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Application of Foam Stopping for Mitigation of Spontaneous Heating In Underground Coal Mines

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Abstract: ***The problem of spontaneous heating is a major threat to safety and productivity in mines all over the world. In India, more than 80% of fires are caused due to Spontaneous Combustion. The applicability of inert gases is expensive, time-consuming and is a very tedious process. Hence the application of advanced technologies becomes essential to be introduced in mines. In this context, Central Mine Planning and Design Institute (CMPDI), Ranchi, India carried out an R&D project entitled "Construction of quick setting stopping in case of fire in an underground mine using expansion foam agent" under the funding from the Ministry of Coal, Government of India.***

Under this project, two Indian mines were selected in consultation with MCL for carrying out the proposed work in Orient Mine No.3 and Bundia Mine of MCL (Ib Valley AREA). Coals from both the mines have been collected and analysed in the laboratory. The proximate analysis and CPT/IPT results show that both the coals are moderately prone to spontaneous heating. Considering both intrinsic and extrinsic properties, two stoppings were constructed in the Hirakhand Bundia mines and four in orient mines. Periodic supervision along with the altering ingress of air from intake was been checked. After careful supervision of nearly 4 years, the stoppings proved to be strong enough to be leakage proof. This paper describes the application of foam technology as stopping to avoid air entry, thus preventing the occurrences of spontaneous heating/fire in a panel of Indian coal mines.

Keywords: ***CPT Analysis, Foam Technology, Proximate Analysis***

I. INTRODUCTION

Mine Fire is a major problem worldwide and has been an area of concern for mine owners, industries, nations and researchers. It is seen that a large number of fires in the world are due to the spontaneous combustion of coal. In India, mine fire due to spontaneous heating has become frequent and is increasing day by day. This is because when coal gets exposed to air, it absorbs oxygen and liberates heat. This slow auto-oxidation of coal increases with the passage of time and ultimately leads to spontaneous combustion in the coal stacks. Spontaneous combustion results in serious accidents causing loss of reserve, life, economic losses and also affecting the environment. Research works and studies reveal that most of the mine fires resulting from spontaneous heating can be avoided if necessary precaution arrangements are made in time.

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They have given prime importance on the susceptibility of coal. Therefore there is a need for protective measures for coal to prevent it from spontaneous combustion. Protective measures for coal can only be applied if we are able to assess the susceptibility of coal towards spontaneous heating. Different types of coal have different susceptibility index and risk rating. This can provide us an idea of how they are to be stored and what protective measures are to be taken. The storage of coal in the stockpile is to be carried out in such a way that there is a minimum chance of spontaneous heating.

With the advancement of technology, the barrier formed by foam can be a suggested method for combating fire. To date, Inert gases were being used for quenching fire but the application during an emergency seems to be impracticable. This is due to certain reasons

1. Unavailability of a large number of inert gases near the mine site.
2. More Time consumption for transportation and subsequent implementation.
3. Loss of gases due to leakage.
4. The high cost will affect the economics of the mine.

Foam technology is one of the methods that can be used for fighting fire in mines. It can act as a barrier/shield to fire propagation. The foam was been used for fight fire on the surface and very rarely been used for underground. Here is an application of advanced technology (Foam Technology) that chemicals in practice in recent years which shows some practical results.

II. GEOLOGICAL DETAILS

The Mahanadi Coal field Limited (MCL) is one of the major subsidiaries of Coal India Limited. Initially, it was a part of the South Eastern Coal filed limited. There are seven opencast and three underground mines under MCL and all are located inside Odisha. It comprises of two different stratigraphic horizons. The upper horizon consists of Barakar formation whereas lower consists of Karhabari formation. The Barakar comprises more than 95% of the coal deposits and has four horizons with partings between them. The topmost consists of Belpahar Coal horizon with a thickness of 24 to 30 m. It is a highly inter-banded coal section and is considered uneconomic in northern part deposits. Underlying, there is a parting of nearly 105 to 195 m. It is followed by shale and carbonaceous material of nearly 0.1 to 0.5 m. It is called as Parkhani Coal Horizon. There is a parting of 92 to 120 meters. Below lies the Lajkura Seam of 15 to 89m thickness.

It is highly banded and is divided into four horizons. It is followed by a parting of 16 to 112m. The Rampur Coal Horizon which lies just below comprises a thickness of 27 to 80 m. It is highly interbedded and contains 5 to 6 sections. It is followed by a parting of 3 to 55m. The Last and the Lowest is Ib Seam which comes under Karhabari Horizon. The thickness ranges from 2 to 20 m. In some parts it is im-persistent, basically from the northern region and gets splits up into three sections.

