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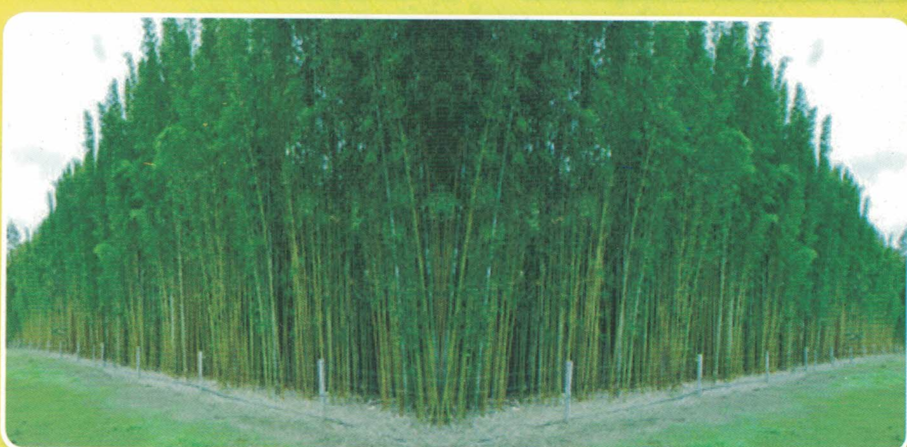

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Contents

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Fugitive Dust Control in a Coal Mine by Deploying Windbreak and Vertical Greenery System

P.C. Jha[1], Abhijit Sinha[2], Amarjeet Singh[3], Pramod Kumar[4], Pushkar[5] A. K. Chakraborty[6]

ABSTRACT

Coal mining activities result in generation of fugitive dust which adversely affect the environment. Dust control is a major challenge for the coal mining industry. Most of the dust generating sources in a coal mine are open to the air and conventional system of water spraying only may not be very effective. In this paper a novel concept of deployment of wind break (WB) and vertical greenery systems (VGS) have been suggested for controlling the fugitive dust generation from various mining activities.

While submitting the application for Environmental clearance (EC) of Gevra OCP Expansion from 41 MTPA to 49 MTPA and Dipka OCP expansion from 31 MTPA to 35 MTPA in November 2017, the concept of WB and VGS was proposed for controlling fugitive dust emission from the mines. EC was obtained from MoEF & CC for these mines and steps are being taken to implement the concept of WB and VGS.

The approximate estimated cost for development of 1000 meter long and 6.5 m high Wind Barrier is Rs.1.11crore, whereas the corresponding cost for 1000 m long and 05 m high VGS is Rs. 24.5 lakhs.

Keywords *:Windbreak (WB), Vertical Greenery System (VGS) & Fugitive Dust.*

INTRODUCTION

Various activities associated with coal mining such as drilling, blasting, loading, unloading, haulage of materials result in generation of dust. Loose materials lying on the road surface become air borne due to action of wind or mechanical turbulence created by the moving vehicles. Coal and overburden dumps also contribute to fugitive dust due to wind erosion. In case of a Thermal Power Plant or a Cement Plant, the major dust generating sources are point sources and engineering control systems such as Cyclone, ESP or Bag House Filter etc. can be very well applied to achieve a control efficiency over 90 %. Most of the dust generating sources in case of coal mining are non-point

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sources such as haul roads (linear sources), coal dumps, overburden dumps, railway sidings and open pits (area sources). The conventional system of water spraying may not be very effective as they are open to the air and subjected to variation in atmospheric conditions. High wind velocity and hot dry atmospheric conditions cause an increase in fugitive dust generation at source level. At the same time, high wind velocity and higher ambient temperature makes the atmosphere unstable and results in higher dispersion of dust. During post-monsoon (October & November) and winter months (December to February), generally higher coal production occurs to meet the target and there is a corresponding increase in various activities associated with coal mining resulting in higher dust generation[1]. During post-monsoon and winter season, wind velocity and ambient temperature are lower than summer months resulting in lower dispersion of dust particulates and resulting in higher concentration of respirable (PM10) and finer dust (PM 2.5) in ambient air. Increase in domestic coal burning during the same period also aggravates the problem.

Combined Application of WB & VGS

Due to limitation of various conventional control measures in a coal mine, it is proposed to use Windbreak (WB) and Vertical Greenery System (VGS) simultaneously to reduce the generation of fugitive dust at source level and to arrest them after becoming air borne. WB reduces fugitive dust generation at source level by reducing the wind speed whereas the VGS acts a dust filter to remove the air borne dust from moving further in the down wind direction. Greenbelt/VGS is quite effective for ground based sources during stable atmospheric conditions prevalent during post – monsoon and winter months [2,3]. The concept of deploying WB and VGS systems has been presented in Figure -1.0.

On the basis of the most prevalent wind direction during summer season, the up wind and down-wind locations are to be decided. WB and VGS should be erected as close to the source as possible. A 6m high wind break is effective in reducing the wind speed significantly up to a distance of 120m downwind from the barrier. Due to reduction in wind speed, the wind pressure on VGS structure will also get reduced. As wind direction during winter and post monsoon season may be different than during summer season and up-wind direction may become down – wind

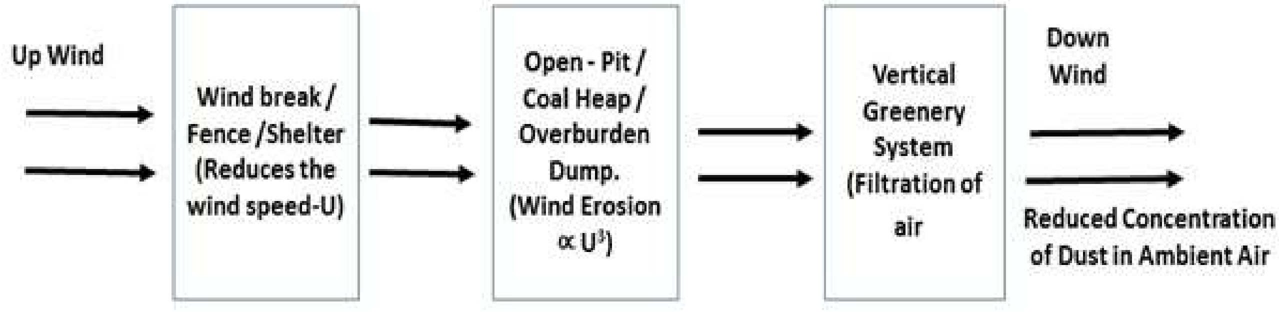

Figure-1: Concept of Windbreak and Vertical Greenery System

one resulting in higher wind pressure on VGS structure. In order to protect the VGS, it may be beneficial to have 3 to 4 rows of bamboo plantation in the down - wind side from VGS. The plantation should be as close to the VGS structure as possible due to availability of space.

WIND BREAK

A windbreak is also known as wind fence or wind shelter. It can reduce wind speed to a great extent [4]. The generation of dust due to wind erosion is proportional to wind speed cubed. Suppose a coal dump is contributing about 1000 kg of dust per month without the presence of windbreak around it. After providing a suitable wind fence, the wind velocity reduces to half of the original value, the same dump will generate about 125 kg per month of fugitive dust. It will result in reduction in wastage of coal as fugitive dust as well as improvement in ambient air quality.

DESIGN OF WIND BREAK SYSTEM (WBS)

The purpose of commissioning a wind break / barrier is to reduce the speed of the wind so that the generation of fugitive dust due to the action of wind on a surface having loose materials gets reduced, as the dust generation is proportional to the cube of wind speed (U^3). While designing a wind barrier, the following factors [5] are taken into consideration:

(i) Wind Direction:

The wind barrier are kept in the upwind and downwind direction with respect to the most predominant wind direction. The wind direction varies a lot with respect to the time. However, the most predominant wind directions reveal the direction from the source in which the pollutants / dust from the existing sources will travel for most of the time.

(ii) Height of Wind Fence / Barrier

The wind barrier of height H is effective in reducing the speed of wind up to a distance of 20H from the barrier. The speed is generally reduced by 1/4th from the original one up to the distance of 20 H. Beyond this distance, the effect of barrier is negligible.

(iii) Porosity of the Barrier:

The reduction in porosity will increase turbulence of the wind and increase in porosity increases the ground level wind speed. The recommended optimum porosity is about 40 % (where 60% of the wind is blocked). Porosity of more than 80% is not effective for useful wind reduction.

(iv) Orientation of the Wind Barrier

The Wind Barrier should be placed at perpendicular direction with respect to the incoming wind for being most effective. The effectiveness decreases as the angle between the barrier and wind direction reduces and finally it becomes least effective if the angle is < 40%. In order to take into account this factor, the portable low height wind barriers are used at some locations particularly for providing animal shelter.

(v) Length of the Barrier:

Despite the fact that the height of a windbreak decides the degree of the protected area downwind, at the same time the length of windbreak also determines the total area getting protection. For the most efficiency, the continuous Length (L) of a windbreak should be more than the height (H). The L/H ratio should not be less than 10:1.

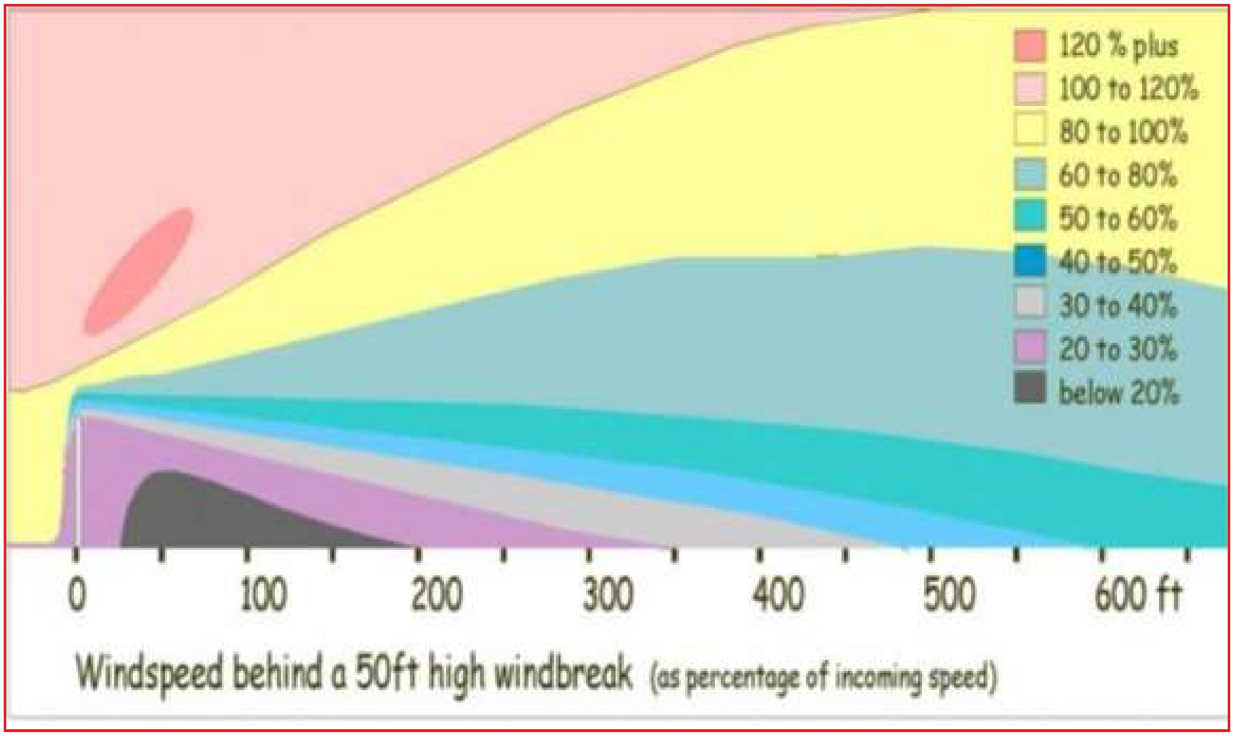

Figure 2: Wind speed behind a Windbreaker as percentage of incoming speed

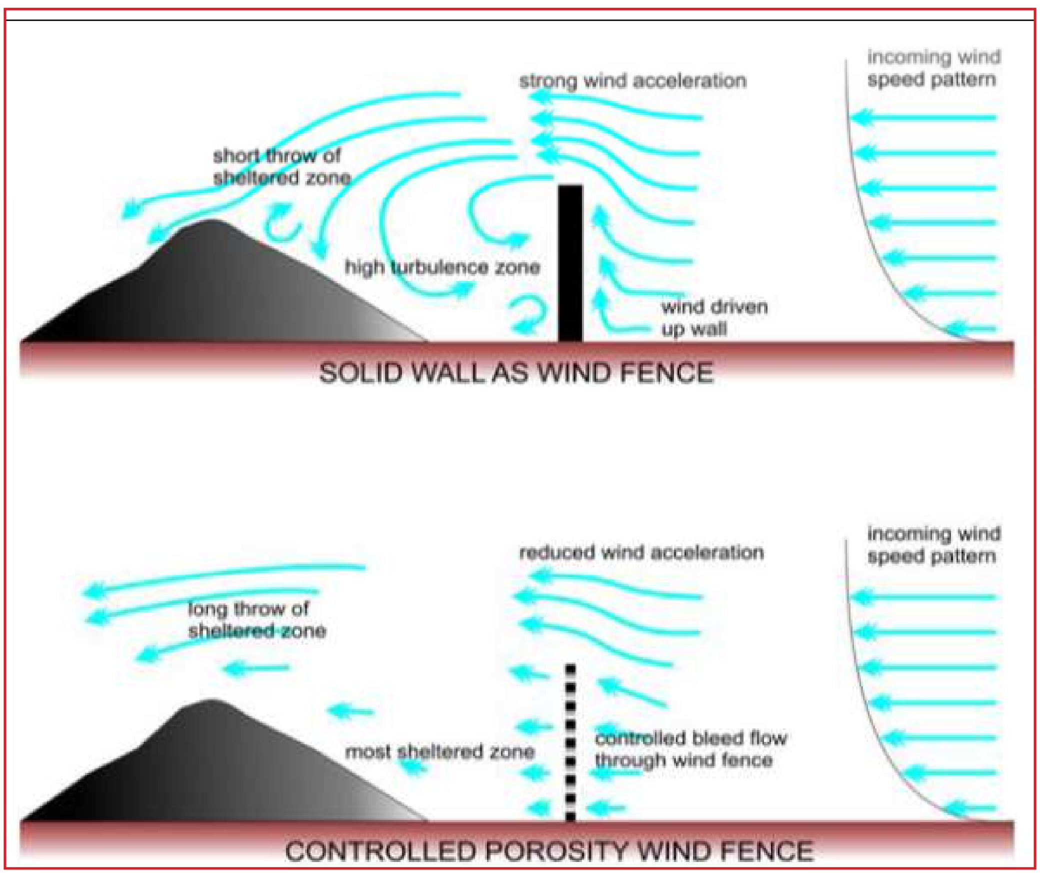

Figure 3: Difference between solid wall and wall with porosity

APPLICATION OF WIND BARRIER

The applications of Wind Barrier around a railway siding [6] and a coal dump have been shown in Fig 4.0 and 5.0 respectively.

APPROXIMATE COST OF WID BARRIER WALL

In Gevra OCP, the height of the wind barrier has been taken as 6 meters from top of pedestal which is 0.5 meters above FGL (Finished Ground Level). The following two different options have been considered for wind barrier system:

Option 1: Where covering is Galvanised Iron Profile Sheets.

The total updated cost per 1000 meters comes to Rs. 121.84 Lakhs excluding GST.

Option 2: Where covering is Wind Break Panels.

The total updated cost per 1000 meters comes to Rs. 111.19 Lakhs excluding GST.

VERTICAL GREENERY SYSTEM (VGS)

Vertical greenery system (VGS) means growing of plants directly on or with the help of plant guiding structure [7]. Vertical greening systems are divided into two main categories: green facades and living walls.

Figure 4: Wind break around a railway siding

Figure 5: Wind Barrier around a coal dump

Green facades typically use climbers, such as ivy, which are planted in containers at ground level and which grow vertically on a building's facade, either unsupported or on a system of wires or a trellis. Living walls, on the other hand, are modular panels comprised of polypropylene plastic containers or geotextile mats, and have vegetation planted throughout the surface of the wall [8].

Plants with APTI (Air Pollution Tolerance Index) > 17, can be used for the development of VGS. The air pollution tolerance index (APTI) is based on four major biochemical properties of leaves which are ascorbic acid, relative water content, total chlorophyll and leaf extract pH. APTI which gives an empirical value for tolerance level of plants to air pollution was determine using the formula. The formula for APTI is

APTI = {[A(T+P)]+R}/10

Where,

A= Ascorbic acid (mg/g), T= total chlorophyll (mg/g),

P= pH of the leaf extract and R= relative water content of the leaf extract

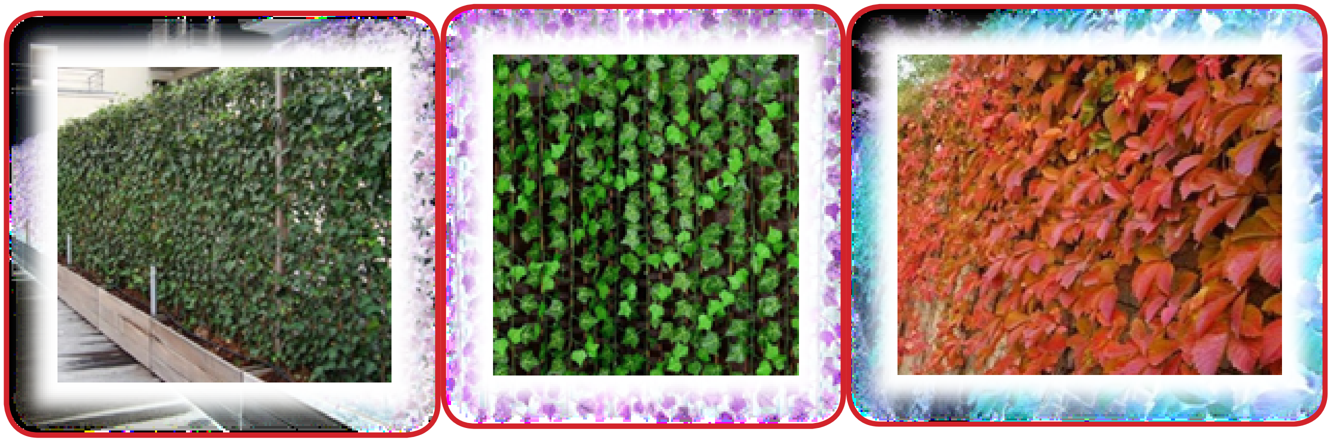

Figure 6: Vertical Greenery System

Table 1: Details of Favourable Species of Climbers Used For VGS

Sl. No.	Botanical Name	Common Name	APTI
1	*Ipomoea palmate or Ipomoea cairica*	Cario Morning glory, Railroad creeper	25.59
2	*Antigononleptopus*	Coral vine, Anantlata	23.98
3	*Thunbergia grandiflora*	Neel lata	23.46
4	*Clerodendrum splendens*	Flaming glorybower, Pagoda flower	23.13
5	*Aristolochia elegans*	Indian birthwort, Duck flower, Hookabel	22.22
6	*Quisqalis indica*	Madhumalti	20.15
7	*Vernoniaela egnifolia*	Curtain creeper, Vernonia creeper, Pardabel	19.75
8	*Petrea volubilis*	Purple wreath, Sandpaper vine, Nilmanilata	19.21
9	*Adenocalymma comosum*	Yellow trumpet vine	18.51
10	*Cryptolepis buchanani*	Wax leaved climber, Kala bel	17.89
11	*Jacquemontia violacea*	Skyblue Clustervine	17.32

Ipomoea cairica

Antigonon leptopus

Thunbergia grandiflora

Clerodendrum splendens

Aristolochia elegans

Quisqalis indica

Figure 7: Photographs of the identified creeper species

FAVOURABLE PLANT SPECIES FOR VGS

The details of the favourable species of plants identified for VGS has been presented in the Table 1.0. The species have been identified for Indian Tropical Conditions by scientists from BHU [7]. The photograph of these species is shown in Figure 7 and 8. Other factors to be considered while designing VGS are average height, water requirements, survival ratio, inter species compatibility and the stability of the structure erected for supporting vertical greening. The bamboo plantation behind the VGS is shown in Figure 9.

USE OF LOW COST MATERIALS FOR DESIGN OF VGS

Nylon net tied to bamboo poles can be effectively used as low cost option for development of VGS in the coal mining areas where the chances of theft of steel structure exists. A schematic diagram has been depicted in the Figure no. 9 and 10.

COST ESTIMATION FOR VERTICAL GREENARY SYSTEM

The total cost for erecting 1000 meters

Vernoniaelaegnifolia

Petreavolubilis

Adenocalymma comosum

Cryptolepis buchanani

Figure 8: Photographs of the identified creeper species

Figure 9: Bamboo Plantation behind the VGS

Figure 10: Photograph of Nylon Net used as support for developing VGS

long Vertical Greenery System (as detailed above) having a height of 05 m above finished ground level comes to Rs. 24.46 Lakhs excluding GST.

RECENT APPLICATION OF THE CONCEPT OF THE WB & VGS

Detailed design of Wind Barrier (WB) and Vertical Greenery System (VGS) for controlling fugitive dust emissions from railway sidings and coal stockyards has been carried out by CMPDI for Gevra OCP of South Eastern Coalfields Limited (SECL). Design of WB and VGS for Lakhanpur OCP, Bhubaneswari OCP and Kulda OCP of Mahanadi Coalfields Limited (MCL) is under progress and final reports will be submitted soon.

