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Support Technical Evaluation Using Q-System Method in Development Area of Grasberg Block Cave (GBC) Mine PT Freeport Indonesia

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ABSTRACT

PT Freeport Indonesia (PTFI) applies two mining systems, open pit mining in Grasberg and underground mining. This study was carried out in the Grasberg Block Cave (GBC) underground in extraction level at panel area, one of the underground mines located just below the Grasberg open pit mine by the block cave method. At present, GBC is in the development process, one of the cycles in development process is supporting installation. Supporting installation is the last cycle which include two operations, namely primary support installation and secondary support installation. The study was conducted on primary support. Primary support is the operation after excavation has been completed and aims to strengthen the rock mass (reinforcement). The use of primary support material actually experiences a significant increase so a technical study is needed to determine the difference between material requirements based on the design and actual conditions. After that, an evaluation is carried out by redesigned the support system based on rock mass classification of the Q-System to obtain a safe support recommendation. The Q value for Panel 16 is 0.7 including to the poor rock mass. The Q value for Panel 14 is 2.9 including to the fair rock mass. According to this study, recommendations are obtained using a split set length of 2.1 meters and 1.3 meters spacing and resin bolt with a length 2.4 meters and 1.2 meters spacing for panel areas with poor and fair conditions. Numerical modelling with finite element method is done with the help of Phase2 software version 8.0 determine the strength factor of the recommendations obtained analytically. Based on the results of the modelling, it is found that the smallest strength factor is 1.3.

Keywords: Primary support; Q-System; Phase2; Block Cave; Underground Mine

1. INTRODUCTION

+Grasberg Block Cave (GBC) is one of the underground mines that is still under development. GBC is one of future mines with the block caving mining method in PT Freeport Indonesia. The development cycle carried out in the GBC mine production area includes surveying, drilling and blasting, loading and hauling, scalling, and supporting installation [1]. Some underground mining areas in PTFI are Kucing Liar, Big Gossan, Deep Ore Zone (DOZ), Deep Mill Level Zone (DMLZ), and GBC [2].

Support is a tool that aims to help the tunnel wall for supporting of the rock mass load from the rib and back of the tunnel, so that the tunnel remains stable. The main function of the support is as reinforce, hold, and retain [3]. Primary support is work that is doing after excavation has been completed that purpose to keep excavation still safe.

Support system can be determined by rock mass classifying according to existing rock conditions. One of the rock mass classification used for tunnels is the rock tunneling quality index or commonly known as the Q-System method. Q-System is based on numerical assessment of the quality of rock mass using six parameters, including Rock Quality Designation, joint set number, joint roughness, joint alteration, joint water, and stress reduction factor (SRF) [4].

Actually, the use material of primary support experienced a significant increase from 9316 pieces of resin bolt based on design become 9645 pieces on actual. The actual use of the material was obtained from the results of the report in April 2019 from operation department. This study intends to find out the differences in the use of materials that are actually used and existing design. After that, an evaluation of the supporting system is used by redesigning the support system that is adjusted to the actual condition.

The drafting of underground excavation design starts from factor of instability due to geological structure, rock stress, weathering, and groundwater [5]. Rock and rock mass characteristics can be known by analyzing rock mechanics in the form of geological data which generally consists of rock types, geological structures and rock characteristic. One method that can be used determine rock characteristics is laboratory testing. Laboratory tests are carried out to obtain physical and mechanical properties of rock through several types of tests [6].

Determine of rock mass characteristics can be done through a method that purpose to estimate the characteristics of rock mass. One method that can be used is Generalized Hoek-Brown criteria of failure with the equation as follows [7]:

$$\sigma_1=\sigma_3+\sigma_{ci} \left(m_b \frac{\sigma_3}{\sigma_1} +s\right)^a \quad (1)$$

With σ_{ci} is UCS, m_b, s, and a Hoek-Brown constant of rock mass, σ_1 and σ_3 is major and minor principal stress. m_b, s, and a can be estimated using following equations:

$$m_b=m_i \exp\left[\frac{GSI-100}{28-14D}\right] \quad (2)$$

$$s=\exp\left[\frac{GSI-100}{9-3D}\right] \quad (3)$$

$$a=\frac{1}{2}+\frac{1}{6} \left(e^{-GSI/15}-e^{-20/3}\right) \quad (4)$$

D is factor depends on the degree of damage caused by blasting and relaxation of the stress.

