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STABILITY STUDY OF SERPENTINE DEPOSITS IN CONTACT (BOU-AZZER-EST, BOUISSMAS AND AIT-AHMANE)

Ismail Zaki[1,*], Mohamed Souissi[2], Abdelkader Larabi[2] and Youssef Zerradi [2]
[1]CeDOC Ecole Mohammadia d'Ingénieurs, Rabat, Maroc
[2]EMI, Ecole Mohammadia d'Ingénieurs, Laboratoire LAMERN, Rabat, Maroc

ABSTRACT
The frank and carbonate serpentines of Bou Azzer are very friable metamorphic rocks. The mining excavations carried out in these rocks, whether permanent structures such as shafts, chutes, chimneys and galleries or temporary structures such as cuttings, suffer from a number of instability problems, which can be summarized as landslides and block falls. The purpose of this project is to make a characterization study of serpentines, whether frank or carbonate and identify the fracturing and mechanical characteristics of these rocks in order to understand their behaviour and design types of support that will be suitable for them. To try to structure the knowledge and to provide tools to help the design, some authors have very early-proposed syntheses in the form of classifications. These methods, quick to use and therefore economical, are based on different geotechnical parameters. It is the choice of these parameters and the way they are used for the design of the structure that will make the difference from one method to the other. In this article, the study was conducted at the scale of the sites Bou-Azzer East, Bouismass and Ait-Ahmane at the mine Bouazzer. My work consists, therefore, to characterize the rock mass in these three sites to design a suitable support. We will try to classify the rock mass of the various structures mentioned in the problem according to the empirical methods namely the RMR, the Q-system and the classification of the AFTES. The facies in question are Frank Serpentine, Carbonate Serpentine, Mineralized Case, Altered Diorite, Altered Chloritized Diorite and Diorite.
Keywords: *Massive rocks, Characterization of Serpentines, Frank Serpentines, Carbonate Serpentines, Empirical approach, Stability of the deposit, Support, Rock mass.*

1 INTRODUCTION:

GENERALITIES

The empirical approach tries to give us the benefit of experiences that have already been lived and succeeded. To do so, it is necessary to find in these experiments the real case closest to the studied case. Researchers have proceeded to the classification of these experiments by means of a certain number of parameters that are preponderant to the stability of the structures. Several classifications exist. Each of them has its particularities and meets a certain number of requirements.

Several authors have proposed geomechanical classification systems, such as RMR (Bieniawski 1989), Q system (Barton et al. 1974), RMi (Palmström 1995), NATM (), RSR (), BQ () and GSI (Hoek 1994). These are important tools, widely used by geotechnicians for the estimation of rock mass and discontinuity properties.

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However, for our study, we have opted for the most used approaches in force, namely: the quality of the rock mass (Q)[1], the geological strength index (GSI)[2], the classification of AFTES[3] and the rock mass index (RMR)[4] as empirical approaches for the characterization of serpentine rock mass at the levels of the different workings: Bouazzer East, Bouismass and Ait Ahmane, located at the level of the mine of BouAzzer, Morocco After the characterization of the serpentine rocks of the different workings, support methods will be proposed to overcome the problems of instability related to excavation in this type of rock.
The aim of this project was to make a characterization study of serpentine rocks, whether frank or carbonate and identify the fracturing and mechanical characteristics of these rocks in order to understand their behaviour and to dimension the types of support, which will be suitable for them.

THE DIFFERENT STRUCTURES STUDIED

The geological study of the Bouazzer mine deposits shows that all the mineralized bodies are in contact, at least by one of their extremity, with a serpentine massif. The mineralization is often trapped between the serpentines and another formation (quartz diorites, Infracambrian volcanic cover of Precambrian III or other formations of Precambrian II), so we conclude that the majority of the contact sizes at the Bouazzer mine are in the presence of a serpentine massif. We are sometimes obliged to trace galleries in full serpentine. Below, we present the different structures studied at the level of the different workings.

