R & D PROJECTS COMPLETED DURING 2004-08

Project title*: *Studies on problems of spontaneous heating in coal pillars and development of techniques for its prevention, early detection and control

Project value: Rs.36.10 lakhs (Jointly executed with CMRI)

Sponsoring Agency: Ministry of Coal, Govt. of India

Project Coordinator: Prof. D. C. Panigrahi.

Objectives*:* The main objective of the study is to classify the pillars with regard to status of auto-oxidation and weathering. In order to accomplish this objective, the following scope of investigations has been included in this research work:

- Studying the factors influencing the occurrence of pillar fires.
- Finding out the susceptibility of pillars to spontaneous heating.
- Categorizing the pillars with respect to their proneness to spontaneous heating.
- Determining the relative importance of different contributing factors to the spontaneous heating susceptibility of coal pillars based on the factors influencing the occurrences of these fires.
- Predicting the susceptibility of coal pillars based on the factors influencing the occurrences of these fires.

Status: Completed.

Summary of findings: On the basis of research work carried out in this investigation, the following conclusions may be drawn:

- Modified sampling set-up developed in this study may be used for collecting gas samples from boreholes put into the pillars. The main advantage of this system is that it will not allow any mine air entering into the borehole while collecting the samples.
- The presence of CH_4 is not taken into account for calculating the values of existing gas indices for assessing the status of fires. In this investigation while applying these gas ratios to assess the status of pillar fires, it has been observed that in highly gassy seams the commonly used gas indices sometimes may yield negative values which are not meaningful for interpretation. The modified gas ratios suggested after incorporating the percentage of CH_4 may be used for assessing the status of heating in pillars.
- In order to categorise the pillars with respect to their proneness to spontaneous heating, overall pillar susceptibility index (OPSI) has been developed and accordingly the pillars have been classified into three categories, viz. less susceptible, susceptible and highly susceptible. The concept of this classification depending upon OPSI values may be useful for categorizing the pillars in all similar situations. The concept of development of OPSI is more important than its absolute values. The range of OPSI values may be different for different coalfields.
- The main contributing factors for OPSI have been identified as susceptibility index of coal in the laboratory, ventilation pressure difference across the pillars, presence of cleats and pore density. In this study, an attempt has been made for the first time to calculate the cleat influence index (CII) to represent the effect of presence of cleats. The above main contributing factors along with the OPSI values have been used for developing a back propagation (BPN) artificial neural network (ANN) model and by using this concept the OPSI values can be predicted accurately with the given set of contributing factors.

- An attempt has been made to find out the relative importance of all contributing factors influencing OPSI. It may be observed from the relative importance values that all contributing factors influence OPSI and their relative importance varies between 19.19 to 35.38%. This reveals that there is no single contributing factor predominantly influencing the values of OPSI.
- The main contributing factors influencing the susceptibility of coal to spontaneous heating are moisture content, volatile matter content, ash content and maceral susceptibility index (MSI). Similarly the BPN of ANN has been used to predict the susceptibility of coal in the laboratory by using these four parameters. The relative importance of the four influencing parameters has been determined by using the same algorithm of partitioning weights between different layers of ANN. The relative importance of these parameters on susceptibility indices of coal varies between 19.46 to 30.23%.
- The findings of this study may be applied in the mines having pillar fire problem and the planners and practicing engineers may follow the following steps for categorizing their pillars:
- A number of pillars may be identified in the mine having geological disturbance, old pillars standing for a long time, pillars located between main intake and main return of the mine subjected to high ventilation pressure difference, and pillars subjected to adverse roof loading (pillars near to the goaf etc.)
- The following parameters may be determined for each pillar:
    - Susceptibility of the coal in the pillar by CPT/DTA. If the facilities for determination of these are not available, the moisture, ash and volatile matter content of coal in the pillar obtained from proximate analysis and the values of maceral susceptibility index may be used for predicting the susceptibility indices (CPT/DTA) by artificial neural network (ANN).
    - Ventilation pressure difference across the pillar, pore density and the cleat influence index (CII) for different pillars may be found out.
- The holes may be put on the selected pillars, gas samples may be collected and values of OPSI may be calculated for categorizing the pillars. When a large data base on OPSI values and the contributing parameters are developed in future, the pillars can be categorized by predicting the values of OPSI by using ANN on the basis of other contributing parameters as identified in this investigation.
- Precautions may be taken to prevent the occurrence of pillar fire in the pillars highly susceptible and susceptible to spontaneous heating.