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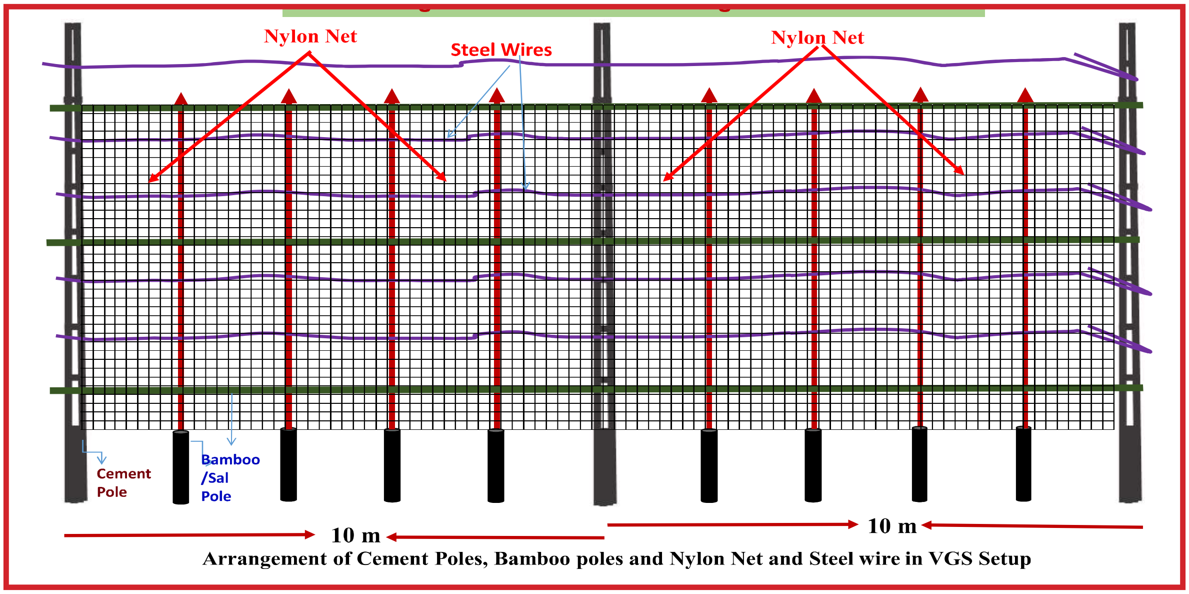

Figure 11: A Schematic Diagram of VGS

in the present paper. The views expressed in the present paper are of the authors and not necessarily of the organisation they belong to or that of CMPDI /Coal India Limited.

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Hydrogeological & Geophysical Investigation for site selection of proposedTube wells, Execution and Findings at Morwa Spur siding, Jayant Open cast project, Singrauli Coalfield, MP

Dr. A.K.Panda [1], Rahul Karki[2] , Vipin Kumar [3]

INTRODUCTION

Main objective of the project is to select appropriate sites for deep well at Morwa spur siding of Jayant project, Singrauli coalfield, Madhya Pradesh.

Geologist, hydrogeological and geophysical team did the field work from 15.3.2017 to 17.03.2017 at Morwa spur siding of Jayant project. The field visit was carried out to understand the local water level scenario and peripheral hydro-morphology of the area.

Two VES were taken at Morwa-spur siding to demarcate the water bearing zones. The location of the two VES points P1 and P2 are given in Figure-1. The acquisition of the data was done by IRIS make Syscal Pro resistivity meter. The data were inverted to obtain the thickness and true resistivity of the subsurface layers and on the basis of the resistivity the water bearing zones are identified. The visit was made in association with civil department, Jayant project, NCL.

GENERAL GEOLOGY AND TOPOGRAPHY

The Jayant Open cast project of Northern Coalfields Limited (NCL) is located in Singrauli Coalfields which is situated in Sidhi district of Madhya Pradesh. The area of interest lies in Morwa geological block in the northernmost corner of Singrauli Coalfield falling in the state of Madhya Pradesh, Singrauli District.

The general strike of the beds is more or less east-west, dipping northerly. The area containing coal seams namely Turra and Purewa merged. The formation above the coal seam Purewa Merged comprising of soil, weathered sandstone and fine to medium grained sandstone with in between thin bands of shale and clay. The lower formations, consisting of compact fine to medium grained sandstone with lamination and intercalation of sandstone with shale and carbonaceous shale bands.

The area has undulating topography with minimum

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elevation of 363.38 m and maximum elevation of 417.50 m, based on borehole data. The entire area is an example of a typical dendritic drainage pattern within the catchment area of Bijul Nala. Bijul nala flows northwardly and changes its course whenever it crosses fault traces.

HYDROGEOLOGY

The formation above Purewa Merged seam are of weathered sandstone and fine to medium grained sandstone with in between thin bands of shale and clay, behaves as unconfined aquifer. In Unconfined aquifer the ground water is under atmospheric pressure and groundwater moves laterally through the inter-granular pore spaces of the formation. The water table in the unconfined aquifer is conforming to the local topography. A flat water table with a gradient of 0.008-0.011, slopping towards north-east has been observed in the area.

The lower formations, consisting of compact fine to medium grained sandstone with lamination and intercalation with thin shale and carbonaceous shale bands with secondary porosity, behaves as semi-confined to Confined in nature and are less potential. Confined aquifers are permeable rock units that are usually deeper under the ground than unconfined aquifers. They are overlain by relatively impermeable rock or clay that limits groundwater movement into, or out of, the confined aquifer. Groundwater in a confined aquifer is under pressure and will rise up inside a borehole drilled into the aquifer. With the presence of intercalated shale and carbonaceous shale beds and reduction in permeability with depth, the lower aquifers are sometimes less potential, but due to development of secondary porosity the yield of aquifers increases.

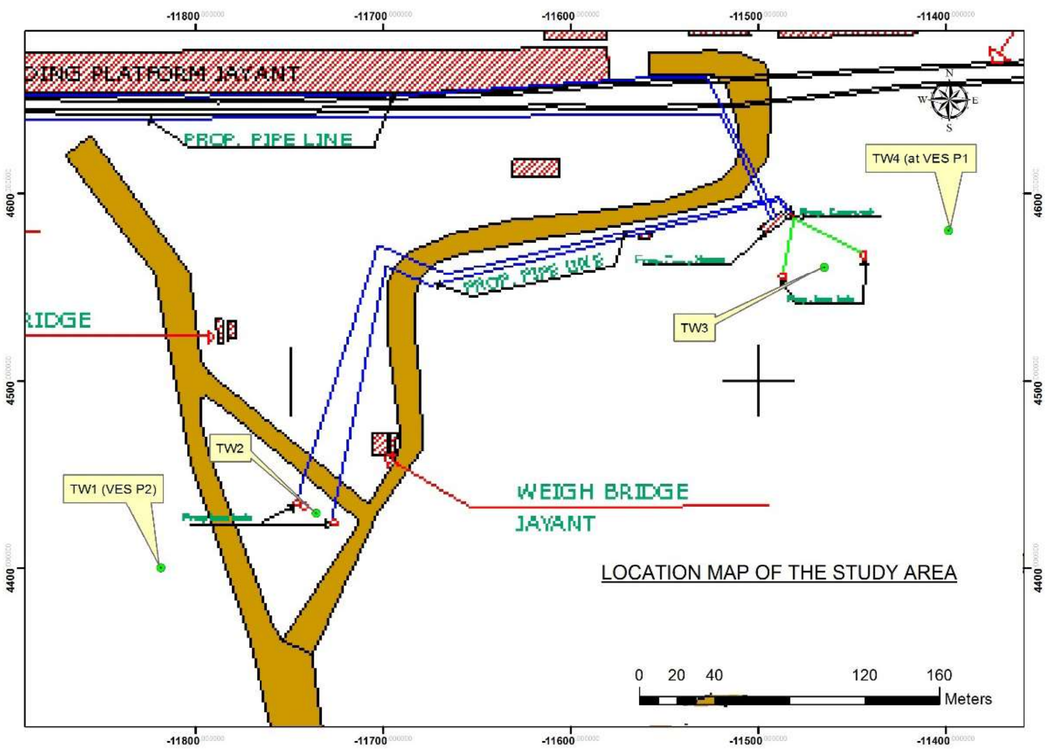

Figure 1: Location Map of the study area

The phreatic aquifer, lying above the Purewa Top coal seam, is directly getting recharged from rainfall, different streams and nalas. Confined aquifers may be replenished, or recharged by rain or stream water infiltrating the rock at some considerable distance away from the confined aquifer.

Table-I: The hydrogeological units developed in the proposed locations are as follows

(Based on Borehole data of dipside of Jayant Open cast project)

Hydrogeological Unit	Formations	Thickness Range in m
Phreatic aquifer	Soil, subsoil, weathered sandstone, Fine to medium grained sandstone with thin bands of Shale, Shaly Coal, Carbonaceous Shale and Coal	302.50-354.50
Aquiclude	Purewa merged Seam	28-31.20
Aquifer	Fine to medium grained sandstone with thin bands of Shale, Shaly Coal, Coal Carbonaceous Shale, and intercalations of Shale and sandstone	65.30-70.20
Aquiclude	Turra seam	20.10-21.80

Table: II Water level data of Dug wells nearby proposed locations

DUGWELLS	2014		2015		2016	
	Pre Monsoon (m. bgl)	Post Monsoon (m. bgl)	Pre Monsoon (m. bgl)	Post Monsoon (m. bgl)	Pre Monsoon (m. bgl)	Post Monsoon (m. bgl)
DW-1	4.43	3.52	7.53	4.85	N.A	1.4
DW-2	8.19	7.8	10.05	8.63	9.93	4.88
DW-3	11.23	11.35	13.67	13.79	N.A	8.29
DW-4	6.21	5.99	7.64	6.27	7.27	4.52
DW-5	9.45	7.69	10.99	9.04	10.49	3.94
DW-6	8.57	7.26	16.8	15.1	9.47	5.67
DW-7	2.00	4.07	3.64	2.17	5.17	0.87
DW-8	1.04	1.03	3.82	1.40	2.30	1.90
DW-9	12.46	13.02	16.69	15.52	15.92	12.52

(Note: m.bgl is meters below ground level)

Ground Water Level

In the present study, to assess the water table configuration, water level of dug wells nearby the target area is measured. Water level data is given in Table no.-II.

Aquifer Parameters

Detailed hydrogeological study was carried out in NCL command area in 1999-2000. Total 40 Piezometers were constructed and pumping test were carried out. The nearest piezometer to the proposed location of tube wells are P-2, P-4 and P-5. The location of P-2, P-4 and P-5 are given in Figure-2.

The Discharge rate was determined for the piezometer P-2 and P-4 using container filling method.

a) P-2

Discharge Rate	1.4 lps
Static water level	Artesian

b) P-4

Discharge Rate	2.2 lps
Static water level	16.81 m

The pumping test was done in piezometer (P-5) in Singrauli Exploration Camp. The following Hydraulic characteristics are found for the unconfined aquifer of Brakar Formation

c) P-5

Discharge rate	2.2 lps
Static water level	19.64 m
Hydraulic conductivity (K)	9.221E-08 m/s
Storativity (S)	4.987 E-04

Recharge and Discharge Zone

Water table contour map (Figure-2) prepared for May'2016 indicates that the recharge is from the elevated grounds, located north and northwest of the Jayant project. The recharge is mainly from rainfall to the phreatic aquifer. Deeper aquifer get recharged from the outcrop region and leakage from phreatic aquifer. Ground water flowing from south-west to north-east direction with a water table gradient of 0.008-0.011.

Discharge zone is the low lying flat terrain, nala beds and GBP sagar located south and southeast of Jayant project. Open pit mines also act as man-made discharge zones.

GEOPHYSICAL SURVEY

Data acquisition method

Vertical Electrical Sounding (VES) is based on the principle that allows the passage of current into the ground by means of current electrodes and measuring the potential drop between potential electrodes. A field setup for Schlumberger vertical electrical sounding is shown in Figure-3 in which A and B represents the current electrode whereas M and N represents the potential electrodes. The apparent resistivity ρA is given by the following formula.

Ground consisting of different lithology with depth, apparent resistivity is measured where the pattern of current flow is influenced by the density, porosity and salinity of the contained fluid in the ground.

Interpretation of VES data

The field data were processed to remove all the noise and the outliers. Thereafter, a deterministic approach is applied to invert the data to obtain the thickness and the resistivity of the layers of the subsurface. The inversion results are then correlated and explained in the following sections. The common resistivity ranges for different rock types are given in Table-III.

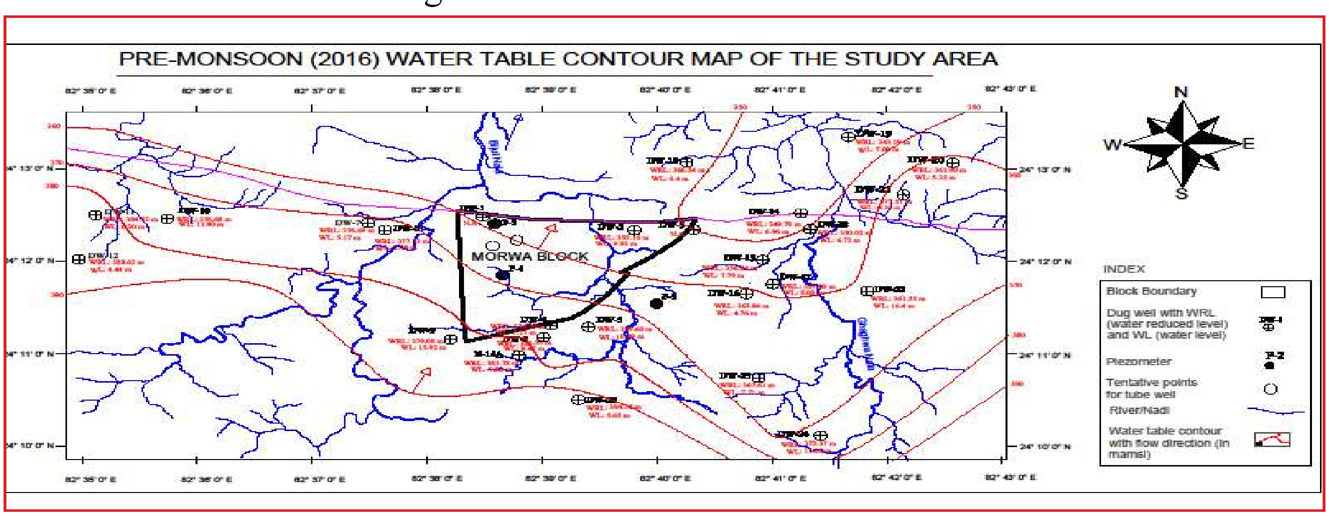

Figure 2: Water table contour map of the study area

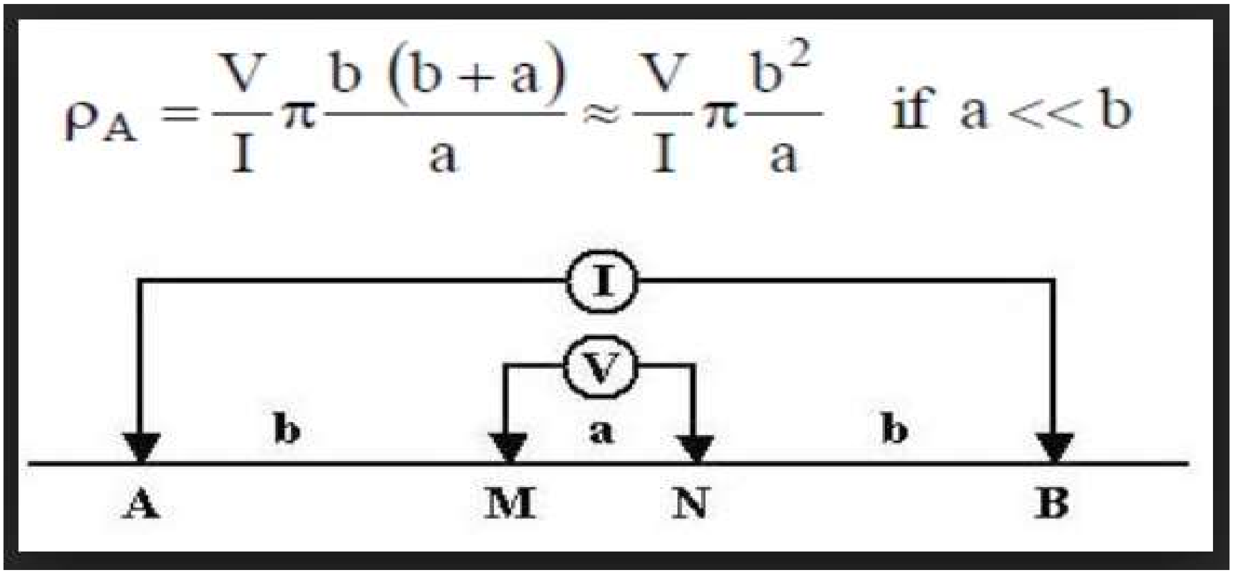

Figure 3: Electrical configuration of data collection (Schlumberger VES)

Table III: Resistivity range of different rock types.

Sl.No	Rock Type	Resistivity Ranges (ohm-m)
1	Massive sulphide	0.001-1.0
2	Igneous and Metamorphic Rocks (Unweathered)	1,000-1,00,000
3	Igneous and Metamorphic Rocks (Weathered)	5.0-2,000
4	Sandstone	50-10,000
5	Water Aquifer (fresh water)	20-150
6	Water Aquifer (salt water)	0.5-1.0
7	Clay	5-100

Result and Discussion

VES Point P1

Field data and the inverted model at point P1 are shown in Figure-4. The percentage RMS error for the final model is 5.612 %. Figure-5 shows the convergence of percentage RMS error with No. of iterations. One can observe that after 8th iterations, the improvement in result becomes negligible. The thickness and the resistivity of the subsurface layers obtained after inversion are given in Table-IV. Two water bearing layers have been identified as per the resistivity of the layers. The depth ranges of these two layers are 10.119 – 13.159 m and 65.13 m to 105.201 m respectively.

VES Point P2

Field data at point P1 and the inverted model are shown in Figure -6. The percentage RMS error for the final model is 5.612 %. Figure-7 shows the convergence of percentage RMS error with No. of iterations. The layer thickness and layer resistivity obtained after inversion is given in Table-V. Two water bearing layers have been identified as per resistivity of the layers. The depth ranges of these two layers are **10.119 – 13.159 m** and below **70.44 m** respectively.

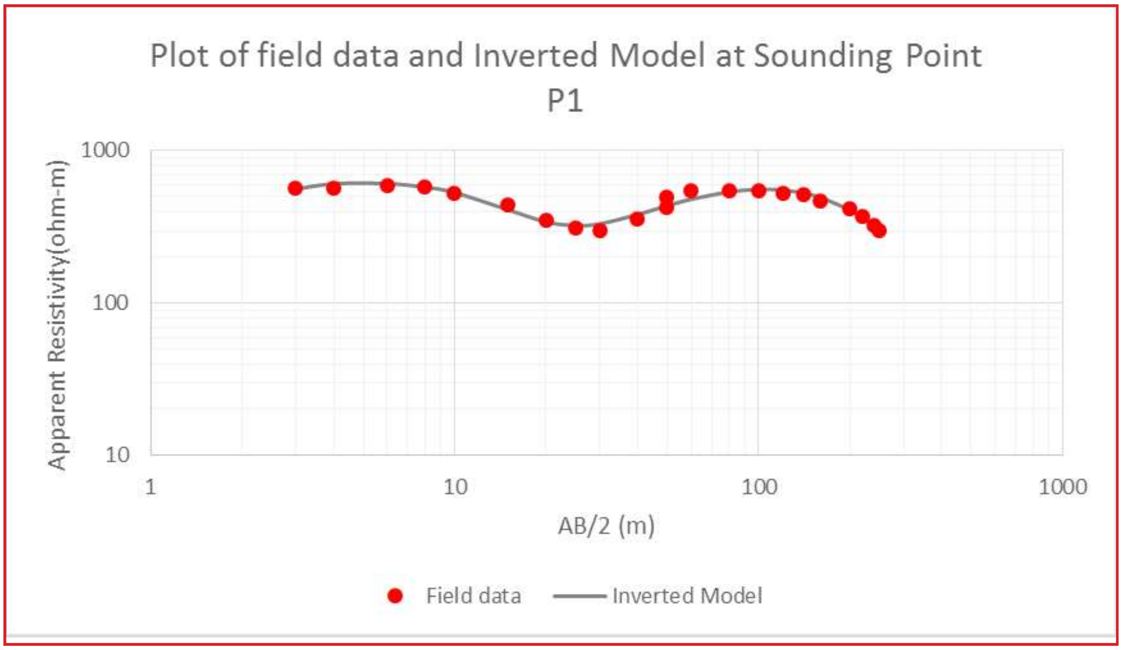

Figure 4: Plot of field data and inverted data

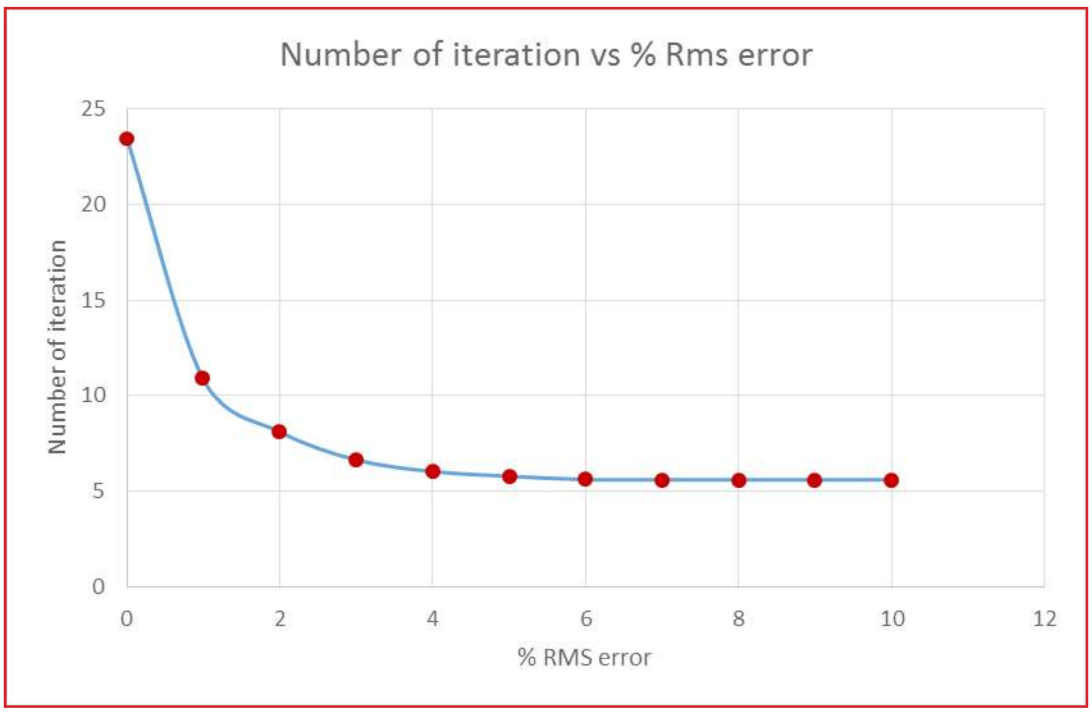

Figure 5: Number of iteration vs .% RMS error

Table IV: Layer parameters obtained after inversion

Layer	FROM	TO	Thickness	Resistivity (ohm-m)	Remarks
1	0	1.53	1.53	486.977	
2	1.53	3.442	1.912	798.747	
3	3.442	5.833	2.391	803.404	
4	5.833	8.821	2.988	172.824	
5	8.821	12.556	3.735	102.351	Ground water potential Zone
6	12.556	17.225	4.669	263.607	
7	17.225	23.061	5.836	1028.464	
8	23.061	30.357	7.296	2386.391	
9	30.357	39.477	9.12	2270.026	
10	39.477	50.876	11.399	1086.182	
11	50.876	65.125	14.249	403.423	
12	65.125	82.937	17.812	149.696	Ground water potential zone.
13	82.937	105.201	22.264	59.108	Ground water potential zone.
14	105.201			24.336	

