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THE STUDY OF LANDSLIDE USING SLOPE STABILITY RADAR WITHIN FAILURE SS_P4_028 IN PT NEWMONT, NUSA TENGGARA BARAT, INDONESIA

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Abstract

PT Newmont Nusa Tenggara (PT. NNT) which is located in Batu Hijau, Sumbawa Island, Indonesia is one of open pit mining company of Au-Cu. Total of mining material planned in this time about 3500 million ton, with the striping ratio of escavation is equal to 1.7:1, consist of 0.49% gr / ton Cu, 0.34% gr / ton Au, and 1.06 gr / ton Ag. Totalize of mining depth level is planned about 1000 metre. The Batuhijau mining have relatively lower mineral grade and heigh tonnage of mineral deposit, becoming consideration to conduct the mining process which resulting economic value by maximizing to form the angle of repose at bench is 65°. With this angle of repose will often result the risk happening of landslides. Thereby require to be studied about the critical limit value of landslide so that applicable to forecast when landslide will be happened and can be used as forewarning. So that loss potency yielded by landslide earns minimization. One of appliance used for the monitoring of landslide in the PT NNT Mining is slope stability radar (SSR).

Based on monitoring using this SSR, is mensurement of landslide of bench in real time and can be used to predict the critical limit value of movement before the occurence of landslide. The aim of this research is to analyse processes of the occurence of landslide in Faillure SS_P4_028 bench of South-West Domain 3 in Batu Hijau open pit mining, including to monitor the time and speed of sliding, and to forecast the critical limit value of repose angle. The method of this study is data collecting covering primary and secondary data. Base on this study, the critical limit value that happened at Failure SS_P4_028 is when the speed moment reaches the value of 13.03 mm/hour. At the moment, the mining activity must be stopped with the existence of forewarning by red alarm from Slope Stability Radar and the speed moment reach 7.43 mm/hour. The landslide at Failure SS_P4_028 became of the speed moment have reached at value of 20.02 mm/hour

Keyword: PT. Newmont, Batu Hijau, Nusa Tenggara Barat, Failure SS_P4_028, Slope stability radar.

