APPLICATION OF SIMPLE DISPLACEMENT MONITORING SYSTEM FOR ROCK/SOIL MOVEMENT AT BINUNGAN MINE OPERATION OF PT. BERAU COAL

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ABSTRACT

This monitoring result illustrates the real slope stability and could be used as datat for back analysis to obtain the real shear strength (c and ö).Study of monitoring system application to detect soil/rock movement at mine slope was conducted bya team from tekMIRA in 2006. The location of trial run was Binungan Mine Operation, PT. Berau Coal. The team used combinations of simple, accurate and relatively low cost monitoring equipment consists of radio modem, data logger and potential transducer. Potential transducers were connected to the observation points using a wire line. When the movement occurs along the mine slope, the wire line will cause a difference potentiometer voltage. The results show a good value of linearity with value of r-square between 0.964 and 0.981.

Keywords : displacement, monitoring, slope stability, transducer

1. INTRODUCTION

The stability of rock or soil slope depends on the combination of strength parameter effects (cohesion and angle of internal friction), scale effect of laboratory test, rock/soil mass heterogeneity, discontinuity and external forces. Resultant of these combination causes rock/soil movement. If rock/soil movement has exceeded the elastic limit of the rock strength, the slope failure will be dangerous. So that the complement of analysis based on laboratory test requires a rock/soil movement monitoring method by using monitoring system instrument which can observe continuously the deformation of the rock. By the displacement monitoring system, will be also obtained the data about strength of rock, which applicable to make back analyze about the condition of slope stability and evaluates the applied slope dimension.

The aims of this project were to test the performance of slope stability monitoring system equipments. This equipment works automatically but relatively low cost and suitable to be applied at mining operation.

The field data was recorded from the observation, the additional geotechnics data can be used as basic in more detail analysis in order to maintain the safety of mine operation (Girard and McHugh, 2004). The data was also processed as the input for early warning system of slope instability and also was used in more detail for geotechnics information that related to the observed slope (Sjoberg. 1996).

This report explains one of slope stability monitoring methods applied at Binungan Mine Operation, one of PT. Berau Coal mining sites.

2. METHODOLOGY

Monitoring concept applied at Binungan Mine Operation (BMO) of PT. Berau Coal is a wire line displacement monitoring system. The instrument

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consists of wire line transducer, radio modem (Alinco, 1995), data logger (Data taker, 2005) and software application. As illustration the concept of monitoring is shown in Figure 1.

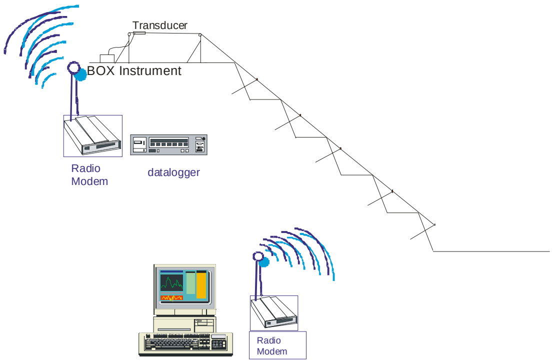

Figure 1 **Illustration of the concept of slope stability monitoring**

3. RUNNING TEST AND CALLIBRATION

Running test was conducted to ensure that all instruments worked well. If the transfer data on both transmitting and receiving from transducer to application software run well it then was continued by calibrating transducer measurement. The calibration was necessary to adjust the transducer in order to match with field condition. Calibration of displacement transducer was conducted by measuring the displacement at certain distance for some different conditions as shown in Table 1. The measurement data then were analyzed by linear regression method to know the trend of resistance changes for some different tensions.

Figure 2 shows the curve of the relation between the change of wireline position (mm) and the change of electric resistance (Ohm) at displacement transducer. From the curves of displacement transducer channels I, II, III and IV were resulted regression equations as shown in Table 2.

