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Research Article

CONTRIBUTION TO THE ANALYSIS OF THE STABILITY OF AN OPEN PIT MINE: CASE OF THE KEF ESSNOUN PHOSPHATE MINE, TEBESSA NORTH-EAST ALGERIA

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ABSTRACT

The problems related to slope stability in open pits have become increasingly complicated, where the stability of the terraces and embankments have a greater influence on the productivity and longevity of the mine, this instability can cause enormous damage to personnel and equipment. In this work, the stability analysis begins with a fieldwork where we could see the mine plan, the geometry of the steps, their heights, the different geological formations ... etc. In this way we have studied the stability of the steps of the kef essnoun open pit by the applying the rock mass classification systems and the calculation of the safety factor by the limit equilibrium method. The results obtained from the empirical analyze RMR, SMR and the limit equilibrium method is in general the same, where the marl layer is the probable cause of a massive instability.

Keywords: landslide; SMR; RMR; Kef Essnoun; limit equilibrium.

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1. INTRODUCTION

The phenomenon of terrains movements is considered a danger in quarries and mines around the world It can take different forms such as the collapse of the land (sinkholes, pinnacles, cavities, etc.), landslides and mudslides, etc. [1]. Where Large, rapidly moving landslides are highly likely to cause loss of life and property damage [2].Furthermore, most of bank movements can be classified into four categories: plane, corner, tilt and circular failures depending on their geometrical and mechanical nature of discontinuity and rock mass conditions [3]. Moreover, slope stability requires a detailed study of all geological and geomorphological conditions [4]. The main factors of slope stability can be divided into intrinsic factors, such as physical-technical properties of soil layers, and external factors (precipitation, seismic and dynamic loads) [5]. Studies on the latter were fewer than the previous because of its uncertainty and complexity of the space-time [6].

The rock slope can be classified according to several measuring parameters, such as the predictors of rock behavior [7], Rock Quality Designation (RQD) which was developed in [8] to provide a quantitative estimate of fracturing influencing rock mass behavior from the examination of cores obtained by drilling, the Rock Mass Classification Geomechanical Classification System (RMR) [9], which is based on the estimation of a number of parameters and evaluated using a table that assigns a number of points according to their value, the sum of all the points makes it possible to obtain the total RMR value. The slope mass rating (SMR) system [10, 11] is oriented towards the stability of rock slopes, it is obtained from the RMR by adding a product of adjustment factors. There were also numerous methods such as the methods of qualitative analysis, quantitative and uncertainty [12]. The qualitative method has a great influence on the stability evaluation [13], the critical slip surfaces obtained by the LEM method and by the two finite element methods (ELSM and SRM) are compared. Several representative examples of two-dimensional slope are analyzed, and the results obtained using the three methods are compared [14].

In this paper, we will carry out a geological and geotechnical study on the phosphate deposit of Kef Essenoun NE ALGERIE Figure 1, which occurred on the north-east side of the pit. A large mass of rock was detached from the massif, almost filling the pit. This is a major accident, both by the volumes mobilized (several million m3) and by the importance of the movement of materials (up to 200m).

Fig.1. Kef essnoun landslide area

2. GEOGRAPHICAL, GEOLOGICAL AND HYDROGEOLOGICAL DESCRIPTION

The layer of Kef Essnoun is located in the south of the massif of the Djebel Onk, 4 kms of city Bir El Ater north east of Algeria (34.726784 E, 7.895978 N), 100 kms of the Wilaya of Tébessa and to 20 kms of the frontier Algéro - Tunisian Figure 2, on the road that connects Tébessa to El Oued. This region constitutes the geographic natural boundary between the Constantine highlands and the Saharan domain.