Title: Development of a new rock characterization methodology for optimizing support requirement in tunnels/mines

Value: Rs. 8.00 lakhs

Agency: MHRD, R&D Scheme, GOI

Coordinator: Dr VMSR Murthy

Status: Completed

Findings: Strata control is a serious concern affecting the safety and productivity of underground coal mines and tunnel even today and also continues to threaten the geo-engineers owing to the complex and diverse geo-mining conditions being encountered as mining goes deeper and deeper. Among the many ground control related problems the roof falls are the major cause of fatalities and injuries in Indian mines. An inability to address these problems effectively can result in resource abandonment and in some cases mine closure which has a significant economic impact on entire community. Irrespective of the well-established support design guidelines based on CMRI-ISM Geo-mechanical Classification, the roof falls in Indian Coal mines still contribute to almost 60-70 per cent of fatalities Sinha et al., 2003. This is a matter of great concern for the coal industry.

- In view of above, there is an urgent need to reconsider the support design methodology practiced in coalmines. Thus the basic objective of this research work is to develop a modified RMR based on an inexpensive, automated seismic rock charactering technique for delineating the characterizing coal mine roof for facilitating roof support design. The proposed seismic rock characterization technique aids in estimating the extent of roof quality deterioration, may it be due to blasting-off-solid or may it be due to redistribution of stresses virgin and induced, and also helps estimates likely rock load.
- The use of seismic imaging is fast gaining ground to monitor the behaviour of a rock mass for detecting hazardous ground conditions and take preventive measures. The seismic refraction technique, used in this research, detects the intactness of the roof. In the refraction method, the vibration sensors and striking points are arranged in the roof for computing the P-wave velocity which is a rock quality parameter being considered in the *modified rock mass rating* RMR_{seis}.
- The research work marks it's beginning by reviewing the characteristic contributors to bad roof and associated roof failure theories in short as a background to design the roof support. Methods of detecting and monitoring roof behaviour and bolt performance provide essential feedback on roof support requirements. The roof bolt design that assimilates roof and support parameters into useful equations helps to decide what bolt types to use and how they should be installed under different roof conditions.
- Field investigations were conducted in different underground coal mines covering different geographic locale of India. The sites included, amongst others, KTK-6 Incline, Bhoopalapalli Area, PVK 5 Shaft, PVK 5B Incline and VK 7 Shaft, Kothagudem Area, JK 5 Incline, Yellandu Area, KTK-2A incline, SCCL and Dobari mine, BCCL. Analyses of these field investigations show clearly that the P-wave velocity is less within the green roof as compared to the velocity determined beyond the green roof. It is also observed that the extent of damage into the roof has increased within the green roof as compared to the extent of damage beyond the green roof. This indicates that the blasting off solid has immense contribution in causing damage. The length of the roof bolts can now be determined realistically from the extent of damage measured using P-wave velocity of different constituent roof layers. Support design for the two mines has been done using the exiting RMR_{seis} and compared. The limitations of the existing RMR and the advantages of modified RMR have been brought out.

- A modified rock mass rating named as RMR_{seis} has been proposed based on the field investigations done to monitor various influencing parameters, namely, Layer thickness, P-wave velocity, Structural features and Slake durability index. Ground water and stress have been considered as adjustment factors as these keep changing from place to place, location to location even face to face. The existing support capacity, it's stability status and rock load monitoring have been used to arrive at the rock loads at different places. The RMR CMRI-ISM Geo-mechanical Classification was also determined for 16 seams and compared with the RMR_{seis}. The proposed RMRseis and rock loads estimated/monitored in some cases have been utilized to arrive at the rock load predictor equation as given below:
- Rock load $t/m^2 = 0.0013\ RMR^2_{seis} - 0.19\ RMR_{seis} + 9.25$ $R^2 = 0.72$
- Varied data from different geo-mining setup could lead to further refinement of the above rock load equation. The approach suggested simplifies the earlier method of rock load estimation and also considers the damage inflicted on the roof due to blasting-off-solid and stress induced fracturing arising out of delayed support and localized redistribution of stresses. The cases selected in this study essentially represent poor RMR in general and thus help rationalize the support capacity which is necessary to avert the roof fall related fatalities in future. The study can further be widened by including more cases for developing a generalized rock load predictor for support design.

***Project title*: Development of Model for Assessment of Blast Induced Damage/Hazards and Formulation of Design Guidelines for Controlled Dragline Blasts in Indian coal Measure Rocks**

Project value: Rs.7.00 Lakhs

Sponsoring Agency: Ministry of Human Resource Development, Govt. of India

Project Coordinator: Prof. P. Sen, ME.