THE DEPOSIT OF BOU-AZZER EAST:

The deposit of "BOU-AZZER EST" is located at approximately 2Km in the East of the mining center of Bou-Azzer. It is part of the workings, which are currently in exploitation. The local geological context of the sector is characterized by the outcrop of the lower Precambrian II terrains, represented by serpentines in contact with quartz diorites. The ST2 structure, the subject of our study, is the main structure that is being exploited today. It has an average extension of 160m in length and a power that varies between 0.5cm and 2.7m with an average grade of 0.80%. This structure is oriented globally NE-SW with a subvertical dip (70° or more) (Figure 1). It is not regular. Closures and openings of the structure are often encountered. It is recognized down to a depth of 560 m.

THE DEPOSIT OF BOUISSMAS:

The Bouismass deposit is part of the deposits located around the serpentine massif of Oumlil. The geological context of the sector shows a contact of quartz diorites with serpentines, the mineralization is of vein type hosted in quartz diorites and contact hosted in carbonate serpentines. The object of our study is the structure of the F1 size of the Level -390 (Figure 1). The reconnaissance work at the -390 level has pushed the development of the CM1 body and its cruisers. The mineralization of the contact has been traced over a length of 30m. Two intra-diorite cruisers are related to this contact mineralization. Cruiser 1 is traced over a length of 6m and cruiser 2 is traced over a length of 21.5m from an access in the diorites of 16m.

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THE DEPOSIT OF AIT AHMANE:

Ait-Ahmane is the last site located east of the Bou-Azzer mine. The geological context of the area shows a contact of quartz diorites with serpentines, the mineralization is of vein type hosted in quartz diorites and of contact hosted in carbonate serpentines.ST4 structure of niv-115 (Figure 1) is the main structure of our study.

SUPPORTING SPECIFICATIONS USED:

THE SUPPORT USED IN BOU-AZZER - EAST :

In the ST2 -560 size of Bou-Azzer East, the support method used is bolting with welded mesh or grating. These grids are used to hold in place the blocks that could break off between the bolts. They are held against the wall by bolts and plates. There are two types of mesh: Zigzag mesh and welded mesh.
Depending on the geometry and the shape of the size, a suitable support estimate is established. For sections with openings up to 2.20 meters, the geotechnical department suggests the following support specification showed in (Figure 2).

THE SUPPORT USED IN BOUISSMAS:

The type of support used in the size F1-390 of the Bouismass site is wooden pushers.
The woodwork in the Bou-Azzer mine is used in different forms, among which we find the pusher. The pushers are wooden beams placed between two facings to ensure their stability. They are recommended in the openings < 80 cm. In prunings, pushers are therefore placed between the shoulders in areas of small openings to slow down the convergence of the land, prevent the closure of the pruning and/or retain blocks that may fall into the workings. Figure 3 shows this type of support.

THE SUPPORT USED IN AIT-AHMANE:

In Ait-Ahmane, two main methods of support are used: The pushers and the Split-Set bolt.
The dimensions of the wooden support (pushers) are the same as those chosen in the case of size F1-390 (Bouismass), and are used only in the openings < 1.70 m. For larger openings, bolting is used, more precisely the Split-Set bolt. This friction bolt consists of a high-strength steel tube split along a generator.
This type of support is installed according to the dimensions shown in Figure 4.