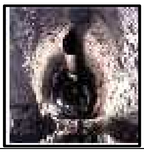
Table 1 shows the D factor for variance rock mass.

Q-System is based on a numerical assessment of the quality of rock mass using six parameters written in the following formula:

$$Q=\frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF} \quad (5)$$

The Q index with stability and support requirements for excavation in underground can be related to additional parameter namely equivalent dimension (De) calculated by dividing between span and excavation support ratio (ESR).The supporting system is one aspect that cannot be separated in a mining plan using the underground mining method [8]. The design of support system is needed to help the rock mass support itself where the reinforcement system on the rock is applied [9].

Table 1. Estimating disturbance factor D

Rock mass appearance	Description of rock mass	D value
	Excellent quality-controlled blasting or excavation by a road-header or tunnel boring machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	D=0
	Mechanical or manual excavation in poor quality rock masses gives minimal disturbance to the surrounding rock mass. Where squeezing problems result in significant floor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	D=0 D=0.5 with no invert
	Poor control of drilling alignment, charge design and detonation sequencing, results in very poor blasting in a hard rock tunnel with severe damage, extending 2 or 3 m, in surrounding rock mass.	D=1.0 at surface with a linear decrease to D=0 at ± 2 m into the surrounding rock mass

METODOLOGY

The methods should be described in detail, including modification and shall be indicated by reference. The purpose of this study is:

1. Evaluate the use of primary support materials based on actual conditions and existing designs.
2. Determine factors that influence the addition or reduction of material use.
3. Providing recommendations based on modelling a support system that is suitable for implementation.

This study was conducted to compare the amount of material used actually based on an existing buffer assessment design. While the data collected in this study are the amount of actual support material, actual tunnel dimensions, GSI, physical and mechanical properties of rocks, heavier conditions, and support collection that is used today.

Data processing and analysis using the help of Phase2 applications to redesign the support system. The results of the support system design are the latest recommendation for the support system, which should be used based on the actual situation in the field. Rock mass classification with the Q-System method is used to obtain supporting recommendations based on the state of the rock at the study site.

3. RESULT AND DISCUSSION

It should be concise and clear. Evaluation of material use is carried out in the GBC mine panel area which focuses on the use of primary support materials. The panel is the opening hole that is used as the main access to the draw point. The primary support material used is wire mesh, split set, and resin bolt. Based on geotechnical recommendations, panels with a size of 4.4 width x 4 height use 8mm diameters wire mesh, 2.25 meters long resin bolt with 1 m spacing, and the distance between floors to the first installation is 0.3 m. Based on these recommendations, the results show that the amount of support used is 9 split sets, and 11 resin bolt per ring. Therefore, in one excavation with a progress of 3.7 m, 6 wire mesh, 27 split sets and 33 bolt resins are needed. The following is a comparison of the number of supports used in the study area.

Figure 1 shows the use of Panel 16 split set material has decreased by 12 pieces and the use of bolt resin material has increased by 7 pieces. Figure 2 shows the use of Panel 14 split set material has decreased by 19 units and the use of bolt resin material has increased by 22 units.

The factor that caused the material reduction was the amount of rock bolt material that was broken during installation, while the factors that cause the addition of material are over breaks, fragile rock conditions. The use of medium and slow resin catridges is also not in accordance with applicable operational standards.

The way to overcome these problems is to redesign the support system which purpose to determine the right amount and support to use.

The design of support system requires knowledge of the characteristics of the rock constituent material around the opening hole.

