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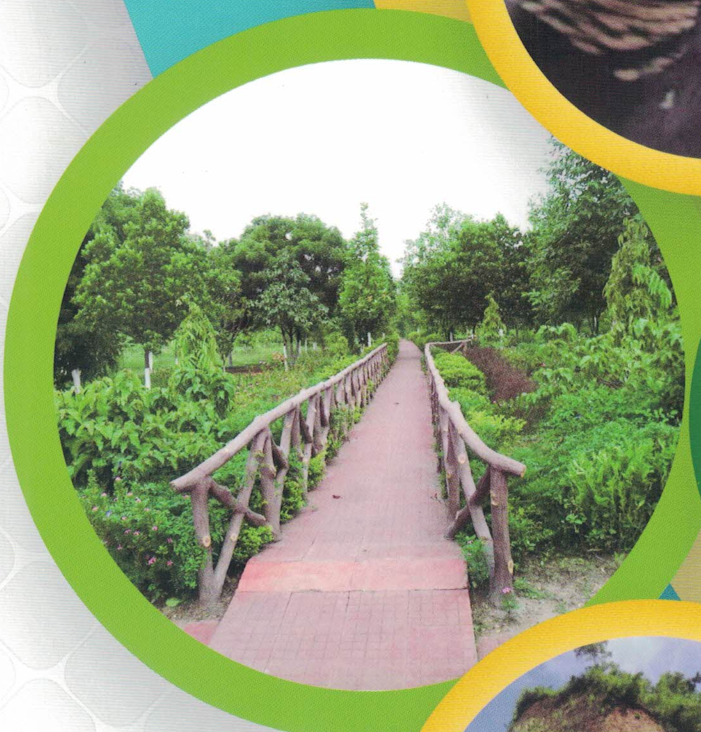

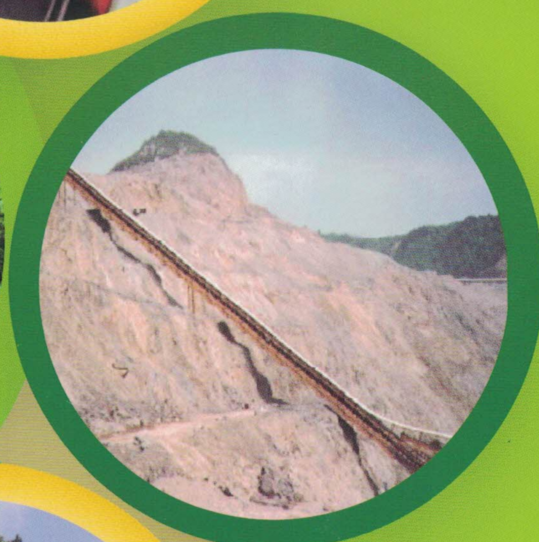

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Geological Structural Modelling and Reserve Estimation of Coal Seams Integrating 2D Seismic, Magnetic and Borehole Data in Bartara Block, Sohagpur Coalfield, Madhya Pradesh

Dr. Sayan Ghosh[1], N.P.Srivastava[2], Bikas Kumar[3], S Pamnani[4], Amit Joshi[5], Ayush[6] , Rohit Pandey[7]

ABSTRACT

This study aims to generate geological models and estimate the coal seams of two major seams VII and VI using 2D Seismic Data and core logs in limited number of wells in Bartara Block, Sohagpur coalfield in Madhya Pradesh. 12 numbers of profile lines were laid across the block in almost N-S direction which is tentatively along the dip direction of the coal seams. 2D seismic data was recorded along the profile lines with a spacing of 5m interval recording 12 fold data among the stations in each line spreading across the block comprising of 8.42 sq. kms. of area and located in the south-western portion of Sohagpur coalfield. The seismic survey was accomplished using End-on pattern shots to avoid ground rolls generated while taking shots using a constrained source like hammer. Bartara block has four prominent coal seams where two seams IX and VIII are shallow and do not occur in the entire block, whereas the seams VII and VI are deep and occur in the entire block. Moreover, the block is also affected by intrusive bodies and the geological evidences suggests it to be mostly of dolerite nature. The 2D seismic sections interpreted provides evidences of 6 numbers of faults all of which striking in almost E-W direction. Moreover, 23 numbers of coring wells drilled by CMPDI are also considered in the correlation of seams and preparation of wells. The total estimated reserve of coal seams VII and VI are estimated to be about 73.1 million tones of grades G5 to G10 as discussed in this paper.

Keywords: *Geological modelling, 2D Seismic, Seam Correlation, Intrusive.*

INTRODUCTION

The energy sector in India is majorly depending upon coal which being a stratified deposit is explored conventionally by drilling wells and analysing the features of seams at different depth ranges. At an international perspective, the exploration of coal is not only to find and map coal seam reservoir but also to make the entire process economically effective (Gochioco, 1990). In Indian scenario, the exploration of coal reservoir is often established using conventional drilling methods, but drilling methodology incurs a significant amount of cost and time and moreover, various drilling limitations in the surface and sub-surface often affects the quality and economic justification *(Ghosh et. al., 2014)*. In many developed countries like USA and Australia, seismic reflection tools has become an established method to decipher the structural features and explore coal seam reservoirs economically and efficiently (Peters & Hendrick, 2004). The most significant advantage of using seismic data over borehole data is its ability to generate continuous data over the profile lines resulting in more prominent image regarding the behaviour of coal seam strata. Gradually, the Indian coal industries are also tending towards the utilization of this geophysical approach and integrating the results of seismic surveys with the boreholes data for optimizing the dependency of exploration solely on drilling approach.

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Many approaches are recently being made in Indian coal industries to utilise the seismic methods for exploring coal. High Resolution 3D Seismic Reflection was implemented on Raniganj sub-basin of West Bengal for delineating faults, depth and thickness of coal seam horizons. In the Ramgundam area of Pranhita-Godavari, the depth of coal seams along with the geometry of the faults were mapped using High Resolution Seismic Reflection methods of the coal seams upto a depth range of 1000m *(Prasad et. al., 2015)*. High Resolution Seismic Reflection was used to map the behaviour of the coal seams within the depth range of 350m to 550m over six profile lines in central part of the Sohagpur basin in Madhya Pradesh *(Dhanam et. al., 2013)*.

This study involves integration of the findings of 2D seismic and seam correlation from few coring wells data for preparation of the geological model of coal seams in Bartara block in Sohagpur coalfield. 12 numbers of profile lines were laid in N-S direction across the block with a patch uncovered due to law & order problems. 2D High Resolution Shallow Seismic (HRSS) data was recorded over the profile lines (shown in Figure 1) in End-on shot pattern (offset 50m) with a station interval of 5m and recording 12 fold data. The exploration in the adjacent blocks like Khairaha block in the south and West of Karkatti block in the south-east showed a probability of occurrence of intrusive bodies, magnetic survey was also carried out for confirmation of the existence of intrusive bodies. A total of 23 coring wells within the block, all mostly concentrated in the south-west and the eastern part of the block, were also considered for coal seam correlation as well as the quality parameters of the coal seams for estimation of the reserve. The source used for data recording was hammer and hence the depth of investigation could be only limited till 250m to 300m. Fortunately, the two major seams VII & VI modelled in the study occurred within a depth range of 300m, which helped in overcoming the constraint of the source in this case study.

The structural behaviour of the coal seams considered in the study was inferred from the interpreted reflectors from the seismic sections, whereas the quality grid was generated from the proximate analysis data of the 23 coring wells considered in the block. The final gradewise reserve was concluded by integrating the structure grid and the quality grids inferred from the geophysical and coring wells data in the block. It worthy to be mentioned that the borehole density considered within the block was less than 3 boreholes per sq. km. for inferring the structure and the reserve in Bartara block in this study.

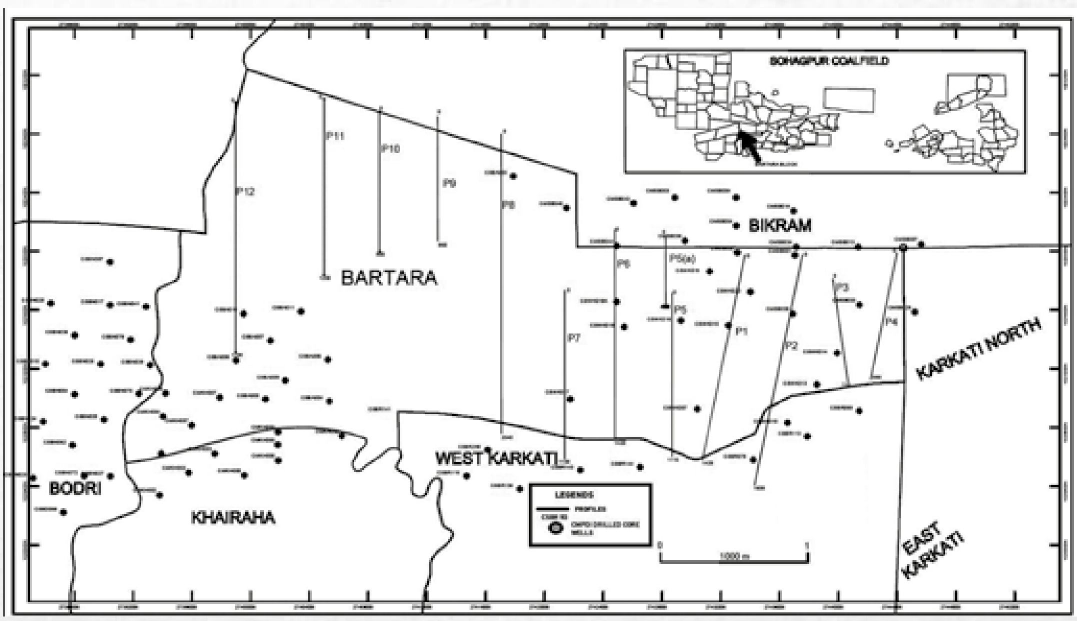

Figure-1

GEOLOGY OF SOHAGPUR COALFIELD

Sohagpur coalfield can be broadly divided into two parts i.e. the North and South Sohagpur, along the E-W trending intrabasinal Bahmni-Chilpi fault. The north Sohagpur represents the down thrown block of the Sohagpur basin where coal measures in general occure under a thick cover of younger Upper Triassic sediments termed as Supra Barakars. The south Sohagpur consists of Amlai-Burhar sub basin, Jamuna-Kotma sub basin and Jhagrakhand sub-basin from west to east. The intervening patches between the sub-basins were considered devoid of workable coal seams. The spread of Sohagpur Coalfields is about 3100 sq. km.

The study area is located almost in the central part of the Amlai-Burhar sub-basin, Sohagpur Coalfield. The area is mainly covered by thin cover of soil and alluvium ranging in thickness from 1.75m to 8.55m. A study of drill hole data reveals that of the nine correlatable carbonaceous horizons present in Amlai-Burhar sub basin, only six coal seams viz. VI Bottom alongwith two splits- VIB(B) & VIB(T), VII,VIII & IX in ascending order have attained identifiable thickness in the study area.

OUTLINE AND OBJECTIVE OF THE ACCOMPLISHED STUDY

The basic objective of this study is to analyse the feasibility of coal seam modelling and grade-wise reserve estimation after fusion of the results obtained from integrated geophysical surface surveys including 2D High Resolution Shallow Seismic (HRSS), resistivity and magnetic surveys and limited core wells data (less than 3 boreholes per sq kms.). The algorithm of the entire study in Bartara block, Sohagpur CF has been demonstrated in the following flowchart (Fig-2).

2D HIGH RESOLUTION SHALLOW SEISMIC (HRSS)

2D HRSS survey is conventionally carried out to delineate the geological structural features at shallower depth (<1000m) from surface. In this study, the depth of investigation was around 150-240m depth due to the limitation of the source used in the survey.

Data Acquisition

A total 12 profile lines were laid in almost N-S direction across the entire block except a patch near Khannath village as shown in Figure 1, due to law and order problems. The interpretation in the said patch has been extrapolated from the behaviour of the data around, using seismic sections and core wells. The station interval in every line was 5m with 12 folded reflection data recorded. 24 channels Geometrics seismograph was used for data acquisition along the profile lines. End-on pattern was used for shot with an offset of 65m

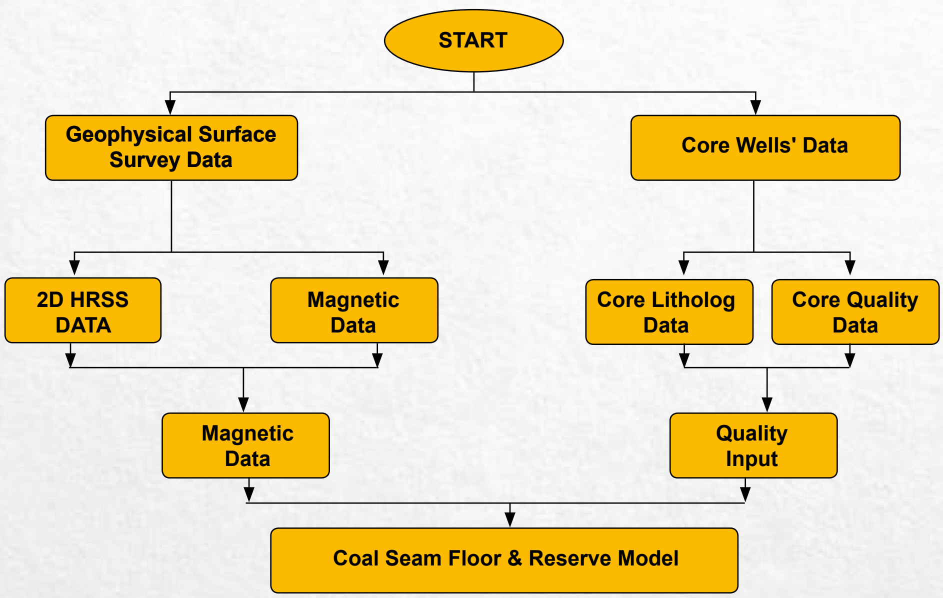

Figure-2

to optimise surface waves and ground-roll being recorded in the geophones. Since, hammer was used as source for generating waves, hence the depth of investigation was constrained in the depth range of 200-220m from surface and thus the target seams VII and VI occurring within the depth range could be mapped using the sections.

The surface terrain of Bartara block is not unusually variable, but still for applying the statics correction while processing, the surface Reduced Level (RL) has been recorded at each station over the profile lines. The spacing between each profile line across the block is about 400m (as shown in Figure 1). The shot pattern is end-on, recorded data being 12 fold and moreover lack of impulsive source results in few noisy sections discussed later. Few of these noise recorded could be dealt while processing whereas some of them could not be removed completely.

The block also being affected by intrusive body at a shallow depth (<100m), the sections across the intrusive were also affected and also showed diffraction tendency corresponding to the affected zone. Moreover, magnetic data over the profile lines confirmed the existence of dolerite along the zone affected in 2D HRSS sections.

Data Processing

2-D Seismic data was recorded in SEG2 format at Bartara Block, Sohagpur Coal Field. Initially the data was loaded for processing purpose through **Paradigm** software. The entire flowchart of the seismic data processing algorithm is stated in Figure 2. The 24 Channel Geometrics instrument which recorded 24 traces for each shot was assigned with geometry headers to access coordinates of each receiver location for the given shot location, RL values, receiver locations and shot locations. After assigning proper geometry, frequency spectrum was generated so as to analyse and feed proper frequency parameter to band-pass filter for filtering the seismic traces, resulting in the output traces constituting only those frequencies that make up the wavelet used in the filtering.

Moving ahead, amplitude correction was applied to seismic traces so that seismic amplitudes accurately portray the values of the reflection coefficient. Further, static correction was applied to bring all the recorded traces on a given datum by picking first break on reflection data.

Predictive Deconvolution was applied which acts along the time axis. It removes the basic seismic wavelet (the source time function modified by various effects of the earth and recording system) from the recorded seismic trace and thereby increases temporal resolution. It was achieved by compressing the wavelet by providing proper operator length and predictive length. Again frequency spectrum was analysed and band-pass

Table-1: The details of geohysical profile lines in Bartara Block, Sohagpur Coalfield

PROFILE NAME	LENGTH (KMS)	ORIENTATION	STARTING COORDINATES				
			X (EASTING in m)	Y (NORTHING in m)	X (EASTING in m)	Y (NORTHING in m)	Datum RL in m
PROFILE1	1.42	NE-SW	2743365	1021976.	2743101.573	1020710.678	484
PROFILE2	1.81	NE-SW	2743758	1021978	2743403.277	1020297.113	484
PROFILE3	0.82	NE-SW	2743963	1021812	2744058.701	1021158.135	482
PROFILE4	0.87	NE-SW	2744399	1021989	2744216.984	1021113.769	478
PROFILE5	1.16	N-S	2742869	1021719	2742869.009	1020643.599	483
PROFILE6	1.42	N-S	2742478	1022099	2742478.795	1020779.956	480
PROFILE7	1.15	N-S	2742136	1021734	2742137.115	1020719.992	479
PROFILE8	2.16	N-S	2741706	1022800	2741707.000	1020748.380	470
PROFILE9	0.75	N-S	2741275	1022929	2741275.750	1022164.500	470
PROFILE10	0.95	N-S	2740878	1022949	2740878.000	1022050.690	470
PROFILE11	1.2	N-S	2740499	1023036	2740499.250	1021933.190	470
PROFILE12	1.7	N-S	2739897	1023015	2739897.750	1021340.500	470

filter was applied so as to keep the seismic traces within the desired frequency.

Now the traces with same midpoint location are grouped together making up a CDP gather and velocity analysis was done by recognising the semblance where velocity was picked at the interval of 25 CDP gathers for different time interval. After picking the proper velocity at different CDP gather Normal Moveout (NMO) Correction was applied. By applying NMO correction to the traces from each CDP gather, and then by summing them along the offset axis results in Stacked Section (Time Section).

Data Interpretation

The acquired 2D HRSS data over the 12 profile lines were processed to generate the two-way time stacked sections. Basically, the main objective of this study is to target two coal seam horizons namely Seam VII and Seam VI and map the behaviour of the floor of the coal seams. The continuity of the coal seams in each section is followed and any disturbance/displacement intersecting the coal seams over the profile lines are marked. The fundamental principle advantage in marking coal horizons is the high acoustic impedance among the coal seam and the preceding/succeeding parting sandstones.

Altogether 12 time sections starting from profile no. 1 to 12 (stacked section of P9 shown in Figure-3) were studied. Among all the correlatable coal seams, seam VII and Seam VI are the most consistent varying in depth from 100m to 180m and 130m to 210m respectively. However seam VIII and IX could not be traced due to very shallow and thin in nature. In some places continuity has also been interrupted by a gap in the survey which may be due to skipping of shots falling in the zone of bushes or swampy areas, resulting decrease in foldage. This gap was bridged by correlation of reflectors.

All the two way travel times (TWT) read from the seismic time sections for floors of the seam was converted to depth using average velocities calculated from stacking velocities of different time sections.

In absence of sonic and density logs from the study area, the average velocity of has been arrived on the basis of R.M.S. and interval velocity for each of the profile.

Magnetic Survey

The basic principle behind the working of magnetic survey is the magnetic force obtained from Coulumb's law for magnetic poles and can be expressed as:

$$F=(m1 \text{ x } m2/\mu r^2)\ \bar{\mathbf{r1}}\ldots\ldots(1)$$

Where F is the force in dynes on m2, the poles are r cm apart and $\bar{r}1$ is the unit vector directed from m1 towards m2.

Here in this magnetic survey, profile lines were laid on the ground by fixing pickets at every 10m interval along a line. In the present survey the profiles were laid in North - South direction covering the entire block. Magnetic observations were taken at every 10m station interval along each profile. The trend of the encountered dyke was obtained by joining the locations of the

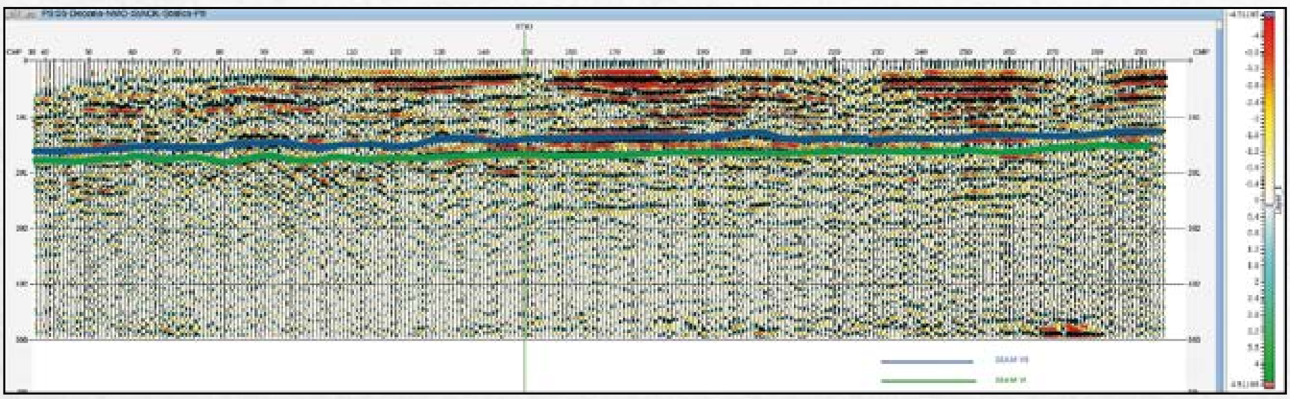

Figure-3

picket's positions having the maximum magnetic anomaly along each of the profile lines over the plan. Due to the forward magnetization, a positive anomaly is seen in all the profile lines except P-3, P-4, P-8 & P-9 (because due to limited field accessibility in terms of forest land area therefore, P-3 & P-4 could not be extended towards southern boundary). About P-8 & P-9 profile lines, it could not be extended further in the southern side due to presence of cultivated crop land.

The pattern of the magnetic intrusive body could be traced using the magnetic anomaly and confirmed by dew boreholes like CSWK013. While initiating the study, it was assumed that the intrusive bodies are uniformly magnetised and due to which the magnetic susceptibility might generate anomaly along the strike of the intrusive bodies.

The magnetic anomalies recorded in nano-Tesla (nT) exhibits anomalies over profiles P1, P2, P5, P6 and P7 as shown in Figure 4 (a) to (d). The variation of the intensities over normal strata ranges close to 45500 nT to 46000 nT whereas the same over the anomalous zone ranges over 48000nT to 50000 nT confirming the presence of a magnetic intrusive body. Moreover, few boreholes drilled within the area like CSWK013 which intersects dolerite formation from surface to 20 m, confirms the findings interpreted from magnetic survey. The details of the stretch of the intrusive body with respect to the zero of the profile lines are shown in Table-2.

CORE DATA OF BOREHOLES' CONSIDERED

A total 28 number of boreholes (locations shown in Figure 1) were considered in the block of area 8.42 sq kms with a density of about 3 boreholes per sq kms. The core data acquired from the boreholes were used to accomplish the study integrating with the results of the geophysical investigations. This study incorporates the litholog for correlating the reflector horizons marked in seismic sections whereas the proximate results obtained from laboratory are used to estimate the grade-wise reserve of the both the considered coal seams VII and seam VI.

Details of the coal seams from core data

Each of the four major coal seams in the study area are encountered in the 28 core wells considered whose details will be discussed in this section. The major coal seams are namely Seam IX, VIII, VII and VI out of which Seams IX and VIII are at shallower depth with minimum depth at 18m and 38m respectively. The shallower depth of the first two seams are matter of concern from seismic sections due to muting to overcome the ground-roll noises recorded. Thus, these two seams are not considered for structural modelling and reserve estimation in this study.

