Quality control of support system in hard rock mines

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ABSTRACT: The main risk factor of underground mines is the falling rock blocks which in its turn, therefore, needs to be mitigated. Knowing the complexity that involves the stabilization of rocks in underground operations mines and this control is indispensable to execute the activities in a safe way, this work aims to improve the risk management and to present the results obtained in the operation Serra Grande from the company AngloGold Ashanti. In the operation Serra Grande, it is used three designs of resin bolts, all of them with diameter 7/8 and length 2400mm. These are installed with Resin Cartridge, using the Jumbo machine. The process of bolts installation have a significant complexity and if it is not done correctly, you may not get the objective, so you need quality control tools to ensure the execution of the procedure. Thereby, a method to analyze the installed rock bolts was applied.

1 GENERAL INSTRUCTIONS

1.1 *Location*

The Mineração Serra Grande (MSG) belongs to the AngloGold Ashanti group. It is located in the center-west region of Brazil, more precisely in the north of the Goiás state, about 320km from Goiânia. MSG currently exploits ore bodies on open pits and underground operations. The underground mines expose depths between 300 and 900 meters deep. (Figure 1)

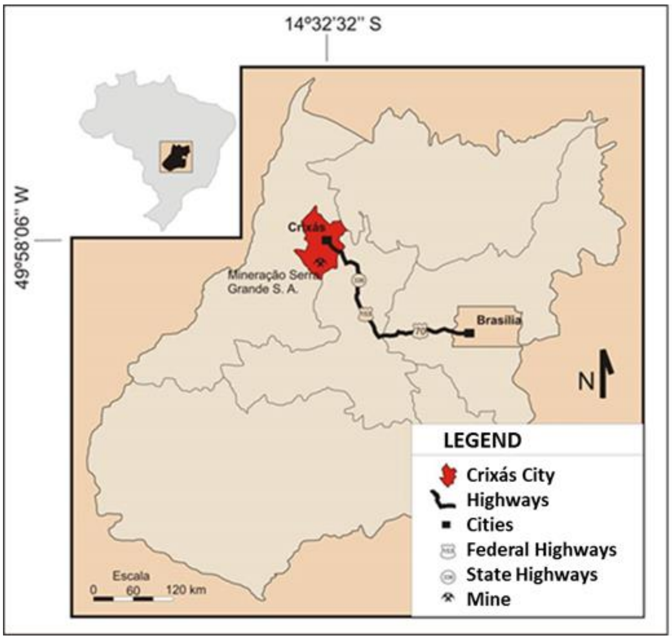

Figure 1 - Location of Crixás/GO

1.2 *Support system*

The support system aims to stabilize the rock mass in order to keep underground operations safe throughout its development. In MSG, these are separated into two groups: punctual support system (Split Set, 7/8 Resin Bolts and Cable bolts) or surface support system (Bematel Mesh and Shotcrete). Among these supports, the bolt is the only one recommended from the rock mechanics team in all development faces. The activities and tolls that will be presented below are to support on risk management and quality control of this support type.

2 CONTEXT

Knowing the complexity involved in the installation of bolts, MSG's rock mechanics team submits the installed supports to tests, aiming to attest the liability of the supports and the operational processes involved in their installations. According to Gontijo (2018), these are controllable and noncontrollable variables. Among the controllable variables will be highlighted: drilling angle, bolt pattern, torque, pull test and grip factor (GF). To control these variables, the processes were studied in order to define the minimum parameters for the adequacy of the supports; each process will be briefly described so that the tools become clearer.

2.1 *Drilling angle*

It is recommended the bolts to be installed as near to 90° degrees as possible. This recommendation aims at greater anchoring and meeting the kinematic constraints, however, the technical limitation of the Jumbo rod used in MSG prevents that in certain points it is possible to install only with an angle greater than 60°. Due to this limitation, bolts with an angle greater than 60° are considered suitable.

2.2 *Bolt pattern*

To set the bolt pattern numerical and limit equilibrium, analyzes were performed using RS2 and Unwedge software respectively. From the obtained results, it was defined that the standard pattern would have 1.5x1.5m between bolts at the same installation line, advancing 1.5m, intercalating by advance the lines in 4 and 5 bolts forming triangles between supports. In this analysis the quality of the pattern, the ratio of installed bolts versus expected bolts and the length of the analyzed pattern will be evaluated.

2.3 *Torque*

In MSG, the bolts are able to be torqued because they are installed with 2 types of resins with different curing times and have all the perforation filled. Torque is realized with a predefined load and its result is a tensioning distribution throughout the entire support system.

