DEFORMATION MONITORING AT LOW-WALL SLOPE OF COAL OPEN PIT IN PT. ADARO, INDONESIA

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ABSTRACT

Low-wall slope is a rock mass slope lay immediately underneath of the coal seam. In general, the rock mass in the low-wall is considered to be a rock mass with bedding plane at an angle parallel to the slope. PT. Adaro Indonesia is one of coal mining companies in South Kalimantan. It can clearly be seen that mining process is getting deeper along with the progress of coal extraction. It is targeted that the mining shall reach RL-204 m from sea level, so the low-wall slope will be formed with the overall height of 298 m. Therefore, deformation monitoring is greatly needed to observe the stability of the lowwall slope.

INTRODUCTION

This paper describes the monitoring activities on the displacement of rock mass at the low-wall slope in Pit PAMA at Tutupan coal mining area of PT Adaro Indonesia. PT. Adaro Indonesia is one of coal mining companies in South Kalimantan. Due to the progress of coal extraction, It can clearly be seen that mining floor is getting deeper. It is targeted that the mining floor shall reach RL-204m from sea level, so the low-wall slope will be formed with the overall height of 298m. In order to understand the stability of the lowwall slope, monitoring aimed to observe the deformation of the slope was carried out using Inclinometer, monitoring prism and crackmeter at several locations. This paper on the other hand, only discusses the result of inclinometer and monitoring prism which inline or close to the line of cross-section no 10A. This location has been chosen since the rock layers at the locations show the change of the dipping and striking.

The rock mass in the low-wall is considered to be a rock mass with bedding plane at an angle parallel to the slope. Therefore, the slope instability was predicted in the form of plane failure (sliding along the bedding plane) and circular failure through the weak plane. The monitoring data were then analyzed using the relations of displacement versus time (Kramadibrata and Kushardanto, 2002 and Kramadibrata et al., 2007). Thus, from the analysis mentioned before, it can be understood the stability of the slope.

GENERAL CONDITION OF TUTUPAN MINE

Geology

The Tutupan mountainous area has 20 kilometers of length, stretching from North-East to South-West. This area is formed and bordered by the movement of two trust faults, which have parallel directions. The fault on the western side of the hill is known as Dahai Trust Fault, separating Dahor Formation at the Western side and Warukin Formation at the Eastern side. The other fault, Tanah Abang –Tepian Timur trust fault appears at the eastern side of the hill. The existence of the fault was interpreted based on seismic and oil well drilling data. An anticline structure, named Parangin anticline, was also found at the Eastern side of the hill, running nearly parallel and closed to the Tanah Abang-Tepian Timur trust Fault (Figure 1).

Low-wall Slope

The basal coal seam mined in Tutupan Mine Area is called as seam T110. The rock strata which are located below T110 coal seam floor has been named by PT. Adaro Indonesia as given in Figure 2 and they are as follow: T110, LMOF, LS1, LM3, LS2, LM5, LS3, and LM7, where T is coal seam, M is mudstone, S is sandstone, and L is representation of layer. The thin coal seams were deposited between mudstone layers and there is no contact between the coal and sand layer. The low-wall slope where the inclino-8 and 13 were installed had an overall angle of 21^{o} and constituted by individual bench of 12 m high. The inclination of the overall-slope is still flatter than the dip of T110 coal seam floor which is 55^{o} (Figure 3 and 4). The rock strata's model where Inclino-8 and 13 were installed on is dominated by mudstone.

