Muckpiles Influence Againts Pillar Stability in Panel 26 and 27 West Drawpoint 43-44 Grasberg Block Cave (GBC) PT. Freeport Indonesia

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Abstract. Changes in stress and increased muckpiles in the block caving method can cause instability in the pillar. The effect of changing stress and increasing muckpiles will cause an increase in displacement and yielded zone in the production tunnel. Based on the results of convergence measurements, on panels 26 and 27 West Drawpoint 43-44, stable results are obtained with displacement speeds of 0.0225 mm / hour and 0.0271 mm / hour using the stability criteria of Zhenxiang. Based on the analysis of the potential squeezing from the actual displacement measurement, Panel 26 and 27 West Drawpoint 43-44 are indicated to have severe squeezing problems with% strain values of 2.51% and 2.56%. Based on the results of the displacement analysis using Phase2 software, on Panel 26 and 27 West Drawpoint 43-44, the% horizontal strain values were 3.36% and 4.11% (severe squeezing problems) and% vertical strain was 3.9% (\severe squeezing problems) and 5.045% (very severe squeezing problems) with a HOD height of 270 meters (Grasberg bottom pit). Based on the results of numerical analysis, the yielded zone will continue to increase until it enters the 10 meter HOD with the assumption that in the 10 meter HOD phase the yield area has reached a stable point.

Keywords: Squeezing, Yielded Zone, Displacement.

1. Introduction

Mining activities at the Grasberg Block Cave (GBC) underground mine are carried out using the collapse method, where in this method is used blasting at the undercut level so that the ore body can collapse. The crumbling material from the undercut will descend towards the drawbell and the excavation material is taken at the drawpoint,where the pile of crumbling material is called muckpiles. The continuous material retrieval process will result in an increase in the height of the muckpiles formed from the loss of support force from the ore body itself and will disintegrate and accumulate in the drawbell. The increase in the height of the muckpiles will result in the greater the load borne by the major pillars around drawpoint. The stress can cause damage to support on each panel and Drawpoint and can pose a risk of failure on the panel and drawpoint, so mining activities cannot be done until the rehabilitation process is carried out.

Finite Element method is used during research activities, the use of such methods is assisted by using Phase2 softwaware. The use of Phase2 software is intended to obtain the amount of displacement and yielded zone on the pillar.

The use of borehole camera and convergence data is used to correlate with Height of Draw (HOD) data with the actual state of pillar during research activities. The final result obtained from the analysis is the influence of Height of Draw (HOD) on pillar stability by paying attention to the size of displacement zone and yielded zone on pillar.

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2. Research Methods

To discuss the issue of the influence of muckpiles on pillar stability, there are several steps taken to obtain data to analyze the influence of muckpiles on pillar stability in the research area in the Grasberg Block Cave (GBC) Area of PT. Freeport underground mines is as follows:

1. Preparation.
2. Data Retrieval.
3. Literature Studies.
4. Discussion.
5. Data Processing.
6. Data Analysis.

Based on the data that has been obtained from the field or literature studies followed by processing and analysis of the data that has been obtained. The formulas used in the data processing are:

A. HOD Calculation (Height of Draw)

HOD is the height of muckpiles where the height of the muckpiles is calculated based on the tonnage of the production activities per drawpoint. The height of the muckpiles will produce vertical stress,where the stress will affect the stability of the pillar. The HOD calculation formula is:

$$\mathrm{HOD} = \frac{\mathrm{Tonnage}}{(\mathrm{Area\ x\ Density})} \quad (1)$$