Objectives: To develop model for assessment of blast induced damage/hazards and to formulate the design guidelines for controlled dragline blasts for Indian surface coal mines..

Status: Completed.

Summary of the findings: Site characteristics relationships Mean Fragment Size (cm) – Burden Velocity (m/s). Mean Fragment Size (cm) – energy Factor (kcal/m^3) and Mean Fragment Size (cm) – Stemming Ejection Velocity (m/s) have been established through plotting of observed field data. Mean fragment size reduces exponentially with increase in burden velocity. Mean fragment size reduces with increase in energy factor. Mean fragment size increases with increase in stemming ejection velocity.

Project Title: Investigation and modeling studies for classification of coal seams with respect to their proneness to spontaneous combustion for improvement of safety in mines

Value: Rs. 10.00 lakhs

Agency: MHRD

Coordinator: Professor D. C. Panigrahi

Objectives: (i) To study the spontaneous heating characteristics of coal by carrying out different experiments. (ii) To study the gaseous products of combustion released by coal while heating coal samples in a controlled condition with gradual increase in temperature. (iii) Development of a mathematical model to categorize the coal seams with respect to their proneness to spontaneous heating.

Status: Completed

Findings:

In the first part of the investigation, the intrinsic properties of coal samples collected from different coalfields have been determined by carrying out proximate, ultimate and petrographic analyses. The spontaneous heating susceptibility of all the coal samples has been studied by different methods, viz. crossing point temperature, differential thermal analysis, critical air blast analysis, wet oxidation potential analysis and differential scanning calorimetric studies. Subsequently, the kinetic studies of the coal samples have been carried out and a spontaneous heating liability index (SHLI) has been developed by using Frank-Kamenetskii model for conductive heat flow. The SHLI developed in this study has got a sound theoretical base and correlates well with the susceptibility of the coal seams in actual field conditions.

An extensive statistical analysis has been carried out to correlate between the intrinsic properties of coal and different susceptibility indices. It has been observed that the moisture, volatile matter and ash correlate well with all the susceptibility indices except wet oxidation potential difference. Other intrinsic properties obtained from ultimate and petrographic analyses do not exhibit good correlation with any of the spontaneous heating liability index. Therefore, for classification of the coal seams, the moisture, volatile matter and ash contents obtained from proximate analysis are taken along with different susceptibility indices except wet oxidation potential difference.

Two approaches, viz. hierarchical clustering and adaptive resonance theory, have been used for the first time and the coal seams have been classified into four categories, viz. very highly susceptible, highly susceptible, moderately susceptible and poorly susceptible. The values of SHLI have been superimposed on different classes of coal seams and range of the values for each class has been specified. Any new coal seam can also be added to this classification exercise and it can be placed in any one of the categories by knowing the constituents of proximate analysis and any one of the aforementioned susceptibility indices.

It is hoped that the outcome of the present study will be used by the planners and practicing mining engineers to take ameliorative measures in advance for reducing the incidences of fires in mines.

Project Title: Development of SMART MEMS gas sensor for improvement of safety in mines

Value: Rs. 38.8 lakhs (Jointly with Jadavpur University; IT, Kharagpur and B.E. College, Sibpur)

Agency: All India Council for Technical Education

Coordinator: Prof. D. C. Panigrahi (ISM-Part)

Objective: To develop all solid state flameproof methane and carbon monoxide gas sensors for underground mines application using silicon MEMS/Metal oxide technology

Status: Completed

Findings:

- Smart MEMS gas sensors have been jointly designed and developed by Jadavpur University; IIT, Kharagpur and B.E. College, Sibpur.
- The suitability of these sensors for using in mines has been studied at Mine Ventilation and Environment Laboratory of Department of Mining Engineering, ISM University.
- These sensors have been found accurate in the laboratory conditions.
- The field trial of these sensors will be carried out in the next phase of the project work.

Project Title: Development of a computer based Mine Information System (MIS) to provide up-to-date database for an opencast mine

Project value: Rs.16.00 lakhs

Sponsoring agency: MHRD, Govt. of India

Coordinators: Dr. P. P. Bahuguna, Dr. B.C. Sarkar & Dr. Dheeraj Kumar

Objectives: Development of an information system using GIS for a mine incorporating base map of mine, contours, building and roads etc.

Status: Completed

Findings: Using GIS and advanced surveying instruments an MIS has been developed for Chasnala West Colliery which incorporates Base Map of the Mine with configuration of Mine, Contours, Building & roads, Area and Volumes.