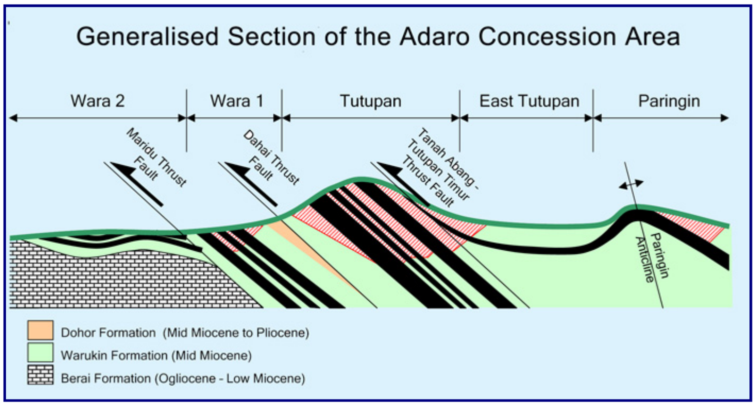

Figure 1. Geological Section of PT Adaro's concession area

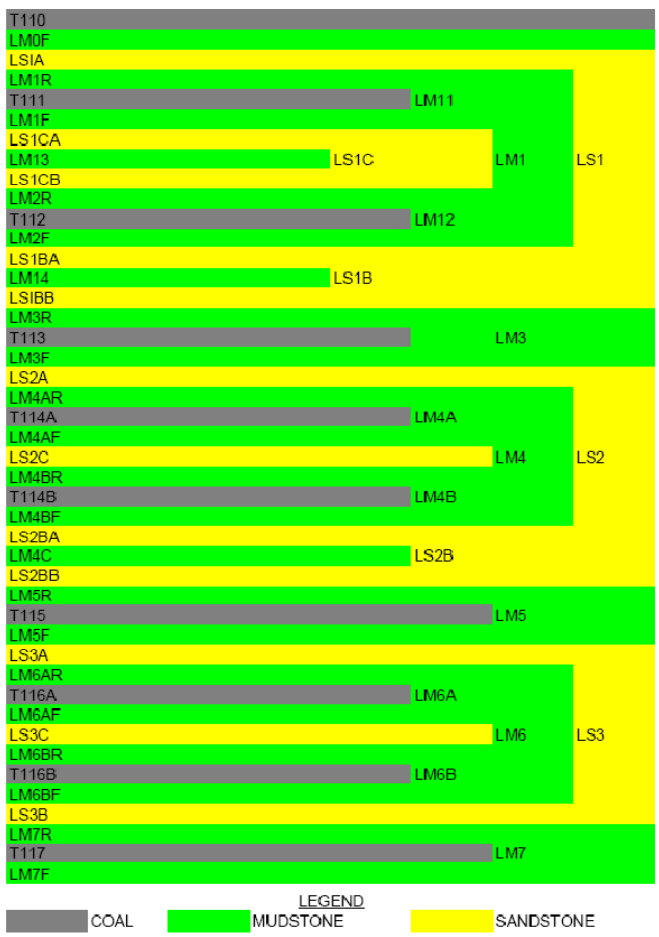

Figure 2. Lythology of the rock mass below T110 coal seam

MONITORING

Deformation Monitoring of the low-wall slope which will be discussed is Inclinometer and monitoring prism. The observations which inline or close to the line of cross-section no 10A are Inclinometer no 08 and 13, and prism no 01, 144 and 145. The rock strata constitute the low-wall at cross section no 10A is shown in Figure 4. The position of those devices is shown in Figure 3.