Based on Table 2, panel 16 has a Q value of 0.7 which justified by a factor of 2.5 for rock mass of medium quality (0.1<Q<10) so that the Q value used in the design is 1.75 with poor rock mass quality.

Panel 14 based on Table 3 has a Q value of 2.9 which is then justified by a factor of 2.5 for rock mass of medium quality (0.1<Q<10) so that the Q value used in the design is 7.25 with fair rock mass quality.

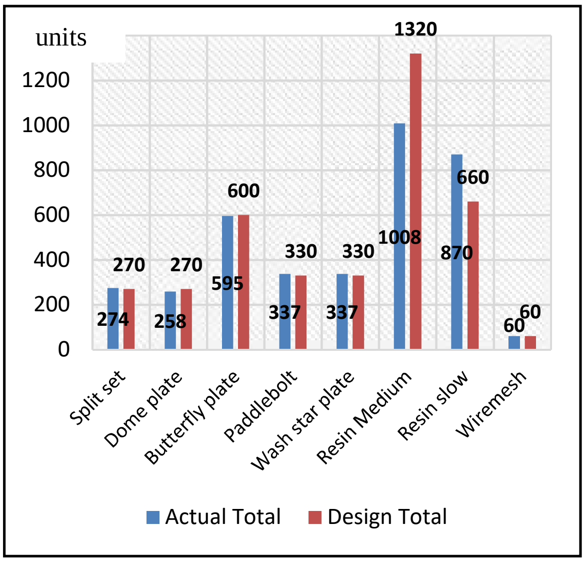


Fig1. Comparison Graph of Material Use in Panel 16

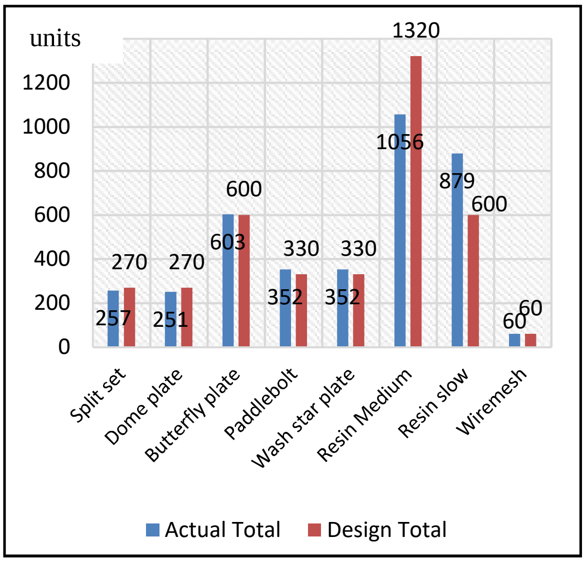


Fig 2. Comparison Graph of Material Use in Panel 14.

Table 2. Q-Value in Panel 16

No	Parameters	Rock Mass Condition	Value
1	RQD	Good	76
2	Jn	Two joint set plus random	6
3	Jr	Slicken sided, planar	0.5
4	Ja	Strongly over-consolidated, non-softening, clay mineral filling (continuous but <5 mm thickness).	6
5	Jw	Medium inflow	0.66
6	SRF	Medium stress	1

Table 3. Q-Value in Panel 14

No	Parameters	Rock Mass Condition	Value
1	RQD	Fair	69
2	Jn	Two joint set plus random	6
3	Jr	Slicken sided, undulating	1.5
4	Ja	Strongly over-consolidated, non-softening, clay mineral filling (continuous but <5 mm thickness).	6
5	Jw	Dry excavation	1
6	SRF	Medium stress	1

Support recommendations obtained for Panel 16 (Fig 3) fall into category 3, namely systematic bolting, fiber reinforced sprayed concrete 5-6 cm. While the support recommendation obtained for Panel 14 area (Fig 4) is included in category 1 namely spot bolting.

