Wireless Data Acquisition System for Chock Shields in Underground Mines - Performance Monitoring and Analysis

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ABSTRACT

Continuous monitoring and analysis of chock shield performance is mandatory for better safety and productivity. Data acquisition from long distance underground multi sensors is complex by conventional method. The conventional data transmissions are required huge data cable for transmitting multi sensors data to long distance. The conventional data transmissions are expensive and require heavy maintenance due to huge data cable. Noise interference and signal attenuation is more in conventional transmissions. Consequently, the data quality is poor. Further, the maintenance of data continuity is difficult due to frequent cable cut due to roof falls, side falls, and mining machinery movement. Therefore, the development of innovative wireless data transmission techniques is imperative for effective data transmissions. Thus, the authors have developed an innovative wireless data acquisition system for monitoring and analysis of powered supports performance in real time.

An innovative wireless data acquisition system was successfully developed and implemented in one of the problematic longwall mines for continuous monitoring and analysis of chock shield performance in real time. First time such an innovative system was successfully implemented in one of the Indian mines. This paper discusses innovations in development and applications.

***Keywords**:* Wireless data acquisition system, Periodic weight, Intelligent dump terminal, Longwall, Leg closure, Shield pressure, Continuous monitoring, Chock shield, Real time

1. INTRODUCTION

Longwall shields provide essential ground control in longwall mining, yet a high percentage of shields are operating at less than peak capacity and many at well below the rated support capacity due to defective cylinders or malfunctions in other hydraulic components. Many hydraulic problems go undetected since the leaks are internal and there are no external visible signs of fluid loss associated with these events. Shields play a vital role in achieving successful, safe and productive long wall mining (Barczak and Conover, 2002). Although shield design has improved considerably through the years, hydraulic leakages and other problems that degrade the support performance are still prevalent particularly on aging supports that have been in service for several years in an Indian long wall mines. Hence, the productivity of Indian longwall operations is not appreciable. Therefore, the continuous monitoring and analysis of shield performance is mandatory for improving productivity.

2. WIRE Vs WIRELESS

The conventional method of transmission of data by multi-pair double armored data cable is complex and cumbersome for transmitting multi sensors data. Moreover, the data quality is very poor in conventional cable data transmissions due to interference of various underground noises. Further, the conventional transmissions are expensive and require a regular maintenance due to huge double armored data cable. Particularly in underground, cable cuts are very frequent due to roof falls, side falls, and movement of mining machinery. Therefore the conventional method is not compatible to long distance data transmissions. Besides the maintenance of data continuity, the quality also is not satisfactory. Thus, the supports performance evaluation is not accurate due to discontinuous manual data. Further, the conventional method is not compatible to implementing real time operations.

The wireless data transmissions have omitted the requirement of huge data cable between the surface monitoring station to the underground detectors (sensors). This new method of wireless transmissions has many advantages over the conventional method. They are briefly: less expensive, more convenient solution, compatibility to underground environment and easy to use because of user friendly operations. Data can be acquired at one location by a distributed I/O (Input/Output) system, and transmitted over the radio waves to the monitoring station. This paper explains further in detail its applications to Indian longwall mining operations (Tadisetty et al., 2003).

The wireless radio modem, radio modem and the SRM 6000 are one and the same. The model number of SRM 6000 wireless radio modem module was used for developing wireless system. The SRM6000 radio modem was successfully interfaced to the data acquisition system as shown in Figures 1 and 2. The radio modem offers the highest level of reliability and performance for wireless serial transmissions. This was ideal for both short- and long-range data transmission applications. The SRM6000 communicates up to 32 km with the line-of-sight antenna placement. The

SRM6000 can also function as a repeater to extend transmission range. The wireless radio modem commissioning was quick and inexpensive, because no FCC site license is required. The SRM6000 ensures error-free transmission using frequency hopping and 32-bit CRC (Cyclic redundant correction) error correction. The data transmission rate was 144 KBPS (kilo bits per second). Even in severe interference of mining noise, the radio modem can achieve the selected data rate. The SRM6000 operates both point-to-point and multipoint data transmissions. Multipoint method permits an unlimited number of slaves. The radio modem has many advantages like excellent immunity to noise, user-friendly configuration, extended operating range, more interface options, and license free frequency bands. The discussions, in this paper are mainly concentrated on applications of wireless data acquisition system.

