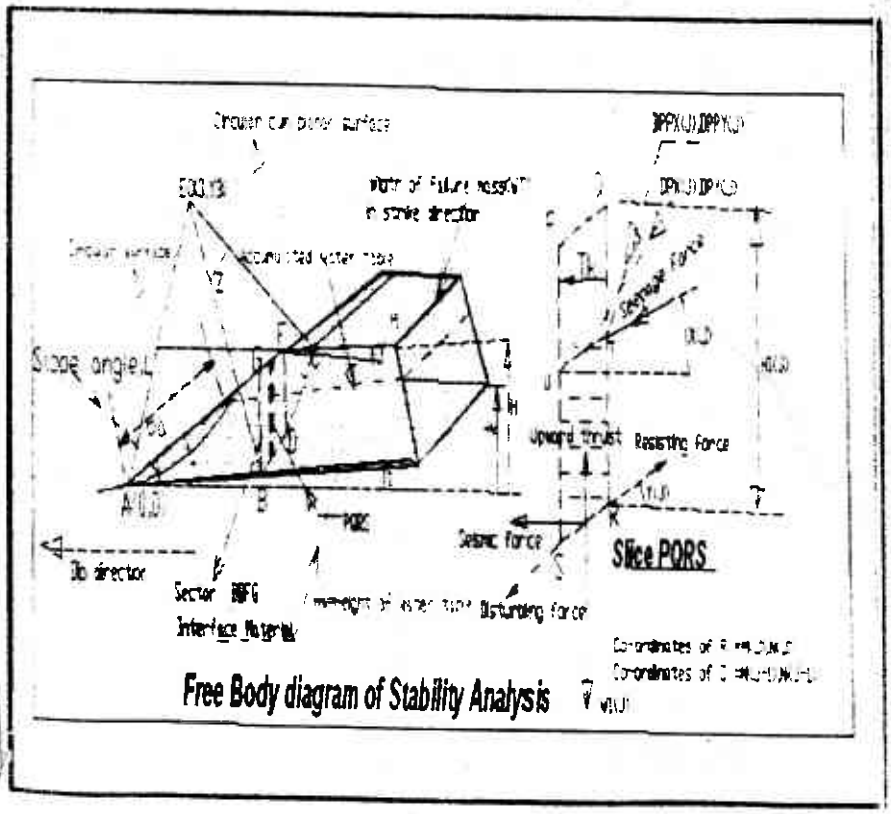
REPORT
of
HIGH POWERED COMMITTEE
on
Accident in the Deep Mining Zone
of
Rajmahal,OCP, ECL on 29 December 2016



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CHAPTER I

INTRODUCTION

1.1 Constitution of the Committee:

In reference to the Office Memorandum, no. CIL/ CH/Secy/36(A)/416, dated 30.12.2016 (copy enclosed at ***Annexure-1),*** issued by the Chairman, CIL, to carry out in-depth analysis of the accident that occurred at the Rajmahal OCP of ECL on 29th Dec.'16 at about 7:30 PM likely involvement of 23(Twenty Three) contractor's workers by a High Powered Committee consisting of the following persons:

1. Sri. Shekhar Saran, CMD, CMPDIL - Chairman of the Committee
2. Sri. P K Sinha, Director (Tech./ P&P), SECL – Member
3. Dr. Phalguni Sen, Professor, IIT(ISM)- Member
4. Dr. V.K. Singh, Head of Slope Stability Divn., CIMFR, Dhanbad, Member
5. Prof. I. Roy, BIT Mesra - Member
6. Sri. A K Nath, GM/ TS to DT, CIL - Member Secretary

The committee has to submit its report within 4 weeks from the date of issue of the said Office Memorandum.

1.2 Scope of the Committee:

The committee was constituted to examine the following aspects:

a) The cause of accident,

b) Human failure, if any,

c) Whether the accident could have been avoided by taking identified corrective measures

d) Measures to avoid recurrence of such accidents in future in Rajmahal OC and other Mines with similar workings in ECL

1.3 Meetings and Visits of the Committee:

Sri Shekhar Saran, Chairman of Committee inspected the site on 05.01.2017. Earlier the site has been inspected by Shri P K Sinha, Director (Tech. /P&P)-SECL, member of the High Power Committee, immediately after the accident on 31.12.2016. Prof. Phalguni Sen, Dr. V.K. Singh and A K Nath, members of the High Power Committee inspected the site on 3rd and 4th of January 2017. Dr. Indrajeet Roy other members of team visited the site and collected sample etc. on 04.01.2017 and 05.01.2017.

i) 1st meeting of the committee was held on 18th January 2017 at CIL, Kolkata, in which, Shri S Saran; Shri P K Sinha; Prof. Phalguni Sen, Dr.V K Singh; Prof. I Roy; A. K. Nath were present.

ii) 2nd meeting of HPC was held on 01.02.2017 at CMPDI, HQ Ranchi. Details of plans and Section were studied along with the documents.

iii) 3rd meeting of HPC was held on 03.03.2017 and 04.03.2017 at CMPDI,RI-I Asansol. The executive, staff and Contractor workers were interrogated and statements were taken.

iv) 4th Meeting of HPC was held at CIL ,HQ on 27.03.2017.

v) 5th Meeting of HPC was held at CMPDI,HQ, Ranchi on 02.04.2017

CHAPTER II

2.1 BACKGROUND OF THE PROJECT

Project Report for Rajmahal opencast was originally sanctioned in August, 1980 for a rated capacity of 5.0 Mty. The project was subsequently expanded to a rated capacity of 10.5 Mty, the PR for which was sanctioned in Nov., 1988. This PR was based on the project documents of Rajmahal-A OC Mine (10.5Mty), prepared by METCHEM, Canada Inc. in Sept. 1987. Subsequently, a Revised Cost Estimate of Rajmahal OCP (10.5 Mty) was sanctioned by the Government of India in Jul., 1993. The project was later expanded to a rated capacity of 17.0 Mty from 10.5 Mty, the PR for which was sanctioned by the Govt. of India in Sept., 2009 for an additional capital investment of Rs.153.82 crore up to the target year.

2.2 PROJECT SITE INFORMATION

2.2.1 Location

The Rajmahal Opencast Coal Project is located in the Godda District of Jharkhand, India, between latitudes 25^0 1' 12" N & 25^0 3' 15" N and longitudes 87^0 21' 0" E & 87^0 24' 0" E. The area is easily accessible, being connected with the Godda-Pirpaiti PWD road. The nearest railway station is at Pirpainti on the Sahibganj loop of the Eastern Railway, about 30 km from the project site. The topography of the area consists of a gently undulating surface, 70-100 m above sea level, with the highest point, Lalmatia Hill, occurring in the northern part of the area at a height of 204 m above sea level. Location plan of the Rajmahal OCP is enclosed at ***Annexure-2.***

2.2.2 Climate

The area has a mild to moderate and tropical to sub-tropical climate with temperatures varying between 8^0 C in winter and 48^0 C in summer. It is influenced by the monsoon from June to September and has an average rainfall of 1153 mm per year (as recorded between 1958 and 1986) with the highest recorded annual rainfall being 1794 mm in 1971 and the highest recorded daily rainfall being 138 mm on August 5, 1982.

2.3 GEOLOGY

Rajmahal OCP lies within Lalmatia Exploration Block, which covers an area of 15 Sq. Km. and has been explored by CMPDI. The geological report of the block was published in March 1984 considering the data from 200 boreholes.

Altogether 8 persistent coal horizons of Barakar formation have been identified in the block. The seams, from bottom upwards are seams I, II (bot), II (Top), III, IV, IX, X & VI. The seams II (bot), II (top) and III merge and split within the area to form various combinations. These seams are also highly inter-banded in nature. More than 95% of the reserves in the block occurs in the seams II (bot), II (top) and III along with their various combinations.

Seam-I is not developed properly in the geological block except in the central part. The approved project report does not include seam-I in the quarry proposal. Therefore, the floor of the seam-II (bot) form the base of the OCP as per the approved P.R.

All the seams are in-cropping in the area under a thick alluvium cover of 15m to 35m in thickness and dips gently (usually 2° to 3°) towards east. However, higher dips up to 10° is also noticed in the vicinity of structural disturbances particularly in the area lying south of fault F_8.

2.3.1 SEQUENCE OF COAL SEAMS AND GEOLOGICAL RESERVES

Seam	Parting	Thickness Range (m)	Geological Reserves (Mt)
XII		01.27 - 02.10	
	Parting	11.05 - 16.09	
XI		01.75 - 05.74	4.037
	Parting	07.29 - 20.31	
X		01.77 - 05.91	5.346
	Parting	03.85 - 21.93	
IX		02.97 - 07.00	8.873
	Parting	02.97 - 09.70	
VIII		00.68 - 02.99	
	Parting	43.27 - 53.69	
VII		00.56 - 03.28	
	Parting	10.91 - 27.80	
VI		00.40 - 04.20	
	Parting	09.15 - 27.68	

Seam	Parting	Thickness Range (m)	Geological Reserves (Mt)
V		00.36 - 02.97	
	Parting	11.40 - 41.50	
IV		00.32 - 02.57	3.716
	Parting	00.00 - 10.88	
III		1.35 - 17.87	69.349
	Parting	00.00 - 44.70	
III & II Comb			61.341
III & II Top Comb			5.781
II Comb			141.041
II (Top)		1.47 - 17.10	146.478
	Parting	00.00 - 26.52	
II (Bot)		10.96 - 26.53	202.546
	Parting	13.04 - 33.66	
I		02.00 - 09.54	33.336
Total			681.844

Note:

(I) Seams II (Top) and II (Bot) normally occur as two different seams within the block except towards south where they combine.