The rest two major seams namely Seam VII and VI were studied and the properties of theses

Table-2: Extent of the dolerite intrusive body intersected in profile lines, Bartara Block, Sohgpur CF

Sl. No	Profile No.	Distance of the dyke from Zero point		
		From (m)	To(m)	Lateral Extent (m)
1	P-1	620	760	140
2	P-2	560	730	170
3	P-3	-----	----	----
4	P-4	-----	----	----
5	P-5	650	800	150
6	P-6	650	770	120
7	P-7	130	290	160
8	P-8	-----	----	-----
9	P-9	-----	----	-----

two seams shall be discussed in this section. The basic properties of the coal seams which are to be analysed for modelling are:

1) Floor Reduced Level (FRL)

3) Ash % and Moisture %

2) Gross Calorific Values (GCV).

4) Effective Thickness (ET)

The sample type considered for proximate analysis is I30 due to the possibilities of underground mining for both the seams. It is observed that both the considered coal seams are almost free of dirt bands in most of the boreholes, so the total thickness is equal to ET in most of the cases as seen Table-3.

The ET of Seam VII varies from 0.65m (CSBR069) to 4.79m (CMSB043) whereas the

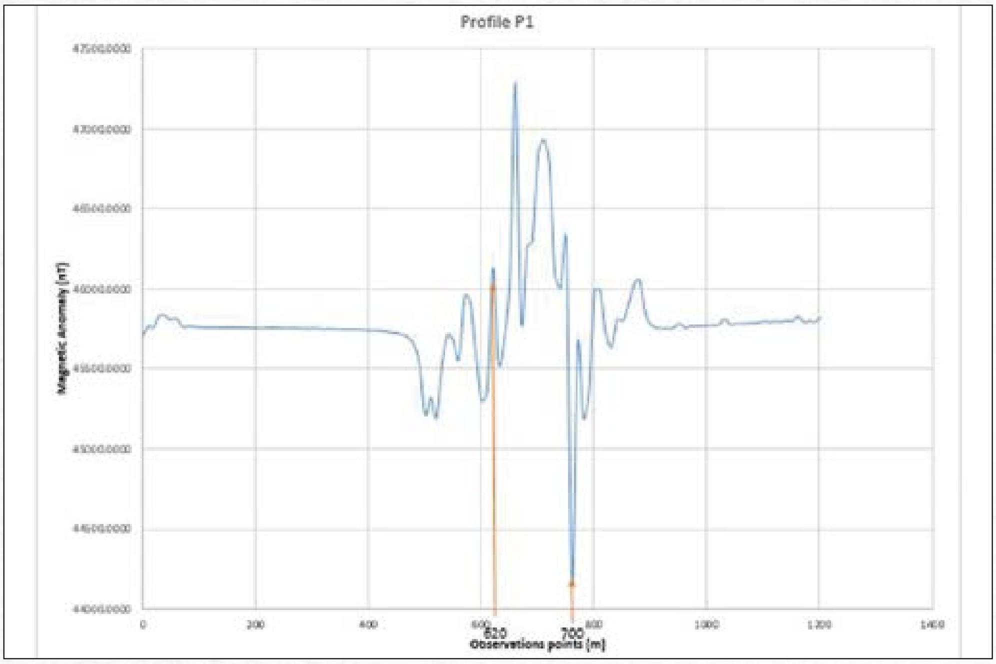

Figure-4A

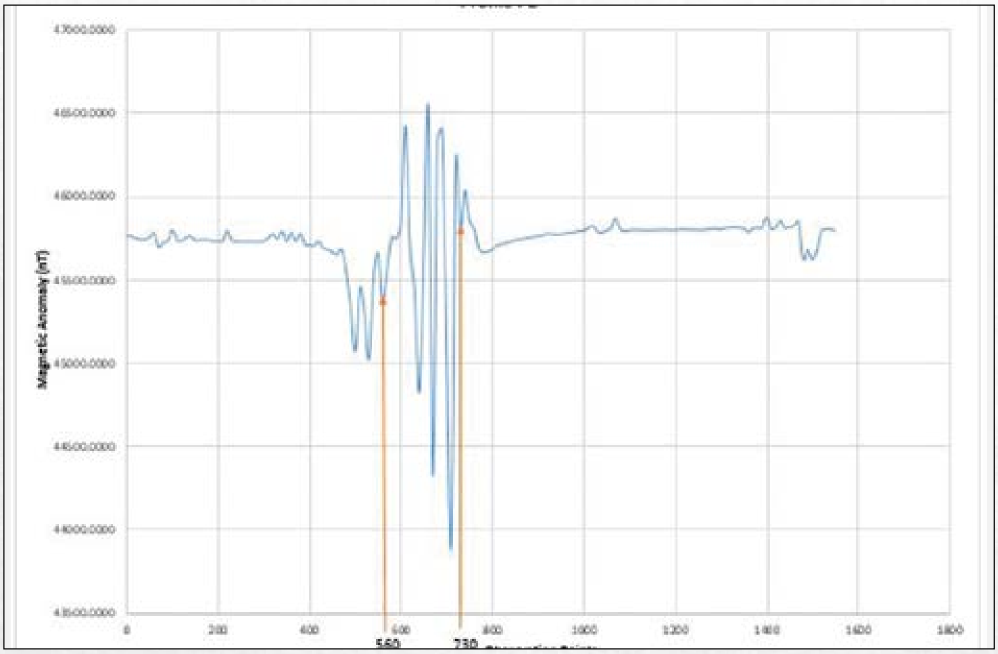

Figure-4B

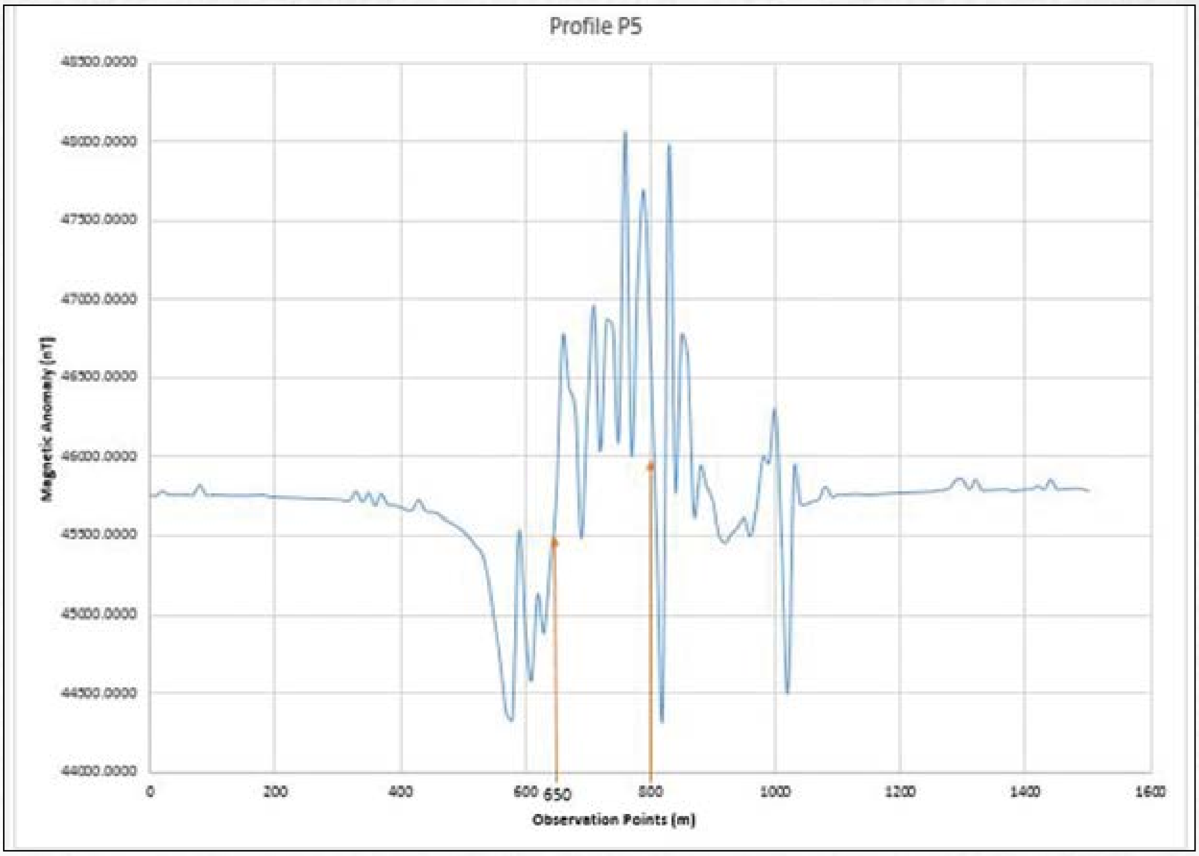

Figure-4C

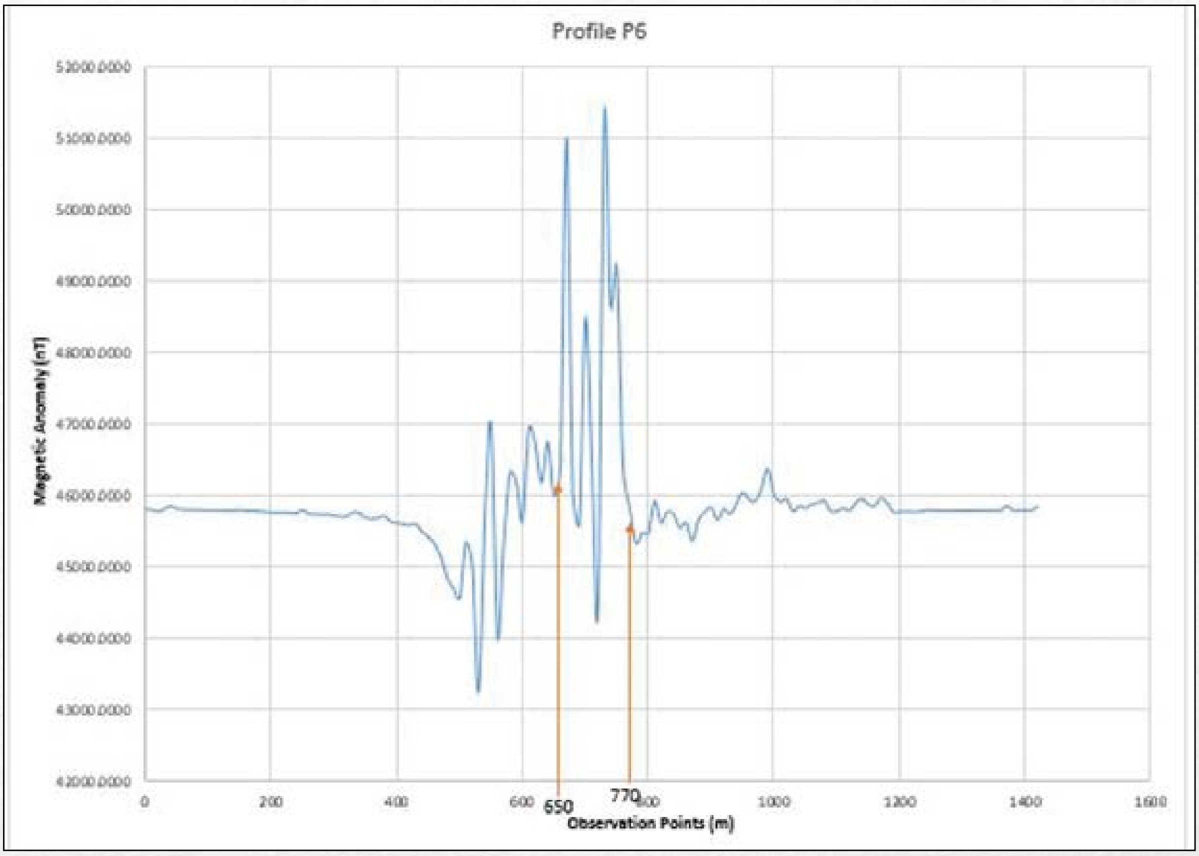

Figure-4D

same varies from 1.45m (CMKH003) to 3.78m (CMSB013). These two seams as discussed earlier are almost free from dirt bands and so naturally ET values are almost equal to the thickness of the seams.

As far as the quality is concerned, Seam VII is found to be of grade ranging from Grade G4 to G10 whereas seam VI is observed to vary from Grade G3 to G8 from the considered core analysis results at standard 40ºC and 60% RH.

Each of the above mentioned four data generates their own grids inside the block boundary, but the advancement in this study is the incorporation of the FRL of the reflectors marked using the 2D HRSS stacked sections discussed above.

The details of the physical and chemical properties of the considered coal seams VII and VI for modelling are described in Table-4.

DATA INTERPRETATION AND ESTIMATION OF COAL RESERVE

The basic objective of this study as discussed earlier is to delineate the structural behaviour of the target seams and finally estimate the gradewise reserve. The challenge before initiating this study was to infer the reserve from boreholes at a density of less than 3 per sq kms. Hence, to confirm the structural behaviour geophysical surface survey was initiated including 2D HRSS and magnetic surveys whereas, the quality and the Effective Thickness (ET) are extracted from the existing boreholes only. It is worth mentioning that the target seams VII and VI does not include dirt bands and is almost uniformly distrusted in the entire block, due to which the grids of ET generated from the widely spaced boreholes is not expected to induce erroneous results.

Three stages of interpretation are discussed in this section including preparation of floor contours, seam folio and isochores and finally estimation of grade-wise reserve of both the target coal seams.

Geological Structural interpretation of Seam VII and Seam VI

One of the major concern while coal reserve modelling is to accurately map the structural features in the study area with the existing data. In this study,we have marked reflector horizons from the 2D HRSS stacked sections, the behaviour of the intrusive bodies from magnetic data and the litholog from the coal core data. The integration of surface geophysical data along with the coal core litholog completes the entire study with much confidence level. The absence of geophysical logs (specially sonic log) generates an issue of determination of the velocities of each of the marked horizons, but that was overcome to some extent by using…….

As per the interpretations, the strike of the coal seams are almost in E-W directions dipping towards north which is typically seen in Sohagpur coalfield. Few boreholes in the adjacent blocks of the study area namely Bikram, Dhanpura blocks in north, West Karkatti, East Karkatti and Khairaha in South, Bodri in West and Karkatti North in East were also considered to observe and establish the structure continuity across the block. A number of faults were identified in the seismic stack sections as well as from the coring well data, all in the strike of E-W direction discussed below.

Six number of geological normal faults F1 to F6 were interpreted in the block all striking in E-W directions with throws varying from 10m to 100m and few of which continuing to the adjacent blocks. The properties of the faults interpreted shown in Table 4, all of which downthrow towards south except F1 whose downthrow is from North-Northeast as shown in Figure 5 (a) and (b) for seam VII and seam VI respectively. The floor grids in the south of P9, P10 and P11 were extrapolated after integrating the correlated results from seismic horizons marked in P8 and P12 and the core wells litholog data of wells CSBA004 to CSBA011 and CSWK017 and CSWK018A. Thus the confidence level in this area is comparatively less than the rest of the block which can be regained by drilling few core wells in the area.(Table-4).

The two seams Seam VII and seam VI occurring at depth ranges 90m to 200m and 110m to 230m respectively where the parting between the seams are more or less consistent varying from 30m to 35m in the entire block.

The floor contours prepared after integrating all the surveys and wells data are shown in Figure 5(a) and (b) and typically both of them follows similar geological structural pattern.

The faults F1, F2 and F3 has continued to the adjacent block Bodri North trending E-W where the maximum throw of about 100m is observed in Fault F3 in the eastern most part of block. The seams dipping towards north has almost uniform dip of around 4^{0} to 5^{0} and striking almost in the E-W direction. Fault F2 dipping south is observed to merge with F1 (dipping north) in the southern portion of the block.

Seam Folio and Isochore Seam VII and Seam VI

After accomplishment of the geological structure, the succeeding step is to model the quality and iso-thickness plans of the seams conventionally termed as seam folio and isochore plans respectively. The limitation of this part of the modelling is that it cannot be materialized using the current 2D HRSS sections due to limitation of frequency generated by hammer source while data acquisition.

The above issue is handled by using the coal core data for generating the quality and ET grids. Although the density of the boreholes are not well enough for generating the quality and ET grids but the advantage in this field is that the seams here considered are more or less dirt band free as well as shows some uniformity in thickness. The fundamental objective here is to classify the coal seams into different grades depending upon GCV values determined in the laboratory. Since, the depth and thickness of both the coal seams preliminarily suggests the underground mining method most suitable for these two seams, hence the proximate results conventionally are considered from I30 sample type. It is widely known that the classification of grades is vital for estimation of costing while preparation of Project Reports for a particular coal block.

Moreover, the isochore grid generated from the core wells data in the entire block boundary is significant for calculation of volume of the seams. The grade of seam VII tends to improve in the eastern part of the block grading to G4 in few patches whereas, in the north-western part of the block, the grade declines upto G5. As far as thickness is concerned, the maximum thickness of seam VII ranges from 4 m to 4.5 m in the central portion of the block whereas the same declines to even 1m in the eastern portion of the block as shown in Figure-6

Reserve Estimation of Seam VII and Seam VI

The geological reserve estimation of coal is established using the following equation:

Reserve (mT)=Area (sq kms) x ET (m)

x Sp. Gravity (g/cc)……….....................(2)

Equation (2) can be dealt with after accomplishing all its parameters in the above sections. After integration of the horizons picked from 2D HRSS sections and core wells data, the area of the individual modelled seams could be evaluated whereas the ET and the specific gravity as discussed above could only be converted in grids using the wells data across the block. But if the 2D HRSS data acquisition be upgraded using suitable frequencies from sources like vibroseis, the thickness of coal seams upto 5m can be resolved which can be further used to model coal reserve.

In the concerned Bartara area of about 8.42 sq kms, using the 12 profile lines and 28 wells data in and across the block boundary, the total reserve estimated for seam VII and VI as shown in Table 5 is 73.10 MT within the block boundary out of which the contribution of seam VII is 40.36 MT and seam VI is 32.74 MT.

The majority of the reserve as per the study is of grade G7 and G8 which contributes about 70% of the total estimated reserve i.e. 52 MT which may be considered as overall good quality coal as far as mining economics are concerned.

Table 3: Borehole-wise details and quality properties of Seam VII and Seam VI in 28 boreholes in Bartara block, Sohagpur coalfield.

SEAM VII									SEAM VI								
Borehole	Sample Type	From (m)	To (m)	Effec. Th. (m)	Ash %	Moist%	GCV (kcal/kg)	RD (g/cc)	Borehole	Sample Type	From (m)	To (m	Effec. Th. (m)	Ash %	Moist %	GCV (kcal/kg)	RD (g/cc)
CMSB002	130	121.46	124.05	2.59	17.4	8.8	5637	1.46	**CMSB002**	130	158.3	161.22	2.92	21.7	7.7	5295	1.497
CMSB044	130	149.1	151.37	2.27	19.9	9.5	5300	1.49	**CMSB044**	130	175.1	178.02	2.92	25.5	8.3	4948	1.535
CMSB036	130	130.55	132.86	2.31	20.7	9.1	5283	1.50	**CMSB036**	130	165.85	169.9	2.65	21.2	8	5396	1.492
CMSB034	130	112.9	114.43	1.53	13.5	8.1	6106	1.43	**CMSB034**	130	149.39	152.56	3.17	28	6.8	4931	1.56
CMSB013	130	107.2	108.95	1.75	19.8	8.8	5411	1.49	**CMSB013**	130	135	138.78	3.78	29.1	6.9	4813	1.571
CMSB007	130	99.75	100.9	1.15	16.2	9.7	5555	1.45	**CMSB007**	130	129.48	132.39	2.91	24.5	8.1	5070	1.525
CMSB033	130	159.45	160.4	0.95	18.5	8.8	5534	1.48	**CMSB033**	130	194.56	196.67	2.11	24.5	7.4	5173	1.525
CMSB029	130	190.01	190.98	0.97	19.5	9.3	5367	1.49	**CSBR111**	130	140.49	142.6	2.11	19.2	8.6	5501	1.5
CMSB035	130	197.2	198.07	0.87	18.2	7.5	5737	1.47	**CSBR113**	130	186.67	189.24	2.57	19	8.6	5517	1.5
CSBR111	130	108.55	110.16	1.61	NA	NA	4917	1.55	**CSBR078**	130	179.87	182.22	2.35	22.3	8.2	5262	1.5
CSBR113	130	155.6	156.6	1	NA	NA	5136	1.51	**CSBR069**	130	183.85	185.6	1.75	31.4	7.3	4538	1.6
CSBR078	130	145.2	147.25	2.05	NA	NA	5305	1.47	**CSBR118**	130	136.25	138	1.75	18.6	10.5	5276	1.5
CSBR069	130	169.7	170.35	0.65	NA	NA	5120	1.51	**CSBR136**	130	124.78	127.41	2.63	15.8	9	5762	1.4
CSBR118	130	101.9	106.6	2.7	NA	NA	4985	1.53	**CSWK020**	130	218	220.65	2.65	28.4	7.5	4797	1.6
CSBR136	130	92.31	94.16	1.85	NA	NA	5111	1.50	**CSWK014**	130	226.5	230	3.5	34	6.8	4368	1.6
CSWK020	130	184	185.2	1.2	26	5.5	5308	1.54	**CSWK016**	130	208.1	211.7	3.6	22.9	8.1	5220	1.5
CSKW019	130	138.20	139.75	1.55	14.7	6.0	6299	1.43	**CMSB043**	130	186.4	189.76	3.36	19.7	9	5392	1.477
CSWK016	130	171.10	172.60	1.50	28.0	6.0	5047	1.56	**CMKH003**	130	116.05	117.6	1.45	17.8	8.7	5614	1.458
CSKW014	130	199.50	200.30	0.80	19.1	2.8	6350	1.47	**CMKH006**	130	153.53	156.91	3.38	12.9	8.5	6104	1.409
CSWK007	130	119.00	120.5	1.50	21.7	3.3	6033	1.50	**CMKH007**	130	165.2	166.55	2.85	21.2	8.6	5309	1.492
CMSB046	130	173.85	178.03	4.18	28.4	7.1	4849	1.56	**CMKH054**	130	141.53	144.61	3.08	20.8	8.8	5317	1.488
CMSB043	130	160.53	165.32	4.79	20.2	8.7	5388	1.48	**CMKH057**	130	147.15	149.9	2.75	19.9	9	5320	1.479
CMSB054	130	130.2	132.8	2.6	23.0	8.8	5110	1.51	**CMSB003**	130	181.65	185.37	3.72	21.1	8.2	5325	1.491
CMSB026	130	93.52	94.73	1.21	16.0	9.6	5652	1.44	**CMSB014**	130	152.57	155.86	3.29	21.2	7.4	5483	1.492
CSBN088	130	171.8	174.8	2.72	27.1	6.7	5025	1.55	**CSBN015**	130	179.1	181.7	2.6	44.5	5.1	3632	1.72

Table-4: Fault properties of the six numbers of faults encountered in Bartara block, Sohagpur CF.

Fault Name	Orientation	Throw in m	
		Minimum	Maximum
F1	NW-SE	20	50
F2	E-W	40	60
F3	E-W	40	100
F4	SW-NE	0	22
F5	E-W	10	30
F6	E-W	40	50

Table 5: Gradewise and depthwise seam reserve details of Seam VII & Seam VI in Bartara block, Sohagpur CF.

