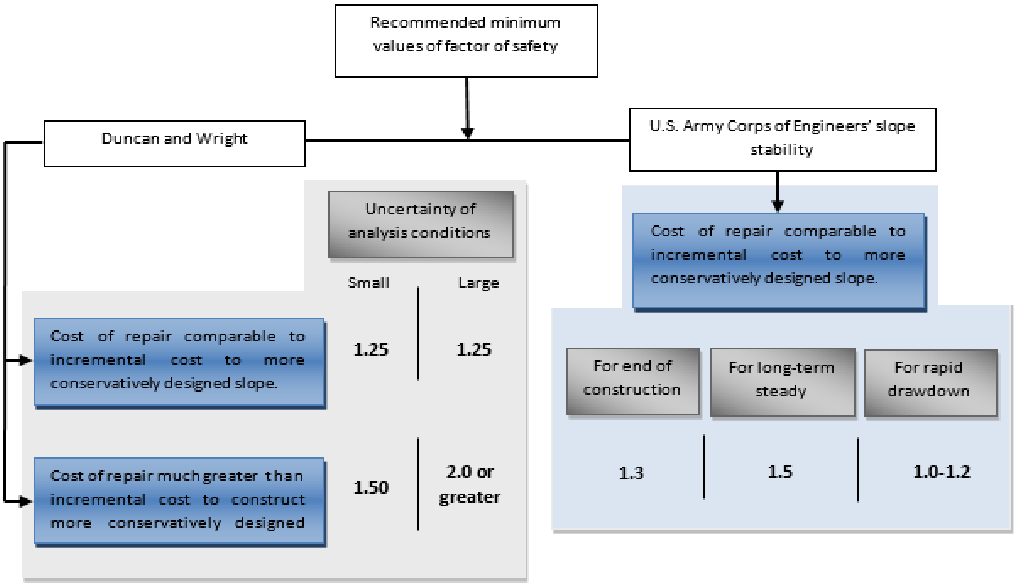

Fig. 2 Recommended value of factor of safety

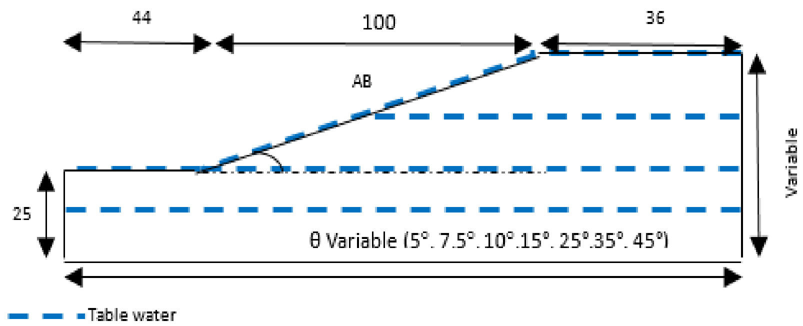

Fig. 3 Geometry of the reference model studied.

II. Model Description

The model dimensions are shown in Fig. 3. The slope height is variable and the depth of basement is 25 m.

The geotechnical characteristics of the reference model are summarized in Table I. We consider only one type of soil taken from the bibliography of PLAXIS 2D code.

A. Mohr-Coulomb Model

The elastic perfectly plastic model without hardening of Mohr-Coulomb was adopted. This model is a first-order approximation of the soil behavior and requires five basic soil parameters: modulus of elasticity (Young's modulus), E, Poisson's ratio υ, Cohesion c, angle of friction φ and dilation angle ψ [8].

B. The Properties of the Building

To investigate the effect of the building loads on the stability of slope, a 2D building model consisting of frame elements as beam and column are used. These elements of the building are modeled with plate elements from the toolbar in PLAXIS software. The beams and columns building dimension are 35 x 35 cm² and for isolated footing dimension is 200 x 30 cm². The density of reinforced concrete is 25 kN/m³ and Young's modulus is 30.106 MPa. A building of one to three stories was modeled with a 3 m height (each story) and 12 m length, for a slope of 5°, as shown in Fig. 4.