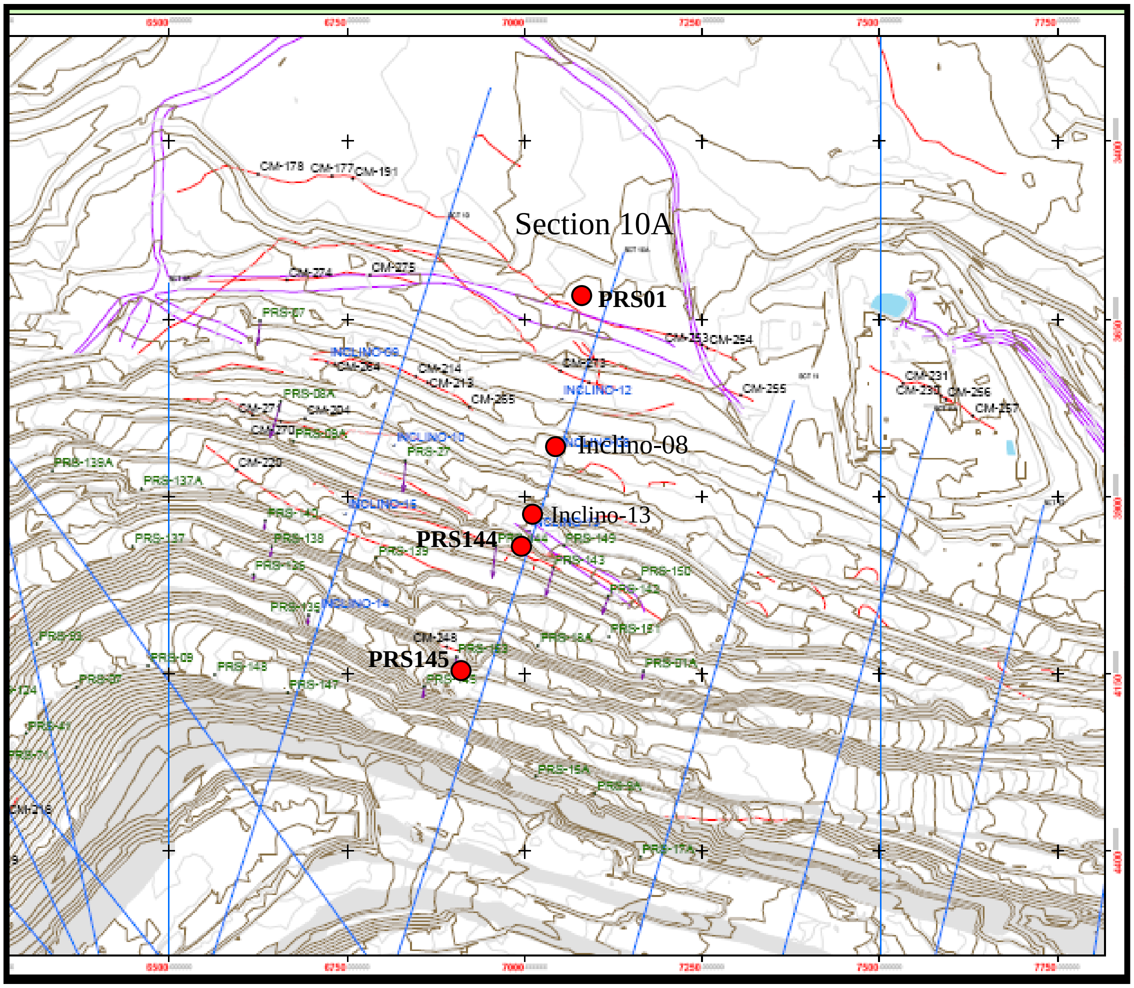

Figure 4. Location of Inclinometer and Prism Monitoring in Low-wall

Inclinometer

Inclinometer is equipment for transverse deformation gages. This equipment is used for observing the displacement perpendicular to the pipe axis, which is measured through the probe inserted into the pipe. This probe contains a gravity-sensing transducer that is designed for measuring a corner's change towards vertical axis. The setting of Inclino-08 was conducted in June 2008, while incline-13 was in September 2008, with the depths from the collar were 50 m and 102 m, respectively. The inclinometer used in this study was produced by RST Instrument Ltd.

The displacement measurement in incline-08 was conducted until 11 February 2009 or 9 month after installation, June 2008, while that of incline-13 is conducted until 27 December 2008 or 3 month after installation, September 2008. The result of the measurements revealed that the horizontal displacement at the collar was 0.34 m and 0.78

m, respectively (Figure 5) moving towards mining area. It can be seen that the displacement obtained from incline-13 is greater than inclineo-08 which located in the upper-side (see Figure 4)