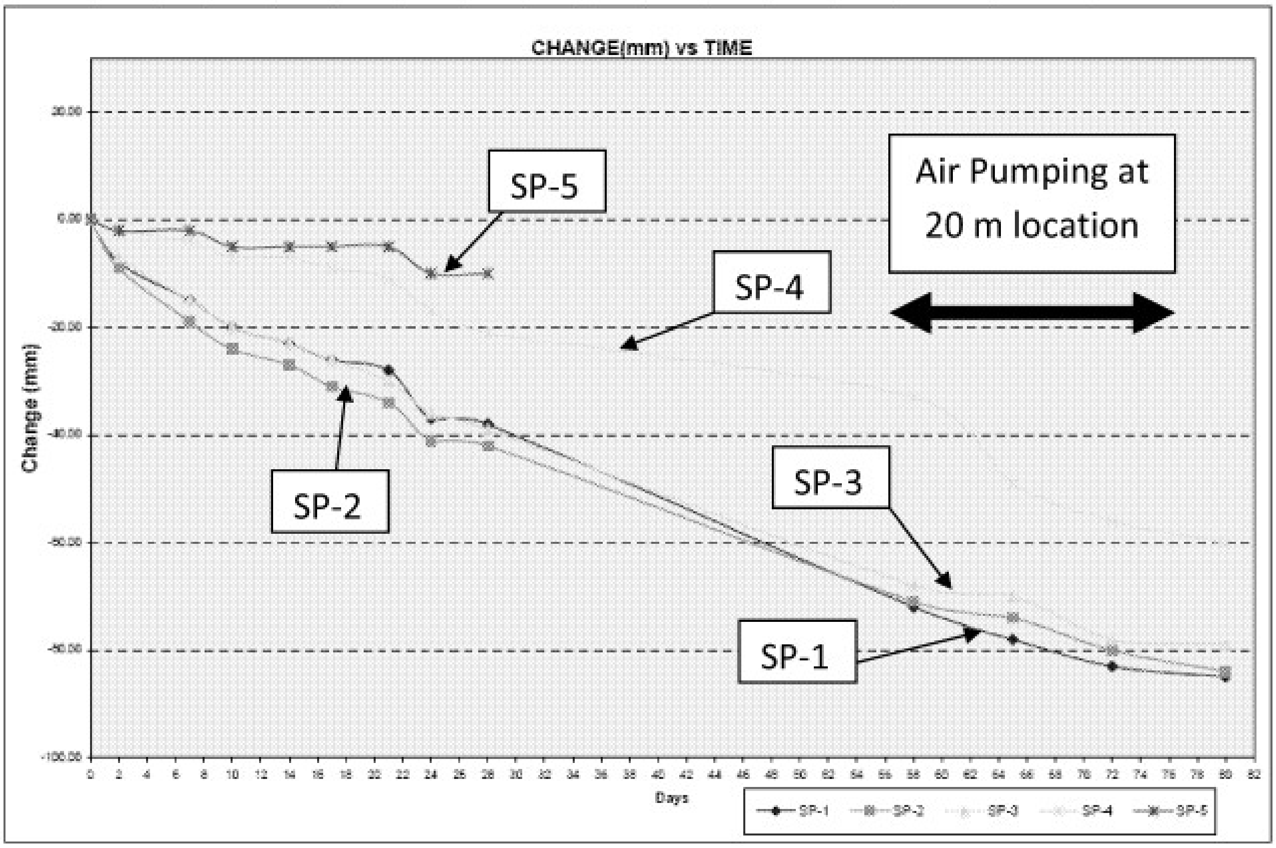

Figure 13, Settlement response of SWP trial 2

6. CONCLUSION

The principle and the advantages of the new Super Well Point method have been reviewed. The effectiveness of this method in lowering ground water table for excavation in soft Singapore Marine clay was found to be verified in Trail 1. Large amount of water was dewatered from the Marine clay within the excavation area, and the ground water table lowering outside of excavation region was to be very small. Hence, no undesired ground settlement outside of the excavation area was observed.

The second trial on SWP treatment on peaty soil was conducted. The preliminary results indicate that the SWP can be effective in treating peaty soils, but the operating parameters still need to be optimized and improved.

It is thus concluded that it is advantageous to employ SWP technique in deep excavation work in soft marine clay in built-up area, as well as to use SWP technique as part of the soil improvement technique for peaty soils.

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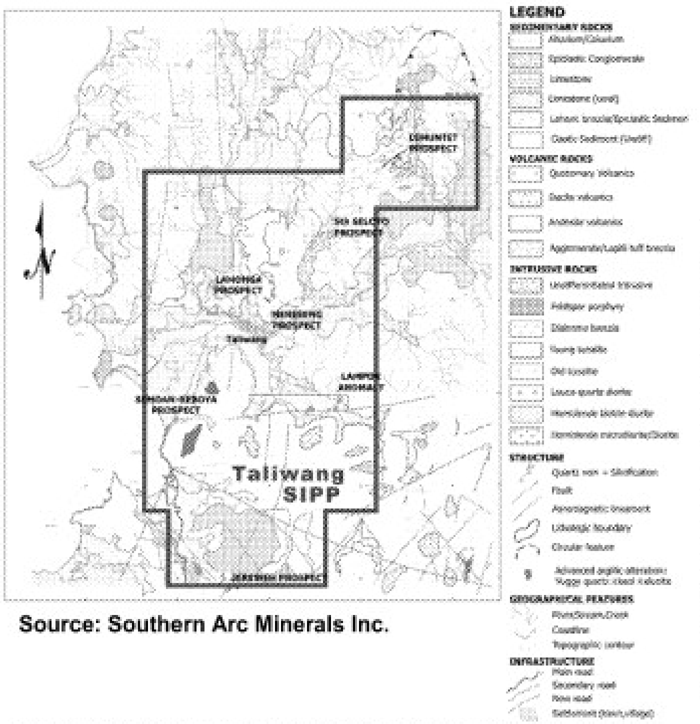
higher magnetite content. Gold typically occurs as minute (<10-15 micron) inclusions in the copper sulphides (Garwin, 2002)

The structural pattern in this area consists of three main structural grains, north-west, north-south and north-east trends, relating to copper and gold mineralization in the region. The NNE to NE trends form the mineralized corridors hosting porphyry Cu-Au mineralization, whereas late-stage epithermal veins and post mineral dykes are developed along the northwest and north-south trending faults.(Maula & Levet, 1996 op.cit. Clode et al., 1999)

The lithology of Batu Hijau Area consists of andesitic tuff interbedded with breccia and vulcaniclastic fine-grained clay, porfiri andesite intrusion, and intrusion diorit quartz. These rocks intruded by the multiphase intrusion of tonalit porfir (Figure 2). In the northern study areas consist of an extensive breccia body, which is an original capping of dacitic volcanic breccia, hydrothermally altered and re-brecciated, with some silica-quartz rich zones preferentially hosting gold-silver-minor barite mineralizationt. In the midle of the study area is dominated by an andesitic sequence of fine grain to coarse pyroclastics and columnar-jointed lava. The exposures are strongly argillically altered at both northern and southern extremities, with a weakly propylitically altered. To the south, this area consist of andesitic lavas overlain by locally finely bedded, fine to medium grained andesitic pyroclastics and epiclastics, which are capped by bedded bioclastic limestones (Figure 2).. Alteration appears predominantly influenced by propylitic alteration, phyllic to argillic alteration and silicification



Source: Southern Arc Minerals Inc.

Figure 2.: Geological map of southwestern Sumbawa Island, Indonesia

Source: Southern Arc Minerals Inc.