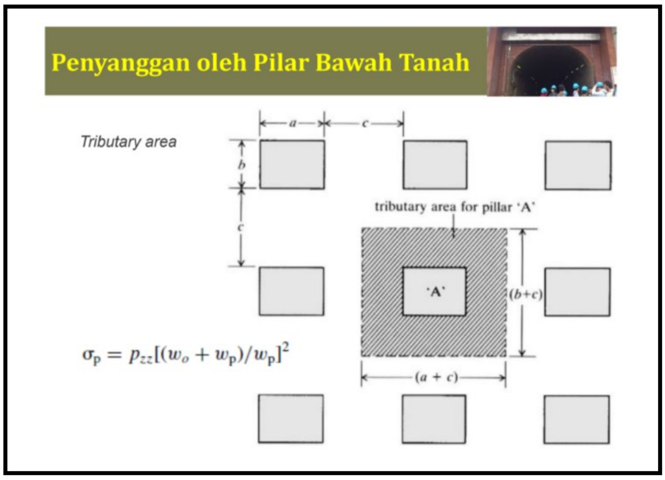
Description:
HOD = Height of Draw (m)
Tonnage= Total mining tonnage at one drawpoint (tons)
Area = Drawpoint Area (m^2)
Density = Density of research area rocks (ton/$m^{3)}$

B. Tributary Load

Tributary load is used to calculate the area of influence of the load received by the pillar,where the area of influence will affect the stability of the pillar. The area of influence is called the tributary area where the tributary area can be calculated by the formula:

$$\mathrm{Tributary\ Area} = (a + c) \times (b + c) \quad (2)$$

Description:
a= pillar length (m)
b= pillar width (m)
c= distance between pillars (m)



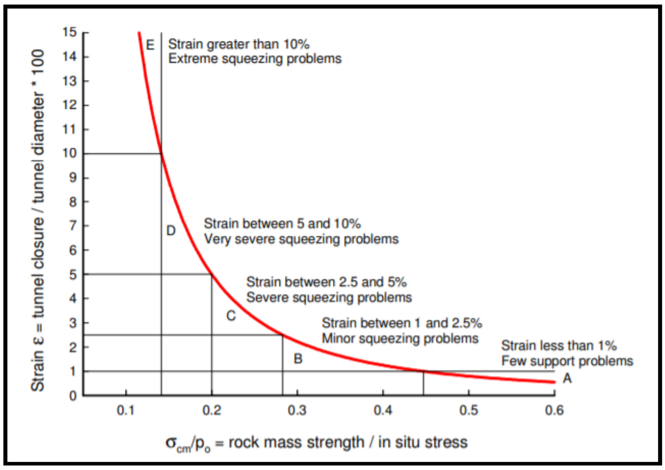
(Source: Beniawski, Z. T., Tributary Area Pillar Loading Concept)

Based on the calculation of the tributary area, the load of the pillar will be multiply by the amount of load on the pillar,so that itcan be calculated Tributary Load with the formula:

$$\text{Tributary Load} = \frac{\text{Tributary Area}}{(\text{Luas Pillar})} \text{ x Vertical Load} \ldots\ldots\ldots\ldots (3)$$

C. Tunnel Deformation In Tunnels

Hoek (1999) published detailed analysis showing the ratio of UCS values of rock mass σ_{cm} to in situ voltage p_0 which can be used as an indicator of potential problems squeezing rock mass around the tunnel. Following Sakurai (1983) analysis was conducted to determine the link between $\sigma cm/p_0$ and percent tunnel strains. Percent strain is defined as 100 x the ratio of teorwongan closure to tunnel diameter.



(Source: Hoek E., Marinos, 2000)

Figure 2 Relationship %strain to σcm/po for tunnel without buffer

To analyze the potential of squeezing on the mass of rocks that are supported, the equation is used:

$$\frac{\partial i}{do} = \left(0{,}002 - 0{,}0025\frac{Pi}{Po}\right)\frac{\sigma cm}{Po}^{\left(2{,}4\frac{Pi}{Po}-2\right)} \text{ .... } (4)$$

Strong uniaxial press σ_{cm} rock mass can be determined by using $\sigma_{ci,}$ $m_{i,}$and GSI values, the value of σ_{cm} can be estimated using equation 5.

