Application of empirical analysis to underground mine a study case In morocco.

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Abstract. The OUMJRANE mine located in the eastern Anti-Atlas in Morocco, is operating underground mining in various sedimentary rocks from sandstones to shales. During operation, several instabilities are recorded in the underground galleries. The present study represents an empirical characterization based on the classification index of the rock mass: RMR (Rock Mass Rating), Q (Tunnel Quality Index) of the stability of the excavation. The input data used for this analysis were based on fracturing surveys, core logging, and laboratory tests. The results of this study show that the rock mass is of low quality.

1. Introduction

In the mining sector, the successful operation of underground galleries requires a stability study to avoid falling rock blocs, which is one of the most serious safety problems in the mining industry. These rock blocks are linked to the quality of the rock mass, the intersection of the gallery surface with the existing discontinuities in the rock mass [7], the state of the constraints (in situ constraints, and the constraints induced by the digging of the gallery), on the other hand, the quality of the rock mass [14] and the convergence of the land following the increase in depth [9, 11].

The OUMJRANE mine is currently being mined underground in sedimentary rocks with a low dip structure (45°). To ensure the viability of the mine and the safety of workers, it is important to make a geomechanical characterization based on two classification methods: RMR (Rock Mass Rating) and Q (Tunnel Quality Index).
2. Description of discontinuities

The discontinuities in the rock mass were mapped using the scan line method [12]. 270 discontinuities have been mapped in the underground galleries at level 80 and 120. Five families are determined (Table 1):

- Three major families: the first family (F1) is oriented EAST-WEST with a dip of 45° to the EAST, the second family (F2) has an N60 direction with a dip of 70° to the SOUTH and the third family (F5) is oriented NORTH-SOUTH with a sub-vertical dip.
- Two minor families, which have a direction N130 with a dip of sub-vertical for F3 and horizontal for F4.

| Family | Orientation |
|--------|-------------|
| F1     | N85, 45° S  |
| F2     | N60, 70° NW |
| F3     | N130, 70° SW|
| F4     | N130, 0°   |
| F5     | N5, 75° N  |

Table 1- Orientation of joint sets.

To determine the characteristics of the discontinuities which cross the rock mass of the OUMJRANE mine, we analyzed three indexes: Jr (Joint roughness number), Ja (Joint alteration number) according to the Q-system method [1] and the last index represents the spacing of the discontinuities used in the RMR classification system [2, 13]. The statistical study is presented in the following table:

|                      | Sandstone | Shale |
|----------------------|-----------|-------|
| Number of joint sets (jn) | 12        | 12    |
| Roughness of the most unfavourable joint or discontinuity (jr) | 1.5       | 1     |
| Degree of alteration or filling along the weakest joint (ja) | 0.75      |       |
| Joint spacing        | 20cm<E<60cm| <20cm |

Table 2- Quantitative descriptions of discontinuities

The RQD (Rock Quality Designation) parameter was calculated according to the DEERE method [4] on 16 drill cores. The results show that the sandstones are of good quality with an average of 54% and the shales are of low quality with an average of 48% (table 3).

| RQD Index | Minimum | Mean | Maximum |
|-----------|---------|------|---------|
| Sandstone | 3%      | 54%  | 100%    |
| Shale     | 4%      | 48%  | 92%     |

Table 3- Values of the RQD index
3. Mechanical properties of the intact rock

The mechanical properties of the intact rocks crossed in the galleries of the OUMJRANE mine, are determined by different tests, essentially:

- 17 specimens of the uniaxial compressive strength;
- 18 specimens of the indirect tensile strength (RT), Porosity and Density;
- 14 specimens of the tri-axial compressive strength.

The results of these laboratory tests are summarized in the following table:

|                          | Sandstones |             | Shales |             |
|--------------------------|------------|-------------|--------|-------------|
| **Uniaxial Compressive** | **Strength** | **Mpa** | **Strength** | **Mpa** |
| Minimum                  | 1.70       | 1.50        | Minimum | 12.34       | Maximum  | 27.00   | Maximum  | 9.00      |
| Mean                     | 40.12      | 12.00       | Mean   | 12.34       | Maximum  | 27.00   | Maximum  | 9.00      |
| Maximum                  | 120.00     | Maximum     | Mean   | 12.34       | Maximum  | 27.00   | Maximum  | 9.00      |
| **Modulus of Elasticity**| **E (GPa)**| **3.00**    | **5.00** | **2.22**    | **2.22** | **2.42** | **2.64**  |
| **Density (t/m3)**       | **2.23**   | **2.22**    | **2.22** | **2.22**    | **2.22** | **2.42** | **2.64**  |
| **Tensile Strength**     | **Mpa**    | **0.30**    | **0.30** | **0.30**    | **0.30** | **1.68** | **3.80**  |
| **Cohesion (KPa)**       | **2 800.00** | **3 266.88** | **750.00** | **4 274.50** | **7 244.00** |
| **Friction Angle (°)**   | **38.00**  | **47.75**   | **32.00** | **40.20**   | **50.00** |