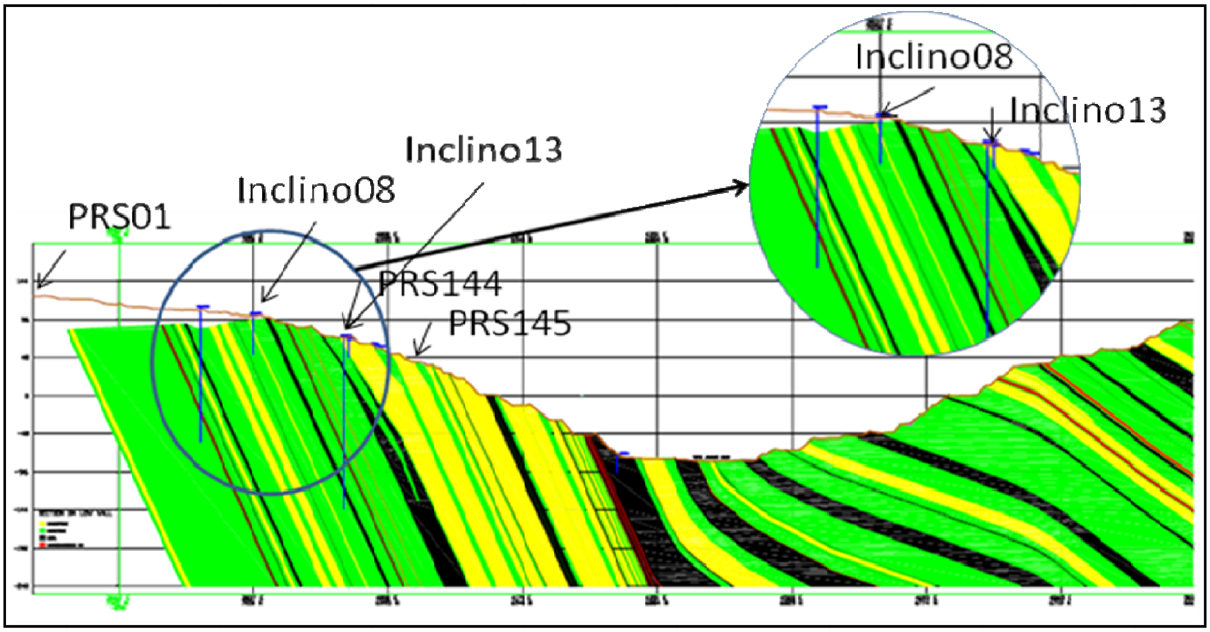

Figure 4. Cross section 10A of the Lowwall at Tutupan Mine

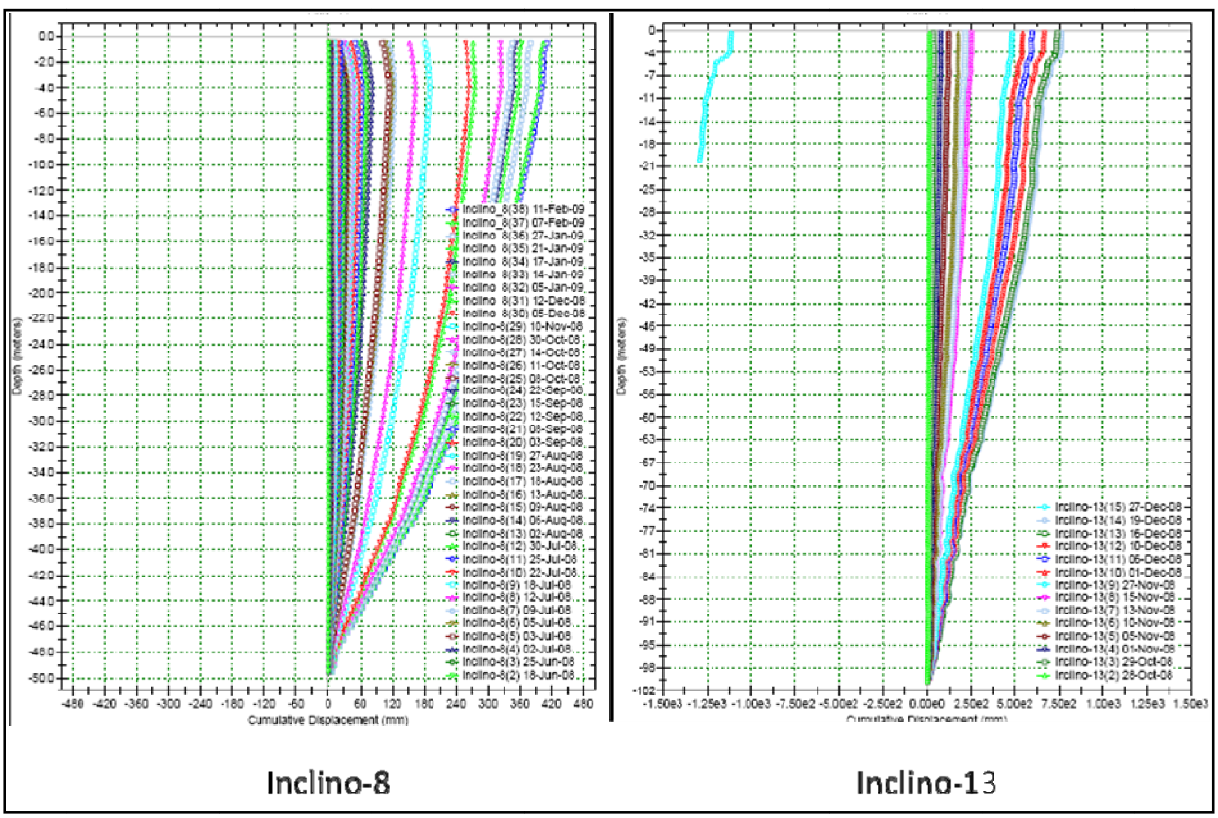

Figure 5. The cumulative change plot of Inclino 13 and 08

Monitoring Prism

The slope displacement is also monitored is using 'Robotic Theodolite' total station. As the target of the total station system, Monitoring Prism is installed in several points at Lowwall slope. The essential parameters obtained from this measurement system are displacements of vertical, lateral and transversal directions (Dunnicliff and Green, 1993).

The Prism-01 was installed in January 2008 and after 9 month later, the displacement monitored was 0.4 m. While prism-145 was