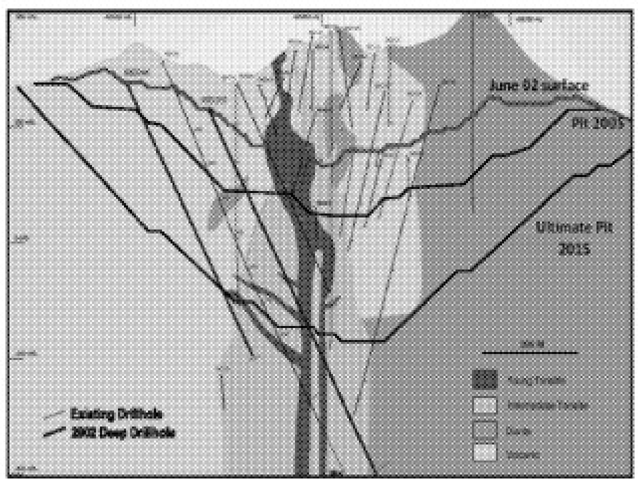


Figure 3: Cross-section of mine geology with projected pit profiles

3. Mining Activities

Open pit mining system of Batu Hijau carried out with a sink which is at the top of the pit 610 m above sea level and the bottom end of the pit is planned at an elevation of 500 m below sea level. Thus the total depth of the pit is 1100 m in diameter and pit about 2 km (1.2 miles) with a high level of bench is 15 m and the slope of Bench Angle of about 650 and Berm varying between 7 m to 21.8 m. This depends on the conditions or characteristics of rock mass. Mining activities carried out in 2 shifts per day with the amount of the average production for the 2007 of 600 tons per day (waste and ore). The main mining activities are conducted in Batu Hijau is excavation materials include activities that include two phases of drilling and excavation materials, loading and transportation (hauling) materials and copper ore processing.

excavation materials used on drilling and blasting method for rock conditions at the Batu Hijau mine PT. Newmont Nusa Tenggara largely classified into a very hard ripping Excavation class (materials that are difficult to break) with a Mohs hardness of about ± 7 Mohs. The purpose of this excavation material is to be releasing material from the parent rock. Thus, in the process of loading and transporting can be done easily. This material is transported by convensional truck and shovel. The primary loading fleet currently consists of one hundred and eleven 240 tonne haul. Material from the blasting is transported to varies location, depending on the type of material carried by trucks haul such as high-grade ore materials transported to the Crusher, a medium grade ore and low grade stockpile transported to Sejorong, whereas the waste material are transported to the waste dump in East Tongoloka and dump.

The ore body is cylindrical in shape (Fig. 3 and 4) and is being mined in a number of concurrent, concentric phases. The concentric nature of the phases and the geometry of the ore body mean that mine sequencing flexibility is relatively limited. In particular, in-pit haul road layouts are relatively inflexible and must be maintained in a spiral configuration. As a result, any larger scale slope instability cannot be left for an extended period and design changes would be required so that mining activities can continue.

Source: Mine Enginnering, PT NNT

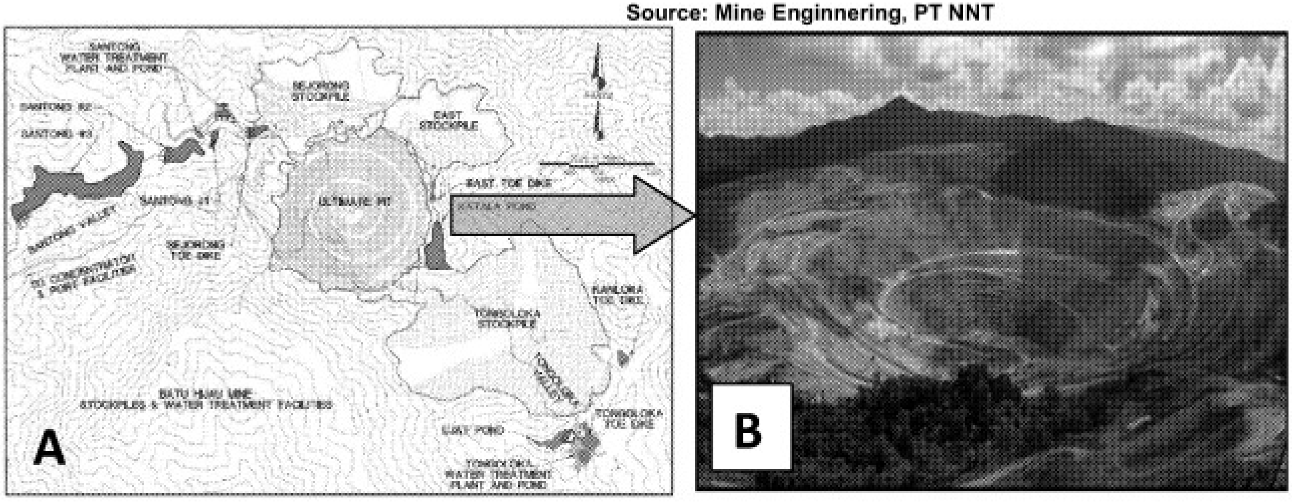


Figure 4. : (A). Map of mine and stockpile areas, (B). Open pit mining in Batu Hijau