2.1 Conventional Method

The conventional method of monitoring supports pressure is to manually taking pressure gauge readings once in a day. This manual method is generating discontinuous data. Further, the hydraulic leakages are detected manually by observing the relative position of the cylinder staging (Barczak and Gearhart, 1993). Moreover, the experimental longwall panel was equipped with 84 supports. Manually observation of so many supports cylinder staging continuously is impossible. Further, the manual detection of hydraulic leakages continuously is not possible due to active longwall operations. Moreover, the hydraulic leaks are internal with no external visible signs of fluid leakages. Therefore the above discussed manual methods are not compatible for continuous monitoring of strata behavior and supports performance. Hence, the authors have developed a new real time (RT) system for avoiding above discussed limitations of conventional method.

The wireless data acquisition system is a part of the RT system. The Real Time (RT) system was successfully developed indigenously and implemented in one of the longwall mine, GDK 10A, SCCL Ramagundem for improving productivity and safety of longwall operations. The new RT system has continuously monitored powered supports behavior and evaluated performance in real time. The RT system also maintains the data quality and continuity due to state-of-the-art wireless operations.

3. EXPERIMENTAL LONGWALL MINE

Longwall panel No.4 was prepared in one seam bottom section leaving the 3m clay/shale coal in the roof at GDK (Godavarikhani) 10A, SCCL (Singareni Collieries Company Limited) Ramagundem. Depth of the panel varies from 247 to 297m. The compressive strength of the stone roof is 13.6 MPa. The overlying strata was highly water bearing. Longwall retreat was 4 to 5 m per day. An average daily production was 2000 t. The panel and face length were of 940 and 116 m respectively. The panel working height was 3.0 m. This panel was equipped with 80 chock shields of capacity 4X800 t. The seam thickness was 6.40 m with a 0.30 m clay band and an average gradient of 1 in 6 towards N73^0 E. The strata overlying in the coal seam was composed of coarse to medium grained ferruginous sandstones, coarse grained kaolinised felspathic massive sandstones with clays and grey shales.

3.1 Wireless Data Acquisition System

Figure 1 Shows block schematic diagram of RT and peripheral systems. All the systems and modules were controlled by RT system. The wireless data acquisition system mainly comprises of wireless transmitting antenna and radio modem as shown in Figures 1 and 2. The pressure and leg closure sensors interfaced to the surface data acquisition system (Figures 1 and 2). The output of data acquisition system is interfaced to radio modem. The output of radio modem is interfaced to the wireless transmitter as shown in Figure 1. The surface monitoring system (Figure 4) is mainly comprises of radio modem with wireless receiver, RT system and intelligent dump terminal. The wireless receiver received data from wireless transmitter, whereas the RT system received data from wireless radio modem. The RT system executes in-built data analysis software routines. The result of the analysis is sent to intelligent dump terminal. Intelligent dump terminal has in-built display. This display also called as a real time display. Therefore the received data is displayed on real time display as shown in Figure 4.