$$\sigma cm = (0{,}0034mi^{0,8})\sigma ci\left(1{,}029 + 0{,}025e^{(-0,1mi)}\right)^{GSI} \text{ .... } (5)$$

Description:
σcm = Strong press rock mass
δi = Tunnel deformation
do = Diameter of the initial tunnel
pi = Ground support strength
po = In situ stress

Table 1. %Strain relationship with geotechnical issues and support types

	strains ε %	Geotechnical issues	Support types	Potential Squeezing
A	Less than 1	Fewer stability issues and simple tunnel buffer design methods can be used. The recommendation of tunnel buffer based on rock mass classification will provide adequate basis for tunnel design.	Very simple tunnel conditions, rockbolts and shotcrete are usually used as buffers.	Some buffering issues
B	1 to 2.5	Convergent measurement methods can be used to predict formations of plastic zones at rock masses surrounding tunnels and interactions between development processes in these zones as well as different types of support.	Minor squeezing problems, generally using rockbolts and shotcrete,sometimesuse lightweight steel sets or lattice girders used for added safety.	Mild squeezing problem
C	2.5 to 5 p.m.	Analysis of elements up to two dimesi, combining buffer elements and digging sequences is usually used for this type of problem. In general, the stability of the face is not a big deal.	Severe squeezing problems that require fast buffer installation and careful quality control. Heavy steel set inside shotcrete required.	Severe squeezing problems
D	5 to 10	Tunnel design is dominated by stability problems on the face and two-dimensional analysis is carried out by estimating the effect on forepoling and strengthening of the tunnel face needs to be done.	Very severe squeezing problems and stability problems on the tunnel face. Forepoling and strengthening face usually by using steel set planted used in shotcrete.	Very severe squeezing problem

E	More than 10	Severe face instability also squeezing the tunnel makes this a severe problem with three-dimensional analysis where there is no effective design so the solution is based on experience.	Extreme squeezing problem. Forepoling and face tunnel strengthening are usually used and yielding support is needed in extreme cases.	Extreme squeezing problems

(Source: Hoek, Marinos, *Predicting Tunnel Squeezing Problem in Weak Heterogeneous Rock Mass)*

D. Vertical Stress

Vertical stress in this study is intended to get the amount of stress on the pillar,where vertical stress is obtained from the amount of HOD that has been converted into a load. The vertical stress formula used in this study is:

$\sigma v = \gamma \text{ x } G \text{ x } H$ .... (6)

Description:

σv = Vertical stress (MPa)

γ = Density of rocks (ton/m 3)

G = Gravity bumo (10 m/s 2)

H = Height of muckpiles (m)

3. Results and Discussion

A. Borehole Camera

Borehole camera is intended to know the amount of depth of failure around the panel, and borehole camera is also intended to know the condition of the pillar that support the panel. Borehole camera activities were conducted in the research area, namely on Panel 26 and Panel 27 Drawpoint 43-44 North and South on May 25, 2019. Based on the results of the size using borehole camera,the amount of depth of failure in the research area is shown in Table 2.

Table 2. depth of failure of the research area

Panel	Drawpoint (m)	Depth of Failure (m)	Broken (m)	Fractured (m)
26 West	43-44N	0.7 (Plugged)	0,7	-
	43-44S	0.2 (Plugged)	0,2	-
27 West	43-44N	1	0,5	0,5
	43-44S	1,2	0,1	1,1

Based on the results of borehole camera measurement on Panel 26 W DP 43-44 obtained depth of faiure average amount of 0.45 meters, where at Drawpoint 43-44N of 0.7 meters and at Drawpoint 43-44S of 0.2 meters. Plugged both sides of panel 26 W DP 43-44 due to the material blocking the camera. Panel 27 West Drawpoint 43-44 obtained an average depth of failure of 1.1 meters, whereas at Drawpoint 43-44N of 1 meter and at Drawpoint 43-44S of 1.2 meters (Table 3).