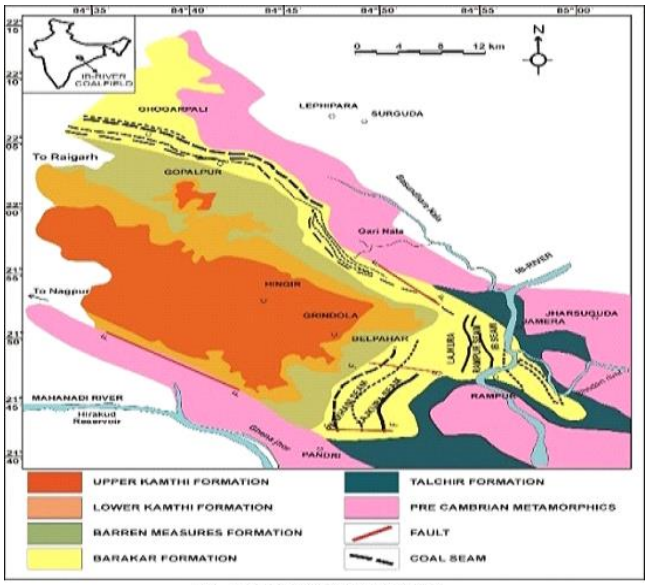


Fig.1. Stratigraphy formation of coal in MCL

III. LABORATORY INVESTIGATION

Coal sample from the mines has been collected and analysed in the laboratory with respect to CPT/IPT determination, proximate analysis.

The table below provides the details of the proximate analysis of four samples. The coal samples are found to be moderate and poorly susceptible.

The graphs of CPT analyses four samples are shown in Annexure I. It ranges from 140℃ to 160˚C. Ash percentage is high in case of MCL1 and Volatile matter is high for MCL2. MCL1 has the highest fixed carbon content.

IV. PROCEDURE

The methodology involves the construction of one casing width as wide as having a thickness of one foot and height half the gallery height. The developed chemicals which would swell and convert into hard foam were poured into the casing. The casing is been extended to roof height and the chemicals are kept pouring until the wall is sealed up to the roof. It works on the principle of exothermic reaction and heat is evolved. After completion of stoping, leakage analysis was studied through air current passing within the district. Thereby, a foam stoping can be constructed within a few hours.

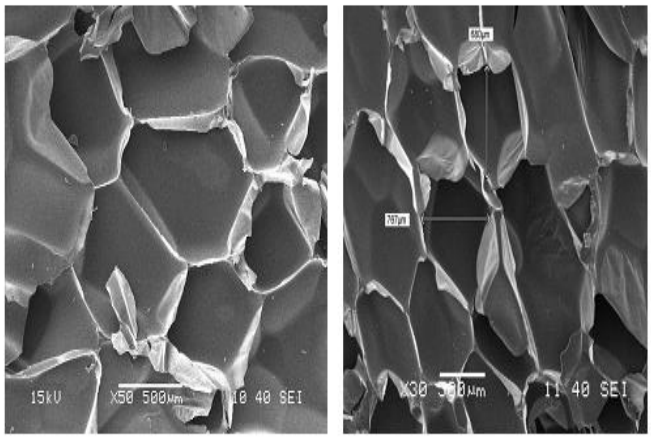
- ✓ Work involved in the construction of one foam stopping
- ✓ Recess cutting all side & key cutting in the roof.
- ✓ Transportation of chemical, cylinder, mat.
- ✓ Transportation of material for temporary stopping.
- ✓ The building of temporary stopping.
- ✓ Mixing of the chemical at the site.
- ✓ Pouring of Chemical.
- ✓ Sealing of roof by a chemical from the pressured cylinder.
- ✓ Final coat on the stopping.
- ✓ Fixing of the flameproof mat.
- ✓ Spraying of Hardening chemicals on the mat.

Table. No.1 Properties of foam

S. No.	Properties	Nature
1	Colour	White
2	Odour	Odourless
3	Specific Gravity	1.4
4	Tensile Strength	28kg/cm^2
5	Elongation at Break	33kg/cm^2
6	Expansion Ratio	40 times
7	Ignition Temperature	550°C
8	Toxicity Index (NCD1409)	1.07
9	Curing Time	Within 1 hour after application
10	Skin Irritation	NIL

V. SEM STUDY

For the expansion capacity, the SEM study of foam was studied. It was seen that the diameter of airspace ranged from 650µm – 800 µm. The SEM study also revealed that the bubble formed is of uniform diameter and the variance among them is very negligible.



VI. RESULTS & DISCUSSIONS

Application of foam technology in dealing with fire from underground coal mines seems to be better than the application of inert gases or any other measures in controlling fire. It is due to the fact that it deals with the condition before mishap by cooling and inertzing the atmosphere for a longer duration. Foam generating machines can be used for small operations and a lot of adverse mishaps can be saved.