installed in September 2008, and the displacement occurred after 4 month later is 1.4 m. It can also be seen that the displacement obtained from prism-145 is greater than Prism-01 which located in the upper-side (see Figure 6).

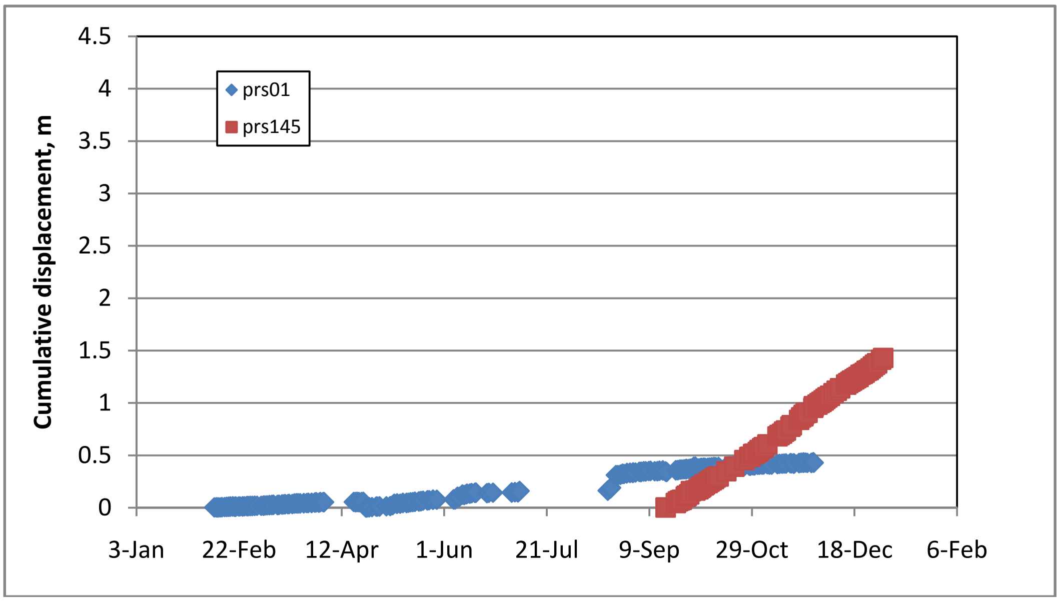

Figure 6. The cumulative displacement on PRS-01 and PRS 145

ANALYSIS

Rockmass Displacement

The result of monitoring obtained from Prism-01, Prism-145,and displacement revealed from the collar of inclino-08 and incline-13 are plotted together and it is shown in Figure 7. The progress of mining floor is also plotted together in Figure 7 in order to know the effect of the mining floor change on the low-wall slope deformation.