SEAM WISE AND GRADE WISE NET INSITU INDICATED GEOLOGICAL RESERVE OF COAL FOR SEAM 0.50m AND ABOVE IN THICKNESS, BARTARA BLOCK, SOHAGPUR COALFIELD FROM HRSS SURVEY AND DRILLED BOREHOLES DATA								
	(RESERVE IN MILLION TONNES)							
COAL SEAMS:	GRADE							TOTAL RES.
	G4	G5	G6	G7	G8	G9	G10	
	RES	RES	RES	RES	RES	RES	RES	
SEAM NAME: VII								
PARTICULARS								
SUB TOTAL, DEPTH 0-300m		1.13	1.53	5.77	21.3	7.96	2.67	40.36
TOTAL SEAM-VII		**1.13**	**1.53**	**5.77**	**21.3**	**7.96**	**2.67**	**40.36**
SEAM NAME: VI								
PARTICULARS								
SUB TOTAL, DEPTH 0-300m		0.15	1.25	13.52	11.16	5.5	1.16	32.74
TOTAL SEAM-VI		**0.15**	**1.25**	**13.52**	**11.16**	**5.5**	**1.16**	**32.74**
TOTAL RESERVE-VI+VII		**1.28**	**2.78**	**19.29**	**32.46**	**13.46**	**3.83**	**73.1**

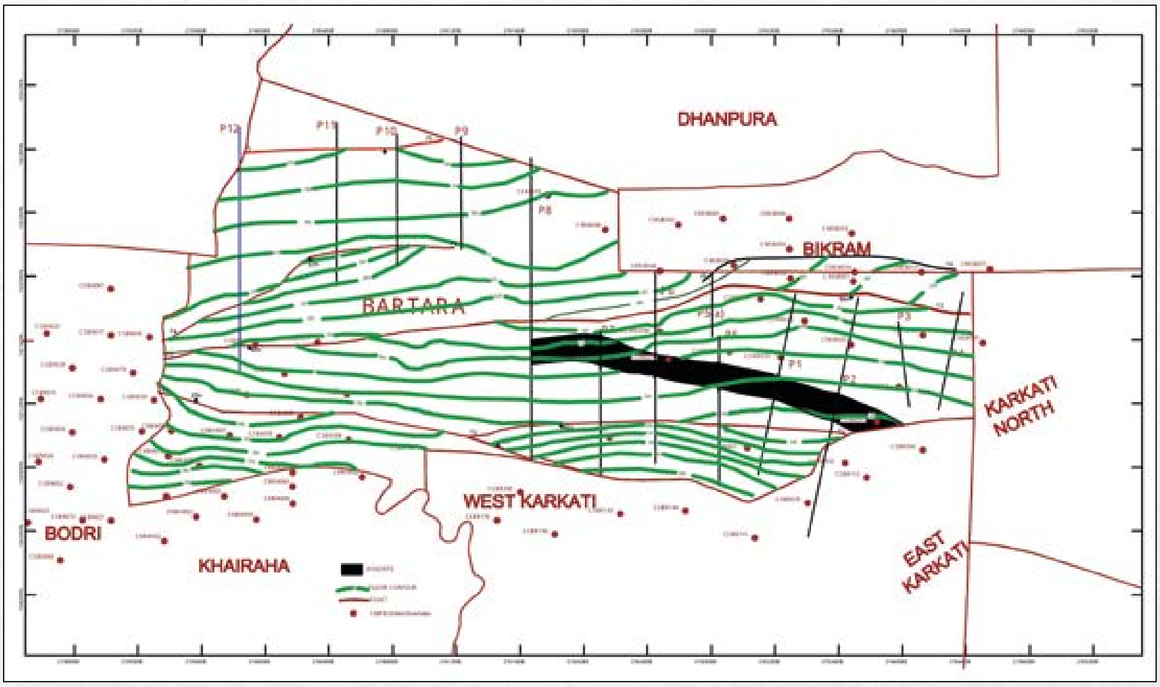

Figure-5A

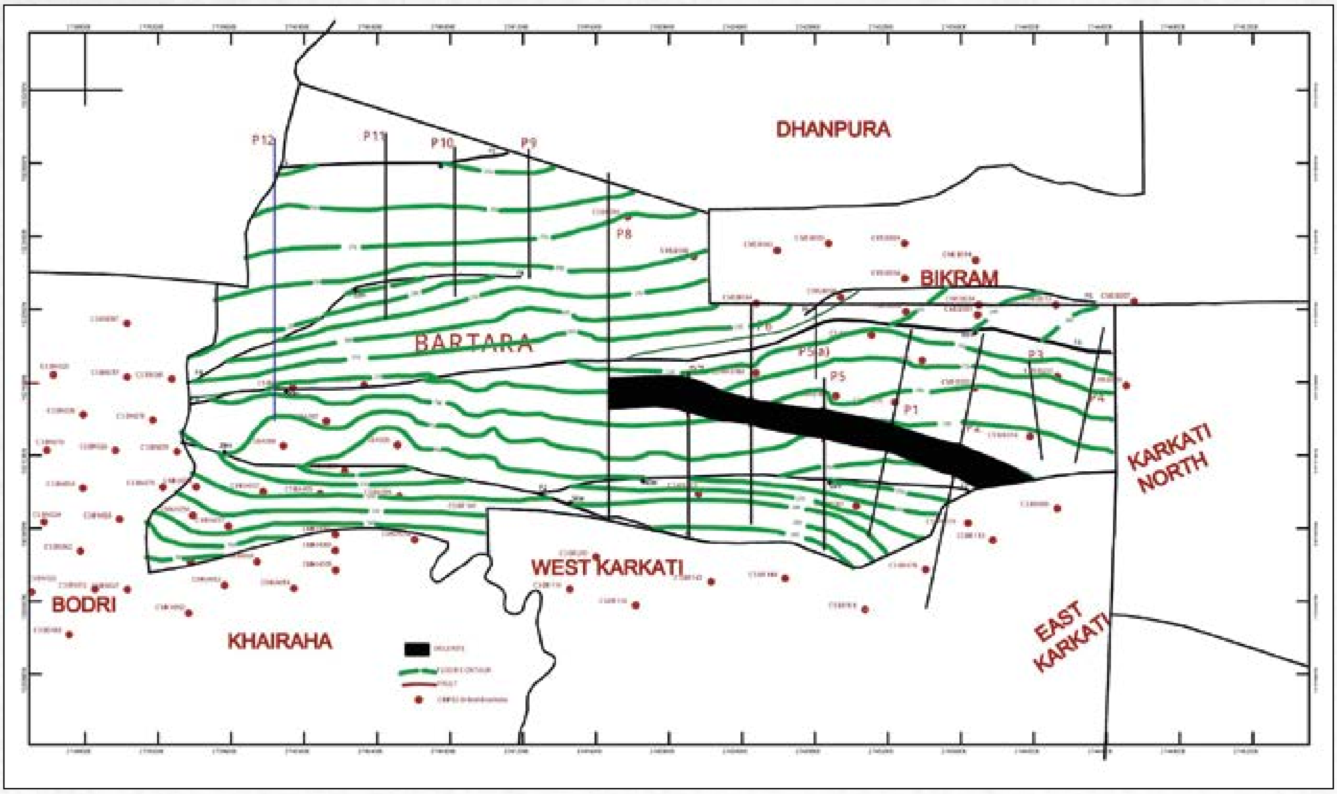

Figure-5B

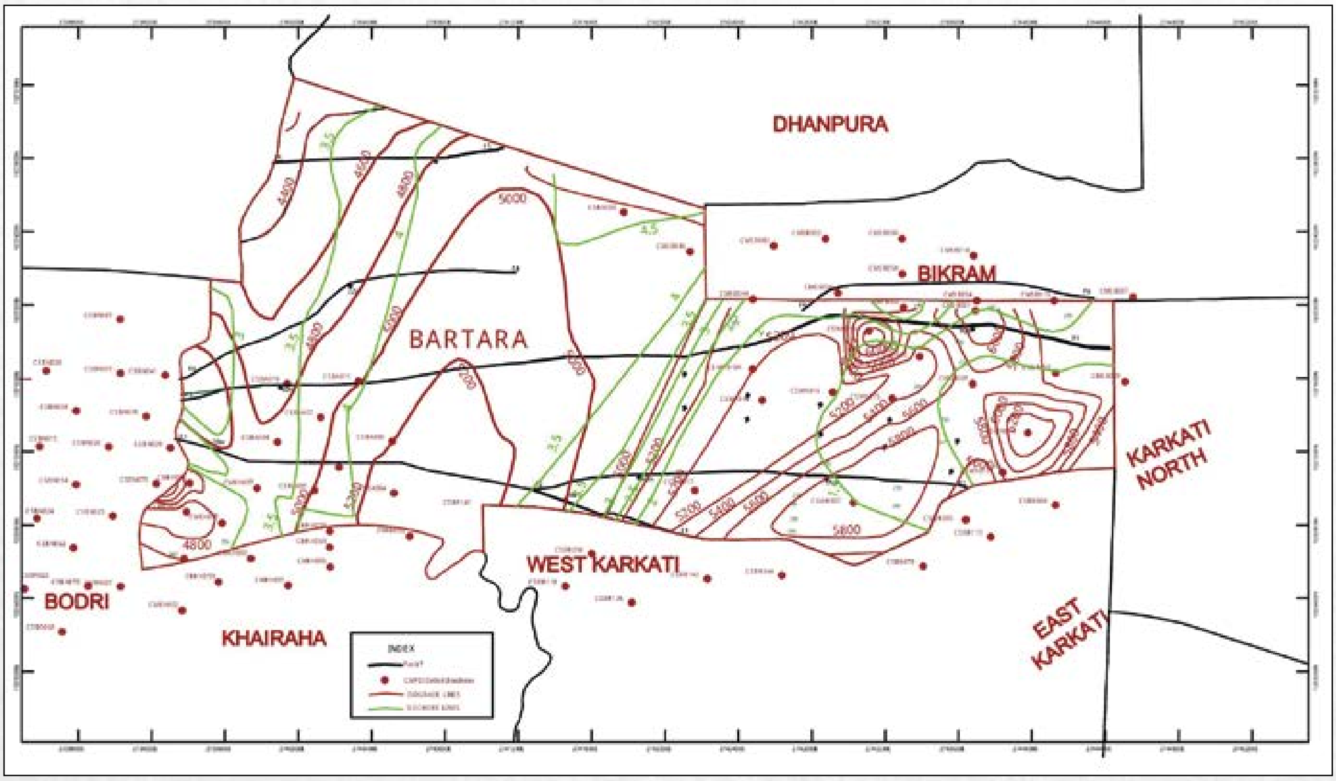

Figure-6

CONCLUSION & RECOMMENDATION

The objective behind this study was to establish the coal seam model along with gradewise and depthwise reserve for the target seams with limited number of boreholes and incorporating the findings of geophysical surface surveys including 2D HRSS and magnetic surveys. Seismic as well as magnetic data were acquired over total 12 profile lines all along N-S directions, where the source for seismic data was manual hammering which again limited the scope of the survey. The shallower seams IX and VIII in the area could not be traced due to muting of the process to eliminate ground-rolls but the remaining two seams VII and VI were marked on the stacked sections. The area in the south of the profile P 9 to P 11 was unreachable due to law and order problems, but the grids generated were extrapolated.

After mapping the subsurface structure, five number of faults were interpreted using the seismic and wells data with a maximum throw of 100m. All the faults were striking E-W which is also the strike direction of the seams dipping towards north. A dolerite intrusion was also interpreted using magnetic and core well data which tends to be at surface in the East and at relatively higher depth towards the centre of the block. The seam folio and the isochore plans were prepared using the core wells data and it was observed that the seam quality tends to improve upto G4 grade in the eastern side of the block and decline upto G10 grade in the western part of the block.

The total reserve estimated for the two target seams was 73.10 MT out of which the dominant grades are G7 and G8 which contributes more than 70% of the estimated reserve.

After accomplishment of this study, it may be recommended to drill few core wells along with geophysical logs in the untouched area beneath profile P9 to P11 which will increase the confidence level of this model and reserve estimation.

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Application of Steep Angle Conveyor in Deep Opencast Coal Mine (A Case Study)

Devendra Pratap Singh[1], Murari Prasad[2], Kintali Naveen[3]

ABSTRACT

In India, over 90% of the total coal production is achieved through opencast mining which requires huge quantity of removal of OB and mining of coal from the quarry and subsequent transport to the surface. We know that the transport cost is one of the major components in the total cost of production and as the depth of mine increases along with quantity of material to be transported increases, the transport cost rises exponentially. Thus the economics of the mine greatly depends on the economics of the transport system used. Moreover, there is huge inflationary pressure with the fuel costs on the rise.

With the increase in depth of opencast coal mines and for steep quarry batter slope, **Steep Angle Conveyor** is a solution for transporting coal from quarry floor to surface with better economy and productivity. It is also an eco-friendly, traffic-friendly and space & energy saving solution.

Due to high initial depth and steep quarry batter slope, it is difficult to install conventional conveyor in one Non-CIL opencast project. Therefore, it has been decided for implementation of Steep Angle Conveyor. Economic analysis of Steep Angle Conveyor system vs Dumper system reflects that the capital requirement & cost of production per tonne for Steep Angle Conveyors along with in-pit conveyors and requirement of 60T coal body dumpers have reduced.

INTRODUCTION

At present, there are two main alternatives proposed for the transport system, e.g. (i) truck system and (ii) conventional belt conveyor system. In Indian context, truck based transport system has been a favorite tool for the transportation of OB and coal. However, there is an increasing pressure to restrict the movement of Trucks from environmental point of view, as outlined while issuing Environmental Clearance by MOEF.

Conventional belt conveyors offer a most economical method for transporting bulk materials at recommended inclination angles up to 140 for most common materials. Internal friction development and the induced dynamics of the moving conveyor belt limit the conveying angle. Conveying angles beyond the angle of internal friction can be achieved by a cover belt which, when pressed against the material, will create a hugging-action to prevent sliding at the contact surface.

Sandwich Belt Conveyors are so named due to the manner in which the material is 'Sandwiched' between two belts before it is inclined at angles up to 70 degrees. Material is 'hugged' by the belts throughout the inclined section to ensure that it does not slide back down the incline, even if the conveyor trips.

A Sandwich Belt Conveyor (Steep Angle Conveyor) consists of two endless belt conveyors that share a common load carrying path. The top and bottom belts are independently driven and tensioned. Along the carrying path the top and bottom belts are alternately supported against closely spaced troughing idlers. Radial pressure, due to belt tension and the curving profile, continuously hugs the material that is sandwiched between the two belts. Internal friction is developed and bulk material can be conveyed at any high angle up to 70 degrees or even more.

With the increase in depth of opencast coal

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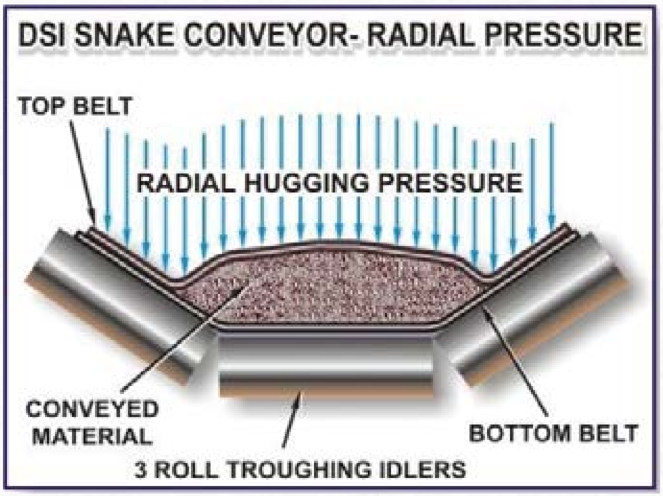
mines and for steep quarry batter slope, Steep Angle Conveyor is a solution for transporting coal from quarry floor to surface with better economy and productivity. It is also an eco-friendly, traffic-friendly and space & energy saving solution.

OBJECTIVE

The objective of implementation of Steep Angle Conveying system in conjunction with Surface Miner/In-pit crushing in Indian geo-mining condition is to make coal transportation in opencast coal mines more economic, highly productive, eco-friendly, traffic-friendly and space & energy saving.



FACTORS GOVERNING STEEP ANGLE CONVEYOR STRUCTURE

Following are major factors governing a Steep Angle Conveyor structure for conveying material in a mine:

- Whether the dip of the seam permits internal dumping
- Rate of advance of coal face and internal dump
- Rate of deepening the pit
- Whether a Dump truck can pass underneath
- Ease of maintenance in a pit environment
- Mine Safety, Blasting parameters, Fire, Slope stability, material rolling back etc.
- Dependability to handle large quantities, breakdown analysis/unscheduled maintenance.

STRUCTURAL DESIGNS OF STEEP ANGLE CONVEYOR

After detailed deliberations and discussions with manufacturers of Steep Angle Conveyor, two types of structural designs are approved for a feasible application in a mine.

Single Run System

A single run system as shown in the drawing is suggested for a mine with Steeply to moderately dipping seams. In steeply dipping seams, as there is no inetrnal dumping, Steep Angle Conveyor can be installed at one suitable positions and modules can be added to compensate for the depth.

The first position of Steep Angle Conveyor can be at a depth of 90m to 100m to reduce truck fleet. Individual cases must be studied in details to arrive at exact depth. If internal dumping is proposed in a moderately dipping seam, the structure can be shifted to a new location and the shifting period can be scheduled accordingly. Advance preparation at new site will certainly bring down this period significantly.

Annual coal production should not be less than 4 to 5 Mtpa to justify investment on Steep Angle Conveyor. Life of mine after Steep Angle Conveyor installation should not be less than 18 years.

A dumper can pass underneath this structure and staircase is provided alongside Steep Angle Conveyor for maintenance personnels. A hydraulic lift can also be used for maintenance purposes.

It has also been noted that the system is quite robust and with proper maintenance and care it can provide sufficient dependebility to handle large production. The system is equiped with latest sensing system, overlaod protection system, fire sensors to avoid any untoward incidence resulting in unscheduled production loss. A shield is provided to protect vulnerable parts of the structure from fly rocks. Sufficent distance is also maintained from active face.

MODULAR SYSTEM

A modular system is suitable for the mines where frequent shifting is required with advancing internal dump benches. Every unit or module is self-sufficient and can be taken to a new site very quickly. The mode of transport can be crawler mounted at both ends, or skid mounted to be pushed or pulled by a Dozer. Another popular design to render mobility is by removable crawler pads that can shift multiple units resulting in less investment on crawlers.

Modules can be time phased and are added to compensate for the growing depth of the pit.

Structural changes are possible where these modules can give sufficient clearance to a Truck passing underneath. This is especially important while internal dumping for OB Trucks plying within a closed circuit.

Inherent problem with design shown above is of shifting as support trestles are provided on alternate benches. This can be obviated by a cantilever design made possible by structural engineering.

Another added advantage of modular system of Steep Angle Conveyor is the enhanced dependability. Extra modules with a little additional cost can be fast replaced in the event of unscheduled break down. Certain modifications are required at the place on the bench to accommodate hoppers and tail endings.

It is understood that the Steep Angle Conveyor system will further evolve over time as more experience is gained in working with it. Indigenous practices for operations, shifting, and maintenance, will develop to greater adoptability. Many structural changes are envisaged while implementation phase of Steep Angle Conveyor as new insight emerge.

APPLICABILITY

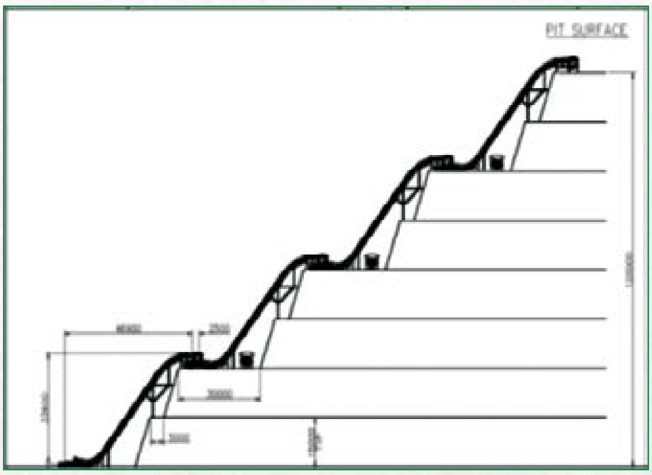
Coal with a lump size of preferably < 200 mm and evenly distributed for effective sandwiching and to avoid material falling back within the sandwich region.

Density-wise suitable for all types of coal and for medium density OB.

Normal Temperature is recommended for the belt and moisture may cause reduction in frictional force while sandwiching.

The best suitable position for Steep Angle Conveyor is along the side batter. Coal can be brought to the bottom most seam floor for 30 to 50 meters parting and for greater parting thickness, a separate unit can be planned for upper seams.

Sandwich Conveyor in a deep Pit



Modular Sandwich Conveyor in a deep Pit

PROJECT IDENTIFICATION AND JUSTIFICATION

PROJECT IDENTIFICATION

One Non-CIL OCP has been identified for implementation of Steep Angle Conveyor.

PROPOSED QUARRY PARAMETERS

(Tabulated below)

Sl. No.	Particulars	Unit	Value	
			Min	Max
1	Quarry Area			
	Along floor	ha	1028.31	
	Along surface	ha	1620.31	
2	External dump area	ha	1447.50	
3	Strike length	m		
	Floor		3200	4500
	Surface		4000	5500
4	Dip-Rise length	m		
	Floor		1800	3500
	Surface		2500	4200
5	Depth of Quarry	m	140	266
6	Extractable Reserves	Mt	427.86	
7	Overburden to be removed	Mcum	2804.11	
8	Stripping Ratio (Average)	cum/t	6.55	
9	Annual production	Mty	15.00	
10	Life of proposed quarry including construction	Year	34	
11	Quarry perimeter	m	190450.00	

MAJOR HEMM PROVISIONS

MAJOR EQUIPMENT	Size	Proposed Maximum No.
Electric Rope Shovel	42cum	7
Rear Dumper	240T	110
Diesel Hyd. Shovel	10-12cum	17
Rear Dumper	100 T	158
Surface Miner	100t class (Wt.)	4
FEL	10-12cum	6
Rear Dumper (Coal Body)	60 T	40
Crawler Dozer	850-860hp	4
Crawler Dozer with Ripper Attachment	850-860 T	2
Crawler Dozer	410hp	24
Wheel Dozer	460-500hp	3
Drill (RBH) Electric	311mm	7
Drill (RBH) Diesel	160mm	17
Steep Angle Conveyor		3

JUSTIFICATION FOR APPLICATION OF STEEP ANGLE CONVEYOR SYSTEM IN THE PROPOSED OCP

- Due to high initial depth & steep quarry batter, it is difficult to install conventional conveyor.
- It improves economy of the mine.
- It is a highly productive system.
- It is an eco-friendly system.
- It is a traffic-friendly system.
- It is a space saving system.
- It is an energy saving system.
- It is a solution for transporting coal from quarry floor to surface at higher depth.