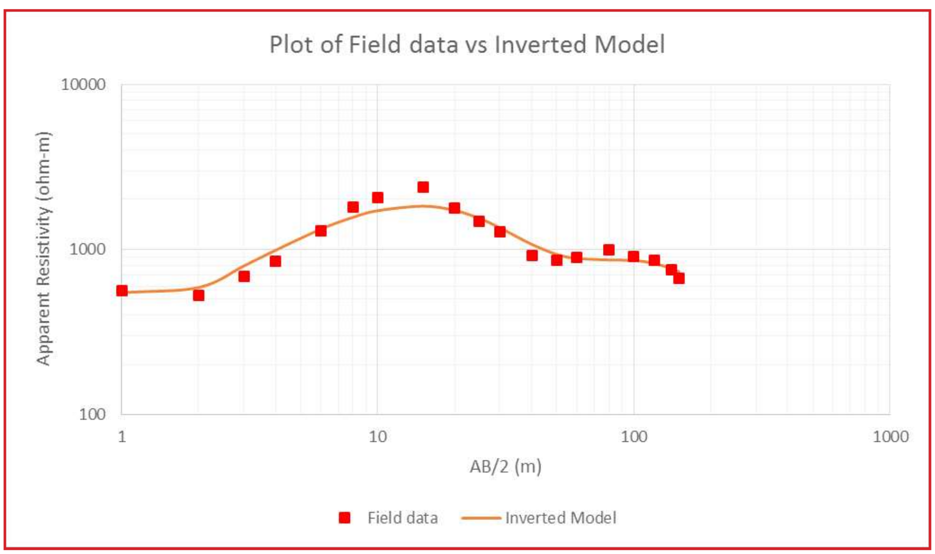

Figure 6: Field data with inverted model

model

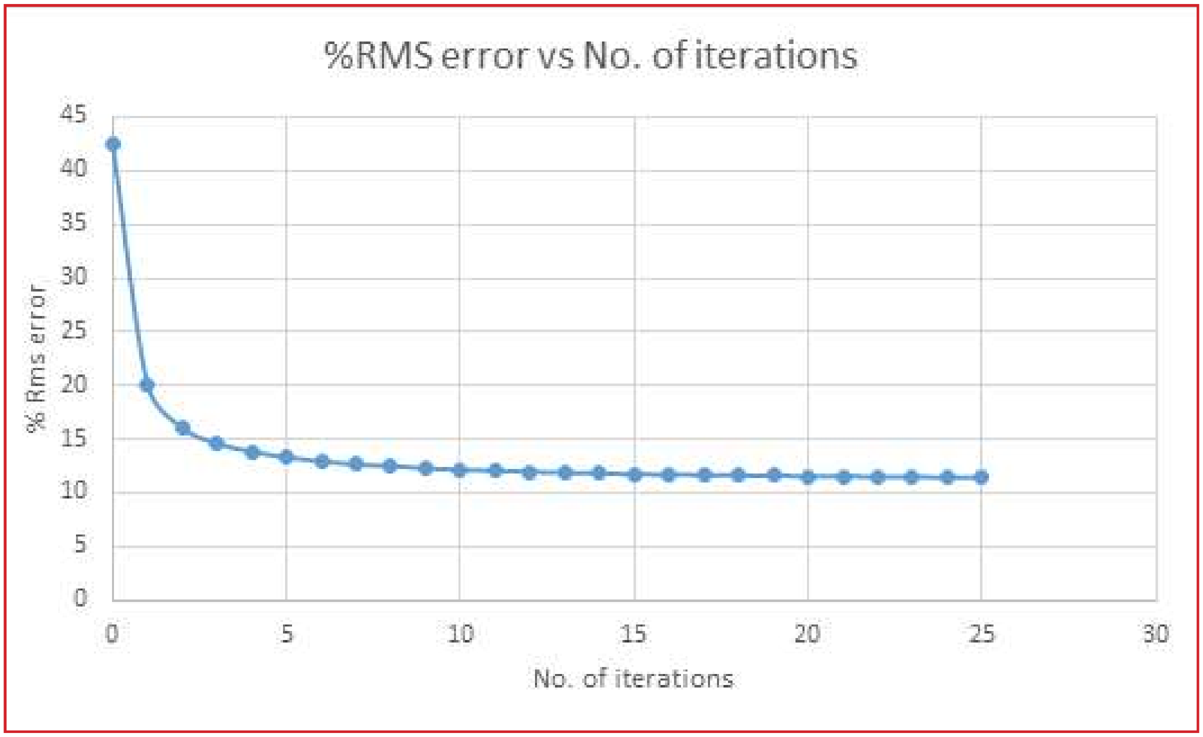

Figure 7: Number of iteration vs. % RMS error.

Table V: Layer parameters obtained by inversion

Layer	FROM	To	Thickness	Resistivity (ohm-m)	Remarks
1	0	0.51	0.51	663.268	
2	0.51	1.148	0.638	276.422	
3	1.148	1.945	0.797	2053.421	
4	1.945	2.941	0.996	8815.233	
5	2.941	4.186	1.245	8315.578	
6	4.186	5.742	1.556	2788.529	
7	5.742	7.687	1.945	776.994	
8	7.687	10.119	2.432	298.374	
9	10.119	13.159	3.04	211.801	Ground water potential zone.
10	13.159	16.959	3.8	304.233	
11	16.959	21.709	4.75	705.958	
12	21.709	27.646	5.937	1770.114	
13	27.646	35.067	7.421	3156.142	
14	35.067	44.344	9.277	2857.266	
15	44.344	55.94	11.596	1261.136	
16	55.94	70.435	14.495	351.504	
17	70.435			80.49	Ground water potential zone.

POSSIBLE WATER SOURCE

To meet this water demand, it is proposed to construct 4 Nos. of gravel packed deep tube wells at Morwa spur siding (TW-1, TW-2, TW-3, TW-4) and also the locations have been marked in the location plan in Figure-1.

CONSTRUCTION OF GRAVEL PACKED TUBEWELL

A well consists of a bottom sump, well screen, and well casing (pipe) surrounded by a gravel pack and appropriate surface and borehole seals. Water enters the well through perforations or openings in the well screen. The purpose of the screen is to keep sand and gravel from the gravel pack out of the well while providing ample water flow to enter the casing.

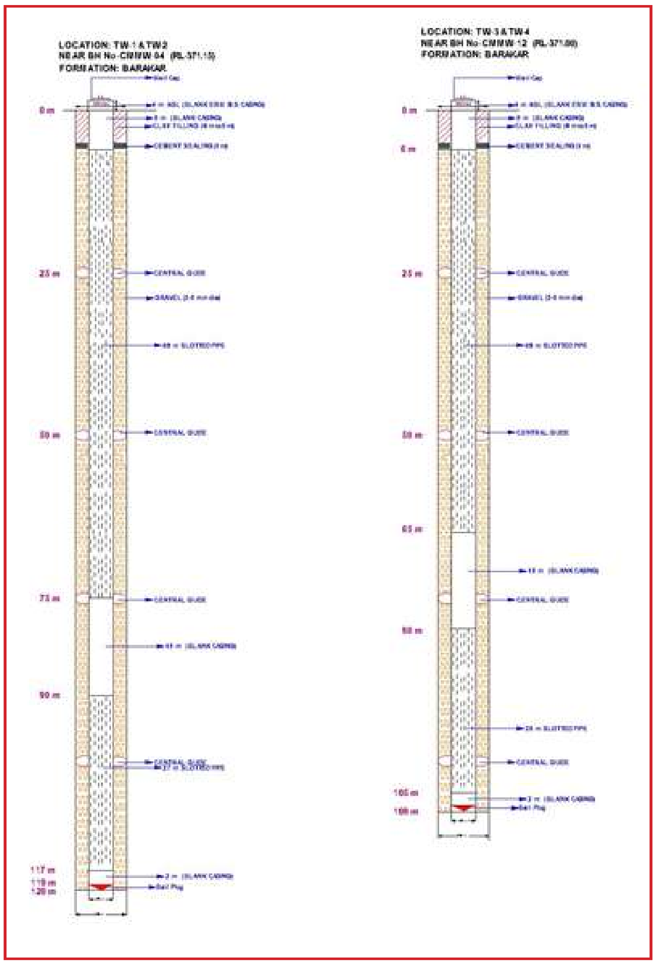

Figure 8: Proposed Tube Well Design

The purposes of the blank well casing between and above the well screens are to prevent fine and very fine formation particles from entering the well, to provide an open pathway from the aquifer to the surface, to provide a proper housing for the pump, and to protect the pumped ground water from interaction with shallower ground water that may be of lower quality. The annular space between the well screen, well casing, and borehole wall is filled with gravel or coarse sand (called the gravel pack or filter pack). The gravel pack prevents sand and fine sand particles from moving from the aquifer formation into the well. The uppermost section of the annulus is normally sealed with a bentonite clay and cement grout to ensure that no water or contamination can enter the annulus from the surface.

After the well screen, well casing, and gravel pack have been installed, the well is developed to clean the borehole and casing of drilling fluid and to properly settle the gravel pack around the well screen.

The diameter of the borehole will be 300 mm and an assembly of 150 mm diameter will be lowered within the boreholes. The tentative assembly chart of the proposed four (4 nos.) tube wells has been provided in Figure-8, based on the nearby borehole lithology and geophysical survey data.

DATA ANALYSIS, SUGGESTION AND EXECUTION

Data Analysis and suggestion

A vertical electrical sounding method has been applied and the results were able to delineate different geo-electric sections which were correlated with available geology; to determine their corresponding geological formations. The most probable water bearing zones are identified on the basis of electrical properties. The Geophysical Survey (VES) conducted in the study area, close to the proposed tube well locations, indicates presence of water bearing formations for P1 in the depth range of 10.119 – 13.159 m and 65.13 m to 105.201 m, and for P2 in the depth range of 10.119 – 13.159 m and below 70.44 m respectively, which can be tapped for exploitation of groundwater.

The ground water data in nearby dug wells for the last 3 years is analyzed (Table-II) and it is found that the average Pre-monsoon water level in the area is 8.65 m and average post-monsoon water level is 6.76 m. Ground water flowing from south-west to north-east direction with a water table gradient of 0.008-0.011.

As groundwater is the only sustainable as well as mitigated resource and furthermore can be developed immediately, so, it is suggested to exploit groundwater through sinking deep tube wells. Thus, it is proposed to construct 4 nos. of gravel packed deep tube wells at Morwa Spur siding (TW 1, TW 2, TW 3 and TW 4).

During construction of the deep tube well, the following matters have to be taken care while choosing method of construction and development of well for proper yield of well:

a) Gravel pack: the annular space is to be filled with clean pea gravel of 4 to 6 mm size. The gravel should be rounded to sub-round in shape and made up of 90% quartz.

b) Well Development: The well should be thoroughly developed for about 24 hours with

Figure 9: Deep Tube wells (TW1 to TW4) with water filling system for dust suppression by water sprinkler at Morwa Spur Siding

air compressor (preferably 100 psi and 300 cfm) to remove the mud cake/fines and clean the well. The development should be carried till the discharge water is free from turbidity and suspended solids.

c) Yield test and pump selection: The yield test may be carried out for at least 6 hrs on continuous pumping. The discharge may be measured with a 200 liter drum or 90o V- notch. After the yield test only the pump specification should be drawn and placed at proposed depth.

Execution

A team of Hydro-geologist and Geologist have visited the proposed sites (TW1 to TW4) in the field and it has been found that all the four tube wells have been successively executed as per suggestion and design. All the four tube wells with water filling system have been found to be operational for the use of dust suppression in the vicinity of the Morwa spur siding area.

Findings and Conclusion

In all the four proposed point ground water was encountered in shallow depths with good potential for water supply. Water is being used in the water sprinkler for sprinkling of water to suppress the coal dust in and around Morwa spur siding of Jayant project, NCL (Figure 9), arrangements to make better working environment. This is very low cost investigation with highest beneficial to the coal company and society in terms of environmental impact.

STUDIES ON THE SEGREGATION OF MINERALS IN DIFFERENT SIZE AND GRAVITY FRACTIONS WHILE TREATING INDIAN COAL

U.S. Chattopadhyay[1], Sudip Maity[2], T. Gouri Charan[3]

ABSTRACT

Gondwana coal makes up to **98 per cent of the total reserves and 99 per cent of the production of coal in India.** These coals are intimately mixed with mineral matter, causing a high level of impurities in the run-of-mine (ROM) coal. Beneficiation of high- ash non-coking coals of India has become the prerequisite for improving the overall economics and efficiency for downstream utilization industries. The association between specific mineral and organic constituents in a typical non-coking coal sample from the Eastern Coalfields, India was studied. For this, raw coals were fractionated by size and density and the variation of major minerals with respect to size and density was examined. Mineral species were identified by X-ray diffraction. The results showed that the concentration of quartz and kaolinite increases with increase of gravity of the coal while concentration of siderite is much lower in the lower size fractions of the coal.

Key words: *Coal, minerals, mineral processing*

INTRODUCTION

Coal is an organic sedimentary rock and very heterogeneous in nature. It contains organic and inorganic matters, respectively, in the form of macerals and minerals. In general, the run-of-mine (ROM) coal requires the removal of ash-forming inorganic matter by suitable processing methods. Indian coals are of Gondwana origin, which are inferior in quality. The characteristics of these coals differ significantly from other coals of Gondwana origin, particularly in their mineral matter chemistry

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and petrographic makeup, which have direct bearing on their utilization potential.

Minerals found in Indian coals may often be distinguished, as megascopic mineral components which include discrete bands and laminae of clay or clay-rich material, lenticles, nodules and concretionary bodies of, carbonate or silica, and, pellets or tube-like aggregates typically made up of crystalline clays such as kaolinite. Other common occurrences, usually formed at a later stage in the coal's diagenetic history, include deposits of minerals such as carbonate, and clay in cleat fractures and in veins cutting across the coal seam. In addition to this megascopic mineral matter, coals may also contain significant mineral components visible only at a microscopic scale. These are often intimately admixed or intergrown with the macerals themselves, and are commonly referred to as the "inherent" mineral matter of the coal seam. Minerals in coal at a microscopic scale may include thin bands or laminae, often containing small subangular particles, such as quartz grains, infillings of cell lumens with clay, carbonate, apatite or silica polycrystalline nodules etc.

Coals vary widely in their response to beneficiation due to differences in the mineral phases present, their particle size, and the degree of association of these minerals with the organic coal matrix, i.e., whether the mineral particles are free from, are completely encapsulated by, or are partially exposed on the surface of coal particles. During the physical cleaning of coal, the major elements partition among the clean coal and the rejects. Physical cleaning of coal provides a more consistent fuel, reduces transportation costs and alleviates ash handling and disposal problems. However, changes in mineralogy during coal beneficiation also play a major role for the end use of this beneficiated coal.

Establishing the relationships between the organic and mineral parts of coal is required not only for a deeper fundamental knowledge of coal structure, but also to design more efficient coal processing methods. Thus, the feasibility of coal cleaning processes essentially depends on the degree of association between maceral and minerals. Furthermore, some minerals are known to have strong catalytic effects (of increasing importance as their association with the organic matter becomes more intimate) in various coal utilization processes. Mineral matter is also a source of a number of technological problems that depend on the mineral-maceral association, e.g. the slagging and fouling behaviour during coal combustion (Huffman et al., 1991; McCaffrey et al., 1995). All of these facts justify the need to develop new methodologies allowing the characterization of the organic-mineral interactions in coal.

In the present study quantitative estimation of the minerals has been made by X-ray diffraction technique where Reitveld Full Profile analysis is used for this purpose and investigations were carried out on coal sample collected from an open cast mine of Eastern Coal Field Limited, India with the objective of determining the distribution of minerals in the size and density fractions of the crushed coal.

Material

The coal sample tested is from Rajmahal area of Eastern coalfield a subsidiary of Coal India is famously called as Raniganj Coalfield, which is, located in the eastern most part of the Damodar Valley Coalfields. Coal seams occur in VII horizons in the Barakar measures and IX horizons in the Raniganj measures. The total thickness of the working seam (RV and RIV) is about 14 m. The mine is being operated in 2 seams by mechanized dragline and shovel dumper combination. The sample was collected from Coal Handling Plant after

Table 1: Distribution of minerals in different size and specific gravity fractions

Sp>Gr.	Size:75-50mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	32.2	33.0	36.3	34.5
kaolin	62.8	62.3	55.7	48.5
Siderite	5.0	4.7	3.7	15.6
lllite			4.3	1.4
	100.0	100.0	100.0	100.0

Sp.Gr>	Size:50-25mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	36.7	31.3	34.4	36.4
kaolin	53.2	60.7	59.5	47.4
Sider-ite	8.1	6.0	3.0	11.4
lllite	2.0	2.0	3.1	4.8
	100.0	100.0	100.0	100.0

Sp>Gr.	Size:25-13mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	42.2	30.4	32.6	39.0
kaolin	45.8	57.2	61.7	48.3
Siderite	8.8	10.0	3.4	10.1
lllite	2.6	2.4	2.3	2.6
	100.0	100.0	100.0	100.0

Sp.Gr>	Size:13-6mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	45.2	31.5	31.1	39.0
kaolin	51.5	62.2	61.5	48.3
Sider-ite	3.3	5.3	4.0	10.1
lllite		1.0	3.4	2.6
	100.0	100.0	100.0	100.0

Sp>Gr.	Size:6-3mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	36.3	33.2	33.8	39.2
kaolin	54.3	61.7	61.8	54.7
Siderite	6.3	5.0	1.7	2.6
lllite	3.1	0.1	2.7	3.5
	100.0	100.0	100.0	100.0

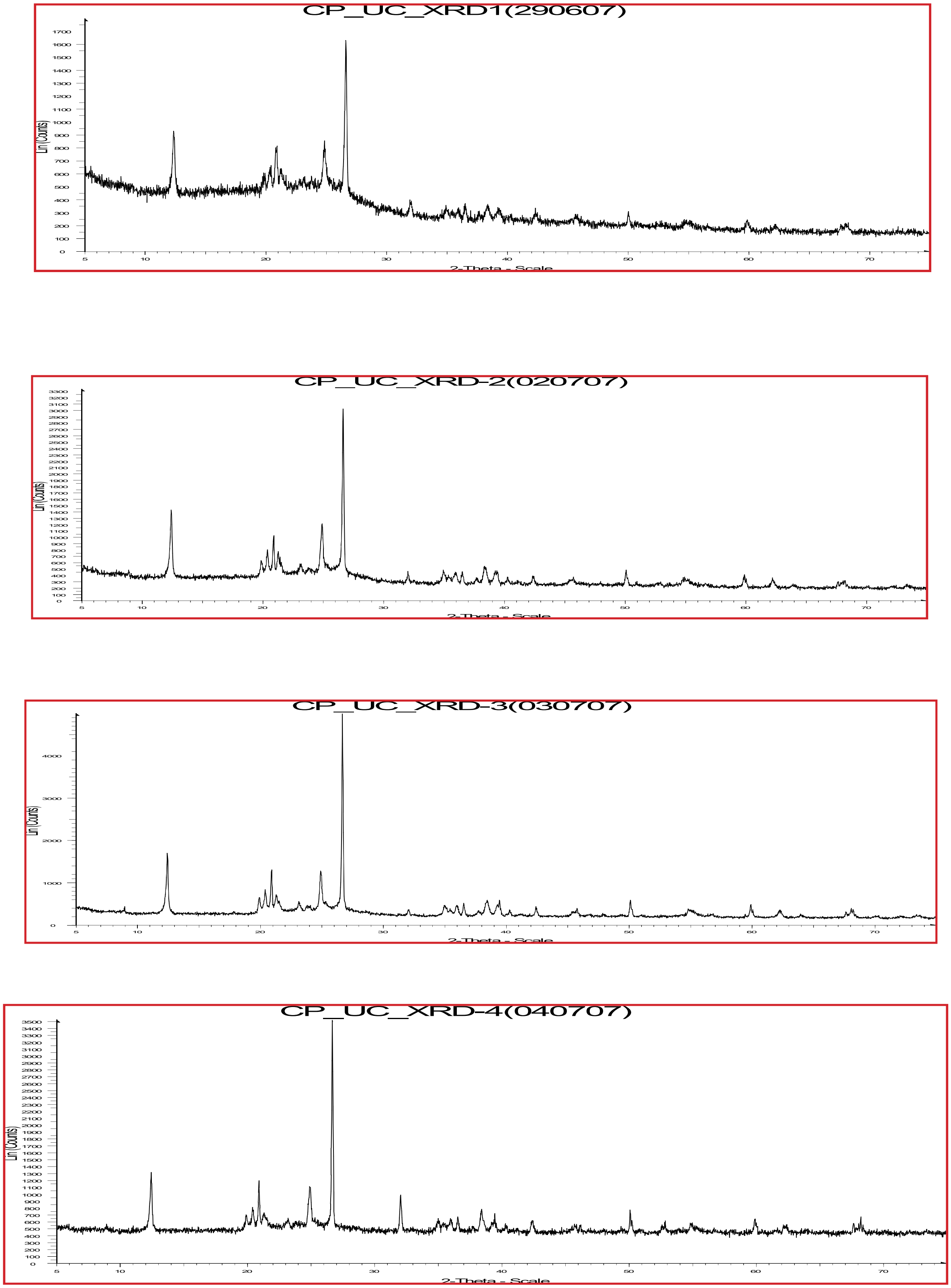
Sp.Gr>	Size:3-0-5mm			
	<1.40	1.50-1.60	1.70-1.80	1.90-2.00
Quartz	44.2	31.0	31.1	36.0
kaolin	49.5	64.8	63.4	60.9
Sider-ite	4.9	3.0	3.8	2.0
lllite	1.4	1.2	1.7	1.1
	100.0	100.0	100.0	100.0

crushing the ROM coal to below 250mm with the help of a pay loader by scraping the entire cross section of the heaps at various places. After proper and thorough mixing, about 10 tons of samples were collected and brought to the laboratory for further studies.