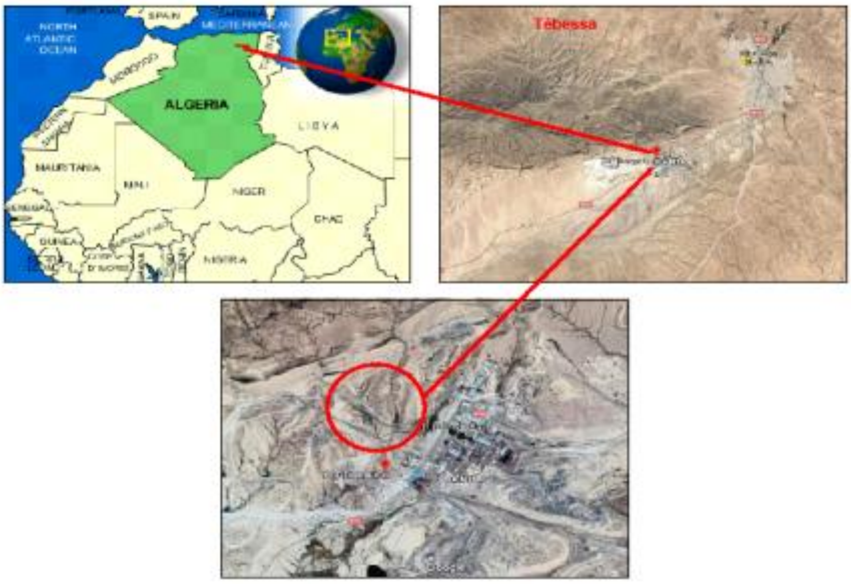

Fig.2. Location map of the study area

The site of study covers a surface of about 250 ha and belongs to the same mining basin of phosphate in Metlaoui (southwest of Tunisia) [15]. Where, the complexity of the structural directions that characterize the region of Djebel Onk, does reference to two major phases of compressive deformation: a post-Eocene atlas phase marked by (NW - HIMSELF) and a post-Villafranchien tightening phase Figure 3.

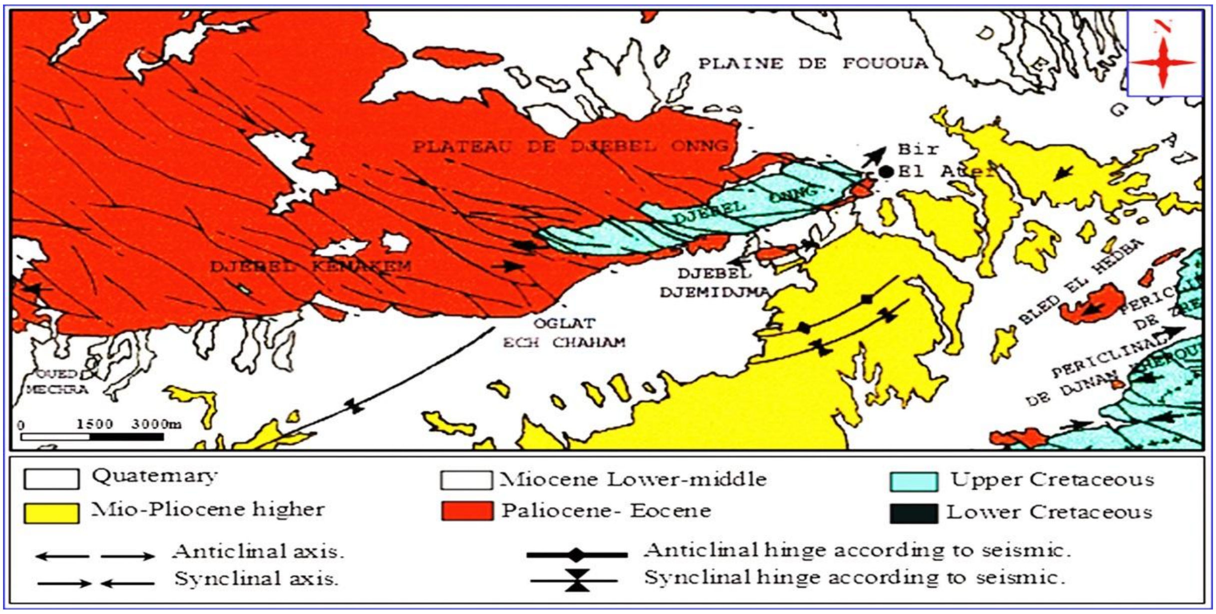

Fig.3. Geological map of the study area [16]

