GEOLOGICAL AND GEOTECHNICAL STUDY OF DRAA SFAR MINE (MARRAKESH, MOROCCO)

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ABSTRACT

Nowadays mining prosperity depends largely on the stability of underground structures. It is then necessary to know the configuration of the deposits. Which means analyze and understand the behavior of enclosing land during Operation Ore.

The Draa Sfar mine, is located 13 Km northwest of the city of Marrakech, and is ranked among the deepest mines in North Africa. Currently, violations depths exceed 1,100 meters.

The geotechnical study can treat the various aspects of the exploitability of downstream level -1000m of the mine Draa Sfar. This work will focus first on the development of this new resource panel to highlight its mineral wealth and polymetallic potential.

Moreover, this work also addresses the behavioural aspects of rheological and mechanical response of the rock mass Mine Draa Sfar, the digging of galleries and various infrastructures works necessary for mining. Thus, the comparison between usual failure criteria and geomechanical characterization of the rock matrix focused on the peculiarity of the facies of the mine, characterized by mineralization vein structure induces stresses which change progressively as the operating level increases, thus generating field instabilities. Hence, the need for adequate supporting quote for maximum productivity and optimum operating cost.

INTRODUCTION

Within the framework of its development strategy continuous, group MANAGEM (multinational of exploitation and mining exploration) aims at exploiting to the maximum the resources of the layer of Draa Sfar. This very promising project will have to be preceded by a technical-economic feasibility study, which treats in details the aspects Geotechnics, the requirement in supporting for the works and the data of mining profitability. This study will help with the decision on the utility to launch out in such a project of scale and to consider the risks to be admitted by specifying the margin of error and the sensitivity of the calculated parameters.

Accordingly, this work is registered which will make it possible to determine the limits of the exploitability of the downstream of the level -1000m according to a two-dimensional approach: technical-economic. Indeed, the general Geotechnical limit, as she was deduced in terms from the study of mass, stops with 1300m. Consequently, our field of study will be limited between 1000m and 1300m, coast optimal for an at the same time sedentary and profitable exploitation. Admittedly, the database, one has limits to the level 1200m. They are all the parameters: mechanical parameters, geological parameters.
Indeed, one will be able to carry out a statistical processing of these parameters by considering each one as a random variable which will be approached by a probabilistic law. This one will be extrapolated to determine the probability values of each parameter beyond the level 1200. In the same way, the estimates of supporting will be dimensioned while being based on the empirical, analytical and digital methods. With this intention, we plan to treat in detail the Geotechnical study of the site.

TALLY GEOGRAPHICAL AND GEOLOGICAL

Tally geographical

The polymetallic layer of Draa Sfar is located at 13 km as the crow flies at the Western North of the town of Marrakech, in the Hercynian solid mass of Jebilet power stations. It is accessible by the minor road N° 2006, which connects the town of Marrakech to the locality of Souihla.

Tally geological and metallogenic

In Draa Sfar, mineralisation is represented by a sulphuretted cluster. It is located on the southern margin of the solid mass of Jbilets power stations and is boxed in the series volcanoc-sédimantaire (métapélites black, pumice turfs, mineralisation) of Sarhlef which dates from Viséen superior-Namurien. This series was deformed at the time of the Hercynian tectonic phases and post Hercynian contemporary of a green schist metamorphism type (Rziki, 2011). It is superimposed on a metamorphism of contact slightly later. This tectono-metamorphic history complexes are at the base of méga-lenses.

The mineral-bearing body is a méga lens stratiform, long 1.5 km and boxed in the volcanogenic plots and sequences. Mineralisation is made up from 90 to 95% of pyrrhotite, mineral-bearing out of Zinc, Lead, Copper. It is intercepted starting from the
coast -50m to the coast -1000m, but remains open in-depth with a pitch of 50° towards the NW.

![Geological map of the solid mass of Jbilets](image)

**Fig. 2 - Geological map of the solid mass of Jbilets (Huvelin, 1977 modified by Essaifi, 1995)**

GEOTECHNICAL STUDY

**Recall of the preliminary conceptual study**

**a. Introduction**

Our work led us to carry out a general study of the exploitability to the Geotechnical direction of the downstream of level -1000 of the mine of Draa Sfar. This study treated the general stability of the mining openings beyond the level -1000m. The assumptions, the recommendations, the conclusions drawn as well as the limits from this concept study will be evoked.

**b. Formulation of the problems**

The terms of the general study of the exploitability already were to 1080 m of depth in the mine of Draa Sfar. With this depth, the mine could hold the record of the Moroccan mining network. However the wealth of this layer pushed group MANAGEM to study the possibility of an exploitation beyond the level -1080m.

This promising project must be initially validated by a Geotechnical preliminary study, which makes it possible to justify that the deep layers could be dug without resorting to modes of expensive supportings. Consequently, our problems were: Is the layer a mineral wealth, but is exploitable from the Geotechnical point of view?