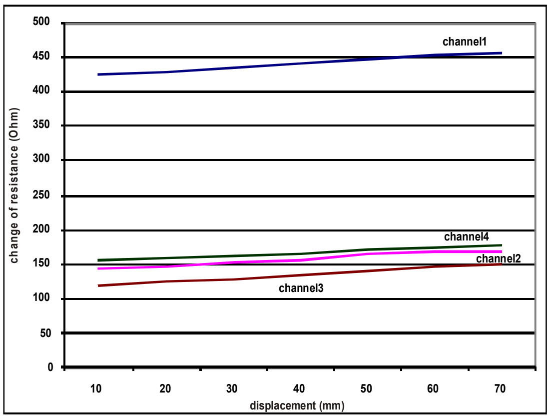

Figure 2 **Change of resistance at channel 1, 2, 3 and 4 versus change of wireline position (displacement)**

Table 1 Change of resistance vs displacement

Displacement (mm)	Change of Resistance Channel 1 (ohm)			Change of Resistance Channel 2 (ohm)		
10	426.23	402.17	401.36	143.73	147.23	148.53
20	429.22	407.17	405.9	147.79	152.93	153.81
30	434.55	411.98	411.61	153.28	158.24	158.79
40	440.15	415.59	416.61	156.12	162.48	163.78
50	445.60	422.92	422.24	163	167	168.5
60	451.97	426.93	427.25	167.78	168.49	172.57
70	456.53	431.55	432.04	168.68	172.55	177.88
Displacement (mm)	Change of Resistance Channel 3 (ohm)			Change of Resistance Channel 4 (ohm)		
10	426.23	402.17	401.36	143.73	147.23	148.53
20	429.22	407.17	405.9	147.79	152.93	153.81
30	434.55	411.98	411.61	153.28	158.24	158.79
40	440.15	415.59	416.61	156.12	162.48	163.78
50	445.6	422.92	422.24	163	167	168.5
60	451.97	426.93	427.25	167.78	168.49	172.57
70	456.53	431.55	432.04	168.68	172.55	177.88

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Table 2 Linear regression equations for each channel (CH)

Displacement transducer position	Linear regression equations	R^2
Channel-1	Y = 0.245 + 0.368x	0.981
Channel-2	Y = 0.232 + 0.421x	0.978
Channel-3	Y = 0.216 + 0.371x	0.999
Channel-4	Y = 0.220 + 0.374x	0.964

4. SLOPE STABILITY MONITORING

Conventional monitoring method for land surveying has two advantages, namely low cost and relatively detail. However, it has some limitations due to human errors, so the resolution and sensitivity are limited. One of new design applied in this project is the equipment for soil movement and rock displacement monitoring system which is installed at Pit H3N BMO. This equipment consists of displacement transducer, datalogger, radiomodem and application software. The method of transferring data is telemetry, so the data are transmitted real-time straightly from pit (the location of transducer) to monitoring room using radio wave.

4.1. Monitoring Instrument Installation

Instrument of displacement monitoring system is installed at one of the pit slopes at H3N BMO about 300m from BMO monitoring office. Relatively short distance is to make the running test simple ready to repair the instrument if broken. The displacement transducer is installed at four observation points and as indicate at datalogger. Those are channel 1, 2, 3 and 4. Installation of the transducer in the field is shown in Figure 3.

Figure 3 Installation of displacement transducer

The next installation is the main panel which consists of power accumulator, radiomodem and datalogger. Radiomodem is Alinco type DR 345 and datalogger is Datataker DT50. Figure 4 shows the instalation process at the observation site.

Figure 4 Main panel installation

In order to maintain power stability of accumulator to supply voltage and current as required by radiomodem and datalogger, the accumulator is continuously charged by a solar cell as shown in Figure 5.

Figure 5 Installed solar cell panel

To receive the field data transmitted by wireline transducer, it needs a software in order to process the data at real-time. In this case the development of a special software named Geotek Version 1.0 is needed. The software also organizes and saves the data in the database and displays them as curves as shown in Figure 6.