2.4 *Pull Test*

The pull test is determined by the rock mechanics team and aims to attest the anchoring capability of the support system. According to the Brazilian standard, this is done in at least 1% of the installed bolts per month.

2.5 *Grip Factor*

The adherence efficiency (Mark et al. 2002) is defined as the bolt anchoring resistance per inch. At MSG, the tests are carried out annually or whenever there is a change of supplier or some process that may influence the anchorage of the bolts.

3 METODOLOGY

The methodologies presented below were divided into 4 categories.

3.1 *Drilling angle and torque*

Data collection for drilling angle and torque is performed over the same activity. For this, a Clar compass and a lifting platform are used. In this analysis, the angle between the bolt and the rock mass, the torque analysis, the location of the bolt, the date of collection and the color of the bolt will be collected. Check the torque by checking whether the plate is tight, i.e. in contact with the rock mass (Fig. 2). At MSG the teams are differentiated by color, and it is necessary that at the end of the installation, the bolt to be painted with the color of the team. In a way that is possible, to perform statistical analyzes comparing the quality of installation according to the teams.

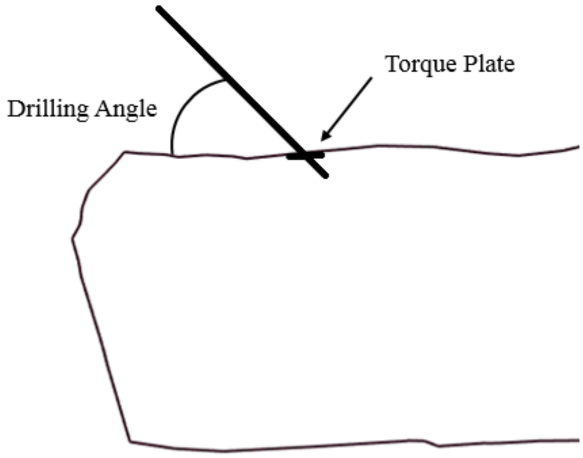

Fig. 2 - Representation of the drilling angle and the torque plate

3.2 *Bolt Pattern*

To collect the exact position of the bolts, the sampling team uses a tachometer. The analysis is done in GEM4D software where, the location of the bolts are plotted as point markers on the topographic excavation surface. After being plotted, the markers are configured as 1.5m diameter spheres and the excavation is colored according to the distance of the nearest marker. To facilitate the interpretation, the scale is divided into three colors, ranging from 0.3m to 1.2m distance. The range of 0.6m to 0.9m is considered adequate to the established standards.

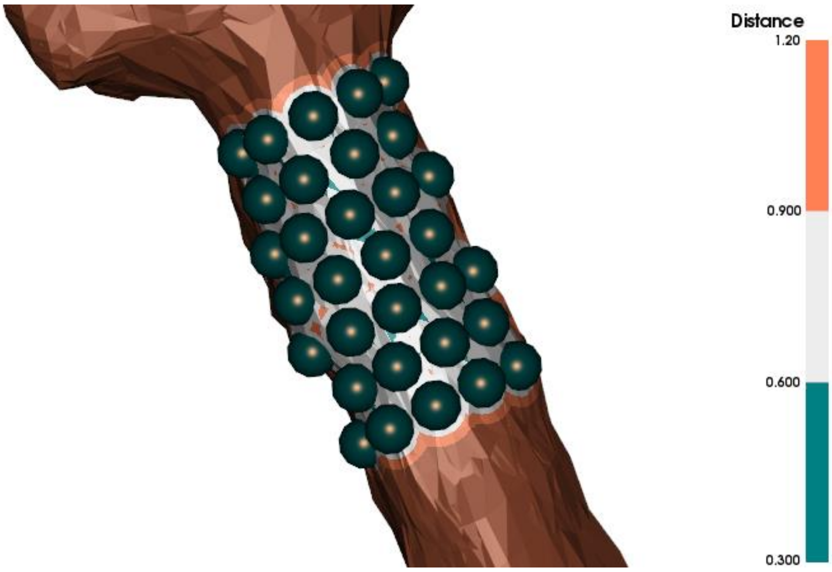

Figure 3 - Visualization of the bolt pattern in GEM4D software.

3.3 *Pull Test*

The pull test performed in the MSG is made using an automatic hydraulic system with constant displacement. Given that the bolts stand up to 25 tons, the test subjects them up to 20 tons. It is interesting to note that whenever the pull test classifies a bolt as inadequate, the support is replaced.