Characterization tests on the raw coal sample revealed that the ash percentage of coal was 36.3%. Moisture percentage (on as-received basis) of the coals was 8.3%. The volatile matter is about 24.8%. Coal sample is friable in nature (H.G.I 94). Gross calorific value (GCV) is 3760 kcal/kg. And ash fusion temperature of the tested coal is above 1400^0 C.

Fractionation into size and density fractions

The raw coal was taken and first screened at 75 mm; the plus 75 mm fraction was crushed in a single roll crusher. The overall combined fraction of the product below 75 mm was subjected to screen analysis at 50, 25, 13, 6, 3 and 0.5 mm. Selection of an appropriate gravity separation technique is based on specific gravity tests (float-and-sink tests) (Sarkar and



a

b

c

d

Figure: 1 X-ray diffractogram of coal (Size: 75-50) at different specific gravity cut (a: < 1.4; b: 1.5 – 1.6; c: 1.7 – 1.8; and d: > 2.0)

Das, 1974). Common minerals of coal such as siderite, kaolinite, quartz and illite have specific gravities of 5.0, 2.6, and 2.7 respectively which are significantly higher than the average specific gravity (~ 1.4) for the organic portion of a coal. Mineral matter associated with coal is heavier than organic matter. For this purpose, gravity separation technique is used for removal of mineral matter from coal. The specific gravity test is accomplished by fractionation of the coal particles in a series of float-and-sink baths of increasing or decreasing density. The individual size fractions were subjected to float – and - sink tests, and the relative density range was 1.40 to 2.00. The weights and analysis of the gravity fractions are determined using standard method for determination of coal washability characteristics in coal preparation laboratories. Washability analysis of the coal sample has been performed using heavy organic liquids with a density from 1.4 to 2.0 g/cm^3 for this study.

Quantification of minerals by X-ray Diffraction (XRD) Technique

XRD is an important tool for identification of crystalline phases and it is also used for determination of minerals in coal. Identification of minerals in coal is mostly done with powdered raw coal or low-temperature ash (LTA) of the coal. The full profile of XRD has been used for quantitative estimation of the mineral matter in raw coal successfully (Ward, 1984; Ward, 2002; Maity, et al; 2003). Rietveld introduced a technique by which a crystal structure model can be refined from an experimental powder diffraction pattern using the method of least squares (Rietveld, 1969). A calculated model can be fitted to the observed powder diffraction pattern in order to obtain parameters which define each reflection. The details of the technique have been described elsewhere (Maity, et al; 2003). Taylor developed personal computer-based software, SIROQUANT™, using Rietveld refinements for quantitative estimation of up to 25 mineral phases at a time from a conventional X-ray diffractogram (Taylor, 1991; Taylor & Hinczak, 2001). The SIROQUANT software has been used for the estimation of the raw coal samples for the present study. X-ray diffractograms of gravity fractionated coals are shown in Fig 1 (a – d). It is observed that background intensities of the diffractograms are decreasing due to the fact that concentration of the mineral matter is increasing towards the higher gravity cuts (Figure: 1a to 1d).

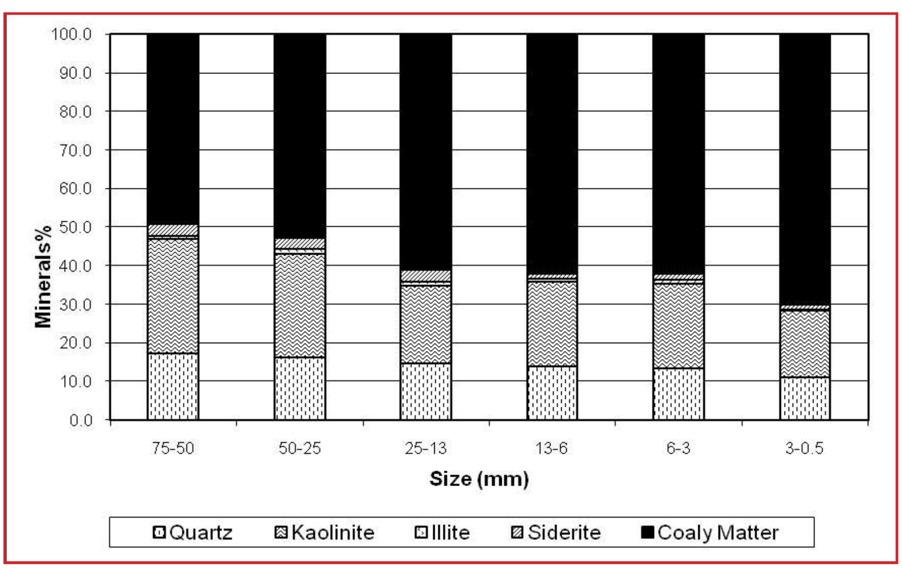


Fig 2: Liberation of inorganic & coally matter with respect to size

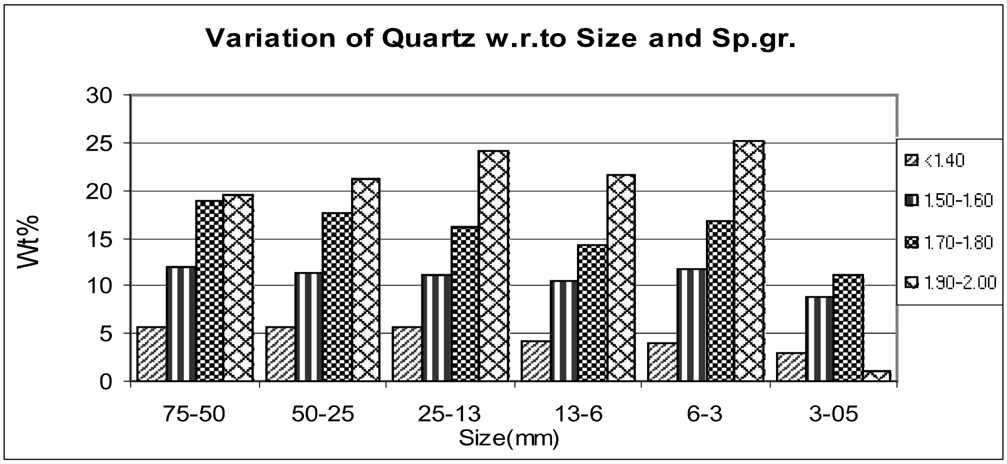


Figure: 3 Variation of Quartz w.r.t. Size and Sp.Gr

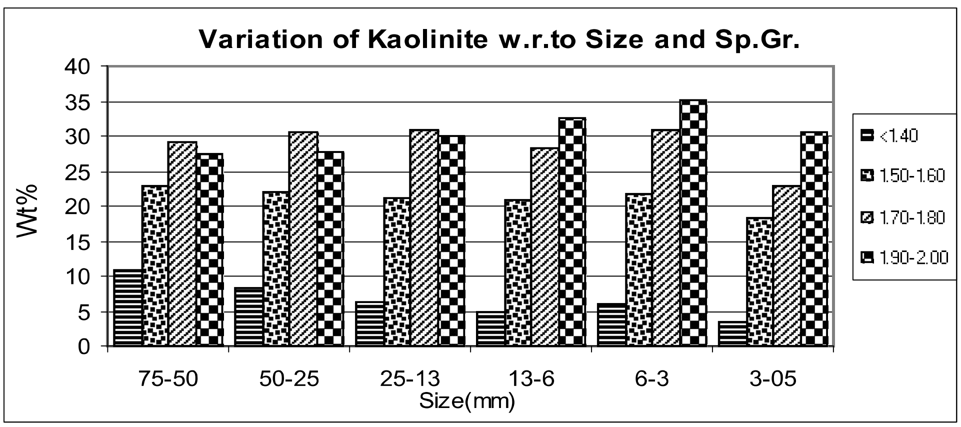


Figure: 4 Variation of Kaolinite w.r.t Size and Sp.Gr.

Figure: 5 Variation of Siderite w.r.t Size and Sp.Gr

The Distribution of Minerals in Coal

Particle size distributions, which are determined on a mineral-by-mineral basis, often show major variations among minerals within a given coal and for the same mineral among different coals. Size distributions are significant in determining the cleanability of a given coal since most cleaning processes, and especially density-based processes, remove primarily the large mineral particles. Therefore, the size distribution for a given mineral may be quite useful for predicting its cleanability. If certain minerals are characteristically larger than other minerals, then they are likely to be preferentially removed, which will result in substantially different ash chemistry for the clean coal compared to the raw coal.

Mineral *data* and particle size distributions are also used together to characterize clean coals for the evaluation of cleaning processes. Results from raw and cleaned coals are compared to determine which mineral phases and particle sizes were removed by cleaning. Such comparisons often show selective removal of one mineral over others, thus indicating better liberation. In some cases, it is possible that coal cleaning is being impaired by factors other than the degree of mineral liberation. In Fig. 2, the size distribution is shown for four major minerals, it can be seen that the dominant minerals are quartz and siderite while Kaolinite and illite are the least abundant minerals respectively.

The abundances and characteristics of the individual minerals are illustrated below.

Quartz: The distribution of quartz in different size fractions is almost uni-modal (Figure: 3). In each size fraction concentration of quartz is higher for higher gravity cut and lower for lower gravity cut with only exception in the fine size fraction of 3-0.5mm, where the concentration of quartz is lowest in the gravity cut of >1.9. It is also observed that concentration of quartz is almost uniformly increasing with respect to the decreasing size fraction for the higher gravity cut (1.5, 1.7, 1.9) but remains more or less similar for the low gravity cut (<1.40).

Kaolinite: The distribution of kaolinite in different size fractions is also uni-modal (Figure: 4). Concentration is low in the low gravity cut and high in the higher gravity cut in all size fractions.

Siderite: Segregation of siderite is conspicuously visible in two modal distributions (Figure: 5). The presence of siderite in lower size fraction is much less than higher size fraction. More over, concentration of siderite is higher in higher gravity cut (> 1.8) of the higher size fraction (75 – 50 mm, 50 – 25 mm & 25 – 13 mm). In the lower size fractions, as siderite has higher specific gravity, its concentration is less in lower gravity cut (< 1.4), but in the 6 – 3 mm size fraction, its concentration is higher in the lower gravity cut.

Illite: Concentration of illite is lowest in all the gravity cuts and size fractions. Moreover, illite is not found in only the two gravity cuts (<1.4 and 1.4 – 1.5) of the 75 – 50 size fraction (Table 1).

DISCUSSIONS

It is clearly visible that coal washing has distinct effect on the mineral segregation in different size and gravity fractions. Quartz is associated with coal from its origin and fractionation of quartz is depending on different gravity fractions. Size of coal is not affecting the nature of distribution of quartz as it remains almost uni-modal distribution for all the size fractions. However, concentration of quartz increases with increase of gravity of the coal. Kaolinite also shows similar behavior as compared to quartz. Segregation of siderite is distinctly different from both quartz and kaolinite as siderite has different genesis history. It is established that siderite is authigenetically produced during the coalification process and it may be associated with some maceral of coal. Concentration of siderite is much lower in the lower size fractions of the coal. Moreover, siderite has the highest density among these three minerals under study; hence the higher gravity cuts have higher concentration of siderite.

CONCLUSIONS

Presence of inorganic material in coal plays an important role during washing and its utilization. The estimation of inorganic material is mostly done in the form of oxides. However, the mineral matter plays a vital role during coal utilization processes namely carbonization, combustion and gasification of coals. It is a fact that melting behavior of minerals are completely different from their constituent oxides, so segregation of mineral matter during coal washing is an important factor and it needs to be determined for more purposeful utilization of processed coal. The crushed raw coal was classified into different size and specific gravity separation, and mineral contents were analyzed in each fraction. The analyzed results indicated that the concentration of quartz and kaolinite increases with increase of gravity of the coal Concentration of siderite is much lower in the lower size fractions of the coal and higher gravity cuts showed higher concentration of siderite. An attempt has been made to understand the facts of mineral segregation during washing of a non coking coal sample.

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STUDY OF VARIATION OF ANGLE OF DRAW IN SINGLE AND MULTIPLE SEAM IN UNDERGROUND COAL MINING

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Abstract

Subsidence in mining is a common problem in many countries. Subsidence brings with it various other problems and issues. Ground subsidence brings about changes in the territorial environment. The purpose of this paper is to identify parameters involving and impacting the Angle of draw in single seam and multiple seams underground coal mines. The study examined the effects of different individual parameters that affect the overall Angle of Draw (AoD) viz. the method of mining, Nature of the overlying strata, Thickness of the extraction, Faults and Cracks, etc. This paper presents the results of the studies carried out on Indian mines and presents the influencing parameters of angle of draw.

Keywords: *Subsidence, Mining, Underground Mining, Overburden.*

INTRODUCTION

The Angle of Draw is the angle between the edge of an underground working and the point of the surface to which subsidence may extend. The angle of inclination between the vertical at the edge of the working and the zero subsidence point at the surface is termed the limit angle or angle of draw. In subsidence of coal mines, this angle is assumed to bisect the angle between the angle of repose of the material and the vertical. It is approximately 20° for flat seams. For dipping seams, the angle increases, being 35.8° from the vertical for a seam dipping at 40° [1].

With basically multiple ways in which a multiple seam underground coal mine can be worked in and the complexities it comes along with, Angle of Draw gets even more complex to analyze and study. Of the four typically recognized underground multiple seam mining

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methods three are being practiced today and the fourth one is almost obsolete. In general, a large number of coal seams are left with incomplete extractions and without subsidence, on account of no proper studies done on the effects of subsidence for extractions in multiple seams in underground coal mines. Due to lack of the knowledge of subsidence behavior of strata overlying coal seams in India more than 1500 million tonnes of coal is sterilized.

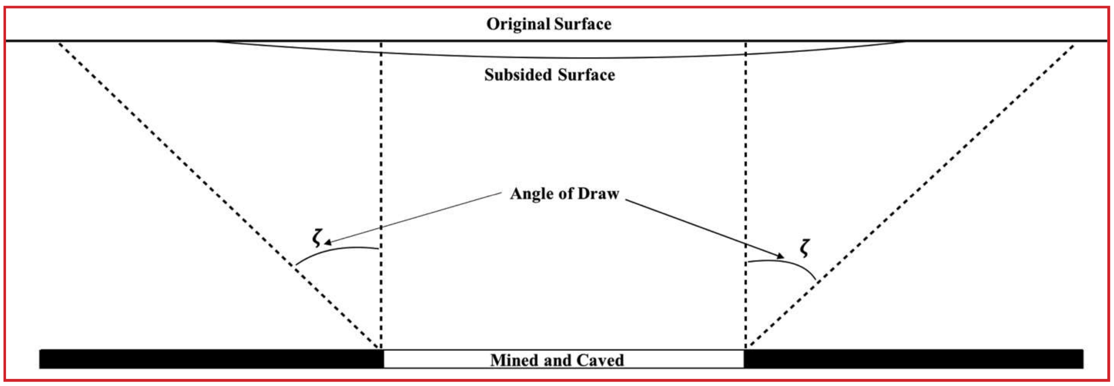

Figure 1 – Schematic of angle of draw

Although, the importance of subsidence research was realized long ago, subsequent observations were limited in precision and scope [2]. A thorough study on the effects of different parameters on the Angle of Draw while extracting multiple coal seams will benefit in proper extractions in future projects. This will help while planning the mine boundaries and the method of working based on other parameters. With properly studied effects one can plan the outcomes and method to work with well in advance. A study of various factors affecting the Angle of Draw and their comparison of their effects to one another has been performed. This paper describes each one of those in detail.

METHODS

There are basically four methods to mine in multiple seam underground coal mines: Undermining, Overmining, Simultaneous mining, Partial mining. The first three mining sequences are being practiced today across few countries but the fourth one maybe considered inferior because if the openings are first developed in an upper seam and then undermined, the openings in the seam may cave totally if the inner burden thickness is small, and the developed pillars or panel will be lost.

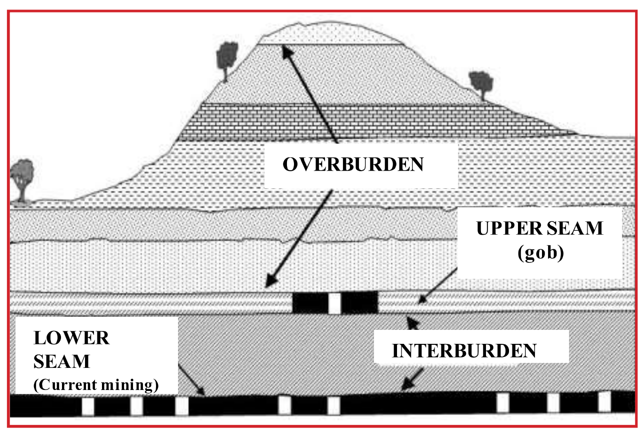

Figure 2- Undermining method of working

While planning future mining projects, the mine planners must evaluate the potential impacts of such multiple seam interactions and when mining beneath old workings, the new developments may be subjected to excessive load transfer (Figure 2). In the overmining situation also (Figure 3) load transfer can occur, and in addition to that, the ground may have been damaged by subsidence. In some peculiar

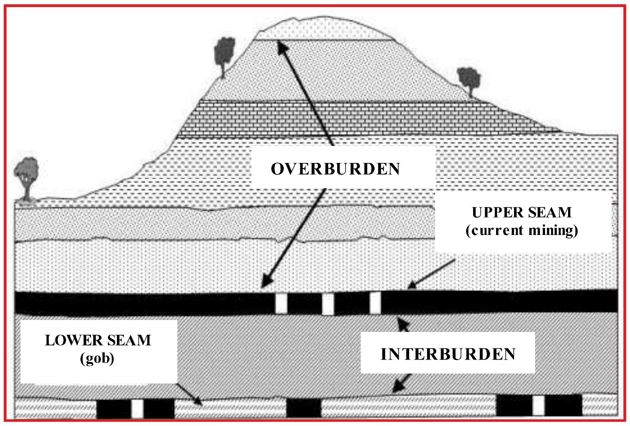

Figure 3- Overmining method of working

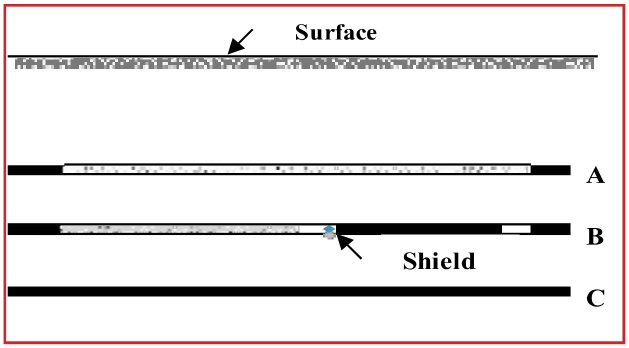

Figure 4 - Mining in descending order (Undermining)

cases, the interactions of multiple seam extraction can be so severe and hazardous that mining becomes impossible [3]. In others, it may be possible to develop pillars but not recover them. In many cases, however, the interaction may be barely noticeable [4].

Undermining method of working

The upper seam is mined out prior to lower seam, i.e. he seams are mined in descending order. Mining of lower seams does not commence until the mining of upper seam are complete. Mining procedures when done in this order are usually called undermining

The following effects appear if the upper seam is worked prior to the lower seam [5];

- The upper seam's roof settles.
- The gob in the upper seam can get filled with water.
- If the seams are highly inclined and the parting is less than the strata breaks may extend from upper seam to lower and affect the mining activities.
- If the parting is very less, then the goaf area of the upper seam may puncture into the lower seam.
- Gas formed may get migrated from lower seam to the goaf of upper seam and may award a gas free lower working seam.
- The stresses, if present, get released when the upper seam is worked and are not much of an issue for lower seam workings.
- The lower seam cannot be worked until the upper seam is completely exhausted.
- More Subsidence and Angle of Draw may be observed by working under ground which is already broken by upper seam working.

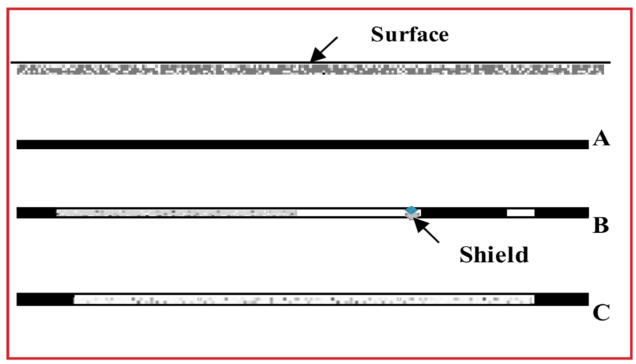

Figure 5 - Mining in ascending order (Overmining)

Overmining method of working

The lower seam is mined out prior to the upper seam, i.e. the seam is mined in ascending order. Mining in the upper seams are not commenced until mining in the lower seams is complete. Mining procedures when done in this order are usually called overmining.

The following effects are to be expected for working in lower seam prior to the upper seam [5]:

- Problems as fractures in roof, floor lifts, uneven surface may be faced in the working seam due to prior working in lower seam.

- If the parting is less, the roof may cave even more in the lower seam and the pillars may get lost forever to be mined in the upper seam.
- Working in lower seam may cause separation of bed and may prove advantageous in upper seam while blasting off rocks.
- If the parting is very less then both the seams can be worked out with the same roadway and it can still be worked out, even if the lower seam is thinned out in certain areas.
- The effects on the surface of upper seam (due to the working of the lower seam) can be violent but will be ephemeral if the working face in the upper seam is followed shortly to that of the lower seam.

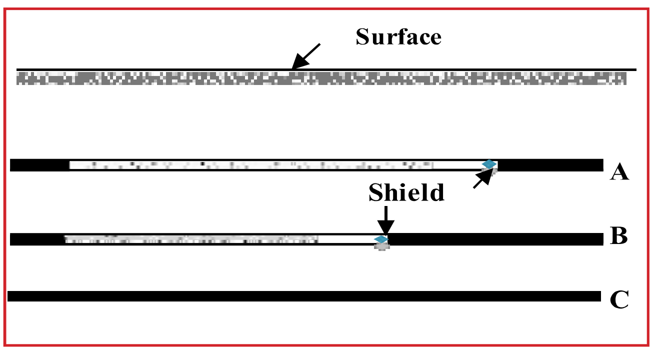

Figure 6 - Simultaneous Mining method of working

Simultaneous Mining method of working

Mining of the upper and lower seam is carried out simultaneously with development and mining being kept in advance in the upper seam. Mining procedures in this order are usually called simultaneous mining.

The following effects may be observed if the workings in both the seams are carried out simultaneously [5]

- Good roof control is possible.
- If the upper seam is mined first, then there is a chance of inundation.
- The effects of simultaneous mining on the surface are violent but ephemeral.