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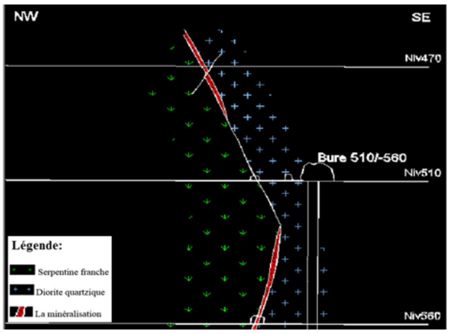
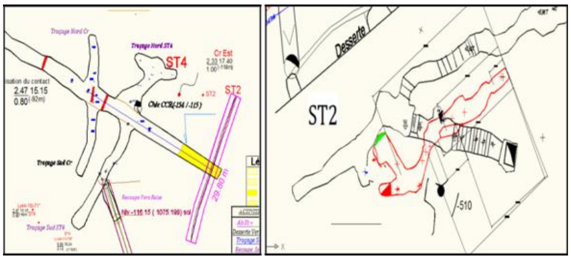
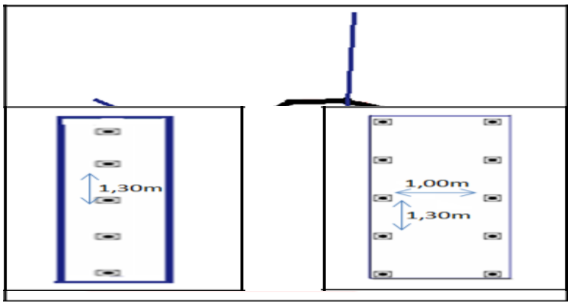


(a)



(b) (c)

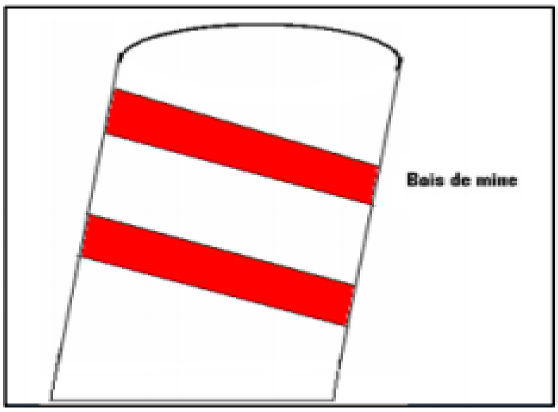
Figure 1: (a):Structure ST2 of BOUAZZER EST,(b):Structure ST4 of AIT AHMANE,(c):Structure F1 of Bouismass



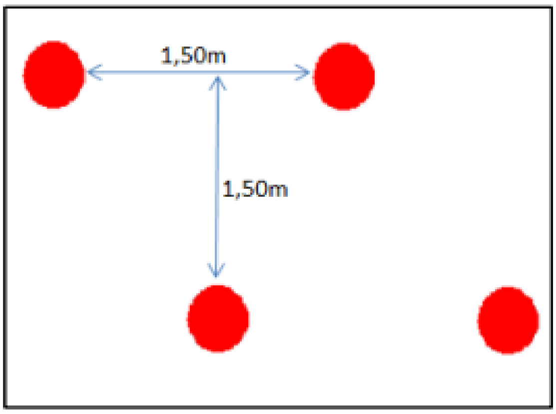
(a) (b)

DOI 10.17605/OSF.IO/QW3AY

Figure 2: (a): Cross section of size ST2 N – 560, (b): Plan view and longitudinal section

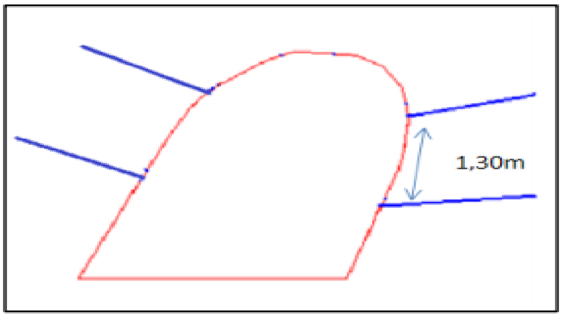


(a)



(b)

Figure 3: (a): Cross section of size F1 N -390, (b): longitudinal section



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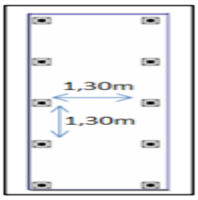

Figure 4: (a): Cross section of size ST4 N – 115, (b): longitudinal section

2 METHODS

The objective of this project is to propose a suitable support method, using a set of design and analysis methods, to deal with the instability problems encountered. The support methods we will use must take into account a system of different constraints: geotechnical, technical and technical-economic, namely:

- The geomechanical conditions of the rock;
- The implementation conditions;
- Economic constraints;

The instability of serpentines can be aggravated or controlled by other parameters, other than their mechanical characteristics.