B. Calculation of The Amount of Stress Each Phase (Stage)

Height of draw is the total amount of mucking on each Drawpoint performed by the dozer to know the total tonnage that has been taken, so that based on the total tonnage per Drawpoint can be converted into height.

The calculation of height of draw is intended to know the height of the material that has been taken, in addition the calculation is intended to know the height of the muckpiles,where theheight of the draw is assumed to be the height of the muckpiles. This assumption is made because of the unavailable open holedata, so theelevation of cave back and airgap cannot be known.

The amount of stress in the unsupported, abutment,and shadow stress phase is obtained from the Ground Support Scoping Tools (GSST) value, where the data is secondary data obtained from research at Geothech GBC PT. Freeport Indonesia. Based on the results of GSST. Based on the HOD calculation, with a density of 2.7 tons/m^3 and gravity of 10 m/s^2 it can be converted into vertical stress and converted into sigma 1 to be inputted into modelling,where theassumption of stress in the research area from the unsupported phase to the end of mine life is shown in Table 3.

Table 3. Amount of stress in the research area of each phase (stage)

Stage	Gravity (m/s^2)	Density (ton/m^3)	Tributary Ratio	Load (MN/m^2)	Sigma 1 (Mpa)
Unsupported	9,8	2,7		26	26
Abutment				26	26
Shadow				25	25
0 m				21	21
10 m			1,5	0,3969	21,3969
25 m				0,99225	21,99225
50 m				1,9845	22,9845
100 m				3,969	24,969
150 m				5,9535	26,9535
200 m				7,938	28,938
270 m				10,7163	31,7163

C. Convergence

Based on the results of convergence measurements in the research area, the amount of displacement obtained in the research area on March 09 - May 30, 2019 is shown in Table 4.

Table 4. Update convergence measurement data

Date	Location	Date	Location
	Panel 26W DP 43-44		Panel 27W DP 43-44
09-March-2019	4019.3 mm	09-March-2019	3738.0 mm
13-March-2019	4015.4 mm	13-March-2019	3737.3 mm
20-March-2019	4002.8 mm	23-March-2019	3740.5 mm
29-March-2019	3995.2 mm	29-March-2019	3729.2 mm
12-April-2019	3988.9 mm	04-April-2019	3714.6 mm
19-April-2019	3980.9 mm	19-April-2019	3689.5 mm
26-April-2019	3978.3 mm	26-April-2019	3686.4 mm
03-May-2019	3973.3 mm	03-May-2019	3669.5 mm

10-May-2019	3971.7 mm	10-May-2019	3696.6 mm
15-May-2019	3973.0 mm	17-May-2019	3692.0 mm
22-May-2019	3968.1 mm	22-May-2019	3682.4 mm
30-May-2019	3965.2 mm	30-May-2019	3967.2 mm

Based on the data in the research area as of January 1, 2019 to July 8, 2019, convergence rate of 0.54 mm/day or 0.0225 mm/h was obtained on Panel 26 W DP 43-44, while in Panel 27 W DP 43-44 obtained convergence rate of 0.65 mm /day or 0.0271 mm / hour dated January 29, 2019 to June 27, 2019. Based on the criteria of displacement according to Zhenxiang convergence rate in both areas of the study, stable results were obtained (Table 5).

Table 5. Panel Stability Criteria Results 26 and 27 W DP 43-44 (Zhenxiang)

Displacement Speed (mm/h)	Stability Criteria	P26W DP 43-44 (mm/h)	Stability Criteria	P27W DP 43-44 (mm/h)	Stability Criteria
≤ 0.2	Stable	0,0225	Stable	0,0271	Stable
0,2 – 3	Relatively stable				
≥ 3	Unstable				

(Source: Zhenxiang, 1984)

Based on the results of convergence measurement obtained displacement results shown in Table 5., where from the results of measurement convergence tunnels undergo displacement or movement. Based on the movement or displacement, the tunnel can be categorized as squeezing,where%strains in Panels 26 and 27 West Drawpoint 43-44 are shown in Figure 5.2.