Any of the above alternatives can be applied as per the requirement of the situation. None of the above are universally applicable. Generally, the extraction when done in the descending order with caving is preferred [6].

Partial Mining method of working

The upper seam maybe partially developed and mined followed by extraction in the lower seam under the development section of the upper seam. This methods is known as Partial Mining.

INFLUENCING PARAMETERS FOR ANGLE OF DRAW

There are many factors which could affect the angle of draw. Some affect to a huge extent while some only affect a little. Some of the factors are as follows:

- The nature of overlying strata
- Nature of the roof
- The existence of faults and their positions
- Universal Compressive strength of Overburden
- Cleavage or natural jointing of rocks
- The thickness of the seam
- Width of the panel
- The dip of the bed and the direction of working in relation to it
- The depth from the surface
- Stiffness of overburden
- The surface contour

Nature of overburden strata

Harder and more coherent the strata is, the lesser is the angle of draw and steeper is the line of fracture. Softer and less coherent the strata is, the more is the angle of draw and the flatter is the line of fracture. Strata heavily charged with water will tend to move more readily than dry strata on account of lubricating effects of water and more subsidence is produced. Permeability of strata will have considerable effect upon the propagation of fractures and earth movements generally.

Sandstone as the material is a likely cause for reduction in angle of draw and also there can be different angles of draw in different districts of the same mines depending upon the nature of overlying strata. For example, mines which tend to have thick massive sandstone in the overburden have consequently smaller angles of draw [7].

The observed differences in the angle of draw for similar mining conditions have generally been explained by differences in sub surface conditions. Large angles of draws have been observed in areas containing thick deposits of unconsolidated materials, while smaller angles of draw have been observed where many thick components of rock strata are present above the mine [8].

Nature of the roof

The modulus of elasticity (E) of the roof strata determines the bending resistance (N) which is given by   (N/cm) where, "d" is the thickness of the rock stratum in "cm" and "b" is its "load bearing capacity". The pressure of joints and fissures decreases the bending resistance [9].

The existence of Faults and their positions

Faults are break in the continuity of the strata and subsidence tends to run into the fault plane thus affecting the angle of draw. It depends upon the direction of working with respect to the strike of the fault plane. When faults are parallel to face line the tendency for subsidence is higher. When the faults are not parallel then the system becomes complicated by the natural break of the fault. The slope of the fault also affects the angle of draw and when it is flat it tends to increase the draw enormously [10].

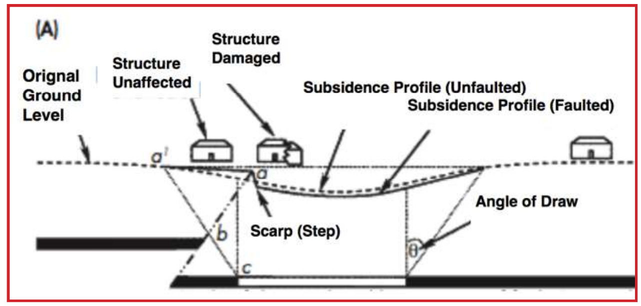

Figure 7(a) – Step like subsidence due to upthrow fault [10]

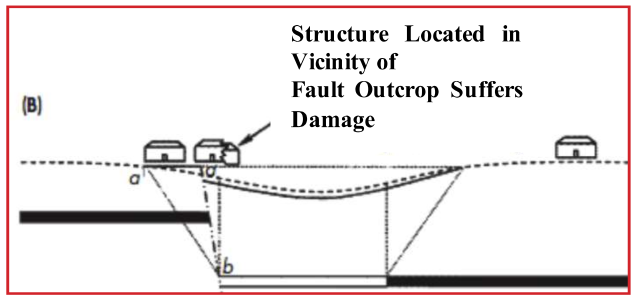

Figure 7(b) – Reduction in angle of draw due to fault [10]

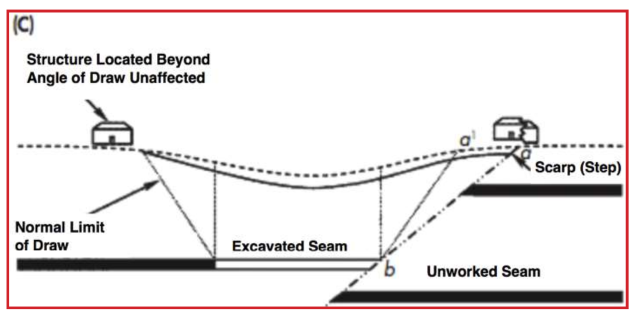

Figure 7(c) – Increase in angle of draw due to fault [10]

In Figure 7(a), the upthrow at the fault causes the step like subsidence profile. This in all causes the reduction in the overall angle of draw. The principle movement take place along the places ab and bc instead of a1bc. In Figure 7(b), the angle of draw is reduced by the presence of fault, Principal movement takes place along planes ab instead of a1b.

In Figure 7(c), the final angle of draw is increased due to the presence of the fault and the principal movement takes place along planes ab instead of a^1b.

Universal Compressive Strength of Overburden

The effect of overburden strength on the subsidence limit characteristics has been reported by Yao et al [11]. Yao and his colleagues performed comparative analysis using a series of Uniaxial Compressive Strength (UCS) as strength index for a bed/beam in the overburden in a finite element model (FEM). The results indicated that the higher the strength of the overburden stratum, the lesser is the angle of draw i.e. the extent of effect of subsidence will also be less in area of strong rock mass overburden.

Cleavage or natural jointing of rocks

If the line of advance is parallel to the natural joints it will tend to reduce the angle of draw. Whilst it is at right angle, the effect will not be so pronounced [12].

The Thickness of the seam

Thick seams when worked by slicing in descending order with caving will result in more subsidence and also in increased angle of draw [12]. This is because, as the super adjacent strata gets broken before the lower lifts are worked and hence behaves as a pulverized mass. This particular behaviour can be found in Saoner Coal Mines.

Width of the panel

The width of the panel will not at all affect the angle of draw. The width of the panel will only affect the surface area affected by the subsidence. In general, for wide extraction panels, the stronger the overburden rocks or the shallower the mining, the smaller the AoD. With weak and thinly bedded strata and where deep soils are present at the surface, the AoD may increase beyond 35 degrees [12].

The dip of the bed and the direction of working in relation to it

According to observations for the Seams dipping at different angles, the angle of draw at the dip side of the panel is greater than the angle of draw at the rise side of the panel.

For such inclined seams, the surface subsidence trough is displaced towards the deeper edge of the opening, and depending on the inclination and the depth of the seam the subsidence trough can also be located outside the edge of the opening. Subsidence is maximum at the point normal to the center and not directly above the centre as for horizontal seams. The angle of draw is not constant and it depends upon the dip of the seam. Angle of draw is smallest at the rise edge of the opening and increases towards the dip of the edge [12].

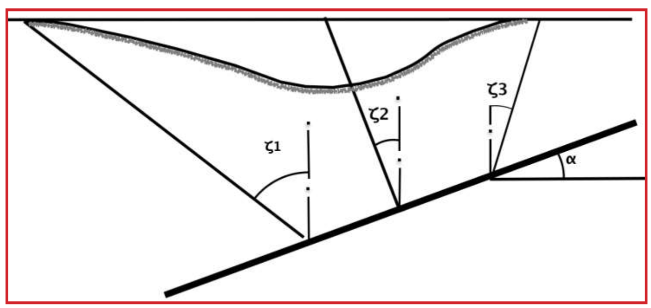

Figure 8 – Seam dipping at α with varying angles of draw ζ1, ζ2, ζ3 [12]

Angle of Draw on rise side $\theta_r = a - \left(\frac{a}{24} d\right)$

Angle of Draw on dip side $\theta_d = a + \left(\frac{24-a}{24} d\right)$

Where

a = Angle of draw in Horizontal Workings
d = Dip of Seam

Depth from the surface

Depth only has effect on the amount of area affected due to subsidence. Depth doesn't affect the angle of draw if only the strata behavior remains constant. If the strata behavior is heterogeneous then the variation in the angle of draw becomes complex and depends on various factors [12].

Stiffness of Overburden

The observations from different parts of the world does not appear to be consistent:

Some observers [13] reported that the weak and soft overburden strata would be associated with a high value of limit angle, whereas others recorded higher value of limit angle over strong overburden layers [14]. The numerical modelling could serve to provide a theoretical basis to analyze of the effect of overburden stiffness on the subsidence profile. The yielding of the overburden material would affect the subsidence characteristics. Under stratum with high Young's modulus the angle of draw would extend further away from the edge of extraction, i.e. a stiffer overburden would result in higher value of angle of draw.

The geological conditions are far more complex in the real world. The angle of draw at surface level is the product of many factors including geological setting, stiffness/strength of overburden strata, mining methods and mining configurations.

- A sub-critical subsidence profile can get developed over a long-wall panel of supercritical width when there is a stiffer/stronger beam layer present in the overburden.
- The value of angle of draw would get significantly greater when a stiffer beam layer is present in the overburden strata.
- The maximum subsidence at center of the subsidence trough is significantly reduced when there is a stiff beam layer present.
- The magnitude of subsidence in the overburden decreases progressively towards the surface and the beam would act as a barrier resisting and preventing the migration of movement upwards depending on the stiffness of the beam. With increasing stiffness of the beam, the "bridging" effect will become more and more profound with relatively little movement in the overburden. Substratum movements usually take place predominantly in the area directly above the panel and below the beat. In practice, this is the area where most of the collapsing and beds separation would occur.

The above findings are reasonably good agreement in the observed subsidence data at the Newcastle coal fields, Australia [15].

The surface contour

Surface damage is more in the vicinity of steep slopes in flat areas. The horizontal movements are greatly increased in undulating ground resulting in more disastrous effects and apparently the angle of draw is increased. The effects are disastrous when the subsidence area encapsulates the hills in a certain area and causes huge landslides [12].

CASE STUDY

The angle of draw in Indian Coal Fields is positive and varies between 4°-31°. The non-effective width varies between 0.3 to 1 times the depth. It has not been possible to establish a direct and perfect relationship between various subsidence parameters and there is need for further and more detailed investigations. Variation in the proportion of sandstone varying from 64 - 95% in the Coal Measures Succession, and its nature, is a major contributing factor in the variation of subsidence behavior [2].

Jharia coal fields in India have been blessed with 17 Billion tonnes of coal in a total of 40 seams in Barakar measures and 10 seams in Ranigunj measures and the total thickness of the seams is on an average around 12% of coal measures. In these conditions almost everywhere multiseam mining has been performed. In some situations, two or three seams are standing on developed pillars [16].

The observed values of Angle of Draw from the vertical, in different coal fields are given below:

Jharia coal fields [2]

Sudamdih Project	
(a seam dipping at 30°)	- 38°-40° dip side
	- 13°-15° rise side
	-18°-20° strike side
Moonidih Project	- 14°
Other Collieries	- 5°-27°

Ranigunj coal fields [2]

Rana	- 12°-13°
Jamuria	- 15°-17°
Dhemomain	- 5°-21°
Shivadanga incline	- 10°-22°
Amritnagar	- 15°-18°
Ningah	- 9°
Moira	- 25°-30°

Korba coal fields [2]

Surakachhar	- 7°-10°

Pench and Kanhan coal fields [2]

North chandametta	- 23°-29°
Sukri	- 20°

Karanpura coalfields [2]

Gidi A Pilot mine	- 14°- 31°

The above values of angle of draw are for a limiting vertical movement of 5mm, and in conditions of general settlement of ground, the values were determined from subsidence profiles [2].

Some other statistical values

The magnitude of the angle of draw varies widely between various coalfields. In the Southern Coalfield of New South Wales, the draw angle varies between 2° to 56°, assuming a cut-off subsidence of 20 mm. The average draw angle was 29° with nearly 70 % of the observed values below 35° [17].

Whittaker and Reddish (1989) compiled the variation in draw angles for different coalfields [8]:

- Yorkshire Coalfield (U.K.): 32°- 38°
- South Limburgh Coalfield (U.K): 35° - 40°
- US coalfields: 12° - 34°
- Czechoslovakian coalfields: 25° - 30°

It's very evident from Table 1 that the nature of overburden plays an important role in determining the magnitude of angle of draw.

CONCLUSION

These parameters that are critically responsible for the variation of angle of draw were studied. It may be observed that the influence of method of working, existence of faults, dip and direction of working on angle of draw is significant with varying degree. The variation on the values of angle of draw in different coal fields and limited observations warrants intensification of investigations. However, the observations have been useful in designing protection pillars for shafts and other surface features and structures and assessing the feasibility of extraction of coal seams underground.

ACKNOWLEDGEMENT

The views expressed in this paper are those of the authors and not of the institutes they represent.

Table 1 - Different angles of draw depending on nature of overburden

Location	Angle of Draw	Composition of overburden
Ostrava-Karvina coalfield, Czechoslovakia[18]	25-39°	-
Limburg coalfield, The Netherlands [19	35–40°	Mainy saturated sands and other unconsolidated materials
Austrian Tertiary Coal Basin [20	41–42°	Weak and saturated strata
Nord-Pas-de-Calais Coal Basin, France [21]	35°	-
Kuho (II) Mine, Japan [22]	40–50°	-
Old Ben Mine No. 24, IL, U.S.A. [23]	43°	-
South African Coalfields [24]	11°	Massive dolerite sill
Western Pennsylvania, U.S.A [25]	25°	-
Newcastle coalfield, Australia [17]	35°	-
Velenje mine, Yugoslavia [8]	33–42°	Clays, silts, sands, marls and gravels
British coalfields	27–38.6°	Mostly seatearth and mudstone
Pench and Kanhan coalfields, India [14]	41°	>62%clays in the overburden

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AN APPROACH TO ASSESS INFLUENCE OF ROCK PROPERTIES ON THE OPERATING PARAMETERS OF SURFACE MINER

Amar Prakash[1], Pradeep Sahu[2], Paratha Sarathi Paul[3]

ABSTRACT

Application of surface miners has increased phenomenally all around the world for rock excavation in varied rock mass conditions. There are numerous models of surface miners with wide range of specifications. Ability of surface miner to operate and cut effectively in rock is limited to strength property of rock. An exhaustive knowledge of rock and machine interaction is imperative for smooth operation and mass production of surface miner. The paper presents the influence of machine operating parameters on power consumption with respect to rock strength. Operating parameters such as cutting depth and cutting speed can be controlled by estimation of power required for cutting. Uniaxial compressive strength is almost exclusively used for description of the strength of the rock. The effect on power in relation to depth of cut were analysed for varied strength of rock. Cutting speed was also studied for different uniaxial compressive strength at varied depth of cut.

Keywords : *Surface miner, machine power, cutting speed, depth of cut, uniaxial compressive strength*

INTRODUCTION

Development of surface miner was initiated in 1970s and was continued into the early 1980s and marks a new pattern in surface mining system. The design concept for the surface miner is based on the milling principle and owes its origin to the road milling machines which cuts the old road surface for road construction. The application of surface miner was extended for coal mining in the year 1999 (Dey, 2012).

The conventional system of mining coal by opencast method involves drilling, blasting, excavating and crushing. The HEMM involves in different process are shovel, drill machine, dozer, dumper, dragline, grader etc. Mining operations are invariably associated with terminal effect of land degradation, ecological disturbances, noise and air pollution and consequent upon overall environmental deterioration. Blasting operation on a large scale give rise to blast-induced ground vibrations, airblast, fly rock, blasting fumes, dust cloud, noise, disturbance to water regimes and damage to nearby structures. The quality management in opencast coal mines with the layers of grey shale/carbonaceous shale, stone bands, dirt bands etc. has

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become a difficult task by conventional method of mining. These factors have prompted the mining community to look for a non-conventional method and to increase "Quality Production" and productivity while meeting the requirement of being environmentally safe operations.

In such situations conveyor transport system may prove to be economical, but that need smaller and sized material, which can be obtained by use of excavation by cutting process. This condition leads the use of surface miner in rock cutting process. Presently, around 422 surface miners are in operation around the world amongst which, 114 are in India (www.media.wirtgen-group.com). This necessitates an in-depth study of different machine configurations, their performance with different rock mass conditions. Operating speed and depth of cut both complement relative to each other. For optimum production of machine an appropriate balance between cutting speed and depth cut is imperative. Exceeding the depth of cut or cutting speed for a given rock strength will increase the cutting force and hence required power for the machine. Therefore, for a given job site, a reliable evaluation of the required cutting speed and depth of cut can be obtained according to the available machine power.

METHODOLOGY

Estimation of cutting force for picks

Many models have been developed in order to evaluate the force between the cutting tools and the rock during the cutting process. Those are the Evans model (Evans, 1972; Evans, 1982; Evans, 1984a; Evans, 1984b; Evans, 1984c; Roxborough and Phillips, 1975) for rolling tools, and the Nishimatsu model (1972) for drag tools, which among all the Evans theory is considered the closest to the force estimation for pick.

Rock breakage with a pick depends basically on the pick penetrating the rock. Numerous theories of rock cutting have been deployed by many researchers. The most relevant theory for point attack picks proposed by Evan's is discussed here as these picks are used in surface miner.

The Evans theory state that, a tool gains initial entry into the rock by reason of the concentration of stress under a sharp edge. Stress concentration is a result of interaction between cutting forces and mechanical properties of the rock being cut (Fig. 1). Stress initially causes some frictional crushing and elastic deformation until the stress exceeds the rock strength and rupture eventually takes place.

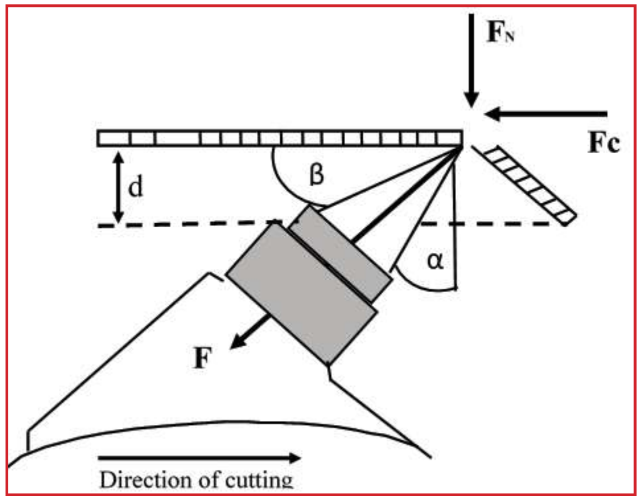

Fig. 1: Force on a cutter pick

Evans's theory for point-attack picks attempts to enable the engineers to estimate the peak cutting force for a given rock, when direct measurement of the cutting force is not available. Theoretical works of Evans were used to establish the basic principles of the cutting process and these have been widely used in the efficient design of excavation machines such as shearers, continuous miners and roadheaders (Ortega and Glowka, 1984). Evans demonstrated theoretically that tensile strength and compressive strength were dominant rock properties in rock cutting with chisel picks and point attack tools as formulated below in:

$$fc = \frac{16\pi d^2 \sigma_t^2}{cos^2\left(\frac{\theta}{2}\right)\sigma_c}$$

This equation is used only for point attack picks, where FC is cutting force in N, d is depth of cut in mm, σt is tensile strength in MPa, σC is compressive strength in MPa and □ is tip angle.

Cutting force for single tool is calculated by this equation. And total cutting force for drum can be calculated by knowing the number of picks coming into the contact of rocks. The total number of picks coming in contact with rock can be calculated when the depth of cut and drum configuration is known including total number of cutting tools. The number of active picks in contact with the rock depends on radius of the drum and is expressed as:

$$n = \frac{N * CA}{2\pi RW} \quad (2)$$

Where, N= total number of picks mounted on drum,

R= radius of drum in m and
W= width of drum in m.

various models of surface miners (2200SM, 2200 SM 3.8, KSM 304) was calculated from the above equations and is shown in Table 1. The specifications of the above models are given in Table 2 (Prakash, 2013).