From an economic viewpoint, with a sparse population the region's economic situation has improved thanks to the installation of the kef essnoun mining complex, which has contributed to the expansion and development of the city. However, from a climatologic viewpoint, the zone of study of Kef Essnoun has a transition climate between that of the semi-arid Tebessa region and that of the sub-arid region of Négrine. Which on an average of 5 years, the temperatures have the same evolution, in winter they fluctuate around 7 ° C. The temperature increases gradually from the month of May, until reaching very high levels (45 ° C) in summer, and gradually decreases in autumn. Consequently, the precipitation during the summer months is extremely rare and periods without rain for more than a month are common. Furthermore, the rainy periods vary between 66 and 107 days / year, while the rainfall is of the order of 200 to 400 mm / year, the thunderstorms are significant and frequent especially during the months of August and September, whereas, the snow and frost is rare, but the temperature often drops below 0 ° C in winter.

The stratigraphy of the Jebel El Onk region, where the outcropping sedimentary series is expressed by a stratigraphic succession from Late Cretaceous (Maestrichtian) to Middle Eocene (Lutetian), topped by continental Miocene and Quaternary sand - clay series, where we can see in Figure 4 Kef essnoun's geological sections.

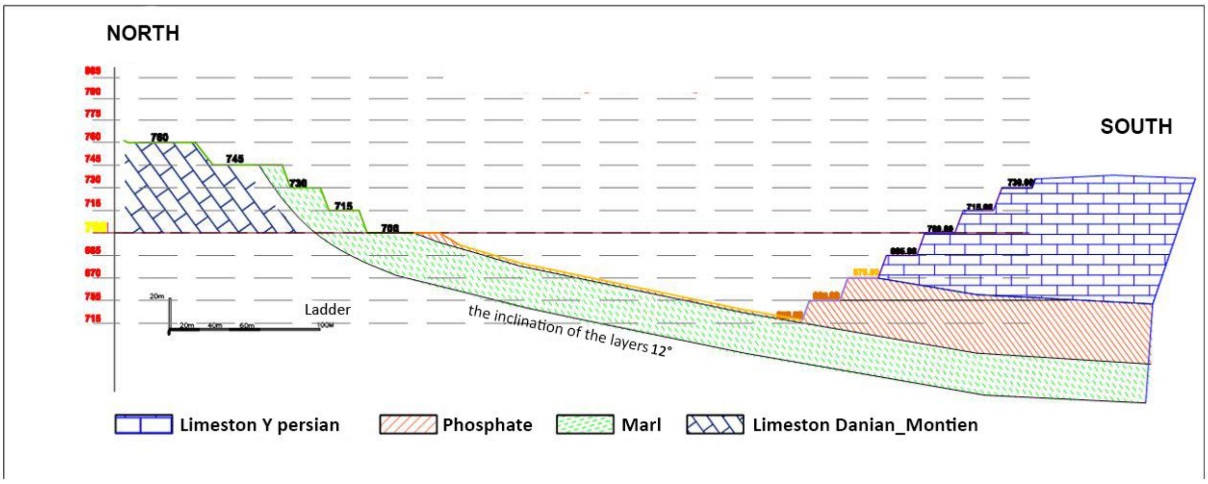

Fig.4. Geological sections of Kef essnoun (2019)