Based on the graph in Figure 5.2, the % of maximumstrains from January 01, 2019 to July 8, 2019 on Panel 26 West was 2.51%, while in Panel 27 West Drawpoint 43-44 for the time of January 29, 2019 to June 27, 2019, the %of maximumstrains was obtained by 2.56%. Based onthe magnitude of the strain%, both research areas can be categorized as both research areas experiencing severe squeezing problems and the potential to continue to increase until experiencing very severe squeezing problems or extreme squeezing problems.

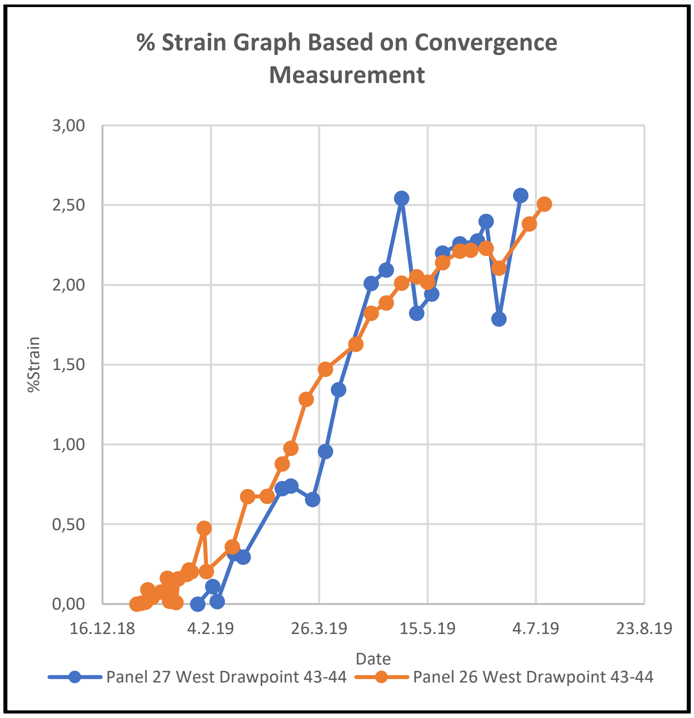


Figure 3. %Strain Graph by Convergence Measurement

D. Modelling Results

Modelling is done using Phase2 software, where the dimensions of the tunnel are 4.4 meters x 4 meters (width x height), with pillar width of 30 meters and pillar height of 20 meters, where tunnel dimensions are shown in Figure 4.

Ground support is adjusted to the standard ground support in GBC, where the ground support used in Panels 26 and 27 West Drawpoint 43-44 is a 4 meter long cable bolt and 2.1 meter long resin bar and in shotcrete with a thickness of 75mm shown in Figure 5.