4. Reseach Methode

The data required is the deformation data or movement of mining wall by using Slope Stability Radar monitoring, detailed data taken from October 8, 2007 until October 15, 2007, this movement of data recorded every 4 minutes as needed, from this data will be obtained movement velocity value of the mine walls were observed. Data movement from the Slope Stability Radar in the form of wall motion changes in the mine is sent to the Central Dispatch Computer (Figure 5) and will continue on the Slope Stability Radar Display Geotech room (Figure 6). From this screen will display a graph pattern is a change in the movement (deformation), which is very helpful to indicate an landslide will occur, and how the speed of movement of them

If the movement of the mine wall indicates an landslide will occur then the Slope Stability Radar will provide a warning alarm that will appear on the screen in the room geotech (Slope stability radar display), a warning alarm, so help the work of geotech team in addressing the movement of the walls of the mine which was observed as well as initial actions to take the next step.

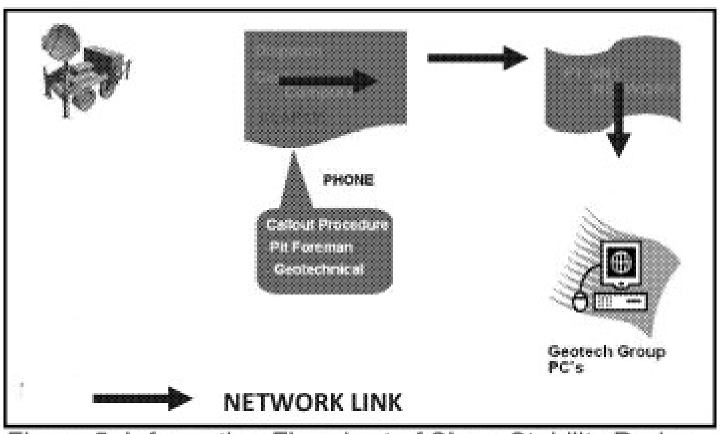


Figure 5. Information Flowchart of Slope Stability Radar

Figure 6.: Slope stability radar display in Geotech room

Here is the data processing combine litologi data and data mining wall movement (deformation) obtained the value of speed and movement patterns of change in the next graph was analyzed to obtain more accurate data to solve the problems being faced in this study. The analysis carried out by observing the process of graphic changes that occurred and movement speed increase the value obtained from the change in movement. This is very helpful for determining the predictive value of the critical limit on the movement of the mine wall, which is very useful for stopping of mining activities are conducted in areas that experienced the movement.

5. Research Study and Discussion

The management of risk to personnel, equipment and continued production associated with slope instability is one of the key roles of geotechnical and mining engineers in open pit mines. The importance of slope angles, slope instability and striping ratios on the economics of open pit operations is well recognised, and it can be quickly appreciated that eliminating all probability of slope instability by reducing slope angles is usually economically prohibitive. Therefore, some degree of risk is usually accepted during the mine design process

To facilitate the process of conducting ongoing monitoring, landslide is called Failure SS_P4_028 defined as the South Sector SS position where landslide are on the South block, P4 shows Phase 4 or stages of the mining process is in progress, and the number 28 is the serial number landslide that have Slope Stability Radar monitoring on the wall at the Southwest South Sector zone associated with the incidence landslide which occurred on October 12, 2007, at 15:05 WIT. Monitoring activities by using the Slope Stability Radar conducted from October 8, 2007 until October 15, 2007, observing the movement of the mine walls is done in real time, so that later will give very good results in the mine wall monitoring process is being done.

Monitoring the movement of the mine walls is focused on the Failure SS_P4_028 located in Domain 3 (Fig. 7) in the Southwest region South Sector zone. Domain is a criterion or a group that has a common design geotecnik of Berm (Level Width) and Bench Angle (BA) the domain is divided based on the structure and the Rock Mass Rating (resting metabolic rate), so one goal of this division can facilitate in the process of monitoring the condition of the mine wall that is experiencing the movement. The mine planning in 2005 to 2007, the Batu Hijau mine there are 12 domains in each domain have Berm varying between 7 m to 21.8 m with 15 m high and the level of the Angle Bench 65° on each domain

Observations of Landslide that occurred in SS_P4_028 Failure is based on changes in speed and value graph pattern that occurred from the transgressive phase (Pattern graph shows a movement condition of the mine wall in a constant state) leading to a progressive phase (Pattern graph shows the state of the mine wall motion changes in dynamic) ends with a critical stage (Pattern graph shows the critical condition that allows an avalanche may occur). After this landslide occurs, the condition of the mine wall in a residual resistant (remaining tension arising from landslide that have occurred, this movement in a stable condition)