(II) Coal seams also occur in the following combinations:

(a) Seam II (Comb) + III

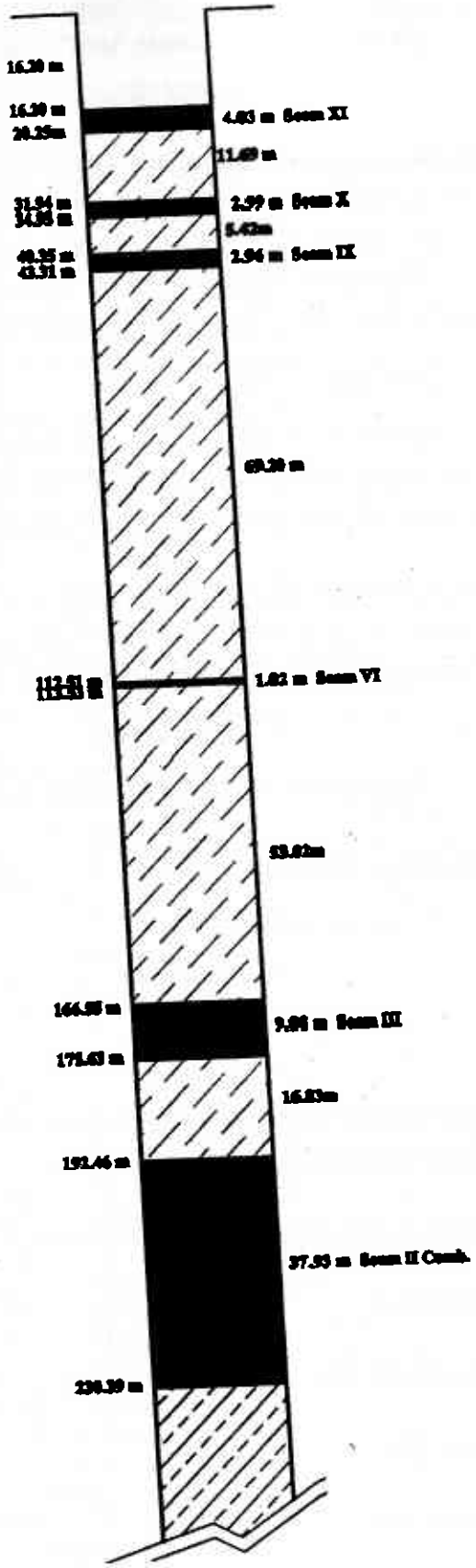
(b) Seam-II (Comb) + III + IV

(c) Seam-II (Top) + III

(d) Seam-II (Top) + III + IV

(III) The parting range between seam-I and II has been taken where seam-I occur as a composite seam.

A representative lithology of Lalmatia Coal Block is shown below.



2.3.2 Faults

17 normal faults have been postulated within the block. Among these, five southward heading faults, namely Fault F1, 6, 8, 11 and 15 are of major magnitude. As borne out of the interpretation, the southern half of the block appears to be structurally more complex.

The description of the fault is shown below:

Sl. No.	Fault	Throw	Remarks
1	F-1	20-40m towards south	Partly marks Northern limit of the block
2	F-2	Up to 25 m towards South	Trending to die out towards East. Partly marks Northern limit of the block
3	F-2A	5-15 m towards South	
4	F-3	0-10 m towards North	Dies out towards East & West
5	F-4	0-5 m towards SW	Dies out towards SE
6	F-5	5-10 m towards North	Throw reduces towards West
7	F-6	10-40 m towards SW	Throw reduces towards West
8	F-7	0-10 m towards NE	Dies out towards SE
9	F-8	5-160 m towards SSW	The strike of the strata is generally NE-SW with 2-3° dip towards East on the Northern side of the fault. On the southern side of the fault the strike is NW-SE with 5-10° dip towards East.
10	F-9	5-10 m towards North	
11	F-10	25 m towards South	
12	F-11	14-35 m towards South	
13	F-12	10-20 m towards SW	
14	F-13	30-70 m towards South	
15	F-14	10-20 m towards SW	
16	F-15	10-20 m towards North	Block boundary in the South
17	F-16	10-20 m towards NW	

2.3.3 Hydrogeology

Detailed hydrogeological investigations have been conducted by CMPDI in the Rajmahal Project area and a report on Hydro-geological investigations was published in November 1994. Later (in July, 1991) a report on the Advance Mine Dewatering Arrangements at Rajmahal Project was published by CMPDI based on further studies.

During the studies, five major aquifer systems were identified as follows.

Aquifer Disposition				
Sl. No.	Aquifer	Lithology	Confining beds	Nature of Aquifer
1	Water table Aquifer	Clay, slit and sand		Unconfined
2	Aquifer-III	Sandstone	Top clay and seam-III	Confined to semi- confined
3	Aquifer-IIA	Sandstone	Seam-III and Seam-II(top)	Confined
4	Aquifer-II	Sandstone	Seam-II (top) and Seam-II (bot)	Confined
5	Aquifer-IA	Sandstone	Seam-II (bot) and Seam-I	Confined
6	Aquifer-I	Sandstone		Confined

Except the top aquifer (Aquifer – III), all the other aquifers are confined in nature and are persistent throughout the area.

From the sump tests, it has been calculated that the permeability of over burden is in between 2m/day to 3m/day and the specific yield is 15%. Whereas, for the lower aquifers, the permeability ranges from 5m/day to 8m/day and the storativity is 14 X 10.5.

2.3.4 Coal Reserves

The mineable reserves as on 01/04/2008 had been estimated as 251.10 Mt requiring 504.81 MCuM of OB removal at an average stripping ratio of 2.01 CuM/t. These reserves included 14 Mt of coal from the deep mine area.

The seam-wise mineable reserves & OB volume as on 01.04.08 were as under:

Sl.No.	Seam	Mineable Reserves (Mt)
1	Seam-III	29.78
2	Seam-II(T)	86.82
3	Seam-II(B)	94.95
4	Seam-II(T)+II(B)	34.20
5	Seam-II+III	5.35
	Total Coal (Mt)	**251.10**
6	Top OB	362.91
7	Part. bet. Seam-III & Seam II(T)/II(T)&II(B)	82.30
8	Part. bet. Seam- II(T)&II(B)	28.25
9	Band in seam-III	9.15
10	Band in seam-II(T)	10.50
11	Band in seam-II(B)	6.25
12	Band in seam-II(T)&II(B)	5.45
	Total OBR(Mcum)	**504.81**
	Av. Stripping Ratio(cum/t)	**2.01**

2.4 MINE LIFE

As per Approved Expansion PR (17.00 MTY) the balance mineable coal reserves 145.60 Mt (as on 01.04.2016) and the balance life at the rated capacity of 17Mty will be about 9 years.

2.5 METHOD OF WORK

As per the approved Project Report, floor of the Seam-II (bot.) forms the base of the quarry.

Top OB (of volume equivalent to the existing HEMM capacity) was proposed to be removed departmentally with the existing equipment i.e. by 20 cum rope shovels with 170T/190T upgraded dumpers and by 10 cum rope shovels /12-14cum/9.5cum/7.5cum/5cum hydraulic shovels in conjunction with 85T/100T upgraded dumpers.

Complete 17 Mty coal, intervening partings & bands and rest Top OB (beyond the departmental capacity) was proposed to be mined by outsourcing means.

2.6 MAJOR EQUIPMENT ON ROLL

The major equipment available during 2016-17 are as follows:

Sl. No.	HEMM	SIZE	Number
1.	ERS (Electric Rope Shovel)	20cum	5
2.	ERS	10cum	2
3.	HS (Hydraulic Shovel)	12-14cum	3
4.	HS	4.3-5.5cum	1
5.	HS	2-3cum	1
6.	Dumper	170T	14
7.	Dumper	100T	35
8.	Dozer	410hp	19
9.	Wheel Dozer	450hp	1
10.	Electric Drill	311mm	5
11.	Diesel Drill	160mm	4
12.	FEL (Front End Loader)	11.5cum	3
13.	Water Tanker	28kl	6
14.	Grader	280hp	6
15.	Crane	120T	1
16.	Crane	70-75T	1
17.	Crane	30T	2
18.	Boom Truck		2
19.	Service Truck		3
20.	Fuel Truck	20kl	2
21.	Line Truck		1

2.7 PRESENT STATUS OF WORKING

Mining is being carried out in two zones in the Project viz. Main Mining Zone and Deep Mine Zone. Broadly north of fault F-8 is Main Mining Zone whereas, the South of this fault is named as Deep Mining Zone.

M/S Rajmahal Coal Mining Ltd. (RCML) was awarded the partial outsourcing for extraction of coal 199.98 Million tonnes including excavation removal of OB/parting 159.39 Million Cubic Meter in 14.04.12 in the Main Mining Zone. Pumping and drainage associated with mining operations was also incorporated in scope of the RCML. Accordingly M/S RCML started working from 01.07.2013.

M/S Somya Mining Pvt. Ltd. (SMPL) was engaged for removal of OB and extraction of coal in the Deep Mining Zone but discontinued its workings since 8th February 2014. A fresh contract for removal of 200 L cum. OB and extraction of 70 L te coal was awarded to M/S Mahalaxmi Infra-contract Pvt. Ltd. – (MIPL – NKAS, JV) on 10.06.2015 by the name of Dahernangi Patch. Accordingly work was being carried out by the said contractor at the time of mishap.

Currently all the departmental HEMM have been deployed for removal of top OB in the Main Mining Zone area.