Based on the SOP standards, rocks with poor and fair conditions are using the same support system. Therefore, the support recommendations for modelling in the Panel 16 and Panel 14 areas are made the same. The recommended bolt length obtained based on mathematical calculations is to use a bolt length of 2.4 meters. Following are the differences in the value of the strength factor produced between the modelling before the reinforcement, the reinforcement using PTFI geotechnical recommendations and research recommendations.

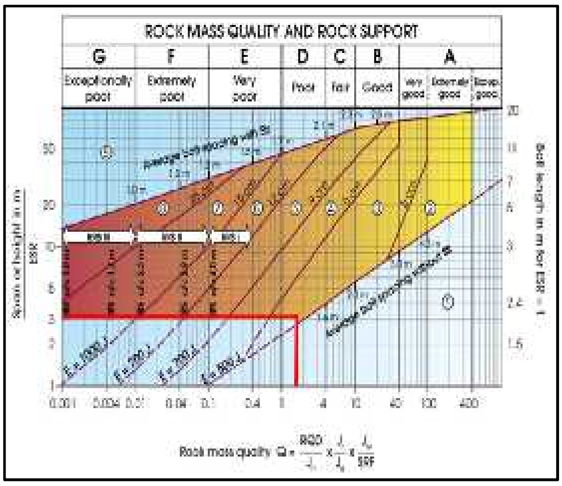


Fig 3. Support Recommendations in Panel 16

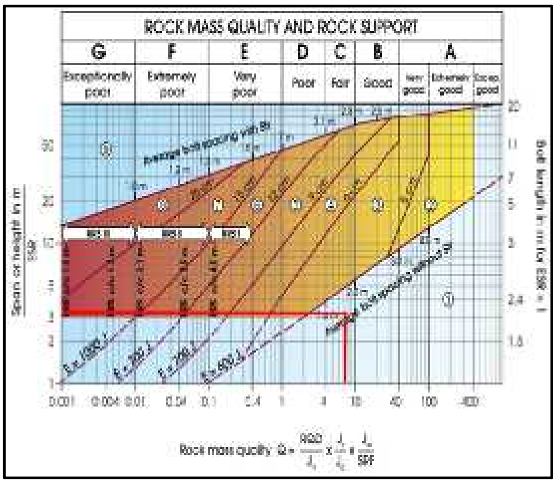


Fig 4. Support Recommendations in Panel 14

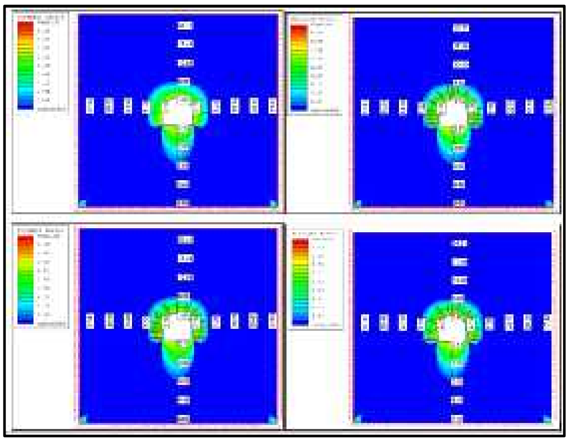


Fig 5. Strength Factor Value in Panel 16

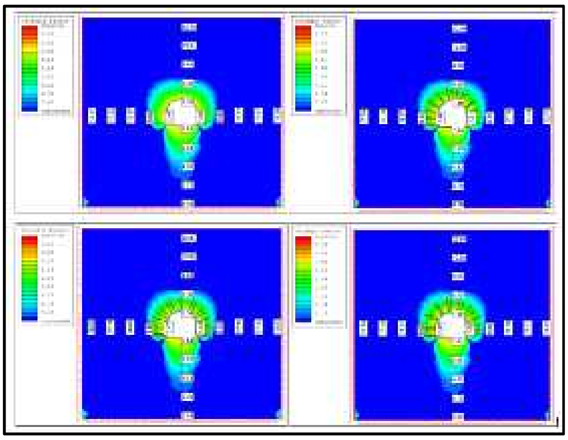


Fig 6. Strength Factor value in Panel 14

Table 4. Strength Factor Value in Panel 16

Location	SF value before supporting	SF value with PTFI recommendation	SF value with research recommendation in 1.1 spacing	SF value with research recommendation in 1.2 spacing
Right Rib	2.164704 7.243456 23.736266 20.546473 17.641837	2.166558 7.258156 23.763452 20.518501 17.623769	2.191277 7.256932 23.761602 20.518052 17.623414	2.191813 7.255219 23.765395 20.517534 17.623363
Left Rib	2.183674 7.185760 24.879519 20.518418 17.427284	2.184355 7.196868 24.893684 20.490399 17.409646	2.184714 7.198708 24.893142 20.490722 17.410447	2.186088 7.196769 24.895217 20.490155 17.410126
Back	1.652859 6.656405 10.983120 17.482434 50.113887	1.654954 6.661252 10.991684 17.493358 50.212062	1.654424 6.661569 10.991568 17.493265 50.208818	1.654882 6.661845 10.991570 17.493257 50.207213
Floor	2.166468 3.503760 5.559523 6.466538 6.685289	2.166960 3.503169 5.557887 6.464703 6.683546	2.166936 3.503200 5.557902 6.464702 6.683509	2.166936 3.503200 5.557902 6.464703 6.683508

Table 5. Strength Factor Value in Panel 16

Locat ion	SF value before supporting	SF value with PTFI recommendation	SF value with research recommendation in 1.1 spacing	SF value with research recommendation in 1.2 spacing
Right Rib	1.504222	1.512202	1.537185	1.501780
	6.841818	6.848716	6.850222	6.849914
	17.374242	17.379921	17.382160	17.381555
	17.468555	17.439779	17.439316	17.439554
	15.592941	15.571781	15.570904	15.571751
Left Rib	1.448181	1.462391	1.465832	1.465264
	6.641514	6.644300	6.646112	6.648502