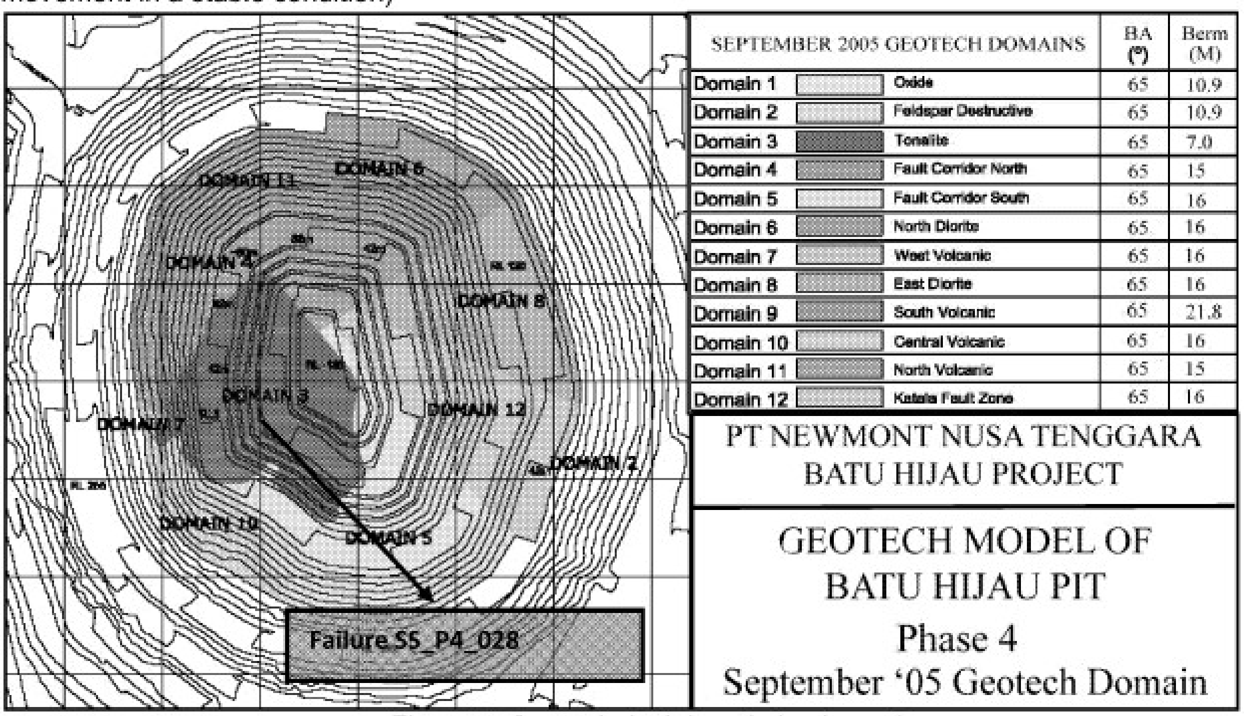


Figure 7: Geotechnical domain in phase 4

The sequence of events on the Failure SS_P4_028 landslide that occurred on October 12, 2007 at 15:05 CIT on PT Batu Hijau MineNewmont Nusa Tenggara is as follows:

1. On October 8, 2007 carried out the installation of monitoring equipment Slope Stability Radar to determine the movement of the mine walls that occur in Domain 3 in the Southwest wall Mine Batu Hijau. Given the speed of movement that occurs for 0.409 mm/hour
2. Observations made from October 9 to October 10 shows the condition of the mine walls stable condition. This indicates that when the condition of the area being monitored is still in the stage trangressive.
3. On October 11, 2007, at 07.05 CIT decrease speed. At 9:07 the speed of movement of return has increased, the speed changes dynamically.
4. On October 12, 2007, exactly at 03.05 CIT, Slope Stability Radar warning of orange alarm indicating that the speed of the movement has reached 4.55 mm/hour. This situation allows for more movement into critical condition, so that the necessary precautions in anticipation of possible danger to come.
5. On October 12, 2007, at 10:07 CIT, the speed of movement in the mine wall has reached 5.03 mm/hour.
6. On October 12, 2007, at 11:05 CIT, Slope Stability Radar warning of a red alarm indicating that the mine wall movement velocity has reached 7.43 mm/hour. Based on these indications, warning Geotech Team to the Senior Foreman (Load and Haul) that the area is doing the monitoring has entered the stage of Critical. To anticipate the possible danger that could happen, Senior Foreman (Load and Haul) to limit mining activities in this area, then followed with a safety embankment making activities by using the Back Hoe
7. On October 12, 2007, at 13:03 CIT, the mine wall movement velocity has reached the value of 13.03 mm/hour. This speed is considered a critical limit value which is used to that mining activities in these areas to stop immediately, because of the possibility of movement velocity on the wall of the mine will continue to increase and will be the possibility for the occurrence of landslides. With graphic patterns that continue to increase, if mining activities still take place, it is feared will be very dangerous for the survival of the mining process.
8. On October 12, 2007 at 15:05 CIT, landslides occurred at the speed of movement 20.0154 mm/hour. This landslide incident occurred 2 hours after termination of mining activities
9. On October 12, 2007 at 17:04 CIT. Geotech Team evacuate the landaslide that have occurred.