From the boreholes studied, we will be able to calculate the average RQD values for each of the facies present in the three workings, taking into account their geological state. The RQD factor was used to determine the quality of the different facies:

- Average to good for the Diorites.
- Poor for the carbonate serpentines.
- Very poor for the frank serpentines.

In one site as in the other, the closer you get to the mineralised structure, the greater the fracture density. Hence the interest in working with the most critical values of the RQD in the empirical methods.

Q-SYSTEM METHOD:

The Tunnelling Quality Index (NGI rock mass classification), or Q[5], was introduced by Barton, Lien and Lunde in 1974. Based on analyses of a large number of underground excavations, this index allows the surface quality of discontinuities to be reported in order to infer the mechanical behaviour of the rock mass. The numerical values of the Q-index vary on a logarithmic basis from 0.001 to 1000, according to the following formula:

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF} \qquad (1)$$

Where:

DOI 10.17605/OSF.IO/QW3AY

RQD is Deere's Rock Quality Designation.
Jn is a number characterising the set formed by the families of joints.
Ja characterises the weathering of the joints.
Jr characterises the roughness of the joints.
SRF is the Stress Reduction Factor.
Jw is the Hydraulic Joint Reduction Factor.
The Tunnelling Quality Index Q can then be considered as a function of only three parameters, which are a direct measure of
1. Block size (RQD/Jn),
2. The inter-block shear strength (Jr/Ja),
3. The overall active and hydraulic stresses (Jw/SRF),

AFTES CLASSIFICATION METHOD:

The Association Française des Travaux en Souterrain (AFTES) [6] was created in January 1972 in response to the recommendations of the International Conference on Underground Works held in Washington in 1970, which advocated the establishment in each country of an organisation bringing together the various actors involved, in various capacities, in underground works.
Rather than giving the massif an overall "grade" determining the conditions for digging a structure, the AFTES preferred to clearly specify the various factors that must be known for the design of an underground project in a rock massif, namely

a) The state of alteration of the rock mass
b) Hydrogeological conditions
c) Discontinuities in the rock mass
d) Mechanical characteristics of the terrain
e) The natural stresses and the height of cover of the structure
f) Deformability of the rock mass
In addition to these criteria relating to the rock mass, the AFTES takes into consideration
1) Criteria relating to the structure and its method of execution:
- The dimensions and shape of the cavity
- The excavation process, which may be either explosive, with or without the use of the pre-cutting technique, or purely mechanical
2) Environmental criteria:
- The sensitivity of the environment to settlement
- The effects of a change in the hydrological balance

ROCK MASS INDEX METHOD RMR

Bieniawski [5] published in 1976 the details of a rock mass classification entitled Geomechanics Classification or the Rock Mass Rating (RMR) system. Since the original version, some modifications have been made. Now several variants of the Bieniawski classification are available. The 1976 and 1989 versions are the most commonly used.