CHAPTER III

CONCEPT AND STUDIES RELATED TO SLOPE STABILITY, SAFETY AUDIT, STATUTORY & ISO INSPECTIOS AND DGMS STIPULATIONS FOR RAJMAHAL PROJECT

3.1 General Mechanism of Slope Failure

Growth imperatives of the country necessitate commensurate level of production of coal and other minerals particularly, through opencast mining methods. But, the major problem encountered by opencast mining is the high level of overburden waste rock production, in general, and its disposal. The mine economics demands minimum waste rock production and dumping the waste rock in a minimum optimal areas. But, there is an urgent need to maintain safety in the opencast mines vis-a-vis mine economics. One of the most important safety aspects of opencast mining operation is slope stability i.e. to maintain stability of the faces of quarry batter and waste dumps (both internal and external).

Optimum waste rock production can be ensured by Slope Stability Study of quarry batter whereas optimum use of land for waste rock disposal can be ensured by Slope Stability Study of waste dump.

3.2 Slope Stability of waste dumps

Opencast coal mining involves handling of large volume of overburden (O.B.), a portion of which can be back-filled in the de-coaled area of the mine. The remaining O.B has to be dumped outside the quarry in a convenient place considering safety, environment and economical aspects. This waste material dumped outside the quarry is termed as external dump whereas, back-filled dump inside the quarry is termed as internal dump.

The stability of spoil / OB dumps comprising of mining waste is being recognized as a major problem area calling attention in view of :-

- Occurrence of many accidents due to failure of OB dumps.
- Increasing volume of OB required to be disposed off with increasing depths of mine
- Scarcity of adequate space for OB dumping.

The most tragic incident of spoil heap failure which brought the problem of stability to the public attention occurred at Aberfan, S. Wales, U.K. in which 144 people were buried under the heap. The number of fatalities in this single disaster exceeded the cumulative number of deaths caused by natural slides in U.K.

In Indian scenario, majority of large opencast mines are facing slope stability problems of waste dump resulting in loss of production, extra stripping cost to remove land-slide

material, reforming O.B dump benches, diversion of haul roads, production delays and sometimes loss of human lives and HEMM.

Opencast mines of the country have witnessed several incidents of dump failures, including some fatal accidents which occurred since 2000.

3.2.1 Geo-technical Properties of OB Dumps

Presence of Clay Material

If there is an existence of clay material within the dump material (like Sonepur-Bazari Opencast project of ECL and Sasti, Umrer, Pimpalgaon, Neeljai, Kolgaon etc. of WCL), determination of its pre-dominance is necessary to assess the expansive properties of clay material. In case of expansive soil, shear strength properties drastically reduce due to swelling after coming in contact with water. Swelling index is also to be determined in case of expansive soil.

Co-efficient of permeability

This parameter is important for assessing the seepage properties of water. It is pertinent here to mention that except for the pure clayey dump, waste rock dumps are permeable.

Bulk density of dump mass

Bulk density of dump mass is one of the important parameters in stability calculation. It determines the weight of waste rock/soil mass which is one of the major influencing factor for the determination of disturbing and resisting force.

Shear strength parameters

Stability analysis in soil mechanics involves a basic knowledge of the shearing properties and shearing resistance of the soil. The shear strength is the most difficult to comprehend and one of the most important of the soil characteristics.

The shearing resistance of soil comprises basically of the following components:

a) The frictional resistance between the individual soil particles at their contact points.

b) The cohesion between the surfaces of the soil particles i.e. the structural resistance to displacements of the soil because of the interlocking of the particles.

c) The shear strength in cohesion-less soil results from inter-granular friction alone, while in other soils, it results both from internal friction as well as cohesion.

The fundamental shear strength equation proposed by French engineer Coulomb is:

$$S = C + \sigma \tan \phi$$

Two sets of Mohr's envelops are drawn based on two different sets of stress on the soil sample. The details of the tri-axial testing can be consulted with the help of any book on "Fundamentals of Soil Mechanics."

The values of C (cohesion) and ϕ (angle of internal friction) depend upon following factors:

a) The Past history of the soil.

b) The Initial state of the soil i.e. whether it is saturated or unsaturated.

c) The Permeability characteristics of the soil

d) The Conditions of drainage allowed to take place during the test.

3.2.2 Hydro-geological parameters influencing dump Slope Stability-

The effect of Hydro-geology in determining stability of dump is as follows:

Effect on the shear strength parameters of dump materials due to water saturation during rainy season.

As majority of the dump failure is reported during rainy seasons, the effect of water saturation due to rain water is to be considered.

Upward thrust of water i.e. hydro-static force due to accumulated water table within the dump.

It is determined by the product of unit weight of water and volume of submerged overburden dump material falling within the failure mass. The upward thrust of water on the dump is applicable when there is a standing or moving water table within the dump itself. Water table exerts upward thrust of water to internal/back-filled dump either during mining operation or after mine closure.

Seepage force of water due to accumulated water table within the dump.

It is determined by the product of unit weight of water and volume of submerged overburden dump material falling within the failure mass and gradient of seepage line. Seepage due to surface drainage of water flowing through the gullies formed at the surface of the dump is also to be considered.

3.2.3 Geo-mining parameters influencing stability of dump

Mine floor inclination

It is one of the major influencing parameter controlling stability of internal dump. As the internal dumps are formed above mine floor which is natural occurrence of coal seam or layer, all the internal dumps are to be designed as per the gradient of coal seam which is not in the control of mine operators.

In case of external dump standing against a hill, it is also a major factor influencing stability of dump.

Profile of the dump

The profile of the dump i.e. berm width and slope angle of individual bench is to be determined by stability analysis. The slope angle has to be made steep as far as possible for saving land and money, but at the same time, safety of men and machine near the dump has to be ensured by making slope as flat as possible. This optimization is utmost necessary for the dump slope which can be done by controlling berm width and slope angle of individual bench within the dump.

3.2.4 Seismicity of the area and blast vibration of quarry on the dump

Both are having adverse effect on the stability of dump. Seismicity of the area is to be considered as per Indian Seismic map and the blast vibration effect due to blasting in the quarry batter. In both the cases, horizontal seismic co-efficient has to be measured and multiplied with dead load to determine horizontal force on the dump.

3.2.5 Various modes of failure

In the opencast mining operation, vast amount of waste rock or soil in the upper strata is excavated for extraction of coal. This waste rock after excavation from the ground swells to more than 30% and one of the major problems in opencast mining operation is the handling and accommodating such huge amount of waste rock/soil. A portion of waste rock/soil dumped outside the quarry/opencast mine is called external dump and rest amount of waste rock back-filled within the quarry is called internal dump.

In case of dump failure, there are different failure modes for external and internal dumps as investigated and observed in actual site conditions.

Formation of internal dump - The internal dump is formed within the quarry or mine. It stands above the de-coaled area i.e. the floor of the quarry or mine in which coal has already been excavated.

Formation of external dump - The external dump is formed outside the quarry and it stands above the ground surface.

Failure modes for internal dump

Circular failure - The circular failure as observed in internal dump occurs in following conditions:-

- As the failure mode or surface finds the path of least resistance, circular failure occurs when the shear strength of dump material is less than that of foundation of dump.
- The internal dump is standing above flat mine floor of not more than 2 degree.

Circular-cum-planer Failure:-This failure is observed when the shear strength of interface material between dump and the mine floor is less than that of dump material. The dump is also standing in steep floor mine floor of more than 3 degree.

[After extraction of coal, a slushy layer of water and coal dust is lying at the floor of the internal dump. This slushy layer at the base of the dump is termed here as circular-cum-planer failure].

Base Failure - This failure is observed when the shear strength of foundation material is less than that of dump material. In case of water table existing at the foundation of dump material, it will exert upward thrust of water at the foundation of dump. It is also one of the causes of base failure.

3.3 Slope Stability Study of quarry batter in coal mines

In a working opencast mine, the stability of quarry batter is dictated by the presence of discontinuity plane like major and minor fault, joints, bedding plane, etc. The major fault plane intersecting running quarry batter may create potential failure block or zone during mine operation.

Different modes of failure in rock slope.

a) Plane failure- It occurs when a geological discontinuity such as major fault plane, bedding plane, minor faults strikes parallel to the slope face at flatter angle than high wall bench as shown in Fig.1. The weight of the sliding mass are calculated from the geometry of the slope and the failure plane. A tension crack running parallel to the crest of the slope can also be included in the calculation.

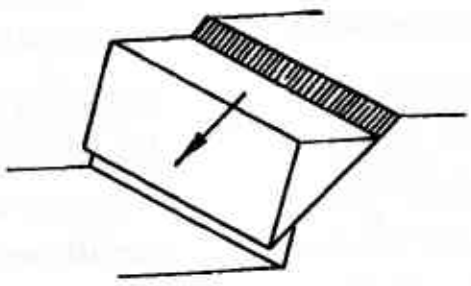
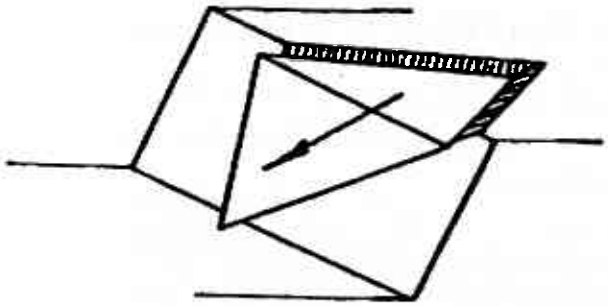


Fig. 1 Plane Failure

b) Wedge failure - When two discontinuities strike obliquely across the slope face and their line of intersection daylights in the slope face, the wedge of rock resting on these discontinuities will slide down the line of intersection . The calculation of the factor of safety is more complicated than that for plane failure since the base areas of both failure planes as well as the normal forces on these planes must be considered for stability calculation. Fig. 2.