PROPOSED STEEP ANGLE CONVEYOR SYSTEM & LAYOUT

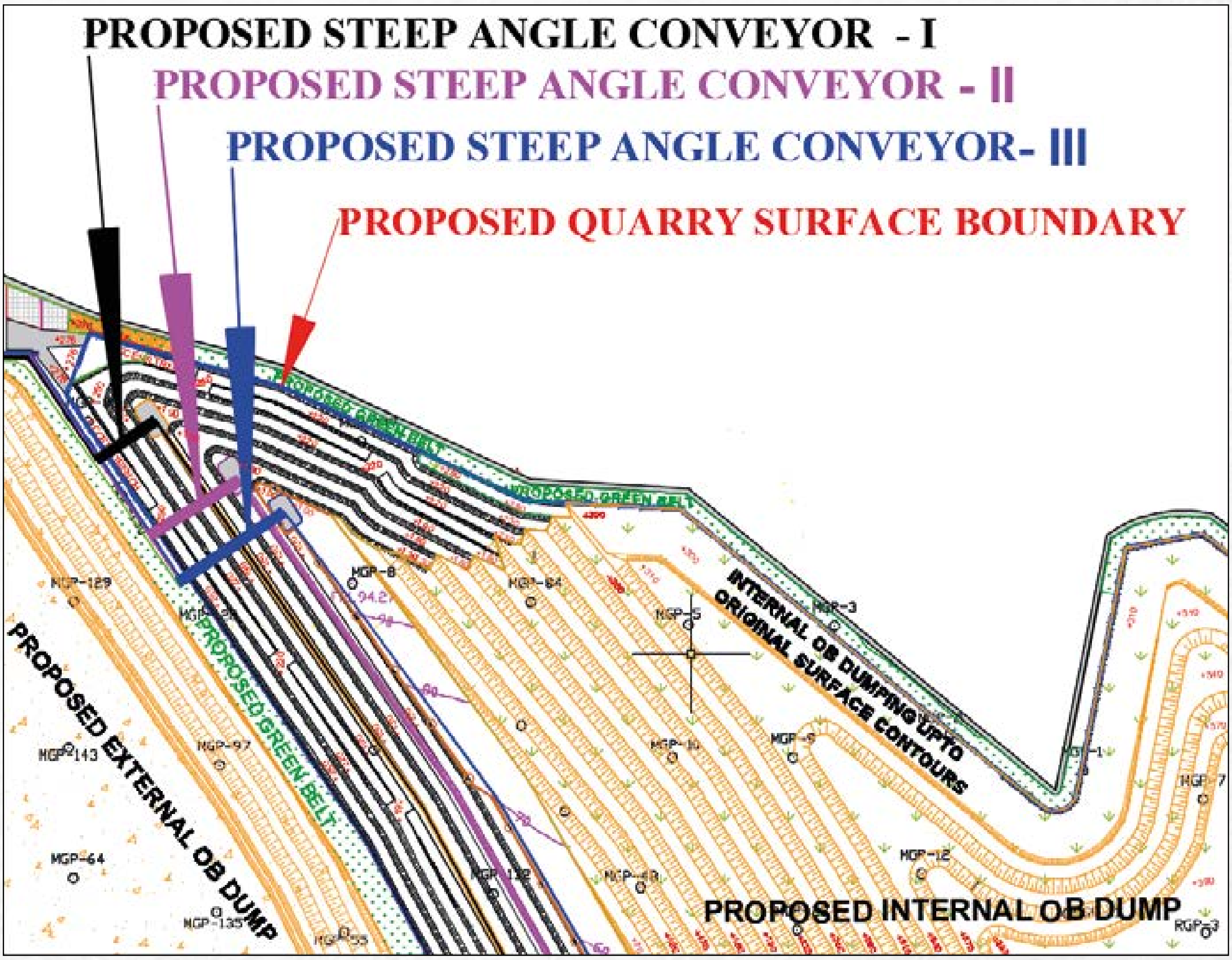
The proposed Project Report for Non-CIL OCP has been prepared for the production of 15Mty of ROM coal from OCP. Coal production has been proposed by surface miner (-100 mm size) as such the crushing is not required for conveying of coal by conveyors. Coal cut by surface miner (-100 mm size) will be loaded on to 60T coal body dumpers through 10-12cum Front End Loaders. 60T coal body dumpers will feed the coal to conventional belt conveyors laid along the Western quarry batter.

The mining condition in proposed OCP is not suitable for conventional conveying system for transportation of coal from quarry floor to surface. Coal from three different coal horizons (top coal horizon, middle coal horizon & bottom coal horizon) conveyed by three conventional belt conveyors laid along the Western quarry batter will be lifted through three corresponding Steep Angle Conveyors from three different coal horizons to surface. Three separate receiving arrangements have been envisaged at three different coal horizons of the quarry for receiving coal.

The Run-Off-Mine (ROM) coal produced by surface miner (-100 mm size) from the quarry shall be received into receiving pits by means of 60T coal body rear discharge dumpers at three different coal horizons / floor of the major seams of the quarry and conveyed up to surface by means of high angle conveyors. Receiving pit hoppers at seam floors have been provided with sufficient capacity to accommodate payload of two dumpers at a time. These receiving pits at different floor will be made as per mine advancement. The ROM coal from receiving hoppers at quarry floor will be reclaimed through feeders and collected by short belt conveyor and further it will be collected by the respective Steep Angle Conveyor (1 to 3) which will carry the coal up to surface.

Coal produced in seams IX & X will be collected at coal horizon-1 and fed to surface through Steep Angle Conveyor-1 of 1500TPH nominal capacity.

Coal produced in seams VII & VIII will be collected at coal horizon-2 and fed to surface through Steep Angle Conveyor-2 of 1500TPH nominal capacity. Similarly, Coal produced in seam V & VI will be collected at coal horizon-3 (quarry floor) and fed to surface through Steep Angle Conveyor-3 of 2000TPH nominal capacity. This arrangement of coal receiving and feeding to Steep Angle Conveyor have been provided at all the three coal horizons / level for each Steep Angle Conveyor. The coal from three different Steep Angle Conveyors will be collected by three different conventional conveyors at surface. It will be finally fed to ground bunkers through series of conventional conveyors at surface.



Proposed Layout of Steep Angle Conveyor

ECONOMIC ANALYSIS OF STEEP ANGLE CONVEYOR SYSTEM VS DUMPER SYSTEM

Steep Angle Conveyor System Technical & Financial Data

Base Date: December 2017

	Top Level							Middle Level							Bottom Level						
Year	HAC length (m)	Production from Top Belt (Mt)	HAC Structure Cost (1500 TPH)(Rs Lakhs)	Conv. Conveyor Length (m)	Conventional Conveyor Structure Cost (Rs. 84000/m)	HAC Belt Cost (Rs. Lakh)	Conv. Belt Cost (Rs.Lakh)	HAC length (m)	Production from Middle Belt (Mt)	HAC Structure Cost (1500 TPH)(Rs. Lakhs)	Conv. Conveyor Length (m)	Conventional Conveyor Structure Cost (Rs. 84000/m)	HAC Belt Cost (Rs. Lakh)	Conv. Belt Cost (Rs. Lakhs)	HAC length (m)	Production from Bottom Belt (Mt)	HAC Structure Cost (2000 TPH) (Rs. Lakhs)	Conv. Conveyor Length (m)	Conv. Conveyor Structure Cost (Rs.86000/m)	HAC Belt Cost (Rs. Lakhs)	Conv. Belt Cost (Rs. Lakhs)
P5	210	4.24	1749.5	350.0	279.3	262.4	14.0														
P6	210	4.66	1749.5	350.0	279.3	262.4	14.0	300.0	5.1	2475.2	765.0	642.6	371.3	32.1							
P7	210	4.66	1749.5	350.0	279.3	262.4	14.0	300.0	5.1	2475.2	765.0	642.6	371.3	32.1							
P8	210	4.66	1749.5	350.0	279.3	262.4	14.0	300.0	5.1	2475.2	765.0	642.6	371.3	32.1							
P9	210	4.66	1749.5	1000.0	798.0	262.4	39.9	300.0	5.1	2475.2	765.0	642.6	371.3	32.1	355.0	5.2	4352.0	770.0	662.2	652.8	33.1
P10	210	4.66	1749.5	1000.0	798.0	262.4	39.9	300.0	5.1	2475.2	1500.0	1260.0	371.3	63.0	355.0	5.2	4352.0	770.0	662.2	652.8	33.1
P11	210	4.66	1749.5	1000.0	798.0	262.4	39.9	300.0	5.1	2475.2	1500.0	1260.0	371.3	63.0	355.0	5.2	4352.0	770.0	662.2	652.8	33.1
P12	210	4.61	1749.5	1000.0	798.0	262.4	39.9	300.0	5.0	2475.2	1500.0	1260.0	371.3	63.0	355.0	5.4	4352.0	770.0	662.2	652.8	33.1
P13	210	3.61	1749.5	1000.0	798.0	262.4	39.9	300.0	3.9	2475.2	1500.0	1260.0	371.3	63.0	355.0	7.5	4352.0	1500.0	1290.0	652.8	64.5
P14	210	3.61	1749.5	1700.0	1356.6	262.4	67.8	300.0	3.9	2475.2	1500.0	1260.0	371.3	63.0	355.0	7.5	4352.0	1500.0	1290.0	652.8	64.5
P15	210	3.61	1749.5	1700.0	1356.6	262.4	67.8	300.0	3.9	2475.2	2200.0	1848.0	371.3	92.4	355.0	7.5	4352.0	1500.0	1290.0	652.8	64.5
P16	210	3.61	1749.5	1700.0	1356.6	262.4	67.8	300.0	3.9	2475.2	2200.0	1848.0	371.3	92.4	355.0	7.5	4352.0	1500.0	1290.0	652.8	64.5
P17	210	3.62	1749.5	1700.0	1356.6	262.4	67.8	300.0	3.7	2475.2	2200.0	1848.0	371.3	92.4	355.0	7.7	4352.0	1500.0	1290.0	652.8	64.5
P18	210	3.62	1749.5	1700.0	1356.6	262.4	67.8	300.0	3.6	2475.2	2200.0	1848.0	371.3	92.4	355.0	7.8	4352.0	2200.0	1892.0	652.8	94.6
P19	210	3.62	1749.5	2400.0	1915.2	262.4	95.8	300.0	3.6	2475.2	2200.0	1848.0	371.3	92.4	355.0	7.8	4352.0	2200.0	1892.0	652.8	94.6
P20	210	3.62	1749.5	2400.0	1915.2	262.4	95.8	300.0	3.6	2475.2	2900.0	2436.0	371.3	121.8	355.0	7.8	4352.0	2200.0	1892.0	652.8	94.6
P21	210	3.60	1749.5	2400.0	1915.2	262.4	95.8	300.0	3.6	2475.2	2900.0	2436.0	371.3	121.8	355.0	7.8	4352.0	2200.0	1892.0	652.8	94.6
P22	210	3.05	1749.5	2400.0	1915.2	262.4	95.8	300.0	3.2	2475.2	2900.0	2436.0	371.3	121.8	355.0	8.8	4352.0	2200.0	1892.0	652.8	94.6
P23	210	3.05	1749.5	2400.0	1915.2	262.4	95.8	300.0	3.2	2475.2	2900.0	2436.0	371.3	121.8	355.0	8.8	4352.0	2900.0	2494.0	652.8	124.7
P24	210	3.05	1749.5	3100.0	2473.8	262.4	123.7	300.0	3.2	2475.2	2900.0	2436.0	371.3	121.8	355.0	8.8	4352.0	2900.0	2494.0	652.8	124.7
P25	210	3.05	1749.5	3100.0	2473.8	262.4	123.7	300.0	3.2	2475.2	2900.0	2436.0	371.3	121.8	355.0	8.8	4352.0	2900.0	2494.0	652.8	124.7
P26	210	3.05	1749.5	3100.0	2473.8	262.4	123.7	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	2900.0	2494.0	652.8	124.7
P27	210	3.05	1749.5	3100.0	2473.8	262.4	123.7	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	2900.0	2494.0	652.8	124.7
P28	210	3.05	1749.5	3100.0	2473.8	262.4	123.7	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	3600.0	3096.0	652.8	154.8
P29	210	3.05	1749.5	3800.0	3032.4	262.4	151.6	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	3600.0	3096.0	652.8	154.8
P30	210	3.05	1749.5	3800.0	3032.4	262.4	151.6	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	3600.0	3096.0	652.8	154.8
P31	210	3.05	1749.5	3800.0	3032.4	262.4	151.6	300.0	3.2	2475.2	3700.0	3108.0	371.3	155.4	355.0	8.8	4352.0	3600.0	3096.0	652.8	154.8
P32	210	0.70	1749.5	3800.0	3032.4	262.4	151.6	300.0	0.7	2475.2	3700.0	3108.0	371.3	155.4	355.0	2.0	4352.0	3600.0	3096.0	652.8	154.8

Steep Angle Conveyor System Technical & Financial Data

Base Date: December 2017 — **Rs Lakhs**

Year	Total							Manpower			
								Cat-6		Cat-3	
	HAC cost (Rs lakhs)	Conventional conveyor structure cost (Rs. lakh)	HAC Belt cost (Rs Lakhs)	Conv. Belt Cost (Rs Lakhs)	HAC/ Conv. Conveyor Life (Yrs)	HAC Belt Life (yrs)	Conv. Belt Life (Yrs)	(No.)	(Salary & Wages)	(No.)	(Salary & wages)
P5	1749.50	279.30	262.43	13.97	18	9	3	18	132.30	32	216.0
P6	4224.70	921.90	633.71	46.10	18	9	3	34	249.90	54	364.5
P7	4224.70	921.90	633.71	46.10	18	9	3	34	249.90	54	364.5
P8	4224.70	921.90	633.71	46.10	18	9	3	34	249.90	54	364.5
P9	8576.70	2102.80	1286.51	105.14	18	9	3	50	367.50	80	540.0
P10	8576.70	2720.20	1286.51	136.01	18	9	3	50	367.50	80	540.0
P11	8576.70	2720.20	1286.51	136.01	18	9	3	50	367.50	80	540.0
P12	8576.70	2720.20	1286.51	136.01	18	9	3	50	367.50	80	540.0
P13	8576.70	3348.00	1286.51	167.40	18	9	3	50	367.50	80	540.0
P14	8576.70	3906.60	1286.51	195.33	18	9	3	50	367.50	80	540.0
P15	8576.70	4494.60	1286.51	224.73	18	9	3	50	367.50	80	540.0
P16	8576.70	4494.60	1286.51	224.73	18	9	3	50	367.50	80	540.0
P17	8576.70	4494.60	1286.51	224.73	18	9	3	50	367.50	80	540.0
P18	8576.70	5096.60	1286.51	254.83	18	9	3	50	367.50	80	540.0
P19	8576.70	5655.20	1286.51	282.76	18	9	3	50	367.50	80	540.0
P20	8576.70	6243.20	1286.51	312.16	18	9	3	50	367.50	80	540.0
P21	8576.70	6243.20	1286.51	312.16	18	9	3	50	367.50	80	540.0
P22	8576.70	6243.20	1286.51	312.16	18	9	3	50	367.50	80	540.0
P23	8576.70	6845.20	1286.51	342.26	18	9	3	50	367.50	80	540.0
P24	8576.70	7403.80	1286.51	370.19	18	9	3	50	367.50	80	540.0
P25	8576.70	7403.80	1286.51	370.19	18	9	3	50	367.50	80	540.0
P26	8576.70	8075.80	1286.51	403.79	18	9	3	50	367.50	80	540.0
P27	8576.70	8075.80	1286.51	403.79	18	9	3	50	367.50	80	540.0
P28	8576.70	8677.80	1286.51	433.89	18	9	3	50	367.50	80	540.0
P29	8576.70	9236.40	1286.51	461.82	18	9	3	50	367.50	80	540.0
P30	8576.70	9236.40	1286.51	461.82	18	9	3	50	367.50	80	540.0
P31	8576.70	9236.40	1286.51	461.82	18	9	3	50	367.50	80	540.0
P32	8576.70	9236.40	1286.51	461.82	18	9	3	50	367.50	80	540.0

Steep Angle Conveyor System Operating Cost

Base Date: December 2017									Rs Lakhs
Year	Salaries & Wages	Stores Cost	Power Cost	Misc. Cost	Interest on Working Capital	Total Cash Cost	Depreciation	Total Operating Cost	Production (Mt)
P5	348.30	52.11	433.15	53.20	21.92	908.68	146.52	**1055.20**	**4.24**
P6	614.40	131.75	1085.20	127.78	42.24	2001.37	371.70	**2373.07**	**9.76**
P7	614.40	131.75	1085.20	127.78	42.24	2001.37	371.70	**2373.07**	**9.76**
P8	614.40	131.75	1085.20	127.78	42.24	2001.37	371.70	**2373.07**	**9.76**
P9	907.50	286.53	2668.75	255.40	70.06	4188.23	771.30	**4959.53**	**15.00**
P10	907.50	302.64	2808.47	268.53	71.47	4358.60	815.89	**5174.49**	**15.00**
P11	907.50	302.64	2808.47	268.53	71.47	4358.60	815.89	**5174.49**	**15.00**
P12	907.50	302.64	2808.47	268.53	71.47	4358.60	815.89	**5174.49**	**15.00**
P13	907.50	318.94	2948.20	281.87	72.90	4529.41	861.23	**5390.64**	**15.00**
P14	907.50	333.93	3087.92	293.75	74.20	4697.31	901.57	**5598.88**	**15.00**
P15	907.50	349.48	3227.65	306.25	75.56	4866.44	944.04	**5810.48**	**15.00**
P16	907.50	349.48	3227.65	306.25	75.56	4866.44	944.04	**5810.48**	**15.00**
P17	907.50	349.48	3227.65	306.25	75.56	4866.44	944.04	**5810.48**	**15.00**
P18	907.50	365.30	3367.37	319.05	76.94	5036.16	987.52	**6023.68**	**15.00**
P19	907.50	380.29	3507.10	330.93	78.24	5204.05	1027.86	**6231.91**	**15.00**
P20	907.50	395.84	3646.82	343.43	79.59	5373.18	1070.33	**6443.51**	**15.00**
P21	907.50	395.84	3646.82	343.43	79.59	5373.18	1070.33	**6443.51**	**15.00**
P22	907.50	395.84	3646.82	343.43	79.59	5373.18	1070.33	**6443.51**	**15.00**
P23	907.50	411.65	3786.55	356.23	80.98	5542.91	1113.80	**6656.71**	**15.00**
P24	907.50	426.64	3926.27	368.11	82.28	5710.80	1154.15	**6864.95**	**15.00**
P25	907.50	426.64	3926.27	368.11	82.28	5710.80	1154.15	**6864.95**	**15.00**
P26	907.50	443.78	4066.00	382.40	83.79	5883.47	1202.68	**7086.15**	**15.00**
P27	907.50	443.78	4066.00	382.40	83.79	5883.47	1202.68	**7086.15**	**15.00**
P28	907.50	459.60	4205.72	395.20	85.18	6053.20	1246.16	**7299.35**	**15.00**
P29	907.50	474.59	4345.45	407.08	86.48	6221.09	1286.50	**7507.59**	**15.00**
P30	907.50	474.59	4345.45	407.08	86.48	6221.09	1286.50	**7507.59**	**15.00**
P31	907.50	474.59	4345.45	407.08	86.48	6221.09	1286.50	**7507.59**	**15.00**
P32	907.50	474.59	4345.45	407.08	86.48	6221.09	1286.50	**7507.59**	3.46
		DESIRED OPRATING COST BASED ON WEIGHTED AVERAGE						**35.10**	
		DESIRED OPERATING COST BASED ON SIMPLE AVERAGE						**42.03**	

Dumper System Technical & Financial data

Base Date: December 2017												
Year	Top Level				Middle Level				Bottom Level			
	Lead (Km)	Productivity (Mcum/yr)	Production from top Coal Horizon	No of Dumpers	Lead (km)	Productivity (Mcum/yr)	Production from middle Coal Horizon	No. of Dumper	Lead (Km)	Productivity (Mcum/yr)	Production from bottom Coal Horizon	No of Dumpers
P5	2	0.2612	4.24	16.24								
P6	2	0.2612	4.66	17.85	3	0.2188	5.10	23.29				
P7	2	0.2612	4.66	17.85	3	0.2188	5.10	23.29				
P8	2	0.2612	4.66	17.85	3	0.2188	5.10	23.29				
P9	2	0.2612	4.66	17.85	3	0.2188	5.10	23.29	3.75	0.1958	5.24	26.79
P10	2.25	0.2508	4.66	18.59	3.25	0.2106	5.10	24.20	3.75	0.1958	5.24	26.79
P11	2.25	0.2508	4.66	18.59	3.25	0.2106	5.10	24.20	3.75	0.1958	5.24	26.79
P12	2.25	0.2508	4.61	18.38	3.25	0.2106	5.04	23.92	3.75	0.1958	5.35	27.35
P13	2.25	0.2508	3.61	14.41	3.25	0.2106	3.92	18.60	3.75	0.1958	7.47	38.16
P14	2.25	0.2508	3.61	14.41	3.25	0.2106	3.92	18.60	3.75	0.1958	7.47	38.16
P15	2.5	0.2404	3.61	15.03	3.5	0.2023	3.92	19.36	4.25	0.1839	7.47	40.63
P16	2.5	0.2404	3.61	15.03	3.5	0.2023	3.92	19.36	4.25	0.1839	7.47	40.63
P17	2.5	0.2404	3.62	15.05	3.5	0.2023	3.72	18.39	4.25	0.1839	7.66	41.67
P18	2.5	0.2404	3.62	15.06	3.5	0.2023	3.59	17.75	4.25	0.1839	7.79	42.37
P19	2.5	0.2404	3.62	15.06	3.5	0.2023	3.59	17.75	4.25	0.1839	7.79	42.37
P20	3	0.2188	3.62	16.54	3.75	0.1958	3.59	18.34	4.5	0.1785	7.79	43.64
P21	3	0.2188	3.60	16.45	3.75	0.1958	3.58	18.26	4.5	0.1785	7.83	43.84
P22	3	0.2188	3.05	13.94	3.75	0.1958	3.17	16.20	4.5	0.1785	8.78	49.18
P23	3	0.2188	3.05	13.94	3.75	0.1958	3.17	16.20	4.5	0.1785	8.78	49.18
P24	3	0.2188	3.05	13.94	3.75	0.1958	3.17	16.20	4.5	0.1785	8.78	49.18
P25	3.25	0.2106	3.05	14.49	4	0.1892	3.17	16.76	4.75	0.1741	8.78	50.43
P26	3.25	0.2106	3.05	14.49	4	0.1892	3.17	16.76	4.75	0.1741	8.78	50.43
P27	3.25	0.2106	3.05	14.49	4	0.1892	3.17	16.76	4.75	0.1741	8.78	50.43
P28	3.25	0.2106	3.05	14.49	4	0.1892	3.17	16.76	4.75	0.1741	8.78	50.43
P29	3.25	0.2106	3.05	14.49	4	0.1892	3.17	16.76	4.75	0.1741	8.78	50.43
P30	4	0.1892	3.05	16.12	4.75	0.1741	3.17	18.22	5	0.1696	8.78	51.76
P31	4	0.1892	3.05	16.12	4.75	0.1741	3.17	18.22	5	0.1696	8.78	51.76
P32	4	0.1892	0.70	3.72	4.75	0.1741	0.73	4.20	5	0.1696	2.02	11.94

Dumper System Technical & Financial Data

Base Date: December 2017				(Rs. Lakhs)			
Year	TOTAL			Manpower			
				Gr-B		Cat-3	
	Dumpers	Cost (Rs. Lakhs)	Life of Dumpers (Years)	(No.)	(Salary & Wages)	(No.)	(Salary & Wages)
P5	17.00	4322.25	7	66	532.62	12	81.00
P6	42.00	10678.50	7	162	1307.34	30	202.50
P7	42.00	10678.50	7	162	1307.34	30	202.50
P8	42.00	10678.50	7	162	1307.34	30	202.50
P9	68.00	17289.00	7	263	2122.41	49	330.75
P10	70.00	17797.50	7	270	2178.90	50	337.50
P11	70.00	17797.50	7	270	2178.90	50	337.50
P12	70.00	17797.50	7	270	2178.90	50	337.50
P13	72.00	18306.00	7	278	2243.46	51	344.25
P14	72.00	18306.00	7	278	2243.46	51	344.25
P15	76.00	19323.00	7	293	2364.51	54	364.50
P16	76.00	19323.00	7	293	2364.51	54	364.50
P17	76.00	19323.00	7	293	2364.51	54	364.50
P18	76.00	19323.00	7	293	2364.51	54	364.50
P19	76.00	19323.00	7	293	2364.51	54	364.50
P20	79.00	20085.75	7	305	2461.35	56	378.00
P21	79.00	20085.75	7	305	2461.35	56	378.00
P22	80.00	20340.00	7	310	2501.70	57	384.75
P23	80.00	20340.00	7	310	2501.70	57	384.75
P24	80.00	20340.00	7	310	2501.70	57	384.75
P25	82.00	20848.50	7	317	2558.19	59	398.25
P26	82.00	20848.50	7	317	2558.19	59	398.25
P27	82.00	20848.50	7	317	2558.19	59	398.25
P28	82.00	20848.50	7	317	2558.19	59	398.25
P29	82.00	20848.50	7	317	2558.19	59	398.25
P30	87.00	22119.75	7	336	2711.52	62	418.50
P31	87.00	22119.75	7	336	2711.52	62	418.50
P32	20.00	5085.00	7	78	629.46	14	94.50