In the higher part, the displacement's change obtained from Prism-01 and Inclino-8 showing the trend in linear progression and quite slow movement. The lower part, the characteristic of the displacement change is still linear mode. However, more rapid movement happened (see Figure 7). It can be seen that until December 2008 the mining progress seems give no effect to the displacement of the higher part of low-wall slope. The incline-13 which is located in the middle is also giving the result and the displacement occurred has linear mode with medium movement. There is indication that the movement with in difference rate happened at low-wall slope.

Based on the lythology mentioned above, the monitored rock strata is dominated by mudstone in the higher part and sandstone in the lower part. As it can be seen from Figure 3, the bedding plane is quite steeply inclined (dip

> 55^o). According to this condition, the failure mode which will be potentially happened in the lowwall is toppling failure or combination of toppling-circular failure. Tension cracks occurred in this slope is relatively parallel to the strike of bedding plane (shown by red line in Figure 3). This phenomenon gives an indication that flexural deformation of rock strata may be happened. By picking the data up at the depth of 12m from inclino-08 and inclino-13 and then plotted versus time (see Figure 8), it is found that the movement in the sub-surface is slower than one in the surface, so the characteristic supports the prediction mentioned before.

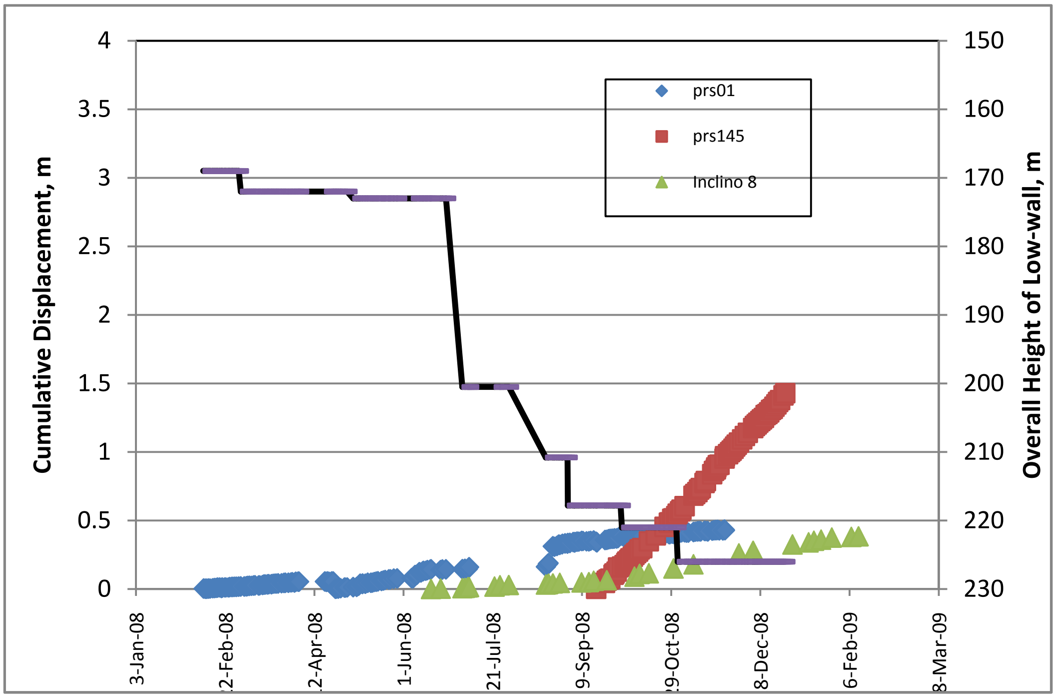

Figure 7. The cumulative lateral displacement and mining floor progress in Pama pit

Velocity of Displacement

Velocity of displacement can be calculated and using this system, any slope movements exceeding the previously specified threshold limit values (THLV) can be identified automatically, so early warning alert can be sign immediately after facing extreme movement at certain monitoring prism (Saptono et.al., 2008).