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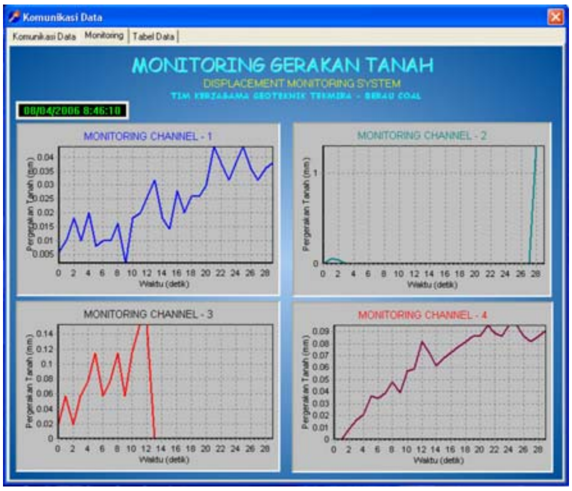

Figure 6 **Curves of soil or rock movement monitoring**

Monitoring system works continuously. The system can be used as early as the warning system for soil movement or rock displacement by monitoring the PC monitor. It is possible to use some addition equipment such as alarm to get effective warning.

Warning within PC monitor is divided into two types namely "BEWARE !" that will be active if soil/rock movement is up to 15 mm and slope is steep. When the movement frequency intensity is increase up to 30 mm with the velocity slope is steep, the second alarm of "DANGER !" will be displayed as shown in Figure 7.

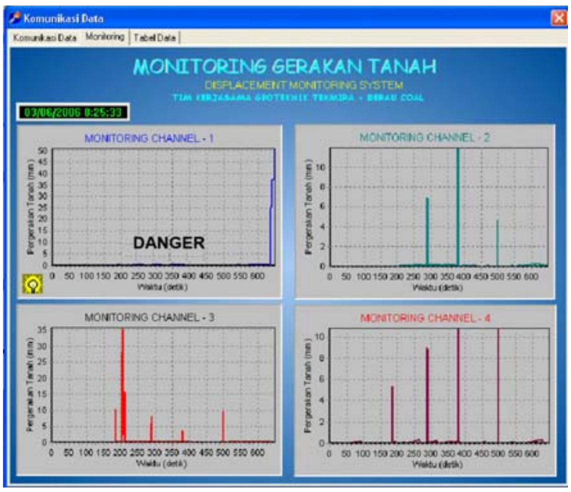

Figure 7 **The alarm of early warning system at application software**

4.2. Data Evaluation

Field data was collected by the measurement at Pit H3N BMO. The data was collected from 7 to 12 April 2006. Data collection from 7 to 8 April 2006 was derived from running test. Others collected from 11 to 12 April 2006 were real field data.. The collected data was not sufficient for analyzing soil/rock movement behavior, due to instrument problem such as power supply instability of accumulator and incontinuation of monitoring.

The collected data was processed by software *Geotek Version 1.0*. To show the measurement sensitivity of sensors, monitoring result before blasting, during blasting time and after blasting are presented in Figures 8, 9 and 10.