To find out more clearly the order of occurrence of avalanches on the wall SS_P4_028 Failure Southwest, can observe the movement of the mine wall in a pattern of graphic changes occur in the figure 8 and Figure 9.

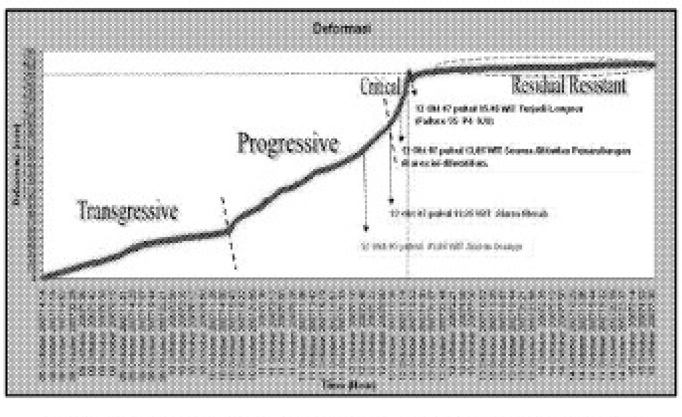


Figure 8: The process of wall mine movemnet of change graph pattern of deformation vs time

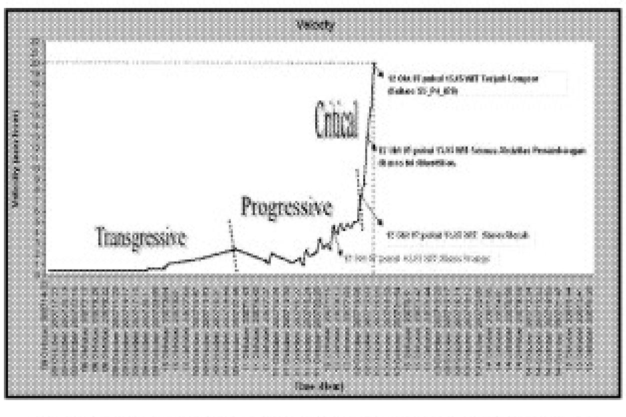


Figure 9: The process of wall mine movemnet of change graph pattern of velocity vs time

From the deformation graphs pattern and velocity graphs look of the pattern changes to the transgressive phase into critical stage causing landslides. In the transgressive phase of the movement and speed are constantly increasing. Whereas in the progressive stages can be seen that the velocity changes occur dynamically, in this case the movement has increased. At the critical stage, the movement that happens to allow the landslide, because at this stage of the movement speed continue to increase.

From observation by the Slope Stability Radar on the visual image and the deformation shown by the Slope Stability Radar (Figure 10), can be seen that the orange color shown increasing, this indicates a progressive step which is going on, until the Slope Stability Radar shows the color red is a critical condition where the landslide took place.. Furthermore ended with the residual resistant condition (remaining strength generated from landslides that have occurred).

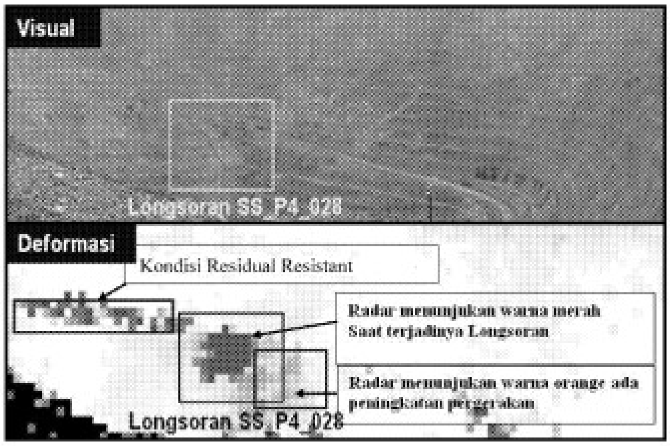


Figure 10: Slope Stability Radar monitoring of visual and deformation in Failure SS_P4_028