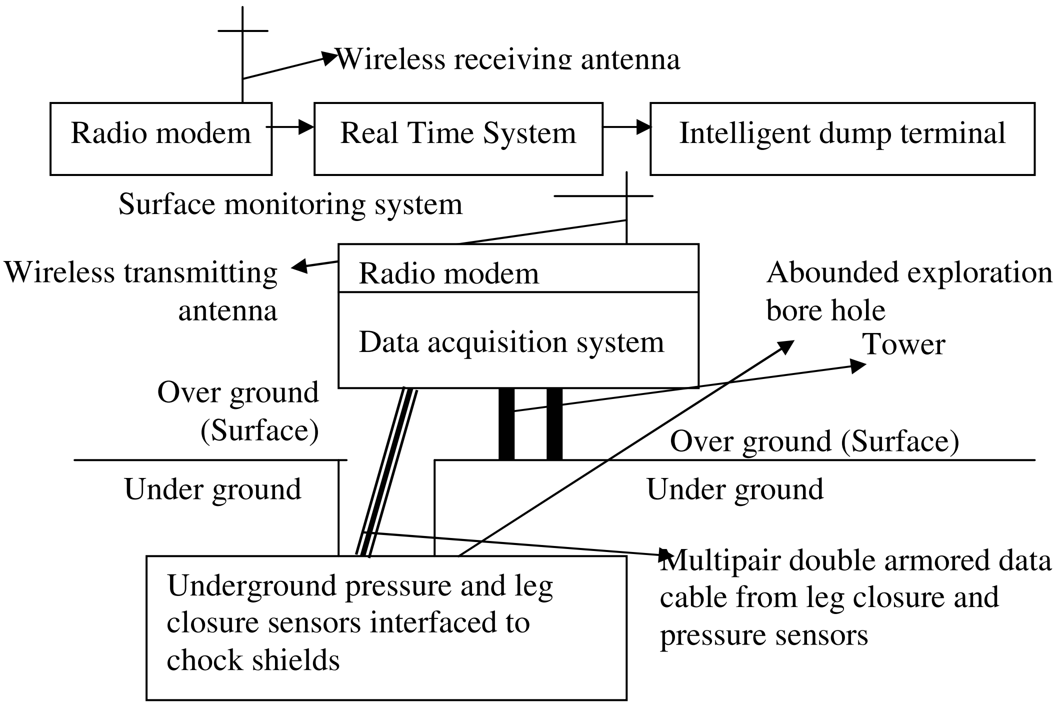

Fig.1 - Block schematic (Line) diagram of surface monitoring station and underground sensors with wireless data acquisition system

3.1.1 Wireless system

The distance between the underground sensors to surface monitoring system is around 10 km. Eight numbers of powered supports were selected for continuous monitoring based on preliminary field investigations. Four supports were from centre of the panel and two each from main and tail gate. The total number of sensors interfaced to chock shields was 16. The data cable required for transmitting 16 sensors data was of 100 km length or more for implementing conventional method. Further, the transmission of 16 sensors data from an active longwall panel with conventional data cable was very difficult and required heavy maintenance due to active longwall operations. The wireless data transmissions, on the other hand, were successfully implemented. The abandoned borehole was located on surface over the longwall workings. All the sensors data cable was taken out from the borehole and interfaced to the data acquisition system. The radio modem received data from data acquisition system as shown in Figure 2. The radio modem was interfaced to the wireless antenna. The wireless antenna was commissioned on top of the tower to maintain the line of sight with the receiver. Consequently the wireless operations were successfully implemented for transmitting the underground sensor data in real time.