TABLE I
GEOTECHNICAL DATA

Model	Type of soil	γd (kN/m³)	γsat (kN/m³)	C' (kN/m²)	φ (°)	ψ (°)	E (kN/m²)	ν -	k (m/ day)
Mohr-Coulomb	Clay undrained	15	18	2	24	0	1 E+03	0.33	E-04

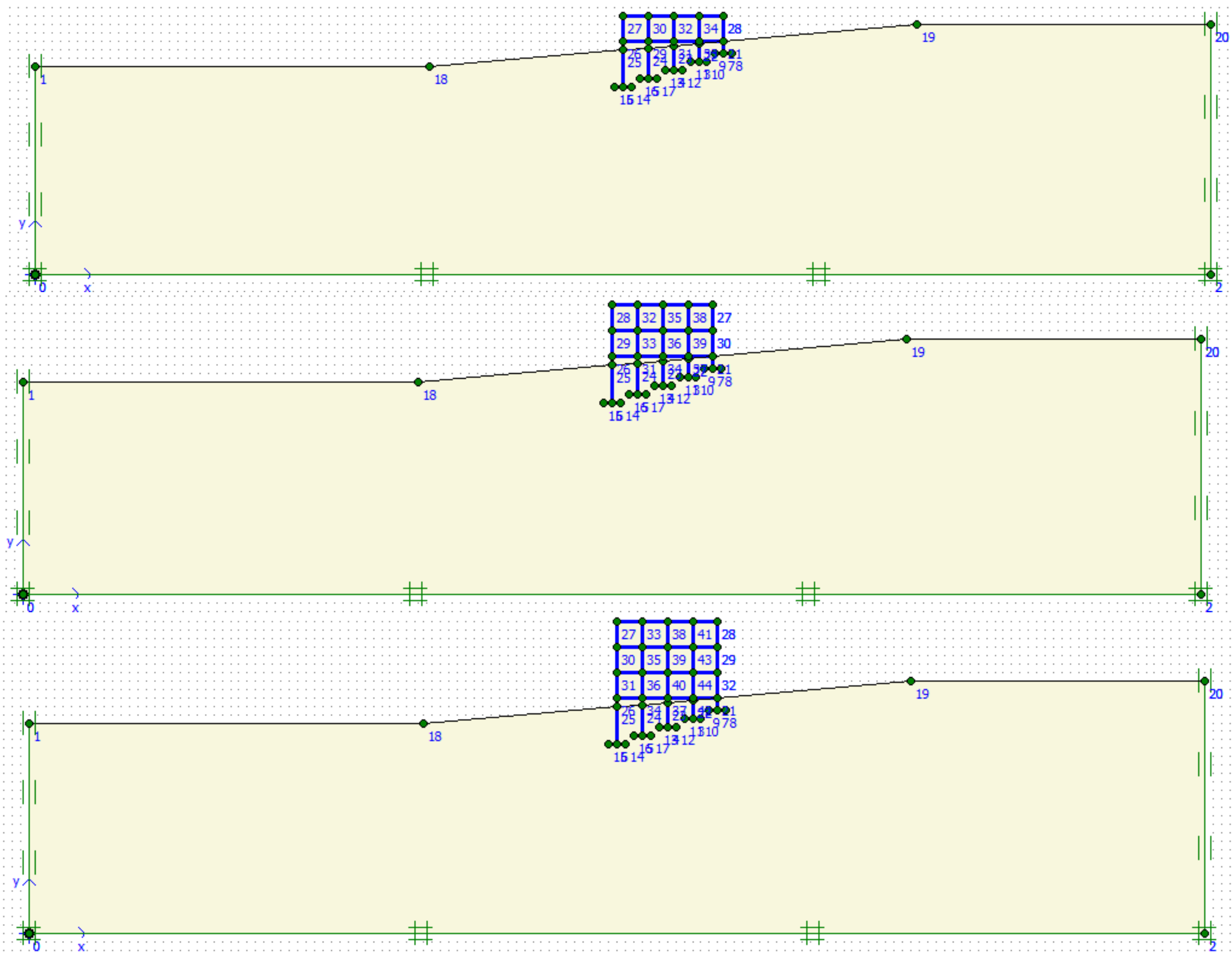

Fig. 4 Hill building reference model studied (Slope of 5°)

TABLE II
VALUES OF SAFETY FACTOR COEFFICIENT

Soil	Actions considered in calculations	Degree of slope						
		θ =5°	θ = 7.5°	θ = 10°	θ = 15°	θ = 25°	θ = 35°	θ = 45°
Clay	Without water table	4.2065	2.8265	2.2111	1.3088	1.1007	collapses	collapses
	With water table	3.5217	2.3727	1.8038	1.0316	collapses	collapses	collapses

III. RESULTS AND DISCUSSION

The results confirmed that both parameters, topography factor (degree of slope) and the hydrology factor, are commonly the major triggers for landslide failures. Table II summarizes the result value of calculations for the safety factor.