Machine power

The estimated power in rock cutting by drum depends on operating speed of the surface miner and cutting force applied by the picks on the rock and is expressed as:

$$P_e = \frac{D_f * CS}{60}$$

Where, D_f= total force on drum and
CS = cutting speed in m/min

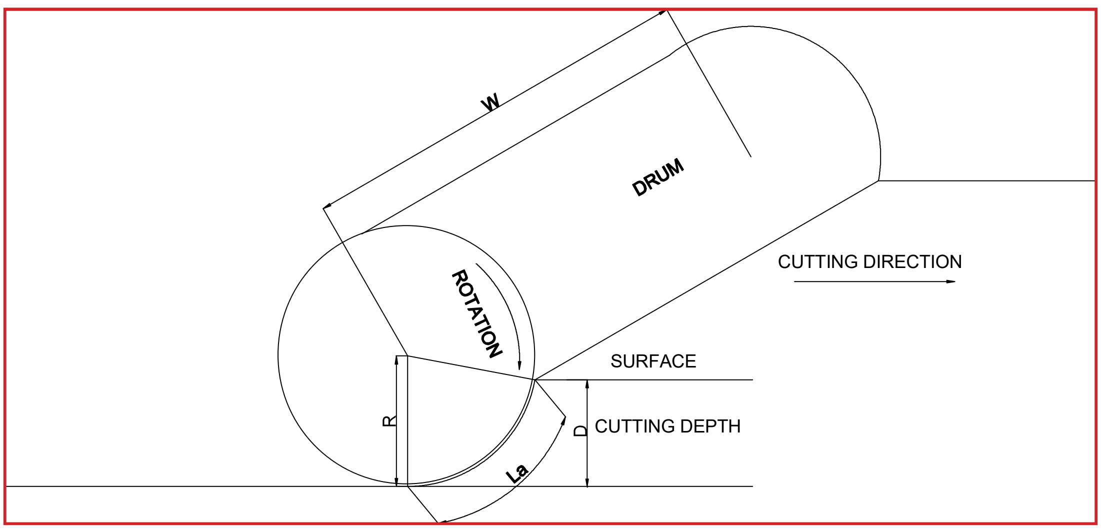

Fig. 2: Number of cutting picks coming into the contact of rock

CA is contact area between rock and drum (Fig. 2) and it is equal to the product of total length of arc of drum and width of the drum.
Length of arc of drum can be estimated by an equation (3),

$$L_a = \frac{2\pi R \cos^{-1}\left(\frac{R-doc}{R}\right)}{360} \quad (3)$$

Where La = contact length of cutting drum in m and
doc = depth of cut in m

By using the equations 1, 2 and 3 total force for drum can be calculated. The contact area (CA) of

Since the actual power of the machine cannot be used for cutting. So for the preventing of overloading of the machine, the condition should be

Pe<Pa
Where, Pa is actual power of the machine

In previous studies this transfer ratio has been taken as 0.45 to 0.55 for roadheaders and 0.85 to 0.90 for tunnel boring machine (Rostami and Ozdemir, 1994). As per SME (2014) 60% of the total actual power can only be utilized for cutting. Hence, power required for cutting can be expressed as:

Pe = 0.6 Pa

Table 1: Contact area and total force for drum on various models

Depth of cut (mm)	KSM 304		2200 SM 3.8		2200 SM	
	Contact Area (m^2)	Force in drum (kN)	Contact Area (m^2)	Force in drum (kN)	Contact Area (m^2)	Force in drum (kN)
5	0.25	0.07	0.31	0.07	0.17	0.06
10	0.35	0.41	0.43	0.40	0.23	0.32
15	0.43	1.13	0.53	1.09	0.29	0.89
20	0.50	2.32	0.61	2.24	0.34	1.82
25	0.55	4.06	0.69	3.92	0.37	3.18
50	0.79	23.05	0.97	22.25	0.53	18.07
100	1.12	131.24	1.39	126.70	0.75	103.03
150	1.38	364.03	1.71	351.57	0.93	286.19
200	1.61	752.36	1.99	726.87	1.08	592.36

Table 2: Specifications of different models of surface miner

Model	Drum Diameter (m)	Drum Width (m)	Total no. of picks	Rated Power (kW)	Depth of Cut (mm)	Cutting Speed (m/min)
2200 SM	1.14	2.2	76	597	0-200	0-25
2200 SM	1.3	3.8	100	708	0-350	0-84
KSM 304	1.35	3	106	900	0-400	0-20

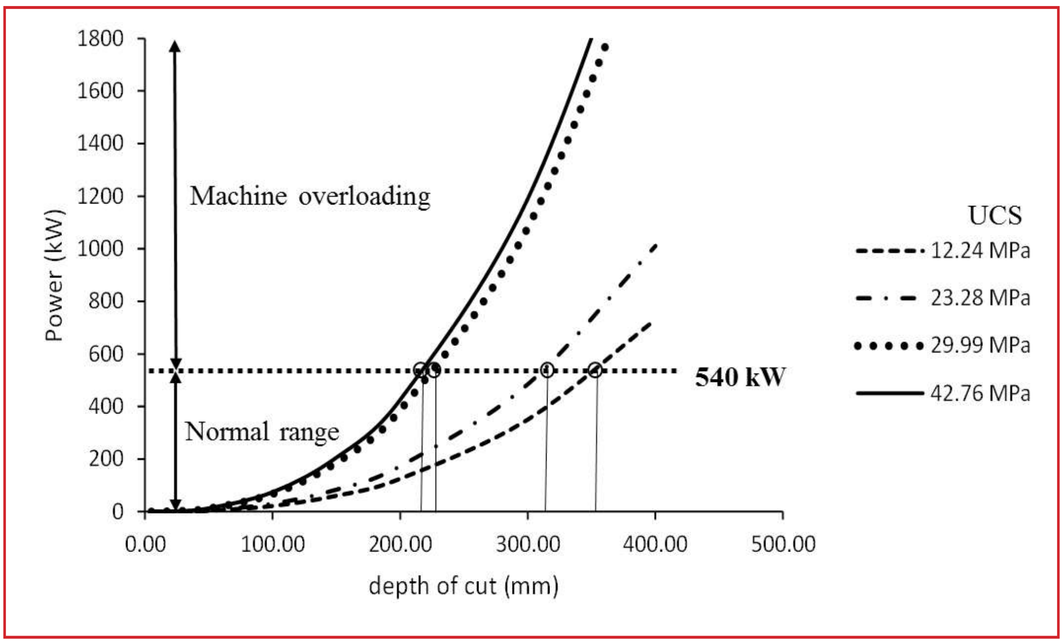

Fig. 3: Power with depth of cut on varied UCS at speed 10 m/min

ANALYSIS AND DISCUSSION

Influence of operating parameters

Analysis on operating parameters was done on the basis of machine power. Study at varied operating speed and cutting depth was performed for different intact rock properties. All the analysis was conducted for KSM 304 model because the total number of picks mounted on drum was available for this model. The boundary limit of cutting speed and depth of cut used for the analysis was taken as per specification given by the manufacturers.

The total actual power specified for KSM 304 is

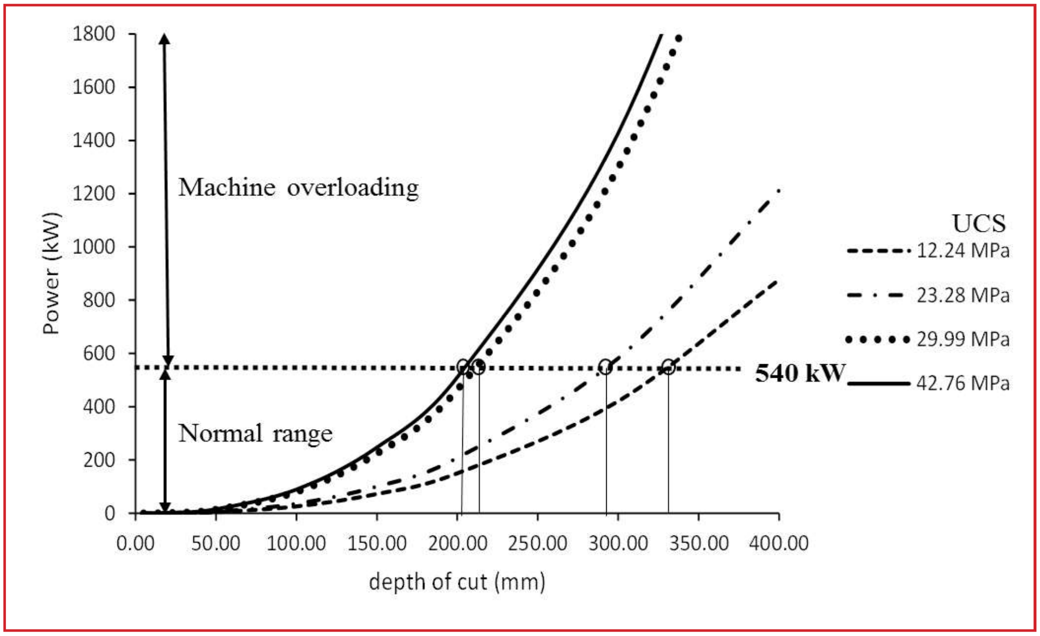

Fig. 4: Power with depth of cut on varied UCS at speed 12 m/min

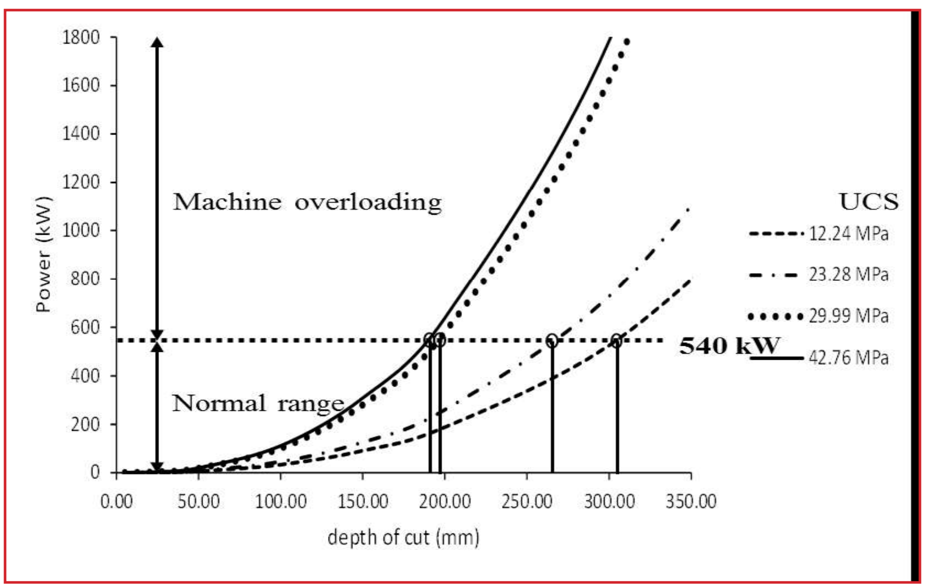

Fig. 5: Power with depth of cut on varied UCS at speed 15 m/min

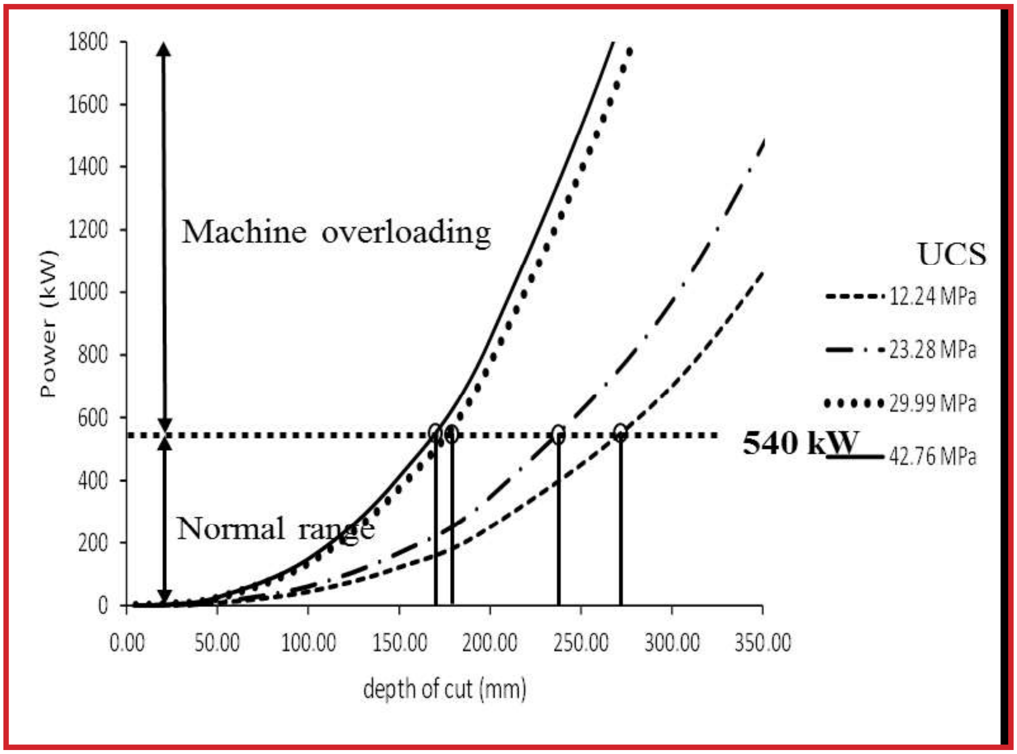

Fig. 6: Power with depth of cut on varied UCS at speed 20 m/min

900 kW. Assuming that only 60% power of the total actual power can only be utilized for cutting, the machine can be operated within a range of 540 kW followed by the equation 5. Total power was calculated for different operating speeds by using equation 4.

Power was projected for the different UCS values of 12.24, 23.28, 29.99 and 42.76 MPa. This range of compressive strength was considered because these values were determined from mines of Eastern Coalfields Limited (ECL) and Mahandi Coalfields Limited (MCL) where surface miners were deputed. The operating speed was taken as 10, 12, 15 and 20 m/min because most of the surface miners were found to operate in this range. Hence, these data were used for analysis as they can bolster in deciding the suitable operating condition under realistic ground condition.

The depth of cut decreases with increase in compressive strength of the rock. The surface miner can operate up to a maximum depth of cut of 355 mm for the uniaxial compressive strength (UCS) of 12.25 MPa at 10 m/min cutting speed. On the other hand, the optimum depth of cut should be 220 mm for 42.76 MPa UCS. The machine can be considered to be overloaded if operated above this range which can be well interpreted in Fig. 3. Hence for a given strength of rock machine should be operated under safe limit to achieve the desired production with minimum maintenance and breakdown.

The optimum depth of cut comes to 330 mm for 12.24 MPa strength of rock at 12 m/min operating speed of surface miner as shown in Fig. 4. The maximum possible depth of cut reduces to 205 mm for 42.76 MPa strength of rock at same speed.

For the cutting speed of 15 m/min and 20 m/min the maximum depth of cut for UCS 12.24 MPa can be 303 mm and 270 mm respectively whereas for UCS 42.76 MPa maximum depth can be 187 mm and 165 mm (Fig. 5 and Fig. 6).

Thus, it can be inferred from the figures that depth of cut, UCS and engine power has a significant impact on the cutting speed. The same was also observed by Chiara *et al.,* 2014.

Based on the developed relations the cutting speed in correspondence to depth of cut for a known

Table 3: speed and depth of cut for different strength of rock

UCS (MPa)	Cutting speed	Depth of cut (mm)
12.24	10	355
	12	330
	15	303
	20	270
23.28	10	315
	12	290
	15	267
	20	238
29.99	10	255
	12	235
	15	215
	20	190
42.76	10	220
	12	205
	15	187
	20	165

Table 4: relation between UCS and speed for given depth of cut

Depth of cut (mm)	Relation with UCS	R^2 value
50	Speed = $189.2e^{-0.024(UCS)}$	$R^2 = 0.90$
100	Speed = $33.108e^{-0.024(UCS)}$	$R^2 = 0.89$
200	Speed = $5.9213e^{-0.024(UCS)}$	$R^2 = 0.91$
300	Speed = $2.0748e^{-0.023(UCS)}$	$R^2 = 0.88$
400	Speed = $0.9889e^{-0.024(UCS)}$	$R^2 = 0.91$

Note: speed is in m/min and UCS is in MPa

strength of rock is given in Table 3. The relation for different depth of cut ranging from 50 to 400 mm was developed to achieve suitable cutting speed of surface miner with UCS as given in Table 4 and represented graphically in Fig. 7. The cutting speed was found to be exponentially related to UCS with encouraging index of determination.

This figure would be helpful in guiding to operate the surface miner in safe range for given strength of rock. Machine breakdown can be reduced if operated by taking into consideration the influence of intact rock property i.e. compressive strength. This will also impart an idea for operators to prevent overloading of the machine. Eventually, machine production can be optimized by the proper utilization of operating parameters.

CONCLUSION

Operating parameters of surface miner (cutting speed and depth of cut) in relation to rock properties are prime factors for optimum utilization of surface miner with minimum breakdown and maintenance. For a given model of surface miner especially with respect to machine power, optimum cutting speed was correlated with UCS by varying the depth of cut.

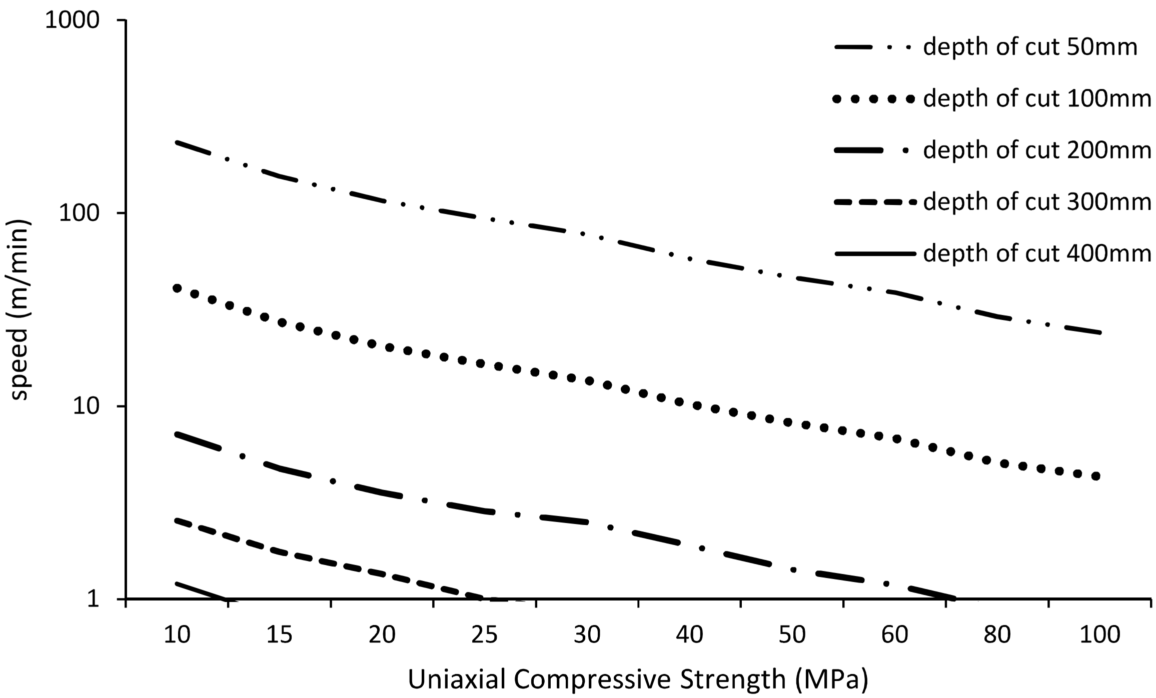

Fig 7: Relation between speed and UCS for different depth of cut

A series of relations were derived to describe the trend of cutting speed according to the rock strength. This will provide a preliminary guideline in pre-estimation of cutting speed and depth of cut to the machine operator (for a given site), so as to prevent the machine from overloading during cutting operation. Cutting speed of surface miner was also correlated with UCS under varied depth of cutting with index of determination varying from 0.88 to 0.90.

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कोयला क्षेत्र के लिए प्रौद्योगिकी आकलन एवं पूर्वानुमान - एक अवधारणा

डॉ पिजुश पाल रॉय[1] , डॉ निशान्त कुमार श्रीवास्तव[2]

सारांश

जीएसआई, सीएमपीडीआई, एससीसीएल एवं एमईसीएल, आदि के द्वारा 1200 मीटर की अधिकतम गहराई तक किए गए जाँच पड़ताल के पीरणामस्वरूप, देश में अब तक कुल 301.56 बिलियन टन कोयले के भूगर्भीय संसाधनों का अनुमान लगाया गया है, जिसका मात्र 30% विभिन्न बाधाओं जैसे वन भूमि, अनौपचारिक निष्कर्षण, उच्च गहराई पर कोयले का जमाव, विभिन्न पर्यावरणीय मुद्दों एवं उपयुक्त प्रौद्योगकियों की कमी के कारण निष्कार्ण/खुदाई योग्य है। इस संदर्भ में कोयला उद्योग को लगभन 90 बिलियन टन कोयले के निकर्षण हेतु सफल तकनीक एवं क्रमबद्ध योजना की आवश्यकता है, क्योंकि अधिकतर कोयला 300 मीटर से नीचे तथा 1200 मीटर गहराई तक है। प्रस्तुत वैचारिक नोट में, वांछित लक्ष्य को चरणबद्ध तरीके द्वारा प्राप्त करने हेतु कोयला क्षेत्र के लिए नई, उन्नत एवं आर्थिक रूप से व्यवहार्य पद्धतियों के तकनीकी मूल्यांकन एवं भविष्यवाणी पर प्रकाश डाला गया है।

ABSTRACT

As a result of exploration carried out up to the maximum depth of 1200m by the GSI, CMPDI, SCCL and MECL etc., a cumulative total of 301.56 billion tones of Geological Resources of Coal have to far been estimated in the country, out of which only around 30% is extractable/mineable due to various constraints like forest land, uneconomic extraction, higher depth of deposits, various environmental issues and lack of suitable technologies. At this juncture, the coal industry needs technological breakthrough and systematic planning to extract nearly 90 billion tones of coal reserves, a majority of which the below 300 m and up to 1200 m depth of cover. In a conceptual note, the present paper highlights the technology assessment and forecasting or new, upgraded and economically-viable methodologies for the coal sector to achieve the desired target stepwise.

प्रस्तावना

भारत में वर्तमान कोयला उत्पादन लगभग 650 मिलियन टन है तथा सन 2030 के लिए कोयले का अनुमानित लक्ष्य 150 मिलियन टन, स्टील का 200 मिलियन टन एवं विद्युत उत्पादन का लगभग 2,00,000 मेगावाट है। इस 12 वर्ष की अवधि के भीतर इस विशाल लक्ष्य की प्राप्ति हेतु भूमिगत एवं ओपनकास्ट खदानों की समुचित योजना तथा मशीनीकरण द्वारा समर्थित नवीन एवं परिष्कृत प्रौद्योगिकियों की नितांत आवश्यकता है। वर्तमान स्तर के मशीनीकरण द्वारा कम गहराई वाले ओपनकास्ट का खनन सीमित तथा शीघ्र ही समाप्त हो जाती है। अत: उच्च गहराई (300 मीटर तथा अधिक) पर कोयले के निष्कर्षण हेतु विशेष महत्व देने की आवश्यकता है। इस संदर्भ में, उल्लेखनीय है कि चीन में 270 मिलियन टन कोयले का लगभग 95% उत्पादन भूमिगत खनन के माध्यम से किया जा रहा है। इस प्रकार, देश में कोयले की विशाल लक्ष्य प्राप्ति हेतु भूमिगत खनन द्वारा उत्पादन एवं उत्पादकता समय की आवश्यकता है।

इस समय, शोध एवं विकास संगठन, शिक्षा संस्थान तथा कोयला मंत्रालय संयुक्त रूप से पूर्वयोजित पद्धति एवं प्रौद्योगिकी नवीनीकरण में एक प्रधान भूमिका निभा सकते हैं (सीसीओ, 2012; सीआईएल, 2012; और एमओसी, 2013).