	18.068295	18.067052	18.067960	18.068346
	17.219764	17.190340	17.191040	17.190186
	15.266193	15.244063	15.244909	15.244059
Back	1.354601	1.355836	1.363419	1.355779
	5.298019	5.302530	5.300817	5.304800
	8.640310	8.648527	8.647982	8.648557
	12.910829	12.922751	12.922443	12.922780
	32.791165	32.876419	32.871239	32.877014
Floor	1.636443	1.636733	1.636752	1.636713
	2.952310	2.951467	2.951476	2.951479
	4.933574	4.931301	4.931301	4.931348
	5.748606	5.745887	5.745912	5.745811
	6.089224	6.086349	6.086403	6.086222

The difference in geotechnical recommendations and the results of Panel 16 and Panel 14 research value of each recommendation shows a number that is not much different. However, the amount of bolt resin used is different from each other. Based on the results of modelling, by using a geotechnical recommendation, the amount of material used is 12 pieces per ring while the results of research recommendations with a space of 1.1 use a total of 11 pieces of material per ring. The results of modelling research recommendations with a space of 1.2 using 10 pieces of material per ring. Based on these results, research recommendations with a space 1.2 are more effective because they can help conserve actual material usage and the material costs incurred by the company will be less.

4. CONCLUSIONS

The conclusions should present the major conclusions of the study. The use of primary support material actually experiences material addition and reduction. Additions occur in bolt resin material caused by over breaks, and fragile rock conditions. While the reduction occurred in the split set material caused by the large amount of broken rock bolt material during installation. The results of recommendations in this study are to use a split set with a length 2.1 meters and 1.3 meters spacing and resin bolt with a length of recommendations can be seen in the value of the power generated. The strength 2.4 meters with a 1.2 meter space. The ideal amount used to conserve actual material usage is to use 9 pieces of resin bolt per ring for panel areas with dimensions of maximum 5 meters width x 4.5 meters height. In addition, the SOP for bolt resin installation must be known by the Operator so that the comparison of the use of catridge resin material is in accordance with the standard.

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