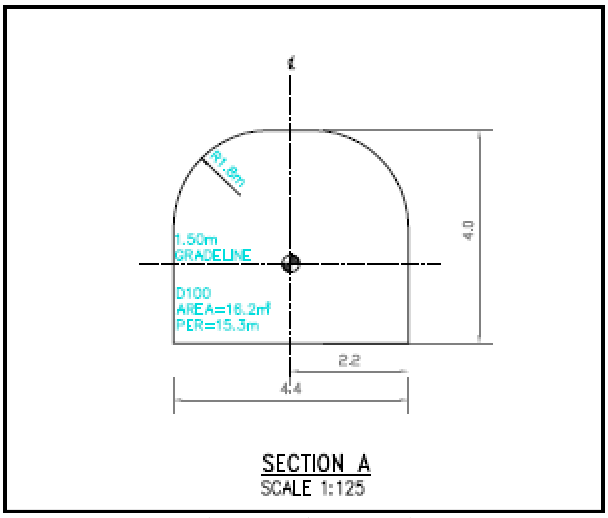


Figure 4. Perimeter Panel

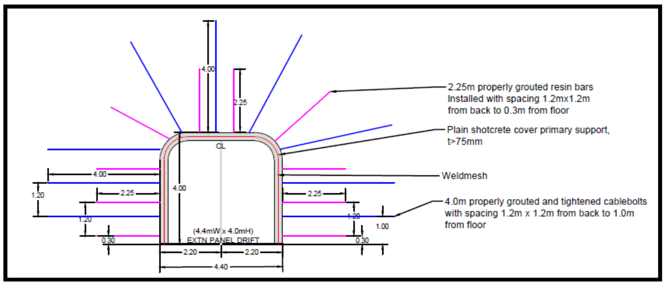


Figure 5. Ground Support Standard EXTN LVL

a. Displacement

Modelling is done by making 11 stages, this is intended to know the effect of stress changes and increased height muckpiles on pillars. The results of the displacement of modelling in phase2 software are shown in Figure 6 and Figure 7.

Based on the graph shown in Figure 6 and Figure 7, it can be known that the largest displacement occurs at the HOD stage of 270 meters, where the total value of vertical displacement and horizontal cement displacement on Panel 26 West Drawpoint 43-44 of 0.21 meters and 0.18 meters. While in Panel 27 West Drawpoint 43-44 obtained vertical displacement and horizontal displacement of 0.27 meters and 0.22 meters.

b. Squeezing Potential

Based on the total displacement, obtained %maximum strains on Panel 26 West Drawpoint 43-44 wall parts by 3.36%, while on Panel 27 West Drawpoint 43-44 obtained %strains on the wall section of 4.11 %. The %strain value uses the total displacement value in the right wall and left wallareas, where the area is a convergencemeasurement point. The roof section on Panel 26 West Drawpoint 43-44 obtained %strain by 3.9%, roof and floorsection, while on Panel 27 West Drawpoint 43-44 folded %vertical strain by 5.045% (Figures 8 and 9).

Based on the % value of the strain, Panel 26 and 27 West Drawpoint 43-44 wall sections can be categorized as experiencing severe squeezing problems. While on Panel 26 West Drawpoint 43-44 roof and floor parts are indicated to have severe squeezing problems, while on

Panel 27 West Drawpoint 43-44 roof and floor parts are indicated to experience very severe squeezing problems.