Dumper System Operating Cost

Base Date: December 2017									(Rs. Lakhs)
Year	Salary & Wages	Stores Cost	Power Cost	Misc Cost	Interest on Working Capiatal	Total Cash Cost	Depreciation	Total Operating Cost	Production
P5	613.62	2537.92	0.00	96.79	157.00	3405.34	617.46	**4022.80**	**4.24**
P6	1509.84	6270.16	0.00	238.97	387.58	8406.55	1525.50	**9932.05**	**9.76**
P7	1509.84	6270.16	0.00	238.97	387.58	8406.55	1525.50	**9932.05**	**9.76**
P8	1509.84	6270.16	0.00	238.97	387.58	8406.55	1525.50	**9932.05**	**9.76**
P9	2453.16	10151.69	0.00	387.12	627.95	13619.92	2469.86	**16089.78**	**15.00**
P10	2516.40	10450.27	0.00	398.28	645.97	14010.92	2542.50	**16553.42**	**15.00**
P11	2516.40	10450.27	0.00	398.28	645.97	14010.92	2542.50	**16553.42**	**15.00**
P12	2516.40	10450.27	0.00	398.28	645.97	14010.92	2542.50	**16553.42**	**15.00**
P13	2587.71	10748.85	0.00	409.64	664.40	14410.60	2615.14	**17025.74**	**15.00**
P14	2587.71	10748.85	0.00	409.64	664.40	14410.60	2615.14	**17025.74**	**15.00**
P15	2729.01	11346.01	0.00	432.33	701.19	15208.54	2760.43	**17968.97**	**15.00**
P16	2729.01	11346.01	0.00	432.33	701.19	15208.54	2760.43	**17968.97**	**15.00**
P17	2729.01	11346.01	0.00	432.33	701.19	15208.54	2760.43	**17968.97**	**15.00**
P18	2729.01	11346.01	0.00	432.33	701.19	15208.54	2760.43	**17968.97**	**15.00**
P19	2729.01	11346.01	0.00	432.33	701.19	15208.54	2760.43	**17968.97**	**15.00**
P20	2839.35	11793.88	0.00	449.47	729.00	15811.69	2869.39	**18681.08**	**15.00**
P21	2839.35	11793.88	0.00	449.47	729.00	15811.69	2869.39	**18681.08**	**15.00**
P22	2886.45	11943.17	0.00	455.45	738.78	16023.85	2905.71	**18929.56**	**15.00**
P23	2886.45	11943.17	0.00	455.45	738.78	16023.85	2905.71	**18929.56**	**15.00**
P24	2886.45	11943.17	0.00	455.45	738.78	16023.85	2905.71	**18929.56**	**15.00**
P25	2956.44	12241.75	0.00	466.78	757.14	16422.11	2978.36	**19400.46**	**15.00**
P26	2956.44	12241.75	0.00	466.78	757.14	16422.11	2978.36	**19400.46**	**15.00**
P27	2956.44	12241.75	0.00	466.78	757.14	16422.11	2978.36	**19400.46**	**15.00**
P28	2956.44	12241.75	0.00	466.78	757.14	16422.11	2978.36	**19400.46**	**15.00**
P29	2956.44	12241.75	0.00	466.78	757.14	16422.11	2978.36	**19400.46**	**15.00**
P30	3130.02	12988.19	0.00	495.07	802.98	17416.25	3159.96	**20576.22**	**15.00**
P31	3130.02	12988.19	0.00	495.07	802.98	17416.25	3159.96	**20576.22**	**15.00**
P32	723.96	2985.79	0.00	113.92	184.81	4008.49	726.43	**4734.92**	**3.46**
			DESIRED OPERATING COST BASED ON WEIGHTED AVERAGE					**112.71**	
			DESIRED OPERATING COST BASED ON SIMPLE AVERAGE					**120.56**	

CONCLUSION

From the tables showing operating costs for Steep Angle Conveyor system and Dumper system, it is evident that the Steep Angle Conveyors along with in-pit conveyors has reduced the 60T coal body dumpers by 87 nos. This has also reduced capital expenditure by about Rs.25 crores and cost of production by about Rs.78 per tonne.

In the proposed OCP, due to high initial depth, steep quarry batter and suitable geo-mining conditions, Steep Angle Conveyor has been proved cheaper, more productive, eco-friendly, traffic-friendly and space & energy saving solution for transporting coal from quarry floor to surface.

RECOMMENDATION

Steep Angle Conveyor is a new technology for Indian Coal Industry. For the success of Steep Angle Conveyor system, strict compliance of Project Report provisions, disciplined work culture, scheduled maintenance, condition-based monitoring and adherence to provisions of DGMS guidelines for the safety of men & machineries are highly recommended.

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Extraction of Jambad Coal Seam (12.5m thick) in Three Lift System

Prantosh Kumar Mitra[1]

BACKGROUND

The new manner of extraction of 12.5m thick coal seam at C L Jambad colliery, Kenda Area of ECL is as below:

Due to haphazard pre-nationalisation developement of Jambad seam, the author did not adopt the normal manner of extraction i.e. top to bottom with leaving at least 3m parting betweenthem and a new method was adopted with the new method (in three lifts) based on following subsidence formula-

$$\frac{w}{d} = 1 \text{ or } < 1$$

Where, w- Width of the Pannel

d- Depth (Surface cover) from surface to roof of extracted coal seam.

INTRODUCTION

In this particular panel in one of its section, the Jambad seam has developed gallery heights of more than five meters and even more in some other places. More than two meters of coal is left on the floor. It is neither possible nor, practical to prepare top-bottom (two sections) of the seam keeping at least three meters parting between them as per regulations. It demands a search for an alternative method of extraction of this seam with sand-stowing in this panel under the prevailing condition.

This also helps to:-

i. Yield better recovery of coal at the site

ii. Easy extractions with ordinary fresh equipment

iii. Production area is concentrated, easy supervision, good air crossing, simple ventilation of the area

iv. Working with thick seam with maximum safety

v. No chance of collapsing of parting

COAL MEASURE FORMATION

Jambad Seam consisting of R-VIII seam of Raniganj Coal Horizon is about 12.5 m thick and lies at an average depth of 80 m to 100 m in this particular area. Kajora seam is 6.5 m thick (approximately) and lies more than 60 m above Jambad seam. The Kajora seam has been developed by board and pillar method. A few portion of developed Kajora seam have also been de-pillared by hydraulic sand stowing and the whole of Kajora seam is water-logged. But where the particular panel of Jambad seam has to be de-pillared, is free from the presence of Kajora seam.

There is a prominent shale/sand stone about 2.6 meter thick which lies at a distance of 5.1 meter from the main roof of Jambad seam. This band serves the purpose of floor of the top section in the top-bottom section method of extraction, which is common in extraction of Jambad seam. This divided the seam into two sections, bottom section is 4.5 meters thick, the top section is about 5 meters thick and the parting between the two is about 3 meter to 3.5 meter thick. This parting is left intact and the thickness of the parting is checked by

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bore-holes and staple pits at about every alternative junction.

PROPERTIES OF COAL MEASURES FORMATION OF JAMBAD SEAM AT THESE MINES

The main roof of coal seam itself is disturbed here. There are numerous fault planes. The seam here meets about 15 meters thick dyke. There are number of slips of various formations such as parallel, 'V' and un-inverted 'V'. There are also numerous intrusions in the coal seam. All these cause difficulties in supporting the roof of the gallery and other places of roof artificially.

The proximate analysis of the seams is given below:

i. Moisture ….. 9.4%

ii. Volatiles ….. 33.7%

iii. Fixed Carbon ….. 43.5%

iv. Ash ….. 13.4%

v. Crossing Point ….. 102°C

vi. Ignition Point ….. 155°C

vii. Grade of the coal ….. Sel. 'B'

EXTRACTION AS SUGGESTED BY THE AUTHOR (New method in three lifts):

The method of extraction as suggested by the author and practiced by him at this mine is safe and encouraging. The production volume rises up to 250 tonnes per day from this panel. Proposed manner of extraction as suggested by the author is stated below.

The extraction of the panel finishes in three lifts in the form of benches and extraction is divided into two parts as North side and South side and also thereafter divided in three parts which are as follows:

i. 8th level to 6th level of 25th dip to 21st dip (Retreating)

ii. 6th level to 4th level of 25th dip to 17th dip (Retreating)

iii. 4th level to 1st level of 25th dip to 17th dip (Retreating)

EXTRACTION OF 1st LIFT from 5th LEVEL TO 7½ LEVEL

a. Each pillar is divided into two equal parts by dividing level split. The width and height of the split gallery shall not exceed more than 4.8 meter and 4.2 meter respectively.

b. Each half of the pillar (dip side) is further divided into two equal stooks by driving split gallery. The size of split gallery shall not exceed 4.8 meters x 4.2 meters. The size of stook so formed shall not be less than 4.5 meters x 4.2 meters in any case.

The above two operations are limited up to 21st dip to 23rd dip of 8th level to 7½ level. After finishing the extraction of coal from the above places, supports are withdrawn in stage and stowing operations at these places are started keeping the drainage level intact. The above two operations are repeated between 23rd dip to 25th dip of 8th level to 7½ level.

EXTRACTION OF IIIrd LIFT from 8th LEVEL TO 7½ LEVEL OF 25th dip to 21st dip

c. Again after completion of stowing operation on the IInd lift from 8th level to 7½ level of 25th dip to 21st dip, extraction of coal of IIIrd lift is started at these places on sand floor of IInd lift and stowing operation started at the IInd lift of 7½ level to 7th level of 25th dip to 21st dip. First heightening of original gallery is completed, and then the heightening of split gallery is done. It is advisable that original gallery is stowed at least partially, if not fully, before starting the heightening operation of split gallery.

d. After completion of extraction of coal from IIIrd lift of 8th level to 7½ level of 25th dip to 21st dip, stowing operation is started at these places. Coal extraction starts on IIIrd lift of 7½ level to 7th level.

e. Maintaining the above sequence of coal extraction and stowing operation, the whole panel is extracted safely in retreating fashion. At least 0.6 meters thick coal shall be left intact against the main roof in the split and original gallery.

Stooks so formed must be maintained vertically and offset survey must be carried out to ensure the verticality and size of stooks. Extraction shall be conducted in such a way that 'V' line of extraction is not formed. Straight line of extraction with sand stowing and extra artificial supports are urgently needed in this manner of extraction. In the IIIrd lift, stooks are judiciously reduced leaving them finally at 3 meters x 3 meters forever.

STOWING ARRANGEMENT

The main stowing arrangement has been laid at the IIIrd level through the main return airway. Two branches of stowing range are entered into the panel, one at 18th dip and other at 24th dip. This divides the section in two parts in respect of stowing operation. It helps stowing operation easily and quickly.

TRANSPORTATION

One A.K.G. 40 HP direct haulage has been installed at about 50 meters out bye of the panel at 2nd dip. It serves the purpose of gathering haulage of the section i.e. hauling out of all the loaded tubs from various loading points and feeds those to the main endless haulage at shaft level of 2nd dip. Then it supplies empty tubs to the various loading points of the section, receiving empty tubs from Main endless haulage. 40 H.P. direct haulage hauls out from 7 loaded tubs in 1st lift to 9 loaded tubs in the IIIrd lift. But at the end of IIIrd lift, between 4th level to 1st level of the panel, the gradient becomes almost flat, rather sagging at the in-bye end, so the 40 H.P. A.K.G. endless haulage has to be installed.

SUPPORTS

a. Permanent & main support is by hydraulic sand stowing

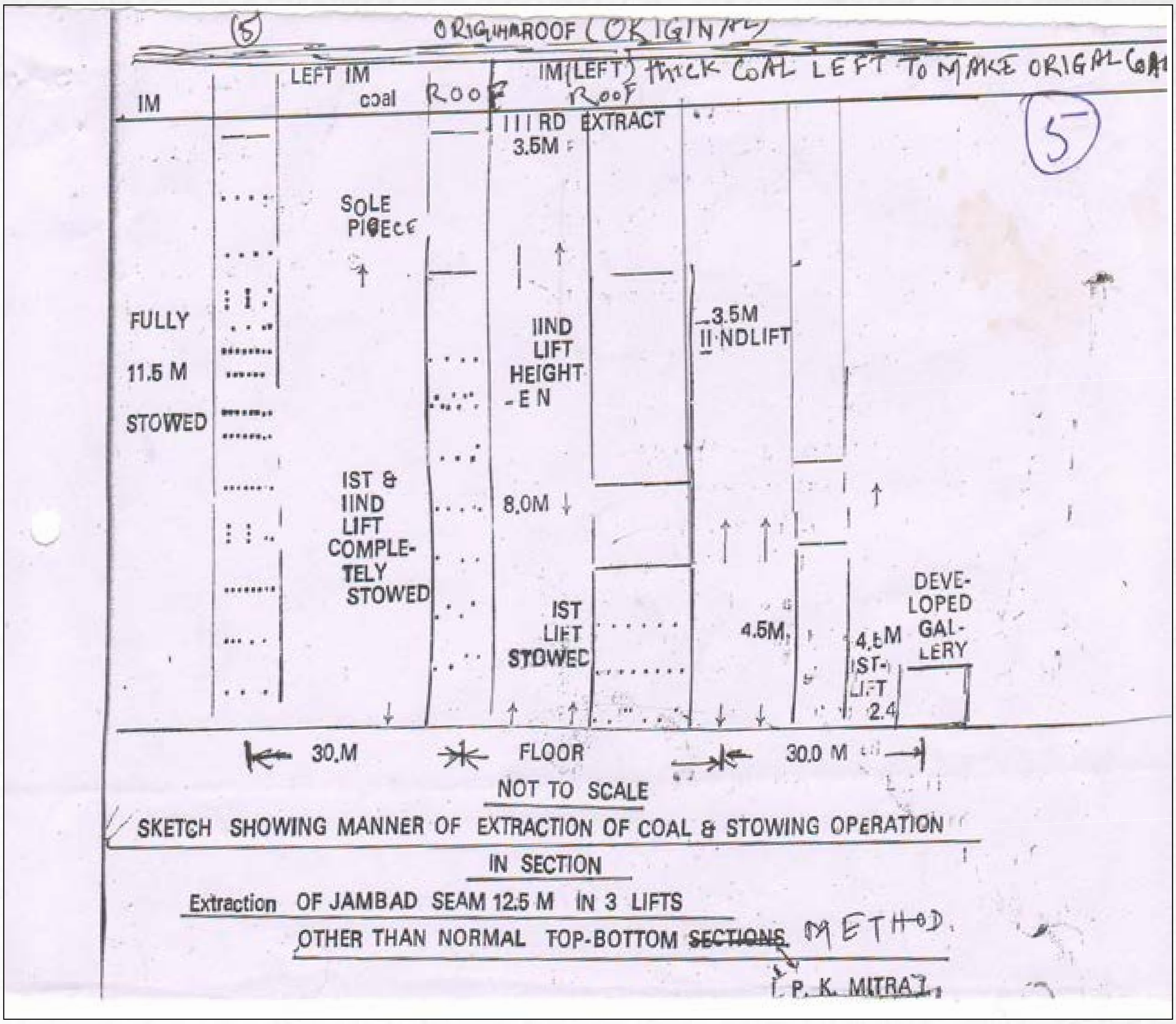
b. Artificial support shall be done by approved systematic support rules. Materials of artificial support shall be of various sizes of wooden props and cogs.

c. As the panel is full of various type of slips etc. we have to give special attention on support and support the disturbed areas with the types of support needed at those places.

MAN POWER & OMS

Sl.No	DESIGNATION	PER SHIFT	TOTAL PER DAY
1	Overmen	1	3
2	Mining Sardar	1	3
3	Short-firer	1	3
4	Pit Clerk	1	3
5	Dresser	2	6
6	Explosive Carrier	2	6
7	Driller	3	9
8	Haulage Khalasi	2	6
9	Trammer	4	12
10	Timber Gang. (General Shift)	6	12
11	Stowing Gang	6	18
12	Line Gang.	6 (GS) + 3 +3	12
13	Fitter Gang	2	6
14	Electrician and Helper	2	6
15	General Mazdur	2	6
16	Barricade Gang. & Ventillation coursing	3	9
17	Loader	25	75

Average Man power per shift = 65 + 5 (extra) = 70
Production per shift = 75
O.M.S. = 75/70 = 1.07



VENTILATION

a. Main surface ventilator is PV-160 which is sufficient for the mine

b. Air has been coursed into section by normal ventilation devices and no problem regarding ventilation of the section has occurred during extraction of coal from the panel

Spontaneous heating, fire, air blast, pre-mature collapse, subsidence, fall of main and immediate roofs even on small areas have not occurred during extraction of coal from the panel. Isolation stoppings have been erected in the first lift of the panel and all the four sides of the panel have been blocked by sand.

CONCLUSION

Fast rate of extraction, maintaining quick artificial support and high rate of stowing are the three vital factors for the success of this method of extraction of coal.

ACKNOWLEDGEMENT

The views expressed in this article are purely of the author, based on experience gained during extraction of coal from the panels. Author is grateful to Mr. K. Pal, Dy. DGMS, Sitarampur Division, West Bengal and Mr. S.K. Mukherjee, DMS, Region-1, Sitarampur Division, West Bengal, as they heard out the modified method of extraction as mentioned in this article and were kind to accept the application for granting permission to try out the above method. With their permissions and approved plans, the author extracted the coal from five panels in this mine successfully and safely.

A study of Corporate Social Responsibility Practices of the Coal Subsidiaries of Coal India Limited and their alignment with the Sustainable Development Goals

Dr Manoj Kumar[1], Sangeeta[2]

ABSTRACT

This paper highlights the organic link that exists between the Corporate Social Responsibilities(CSR) activities undertaken by different mining complexes the major coal producing company of India and their alignment with the Sustainable Development Goals (SDGs) in the year 2017-18. i.e three years after the period when mandatory CSR came into existence as per Indian Companies Act 2013. In this study, we identify critical areas pertaining to SDG goals neglected and highlighted the positive area as far as CSR investments are concerned. Activities related to SDG 3, SDG6 and SDG9 were found in all the mining complexes. SDG 7 and SDG 17 not being represented in any of the mining complexes. SDG 11 & SDG 12 being least represented. CSR activities in mining complexes are more aligned towards SDG 4 on Education followed by SDG 9 on infrastructure, SDG 6 on Drinking water & Sanitation followed SDG 15 on Ecosystem; and the SDGs least addressed are SDG 12 on sustainable consumption and production, SDG 11 on Habitation, SDG 13 on climate change. The geographic analysis revealed that Eastern part of India attracts maximum benefits as far as expenses on different heads of CSR is concerned. A comprehensive study could be undertaken to prioritise SDGs and its linkage with the corporate CSR activities. Efforts must also be there to see how CSR projects could be aligned with national- and state-level SDG priorities. Need assessment studies before starting a CSR project might be helpful in understanding the needs of target communities and other stakeholders.

Keywords: *Corporate Social Responsibility, mining complexes, Sustainable Development Goals(SDGs)*

INTRODUCTION

The paper aims to identify the Corporate Social Responsibility (CSR) practices adopted by different subsidiary of Coal India Limited, the prime coal producing company of India. the CSR practices analyzed as per mandate of Company Act 2013 and the alignment of those CSR practices against the United Nations (UN) Sustainable Development Goals (SDGs). The literature indicates that if CSR and SDGs are integrated, they can significantly improve the social as well as economic and environmental conditions of the country (Le Blanc, 2015; S, Banks & Hughes 2016). The paper contributes in terms of identifying the CSR activities undertaken by the Indian company and their alignment with the SDGs suggested by the UN.A set of 17 SDGs through consensus of its 193 member countries UN were developed in 2015. SDGs set out to tackle issues 17 goals and 169 associated targets to be achieved by 2030.The MDGs' shortfall, that is, the lack of inclusion of the businesses, has now been covered in the SDGs. SDGs focus on achieving sustainable development in all three dimensions: economic, social, and environmental (Hopkins, 2016; Klein, 2016; UN SDGs, 2016). These goals are relevant to all countries (developed, developing,

[1]Mgr(M), [2]Ch. Mgr(E),(E&F), CCL, Ranchi.

and underdeveloped); contribution by all sectors (government, civil society, and businesses) is also possible. Without contention, the 17 goals are directly or indirectly relevant to the business sector as they can contribute towards the alleviation of global crisis by accommodating priority changes for the society.

FACETS OF CSR

The concept of CSR has been in place for decades. Many terms like corporate citizenship, corporate accountability, business ethics, sustainability, triple bottom line, corporate responsibility, corporate governance, and corporate social entrepreneurship have been used interchangeably by researchers refereeing to CSR. As per World Business Council for Sustainable Development (WBCSD, 1999, p. 3), CSR is the continuing commitment by businesses to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as the local community and society at large. Quality of worklife (Kumar Manoj (2017)) further improves production and productivity. The WBCSD definition had emphasized on the 3Ps—people, planet, and profit, is still relevant and in line with the SDGs.