[1] निदेशक, बीसीआरईसी, दुर्गापुर, [2]प्रधान वैज्ञानिक सीएसआइआर-सीएमआरआई, धनबाद

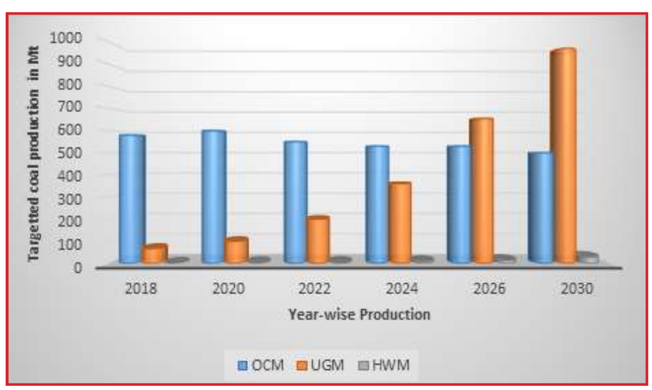
उत्पादन का पूर्वानुमान

वर्तमान में, भारत में 595 कोयला खदानों द्वारा लगभग 650 मिलियन टन कोयले का उत्पादन होता है, जिसमें 384 भूमिगत कोयला खदानों से लगभग 70 मिलियन टन तथा शेष 580 मिलियन टन उत्पादन 211 ओपनकास्ट कोयले की खदानों से होता है। सन् 2030 तक 1500 मिलियन टन के लक्षित उत्पादन को प्राप्त हेतु वर्तमान परिदृश्य को बदलना होगा और सतही भूमि अधिग्रहण, जनसंख्या वृद्धि एवं पर्यावरणीय समस्याओं एवं उपलब्ध कायले के जमाव के आधार पर गहरे कोयले की खानों (300-1500 मीटर तक) पर ध्यान केंद्रित करना होगा। अत: वर्षवार परिदृश्य निम्नलिखित हो सकता ह।

2018 (650 मिलियन टन)	ओपनकास्ट खदान-211, उत्पादन : 580 मिलियन टन (89.23%) भूमिगत खदान; 384 - उत्पादन : 67 मिलियन टन (10.3%) हाईवॉल खनन - उत्पादन 2 मिलियन टन
2020 2019 (705 मिलियन टन)	ओपनकास्ट खदान -2015, उत्पादन 600 मिलियन टन (85%) भूमिगत खदान - 400, उत्पादन: 100 मिलियन टन (14%) हाईवॉल खनन - उत्पादन: 5 मिलियन टन
2022 (756 मिलियन टन)	ओपनकास्ट खदान -210, उत्पादन: 550 मिलियन टन (72.75%) भूमिगत खदान; 415 - उत्पादन: 200 मिलियन टन (26.45:) हाईवॉल खनन - उत्पादन: 6 मिलियन टन
2024 (900 मिलियन टन)	ओपनकास्ट खदान- 200, उत्पादन: 530 मिलियन टन (59:) भूमिगत खदान; 425 - उत्पादन; 360 मिलियन टन (40:) हाईवॉल खनन - उत्पादन; 10 मिलियन टन
2026 (1200 मिलियन टन)	ओपनकास्ट खदान- 190, उत्पादन: 530 मिलियन टन (44:) भूमिगत खदान; 450 - उत्पादन; 655 मिलियन टन 54.75:) हाईवॉल खनन - उत्पादन; 15 मिलियन टन
2030 (1500 मिलियन टन)	ओपनकास्ट खदान- 170 , उत्पादन: 500 मिलियन टन (33:) भूमिगत खदन; 550 - उत्पादन; 970 मिलियन टन (65:) हाईवॉल खनन - उत्पादन; 30 मिलियन टन

कोयला खानों द्वारा अपेक्षित उत्पादन लक्ष्य

उपर्युक्त लक्ष्य की प्राप्ति हेतु कोयला उद्योग को नई तकनीक पर ध्यान केंद्रित करना है तथा वर्तमान खनन संचालन को और अधिक प्रभावी रूप से प्रारम्भ करना है ताकि 300 से नीचे तथा 1500 मीटर की गहराई तक भूमिगत खदानों से कोयले का उत्पादन किया जा सके। गहराई में जमे कोयले के उत्पादन हेतु भूमिगत खानों की व्यापक उत्पादन तकनीक जैसे लौंगवाल खनन एवं खनिकों का निरंतर उपयोग सबसे व्यावहारिक विकल्प हो सकता है। कुछ कोयला खानों में मशीनिंग के माध्यम से खनिकों के निरंतर उपयोग द्वारा कोयला निष्कर्षण पहले ही लोकप्रिय हो चुका है। लॉक-अप कोयले की एक महत्वपूर्ण मात्रा को पुनर्प्राप्त करने के लिए



चित्र-1-भारतीय कोयला खानों के लिए उत्पादन का पूर्वानुमान

विभिन्न क्षमताओं वाले हाईवॉल माइनर को अपनाया जा सकता है।

सन् 2018 एवं 2030 के दौरान कोयला उत्पादन का अनुमानित ब्रेक-अप नीचे सूचीबद्ध है। चित्र-1 में भारतीय कोयले की खानों के सालाना उत्पादन के पूर्वानुमान दर्शाया गया है।

वर्तमान

2018 ओपन कास्ट खदान : 2000 - 30,000 टन/दिन
भूमिगत खदान : 200 - 500 टन/दिन (बोर्ड एवं स्तंभ)
2000 - 3000 टन/दिन (सतत खनिक)
1500 - 2000 टन/दिन (लॉन्गवॉल खनन)

लक्ष्य

2030 ओपनकास्ट खदान : 5000 - 50,000 टन/दिन
भूमिगत खदान : 1000 - 2000 टन/दिन (बोर्ड एवं स्तंभ)
8000 - 5,000 टन/दिन (सतत खनिक)
8000 - 20,000 टन/दिन (लॉन्गवॉल खनन)
5000 - 8000 टन/दिन (हाईवॉल खनन)

तालिका-1, कार्बन डाई ऑक्साइड के समकक्ष वर्तमान वैश्विक उत्सर्जन (मिलियन टन)

देश	उत्सर्जन (मि टन)	वैश्विक शेयर (:)
चीन	7219-2	19-1
अमेरिका	6963-8	18-4
यूरोपीय संघ	5047-7	13-3
रूस	1960-0	5-1
भारत	1832-9	4-9
जापान	1342-7	3-5
ब्राजील	1014-1	2-7
जर्मनी	077-4	2-6
कनाडा	731-6	1-9
ब्रिटैन	639-8	1-7

ग्लोबल वॉर्मिंग

ग्लोबल वार्मिंग का विषय विश्व ऊर्जा नीति का एक प्रमुख एवं अपरिहार्य अंग बन गया हैं मानव गतिविधियों द्वारा वर्ष लगभग 29 बिलियन टन कार्बन-डाई-ऑक्साइड उत्पन्न हो रहा है, जबकि 23 अरब टन का योगदान जीवाश्म ईंधन दहन एवं उद्योग से है (आईपीसीसी, 2001) जिससे कारण वायुमंडलीय व्यवस्था अस्त-व्यस्त होती जा रही है। भारत में, वर्तमान में लगभग 1850 मिलियन टन कार्बन-डाई-ऑक्साइड उत्पन्न हो रहा है इस भयावह स्थिति से मुक्ति हेतु हमें 2,00,000 मेगावाट बिजली के वांछित लक्ष्य को प्राप्त करने के लिए कोल बेड मीथेन/कार्बन माइन मीथेन के प्रति ध्यान देना होगा।

कोपेनहेगन में आयोजित 15वां संयुक्त राष्ट्र जलवायु परिवर्तन सम्मेलन में 2 साल पहले ही विश्व को एक समय सीमा का निर्धारण हो चुका है। इस महत्वपूर्ण बैठक में 192 देशों ने भाग लिया तथा औद्योगिक एवं विकासशील देशों के विभिन्न कार्यों के माध्यम से वर्ष 2012 के बाद के वर्षों में अर्थ-वार्मिंग कार्बन-डाइऑक्साइड एवं अन्य ग्रीन हाउस गैसों के उत्सर्जन को कम करने या सीमित करने के लिए उचित रणनीतियों को अंतिम रूप दिया गया। चीन का कुल उत्सर्जन दुनिया में सबसे ज्यादा हैं तथा इसमें भारत पाँचवें स्थान पर है (तालिका-1)

सीएसआइर्कआर-केंद्रीय खनन एवं ईंधन अनुसंधान संस्थान अग्रणी पथ प्रदर्शक के रूप में

संपूर्ण रूप से ऊर्जा के विभिन्न आयाम पर महत्व प्रदान करते हुए 2 अप्रैल, 2007 को भारत सरकार ने केंद्रीय खनन अनु. संधान संस्थान (सीएमआरआई; 10 मई 1956 में स्थापित), और केंद्रीय ईंधन अनुसंधान संस्थान (सीएफआरआई; 17 नवम्बर 1946 में स्थापित) को ''खनन एवं ईंधन अनु. संधान में वैश्विक लीडर एवं पथ प्रदर्शक'' उद्देश्य से सीएसआईआर- केंद्रीय खनन एवं ईंधन अनुसंधान संस्थान (CSOR-CIMFR) नामक एक नई इकाई में विलय कर दिया है। इस संस्थान में योग्य एवं प्रशिक्षित वैज्ञानिक लगभग 50 विभिन्न शोध क्षेत्रों में काम कर रहे हैं ताकि खनिज क्षेत्र में बेहतर सुरक्षा, अर्थव्यवस्था तथा संरक्षण, पर्यावरण प्रबंधन आदि के लिए खनन और ईंधन विज्ञान प्रौद्योगिकियों के सफल क्रियान्वयन हेतु उचित वैज्ञानिक एवं तकनीकी इनपुट प्रदान किया जा सके। संस्थान के वर्तमान शोध एवं विकास कार्यक्रम निम्नलिखित है (CSIR-CIMFR] 2016&17)

- विभिन्न भू-खनन परिस्थितियों उपलब्ध कोयला एवं खनिज के सुरक्षित तथा आर्थिक उपयोग हेतु प्रौद्योगिकियों का विकास
- खानों में सुरक्षा मानकों को सुधारने के लिए विधियों एवं उपकरणों का विकास
- सुरंगों, बांधों, गुफाओं तथा चट्टान ढलानों के स्थिरीकरण जैसे भूमिगत खुदाई का विकास
- सुरक्षित विस्फोट एवं अन्य उत्खनन तकनीकों और विस्फोटकों का विकास
- खानों, सुरंगों एवं भूमिगत गुफाओं में कम्प्यूटर और सूचना प्रौद्योगिकी के गणितीय मॉडलिंग तथा उसके अनुप्रयोग
- कोल बेड मीथेन (CBM) एवं भूमिगत कोयला गैसीकरण (UCG)
- परीक्षण, मूल्यांकन एवं अंशांकन हेतु राष्ट्रीय सुविधाएं
- कोयला एवं अन्य वैकल्पिक ईंधन का गुणवता मूल्यांकन
- कोयले से तरल प्रौद्योगिकी एवं कोयला गैसीकरण
- पावर कोल एवं अभिलक्षण

इस संस्थान में सुरंग समर्थन डिजाइन और स्थिरता, नाजुक चट्टानों की भंजन शक्ति एवं संख्यात्मक मॉडलिंग आदि विषयों पर ऑस्ट्रेलिया, जापान, अमेरिका, चेक गणराज्य तथा यूक्रेन के साथ कई सहयोगी परियोजनाएं हैं।

सीएसआईआर- केंद्रीय खनन एवं ईंधन अनुसंधान संस्थान द्वारा विकसित कुछ स्थापित तकनीकों के अतिरिक्त पिलर स्ट्रेन्थ परीक्षण, वाइड-स्टाल खनन, हाईवॉल खनन, मल. टीजोनल वेंटिलेशन सिस्टम, संवेदनशील क्षेत्रों में नियंत्रित विस्फोटक तकनीक, 3-डी सबसिडेंस मॉडलिंग, उड़न राख भराव, केबल-बोल्टिंग विधि, इत्यादि, संस्थान ने हाल ही में उच्च-राख भारतीय कोयलों के गैसीफिकेशन गुणों का अध्ययन करने के लिए 20 किग्रा/घंटा प्रेशराईज्ड फ्लूडाइज्ड बेड गैसीफायर (PFBG) को स्थापित किया है। ताप विद्युत संयंत्रों में उपयोग से पहले देश के सभी कोयला क्षेत्रों से कोयले के नमूनों का गुणवता निर्धारण किया जा रहा है। गैसीफिकेशन गुणों का अध्ययन विशेष रूप से कोयले की गैसीफिकेशन, राख के संचलन व्यवहार और विभिन्न ऑपरेटिंग स्थितियों और कोयला गुणों के साथ विभिन्न कोयलों के प्रवेश की दिशा में कोयले की प्रतिक्रियाशीलता हेतु नमूनों का भी चयन किया जाता है। इन अध्ययनों से प्राप्त आकड़ो का उपयोग उच्च-राख कोयले का उपयोग करने वाल उपयुक्त गैसीफायर के चयन के लिए किया जा सकता है। कोयला से तरल (FT process) पर कोयला मंत्रालय द्वारा अनुदानित परियोजना पर कार्य किया जा रहा है। सीएसआईआर-सिंफर मैसर्स सिंगरेनी कोलियरीज कम्पनी लिमिटेड (SCCL) और क्वारी (SEB & AB) के रामग. ुंडम ओपकास्ट प्रोजेक्ट -11 में पहली दो हाईवॉल खनन साइटों के लिए वैज्ञानिक निष्कर्षण डिजाइन प्रदान करके भ. ारतीय भूगर्भीय स्थितियों के लिए हाईवॉल खनन प्रौद्योगिकी को अनुकूलित करने में महत्वपूर्ण भूमिका निभा रहा है। मेसर्स टाटा स्टील लिमिटेड (TSL), पश्चिम बोकारो द्वारा न्यूमेरिकल सिमुलेशन के माध्यम से स्वदेशी प्रौद्योगिकी एवं आधारभूत-आंकणों का उपयोग करके लॉक-अप कोयले की विशाल मात्रा को निकालने में उपयोग किया। संस्थान ने नवीनतम और उन्नत वैज्ञानिक तकनीकों का उपयोग करके वर्गीकरण, निष्कर्षण, परीक्षण तथा भंडारण के क्षेत्रों में कोल माइन मीथेन एवं कोल बेड मीथेन पर व्यापक अनुसंधान एवं विकास में दक्षता भी हासिल की है।

प्रमुख ज्ञान-क्षेत्र की पहचान

विभिन्न संगठनों द्वारा कोयले के निष्कर्षण एवं उपयोग पर भारत में किए जा रहे शोध एवं विकास के प्रयासों को देखते हुए लेखको का मानना है निम्नलिखित चिन्हित क्षेत्रों

में उच्च-तकनीक, आधारिक संरचना एवं मानव संसाधनों का कुशल उपयोग का करते हुए अधिक केंद्रित प्रयास की आवश्यकता है।

अ) खदानों में कार्य-पर्यावरण में सुधार

i) डी-गैसीकरण - कोल बेड मीथेन
ii) गर्मी, आर्द्रता एवं वेंटिलेशन
iii) कम शोर, धूल, कंपन, गैस तथा धुएं
iv) शुद्ध जल प्रबंधन

ब) **रॉक मास विश्लेषण**

i) तनाव मैपिंग
ii) स्वच्छ कोयला खनन
iii) तरल कोयला रूपांतरण (प्रत्यक्ष एवं अप्रत्यक्ष)
iv) कुशल उपयोग के लिए कोयला गुणवत्ता आकलन

स) **उन्नत कोयला निष्कर्षण तकनीक**

i) दूर तक गहराई में (UG)
ii) सतही संरचनाओं के आस-पास (ओपनकास्ट)
iii) विस्तृत मोर्टार, जल प्रतिरोधी एएनएफओ, गैर-डिटोनेट कारतूस जैसे ऑटो स्टेम, कैप्सुल्ड संपीड़ित गैस कारतूस जैसे एयरडॉक्स, तरल जेट सिस्टम, मैके. निकल/इलेक्ट्रिकल विधि, आदि।

वर्तमान प्रौद्योगिकी परिदृश्य

भारत में भूमिगत कोयला खनन ने अपने कम उत्पादन और उत्पादकता के कारण कम लोकप्रिय है। निसंदेह कम विकसित तकनीक इस परिदृश्य का मुख्य कारण है। भारतीय खनन उद्योग को उपयुक्त तथा उन्नत तकनीक की अत्यंत आवश्यकता है क्योंकि परंपरागत डी-पिलरिंग तकनीक से उत्पादकता की कमी हो रही है। भारत में कोयले की बढ़ती मांग को पूरा करने के लिए पिलर गठन से बड़ी संख्या में कोयला सीम विकसित किए गए हैं। यह भूमिगत कोयले की खानों से कोयला उत्पादन की एक सरल और सुरक्षित विधि है। सक्षम कोयले के तहों एवं आसपास के चट्टानी की उपस्थिति के कारण पिलर के गठन द्वारा कोयले के निष्कर्षण की प्रक्रिया को और सहज बनाया जा सकता है। भारतीय कोयला खान विनियमन, 1957 (CMR, 1957) पिलर निर्माण के लिए भी काफी उदार है। कम पूंजी निदेश और छोटी तकनीकी विशेषज्ञता की भागीदारी के कारण कोयला उत्पादन की यह रणनीति भारतीय कोयला खनन उद्योग के लिए भी उपयुक्त पाई गई। परिणामस्वरूप, भारत में कोयला रिजर्व की भारी मात्रा पिलर में अवस्थित है, इन पिलर्स से पारंपरिक डी-पिलरिंग जो कम उत्पादन, उत्पादकता एवं कम लाभप्रद होने के कारण उपयुक्त नहीं है। परंपरागत डी-पिलरिंग द्वारा प्रायः स्तर-नियंत्रण की समस्या का सामना करना पड़ता है। वास्तव में मुख्य रूप से 200 मीटर के भीतर कवर की कम गहराई के नीचे पिलर पर बड़ी संख्या में कोयला सीम उपलब्ध हैं तथा इसके सुरक्षित एवं लाभप्रद सुनिश्चित निष्कर्षण के लिए उपयुक्त भूमिगत खनन प्रौद्योगिकी की अति आवश्यकता है। सीएसआईआर (वैज्ञानिक और औद्योगिक अनुसंधान परिषद) द्वारा कृत्रिम कोयले के पिलर की अवधारणा के उपयोग पर सीएसआईआर-सिंफर को एक नेटवर्क परियोजना अनुदानित की गई थी। लेकिन उक्त अध्ययन किसी भी क्षेत्र परीक्षण के बिना वैचारिक मोड में ही बना रहा। इसके अतिरिक्त इन विकसित कोयला सीमों के निष्कर्षण के दौरान कोयला उद्योग को गंभीर तकनीकी-आर्थिक चुनौतियों का सामना करना पड़ रहा है।

मेसर्स साउथ ईस्टर्न कोलफील्ड्स लिमिटेड (एसईसीएल) के अंजन हिल खान, ईस्टर्न कोलफील्ड्स लिमिटेड के झांजरा कोलियरी तथा सिंगरेनी कोलिरीज लिमिटेड में कुछ भूमिगत खानों कम उत्पादन एवं उत्पादकता की समस्या से निपटने के लिए भारत के व्यापक उत्पादक सतत माइनर के द्वारा डी-पिलरिंग पैनल से भूमिगत खानों में पिलर में फँसे हुए कोयले के निष्कर्षण हेतु उपयुक्त विधि को भी अपनाया है। परंतु, इस प्रौद्योगिकी के यत्र-तत्र अनुप्रयोग द्वारा भारतीय कोलफील्ड्स के तकनीकी वैक्यूम को हल नहीं किया जा सकेगा। विकसित एवं नवीन कोयला सीमों के निष्कर्षण के लिए भारत के स्वदेशी निरंतर खनिक प्रौद्योगिकी को बड़े पैमाने पर कार्यान्वित करने हेतु एक विस्तृत अध्ययन की आवश्यकता है।

भारत में कई जगहों पर लौंगवॉल खनन के प्रयास किए गए हैं, लेकिन संक्षेप में कहा जा सकता है कि यह तकनीक कई कारणों से अभी भी सफल नहीं हो पायी है। इस प्रकार देश अभी भी कोयले के भूमिगत निष्कर्षण के लिए उपयुक्त प्रौद्योगिकियों के लिए प्रयास कर रहा है।

भविष्य के लिए प्रौद्योगिकी

अ) वर्तमान प्रौद्योगिकी का परिष्करण/संशोधन

सीम के कवर की गहराई के आधार पर कोयला निष्कर्षण हेतु प्रौद्योगिकी को संशोधित/विकसित किया जाना चाहिए। कवर की सतही गहराई के लिए इंटरमीडिएट, मध्यम या

उच्च तकनीक का प्रयोग किया जा सकता है। परंतु कवर की उच्च गहराई हेतु चयन के लिए पर्याप्त विकल्प नहीं है।

ब) कवर की सतही गहराई के लिए प्रौद्योगिकी

i) कम निवेश में बेहतर मध्यवर्ती प्रौद्योगिकी/मशीनीकरण का उपयोग

बेहतर मध्यवर्ती प्रौद्योगिकियों को उन क्षेत्रों में लागू किया जा सकता है जहाँ आर्थिक कारणों जैसे सीमित रिजर्व, सतही सुविधाओं की उपस्थिति, आदि द्वारा मध्यम से भ. ारी निवेश लाभप्रद नहीं है। भूमिगत कोयला खानों के मशीनीकरण में, एसडीएल (साइड-डिस्चार्ज लोडर) एवं एलएचडी (लोड-हाल-डंपर) का उपयोग होता है। ये मशीनें तब तक किफायती नहीं हैं जब तक कि ऐसी मशीनों के लिए पर्याप्त कोयला उपलब्ध न हो। ड्रिलिंग एवं विस्फोट में, बढ़ते उत्पादन तथा उत्पादकता हेतु परंपरागत ठोस विस्फोटक विधि के स्थान पर नई पद्धतियों को शामिल किया जाना चाहिए। सीएसआईआर-सिंफर की रॉक खुदाई इंजीनियरिंग डिवीजन द्वारा स्थापित एससीसीएल के जीडीके-5 ढलान में संशोधित कोणीय-कट पैटर्न ऐसी प्रौद्योगिकियों में से एक है जो उच्च उत्पादन और उत्पादकता के लिए पारंपरिक ठोस विस्फोट पैटर्न को प्रतिस्थापित कर सकता है।

ii) सतत खनिक के उपयोग द्वारा मध्यम निवेश

मध्यम निवेश के अंतर्गत कम गहराई के कवर रेंज की रिजर्व के लिए सतत खनिक एवं शटल कार जैसी मास उत्पादन तकनीक लागू की जा सकती है। असंतुलित ढुलाई प्रणाली के साथ सतत खनिकों के उपयोग से दुनिया भर में भूमिगत हाई कोयला खनन के लिए कोयला निष्कर्षण सबसे महत्वपूर्ण खनन विधि है। पिछले वर्षों के दौरान, कई देशों में रूम एवं पिलर खनन परिचालन की उत्पादकता ने एक अलग ही प्रगति की है। सतत खनिक के उपयोग द्वारा उच्च स्तर पर कोयला निष्कर्षण की संभावना प्रदान करता है तथा विश्व स्तर पर इस तकनीक का सफलतम प्रयोग किया जाता है। हालांकि, यूरोपीय कोलियरीज में इस कोयला स्तंभ निष्कर्षण विधियों का व्यापक रूप से अभ्यास नहीं किया जाता है, क्योंकि आंशिक रूप से कोयला किनारे की सतह के 300 मीटर नीचे या उससे अधिक की गहराई पर स्थित होते हैं। इन गहराई में, अन्य उच्च उत्पादन खनन तकनीकों जैसे लांगवालिंग का व्यापक रूप से उपयोग किया जाता है, क्योंकि यह उच्च तनाव की स्थिति के कारण स्तंभ निष्कर्षण से स्वाभाविक रूप से सुरक्षित है।