Fig. 2 Wedge Failure



c) Circular failure - When the material is very weak, as in a soil slope, or when the rock mass is heavy jointed or broken, as in a waste rock dump, the failure will be defined by a single discontinuity surface but will tend to follow a circular failure path. Such type of failure is very common in case of soil strata in the high-wall or the waste rock dump backfilled or dumped outside the quarry (Fig 3).

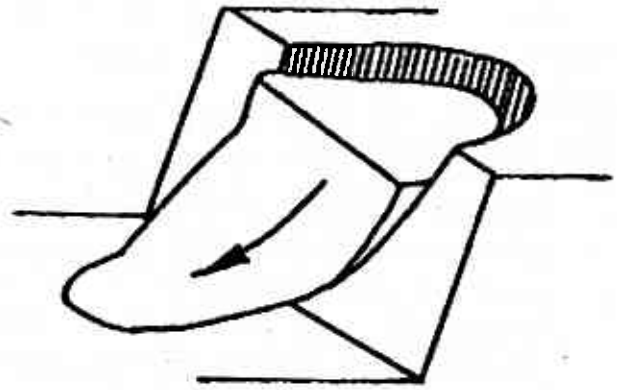


Fig 3 Circular Failure

3.4 Some of the Recent Slope failures in Indian Coal Mines and their Characteristics

Date	Mine & Company	Brief description	Major contributing factors of OB Dump failure
17th Dec, 2008	Jayant OCP, NCL	Dragline dump failed and a large volume of overburden (OB) slid down from the failed dump (1,46,000 cum) pushing 8 cum shovel towards high-wall across the access road. 5 persons were buried under the OB mass.	Insufficient corridor width at coal rib roof level and at the dragline sitting level and also steep slope below dragline sitting level contributes to steep slope of dragline dump. Steep slope is one of the prime contributing factor for dragline dump failure. Wrong system of creation of dumb-bell, which resulted into saturation of dump base due to blocked water along the interface. Presence of water at dump base which resulted into reduction of the strength of the dump base material. Not puncturing the coal rib intermittently resulted in built up of hydro-static pressure behind the coal rib in the newer dragline dump. Lack of infra-structure for monitoring of slope stability.
4th Jun, 2009	Sasti OC, WCL	Dragline OB dump near 16th cut slid at NE flank section resulting into sliding of about 2 lac cum. of OB materials measuring 125m (length)x 24m (height) x 60m (width) from the OB dump of 14th and 15th cuts. As a result one P.C. operator and one Sr. Overman were buried under the OB.	Insufficient corridor width at coal rib roof leve and at the dragline sitting level and also stee slope below dragline sitting level contributes t steep slope of dragline dump. Steep slope is one of the prime contributi factor for dragline dump failure. Presence of black-cotton soil of 15m heig overlying Argillaceous (clay) rock of 25 m hei above sandstone strata (50m) along w seepage of water from Wardha river is other contributing factor for dump failure. Due to presence of black-cotton soil fragmented clay rock with predominance Montmorillonite group of clay minerals, du material swells in presence of seepage w

			from Wardha river. This phenomenon reduces drastically shear strength of dragline dump material coupled with seepage from Wardha river which led to slope failure. Dragline OB materials from 16th cut were dumped at the sump portion of de-coaled area at 15th cut. As a result there was accumulation of sludge at the dump base facilitated in sliding of OB dump at dip direction from 15th cut. Lack of infra-structure for monitoring of slope stability.
28th Sept, 2010	Umrer OCP, WCL	The Amb river embankment breached and the high-wall side OB benches failed. The slid OB material pushed one Dragline and its operator burying them in the debris OB.	As per geological report, only one fault plane in strike direction with 5m throw was shown near the failure site. But, actually the above mentioned fault plane (in strike direction) is having throw of 40m. There was existence of other two fault planes in dip-rise direction which was not mentioned in the geological report. These three fault planes (one is in strike direction and another two in dip-rise direction) encompassing a wedge block which slid on the dragline and its operator.
10th Aug, 2013	Kulda, MCL	An incidence of OB dump slide occurred causing fatalities to 13 persons from nearby villages who had trespassed in to O.B dump area of Kulda OCP.	The most likely cause could be seepage of water through cracks for many days during heavy rain affecting the stability and leading to eventual failure external OB dump.

3.5 Highwall Slope Stability Study of Lalmatia Hill Patch of Rajmahal OCP

CIMFR was entrusted with the job, in the year 2011, to study the stability of final high wall slopes of Lalmatia hill patch. After doing necessary geo-technical mapping, the data was used in GALENA software for analyzing the slope stability. Key recommendations of the study, with precondition of pre-splitting, drained ground water condition & slope monitoring, were given as below.

Recommendations of the study (salient points only):

i) Profile parameters of the final high-wall slopes was recommended in which minimum effective exposed bench width on the seam floor was 5m and on the seam roof was 10m & 15m at two different locations. The bench angle of the high-wall was recommended as 60 deg.

ii) Pre-split blasting should be done to prevent hanging loose boulder in the wall & back crack

iii) Blast design should be such as to prevent back breaks. The designed effective bench width should be maintained, which do not include back breaks.

iv) Proper benching should be done from top to bottom, in such a manner that individual bench slopes shall not be steeper, apart from the lower overall angle of slope.

v) Ripper dozer may be used in place of blasting. Mining activity should be stopped during rainy season in the patch.

vi) Mine and monitor philosophy shall be adopted. Slope monitoring should be done to detect onset of failure, so that effective stabilization measures can be taken at the earliest. If the instability is unavoidable, it can be brought down in a predictable manner.

vii) Report shall be implemented in total and under the supervision of competent scientific agency.

The details of the report is given in ***Annexure 3***

3.6 Statutory and ISO Inspections of the mine workings

To supervise day to day mining operations at Rajmahal Opencast project, the colliery manager is assisted by 11 First Class Certificate Assistant Managers and 11 Second Class Certificate Assistant Managers. Further to assist them, 60 supervisory officials (Mining Sirdars and Overmen) are on the roll of this project. Similarly it has sufficient numbers

of Workmen Inspectors and a VTC. It can be concluded that the project has sufficient manpower to supervise safe mining operations.

ECL HQ is also manned by a full-fledged Internal Safety Department headed by GM (Safety). It regularly conducts safety inspections of all the mines of the company and investigates all the incidences and accidents. All safety related issues are also dealt by the ISO.

But during enquiry, the High Power Committee did not find any document where any member of ISO has highlighted the impending dangers from 140 meters high OB dump, immediately below which coal extraction work was going on.

3.7 Safety Audit of the mine

Safety Audit of Rajmahal Project was carried out during April, 2015 and March, 2[illegible] the team from Sonepur Bazari Area, ECL. However, in both audits, the team did not mention any impending dangers due to excessive height and danger of failure of OB slopes. Copy of report is enclosed at ***Annexure- 4***

3.8 Salient provisions of clauses of DGMS permissions related to d[illegible]d slope stability of opencast working and safety features thereof:

Permission for removal of overburden and extraction of coal in Rajmahal Open Cast Project was obtained vide Permission letter no. S4/0326/006/II-B(87)/ 08.04.1987. Another permission with certain modifications was obtained vide letter no. S3/010357/II-B/98(1), (3) &100(1)/1637 dated 05.07.2012.

Key stipulations in the permission letter of ROCP, regarding maintaining safe operations, with respect to working near geological disturbances and slope stability are as under:

(I) **Permission no. S4/03/26/006/II-B(87)/1182 dated 08.04.1987 under Regulation 98(1), 98(3) and 100(1) of CMR 1957.** (Clause reference mentioned along with the clause)

II. Opencast Working

2.0 Height & Width of Benches

2.1 The height of the benches in overburden and coal shall not be more than the digging height of the machine used for digging, excavation of removal.

2.2 The width of any bench shall not be less then –

2.2.1 The width of the widest machine plying on the bench plus two meters, or

2.2.2 If dumpers ply on the bench, three times the width of the dumper, or

2.2.3 The height of the bench, whichever is more.

3.0 GENERAL

3.1 Quarrying operations shall be conducted from top to downwards.

3.2 The provisions of Sub-Regulations (4) and (5) of the Regulations 98 shall be complied with.

3.3 When persons are employee within 5 m of the working face, adequate precautions shall be taken to ensure their safety by dressing the sides of the benches.

3.4 Special care shall be taken when any slip or other planes of weakness or other geological disturbances exist, so as to prevent danger to the work persons.

3.5 No persons shall be engaged or work allowed to travel close to high sides/benches, from which he will be likely to fall more than 1.8m vertically down, unless he is provided with the uses a safety belt or rope.

3.6 The sides in overburden coal shall be kept sloped to prevent danger from fall of slides.

(II) Permission no. S3/010367/II-B/98 (1), (3) & 100 (1)/1637 Sitarampur dtd. 5th July, 2012.

2.0 OPENCAST WORKINGS

2.3 The height of benches in overburden and coal shall not exceed 10m or the digging height of the machine whichever is less at any time.

2.4 Unless and otherwise permitted by this Directorate by an order in writing. The width of the bench shall not be less than three times the width of the largest machine working on the bench or the bench height, whichever is more provided that where there is one-way traffic over the bench, width of bench may be reduced to not less than twice the width of largest machine working on the bench.

2.5 No blasting operation shall be done within 300 m of any structure in village/Bustees, buildings/surface Structures and 42m of public road in proposed seam II Top of Lalmatia Hill patch of Rajmahal Opencast Projects, M/S E.C Ltd. Without obtaining separate permission under Regulation 170(a) (b) & (c) and 170(1B)(a).