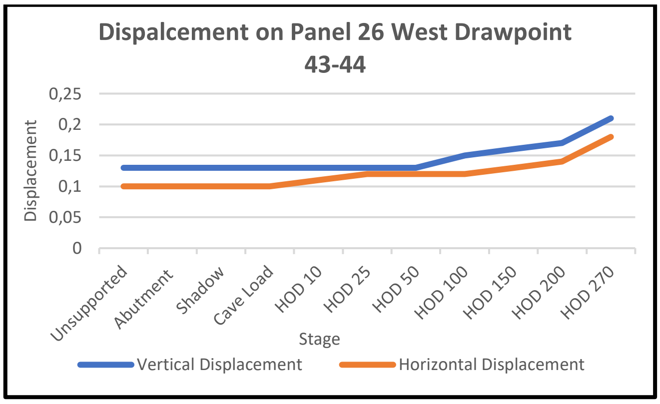


Figure 6. Displacement on Panel 26 West Drawpoint 43-44

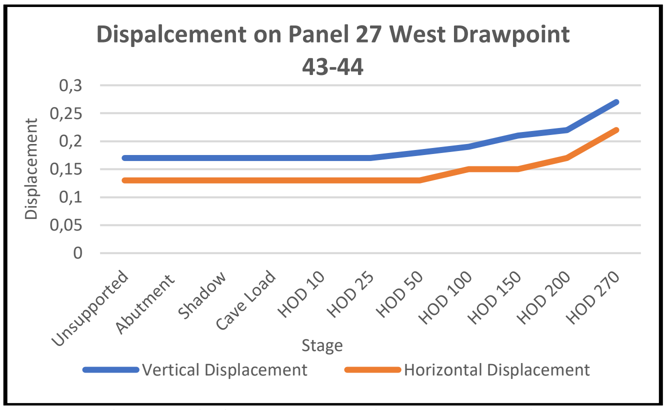


Figure 7. Displacement on Panel 27 West Drawpoint 43-44

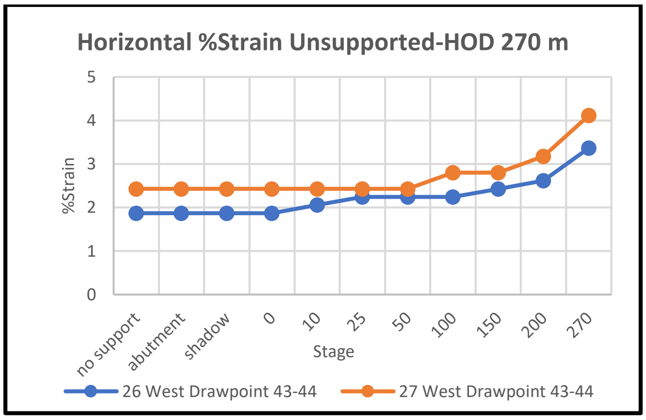


Figure 8. Horizontal %Strain Panel 26 and 27 West DP 43-44

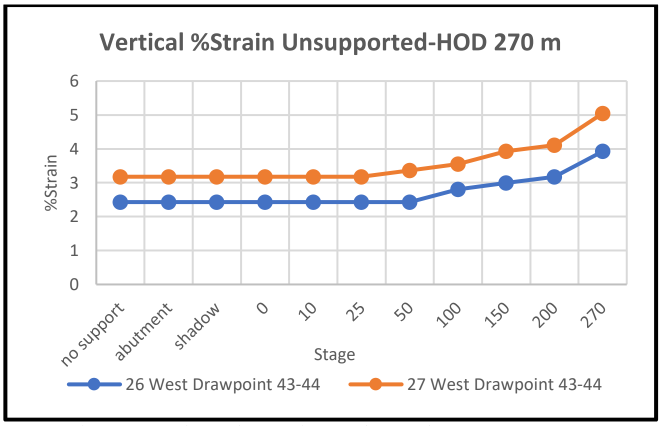


Figure 9. Horizontal %Strain Panel 26 and 27 West DP 43-44

c. Yielded Zone

Modelling is done by making 11 stages, this is intended to determine the effect of changes in stress and increased height of muckpiles on pillars. The results of the yieleded zone of modelling in phase2 software are shown in Figure 10 and Figure 11.

Based on the results of modelling using Phase2 software, yielded zone results are obtained,where the yielded zone is used to know the limits of plastic and elastic zones in each phase. Based on Figures 10 and 11,it is known that the final limit of the increase in plastic and elastic zones of the eleven phases can be known.

Based on the results of the modelling, the increase in plastic zones continues to occur from the unsupported phase to the cave load phase. The increase of plastic zone in the unsupported phase up to HOD 10 meters is estimated to be caused by changes in stress and is also thought to be caused by the influence of plastic zones that make the area around the plastic zone weakened so as to make the occurrence of an increase in plastic zones due to changes in stress or increased load borne by pillars. At HOD 10 meters to HOD 270 meters, no increase in plastic zone is estimated to be caused by rocks that have reached the end plastic boundary and become stable, rocks in pillar in the HOD phase of 10 meters to 270 meters are estimated to remain strong, so the increase in plastic zone does not occur.