3. METHODOLOGY

The main objective of this study is the application of different rock mass classification systems, such as (RQD, RMR, SMR) which gives us the possibility to quantify the state of Stability of the different facies (Marl, phosphate, limestone) of the kef essnoun massif. Then, another method presented by a numerical approach is used to calculate the safety coefficient of the rock mass. The SMR system (Slope Mass Rating) [10] addresses the stability of rock slopes, practically, the SMR is the product of the sum of the RMR [17] and the adjustment factors depending on the joint - slope relationship and adding a factor depending on the excavation method:

$$SMR = RMR + (F1.F2.F3) + F4 \quad (1)$$

Where

- *F1* depends on the parallelism between the directions of the joints and slopes.

$$F1 = (1 - \sin A)^2$$

- *F2* depends on the dip of the joints for the plane failure mode.

$$F2 = tg^2\beta j$$

- *F3* is related to the relationship between slope and joint dip [9].
- *F4* takes into account the excavation method.

The RMR (Rock mass rating) classification system, is based on the simplicity to determine the following parameters [9]

$$RMRbasic = A1 + A2 + A2 + A3 + A4 + A5 \quad (2)$$

Where

- *A1*: compressive strength of the rock
- *A2*: RQD (Rock Quality Designation)
- *A3*: spacing of discontinuities
- *A4*: discontinuity conditions
- *A5*: condition of water inflows.

As part of this study, the calculation was started with the Geo slop 2018 code. This code allows the use of boundary equilibrium laws to correctly describe soil behaviour, as well as to model the steps of the kef essnoun mine, by applying the results of experimental and parametric analyses of the rocks composing the massif and the actual geometry of the site.

4. RESULTS AND DISCUSSIONS

The results of the RQD show that the quality of the massif is between average and good, (Table 1).

Table 1. RQD value of different geological formations

Facies	RQD	Rock quality
limestone Ypresian	72	Average
Phosphate	76	Good
Marl	48	Average
limestone Danian-Montien	85	Good

The condition of the rocky massif in the study area has slightly rough discontinuities, with openings less than 1 mm and soft to hard surfaces. The results of the RMR indicate that the massif is classified as good and medium rock (Table 2).

Table 2. Value of the RMR of the different geological formations

Facies / parameter	limestone Ypresian		Phosphate		Marl		limestone Danian-Montien	
	Measure	**Note**	**Measure**	**Note**	**Measure**	**Note**	**Measure**	**Note**
Rc(MPa)	52	7	22	2	7	2	35	4
RQD (%)	72	13	78	17	48	8	85	17
Nature of joints	Slightly rough surfaces Thickness <1 mm Eponte unaltered	25	Slightly rough surfaces Thickness <1 mm Eponte unaltered	25	Slightly rough surfaces Thicknes s <1 mm Altered eponte	20	Slightly rough surfaces Thickness <1 mm Eponte unaltered	25
Joint spacing (m)	0,2-0,6	10	0,2-0,6	10	0,2-0,6	10	0,2-0,6	10
Hydrogeology	Completely dry	15	Completely dry	15	Completely dry	15	Completely dry	15
RMR Basic	70		69		55		71	
Class of rocky massifs	II		II		III		II	
Rock quality	Good rock		Good rock		Average rock		Good rock	

From the SMR classification established based in situ observations, we deduce that the quality of the massif varies according to the different facies (Table 3)

Table 3. Value of the SMR of the different geological formations

Geological formation	limestone Ypresian	Phosphate	Marl	limestone Danian-Montien
RMR basic	70	69	55	71
F1	0,7	0,7	0,7	0,7
F2	0,4	0,4	0,4	0,4
F3	-60	-60	-60	-60
F4	-8	-8	-8	-8
SMR	45,2	44,2	30,2	46,2
Class	II	II	III	II
Description	Good	Good	Average	Good

Stability: unstable.
Rupture: possible break in the marl layer
Reinforcement method: reprofiling

Based on the empirical classifications, it has been deduced that the possible slippage affects the marl layer, to confirm our result and according to the parameters of the table 4, we will make a model by the geoslop limit equilibrium method Figure 5.