2.6 The provision of sub-regulation (4) & (5) of Regulation 98 shall be complied with strictly.

2.7 OCP Working in proposed patch shown "A,B,C,D,E and F" on, the accompanying plan and no working shall be extended within 15 m of the water tanks. The Nallah flowing in west part of the proposed patch from north to south shall be diverted beyond 60 m of the proposed quarry and embankment of height not less than 3 mts. Above HFL and width not less than 10 m at top shall be made to guard the inrush of water towards the proposed patch.

2.8 OCP working in proposed patch shown "A,B,C,D,E and F" on, the accompanying plan shall not be extended within 60 m of the underground waterlogged workings of seam II top. The working shall be started from Rise side of the property. An arrangement for pumping from surface by putting boreholes at a distance not more than 30 m by making a vertical Boreholes and installation of submersible pumps shall be done to keep water body at least 60 m away from the working of the quarry. A rigorous pumping shall be done to ensure the dewatering and keeping water logged area beyond 60 m from the workings made by opencast method.

2.9 Special care shall be taken when any slip plane or other weakness or other geological disturbance exist, so as to prevent danger to the work person.

2.10 No person shall be engaged on work or allowed to travel close to high sides/benches, from which he is likely to fall more than 1.8 m vertically down unless he is provided with and uses a safety belt or a rope or life-line.

2.11 No person other than those required for operating the machinery shall be allowed to remain near the foot of the benches exceeding 3.0 m in height. When persons are employed within 5.0m of the bench sides adequate precautions shall be taken to ensure their safety by dressing or/ and supporting the sides of the benches.

2.12 As a final operation, in each cycle of operation, width of the benches may be reduced but in any case not less than 3.0m. During or after this operation no work shall be done at the bottom of the quarry or below such benches, until such time proper benches as required at Para 2.3 &2.4 are formed by working from top downwards.

2.13 After the extraction of the coal, the area shall be back filled by the overburden soil up to the adjacent ground level.

2.14 No person shall be employed on coal benches within a radius of 50.0 m of the OB benches being worked with heavy earth moving machineries at any time.

4.0 SPOIL BANKS AND STOCK YARD/PILES

4.1 The slope of spoil bank's face shall be determined by natural angle of repose of the material being deposited, but in no case exceed 370 from horizontal and the

spoil bank face shall not be retained by artificial means at an angle in excess of its natural angle of repose or 37°.

4.2 Any spoil bank exceeding 30m in height shall be benched so that no bench exceeds 30m in height and the general slope does not exceed 1 vertical to 1.5 horizontal.

4.3 The toe of a spoil bank face shall not be permitted to approach a railway or other public works, public road or building or other permanent structure not belonging to the owner of the mine, closer than a distance equal to the vertical height of its face

4.4 No person shall remain or be permitted to approach the toe of an active spoil bank or stock yard/pile where he may be endangered from the material rolling down the face

4.7 Extraction of mineral by reclamation from dump or stock pile/yard shall be treated as working of opencast benches with loose overburden and all the precautions in respect of working of opencast benches with loose overburden shall be taken.

4.8 A suitable Code of Practice approved by tripartite committee for prevention of injuries to persons engaged in tipping on stock piles, dumping of overburden at dump yards, at loading points etc. shall be framed and enforced.

8.0 SUPERVISION

8.2 The In charge/supervisor shall in particular

a) Make frequent inspections for evidence of slides or of material that may slide or roll from the high walls (including the face and sides) or spoil bank.

b) Not allow any person to work under overhanging ledges or where there is evidence of slides, until such danger has been removed.

19.0 To minimize accident to those engaged on surface operations' it shall be ensured that:

a) All persons engaged through the contractors at any work within the mine premises have received relevant training and other job-related briefings. The drivers of vehicle belonging to contractors entering the mine premises shall additionally be explained the salient provision of "code of Traffic Rules". Appropriate training schedules for contractor's worker shall be drawn and implemented from time to time. ..

b) Each and every operation, including the operation carried out through contractor's workers or by outside agency, is placed under the charge or a competent supervisor, duly appointed and authorized by the Manager whose jurisdiction shall be clearly demarcated.

Copies of permission letters referred above are enclosed as ***Annexure – 5***

DGMS Circulars and other statutory references.

1. **Circular No. DGMS (Tech.) (S&T) Circular 2, dated 20/06/2001. Relevant extracts of the circular are;**

Quote:

"A systematic detailed work needs to be undertaken for solving or understanding the problems of slope failure in open pit mines. The objective of such type of work could be (1) increase the knowledge of the behavior of mine slopes , (2) improve the ability to estimate rock mass strength for such slopes, and (3) develop an improved design methodology for forward design of rock slopes in the open pits. The fourth objective could be formulation of a detailed slope monitoring protocol for such slopes.

A geo-mechanical model needs to be developed based on extensive field work and review of previous studies at the sites. The model may comprise of a detail description of geology, joint sets and structures, mechanical properties of intact rock and joints, geo-hydrological conditions, and virgin stress state. From this, a representative design cross-section and parameter values need to be established which could later be used as input to stability analysis of the pit slopes."

Unquote:

2. **DGMS Tech. Circular no. 02 of 2010: Relevant extracts of the circular are;**

Quote:

"It is essential to take following steps immediately:

(i) Design mine and the pit as well as dump slope scientifically taking into consideration of geotechnical parameters of rock and the dumps including hydro geologic and weather conditions to ensure stable Pit and Dump slope profile not only during mining but also thereafter; and

(ii) Deploy Slope Stability Radar (SSR) with integrated visual imaging system or any similar such technology giving a real time monitoring of displacements of strata or

dumps well in advance of any failure and providing mine management sufficient time to safely withdraw men and machinery from such prone areas. Such systems would not only increase safety but also the productivity and efficiency of opencast operations.

In view of the seriousness of the implications of ground movements in openpit excavations, all mining companies having openpit excavations are urged to immediately initiate a time bound concrete action plan on the above matters"

DGMS circular 8 of 2013 refers to the clarification of above circular in which the specific type of slope monitoring equipment was replaced by suitable slope monitoring system in mines.

3. **DGMS circular (S&T) no. 5 of 2016 : Integrated approach for development of Safety Management Plan for coal and metal mines : Previous references :**

   a) Circular 13 of 2002

   b) Circular 2 of 2011

   c) 9th, 10th and 11th National conference on safety in Mines.

The circular recommended for adoption of the process of safety management system and commitment for proper formulation & implementation of the same in totality. The circular mentions that successful implementation of safety management system in mines would warrant sorting out perception issues among all then stake holders and the success may depend on, among others adoption of an integrated approach. Accordingly, it has been advised in the circular, to develop a safety management plan at all the mines and submit the same to regional inspector of mines, for acceptance/ approval.

CHAPTER IV

ACCIDENT, RESCUE AND RECOVERY OPERATION

4.1 Brief description of the accident

Rajmahal OCP of Eastern Coalfields Ltd. is located near Lalmatia in Godda district of Jharkhand. It is targeted to produce 17 million tonne per year. Entire coal is dispatched to NTPC Kahalgaon, Farakka, Barh.

The mine is partially outsourced. At present there are two outsourcing agencies (a) RCML (period of contract: 22.10.2012 to 21.10.2025) and (b) M/s MIPL-NKAS (period of contract:-07.04.2015 to 06.04.2017). A part of the OB is removed departmentally by HEMM. One part of OCP is Deep Mining Area where coal is found on the lower level mainly due to presence of a 60 meters down throw fault. Same agency i.e. M/s MIPL-NKAS was awarded the work for removing loose OB (Re-handling) from the Kaveri Dump.

The accident took place on 29.12.2016, during 2nd shift (2-10 pm), at Dahar Nangi Patch, where about 30 tippers, 5 excavators and one Dozer were deployed for removing loose OB material from the top of the dump.

The followings have been gathered from the statements collected from the mine personnel/officials/officers and contractual employees, during the different stages of enquiry.

4.1.1 Status prior to the Accident:

- Before the OB dump failure about 30 tippers, 5 excavators and one dozer were deployed for removing loose OB material in the topmost OB bench.
- In the second shift work was also being done in the coal bench of the deep mining patch along with the removal of OB parting, while the re-handling in the Dahernangi patch for benching was going on the northern side of the working patch.
- Work in coal bench and the parting, and the OB dump was stopped at about 4:30 PM, due to indications of disturbance. However, the working in the OB dump for re-handling in the northern side resumed shortly thereafter.

4.1.2 At the time of Accident:

While operation of removal of loose OB was going on, at about 7:30 PM a large area (measuring 600m X 110 m) slid down due to failing of the floor batter as a result of which 12 out of 30 tippers and 05 excavators along with their operators got buried by fallen material. It was also gathered from the statements that a "bang" sound was heard just before the slide, which indicated the failure of in-situ strata. Simultaneously the mine lights went off, due to dislodging of electrical poles.