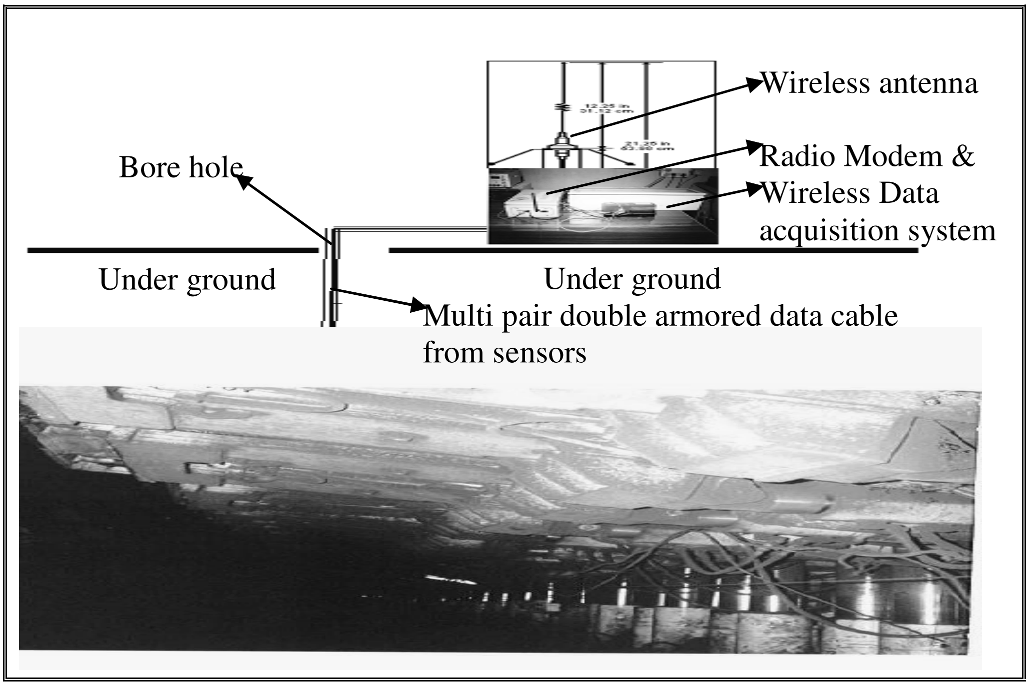

Figure 2 Wireless data acquisition system interfaced to sensors

The wireless operations can be implemented in underground. But, the transmission range will reduce due to many problems like signal attenuation, absorption, obstacles and so on. Moreover, the main important task is to maintain line of sight in underground. Therefore, it requires more wireless modules and complex operations, which ultimately increase the cost of monitoring. Thus, the simple and economical solution is to locate the old or abandoned borehole for implementing wireless data transmissions as discussed above.

3.2 Leg Closure and Pressure Sensors

Leg closure and pressure sensors were interfaced to the chock shields as shown in Figure 3. Pressure sensor of strain gage type has a maximum range of 1000 bars. The accuracy was 1% FSD (Full scale division). The pressure sensors were interfaced to the chock shields test port as shown in Figure 3. The leg closure sensor of potentiometric type has a maximum range of 1000 mm. The accuracy of the leg closure sensor was 0.01 mm. The leg closure sensors were interfaced between canopy and top cylinder of the chock shield as shown in Figure 3. All the underground sensors were interfaced to the wireless data acquisition system through the borehole as shown in Figures 1 and 2. The sensors were intrinsically safe and compatible to underground mining environment. The data accuracy also depends on the status of sensors calibration. Therefore, the sensors calibration was automatically detected and corrected by the surface real time system due to inbuilt calibration facilities. Therefore, the data accuracy and reliability was maintained.

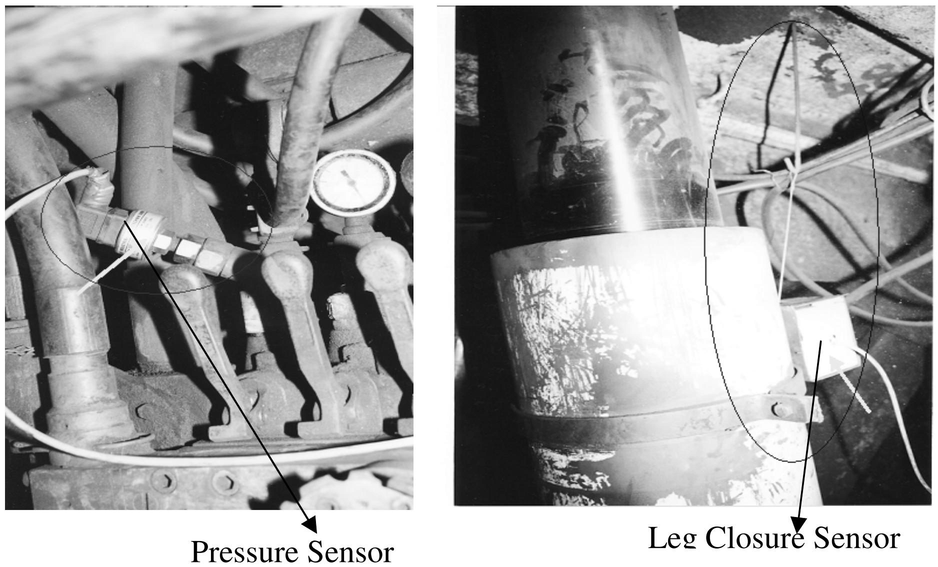

Fig. 3 - Pressure and leg closure sensors interfaced to the chock shield

3.3 Real Time Display

The intelligent dump terminal was interfaced to RT system. The RT system interfaced to radio modem and wireless receiving antenna as shown in Fig. 4. The display of intelligent dump terminal can be called as real time display or display or monitor. The real time system has 40 channels. The number of channels can be extended depending on requirement. The acquisition time is selected one minute and user selectable. All the operations are menu driven and user friendly. The acquired data was analyzed in real time and displayed on real time display as shown in Fig. 4. The chock shield behavior was displayed in graphical form on real time display. The rate of change in chock shield pressure was displayed in numerals. Warning status is displayed in Fig. 4. In addition, comprehensive information of various sensors like type of sensor, units, location, exicitaion, and calibration status are also displayed. The complete data is stored in standard format to retrieve quickly and easily.