The answer to this question requires to evaluate balance Forced/Resistance. With this intention, one carried out a calculation in extreme cases of balance by a digital model and thereafter one examined the behavior of the layers of rocks in the vicinity of a gallery by measuring the values of the safety factor (FS).

**c. Expression of the results and prospects**

The study is carried out by a software phase2 (software of stress measurement in the surroundings of the gallery before and after the excavation) and with modelings by a continuous medium. It was carried out with a step by 100m to sweep the interval -1000m at -1500m. One presents, as an example, the results got for the level -1500m:
In short, the answer to the question of exploitability to the Geotechnical direction of 1000m with 1500m is relatively positive. The curve of the ISO values of the safety factor (FS) which show values > 1.

**Context of the geotechnical study**

The general Geotechnical limit as she was deduced in terms from the study of mass stops with 1300m. Consequently, our field of study will be limited between 1000m and 1300m provided with finding the coast optimal for an at the same time sedentary and profitable exploitation.

It is advisable to recall that the mining works of the downstream will be built in the same rock prolongation of the upstream of the level 1000m. I.e. the slope, the crosseuts, the galleries of attack and the galleries of access will be created in the faces of the black métapélites and the rooms of exploitations will be elaborated in mineralisation. The geographical location of these works is represented in the following figure:
Mechanical and geological characterization

The study was carried out by using two approaches which are based on the systems of classification of the fractured rock masses (Rock'n'roll Mass Rating (RMR: Bieniawski, 1989); Rock'n'roll Farmhouse Quality- Q-system (Barton, 1974); Geological Strength Generalized Index (Hoek and Brown, 2002)) and on the criteria of rupture.

a. The properties géomechanics of the facies

Table 1 - Property géomechanics of the facies of Draa Sfar

<table>
<thead>
<tr>
<th>Paramètre géo-mécanique</th>
<th>Métapélite noires</th>
<th>Tufts</th>
<th>Mineral</th>
<th>Tufs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Densité (Kg/m³)</td>
<td>0,027</td>
<td>0,0272</td>
<td>0,04</td>
<td></td>
</tr>
<tr>
<td>RC (MPa)</td>
<td>31</td>
<td>34</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>E (Mpa)</td>
<td>16874</td>
<td>15174</td>
<td>27534</td>
<td></td>
</tr>
<tr>
<td>ν</td>
<td>0,15</td>
<td>0,2</td>
<td>0,25</td>
<td></td>
</tr>
<tr>
<td>Paramètre M-C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (Mpa)</td>
<td>1,4</td>
<td>1,74</td>
<td>7,2</td>
<td></td>
</tr>
<tr>
<td>φ (°)</td>
<td>25</td>
<td>31</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Paramètre H-B (roche intacte)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSI</td>
<td>51</td>
<td>54</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>m₀</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Paramètre H-B (roche sur terrain)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m₃</td>
<td>1,38</td>
<td>2,02</td>
<td>2,41</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>0,0043</td>
<td>0,0057</td>
<td>0,0067</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>0,5</td>
<td>0,5</td>
<td>0,5</td>
<td></td>
</tr>
</tbody>
</table>

b. Analysis of causes of instabilities

The data analysis of the falls of blocks made it possible to determine the main causes of this phenomenon, indeed the computation results are presented in the following table:

Table 2 - Causes of instability

<table>
<thead>
<tr>
<th>Année</th>
<th>Faille</th>
<th>Manque de boulons</th>
<th>Sous dalle</th>
<th>Ouverture</th>
<th>Zone mince</th>
<th>Eponte friable</th>
<th>Mineral friable</th>
<th>Zone de fermeture</th>
<th>Pendage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>52</td>
<td>29</td>
<td>10</td>
<td>17</td>
<td>23</td>
<td>14</td>
<td>7</td>
<td>18</td>
<td>2</td>
<td>172</td>
</tr>
<tr>
<td>2008</td>
<td>56</td>
<td>31</td>
<td>15</td>
<td>40</td>
<td>17</td>
<td>35</td>
<td>10</td>
<td>29</td>
<td>3</td>
<td>236</td>
</tr>
<tr>
<td>2009</td>
<td>36</td>
<td>20</td>
<td>11</td>
<td>22</td>
<td>10</td>
<td>12</td>
<td>7</td>
<td>12</td>
<td>3</td>
<td>133</td>
</tr>
<tr>
<td>2010</td>
<td>17</td>
<td>12</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>64</td>
</tr>
<tr>
<td>2011</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>2012</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>2013</td>
<td>9</td>
<td>14</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>2014</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>2015</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>121</td>
<td>44</td>
<td>99</td>
<td>57</td>
<td>76</td>
<td>28</td>
<td>67</td>
<td>13</td>
<td>704</td>
</tr>
<tr>
<td>% de chute</td>
<td>28,3%</td>
<td>17,2%</td>
<td>6,3%</td>
<td>14,1%</td>
<td>8,1%</td>
<td>10,8%</td>
<td>4,0%</td>
<td>9,5%</td>
<td>1,8%</td>
<td>100,0%</td>
</tr>
</tbody>
</table>
These statistics made it possible to determine the diagram of the frequencies of the causes of fall of blocks what will enable us to react to the level as of estimate of supporting.