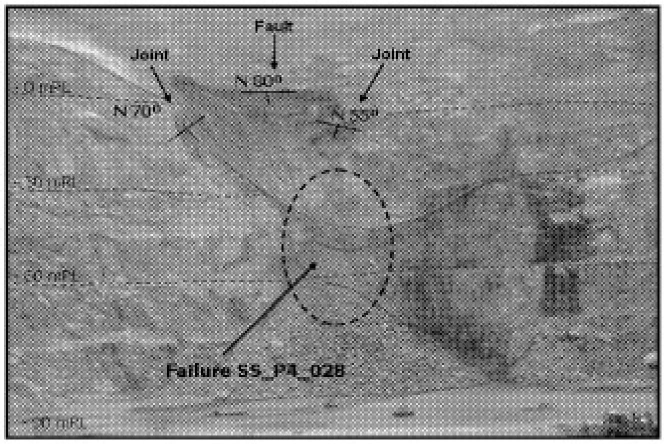


Figure 11: The condition of Failure SS_P4_028 on Domain 3

In the monitoring process by the Slope Stability Radar is necessary to be documentation processes as one consideration to determine which areas are experiencing tobe movement and also helps give you what to do next. Documentation done at the time of the landslide (Figure 11), in periods of 8 hours, 5 hours and 2 hours to the occurrence of landslides and documentation taken during the evacuation process is carried out, 2 hours after the occurrence of landslides (Figure 12).

Critical limits movement (threshold) is required to perform the action or anticipation of an instability that meant to hazards caused by the movement of the mine walls can be minimized. Critical limit values from the results of monitoring using Slope Stability Radar is based on the pattern of movement changes (deformation) which can be determined from the pattern of the graph changes, so that from this movement will get a speed value and level of conducive speed that allows landslide can occur (Figure 13)

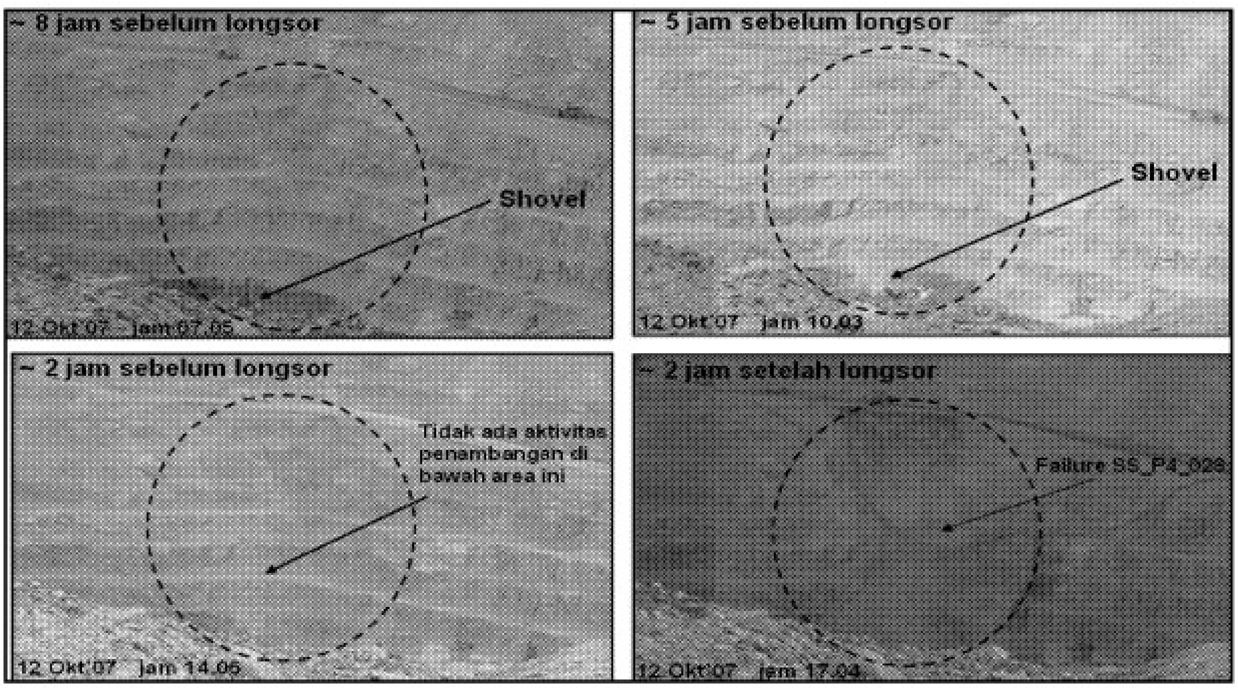


Figure 12: The evant process of sliding at Failure SS_P4_028 in Domain 3 south western wall

Predictive value of determining the critical limit is intended to mining activities are taking place in areas that are monitored can be controlled properly, otherwise this critical limit values can be used as reference to make recommendations whether the mining activities are still ongoing to continue or be stopped, given the conditions at that time is a condition that must be wary of. Determination of critical limit is very helpful in enhancing the safety and provides security for workers and can increase the productivity value of the ongoing mining at the time. The velocity value of movement in the Failure SS_P4_028 obtained from the difference value changes from the movement distance (Millimeter) divided by time (hours) between the movement happens. The calculation of this velocity can be written with the formula.

The minus sign (-) showed a decrease in speed of movement occurred after the landslide; this situation is the condition when the rocks to find a new equilibrium that will be ended by the state of residual resistant. Further calculations on the value of the speed of movement during and after the landslide is calculated every 1 hour can be seen in Table 1 used to obtain the ground motion velocity graphs during and after the occurrence of landslides by comparing the value of Velocity (mm/h) with time (hours).