Table 4. The physical and mechanical properties of the different facies

Geological formation	Volume weight KN / m3	Internal friction angle in (^{o})	Cohesion in Mpa
limestone Ypresian	27	37	2.7
Phosphate	21	37	1.15
Marl	23	15	0
limestone Danian-Montien	27	37	1.8

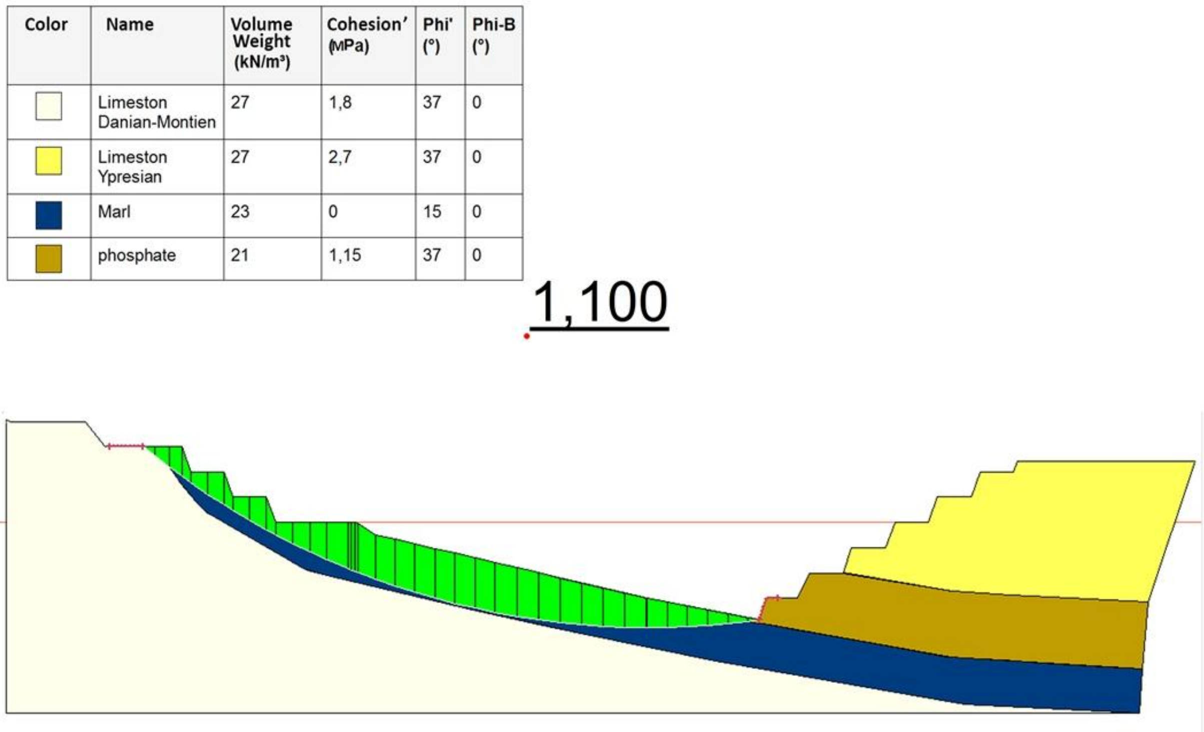

Fig.5. Illustration of safety factor and sliding surface

5. CONCLUSION

The detailed knowledge of the massif and its empirical geo-mechanical classification, RQD, RMR, SMR allows to evaluate the quality of the massif which is varied according to the different geological formations of good for limestone Ypresian, phosphate, limestone Danian - Montien and average for marls According to the SMR classification results, it can be seen that the marl interface is the probable cause of instability of the massif, due to its poor quality. In order to confirm the results obtained by the empirical classification systems, the boundary equilibrium method (Geoslope) is used by determining a safety coefficient (fs) that evaluates the state of stability of the massif Analysis by the Geoslope boundary equilibrium method (slope W) gives a safety factor of 1,100 confirming the SMR results.

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