Thus the causes of falls of blocks can be gathered in two large families. The first can be classified like natural and second is technical. The family of the natural causes includes the following causes: Fault, friable vein wall, mean zone, friable ore, zones of closing and the dip.

The frequency of the family of the technical causes knew an increase as from the year 2007 and until 2010. However the frequency of the family of the natural causes decreased starting from 2007 until 2010 so that she believes again in 2011 and decreases as from this year.
In the objective to follow the annual evolution of the falls of blocks, we plotted the curve of full of blocks according to the years (figure 8). This curve shows a considerable reduction in the level as of falls of blocks as from the year 2008 until the year 2012. However, one notes an increase in fall of blocks in 2013 compared to the previous year.

**c. Synthesis**

In terms of this analysis, one concludes that instabilities on the level of the Southern block of Draâ Sfar are multiple. One attends a phenomenon of fall of the blocks which is omnipresent in the mineralized faces, especially, and Pelite. The buckling of the facings in the excavations directed schistosity parallel to constitutes also a factor of instability.

**Estimate of supporting**

**a. Creation of the design and importation of the surveys**

In terms of this analysis, one concludes that instabilities on the level of the Southern block of Draâ Sfar are multiple. One attends a phenomenon of fall of the blocks which is omnipresent in the mineralized faces, especially, and Pelite. The buckling of the facings in the excavations directed schistosity parallel to constitutes also a factor of instability.
b. Result of simulation of dimensioning of supporting by RMR

Our approach is based on the development of the estimates of supporting per block whose objective is to optimize the estimates of supporting.

![Fig. 10 - Spatial 3D of the classes of the rock solid mass according to RMR](image)

Fig. 10 - Spatial 3D of the classes of the rock solid mass according to RMR

c. Confirmation of estimate of supporting by the Unwedge software

A bloometric analysis using the Unwedge software (a software which makes it possible to define the geometry and the stability of the blocks in the neighbourhoods as of excavations) after having defined the families of fracturing, makes it possible to arise and dimension a system of adequate supporting for stabilization of the rock solid mass after the excavation of the galleries:

| Table 3 - Results of supporting for an excavation of 4m by Q-system |
|------------------------|-----------------|-------------------|----------------|-----------------|-----------------|
| N° du Bloc Instable | Poids du bloc | Type de Boulons | Longueur des Boulons | Maillle de Soutènemment | Facteur de sécurité avant soutènement | Facteur de sécurité après soutènemment |
| 7                    | 0.85 t        | Swellex          | 2.37 m | 1.5 m x 2 m    | 0.133            | 1.6             |
| 3                    | 86.50t        |                  |        |                | 0.347            | 7.4             |

CONCLUSION

The analysis enabled us to deduce that the natural causes which cause falls of the blocks: the structure of the layer (faults, friable ore, mineralisation-boxing contact with friable nature…). And the technique causes related to the completion of the work are: pose bolts of supporting, excavation under flagstone.

To make safe the exploitation (staff, layer, machines…), it is paramount to implement of the estimates of adequate supportings to support the solid mass, especially that the faces present is fractured rocks (results of the surveys of fracturing) having resistances relatively weak (results of the mechanical tests). Generally the mineral-bearing solid mass is present in a geological context dominated by sand, carbonated pellets and turfs. The totality of
the rock solid masses are poor qualities and characterized by an intense fracturing, this is proven by the calculation of the RQD which.

Considering the heterogeneity of the solid mass from any point of view, a model 3D which presents the distribution of the estimates of supportings by a block whose size can reach the precision of 5m can only eliminate the effect of heterogeneity from the solid mass and optimize the estimates of supporting in the solid mass. Thus, one can avoid the problem of over-estimating or undervaluation of the estimates of supporting.

The blocks 3D constitute a tool of decision-making aid during planning; indeed the first drawn information is that to on the west side carry out the tracings of the mineralisation of layer which presents a relatively important RQD by comparison to on the east side of mineralisation.

The in situ reports showed that it is necessary to think about the durability of the modes of supporting after their implementation because of:

- The orientation of the galleries of attacks parallel to the direction of schistosity accentuates the problem of buckling. For this reason it is necessary to think of a reorientation of the galleries of attacks to solve this problem.
- Optimal Ø Distance with laisserentre galleries of attacks and the rooms of demolitions is equal to 32m. However, that to leave between two parallel accesses is about 9m. These distances are the minimal distances to avoid the interference between the works.
- The aggressiveness of the mining environment of the mine (salinity of water, moisture, temperature, ventilation…). The degradation of the anchor bolts and netting are accelerated in such environment.

REFERENCES