INDIA, CSR and SDGs

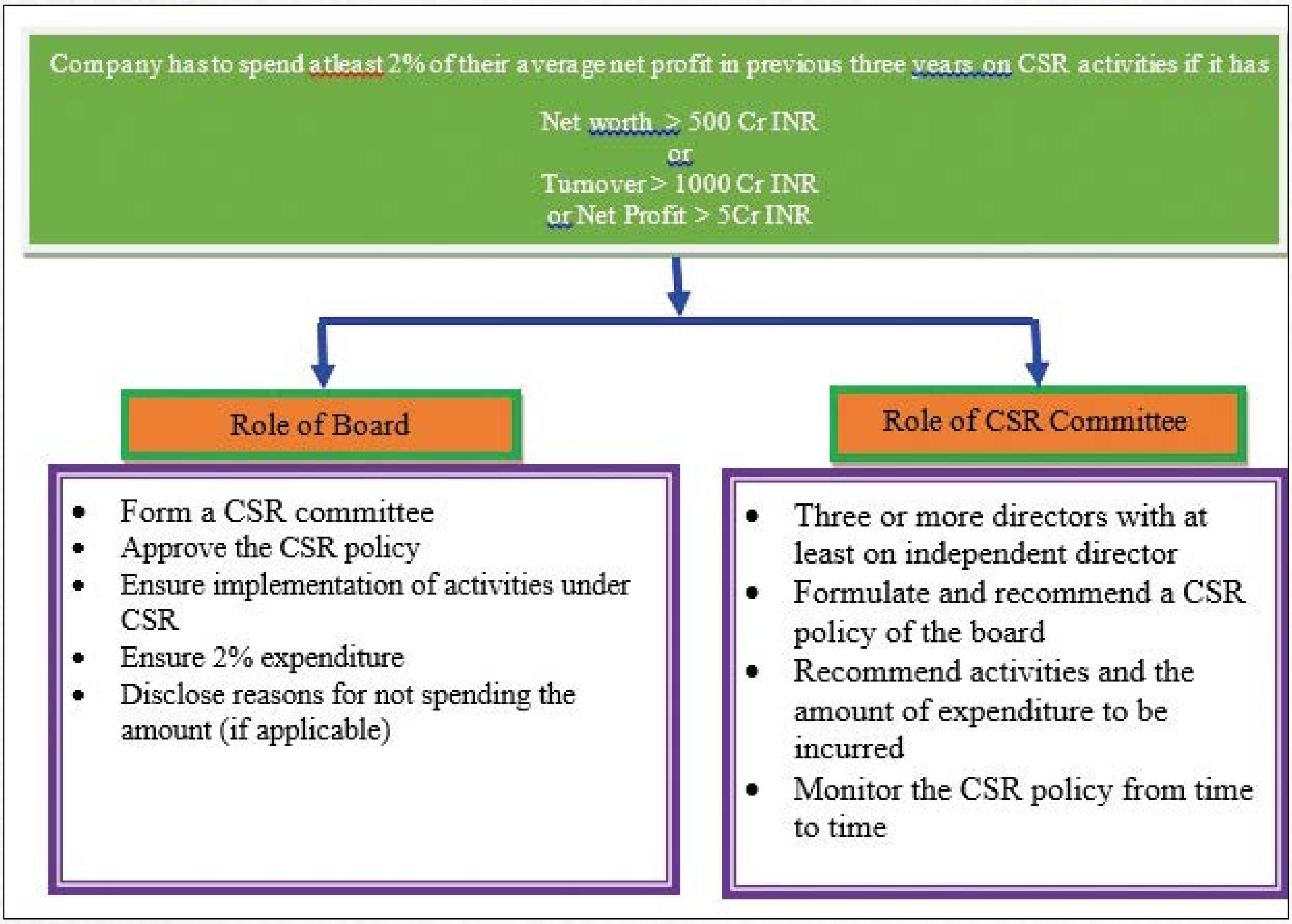
Indian history has a strong sense of social responsibility. Traditions of "trusteeship" propounded by Mahatma Gandhi have also evolved in India. Industrial welfare have existed as early as the 19th century, gained prominence with time, and could be witnessed in the economic policies during the British regime. This involved philanthropic donations to charity, service to the community, enhancing employee welfare, and promoting religious conduct. Many company implemented several CSR initiatives in the name of charity, donations, employee welfare, and community welfare (Pritwani, 2016) in pursuit of upliftment of the society. The CSR journey in India took a turn when on February 27, 2014, the Ministry of Corporate Affairs amended Section 135 of the Companies Act, 2013. A company having a net worth of INR 5,000 million, or a turnover of INR 10,000 million or more, or a net profit of INR 50 million or more, during any financial year, had to ensure that the company spent 2% of its average net profits that it generated during the three immediately preceding financial years, in pursuance of its CSR activities. The activities under which a company can allocate its CSR funds are specified under the Schedule 7 of the Act. The Act came into effect on April 1, 2014. Figure-1 shows the overview of the significant changes introduced in the Companies Act, 2013, concerning the CSR including the role of the board members and the constitution of the CSR committee.

India is one of the largest emerging nations. India is also implementing the SDGs by aligning them with the national development agenda and has accordingly formulated its policies such that they address the SDGs, and funds are allocated for sustainable growth by 2030. National priorities like skill development health and sanitation, education and clean drinking water, and clean India campaign are contributing to a focused agenda. CSR trends show that there has been an increase in the CSR initiatives that focus on this national development agenda. These factors highlight the need for Indian companies and government to commit towards achieving the SDGs. India is a member nation of the UN, and the Indian companies in the past had also been following the guidelines issued by the UN, like the United Nations Global Compact and the MDGs. For the corporate sector, CSR can play an integral role in achieving the SDGs. India as a developing nation can help meet these development goals by directing CSR funds towards the SDGs.

COAL COMPANY, CSR AND SDGS

Coal India being pioneer in coal production and meeting the target of nations energy demand through its different subsidiaries with a mission of "To produce and market the planned quantity of coal and coal products efficiently and economically in an eco-friendly manner with due regard to safety, conservation and quality" (CIL's Annual Report 2017-18). The coal producing subsidiaries are Eastern Coalfields Limited (ECL), Bharat Coking Coal Limited (BCCL), Central

Coalfields Limited(CCL), Western Coalfields Limited (WCL), South Eastern Coalfields Limited (SECL), Northern Coalfields Limited (NCL), Mahanadi Coalfields Limited (MCL) along with brain of CIL – the Central Mine Planning & Design Institute Limited (CMPDI)- parting services like exploration, planning and design, coal preparation, management services, research and development, ICT services, environment, mining electronics, geomatics, specialized services, laboratory services, coal bed methane etc. In addition, CIL has a foreign subsidiary in Mozambique, Coal India Africana Limitada (CIAL). The mines in Assam i.e. North Eastern Coalfields is managed directly by CIL. Mahanadi Coalfields Limited, a subsidiary of Coal India Ltd is having five Subsidiaries i.e. MJSJ Coal Limited with MCL share (60%), MNH Shakti Ltd with MCL share (70%), Mahanadi Basin Power Limited with MCL share (100%), Mahanadi Coal Railway Limited with MCL share (64%) and Neelanchal Power. After 2013, when the new Companies Act made it mandatory for Indian companies earning above a certain threshold to spend 2% of its average net profit towards CSR, different subsidiaries of CIL are taking leaps to pursue the development agenda and it is worthwhile to explore the linkage between CSR efforts and implementation of SDG goals in these subsidiaries of CIL.



Source: Section 135 of Companies Act

Fig-1: CSR in Indian Companies Act 2013- Regulatory Framework

Coal India is rated as Maharatna Company and its subsidiaries as Miniratna Company. Thus these can significantly contribute towards realisation of the SDGs as they have the power to exercise regarding reach, technology, resources, knowledge development, and management skills. Companies may, directly and indirectly, benefit by embracing in the SDGs, as it will facilitate in combating the regulation of the carbon emissions, climate change, fiscal crisis, and energy prices (Ahmad et al., 2016). The new SDG agenda has further clarified roles and responsibilities of businesses in sustainable development through innovation and collaboration with peers globally (Hopkins, 2016; Le Blanc, 2015; Panigrahi,2016; Rosati &Faria, 2018).

CIL has implemented the provisions of Companies Act 2013 since 2014 after its implementation and are working on achieving the SDGs of nation since 2015. There is well laid CSR policy duly approved for CIL. In this paper efforts have been made to develop organic link existing between the CSR activities undertaken by the CIL and their alignment with the SDGs. These companies can experience a number of benefits by synchronizing the CSR and SDGs. First, the CSR activities will become more focused as the SDGs are elaborately spelt out. Secondly, the companies will be able to contribute towards the national development goals and the SDGs in a more systematic manner. Thirdly, the companies will undoubtedly uplift its image in terms of being more socially and environmentally conscious as working towards the SDGs makes a company more focused.

Linkage of CSR and the SDGs

Indian context coincidentally, both SDGs (2015) and CSR(2013) regulation arrived on Indian shores around the same time and thus led to immense potential to develop a cohesive framework for sustainable development. The Schedule 7 of the Indian Companies Act, 2013 (Figures-2), provides a broader framework in India, and the SDGs provides a micro view of it (Figure-3). Furthermore, unlike MDGs, the SDGs itself encourage to indulge in developmental goals.

SDGs bring companies towards the common agenda on sustainable development and help improve the socio-economic and environmental challenges prevailing in the country. Working on one SDGs will have impact on several SDGs. Table-1 maps various SDGs with the Schedule 7 activities of the Act.

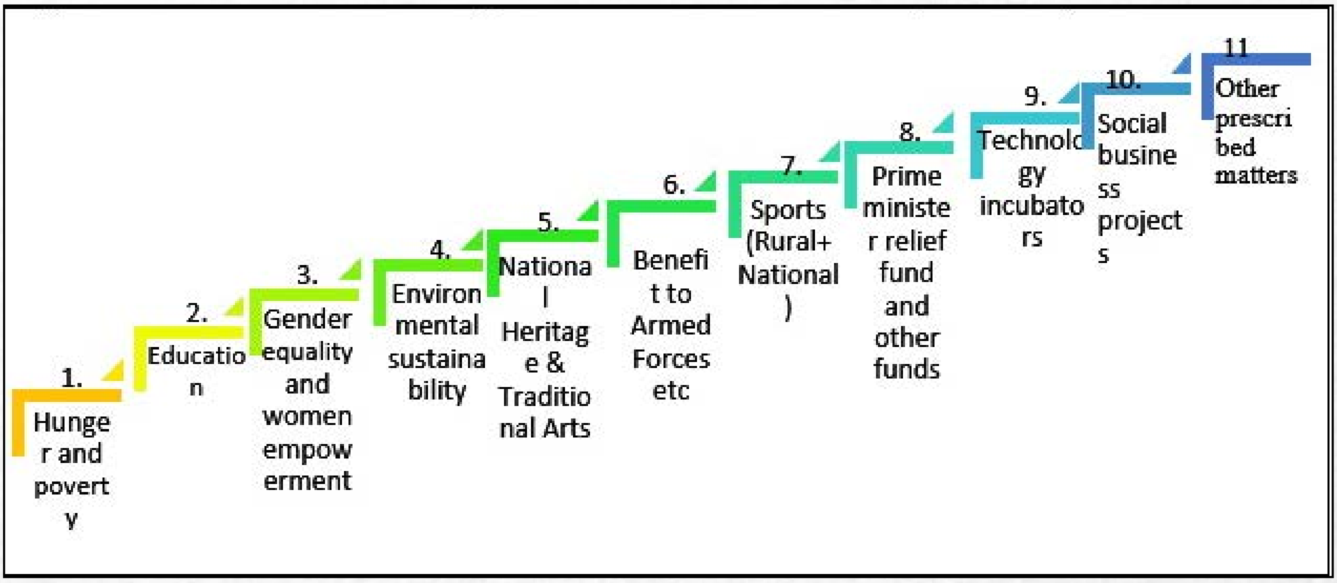


Fig-2: Framework of CSR as per Schedule 7 of Indian Companies Act, 2013

Table-1 : SDGs mapped with Schedule 7 activities of the Companies Act, 2013

Sl. No.	CSR Activities as of Companies Act, 2013	SDGs No.
1	Eradicating hunger, poverty and malnutrition, promoting preventive health care and sanitation and making available the safe drinking water.	1, 2, 3,5, 6 and 12
	• Hunger and poverty	
	• Child mortality and mental health (2,3,5)	
	• Diseases (1,2,3, 6 & 12)	
2	Promoting education, including special education and employment enhancing vocation skills especially among children, women, elderly, and the differently abled and livelihood enhancement projects;	1, 4, 8,9, 10 & 11
	• Education (1,4, 9)	
	• Vocational skills (8,10,11)	
3	Promoting gender equality, empowering women, setting up homes and hostels for women and orphans; setting up old age homes, day care centers and such other facilities for senior citizens and measures for reducing inequalities faced by socially economically backward groups;	1, 4, 5, 8 and 10
	• Gender equality and women empowerment	
4	Ensuring environmental sustainability, ecological balance, protection of flora and fauna, animal welfare, agroforestry, conservation of natural resources and maintaining quality of soil, air and water	
	• Environmental sustainability	
5	Protection of national heritage, alt and culture including restoration of buildings and sites of historical importance and works of art; setting up public libraries; promotion and development of traditional ans. And handicrafts;	
	• National Heritage & Traditional Arts	
6	Measures for the benefits of armed forces veterans, war widows and their dependents	
	• Benefit to Armed Forces etc.	
7	Training to promote rural sports, nationally recognized sports, para Olympics sports and Olympic sports;	7, 9, 12, 16 & 17
	• Rural Sporta	
8	Contribution to the Prime Minister's National Relief Fund or any other fund setup by the Central Government or the State Governments for socio-economic development and relief and funds for the welfare of the Scheduled Castes, the Scheduled Tribes, other backward classes, minorities, and women	All
	• Prime minister relief fund and other funds	
9	Contribution or funds provided to technology incubators located within academic institutions which are approved by the Central Government.	All
	• Technology incubators	
10	Rural development projects.	All
	• Social business projects	
11	Such other matters as may be prescribed	All

SDG1	Poverty
SDG 2	Hunger and Food Security
SDG 3	Health
SDG 4	Education
SDG 5	Gender equality
SDG 6	Water and sanitation
SDG 7	Energy
SDG 8	Livelihood
SDG 9	Infrastructure
SDG 10	Inequalities
SDG 11	Habitation
SDG 12	sustainable consumption and production
SDG 13	Climate change
SDG 14	Marine
SDG 15	Ecosystem
SDG 16	Peace
SDG 17	Global sustainability

SDG→ Sustainable development Goal

Directly
Indirectly
unknown

Fig-3 : Wagonwheel of Sustainable Developement Goals (SDGs)

OBJECTIVE

The objective of this research is to examine and establish relationship with the CSR expenditure done by different Mining Complexes vis-à-vis SDGs, across their spread and extent of working.

METHODOLOGY

As per mandatory CSR, the coal company also comes under Section 135 of the Companies Act, 2013. Hence different subsidiary of the major coal producing company of India were selected for this study. The different subsidiary will be hereby termed as mining complexes viz. MC1, MC2….. so on, for this study. All the mining complexes falls in "Red" zone as per Central pollution control Board classification of industries on color zone basis. Preliminary analysis of the secondary data (annual reports, sustainability reports, data base on company website) has been made for the year ending in March 2018, revealed that all the complexes under study have explicitly reported their CSR activities in their annual reports. After the mandate became effective in April 2014, the mining complexes are consistent in reporting after 2015-16, as such the year 2017–2018 was taken up for the study, as the data for the year 2018–2019 were not available at the time of writing this paper.

The data were immense and scattered; therefore, it was extracted from mainly three sources in sequence: first, from database; second, from annual reports; and last, from sustainability reports. The activities were classified under different projects in three phases (Figure-4).

Phase 1

The data for different mining complexes under study area were collected and tabulated at Table-2. The budgeted CSR expenditure and the actual amount spent were compared with the minimum prescribed CSR expenditure of each mining complexes.

Phase 2

The mining complexes under consideration were classified based on activity (coal producing, Consultant/non coal producing) The budgeted and actual expenditures spent on various areas under the Schedule 7 by mining complexes were analysed next. For this, the activities undertaken by the companies were segregated under implementation areas enumerated under the Schedule 7 of Companies Act, 2013, and 17 SDGs prescribed by the UN. Activities not listed under the Schedule 7 were put under Point 11 and, as per SDGs, such as

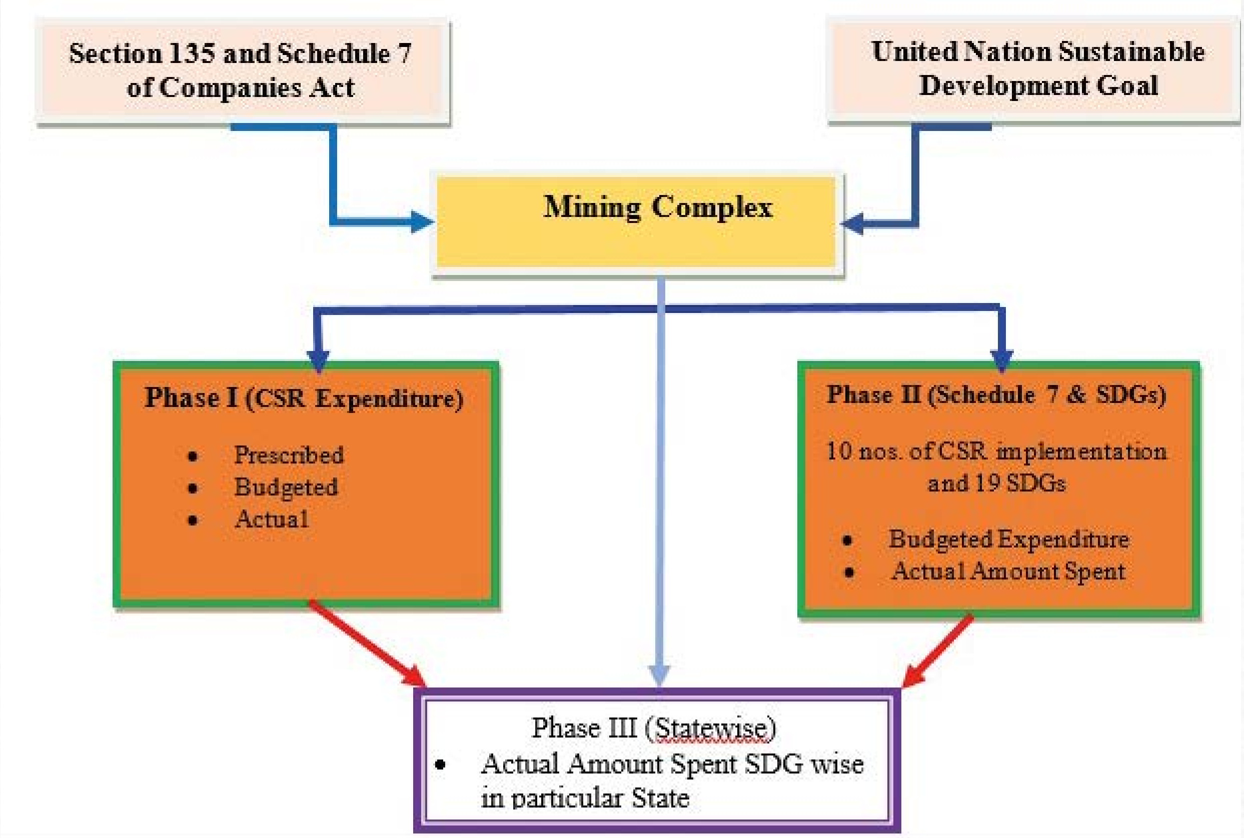


Fig-4: Methodology of Study

Table-2: Financial Component for Mining Components

Sl. No.	Mining Complex	Profit (PBT less Dividend in Rs. Cr.			Average in Cr	Prescribed CSR Expenditure in lakhs
		2014-15	2015-16	2016-17		2017-2018
1	MC 1				498.94	998
2	MC 2	2740.34	3108.61	2371.30	2740.18	5480
3	MC 3	15.30	1299.79	1781.31	1032.11	2064
4	MC 4	5314.24	6260.43	6853.32	6142.66	12285
5	MC 5	3713.47	4065.51	3091.08	3623.35	7247
6	MC 6	5659.54	5148.84	3186.84	4664.57	9330
7	MC 7	11.07	56.17		4.542	9.08
8	MC 9	39.33	42.54	65.33	49.13	98.27
9	MC 1	640.17	373.44	168.00	393.87	787.77

the administrative expenses, were classified under the category "Others" in the list. (Table-4)

Phase 3

In the third phase of the study, the results from Phases 1 and 2, were analysed across the different states of India where the workings of mining complex under study are spread. The data for different mining complexes were converted into a uniform state-wise data. In many cases, a single mining complex was running in more than one state and due to no availability of data regarding

Table-3 : CSR expenditure incurred by Coal Mining Complexes

Sl. No.	Mining Complex	Prescribed CSR Expenditure		Budgeted CSR Expenditure		Actual Spent in CSR		The amount actually		Ranking as per actual amount spent
		In Rs. cr	In % of Profit	In Rs. cr	In % of Profit	In Rs. cr	In % of Profit	Under Spent	Over spent	
1	MC1	9.98	2%	128.77	26%	2.74	1%	-7.24		8
2	MC2	54.80	2%	54.80	2%	45.68	2%	-9.12		3
3	MC3	20.64	2%	20.65	2%	12.68	1%	-7.96		6
4	MC4	122.85	2%	122.85	2%	267.52	4%		144.67	1
5	MC5	72.47	2%	67.49	2%	36.59	1%	35.88		4
6	MC6	93.30	2%	397.69	9%	93.62	2%		0.32	2
7	MC7	0.09	2%	9.13	201%	7.23	159%		7.14	7
8	MC8	0.9827	2%	1.50	3%	1.37	3%		0.39	9
9	MC9	7.877	2%	110.83	28%	24.31	6%		16.43	5

Table-4: Schedule 7 and SDG- wise CSR expenditure undertaken by selected Mining Complexes

SDGs (Sustainable Development Goals)	Schedule 7 (in INR)											Total	Ranking
	Sch 7(1)	Sch 7(2)	Sch 7(3)	Sch 7(4)	Sch 7(5)	Sch 7(6)	Sch 7(7)	Sch 7(8)	Sch 7(9)	Sch 7(10)	(11) Other		
	Actl	Actl	Actl	Actl	Actl	Actl	Actl	Actl	Actl	Actl	Actl		
SDG 1	4.12	6.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.00	15.70	**6**
SDG 2	0.12	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.72	0.00	7.93	**9**
SDG 3	20.47	1.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	22.02	**5**
SDG 4	0.01	172.17	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	172.22	**1**
SDG 5	0.54	1.34	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	3.07	**10**
SDG 6	56.27	0.51	0.69	0.63	0.00	0.00	0.00	0.00	0.00	3.91	0.00	62.01	**3**
SDG 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SDG 8	0.08	2.15	0.13	0.06	0.00	0.00	0.00	0.00	0.00	0.55	0.00	2.97	**11**
SDG 9	8.58	69.67	1.98	0.26	0.53	0.00	0.00	0.00	0.00	28.05	0.00	109.06	**2**
SDG 10	2.16	2.01	0.00	0	0.00	0.00	0.00	0.00	0.00	5.08	0.00	9.26	**8**
SDG 11	0.00	0.22	0.00	0	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.26	**13**
SDG 12	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	**14**
SDG 13	0.22	0.22	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.35	0.00	1.47	**12**
SDG 14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SDG 15	0.00	0.00	0.00	32.31	0.00	0.00	0.00	0.00	0.00	1.25	0.00	33.56	**4**
SDG 16	0.00	0.00	0.00	0.00	0.00	0.00	9.96	0.00	0.00	0.50	0.00	10.06	**7**
SDG 17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Others	0.52	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	3.12	1.62	5.75	
Total	93.08	252.93	4.04	33.96	0.53	0.50	9.96	0.00	0.00	44.45	1.62	187.84	
Ranking (excluding others)	**2**	**1**	**6**	**4**	**7**	**8**	**5**	**X**	**X**	**3**	**X**	**X**	

the proportion of funds utilized in each state, for purpose of analysis, the amount actually spent was distributed between states on the basis of extent of working. In many cases data regarding proportion of funds utilised in one particular schedule to different SDGs and vice vera, were distributed equally.

ANALYSIS

CSR expenditure undertaken by different mining complexes in the study area as tabulated at table no. 3 reveals that coal producing units has most share. Amongst them MC4 is highest. Most of the mining complexes (MC4, MC6, MC7, MC8 & MC9) spend more than the prescribed amount required by law on CSR activities. Mining complexes MC1, MC2, MC3 & MC5 lags behind the prescribed amount as required by Law on CSR activities. The complexes that have a higher environmental footprint and impact are more, are concerned about taking up initiatives through CSR. The reason for the same could be attributed to either the governmental regulations' or perceptions and pressure from other stakeholders and hence a compulsion to sustain themselves. CSR activities are primarily undertaken by mining complexes to enhance its brand image in the eyes of customers. However, CSR expenditures are increasing year on year but for some MCs are not spending the mandated amounts (MC1, MC2, MC3 & MC5). This highlights that the legal system needs to be further tightened and regulated.