Table 4- Mechanical properties of the intact rock

4. ROCK MASS CLASSIFICATION OF OUMJRANE mine

In this part, we used the most used empirical classification methods in the mining field: RMR: Rock Mass Rating [3] and Q-system [1, 10].

a- RMR classification system

The RMR index, was developed by Bieniawski in 1973, then was modified in 1989 [3]. This classification, especially the RMR89 version, uses six parameters that are as follows:

- The uniaxial compressive strength of the rock intact;
- The RQD value (Rock Quality Designation);
- Spacing;
- Condition of discontinuities;
- Condition of the groundwater;
- Condition of orientation discontinuities;

Following the score assigned to each parameter, the quality of the rock mass is then divided into five classes ranging from 0 to 100.
The results of this index show that the OUMJRANE mine has a rock mass formed by medium quality sandstones and low-quality shales (table 5).

| Parameters                                      | Sandstones | Shales |
|-------------------------------------------------|------------|--------|
| Rock mass quality system (Q – system)           |            |        |
| Index Q for rock mass is a tunneling databased empirical classification system. It is developed by Barton in 1974 [1]. Multiple revisions have been proposed for the system [5, 10]. It is a quantitative classification system for estimates of tunnel support. On a logarithmic scale, the system categorizes the ground into nine classes. The index ranges from 0.001 to 1000, is determined using Equation: |
| $Q=(RQD/Jn)\times(Jr/Ja)\times(Jw/SRF)$          |            |        |
| Ground water                                    | Damp       | Damp   |
| Slightly rough surfaces, separation < 1 mm, slightly weathered walls | 25         | 10     |
| Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm continuous | 10         | 10     |
| Parameter adjustment for joint orientations     | -12        | -12    |
| The works carried out are oriented EAST-WEST and NORTH-SOUTH, which are parallel to two discontinuities: F1 and F5 with a limited dip between | -12        | -12    |
| 45 and 90°                                     |            |        |

Table 5- RMR parameters values

b- Rock mass quality system (Q – system)

Index Q for rock mass is a tunneling databased empirical classification system. It is developed by Barton in 1974 [1]. Multiple revisions have been proposed for the system [5, 10]. It is a quantitative classification system for estimates of tunnel support. On a logarithmic scale, the system categorizes the ground into nine classes. The index ranges from 0.001 to 1000, is determined using Equation:

$$Q=(RQD/Jn)\times(Jr/Ja)\times(Jw/SRF)$$  \hspace{1cm} (1)

Where:

- RQD: Rock quality Designation, (Deere 1963);
- Jn: Number of joint sets;
The results of this index are summarized in the following table

| Parameters | Sandstones | Shales | Designation                                      |
|------------|------------|--------|-------------------------------------------------|
| RQD        | 54         | 48     | Fair and Poor Rock                              |
| Jr         | 12         | 12     | Three joint sets plus random joints             |
| Jr         | 1.5        | 1      | Slickensided, undulating and smooth, planar     |
| Ja         | 0.75       | 2      | Easily healed, hard, non-softening, impermeable filling, i.e., quartz or epidote and slightly altered joint walls. Non-softening mineral coatings; sandy particles, clay-free disintegrated rock, etc. |
| Jw         | 1          |        | Dry excavations or minor inflow (humid or a few drips) |
| SRF        | 2.50       |        | Single weak zones with or without clay or chemical disintegrated rock (depth > 50m) |
| Q          | 3.60       | 0.80   | Q' = (RQD/Jn) * (Jr/Ja) * (Jw/SRF)              |

Table 6- Q parameters values

5. Conclusion

The objective of this article was to characterize the rock mass of the DOUMJRANE mine to predict the geomechanical domain encountered during the excavation. For this, we used statistical analysis of data mining and the main classifications proposed in the literature in particular, those of Bieniawski (RMR) and Barton (Q-system). These two classifications have shown that the OUMJRANE mine has a low-quality rock mass. This study is a basis for carrying out a dimensioning of the support necessary to ensure the stability of the underground galleries.

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