3.4 *Grip Factor*

At MSG, the Grip Factor is checked for the worst anchorage conditions, installing bolts parallel to foliation, in fractured rock masses, with RQD between 50 and 75. Anchoring only the last 0.3m of the hole (Fig. 4). The guides Roof Bolting Guidelines in South African Collieries (2006) and HSE-CM (Health and Safety Executive – Coal Mines, 1996) define the number of tests performed.

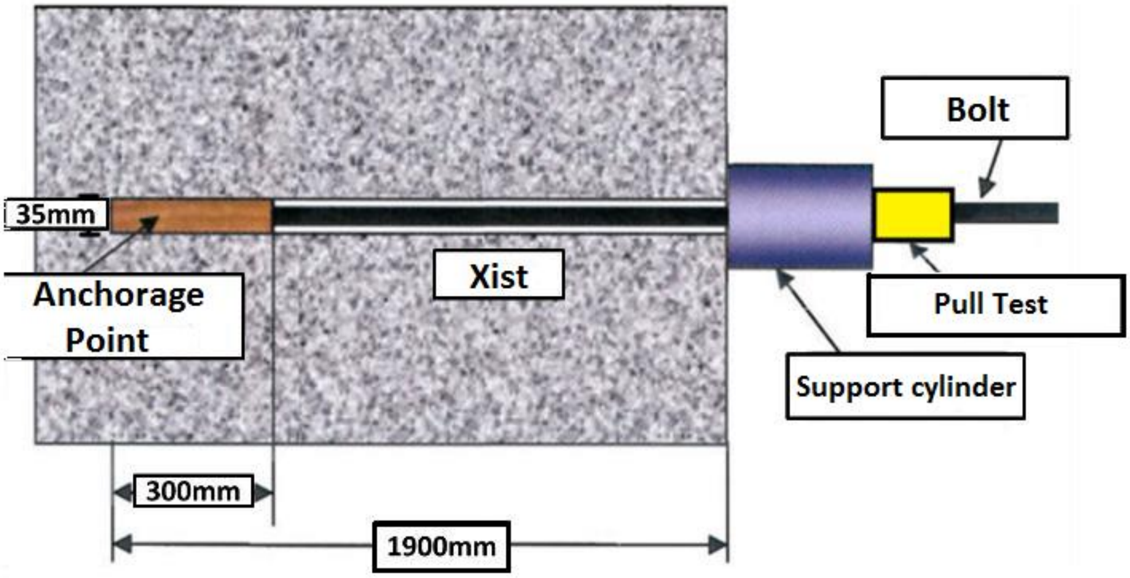

Fig. 4 - Grip factor with 0.3m of anchoring

4 RESULTS AND DISCUSSION

4.1 *Drilling angle and torque*

For drilling angle and torque, 2243 tests were performed showing an annual average of 20.6% bolts with an angle below what´s recommended by the rock mechanics team and 21.7% of bolts without torque.

4.2 *Bolt pattern*

In 2018 exactly 9905 bolts were analyzed, which corresponds to 3570m of development. This figure represents 27% of the excavations developed at MSG (Fig. 5). With this data, were generated monthly reports where the main product was the image of the bolt patterns. Understanding the importance of this work, from the beginning of 2019 were added to the monthly reports the inadequate pattern quantification and the relation of bolts installed versus the expect ones.

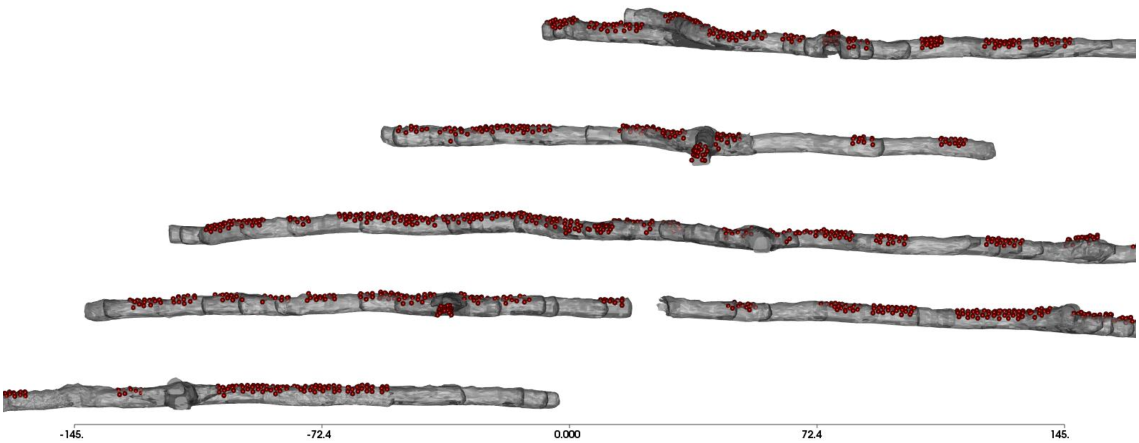

Fig. 5 - Points with bolts installed in the Ingá Mine in 2018.