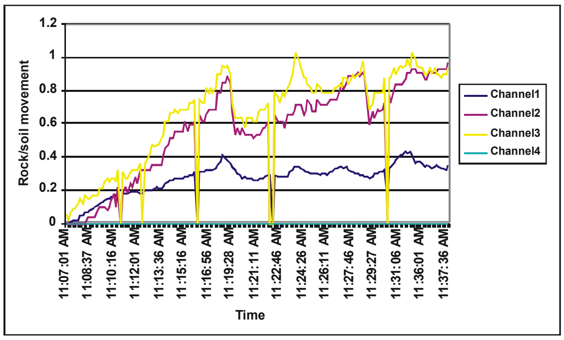

Figure 8 **Curve of soil/rock movement before blasting**

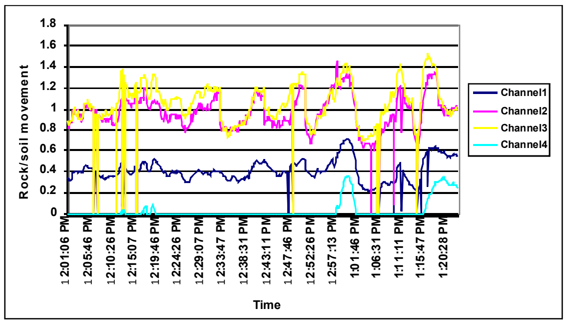

Figure 9 **Curve of soil/rock movement while blasting**

Figure 9 shows that curve trend are stable. However, the soil movement tends to increase at next minutes but still in normal condition. When blasting occurs, the movement was increased significantly when fluctuated from 1 up to 2.5 mm. These

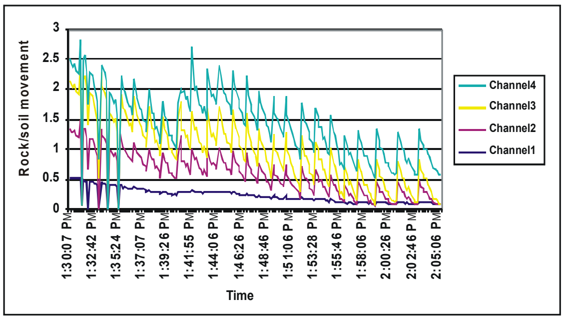

Figure 10 **Curve of soil/rock movement after blasting**

conditions were caused by transversal wave but did not disturb the stability of slope at the observation area. Due to the relaxation of shock wave, the fluctuation of movement was decreased when the "saw wave" tends to be smaller and then back to the normal position (Figure 10). Based on the data, soil condition at observation site is elastics and tends to be in stable conditions.

4.3. Problems

The movement of soil/rock could be temporarily monitored at the real-time as shown in Figures 8 ,9 and 10 respectively. However, the process of soil/rock movement for long time (for example 1 month or 1 year observation data) are not available. As a result, the behavior of soil/rock could not be analyzed in detail.

Soil movement criteria might be change from elastic to creep, crack or even collapse conditions (Duncan and Stark, 1992). For this reason, it needs to continue the observation for studying movement velocity and trend.

5. CONCLUSIONS

Some conclusions of this project are as follows :

– slope stability monitoring is necessary especially at area with unstable rock/soil mass;

– precision, quick and accurate measurements can be conducted by applying electronic instruments and ignoring human error. However it is expensive and has high technology;

– it is possible to apply inexpensive instruments for soil/rock movement displacement in mining operation. Using some electronic telecommunications and computer instruments which are sold freely and available in market can make the instrument;

– soil/rock displacement monitoring system applied at Pit H3N BMO of PT. Berau Coal was successfully tested. The result was real-time, precisied and accurate;

– collected data was limited due to limited time during the running test. The data was sufficient only for limited geotechnics analysis. However, it showst soil/rock slope at H3N BMO tends to be elastics and stable.

6. SUGGESTIONS

1. In order to get deeper geotechnics analysis, it is necessary to record field data at least for 30 day observation.

2. Observation using this equipment should be conducted continuously; by not turning off field equipment or application software.

REFERENCES

Alinco, 1995. Alinco Radiomodem DR 435 User Manual, Alinco Electronics, *www.alinco.com*

Datataker, 2005. Datataker User Manual, *www.datataker.com*

Duncan, J.M. and Stark, T.D., 1992. Soil Strengths from Back Analysis of Slope Failures, *ASCE Publication*, 1801 Alexander Bell Dr.

Girard, J.M. and McHugh, Ed. 2004. Detecting Problems with mine slope stability, National Institute for Occupational Safety and Health, Spokane Research Laborator.

Sjöberg, J. (1996). Large Scale Slope Stability in Open Pit Mining, A-Review. *Technical Report 1996*:10T, Division of Rock Mechanics, Lule University of Technology, Sweden.

Szwedzicki, T., (ed.) (1993): Geotechnical Instrumentation and Monitoring in Open Pit and Underground Mining – *Proceedings of the Australian Conference*, Kalgoorlie.

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