4.1.3 After the Accident:

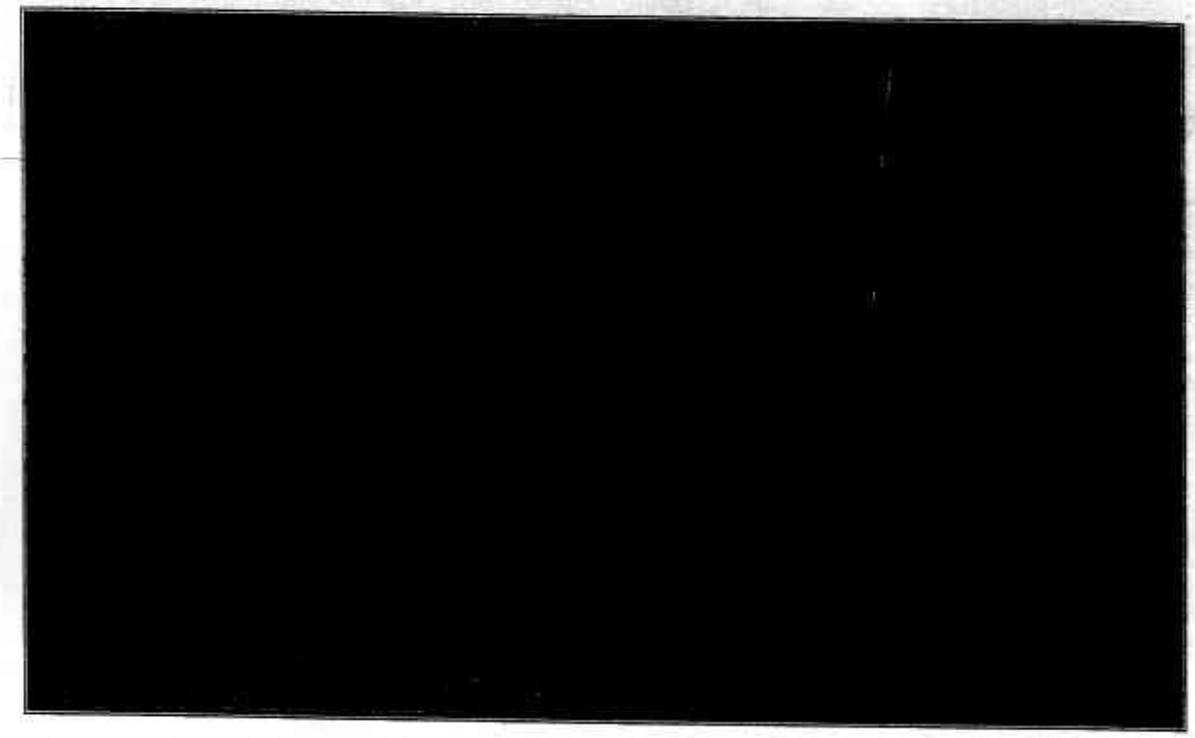
All the concerned officials, including DGMS, were informed immediately and rescue & recovery work was started by ECL Management. Information was given to ECL HQ and State/District Administration. On receiving the information, two rescue teams along with one Superintendent (Rescue), ECL rushed to Rajmahal from Mines Rescue Station, Sitarampur. Director (OP) and Director (P&P), ECL also rushed to the site and were present at the site on the same night from 1:30 onwards. ED (Safety), CIL HQ also reached the site on 31.12.2016.

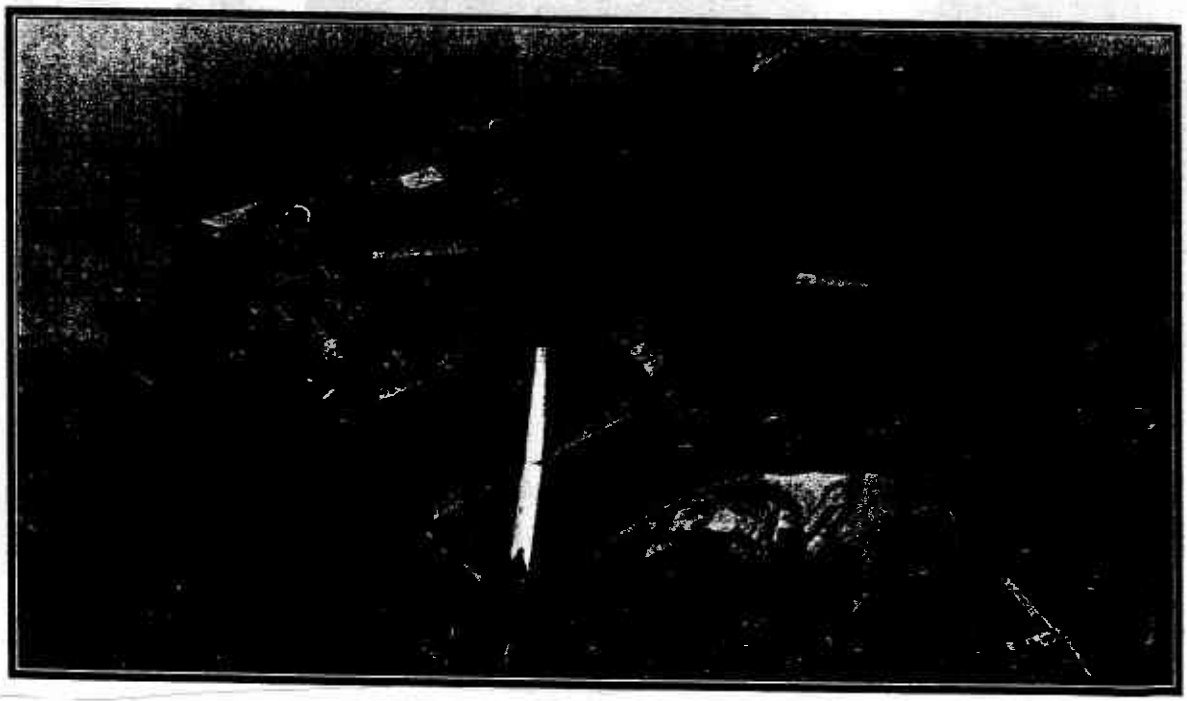
By the morning of 30.12.2016 it was confirmed that only one ECL employee i.e. a mining Sirdar was injured whereas quite a number of contractor's employees were missing and feared to have been buried. Later on 18 bodies of the contractor's employees were recovered and five are still apprehended to be buried within the failed dump.

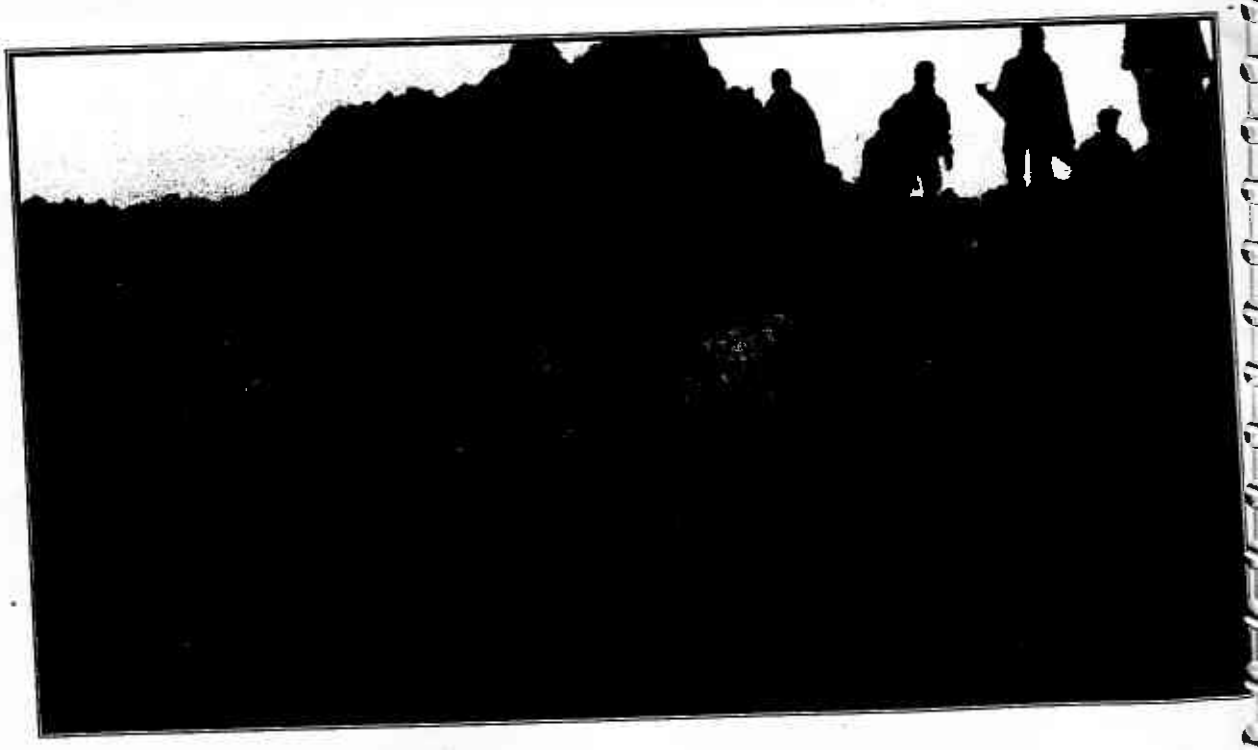
Corporate Safety Board members of ECL and other senior union representatives also visited Rajmahal where they were apprised with the development regarding rescue operations, disbursement of benefits etc.