A. Influence of the Water Table

Ground water is an important influence on slope stability, the presence of the water table in the three cases has an effect on the decrease of the value of the safety factor by approximately 16-20%. If the level of water is considerable, there is a collapse risk for slopes greater than 15° (Fig. 5). In fact, the main reason for reducing the stability of a slope is the union of two actions; increase and decrease of stresses in the soil. The increase is related to the additional load resulting from the weight of construction builds near or on a slope, vibration effect of gear or other. On the other hand, the shear strength can be decreased by a small increase in the pore pressure at the sliding surface caused by the water table and the infiltration of water.

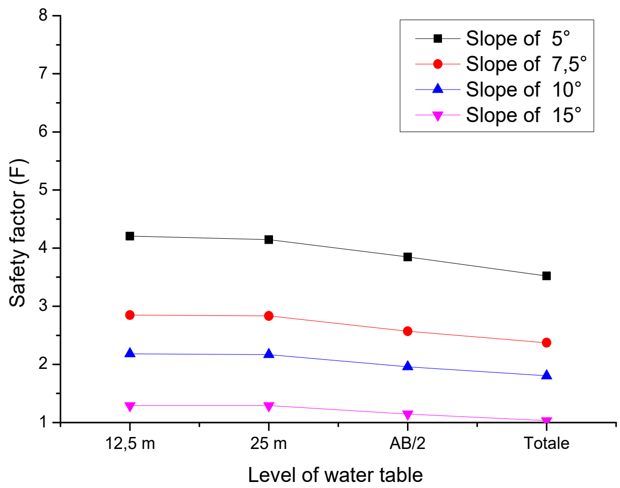

Fig. 5 Evolution of the safety factor depending on the level of the water table

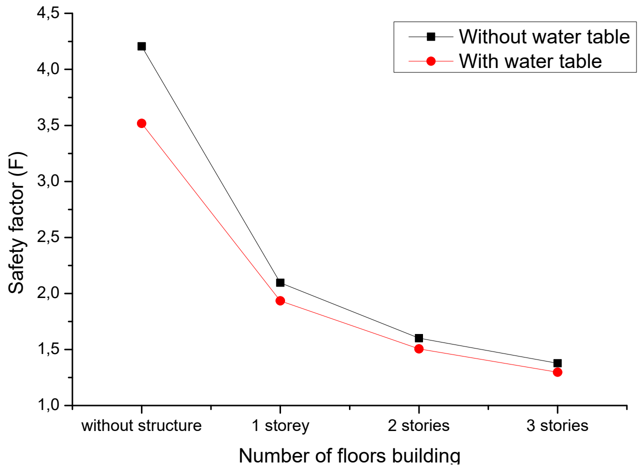

Fig. 6 Evaluation the value of safety factor with the number of floors (slope 5°)

B. Building Influence on Slope Stability

The presence of a foundation in the ground causes a change in the characteristics of the soil; the value of the safety factor was reduced by approximately 50% for clay soil. When the number of floors increases, the value of the safety factor continues to decrease. The presence of the water table (phreatic) in the studies at the slope of 10° leads to risk of collapse, and for the slope of 15°, the soil is unstable in both cases (Figs. 6-8).

From the results of this study, it is recommended that urbanization on sloping ground be limited to slopes less or equal to 8° for individual houses and for buildings of floors less than three floors. All probable factors that may influence the slope instability were considered in the scope of this study. The value of the safety factor should be higher than that given by the building regulations or recommendations. A landslide rarely has a single cause; it is the combination of several unfavorable factors that cause instability. Under the joint action of topographic, building loads, rainfall and water fluctuation, the safety factor of this landslide would have an observable decrease.