The real time system was successfully recorded periodic falls, hydraulic leakages, periodic weights, goaf falls, face falls and gate roads convergence. The display was updated with latest information for every minute. Therefore continuous information of the chock shield performance was available for quick decisions to implementing precautionary measures for achieving effective and efficient longwall operations.

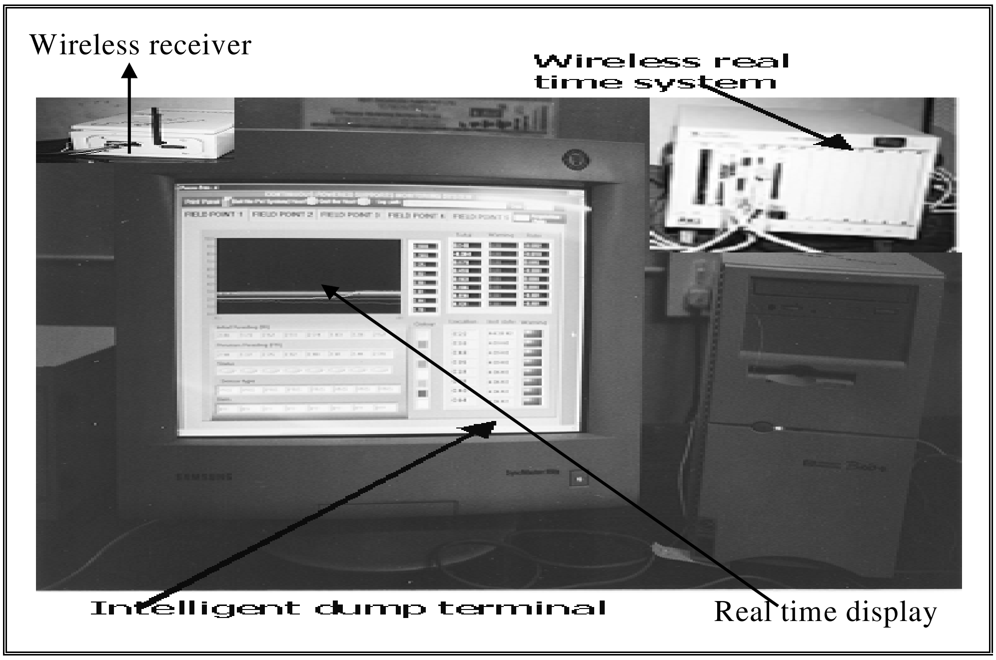

Fig. 4 - Real time display of chock shield behavior

3.4 Field Data Analysis and Interpretation

The panel was equipped with 80 chock shield of 4X800 t IFS (immediate forward support). The RT system has successfully generated a huge data base of panel Nos. 4 and 11 in the years 2002 and 2003 respectively. The analysis and interpretations of selected cases are as follows.

The initial setting pressure of chock shield C22 was 240 bars at 19.09 hrs on 13th May 2002 as shown in Fig. 5. The increase in the pressure before the advancement at 21.00 hrs was due to cut and release of adjoining shield for advancing. The shield was advanced at 21.19 hrs. The shield pressure increased immediately after advancement at 22.00 hrs due to overhang in the goaf. The pressure was reduced to 100 bars at 22.54 hrs due to minor leakage in the hydraulic system. Shield C22 was near the main gate. The RT system has successfully recorded chock shield C22 behavior as discussed above.