DOI 10.17605/OSF.IO/QW3AY

The Bieniawski classification provides for the evaluation of different parameters for each of which a numerical coefficient is assigned. The sum of these coefficients determines the value of the CMA, which can vary between 0 and 100. The following six parameters are needed to estimate the compressive strength of a rock mass using the RMR system:

1. The uniaxial compressive strength of the rock,
2. The RQD value for the rock mass,
3. The spacing of the discontinuities,
4. The state of the discontinuities,
5. The hydraulic conditions,
6. Orientation of the discontinuities

The quality of the rock mass is divided into 5 classes (Table 1):

Table 1: Quality of the rock mass according to Bieniawski

Class	RMR	DESCRIPTION
1	81-100	Very good quality
2	61-80	Good quality
3	41-60	Average quality
4	21-40	Poor quality
5	<20	Very poor quality

3 RESULTS

In this chapter, I present the result of the classification of the rock mass according to the three empirical methods in order to calculate the required support for the different deposits.

SUMMARY OF THE AFTES METHOD:

The AFTES proposes the most suitable support method that meets the mechanical and hydrological conditions on the different sites. The type of support obtained using the AFTES classification is summarised in the table 2 below:

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Table 2. Support obtained from the use of AFTES for diorites and serpentines.

- In the case of diorites:

Rock	Bouissmas altered diorite	Bou-Azzer East Diorite	Chloritized and altered diorite (Ait-Ahmane)
The support given by AFTES	-Shotcrete with drainage -Point-anchored bolt with continuous mesh -Distributed anchor bolt with continuous mesh -Heavy duty hangers with wooden or metal shoring -Lightweight sliding hangers with wooden or metal armouring	-Shotcrete with drainage -Point-anchored bolt with continuous mesh -Distributed anchor bolt with continuous mesh -Heavy duty hangers with wooden or metal shoring -Sliding light hangers with wooden or metal armouring	-Shotcrete with drainage -Heavy hangers with wooden or metal wood or metal shielding -Sliding light hangers with wood or metal shoring

- In the case of serpentines :

Rock	Carbonate serpentine (Bouissmas)	Frankish serpentine (Bou-Azzer East)	Carbonated serpentine (Ait-Ahmane)
The support given by AFTES	-Shotcrete with drainage -Heavy hangers with wood or metal armouring -Sliding light hangers with wood or metal armouring -Assembled metal plates -Shotcrete with drainage	-Shotcrete with drainage -Heavy hangers with wooden or metal armouring + shotcrete -Light sliding hangers with wood or metal armouring + shotcrete -Assembled metal plates -Shotcrete with drainage	-Shotcrete with drainage -Heavy hangers with wooden or metal shoring -Sliding light hangers with wood or metal armouring

SUMMARY OF THE Q-SYSTEM METHOD:

With the help of core drilling and field observation, the rock mass of the three study areas could be classified according to Barton's classification, calculating the Q for the three rock types that were identified. Table 3 shows the results obtained.

For the De (equivalent excavation size), a maximum opening equal to 6 metres was considered (the case of the exploitation size), while ESR equals three (Temporary Mining Excavations). Therefore De =2

DOI 10.17605/OSF.IO/QW3AY

Table 3: Support specifications for each facies given by the Q-System.

Rock	Q	Classification Barton	De	Support
Carbonate serpentine (Bouismass)	0,48	Extremely poor	2	Shotcrete 40 - 100 mm with bolting Lb = 1,60 m
Frankish Serpentine (Bou Azzer -East)	0,00375	Extremely poor	2	Mesh + shotcrete 90 - 120mm with bolting Lb = 1,60 m
Carbonate serpentine (Ait-Ahmane)	0,75	Very poor	2	bolting Lb = 1,60 m , Es = 1,30m
Altered diorite (Bouissmas)	5,06	Average	2	Bolting Lb = 1.60 m , Es = 1.30m
Diorite (Bou Azzer - East)	2,06	poor	2	Bolting Lb = 1.60 m , Es = 1.30m
Chloritized diorite weathered (Ait-Ahmane)	2,53	poor	2	Bolting Lb = 1.60 m , Es = 1.30m
Mineralized body	0,3	Very poor	2	Mesh + shotcrete 50 - 90mm with boltingLb = 1,60 m

CORRELATION BETWEEN THE TWO CLASSIFICATIONS RMR AND Q-SYSTEM:

A correlation between the two classifications RMR and Q-system [7] has been elaborated through the study and analysis of several case histories. 68 cases in Scandinavia, 28 cases in South Africa, and 21 cases in the USA, Canada, Australia and Europe are cited.