Schedule 7 and SDG-wise CSR expenditure is undertaken for selected Mining complexes as per activities listed in the Schedule 7 of the Companies Act, 2013 and were extrapolated for each SDGs. (Table 4). Though the SDGs are interrelated (Cutter, Osborn, Romano, & Ullah, 2015; Le Blanc, 2015), these were segregated according to the key topics falling under each SDG (United Nations Sustainable Development Goal, 2016 UN SDG Factsheet, 2015). In this way, by collating the data about specific activities in the Schedule 7 at the project level, the actual amount spent was generated. It is clear from table no. 4 that the highest amount of money is spent on activity to Education and Vocational Skill [7(2)] followed by Eradicating hunger, poverty and malnutrition, promoting preventive health care and sanitation and making available safe drinking water [7 (1)] as per Company's Act 2013. The next category for expenditure was in the area of Social business

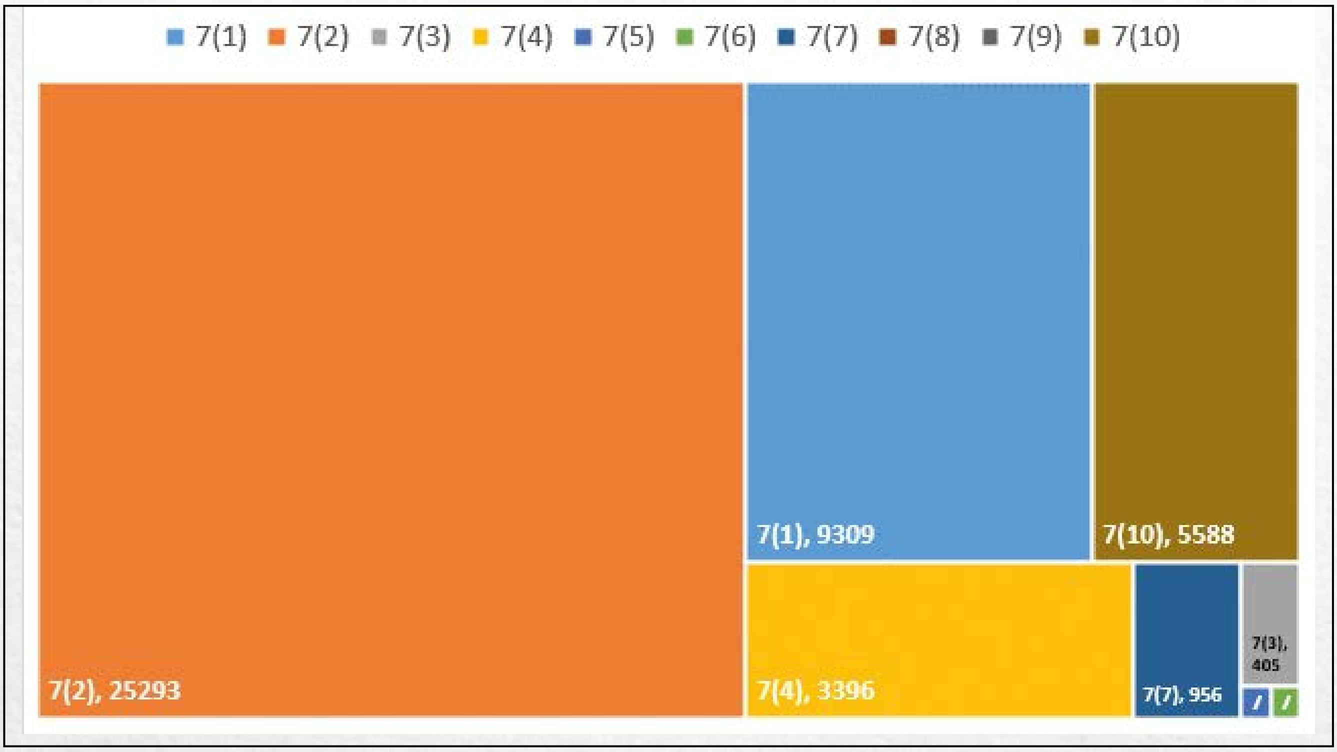


Fig-5: Tree Diagram of CSR Expenditure as per Scheule VII-Section 135 of Companies Act 2013

projects [7(10)], Environmental sustainability [7(4)], Rural sports [7(7)] and Gender equality and women empowerment [7(3)]. National Heritage & Traditional Arts [7(6)] is placed before Benefit to armed forces [7(6)], which incorporates a vast ambit of activities as mentioned in Table 1. Activities related to schedule 7(8) & 7(9) shows nil expenditure.

The extrapolation from the activities laid down as per schedule towards the SDGs shows that the CSR activities in mining complexes are more aligned towards SDG 4 on Education followed by SDG 9 on infrastructure, SDG 6 on Drinking water & Sanitation followed SDG 15 on Ecosystem; and the SDGs least addressed are SDG 12 on sustainable consumption and production, SDG 11 on Habitation, SDG 13 on climate change. As the SDGs are more detailed than the points laid down in the Schedule 7, the schedule-wise analysis found that mining complexes were spending highest amount in Education, developing infrastructures followed by water and sanitation-related activities. The Swachh Bharat Abhiyan that came into being on October 2, 2014, took up the agenda to achieve Swachh Bharat (Clean India) and therefore, it got a lot of attention and funding. The primary agenda of this mission is to provide clean drinking water, build toilets, and promote proper sanitation in India. Expenditures on Environmental sustainability [7(4)] though ranked 4th as per scheduled activities of Company's Act 2013, attracts handsome expenditure on SDG 15 (Ecosystem – Rank 3),), SDG 13 (Climate change – Rank12) and SDG 12 (sustainable consumption and production – Rank14) shows mining complexes are more of concern with and national determined commitment made in Paris agreement 2014 and thereafter. The lowest emphasis concerning expenditure was in the areas of SDG7 on Energy , SDG 14 on marine life, and SDG 17 on global sustainability.

Attempts to link the SDGs with the government schemes can also prove to be beneficial, as NITI Aayog, Government of India is making efforts to synergize SDGs with the national development goals. Collaborations with non-governmental organizations can assist to overcome hurdles like lack of data in areas of health initiatives and improvement. Non-governmental organizations generally work closely with the communities and, therefore, can understand the problems and recommend and provide quick solutions to them. The analysis found that companies have underspent the allocated funds as compared with the budgeted CSR expenditure as per the Schedule 7 and the SDGs. This finding indicates that the companies may be lacking focus or proper planning, as the allocated amount to these activities is not being spent to the optimal capacity.

Table-5 provides the ranks to particular SDGs of the mining company in the Indian context, which provides an overview of CSR activities currently being undertaken towards the fulfilment of SDGs. This analysis could act as an impetus to these mining complexes with social acceptance as responsible company.

State-wise spread of activities of Mining Complexes are shown at Table- 6 and are mapped with the help of check marks. The state Jharkhand & Madhya Pradesh have been represented each by by 5 nos. of Mining Complexes followed by representation of 4 nos. of MCs for state Odisha & West Bengal. The mining Complexes wise and SDG-wise CSR expenditure were classified as per different activities and has been depicted through tick box approach (Table-7). Activities related to SDG 3, SDG6 and SDG9 were found in all the mining complexes. SDG1, SDG4 and SDG5 being represented in eight out of nine mining complexes. SDG 7 and SDG 17 not being represented in any of the mining complexes. SDG 11 & SDG 12 being least represented.

The state-wise CSR expenditure (Fig.-6) shows that Odisha has attracted the highest amount of CSR funds (26833 Cr). One of the mining complex situated in Odisha has embarked on the construction of Mahanadi Institute of Medical Science and Research (MIMSR), Talcher. The MIMSR will have a 100-seat medical college with 500 bedded multi-specialty Hospital with the state-of-the-art medical facilities. The project envisages a hostel for 300 boys, a separate hostel for 200 girl students, two blocks of Hostel for 100 interns, a hostel for

Table-5: SDG-wise classification of CSR projects

SDGs	Ranking as per Table-2	Actual CSR amount spent (in Cr)	Major activities covered under CSR heads by private sector companies as per the author's primary observations
SDG1	6	15.70	• Donations to schools • Donations to NGOs working for poverty eradication • Poverty alleviation project
SDG2	7	7.93	• Providing food in old age homes
SDG3	5	22.02	• Health awareness programmes • Financial assistance for Hospitalization • Financial support towards setting IILDS • Cure and better management of disease in Thalassemia patients • Cataract surgery operations campaign • Medical camps
SDG4	4	172.22	• Education to underprivileged girls • Science labs • Scholarships • Education through Knowledge cum Resources Centers • Treatment of villagers through Mobile Medical Vans • CCL ke Lal / CCL ki Laadli • BPL scholarships
SDG5	11	3.07	• Skill development of women for various trades • Women development—mental and capacity building • Sabka Saath, Sabka Vikas Sammelan
SDG6	1	62.01	• Drinking water • Pond management • School toilets • Swachh Bharat Abhiyan (Clean India)
SDG7		0.00	No activity currently being pursued that helps fulfil SDG 17
SDG8	10	2.97	• Installation of fish smoking kilns • Training youth • Vocational training • Computer training programmes
SDG9	2	109.06	• Maintenance of school building • Construction of Medical College and hospital • Construction of connecting road • Constructions of pre University College block • Construction of student community hall
SDG10	9	9.26	• Financial support towards setting IILDS • Detoxification and rehabilitation of children • Welfare of Differently abled
SDG11	13	0.26	No significant Activity
SDG12	14	0.01	No significant Activity
SDG13	12	1.47	• Research and development of climate change mitigation • Promoting renewable solutions • LED lighting

SDGs	Ranking as per Table-2	Actual CSR amount spent (in Cr)	Major activities covered under CSR heads by private sector companies as per the author's primary observation
SDG14		0.00	No activity currently being pursued that helps fulfil SDG 17
SDG15	3	33.56	• Plantation of trees • Rainwater harvesting • Agriculture, greening and capacity building initiatives • Adoption of Green Highway
SDG16	8	10.06	• Training to promote nationally recognized sports • Flag day contributions • Sponsorship of sports championship • Promotion of rural sports
SDG17	6	0.00	No activity currently being pursued that helps fulfil SDG 17

Table-6: State wise Spread of Mining Complexes

State ↓	Mining Complexes →								
	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9
Bihar									✓
Chhattisgarh						✓		✓	✓
Haryana									✓
Jharkhand	✓	✓	✓					✓	✓
J&K									✓
Karnataka									✓
Madhya Pradesh					✓	✓	✓	✓	✓
Maharashtra							✓	✓	✓
North east									✓
Odisha			✓	✓				✓	✓
Uttar Pradesh					✓	✓			✓
West Bengal			✓			✓		✓	✓
Other State									✓

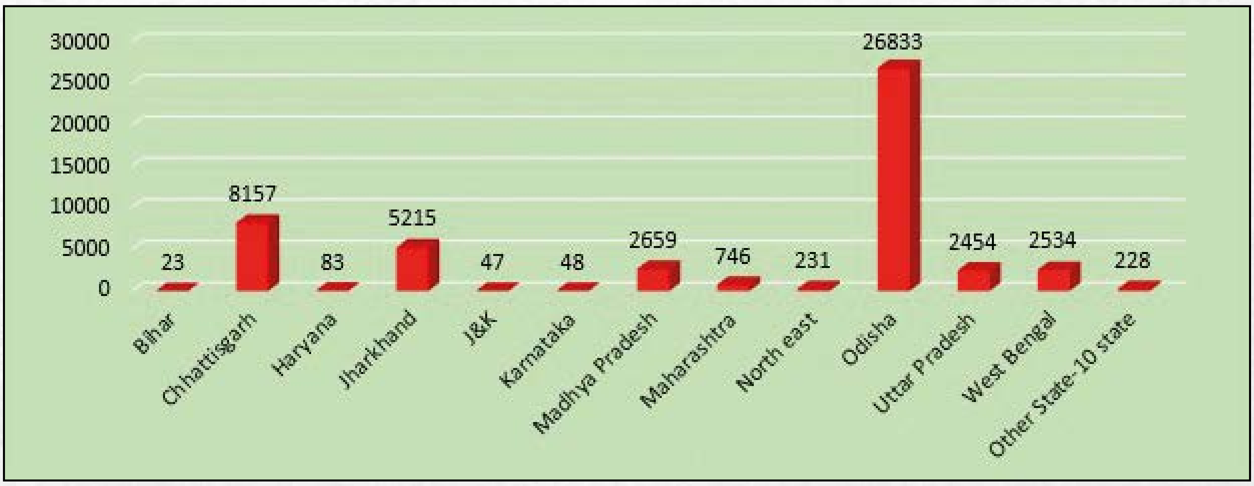


Fig-6: Statewise CSR Expenditure Pattern (in Cr)

Table-7: Mining Complex-wise CSR expenditure regarding SDGs

SDGs ↓ / Mining Complexes →	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9
SDG1	✓	✓	✓	✓	✓	✓		✓	✓
SDG2		✓					✓	✓	
SDG3	✓	✓	✓	✓	✓	✓	✓	✓	✓
SDG4	✓		✓	✓	✓	✓	✓	✓	✓
SDG5	✓		✓	✓	✓	✓	✓	✓	✓
SDG6	✓	✓	✓	✓	✓	✓	✓	✓	✓
SDG7									
SDG8		✓	✓		✓	✓	✓		✓
SDG9	✓	✓	✓	✓	✓	✓	✓	✓	✓
SDG10		✓	✓	✓	✓	✓	✓		✓
SDG11			✓				✓		
SDG12			✓						
SDG13		✓	✓		✓	✓			✓
SDG14									
SDG15	✓	✓		✓	✓	✓	✓	✓	✓
SDG16		✓	✓	✓	✓	✓	✓		
SDG17									

57 junior resident doctors and a 50-bedded nurses' hostel. An amount of Rs.492.62 Crore has been allocated to MIMSR out of which this mining complex has spent Rs 209.57 Crore in the FY 2017-18. Chattisgarh comes next to Odisha which shows an expenditure of Rs. 8157 Cr. Jharkhand stands 3rd in expenditure on CSR activities status were an amount of approximately 5215 cr have been spent by these mining complexes. (Fig-6).

It has also been observed that 15 out of 17 SDGs have their impact at different state of India. It is visible through the mapping that SDGs 3, 6 and 15 have their presence across all the states where activities of mining Complexes are concentrated. However, SDGs 7, 14 and 17 are not operational in these states.

CONCLUSION

The purpose of this research was to examine the CSR expenditure done by different Mining Complexes vis-à-vis SDGs, across their spread and extent of working. It was found that the expenditure made either as per schedule VII of Company's Act 2013 or SDGs goal were inconsistent in type and area of project undertaken. Even though temporal trends have not been examined due to the paucity of data, the CSR expenditure for 2017-18 were linked with Schedule VII and SDGs.

The state-wise sectoral analysis found that the Eastern part of India attaracts maximum brenefits as far as expenses on different heads of CSR is concerned. The state Jharkhand & Madhya Pradesh have been represented each by by 5 nos. of Mining Complexes followed by representation of 4 nos. of MCs for state Odisha & West Bengal.

Activities related to SDG 3, SDG6 and SDG9 were found in all the mining complexes. SDG1, SDG4 and SDG5 being represented in eight out of nine mining complexes. SDG 7 and SDG 17 not being represented in any of the mining complexes. SDG 11 & SDG 12 being least represented.

CSR activities in mining complexes are more aligned towards SDG 4 on Education followed by SDG 9 on infrastructure, SDG 6 on Drinking water & Sanitation followed SDG 15 on Ecosystem; and the SDGs least addressed are SDG 12 on sustainable consumption and production, SDG 11 on Habitation, SDG 13 on climate change. As the SDGs are more detailed than the points laid down in the Schedule 7, the schedule-wise analysis found that mining complexes were spending highest amount in Education, developing infrastructures followed by water and sanitation-related activities.

The analysis revealed concerning SDGs reflected that efforts need to be made to increase CSR expenditure on Energy (SDG 7), Habitation (SDG 11), Sustainable Consumption And Production (SDG 12), Marine (SDG 14) and Global Sustainability (SDG 17).

It is suggested that a working group should examine the Act to bring in parity and to divert the flow of funds. Efforts need to be made to integrate climate change issues as part of their business models. For better alignment of CSR projects towards SDGs, it is essential to enhance awareness of SDGs amongst CSR managers and top management.

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Protecting Structural Damage and Human Annoyance during Blasting in Sensitive Hilly-Terrain

Pijush Pal Roy [1], Chhangte Sawmliana [2], Rakesh Kumar Singh [3]

ABSTRACT

The paper describes the controlled blasting operations in close-proximity of residential houses on hilly slopes at the road construction site of Kaladan Multi-Modal Transit Transport Project of Mizoram State of India. Human response and sensitivity were predominantly considered while fixing the safe level of ground vibration in contrary to the prescribed level suggested by the regulatory agency in India i.e. Directorate General of Mines Safety (DGMS). Experimental blasts were conducted using jackhammer drillhole (32 mm diameter) of 1.5 m (5 ft) depth and 25 mm diameter cartridged explosive combined with short-delay electric detonators. Ground vibration level of 1.85 mm/s was even found to be very unplesant and non-acceptable to the inhabitants. To avoid complaints and inconvenience, controlled blast design parameters were established with limited number of holes and maximum charge per delay in each blasting round so as to confine the ground vibration level within 1 mm/s which was acceptable to the residents.

Keywords: *Controlled blasting; ground vibration; Structural damage; Human response; Air overpressure; Dominant frequency; Fast Fourier Transform (FFT)*

INTRODUCTION

Ground vibration is one of the most perceptible side-effects of rock blasting which causes human annoyance and structural damage, although damage only occurs at levels many times higher than those that cause annoyance [1]. The safe values of ground vibration generated from blasting for different surface structures have been laid down by different countries based on their respective research works. As such, the threshold values of ground vibration prescribed in a particular country may not be applicable in other countries. In India, ground vibration standards have been prescribed by three different organizations viz. Indian Standard Institution (ISI), Directorate General of Mines Safety (DGMS) and erstwhile Central Mining Research Institute (CMRI). The vibration standard prescribed by ISI (IS: 6922 -1973) [2] under 'Criteria for safety and design of structures subjected to underground blasts' is intended for the safety of normal structures constructed on/in more or less homogeneous soil or rock strata. The term 'underground blasting' had been specified as detonation of explosive in drillholes and boreholes for rock excavation and quarry blasts. Hard rocks refer to granite, basalt, quartzite, marble, crystalline schists, massive slates and other hard massive crystalline rocks whereas soft rock refers to shale, sandstone phyllites, laminated slates, mica schist, weathered hard rocks and other soft rock materials.

The DGMS vibration standard [3] grouped the type of structures into two categories viz. (A) Structures not belonging to owner and (B) Structure belonging to owner. Each group is again classified

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based on the type of construction, their importance and sensitivities. In such classification, dominant excitation frequency was given due importance.

The CMRI (presently CSIR-CIMFR) vibration standard prescribed in the year 1993 [4] categorized three different types of structures and formulated the threshold values of ground vibration based on dominant frequency of ground vibration. While framing the safe value of ground vibration level, CMRI vibration standard considered the ages as well as the state of condition of the structures in addition to human perceptions. This has a practical implication that the residents would never allow any blasting activity whenever the level of vibration exceeds some perception level whether it is harmful for structures or not.

In India, from practical point of view, it is difficult to follow a particular standard due to different psychological response of human being residing in the vicinity of mining areas and their consequent repercussions. Complaints of structural damages may still be raised even if the level of ground vibration falls below the prescribed threshold level of structural damage. It is normally seen that in many projects, the vibration thresholds are based on human response than on the probability of damages [5]. The authors also experienced the similar incident while working in a road construction project wherein the blast-induced ground vibration levels were forcefully confined within the tolerable limit of the nearby populace in a sensitive hilly area of Mizoram state in India. This paper describes the controlled blasting operations executed at the road construction site of Kaladan Multi-Modal Transit Transport Project, Mizoram wherein the ground vibration level was kept at 1 mm/s as per the acceptable level of nearby inhabitants keeping aside the prescribed limits of the regulatory agencies.

THRESHOLD VIBRATION LEVELS

The threshold values of ground vibration established by the Indian Standard Institution (ISI, 1973), CMRI (presently CSIR-CIMFR, 1993) and the DGMS vibration standards (1997) are shown in Tables-1, 2 and 3.

INVESTIGATIONAL SITES AND THE PROBLEMS

The Kaladan Multi-Modal Transit Transport Project was initiated by the Government of India under the Look-East Policy to connect India's land-locked Northeastern states with the southern coast of Myanmar. The project would connect the seaport of Kolkata with Sittwe port in Myanmar; it would then link Sittwe to the land-locked region of Mizoram in northeastern India via inland water transport and road transport (Figure 1). The project included construction of nearly 100 km long

Table-1: After Indian Standard Institution (IS: 6922 -1973)

Soil, weathered or soft rock conditions	Hard rock conditions
70 mm/s	100 mm/s

Table-2: CMRI vibration standard

Type of structure	Threshold value of ppv (mm/s)	
	$\leq$ 24 Hz	$\geq$ 24 Hz
Domestic houses, dry wall interior, construction structures with plasters, bridge	5	10
Industrial buildings, steel or reinforced concrete structures	12.5	25
Objects of historical importance, sensitive structures, more than 50 years old construction and structures in poor state of condition	2	5

Table-3: DGMS Vibration Standard (DGMS Technical Circular Number 7 of 1997)

Type of structure		Dominant excitation frequency, Hz		
		< 8 Hz	8-25 Hz	>25 Hz
(A) Buildings/structures not belonging to the owner				
1	Domestic houses or structures (Kuchcha, brick & cement)	5 mm/s	10 mm/s	15 mm/s
2	Industrial buildings	10 mm/s	20 mm/s	25 mm/s
3	Objects of historical importance and sensitive structures	2 mm/s	5 mm/s	10 mm/s
(B) Buildings belonging to owner with limited span of life				
1	Domestic houses/structures	10 mm/s	15 mm/s	25 mm/s
2	Industrial buildings	15 mm/s	25 mm/s	50 mm/s

highway starting from Lawngtlai Town, NH-54 (in Mizoram) up to Myanmar border. The initial portion of the road alignment passed through the periphery of Lawngtlai town, the capital of Lawngtlai district, Mizoram with a span of about 4 km. Residential houses were located on the hilly slope within 90 to 100 m above the road alignment. In the initial portions viz. at Ch: +400 m and Ch: +2150 m, hard rock formations were encountered during formation cutting which required drilling and blasting operations. The full cutting was required as there was no chance of widening by retaining wall at downhill side due to steep gradient. Hence, blasting operations were carried out for the construction of road in these rocky portions. However, the nearby residents alleged damages to their houses due to ground vibrations and noises generated by the blasting operations. Accordingly, the total blasting operation was stopped following the instruction given by the Deputy Commissioner (DC), Lawngtlai District, Mizoram. Hence, the formation cutting work was delayed in a small segment (about 100 m stretch only) due to the complaints raised by the nearby residents whereas the formation cutting works in other portions of the road were almost completed. In order to restart the blasting operations nearby the residential areas, the controlled blasting study was awarded to the Blasting Department of CSIR-Central Institute of Mining & Fuel Research (CSIR-CIMFR), Dhanbad.

At Ch: +400 m, the unfinished rocky portion which required drilling and blasting operations for the excavation work was about 100 m length. The required excavated height using drilling and blasting varied from a few metre to 25 m with maximum width of 8.0 m (Plates 1 & 2). The top portion containing soil and softer rock formations had already been extracted using excavator. The rock formation consisted mainly of shale and shaley sandstone of softer formation. Harder sandstone formation of grey colour with thickness varying from 2 to 2.5 m was present in the top portion of the rock strata. The rock strata were dipping against the excavated slope of the highwall, favouring better slope stability. The residential houses were located above the road alignment. The nearest residential house at Ch: +400 m from the required blasting site was 90 m. One hospital was also located at a distance of less than 200 m above the required blasting site

At Ch: +2150 m, the rock strata mainly consisted of shale with heavily jointed formation. Hard sandstone formation was not found in the required excavated slope. However, the shale strata required

Fig.-1: An outline of Kaladan Multi-Modal Transit Transport Project

drilling and blasting as the excavator deployed at the site could not excavate it. The length of road stretch which required blasting operation was more than 125 m. However, more than 60% had already been excavated. The residential houses were located above the required blasting site and the distance of the nearest house from the blasting site at Ch: +2150 was 89 m.