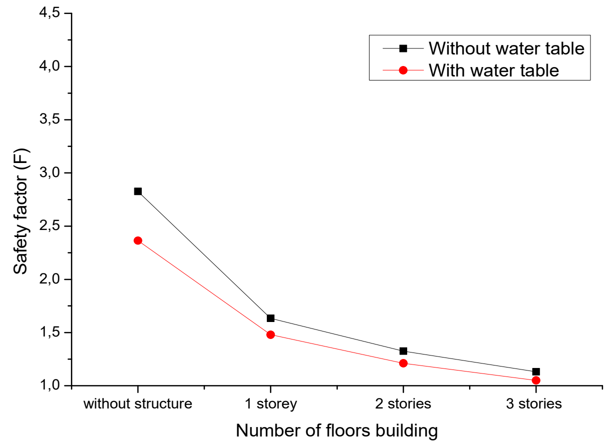

Fig. 7 Evaluation the value of safety factor with the number of floors (slope 7.5°)

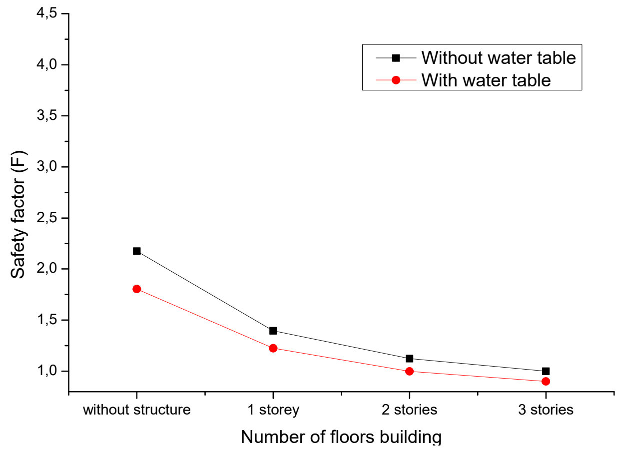

Fig. 8 Evaluation the value of safety factor with the number of floors (slope 10°)

IV. Conclusion

This paper summarizes a numerical study of slope stability with the numerical simulation tool PLAXIS 2D, in order to quantify in terms of safety factor stability and to understand the kinematics of the problem. For this, a parametric study was conducted to determine the effect of topography, number of floors, and the water table on the safety factor value. The results obtained confirm what is mainly reported in the literature, namely, that the factors mentioned in this paper are the main causes of landslides. In order to reduce the damage induced by landslide land, it is recommended to identify any problems that may arise and solutions to be undertaken prior to any construction.

REFERENCES

[1] Sarma SK, 1999, Seismic bearing capacity of shallow strip footings adjacent to a slope, 2nd International Conference on Earthquake Geotechnical Engineering, Publisher: A Balkema Publishers, Pages: 309-313.

[2] Sarma SK, Srbulov M, 1996, A simplified method for prediction of kinematic soil-foundation interaction effects on peak horizontal acceleration of a rigid foundation, Earthquake Engineering & Structural Dynamics, Vol: 25, Pages: 815-836, ISSN: 0098-8847.

[3] Kumar, J. and Rao, V.B.K.M. (2002), Seismic bearing capacity factors for spread foundations. Géotechnique 2002; 52(2):79–88.

[4] Askari F, Farzaneh O, Upper-bound solution for seismic bearing capacity of shallow foundations near slopes. Geotechnique 2003; 53(8):697–702.

[5] Paul, D. K., and Kumar S. (1997). Stability analysis of slope with building loads. Soil Dynamics and Earthquake Engineering 16:(6), 395-405.

[6] Kourkoulis R., Anastasopoulos I., Gelagoti F, and Gazetas G., “Interaction of foundation-structure systems with seismically precarious slopes: numerical analysis with strain softening constitutive model,” Soil Dynamics and Earthquake Engineering, vol. 30, no. 12, pp. 1430–1445, 2010.

[7] DTR-BC 2.331, Document technique réglementaire algérienne « Règles de calcul des fondations superficielles ». 2005.

[8] Brinkgreve R.B.J. 2003. PLAXIS manuel de référence. DELFT, 2003. 90-808079-3-1.

[9] Duncan, J.M. and Wrigth, S.G. (2005) Soil strength and slope stability. John Wiley et Sons, Inc., pp.199.

[10] U.S Army corps of engineers, (2003) Engineer manual. Online available:http://www.usce.army.mil/publications/engmanuals/em1110-2-1902/entire.pdf.