Fig. 6 - Bolt pattern of the Pequizão mine.

4.3 *Pull tests*

The pull tests were performed in 341 bolts, of this number, 330 tests were classified as adequate. The non-adherent tests were separated according to the problem, in three tests there was the rupture of the bolt and in eight the resin slip.

4.4 *Grip Factor*

The GF was verified in nine bolts, among the tests performed, two were discarded because operational failures were identified. The tests had a minimum average value of 0.46 Ton/cm. Considering this value, it is possible to define the minimum anchoring length required to break a bolt (25 ton.).

Defining a minimum anchoring length, which in this case is 0,54m, a load transfer diagram was drawn, illustrating the GF effect along the length of the bolt (Fig. 7).

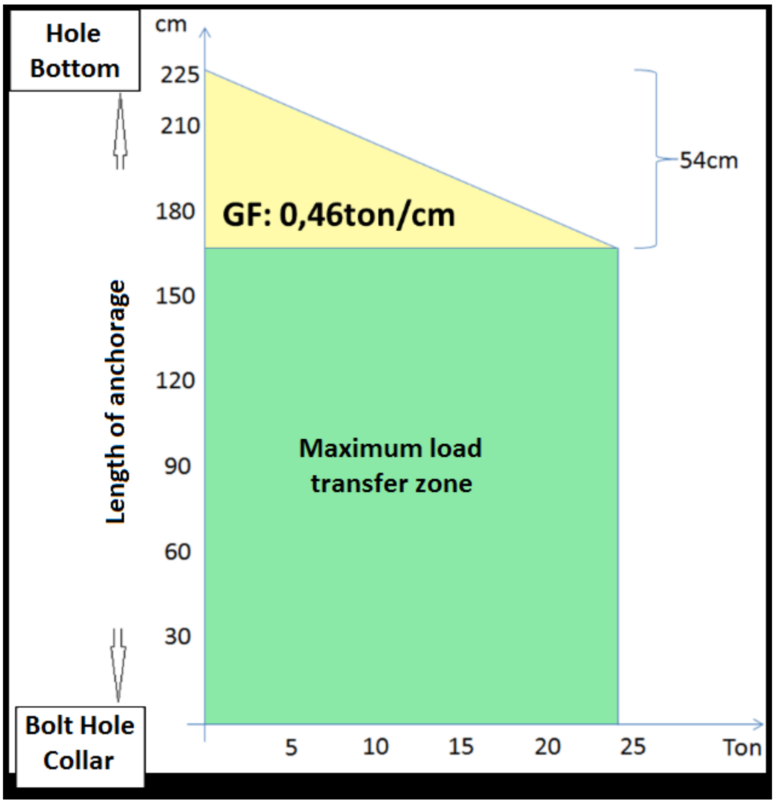

Fig. 7 - Load transfer diagram

5 CONCLUSION

This work was of great relevance to MSG's rock mechanics team. Quality control tools were created to analyze five controllable variables within the bolt installation process. These analyzes gave feedback to the operational team and, supported by the large volume of data, caused actions to be taken in order to improve the support system.

From the data obtained regarding angle, torque and bolt pattern in 2018, a training was carried out for the jumbo operators. The possibility of reducing the equipment rods is being studied in order to have a greater adhesion in these analyzes and make the installation of bolts more practical.

Processes were added to the positioning of bolts in order to follow the pattern, this measure will result in a greater stability of the rock mass and a greater risk management.

The pull test does not have a proposal for improvement, since it is necessary to exercise caution with its results because, the test is carried out along the entire length of the bar and in the excavations only a part of the support is anchored above the plastification zone.

The Grip Factor will be performed in other lithologies, in different directions in relations to the main structure (foliation), in order to create an abacus with the minimum anchoring length in relation to these variants. These actions aim to better understand the relation rock versus resin versus bolt.

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