The chock shield C18 behavior with respect to leg closure is shown in Fig. 6. The initial closure was 550 mm at 10.20 hrs on 19th May 2002. The down ward spikes at 13.30 and 15.51 hrs were due to the slight release of support canopy. The support advanced at 14.51hrs. Influence of the adjacent shield advancing is measured at

16.21hrs. The chock shield was near the main gate. The RT system has also successfully recorded chock shield C18 behavior as discussed above (Fig. 6).

Support setting pressure of C30 chock was 300 bars at 8.29 hrs on 27th March 2003 as shown in Fig. 7. The support was advanced at 15.00, 16.13, and 19.31 hrs. The support pressure has increased to 400 bars at 21.00 hrs due to onset of periodic weighting. The support pressure, subsequently reduced to 250 bars at 21.44 hrs due to face (hydraulic) leakage. It may be noted that the support was in the centre of the panel. The RT system has again shown its usefulness by successfully forecasting periodic weight and hydraulic leakages.

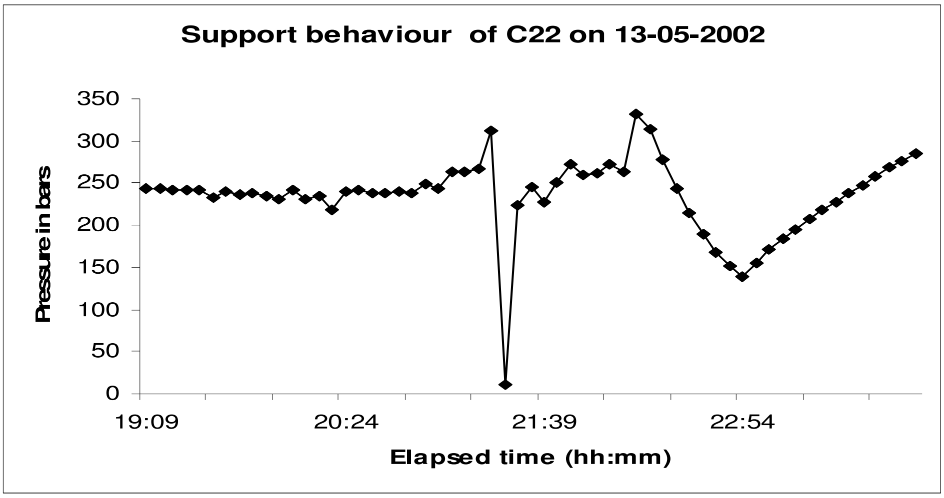

Fig. 5 - Chock Shield C22 behavior on 13th May 2002

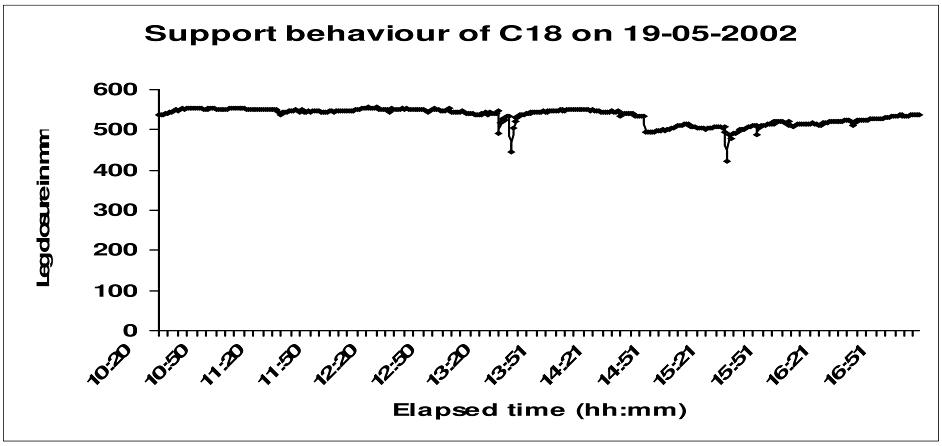

Fig.6 - Chock shields C18 behavior on 19th May 2002

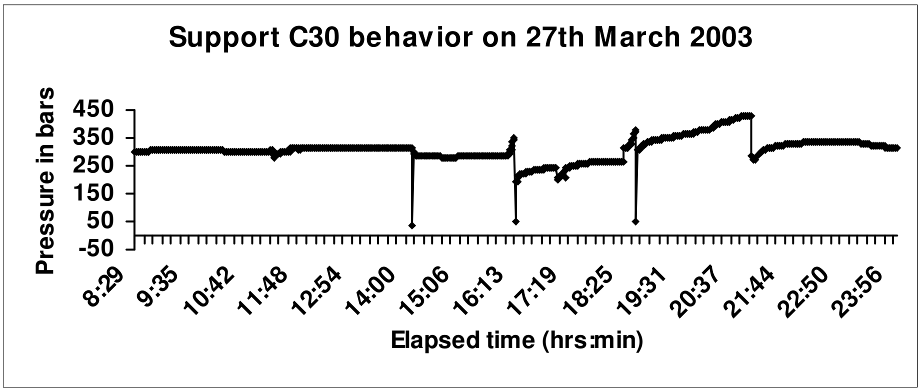

Fig. 7 - Chock Shield C30 behavior on 27th March 2003

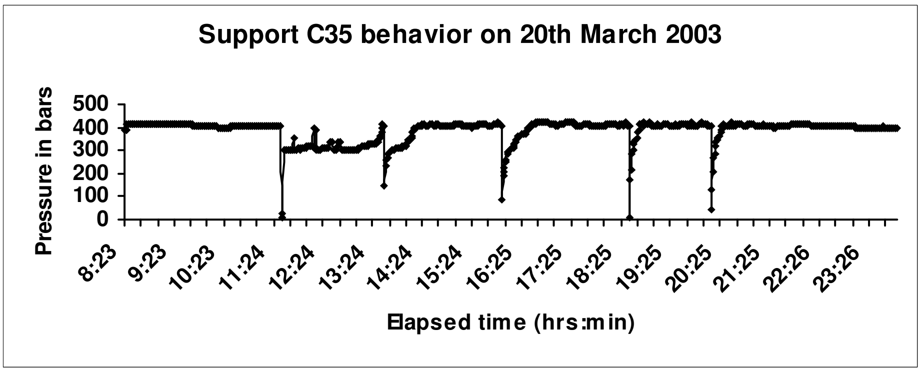

Fig. 8 - Chock Shield C35 behavior on 20th March 2003

Support setting pressure of C35 chock was 380 bars at 8.23 hrs on 20th March 2003 (Fig. 8). The support was advanced at 12.24, 16.25, 19.25 and 20.25 hrs. The support pressure was reduced to 150 bars at 14.24 hrs due to face (hydraulic) leakage. Support pressure was yielding from 15.24 to 21.25 hrs due to periodic weight. The support was in the centre of the panel.

3.5 RT System Maintenance