परंतु आर्थिक दृष्टि से, लौंगवॉल खनन प्रणालियों के कार्यान्वयन हेतु उपकरणों के मूल्य एवं श्रम की लागत का उच्च अनुपात एक बाधा है। यहाँ तक कि सफ. लतम लौंगवाल शीर्ष कोयला कैविंग (LTCC) विधि का भू-तकनीकी सीमाओं के कारण भारतीय कोलफील्डस में सीमित अनुप्रयोग है। यह विधि अपेक्षाकृत कमजोर एवं वर्जिन कोयला सीम में लागू किया जा सकता है। हालांकि यह ध्यान देने योग्य बात है कि भारतीय कोयले के सीमों में अपेक्षाकृत अधिक शक्ति है। लौंगवॉलिंग हेतु वैकल्पिक उच्च निष्कर्षण प्रणाली के रूप में स्तंभ निकासी ऑस्ट्रेलिया (न्यू साउथ वेल्स), यूएसए तथा दक्षिण अफ्रीका में सफ. लतापूर्वक प्रयोग की जाती है। ऑस्ट्रेलिया में 70 से अधिक वर्षों से अधिक समय तक स्तंभ निष्कर्षण का एक लम्बा इतिहास है। लगभग 60 वर्ष पूर्व पहला जॉय सतत खनिक (CM) प्रस्तावित किया गया था। ऑस्ट्रेलियाई जैसे वा. ेंगवाली, मुनमोरा एवं ओल्ड बेन द्वारा तीन अत्यधिक सफल तथा उत्पादक स्तम्भ निष्कर्षण प्रणालियों को विक. सित एवं परिष्कृत किया गया था। यदि खान में स्तम्भ पर कोयले का रिजर्व विकसित किया जाता है, तो पारंपरिक/ अर्थ-मशीनीकृत बोर्ड एवं खनन के स्तम्भ प्रणाली द्वारा उन्हें निकालने के उद्देश्य से उस रिजर्व को सतत खनिकों का उपयोग करके आसानी से निकाला जा सकता है। सुविध ाजनक विधि पॉकेट एवं फेंडर' विधि हो सकती है। व्यापक विभाजन हेतु फेंडर (stooks) के बीच 'पॉकेट' (void) बनाने के लिए प्रेरित किया जा सकता है। पारम्परिक बोर्ड एवं स्तम्भ खनन में 'स्लाइसिंग' के समान इस फेंडर को तुरन्त 'उठाया' (यानी निकाला जाता है)। बेहतर मशीन की गतिशीलता एवं आसानी से उत्पादन हेतु इन स्लाइसों को स्प्लिट के धुरी से लगभग 60 डिग्री झुकाव पर होना चाहिए जहाँ से स्लाइस शुरू हो रही है। पॉकेट और फेंडर विधि 'का स्प्लिट एवं फेंडर' विधि के साथ कई समानताएँ हैं, जो पहले ऑस्ट्रेलियाई खानों में व्यापक रूप से उपयोग जाती थी। भारत में भी सुरक्षा एवं उन्नत उत्पादन की दृष्टि से ऐसी प्रौद्योगिकियों को अपनाया जा सकता है। पहले से ही काम कर रहें सीएम पैनलों में सुरक्षा एवं उत्पादकता से संबंधित विभिन्न डेटा का विश्लेषण भूमिगत कोयला खनन परिचालनों के लिए सतत खनिकों का उपयोग करके कोयला निक्ष्कर्षण हेतु एक अच्छा तरीका हो सकता है।

iii)शॉर्टवॉल खनन आधारित तकनीकी विकास

शॉर्टवॉल खनन तकनीक लांगवॉल खनन के समान है जिसकी लम्बाई की क्षमता 40 से 90 मीटर तक हो सकती है। शॉर्टवॉल खनन बोर्ड एवं पिलर प्रणाली द्वारा विकसित स्तम्भ निष्कर्षण के लिए एक अच्छा विकल्प हो सकता है, परन्तु यह विधि अभी तक अपनी तकनीकी सफलता साबित नहीं कर पाया है। बड़े पैमाने पर उत्पादन हेतु अपनी तकनीकी व्यवहार्यता साबित करने के लिए विभिन्न भू-तकनीकी एवं परिचालन समस्याओं के बारे में कई विषयों का समाधान किया जाना है।

iv) ब्लास्टिंग गैलरी (BG) विधि

रिमोट एलएचडी के उपयोग से ब्लास्टिंग गैलरी (बीजी) विधि द्वारा मोटी सीमों से कोयला उत्पादन सिंगरेनी कोलियरीज कम्पनी लिमिटेड (SCCL) में काफी हद तक सफल रहा, परन्तु कम उष्मायान अवधि (6 से 8 महीने के बीच) के कारण ऐसी उत्पादक विधि को लागू करने में अक्सर आग की समस्या उत्पन्न हो रही थी जो एक मुख्य बाधा थी। वर्तमान में नेटवर्किंग एसडीएल/एलएचड) के साथ ड्रिलिंग/विस्फोट में भूमिगत कोयले की खानों से बड़े पैमाने पर उत्पादन के लिए सीमित सम्भावना थी तथा यही वजह है कि बीजी विधि को भूमिगत कोयला खानो से लक्षित उत्पादन प्राप्त करने हेतु गम्भीरता से प्रयास किया गया था। वर्तमान में बीजीएमएस आग से संबंधित होने वाले कठिनाइयों के कारण बीजी विधि से कोयला निष्कर्षण हेतु कोई स्वीकृति नहीं प्रदान कर रहा है।

v) हाईवॉल खनन प्रौद्योगिकी

हाईवॉल खनन एक नई तकनीक है जो सतह पर निवासियों को परेशान किए बिना ओपनकास्ट खानों का जीवन बढ़ा सकती है तथा अर्थव्यवस्था एवं उत्पादकता को बनाए रख सकता है। यह एक रिमोट से संचालित कोयला खनन तकनीक है जहाँ कोयला सीम में हाईवॉल के सामने से चलने वाली समांतर प्रविष्टियों की श्रृंखला से कोयले का निष्कर्षण शामिल है। ये प्रविष्टियाँ मानव रहित, असमर्थित और अनियंत्रित होंगी।

भारत में पहली हाईवॉल खनन प्रणाली 10 दिसम्बर 2010 को ओपनकास्ट प्रोजेक्ट- 2 (OCP-2) रामागुंडम एरिया- 3 (BG- 3) में सिंगरेनी कोलियरीज कम्पनी लिमिटेड (SCCL) और बाद में एसईसीएल (SECL) के शारदा ओसीपी तथा देश के अन्य खानों में शुरू हुई। जुलाई 2017 तक लगभग 4.3 मिलियन टन कोयला जिसकी लागत 120 मिलियन अमेरिकी डॉलर से अधिक हैं का निष्कर्षण किया गया, जिसमें ओसीपी- 2 से 0.15 मिलियन टन, मेडापल्ली ओसीपी से 1.0 मिलियन टन, शारदा ओसीपी से 2.7 मिलियन टन तथा नई टीएसएल के पश्चिम बोकारो कोलियरी से 0.44 मिलियन टन हुआ। क्षेत्र की स्थितियों के आधार पर आउटसोर्सिंग शुल्क 14 से 18 अमेरिकी डॉलर प्रति टन कोयला उत्पादन के बीच होता है, जिसे कोयले के अन्य भूमिगत तरीकों की तुलना में बहुत किफायती माना जा सकता है।

इस तकनीक द्वारा कुल निवेश 125 करोड़ (18.4 मिलियन अमेरिकी डॉलर) के साथ 4000-5000 टन/दिन 20 से 30 कुशल जनशक्ति के साथ कोयले का निष्कर्षण सम्भव है और पूंजीगत निवेश 6 महीने के अंदर पुनः प्राप्त हो सकता है।

स) उच्च गहराई के लिए कवर-हाई निवेश लॉन्गवॉल प्रौद्योगिकी

पहले से ही यह उल्लेख किया जा चुका है कि कवर की उच्च गहराई के लिए बहुत अधिक विकल्प नहीं है। कवर की उच्च गहराई के लिए वर्तमान में लांगवॉल प्रौद्योगिकी लागू की जा सकती है। रॉक विस्फोट हार्ड छत प्रबंधन इत्यादि से निपटने के लिए उचित उपाय किए जाने पर यह तकनीक सफल होगी।

i) अभिनव प्रौद्योगिकी का विकास

कवर रेंज की उच्च गहराई के लिए नई प्रौद्योगिकियों को विकसित करने के प्रयास किए जाने की आवश्यकता है। हाइब्रिड टेक्नोलॉजी का विचार किया जा सकता है तथा इस तरह की तकनीक के विकास को विभिन्न सहयोगी संगठनों द्वारा संयुक्त रूप से शुरू किया जा सकता है, यदि आवश्यक हो तो विदेशी संस्थानों एवं सहयोगियों से समर्थन लिया जा सकता है।

उपलब्धि हेतु रोड मैप

अ)**सामरिक (strategic)**

* कम समय के भीतर लक्ष्यों को प्राप्त करने पर बल देने के साथ कम, प्रबंधनीय परियोजनाओं में कार्य

का एकीकरण

* अनुसंधान फैलोशिप एवं सहयोगी सब्बाटिकल योजनाओं और त्वरित पारिश्रमिक विकल्पों के साथ समय-समय पर नई प्रतिभाओं को शामिल करना।
* संयुक्त परियोजनाओं एवं संगठनों को वित्त पोषित करने हेत संसाधनों के लिए संयुक्त बीड के माध्यम से अन्य अकादमिक तथा अनुसंधान एवं विकास संस्थानों के साथ कार्यात्मक सहयोग को सुदृढ़ करना।
* परामर्श सेवाएं और प्रौद्योगिकी प्रदर्शन गतिविधियों को पोषित करना जो स्वतंत्र संस्थाओं और लाभ केंद्रों के रूप में स्पिन-ऑफ कर सकते हैं।
* संगठनों के विशिष्ट डोमेन में राष्ट्रीय एवं अंतरराष्ट्रीय सम्मेलनों तथा प्रशिक्षण कार्यक्रमों का प्रबंधन।
* कार्य डोमेन में बुनियादी शोध और प्रौद्योगिक हस्तांतरण शुरू करके उत्कृष्टता, उद्योग और परामर्श कम्पनियों के अकादमिक केंद्रों के साथ संबंधों को सुदृढ़ करें।
* संगठनात्मक क्षमता को तेज करने में अन्य देशों, विशेष रूप से ऑस्ट्रेलिया, कनाडा, चीन, चेक गणराज्य, जम. र्नी, पोलैंड, रूस, दक्षिण अफ्रीका, यूके और यूएसए के साथ विभिन्न संगठनों के द्विपक्षीय कार्यक्रमों का पूर्ण लाभ लें।
* अर्थव्यवस्था की गतिशीलता के साथ वैश्विक ज्ञान को संदर्भित करना।
* रचनात्मक सोच एवं उच्च उत्पादकता के साथ समय-समय पर प्रतिभाशाली कर्मियों को आकर्षित करने एवं बनाए रखने के लिए अनुकूल वातावरण एवं प्रोत्साहित करने हेतु प्रबंधन प्रक्रियाओं तथा सूचना प्रणाली को स्थापित करना।

ब) इंफ्रास्ट्रक्चर सुविधाएं

* रॉक द्रव्यमान गुणों के परीक्षण हेतु बुनियादी ढांचे को विकसित करने की आवश्यकता।
* रॉक द्रव्यमान गुणों के लिए मुख्य रूप से कवर की उच्च गहराई के लिए एक डेटा बैंक को विकसित करना।
* भूवैज्ञानिक प्रकृति का आकलन करना।
* अधिक गहराई में रॉक द्रव्यमान गुणों के उचित मूल्यांकन हेतु भौगोलिक और भू-विद्युत विधियों को विकसित करने की आवश्यकता।
* खनन के दौरान पूर्ण भूमिगत स्तर व्यवहार विश्लेषण हेतु उचित सॉफ्टवेयर/उपकरणों के विकास की आवश्यकता।
* भूमिगत जाँच के चुनौतीपूर्ण काम करने के लिए सक्षम एवं ऊर्जाशील जनशक्ति की आवश्यकता।
* भविष्य की आवश्यकता के अनुसार शोध एवं विकास की गतिविधियों के लिए दुनियादी ढांचे का विकास।
* संचार प्रौद्योगिकी का विकास जो वैश्विक आधार पर अनुभवों और अनुसंधान निष्कर्षों को साझा करने का नेतृत्व करेगा तथा जब समस्या उत्पन्न होती है तब संस्थान को फिर से शुरू करने की आवश्यकता नहीं होगी।
* एक सशक्त शोध एवं विकास सुविधा की आवश्यकता होगी, जिसमें क्षेत्रीय प्रयोगशालाओं के लिए जाँच कार्यक्रमों को पूरा करने और इन-हाउस तकनीकी सहायता प्रदान करने की सुविधा शामिल हो और जो स्वयं शोध एवं विकास द्वारा पर्यावरण अनुकूलन हेतु अपनाएगा।
* प्रभावशीलता एवं अनावश्यकता हेतु संस्थान की मू. लभूत संरचनाओं का मूल्यांकन, जिसे वांछित उद्देश्य प्राप्ति हेतु पुनर्गठन की आवश्यकता है।
* पर्यवेक्षी भूमिका को ''कर्ता'' से ''सुविधाकार'' में बदलने की जरूरत है जिसके लिए सुविधा, टीम निमार्णण एवं संचार में नए कौशल तथा ज्ञान की आवश्यकता होगी।
* किफायती प्रभावी एवं नई तकनीक के लिए खोज की जा रही हैं।
* सभी शोध एवं विकास कार्यक्रम ''जोखिम प्रबंधन'' सिद्धांत पर आधारित होना चाहिए।

स) प्रतिबद्धतायें

* भारतीय भू-खनन स्थितियों में खड़े एवं मोटे कोयले के निष्कर्षण हेतु उपयुक्त खनन विधि से परीक्षणों के लिए संसाधनों की आवश्यकता।
* पूरी तरह से मशीनीकृत खनन विधि (मास उत्पादन प्रौद्योगिकी) द्वारा मोटे कोयला सीम के निष्कर्षण हेतु स्वचालित भूमिगत खनन उपकरण की आवश्यकता है। सीआईएल, सीसीआईआर-सीएमईआरआई, आईआईटी-आईएसएम जैसे संगठन सीआईएल, एससीसीएल एवं टीएसएल,

आदि के सहयोग से अश्वासन सुरक्षा के साथ भ.ूमिगत उत्पादन और उत्पादकता में वृद्धि के लिए आवश्यकता-आधारित विकास हेतु सक्षम परियोजनाओं को तैयार करने हेतु एक साथ पहल कर सकते हैं।

* स्वदेशी पूर्ण मशीनीकृत खनन प्रौद्योगिकी के साथ-साथ हमारे देश में प्रौद्योगिकी में उपयोग की जाने वाले सभी मशीनों/उपकरणों की विनिर्मार्ण सुविधाओं का विकास।
* डिपिलरिंग फेस के चारों और स्ट्रेटा बिहैवियर की निरंतर जाँच हेतु कम्प्युटर डेटा-लॉगर इंटरफेस की व्यवस्था।
* खनन क्षेत्र की भू-मानचित्रण प्रणाली के लिए सुविधाएं, जो क्षेत्र में सभी भूगर्भीय विघटन/सुविधाओं की उपस्थिति के बारे में जानकारी प्रदान कर सकती हैं।
* एक खनन प्रौद्योगिकी के इन-सीटू प्रदर्शन मूल्यांकन हेतु कंपन-तार तलाव मीटर, उपकरणीय बोल्ट रिमोट अभिसरण संकेतक एवं बोरहेल एक्सटेन्सोमीटर का उपयोग।
* उन्नत स्वच्छ-कोयला विधियों का विकास।
* जैव-द्रव्यमान के साथ कोयले का सह-दहन/सह-गैसीकरण।
* सोंपे गए कार्य हेतु युवा पीढ़ी की समर्पित भागीदारी।

द) **प्रौद्योगिकी उन्नयन**

* भूमिगत खनन में मोटी या तीव्र ढलान वाले सीमों सें सुरक्षित तथा लाभप्रद निष्कर्षण के लिए बड़े पैमाने पर उत्पादन प्रौद्योगिकी के विकास और अनुकूलन।
* खनन समस्याओं के लिए संख्यात्मक तरीकों के प्रयोग हेतु उत्कृष्टता केंद्र स्थापित करना।
* कोयला धारक राज्यों में अधिमानतः खान समर्थन एवं खनन उपकरण, अन्य संयंत्र एवं प्रसंस्करण उपकरण के डिजाइन एवं विकास के लिए केंद्र स्थापित करना।
* कोयला पेट्रोलोजी के लिए उत्कृष्टता केंद्र स्थापित करना।
* तटीय प्लेसर खनन।
* गैस एवं आग का नियंत्रण।
* भारतीय खानों के लिए वायरलेस मल्टीमीडिया संचार का विकास।
* कठिन एवं खतरे की परिस्थितियों में 'रोबोट' का प्रयोग।
* पुरानी और अप्राप्य कार्यप्रणाली का पता लगाने तथा मानचित्रण और अस्थिर क्षेत्रों की स्थिरीकरण।
* निम्नलिखित आपदा मुद्दों में विशेष रूप से भूमिगत कोयले की खानों में 'आपदा प्रबंधन समूह' को वै.ज्ञानिक सहायता प्रदान करना।

  1. शीघ्रातिशोध तापमान की किसी भी वृद्धि का पता लगाना
  2. खानों में जल निकायों की पहचान एवं सीमांकन
  3. जल प्लावन को अंकित करते हुए मानचित्र का निर्माण
  4. बाधा आकलन हेतु भू-प्रवेश रडार का उपयोग
  5. फंसे हुए खनिकों के स्थान हेतु उचित तकनीक का विकास
  6. सुरक्षा कक्षों के डिजाइन एवं स्थापना जहाँ खनिक आपातकाल के दौरान आश्रय से सकते हैं।

य) **पर्यावरण संबंधी मुद्दे**

* उड़न राख का उपयोग एवं निपटान।
* खनन परिचालन के पर्यावरणीय प्रभावों को पेश करने हेतु एक संख्यात्मक-सह-सांख्यिकीय मॉडल का विकास करना।
* खनन क्षेत्रों में बंजर भूमि का पुनरूद्धार।
* खान-बंद करने हेतु संचालन एवं पारिस्थितिकी के अनुकूल खनन क्षेत्र का विकास।

र) **वैकल्पिक ऊर्जा श्रोत**

* कोल बेड मीथेन (CBM)
* भूमिगत कोयला गैसीफिकेशन (UCG)

स्वच्छ कोयला हेतु पहल

* कोयले में निहित गंदगी को बाहर करने हेतु अभिनव खनन पहल
* गहरे कोयला खानों में कार्बन डाई ऑक्साइड के अनुक्रमण हेतु इन-सीटू कोयला, सॉर्पशन व्यवहार एवं गैस प्रसार विशेषताओं की पारगम्यता के संबंध में डेटा बैंक का निर्माण
* कोयले की गुणवत्ता के उन्नयन हेतु शुष्क एवं नम उन्नत परिष्करण तकनीक
* परिष्कृत कोयले के उपयोग के माध्यम से बिजली उत्पादन की प्रभावकारिता में सुधार तथा को-जेनेरेशन

सिस्टम एवं निकट-शून्य उत्सर्जन प्रौद्योगिकियों को बढ़ावा देने सहित अधिक कुशल विद्युत उत्पादन चक्रों का सहारा लेना

* बिजली, रासायनिक फीडस्टॉक एवं तरल ईंधन की पीढ़ी के लिए उच्च राख भारतीय कोयलों का गैसीकरण
* जैव द्रव्यमान के साथ कोयले का सह-दहन/ सह-गैसीकरण;
* ऑक्सी-ईंधन दहन एवं पोस्ट दहन कैप्चर
* विनिर्देश ग्रेड तरल ईंधन के लिए उच्च सल्फर भ. ारतीय कोयलों (उत्तर-पूर्व क्षेत्र) की प्रत्यक्ष तरलता
* विभिन्न उद्योगों के लिए उत्तर-पूर्वी कोयले का उपयोग
* कमजोर कोयलों से इस्पात बनाने तथा अन्य धातुकर्म उद्देश्यों के लिए बेहतर स्वदेशी प्रौद्योगिकी का विस्तार
* अपशिष्ट उष्मा से बिजली उत्पादन सहित कुशल ऊर्जा कोक ओवन का डिजाइन एवं विकास
* विभिन्न विनिर्देशों के आधार पर कोयले से मूल्यवधि ित कार्बन का विकास
* कोयले या कार्बनिक कचरे को सिंथेटिक ईंधन और अन्य रसायनों/फीड स्टॉक में बदलने के माध्यम से पेट्रोलियम फीड स्टॉक पर निर्भरता को कम किया जाय
* कोयला उत्पादक उद्योगों के साथ गठबंधन में संसाधन गुणवत्ता मूल्यांकन के राष्ट्रीय कार्य को जारी रखना।

आभार

इस पेपर में कुछ विचार एवं योजना है जिन्हें भारतीय खनन उद्योग में लागू किया जा सकता है और देश में कोयले के उत्पादन को बढ़ाने के लिए मार्गदर्शक बल के रूप में उपयोग किया जा सकता है ताकि राष्ट्रीय ऊर्जा आवश्यकता को पूरा करने हेतु सुरक्षा सुनिश्चित हो सके। इस प्रकार के वैचारिक एवं महत्वपूर्ण शोध पत्र कई लोगों की संख्यात्मक सहायता एवं मार्गदर्शन के बिना संभव नहीं हो सकता है जिसमें डॉ प्रभात कुमार मंडल, वरिष्ठ प्रधान वैज्ञानिक, डॉ० अमर प्रकाश, प्रधान वैज्ञानिक एवं डॉ० प्रदीप कुमार चटर्जी, सीएसआईआर-सीएमईआरआई के मुख्य वैज्ञानिक को समय-समय पर सहायता एवं उचित सलाह के लिए विशेष धन्यवाद एवं कृतज्ञता व्यक्त की जाती है। प्रस्तुत शोध पत्र में उद्धत कई डेटा और टिप्पणियाँ विभिन्न वे. बसाइटों के सार्वजनिक डोमेन में उपलब्ध हैं, जिन्हें इंटरनेट सर्फिंग के माध्यम से प्राप्त किया जा सकता है।

संदर्भ

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