There is an almost linear correlation between the two classifications given by equation (2):

$$RMR = 9\ \mathrm{Ln}\ (\mathrm{Q}) + 44 \qquad (2)$$

RÉSULTATS DE LA RMR CORRÉLÉE :

The numerical application of this formula (equation (2)) allows us to classify the facies into five decreasing classes. Table 4 summarises the results obtained. Class N° 5 indicates a highly fractured massif.

Table 4 Calculation of correlated RMR from the Q-System

Facies	Q-System	Correlated RMR	Class
Carbonate serpentine (Bouismass)	0,48	37,39	4
Frankish Serpentine (Bou Azzer -East)	0,00375	-6,27	5
Carbonate serpentine (Ait-Ahmane)	0,75	41,41	3
Altered diorite (Bouissmas)	5,06	58,59	3

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Diorite (Bou Azzer - East)	2,06	50,50	3
Chloritized diorite weathered (Ait-Ahmane)	2,53	52,35	3

It can be seen that the BouAzzer-East serpentine is a highly fractured massif and requires surface support (shotcrete, metal arches)

4 DISCUSSION OF RESULTS

It is noted that the AFTES classification method tolerates the use of bolting for both the Bouismass and East BouAzzer diorites. In the serpentine case, only shotcrete and hangers are recommended.

The results obtained by the Q-System method indicate that the first two facies (Serpentine carbonate BSM and serpentine frank BE) are qualified as extremely poor. Bolted support with shotcrete is strongly recommended in this case.
The RMR method confirms the non-compatibility of bolting in free-form serpentine. Its use in carbonate serpentines requires reinforcement with welded mesh.

Thus, the application of empirical methods on the different facies of Bou-Azzer gave as a support method:
- For the diorites: Bolting (Lb 1.60 m, Es: 1.30 m).
- For the carbonate serpentine: 40 - 100 mm shotcrete with bolting (Lb 1.60 m, Es: 1.30 m).
- For free serpentine: Mesh + shotcrete 90 - 120 mm with bolting (Lb 1.60 m, Es: 1.30 m).
- For mineralization: Mesh + shotcrete 50 - 90 mm with bolting (Lb = 1.60 m, Es: 1.30 m).

The application of these supporting means in the field shows satisfactory results for the Q-System method compared to other methods. The method is suitable because it takes into account the equivalent dimensions of the gallery when defining the support system. Furthermore, the efficiency of the Q-System is further increased because the method takes into account the effective in-situ stress and the surcharge height during excavation.

5 CONCLUSION

From the drill holes studied, we were able to calculate for each hole the average value of the RQD by facies, taking into account the geological state. The calculations indicate average to good qualities for the diorites, mediocre for the carbonate serpentines and very mediocre for the frank serpentines. The mechanical characterisation of the intact rock showed that the rock characteristics (strength and deformability) degrade as one approaches mineralisation. These parameters will be influenced by hydrogeological conditions, depth, and the state of fracturing around the excavation.
After identifying the Hoek-Brow parameters, we were able to establish a support mode through the classical empirical methods: AFTES, Q-System and RMR. The application of these methods on the different facies of Bou-Azzer resulted in the following support modes Bolting (Lb 1.60 m, Es: 1.30 m)

DOI 10.17605/OSF.IO/QW3AY

for the diorites, Shotcrete 40 - 100 mm with bolting (Lb 1.60 m, Es: 1.30 m) for the carbonate serpentines and Mesh + shotcrete 90 - 120 mm with bolting (Lb 1.60 m, Es: 1.30 m) for the frank serpentines.

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