The RT system is a virtually maintenance free system. However, the major maintenance of the system was only sensors. The life of the sensors is almost two years. Further, the sensors can be reused by reconditioning. The surface monitoring system was commissioned in an air-conditioned room. The uninterrupted power supply is essential for continuous data acquisition and for maintaining data continuity. The problems of various modules are displayed on real time monitor as and when they are not functioning. The modules subsequently are replaced. In this system the software is dominating and less hardware is used. Therefore, the maintenance of the system is minimized.

4. CONCLUSIONS

The real time (RT) system including wireless data acquisition system were successfully developed and applied to chock shield data transmission for the first time in Indian mines. The wireless data acquisition system is part of the real time (RT) system. Extensive field investigations have proved that the system is compatible to Indian mining conditions. The main role of the wireless data acquisition system is to transmit the reliable data from underground multiple sensors. The role and its impact were discussed in details with the field data. It has many advantages over the conventional data transmissions.

The economic way of implementation of wireless operations is to identify an abandoned borehole on surface over the longwall workings. Most of the Indian mines have many abandoned or exploration boreholes. These boreholes could be effectively utilized for implementing this cost-effective method for data transmissions to evaluate chock shield performance.

The RT system has many applications. The RT system can be used for monitoring of any type of geomechanical parameters. It can be used for monitoring underground gases. The system can be interfaced to monitor shearer performance. Further, it can be used for networking of all the mines. Therefore, the information of all the mines data will be available at every mine for better interactions and conclusions on safety and productivity.

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