Plate-1: Far view of the rock formation at Ch: +400 m.

Plate-2: Closer view of the rock formation at Ch: +400 m

EXPERIMENTAL BLASTS AND GROUND VIBRATION MONITORING

Before conducting the experimental blasts, an official notice was given by the Deputy Commissioner to the nearby residents of blasting sites regarding the controlled blasting programme. Since the residential houses were located within 100 m from the required blasting sites, it was decided to use 32 mm blasthole diameter, drilled with jack hammer. It was also planned to use short delay electric detonators of 25 milliseconds interval with delay series of zero to 10 numbers. However, due

Plate-3: View of rocky portion that required blasting operation at Ch: +2150 m

to remoteness of the area and difficulty in acquiring explosive and blasting accessories, only delay series of 0, 2, 5, 6, 7 & 10 numbers were available. The depth of blasthole used in all the experimental blasts was 1.5 m (5 ft). Small diameter (25 mm) cartridged explosive of 125 g weight was used.

Initially, the experimental blasts were conducted with limited number of holes. At Ch: +400 m, the first round of experimental blast was conducted with seven holes in shale strata of softer formation. The total explosive charge was 2.06 kg and maximum charge per delay was 0.624 kg. Blast induced ground vibration was monitored near the foundation as well as on the first floor of adjoining residential houses (Plates 4 & 5). In the next round of experimental blasts, the number of holes was increased in the blasting rounds. In total, eight experimental blasts were conducted at Ch: +400 m wherein the total number of holes in a blasting round varied from 4 to 17. The explosive charge per hole varied between 0.19 and 0.31 kg. The total charge used in a blasting round varied from 1.15 to 5.31 kg and maximum charge per delay varied from 0.31 to 0.94 kg. The firing pattern of holes for experimental blasts conducted with 17 holes at Ch: +400 m is shown in Figure 2. The depth of hole used in all the experimental blasts was 1.5 m (5 ft). In shale strata of softer formation, burden and spacing were 0.8 and 0.8 – 0.9 m respectively. In case of hard sandstone strata, burden and spacing were reduced to 0.7 m and 0.8 m respectively. In order to prevent flyrock, top stemming column was maintained more than 1.0 m in all the blasts.

At Ch: +2150 m, only shale rocks of softer formation were present. Therefore, burden and spacing were 0.8 m and 0.9 m respectively and the total number of holes varied from 11 to 23. The explosive charge per hole varied between 0.19 and 0.31 kg. The total charge in a blasting round varied from 3.44 to 6.44 kg and maximum charge per delay varied from 0.625 to 1.25 kg. The firing pattern of holes for the experimental blast conducted with 23 holes at Ch: 2250 m is given in Figure 3. During the experimental blasts conducted at Ch: +2150 m, one seismograph was always fixed on the first floor of the nearest residential house and another one on the ground surface near the foundation of the house (Plate 6). The distance of vibration monitoring points from the blasting sites varied from 85 to 100 m.

Plate- 4: View of vibration monitoring point near foundation of an adjoining residential house at Ch: +400 m blasting location

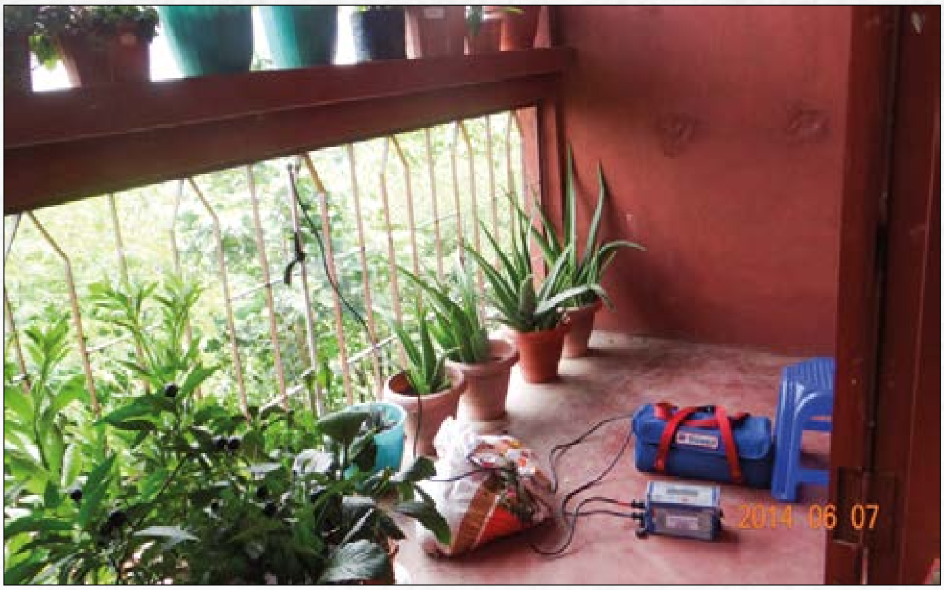

Plate-5: View of vibration monitoring point on 1st floor of an adjoining residential house at Ch: + 400 m blasting location.

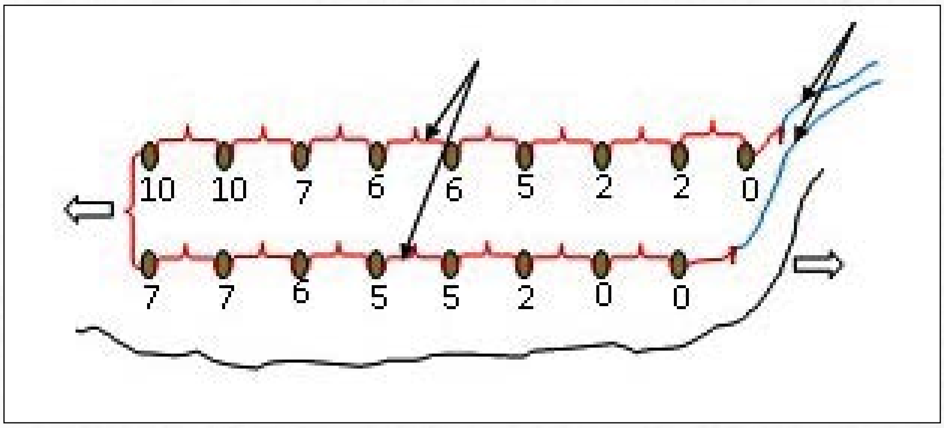

Fig.-2: Firing pattern of holes in the experimental blast conducted in hard sandstone with 17 holes at Ch: +400 m (0, 2, 5, 6, 7 and 10 are delay series)

GROUND VIBRATION RESULTS AND DISCUSSIONS

The magnitude of ground vibrations recorded during the experimental blasts at Ch: +400 m varied from 0.66 to 1.84 mm/s. The triggering levels of the seismographs were set at 0.50 mm/s. During blasting time, the people resided nearby the blasting sites were requested to stay indoors. Some were asked to sit in chairs while others to stand so that vibration could be felt differently.

When blasting was conducted in shale strata of softer formation using maximum charge per delay of 0.624 kg and total charge of 3.00 kg, ground vibration could not be recorded at adjoining residential houses. It also could not be felt by the people staying inside the house. However, when blasting was conducted in harder formation of sandstone strata, ground vibrations as well as blasting sound were higher than those conducted in shale strata. When the ground vibration value exceeded 1.25 mm/s, the nearby residents could feel the vibration and expressed their annoyance. With the ground vibration level of 1.84 mm/s, they felt frightening and said that the vibration was very severe. It was also leant that those people who were sitting on chairs could feel more vibration than those who were standing.

No vibration data could be recorded during experimental blasts at Ch: +2150 m. The ground vibration could not be felt although number of holes, total charge fired in a round of blast and maximum charge delay were higher in comparison to the experimental blast conducted at Ch: + 400 m. The nearby residents were also satisfied with the experimental blasts as they could not feel any ground vibration. The air overpressure levels recorded from the experimental blasts varied between 104.2 and 115.9 dB (L). Although the blasting sound could be heard and noticed by the nearby residents, no adverse comment was made on the blasting sound. The nearby resident were informed during blasting time and with no ground vibration to feel, they were comfortable with the air overpressure level below 116 dB (L). Maximum care was also taken to reduce the blasting sound by using electric detonators and larger top stemming column.

The Fast Fourier Transform (FFT) analyses of the vibration data showed that the dominant excitation frequency of vibration waves recorded on the ground surface (near the foundation of houses) varied between 8.0 and 15.6 Hz. However, the dominant excitation frequency measured on the first floor of the house varied between 7.25 and 7.38 Hz. Considering such dominant excitation frequency, the safe level of ground vibration for the residential houses as per the DGMS Standard comes to 10 mm/s. However, with the ground vibration level of 1.85 mm/s, the residents felt unsafe and expressed their annoyance to the blasting operation. When explained to them that the measured levels of ground vibration were much lower than the threshold values prescribed by the regulating agency, it was not convincing to them. They had claimed that the cracks had already developed in their houses due to previous blasting operations and any further ground shaking would destabilize their houses.

Therefore, considering the sensitivity and sentiment of the nearby residents, it was decided to reduce the number of holes

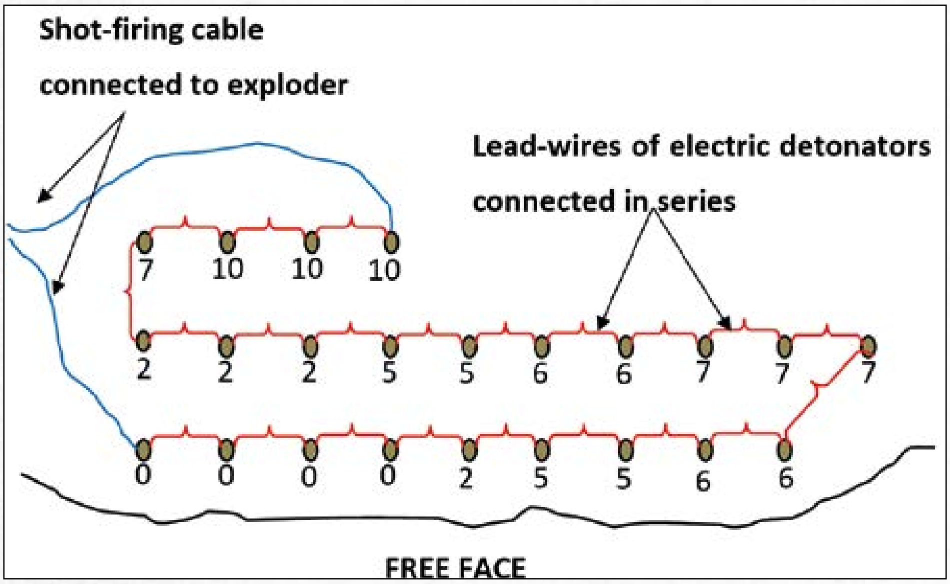

Fig.- 3: Firing pattern of holes in the experimental blast conducted with 23 holes at Ch: +2150 m (0, 2, 5, 6, 7 and 10 are delay series)

Plate-6: View of vibration monitoring point near the house at Ch: +2150 m

in a blasting round so that ground vibration level would not cross 1.0 mm/s and further complaints and any untoward incidents could be avoided. The number of holes in a blasting round was restricted to 10 in hard rock and to 15 in softer rock i.e. shale at Ch: +400 m area. Hence, the maximum charge per delay was less than 0.625 kg in case of blasting in hard rock and 0.94 kg in case of blasting in softer rock using the available short delay electric detonators. Since no hard rock was

Plate-7: Final excavated road at Ch: +400 m

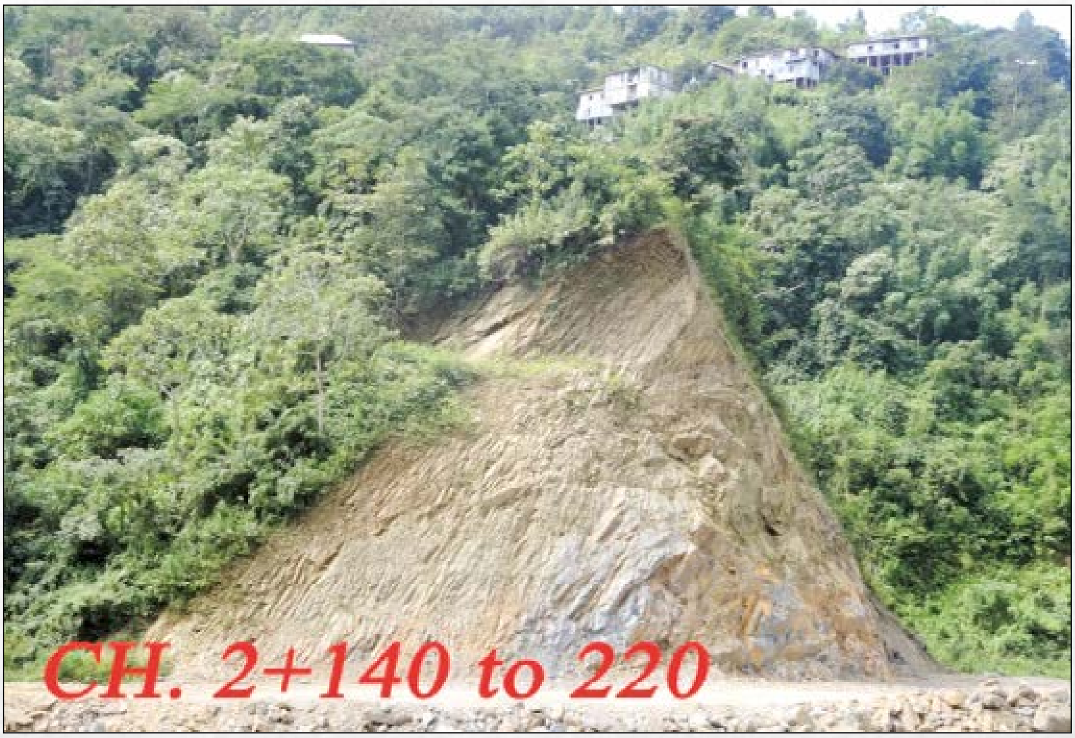

Plate-8: Final excavated road at Ch: +2150 m

present in Ch: +2150 m area and no vibration data could be recorded during the experimental blasts, the total number of holes in a blasting round was restricted to 23. The excavation work using controlled blasting was finally completed without any complaint from the nearby residents. Plates 7 and 8 show the excavated road after the completion of the formation cutting work using controlled blasting.

CONCLUSION

When blasting operation is to be conducted nearby sensitive human habitants with hostile attitudes, human response to ground vibration cannot be ignored in deciding the safe level of ground vibration. To avoid any critical situation, it may often require reducing the permissible level of ground vibration to much below the damage threshold level prescribed by the regulatory agencies. Based on the experience stated in the paper, the vibration level of 1.85 mm/s was found to be very severe and detrimental in respect of the perception of the nearby habitants though the damage threshold level of ground vibration was 10 mm/s as per the prescribed standards. Therefore, caring the sentiment of the people and maintaining good relationships are absolutely necessary to accomplish any blasting project in sensitive environment of hilly terrain.

Note: *An earlier version of this paper was submitted for poster presentation in IMCET-2015, Turkey but it was neither displayed in a poster nor presented in the said Mining Congress.*

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KAYA KALP VATIKA

A Unique Mine Reclamation & Eco-restoration Initiative

Sanjay Kumar[1]

Piparwar OCP in Piparwar Area is one of the prestigious project of CCL commissioned in 1990 as a green field project with Inpit - Crusher and conveying technology. Since its commissioning, Piparwar OCP has produced more than 200 M.te of coal and handled about 100 M.M^3 of Over Burden. In the year 2014-15, Piparwar OCP produced 13.20 M.te. of coal and thereby achieving the highest coal production in a financial year.

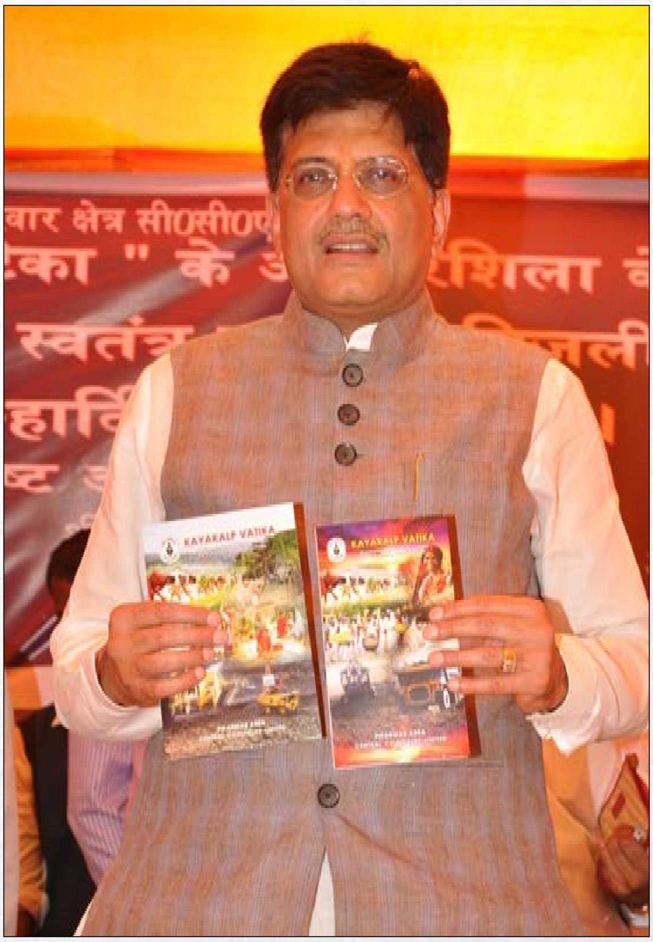
Coal is the most abundant fuel resource in India & the mainstay of India's energy matrix contributing to more than 60% in electricity generation. With increasing population, growing economy and a quest for improved quality of life, electricity demand in the Country is rising. Coal mining is not only fulfilling the increased demand of the industry but also plays an important role in the economic development of the Country. India has some of the largest reserve of Coal in the World and Coal will continue to maintain it's dominant position in India's energy scenario.

Opencast coal mining being a site specific activity is associated with substantial environmental challenges as it's creates significant and often irreversible impacts like changes in landscape, loss of vegetation, disturbance in water regime, loss of bio-diversity apart from Air & Water pollution.

Coal production with sustainable Environmental Management has been a hall mark of coal mining operations in Piparwar OCP in which OB removed is back-filled in the mine void up to the original ground level and thereafter soil / top soil is spread over the reclaimed land and plantation is done.

In Piparwar OCP, a unique mine reclamation & eco restoration initiative, in the form of Kayakalp Vatika has been conceptualised, foundation of which was laid by the Hon'ble Sri Piyush Goyal, the then Minister for Coal, Power & New Renewable Energy, Govt. of India on 4th May 2015 during his visit to the Piparwar Area.

Kayakalp Vatika is an in-house initiative conceptualised with many unique interventions



[1] *Area Environment Officer, Piparwar Area, Central Coalfields Limited.*

like landscaping, soil enrichment, rain water conservation, development of water bodies apart from plantation over the reclaimed land. The interventions in Kayakalp Vatika is to accelerate the natural process of regeneration/succession. Initially, the Kayakalp Vatika initiative was started over an area of 5 Ha. which now covers 50 Ha. of reclaimed land with plantation over 24 Ha. of land and may further extend to over 100 Ha. of reclaimed land as the mining activities slows down.

The present 50 Ha. of reclaimed land within Kayakalp Vatika initiative covers land – scaped area with plantation over 24 Ha. of the reclaimed land with 3 no. of water bodies which holds rain water up to 4 months after monsoon. Slopes have been spread with top soil. Top soil being rich in humus and fertile and is left untouched to aid in return of vegetation on the slopes.

Landscaping – Landscaping gives an opportunity to modify the features of the reclaimed area in such a manner & shape so as to conserve rain water, minimise soil erosion thereby enabling vegetation to return. Landscape restoration contributes to both Climate change mitigation & adaptation, capturing CO_2 and increasing climate resilience. Landscape helps in optimising water conservation, enable vegetation to return and improve flow of water, carbon & other nutrients through the ecosystem.

Soil Enrichment – Soil is the basis of all terrestrial life. As a result of mining operations, soil gets degraded with loss in soil quality and decline in nutrient level. Since the mine void has to be backfilled with overburden, consisting mainly of alluvium, sandstone & shale for reclamation. Soil enrichment is therefore very essential for sustaining vegetation & plants on the reclaimed land. For improving soil health, moisture level & Organic matter needs to be increased / added. To increase moisture level in the soil, bunds, contours, trenches & small water bodies have been made in the Kayakalp Vatika whereas manure / vermi compost is added to increase the level of Organic matter in the soil. A vermi Compost unit has been setup at the Kayakalp Vatika and Compost piles have also been built at different places over the reclaimed land.

Water Conservation – Water sustains biodiversity and therefore during reclamation a conscious effort has been made to ensure that rain water is conserved within the Kayakalp Vatika by making bunds, contours, trenches, small voids & water bodies. While bunds, contours, trenches & voids helps in maintaining moisture level of the soil, the small water bodies are able to hold rain water upto 4 months after monsoon. The water so conserved in Kayakalp Vatika helps to meet the water need of the vatika and also helps in sustaining both flora & fauna, support habitat for numerous plants & animals apart from recharging ground water.

Plantation - Plantation is the most important activity for eco-restoration. Plantation & survival of saplings over a reclaimed land is a challenge. Overburden material consisting mainly of alluvium, sandstone & shale etc is itself deficient in all types of soil nutrients. Before taking up plantation, the plantation site at the reclaimed area is spread with top soil and thereafter plantation is done. Spread of top soil helps in conserving soil moisture besides providing nutrients. Under the Kayakalp Vatika initiative, preference is given to plant native species like Mahua, Gamhar, Sal, Shisham, Bargad, Gular, Palash etc with a mix of other resilient species like Neem, Karanj, Jamun, Amla etc which can survive the harsh conditions of the reclaimed land and help in growth of other species by enriching soil quality. On the 24 Ha. of reclaimed land about 60,000 saplings have been planted during last 3 years i.e from 2017 monsoon to 2019 monsoon. Another 15,000 saplings will be planted over an area of 6 Ha. of reclaimed land in the coming 2020 monsoon.

The reclaimed land under Kayakalp Vatika initiative has been undergoing a gradual change in to a lush green land with increased soil moisture level and soil fertility, with grasses & shrubs coming over, with several tree growing over 10ft height. Slowly the reclaimed land is getting converted into a rich bio-diverse area. In the years to come, this area will grow in to a forest with diverse habitats sustaining each other and developing into as a self sustainable eco-system.

The Comptroller & Auditor General of India (CAG) in it's Performance Audit Report no. 12 of 2019 on *" Assessment of Environmental Impact due to Mining activities and it's Mitigation in Coal India Limited and it's Subsidiaries"* has appreciated the works being undertaken in Kayakalp Vatika as a *"Good Practice & Green Initiative "*.

Greening mines is no longer a statutory requirement but an Environmental imperative & obligation. It is a fact that developing forest is the most realistic defence against global warming & climate change. Kayakalp Vatika initiative is an endeavour towards developing a unique mine reclamation and eco restoration model to reclaim & restore degraded mining land and to facilitate development of forest by letting Nature heal through natural regeneration & succession.