To be more specific examples of calculations performed at 1 hour prior to the occurrence of landslides

$$V = \frac{So - S1}{t}$$

So = 256.56 mm
S2 = 246.26 mm
t = 1 hour
V = $\frac{256.56 - 246.26}{1}$
= - 10.30 mm/jam.

After the landslide, the movement of the wall mine shows the residual resistant conditions, which in this case the mine wall to find a new stability, illustrated by a decrease in the value until the speed of movement velocity movements in a stable condition. From the Table 1 can be made a graph by comparing the speed value during and after the occurrence of landslides with time difference in each hour (Figure 5.8). This condition is a condition that is safe in mining activity.

Monitoring was done by the Slope Stability Radar has provided very useful information regarding the movement of the mine wall that led to landslide on Failure SS_P4_028 and what actions should be performed, and the recommendation to stop mining activities are in progress with determining the value of the critical limit at the wall mine which are experiencing motion. In addition Slope Stability Radar can help facilitate the process of analysis of the landslide that occur, because the monitoring is done with equipment in real time, so that movement which happens every time can be monitored by both

In connection with the incident of landslide in Failure SS_P4_028 that have occurred on October 12, 2007 at 15:05 CIT, obtained a value of the speed of change in the pattern graph from the beginning to the landslide, so that can make a table of actions taken with respect to the addition of the speed and pattern of change graph is happening. This table can be used as an assumption of the movement that will occur after the landslide was the condition of the same domain; this assumption is based on observations of the movements that occur in Failure SS_P4_028 the Domain 3 of SWE wall of Batu Hijau mine (Table 2).

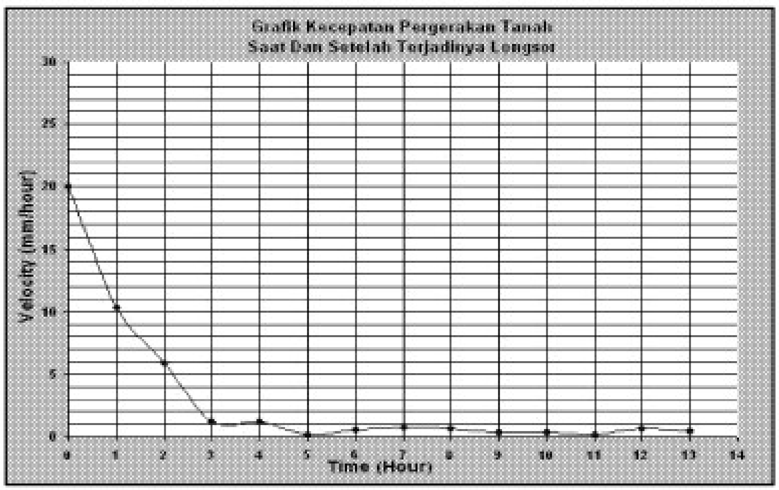


Figure 13.: Grphic which show the velocity of land movement after and event landslide occured

Hours	Velocity
13	0.49
12	0.68
11	0.21
10	0.40
9	0.34
8	0.64
7	0.79
6	0.60
5	0.15
4	1.21
3	1.23
2	5.92
1	10.30
Failure	20

Table 1. Time and the speed of landslide, after and event landslide

Speed (mm/hour)	Action
0-3	Instability Indications - Regular Monitoring: Visual;Instrumentation (Slope Stability Radar)
3-5	Increased vigilance (alarm orange) Monitoring Details: Visual monitoring; Increasing Instrumentation
5-13	Possible avalanches (red alarm): Avalanche danger warning; Evaluation and recommendations: Restrictions on mining operations
>13	Potential landslide for walls termination of mining activities

Table 2: Measures that have done to change the speed value, which is connection with the potential for instability in Failure SS_P4_028 area using Slope Stability Radar

6. Conclusion

1. Monitoring activities aimed at identifying areas which have potential landslide
2. Slope Stability Radar is very useful to conduct detailed monitoring of the mine wall movement in real time and assist in the analysis process in an landslide
3. .Slope Stability Radar is an appropriate action to help minimize the impact caused by the landslides from people, equipment and mining process is in progress
4. Critical limit values that occur in Failure SS_P4_028 at the speed to reach the value of 13.03 mm/hour. At the time of the dismissal was carried out against mining activities in progress, beginning with the early warning by a red alarm from the Slope Stability Radar at speeds of 7.43 mm/hour.
5. Determination of the predictive value of the critical limit is intended to make improvement of safety and provide security for workers and can increase the productivity value of the ongoing mining at the time. Besides the determination of critical limit values are intended to be a consideration for the transfer of mechanical equipment that was operating prior to the occurrence of landslides, because in the process of moving these tools require a very long time.
6. Landslide in Failure SS_P4_028 happen at the speed has reached the value of 20.02 mm/hr

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