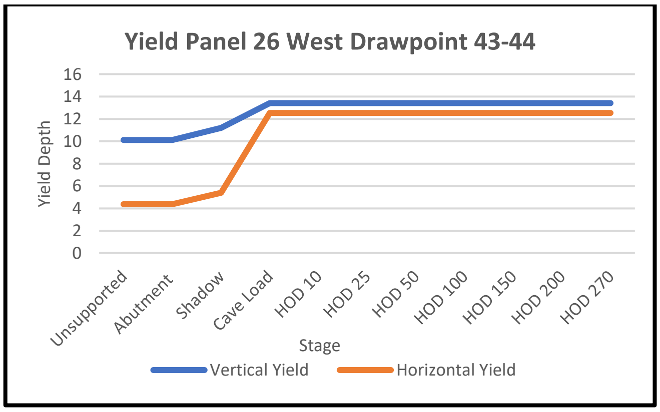


Figure 10. Yielded zone Panel 26 West Drawpoint 43-44

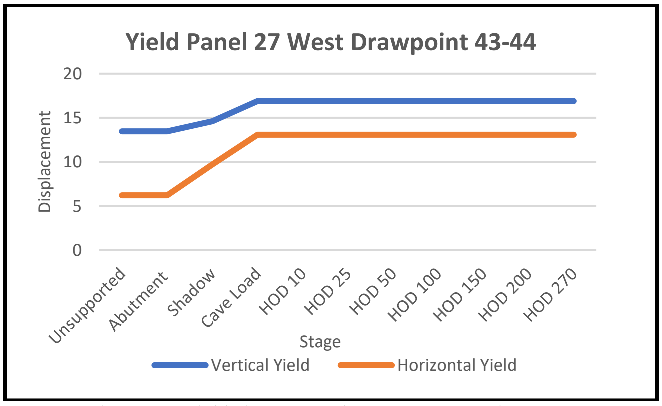


Figure 11. Yielded zone Panel 27 West Drawpoint 43-44

4. Conclusion

Based on the results of the discussion from the previous chapters on pillar stability analysis in Panels 26 and 27 W DP 43-44, the following conclusions were obtained:Based on stability criteria accordi ng to Zhen Xiang, stable results were obtained with a displacement speed value of 0.0225 mm/h on Panel 26 W DP 43-44 and 0.0271 mm/h on Panel 27 W DP 43-44. Based on the measurement of depth of failure using borehole camera obtained results on Panel 26 W DP 43-44 N of 0.7 meters with plugged condition and Drawpoint 43-44 S of 0.2 meters with pluggedcondition. While in Panel 27 W DP 43-44 N obtained depth of failure of 1 meter, and at Drawpoint 43-44 S of 1.2 meters.. Based on convergencemeasurementresults, the tunnel is indicated to have severe squeezing problems, where the %strain on Panel 26 West Drawpoint 43-44 is 2.51% and on Panel 27 West Drawpoint 43-44 is 2.56%. Based on the total displacement result of Phase2 software, Panel 26 West Drawpoint 43-44 obtained %horizontalstrain by 3.36% and %verticalstrain by 3.9% so that it is indicated to experience severe squeezing problems, while in Panel 27 West Drawpoint 43-44 obtained %horizontalstrains of 4.11% and %verticalstrains of 5.045% so that on the wall is indicated severe squeezing problems and on the roof and floor is indicated to have a very heavy squeezing problem.

Based on the results of modelling using Phase2 software, the plastic zone in the research area will continue to grow from the unsupported phase to the cave load phase, but after entering the HOD phase 10 meters plastic zone does not increase, where in the HOD phase 10 meters to HOD 270 meters of rock around the research area has reached the boundary of the plastic zone. The advice that can be given on monitoring and geotechnical analysis activities of PT. Freeport Indonesia is as follows: Routine measurement is required using convergence tools in the research area to monitor the speed of displacement in the research area, as well as the need for three-point monitoring of convergence. Borehole camera measurement needs to be done regularly, as well as for plugged locations need to be flushing activities so that borehole camera observation activities can be done. The total displacement result of modelling using Phase2 software needs to be done monitoring displacement to get the suitability of modelling results with the actual circumstances in accordance with the running of production activities. More routine data borehole camera is needed to know the amount of yielded zone on the pillar in order to be paired with the modelling results of Phase2 software. Actual rock parameter data is required so that the modelling results can be close to or equal to the actual conditions on the pillar. More in-depth data and analysis is needed to determine the condition of pillar as production activities progress.

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