The THLV specified by the Golder Associates is shown in Table 1. Based on the velocity of displacement, the risk scheme are specified into 4 conditions namely, absolute check, long time, short time and regression check as given in Table 1. For example, if we had an average displacement longitudinal of 15 mm per day the slope could be considered safe. On the other hand, when the displacement reaches 250 mm over 12 hours the activity should be stopped in order to release the load or mass of the slope.

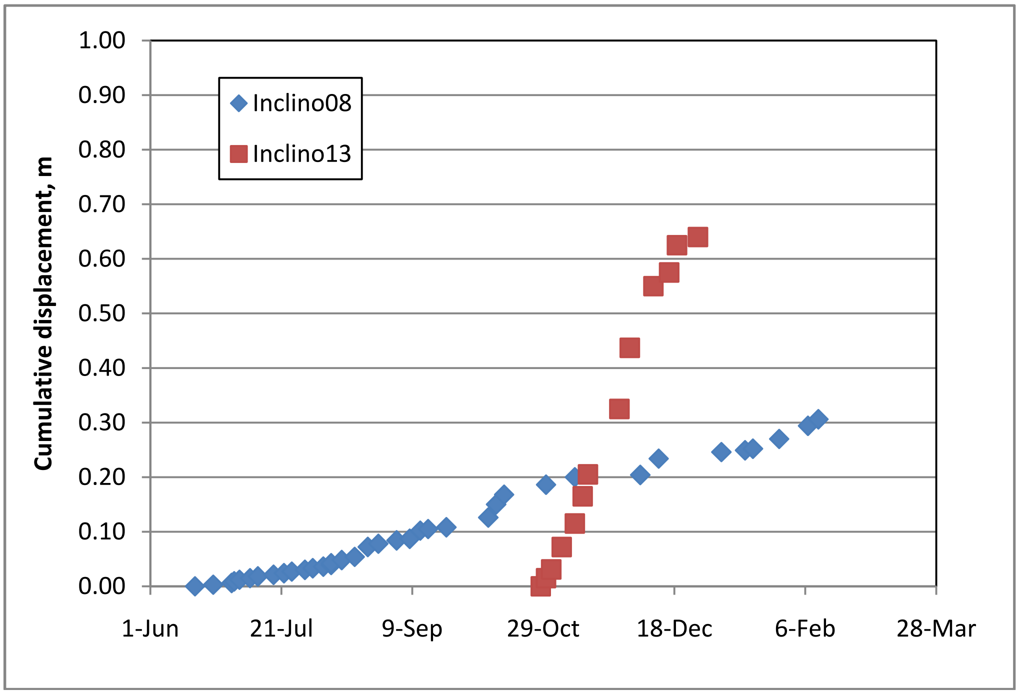

Figure 8. Curve of cumulative displacement in Inclino-8 and 13 on 12 m depth

Table 1. Limit values longitudinal displacement of different rate for different risk scheme proposed by Golder Associates (Golder, 2004)

	Interval (hours)	Limit 1 (m)	Limit 2 (m)	Limit 3 (m)
Absolute check		0.020	0.040	0.100
Short time check	24	0.015	0.020	0.075
Long time check	72	0.030	0.060	0.150
Regression check	12	0.050	0.100	0.250
Remarks		Safe	Caution	Stop

The displacement rate of Prisma-145 is 13 mm/day. While from the inclinometer data i.e. Inclino-13 and Inclino-8, the velocity of displacement in 12 meter depth are 11 mm/day and 1 mm/day respectively. Based on the THLV, the slope is in stable condition. The result of displacement's rate obtained from Prism-01 and Inclino-08 is similar i.e. 1 mm/day. This phenomenon indicates that the movement occurred in the slope surface is categorized as creep phenomenon.

CONCLUSION

a. This study shows that the displacement at the low-wall slope can be monitored using inclinometer and monitoring prism.
b. Based on the data obtained from inclinometer and Monitoring Prism, it can be said that creep movement occurred at the low-wall slope, and the movement follows the flexural toppling failure mode.

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