Table No. 2 Details of Stoppings (Hirakhand Bundia Mine)

Details of Panel	Hirakhand Bundia Mine	
Panel	2	3
Seam Thickness (m)	10.5	10.5
Gradient	1 in 10	1 in 10
Grade	E	E
Depth , min/max (m)	185/ 197	195/ 214
Date of Construction	09/08/13	24/08/13
Status	Unsuccessful	Unsuccessful

The stopping constructed at Hirakhand Bundia mine was on an experimental basis. It was carried for a preliminary study and the erected stopping lasted for only 6 months. The stoppings constructed at Orient Mines number 2 were successful. Five such stoppings were constructed and it withstood for more than 3 years. The details of the stoppings are laid in table no. 3 and 4.

Table No. 3 Details of Stoppings (Orient Mine No. 3)

Details of Panel	Orient Mine No. 3	
Panel	5D/64LN	Panel – 1B
Seam Thickness 'm'	11	11
Gradient	1 in 6	1 in 6
Grade	D	D
Depth , min/max 'm'	171// 186	188/ 225
Date of Construction	26/08/13	26/08/14
Status	Successful	Successful

The stoppings were constructed on time gap to study their longevity and durability to drilling and blasting.

Table No. 4 Details of Stoppings (Orient Mine No. 3)

Details of Panel	Orient Mine No. 3		
Panel	Panel -2A	Panel -2 B	Panel -2C
Seam Thickness 'm'	11	11	11
Gradient	1 in 6	1 in 6	1 in 6
Grade	D	D	D
Depth , min/max 'm'	135/157	125/165	146/173
Date of Construction	28/8/14	11/3/15	13/3/15
Status	Successful	Successful	Successful

The results suggest that foam stopping can be constructed in less duration of time and can be used in combating the chances of fire.

VII. CONCLUSION

On the basis of the research work carried out in Orient mines of MCL, foam stopping can be practically implemented in mines. The foam stopping has lasted for over 3 to 4 years. It could be erected in a single shift if preliminary works of notch cutting are carried out earlier. Hence foam stopping can be used in case of an emergency rather than the application of inert gas.

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AUTHORS PROFILE

Mr. Alok Ranjan Mahananda, has completed his B.Tech and M.Tech in Mining Engineering from Government Engineering College (Keonjhar) and from N.I.T, Rourkela in 2011 and 2014. At present, he is pursuing Ph.D. in N.I.T, Rourkela. It is an enhancement of the work done in M.Tech and is in the final stage of completion (Objectives achieved). His area of work is on Coal, Mine Fire, Mine Safety and Mine Environment. Being a mining expert, he has taken classes of B.Tech, Dual Degree (B.Tech & M.Tech) and Ph.D. students on Mine Fire and spontaneous heating, Mining Methods and Metal Mining in N.I.T, Rourkela. He used to take a laboratory class on Special topics of Mining Engineering which involves all computational work. He has successfully published papers in National Journals and in International Conferences (06).

Dr. B. K. Pal, (58) did his B.Tech, M.Tech. and Ph. D. in Mining Engineering from IIEST (Sibpore) and IIT, Kharagpur. He was awarded the Chartered Engineer (India) in 1989 and presently the Fellow Member of Institution of Engineers (India) and also International Institution of Engineers. At present working as a Senior Professor in Mining Engineering at NIT, Rourkela.. He worked as Head; Dept. of Mining Engineering from 2003-2007 and as Dean from 2007-2010. Dr. Pal has published more than eighty research papers in referred to National/International Journals and Conferences. He has successfully supervised Ten Research Students and three more are on-roll for completion. He has completed more than Ten Scientific Research and Industrial Consultancy (SRIC) Projects and three more are on-going. He has attended Eighteen International Programs. In September 2004, he represented India in an Inter-Governmental Program organized by Colombo Plan Staff College, Manila which was held at Seoul, and Republic of Korea where he has been nominated as the National Coordinator for Accreditation (NCA) of India. He is an active Honorary Member of Asia Pacific Accreditation and Certification Commission (APACC). In August 2005, he received the invitation to represent India in the Inter-Governmental Program organized by CPSC, held in Philippines also. He is the active Member at many International Symposiums viz. “Mine Planning and Equipment Selection” (MPES); “Safety in Mines Research (SMR)”; “Case Histories in Geotechnical Engineering”; “International Council on Environmental Research (ICER)”; “Tsunami Reconstruction with Geo-synthesis – Protection, Mitigation and Rehabilitation of Coastal and Waterway Erosion Control” (Gpmrce) held in different countries and also the SME Paper Meeting (USA). He is the Editorial Board Member of many important Journals like Journal of Institution of Engineers (India); International Institution of Engineers; International Journal of Mining Science & Technology; International Journal of Environmental Sciences and Mining Engineering etc. His area of specialization is Environmental Management, Safety Risk Assessment and Management. Dr. Pal has extensively traveled to many countries, viz. Australia, Canada, Germany, Indonesia, Japan, Kingdom of Thailand, Malaysia, Philippines, Rep. of Korea, Singapore, UK and USA many times either for Project related works or attending Conferences where mostly he Chaired the Technical Session along with delivering the speech as an Invited Speaker.

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