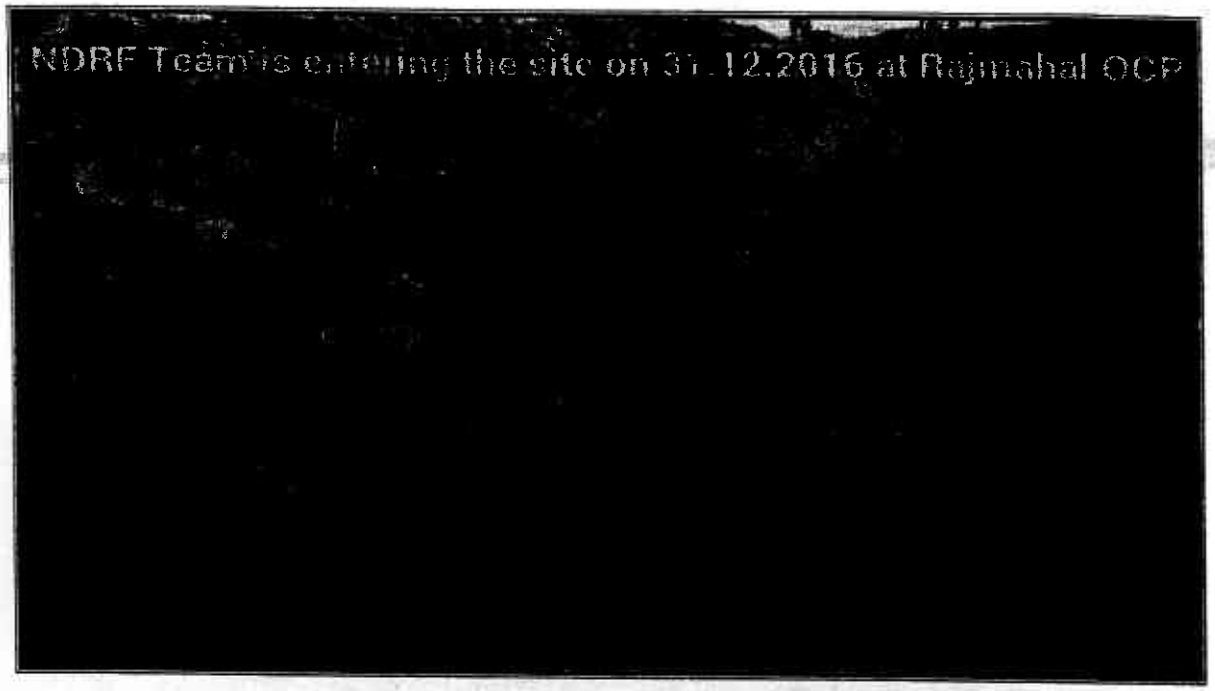
Emergency Control Room at Area and Project were immediately established. Similarly control rooms at ECL HQ, CIL HQ and at Ministry of Coal were established and officers were posted in each shift at all these places. Also the police and State administration were informed for necessary assistance. Lighting arrangements were made at the site to make approach roadways for rescue & recovery work. Ambulances and Doctors were also ready at project site. DC and SP, Godda also camped at Rajmahal from 30th December '16 onwards to handle any unpleasant law and order problem.

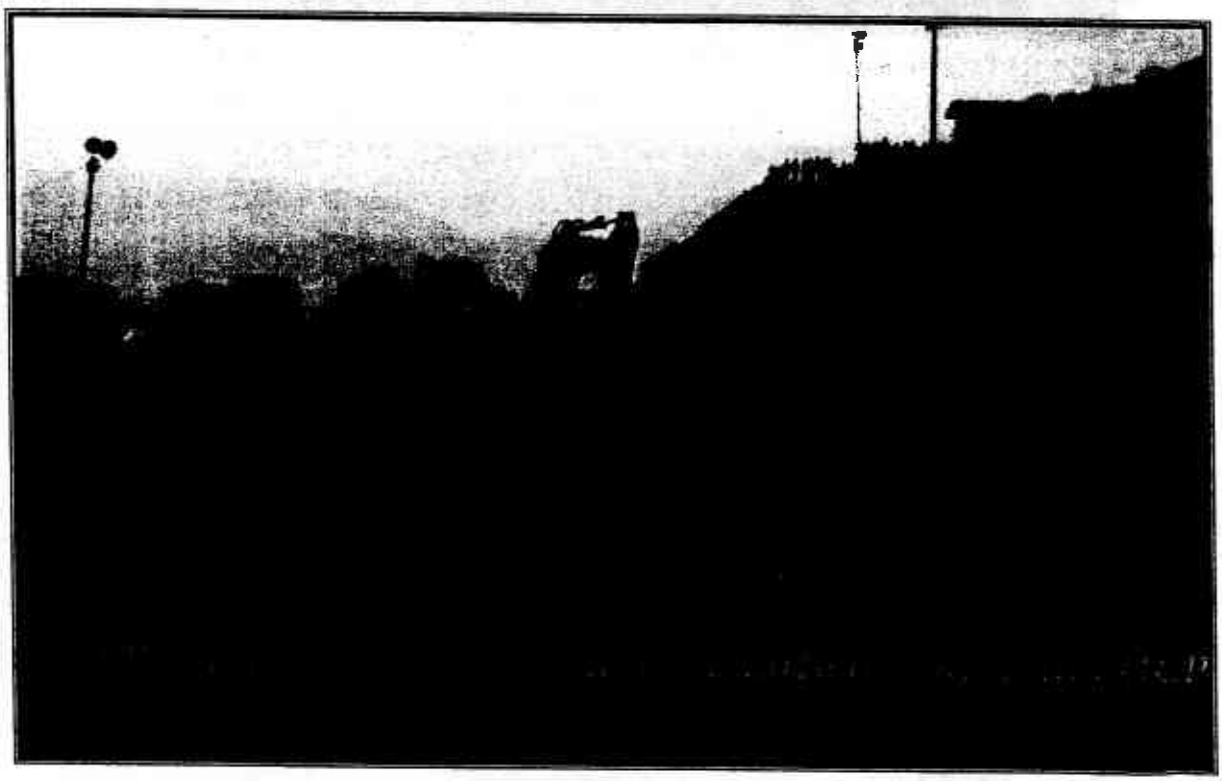
4.2 Photographs taken from the accident site:

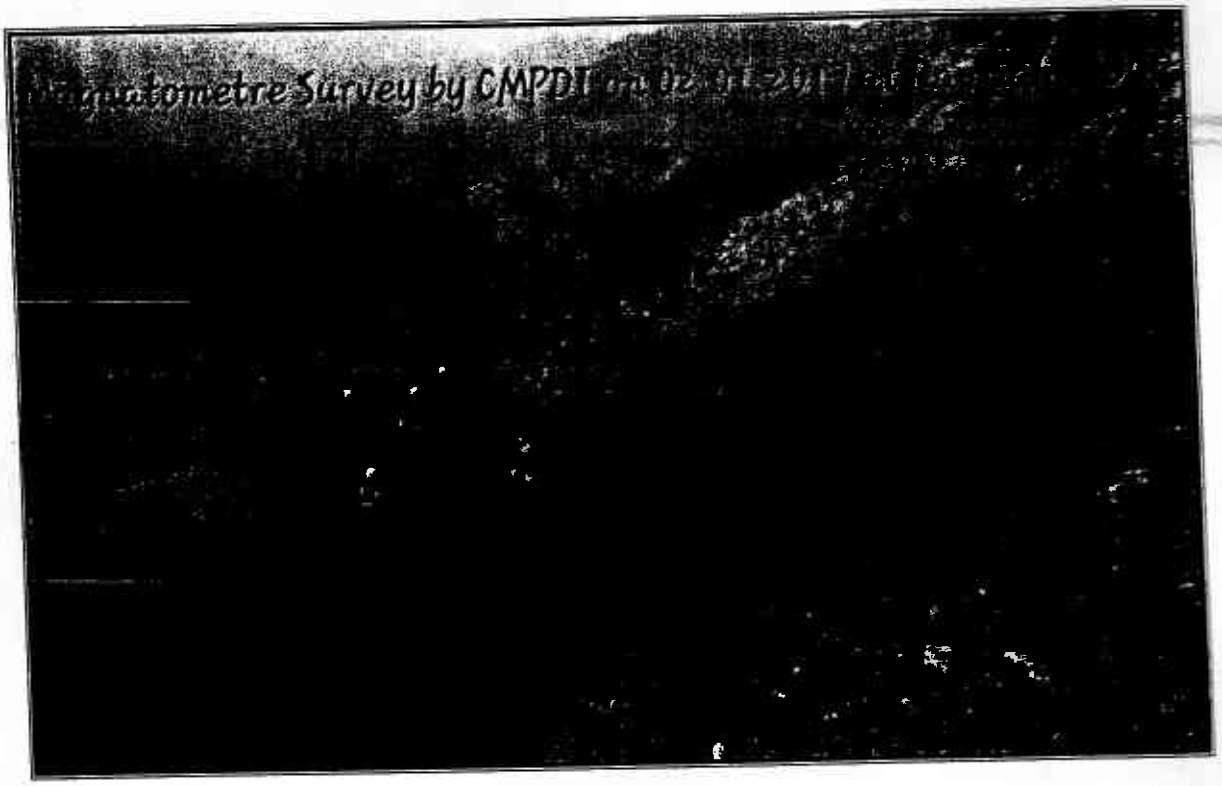


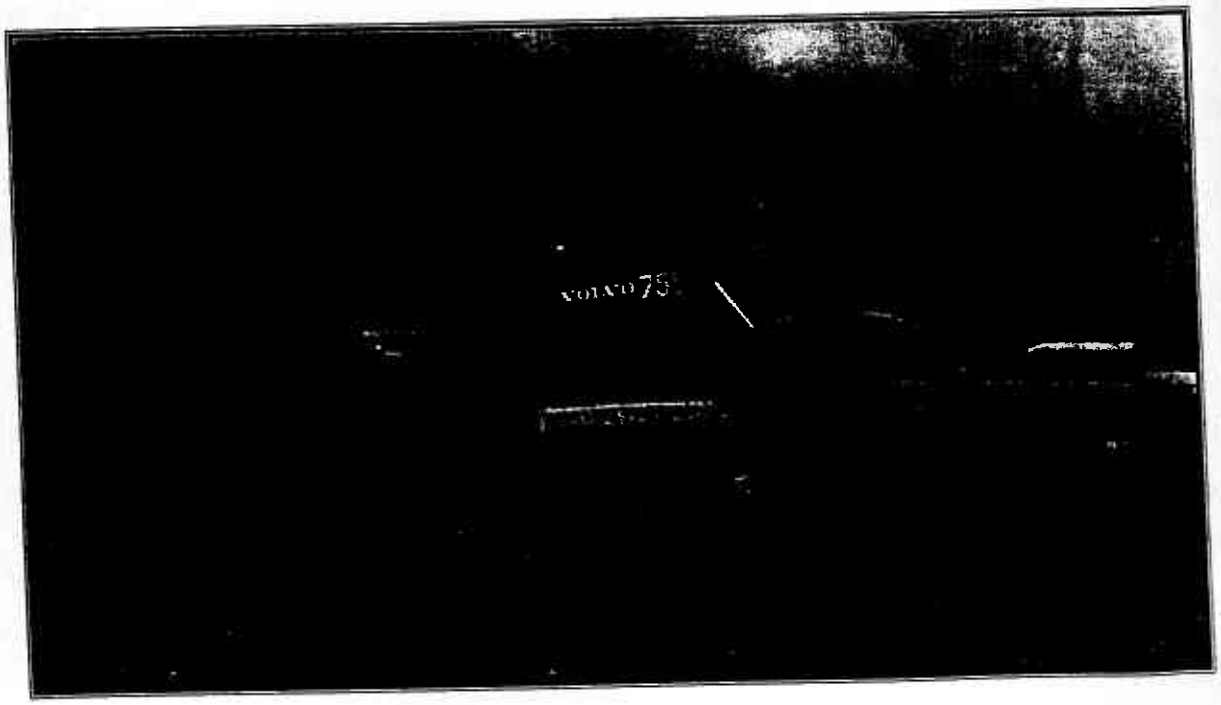





NDRF Teams is entering the site on 31.12.2016 at Rajmahal OCP




Magnetometre Survey by CMPDI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4.3 Rescue & Recovery Operation and Compensation:

4.3.1 Rescue & Recovery Operation:

NDRF Teams and Rescue teams with cutting tools, lighting tower, spader, hydraulic Jack, and medical team and Sniffer dogs were continuously involved in the rescue operation.

The outsourcing agency (MIPL-NKAS) later submitted Area management a list of equipment (12 tippers, 6 excavators and 1 dozer) and names of 23 persons, who were most likely entrapped in the debris as they were not found. 08 tippers, 05 excavators and 01 Dozer have been traced out and 18 bodies have been recovered till 2:00 pm of 05.01.2017. No further bodies could be traced out after 05.01.17.

As soon as the recovery work started the Area authorities have requisitioned the services of the geophysical team for conducting the magnetic survey to locate the magnetic bodies like dumpers, excavators and dozer etc. from RI-1, CMPDI, Asansol. The survey was done by that team and they successfully located a number of magnetic bodies, the details of which has been given as under.

4.3.2 Geophysical Survey Conducted by CMPDI Team at Accident site of Rajmahal OCP:

The Geophysical team of CMPDI was instructed in the morning of 30/12/2016 to proceed immediately to the accident site at Rajmahal OCP area following massive OB dump slide that took place on 29/12/2016 under the ECL command area. The team reported at the area office, Rajmahal by the evening of 30/12/2016. No work could be taken up on that day since it was already dark. The first-hand information about the ground conditions and visit to the site could be possible by the evening of 31/12/2016 due to security considerations. The Magnetic survey field work was taken up early in the morning of 01/01/2017 and five locations were identified and pointed to the excavation team to recover the buried HEMM objects.

The excavation team immediately undertook the clearing work at 3 of the reported locations and successfully recovered the machines and few bodies from the indicated sites.

i) The team on second day of survey work i.e. on 02/01/2017 could locate 3 additional locations with major anomalies (anomalies arising out of buried heavy HEMM) and 5 locations with minor localized anomalies (anomalies arising due to scattered metallic parts of HEMM or other debris).

ii) All the locations were shown to the Area Surveyor, Shift In-charge, the operators etc. and the places were even marked on the ground with Chuna (Lime powder) and the coordinates in WGS-84 format were given to the survey team for precise location and earliest excavation operations to recover the Men and Machine without any delay.

iii) The depths of the buried objects were estimated with the help of Euler's deconvolution method and along with the actual anomalies observed. For the sake of completeness and presentation, all the obtained results have been transferred on to the Google-Earth.

iv) The accident area was covered thoroughly and the readings were cross checked by two independent instruments. The data gap areas were inaccessible were ruled out of any anomaly by employing the Flux-Gate light weight instrument to the extent possible.

v) The WGS-84 coordinates of the HOT SPOTS, i.e. the highest priority points over which the debris clearance activity is recommended are given in Table-I below:

TABLE-I:

MAJOR ANOMALY POINTS		
Point No.	**Coordinates in WGS-84 as recorded on GPS**	**Depth (m)**
1	87.3705, 25.0278	< 4
2	87.3703, 25.0278	8 to 12
3	87.3702, 25.0279	< 4
4	87.37015, 25.02783	< 4
5	87.3701, 25.0278	< 4
6	87.3694, 25.0284	< 4
7	87.36922, 25.02854	< 4
8	87.36921, 25.0285	> 16
9	87.3691, 25.0292	> 16
10	87.36901, 25.02922	> 16
11	87.369, 25.0292	> 16
12	87.369, 25.0293	> 16
MINOR LOCALIZED ANOMALY POINTS		
13	87.3706, 25.0279	12 to 16
14	87.3705, 25.0285	< 4
15	87.3701, 25.0287	< 4
16	87.3696, 25.0295	4 to 8
17	87.3695, 25.0294	8 to 12

vi) All the estimated depths and the anomalies taken as a snapshot, as was observed on 02/01/2017 at 14:00 hours were likely to change after fresh bouts of OB slides or removal of debris that could have been performed after the study.

vii) The geo physical study concluded that all the anomalies have been identified and there are no further anomalies present within the area surveyed.

viii) The Results, discussion along with the recommendations, for focused, pin pointed and earliest possible recovery of Men and Materials are presented in the note enclosed at ***Annexure-6***

4.3.3 Monitoring by state administration and statutory bodies.

Officials from State administration, Senior Officials of DGMS (Dhanbad and Sitarampur), CIL, ECL, CMPDIL, SECL and NCL continuously monitored and supervised the rescue operations. Up to 5th January'2017, total 18 bodies were recovered and sent for postmortem.

One mining sirdar was also injured who was admitted to Mission Hospital Durgapur who was subsequently released after treatment.

The bodies of the deceased were later sent to their respective home towns (Jharkhand, Bihar, Madhya Pradesh and Uttar Pradesh) which were escorted by the project officials of ECL, Unions & Contractors. The officials were sent to the hometowns to meet the family members of the deceased to express the condolence on behalf of the ECL management and to collect the details of legal heirs/nominee, their bank account etc. so that the terminal benefits can be remitted to them.

On 3rd January, a meeting with SDM, Godda and SDO, Mahagama in which DT (OP), DT(P&P) and D(P) of ECL participated in above said meeting. The following points were discussed:-

1. Law and order situation in the area.
2. Maintaining safety in rescue and recovery operation.
3. Regarding dispatch of coal to STPP of NTPC Kahalgaon and Farakka.

On 4th January, another meeting was held with SDO, Mahagama on the above points including how compensation can be paid those 05 persons missing bodies have not been located.

The members of the High Power Committee appointed by Coal India Limited also inspected Rajmahal accident site during this period and interacted with all those who could provide information related to the accident. Chairman of the High power committee also visited the site on 05.01.2017

4.3.4 Stoppage of recovery operation on 05.01.2017:

The recovery operation was stopped from 05.01.2017, when major strata movement was noticed at the site. Recovery operation therefore had to be suspended to ensure safety of the rescue personnel. Subsequently a meeting of DGMS officials and Expert Committee members with Area officials was held to decide about further course of action. To ensure safety of all those involved in recovery operation it was decided first to prepare an action plan for removal of debris from the affected OB dump, which was to be vetted by ISO and Expert Committee members and then was to be submitted to DGMS officials for approval. Recovery operation were to start only after the permission was accorded by the DGMS.

Later a team of research scholars from NIT, Rourkela, Department of Mining Engineering was also engaged to monitor the strata movement using remote readable vibrating wire type sensors. Accordingly they started their work from 13.01.2017. Their observations are recorded at ***Annexure - 7***

Further a meeting, in the chairmanship of Dy. DGMS, Sitarampur (EZ) was organized to decide the further course of action for recovery of remaining bodies trapped in the fallen material on 08.02.17 at ECL HQ. It was decided that further recovery action will be carried out as suggested and recommended by ISO of ECL and Experts of High power committee (copy of minutes of meeting is enclosed at ***Annexure-8***)

4.3.5 Compensation:

Following compensation amount have been paid to the deceased families after the accident:

i) As declared by Hon'ble MoS (Coal), Ex-Gratia of Rs. 5 lakhs each was paid by the ECL to the family of deceased.

ii) Employee compensation was paid as per the provisions of Employees Compensation Act. The amount (as mentioned in table-2 below), was calculated, as prescribed in the Act, which was deposited with the Commissioner cum presiding officer, Labour court, Deoghar, by ECL. The amount would later be recovered from the contractor's bills.

iii) Ex-gratia of Rs. 5.0 lakhs per family was paid by MIPL to the families of deceased.

iv) Rs. 16,000/- for cremation-already paid during handling over of the dead bodies after post-mortem as last rights of the deceased.

v) Vehicles for transportation the bodies for cremation were provided.

vi) Honorable Chief Minister of Jharkhand declared Rs 2.0 Lakhs to family member of each deceased.

The compensation paid to victims & date of bodies recovered are given in Table-2 below:

Table-2

SN	Name of deceased & Designation	Date of Body Recovered	Compensation as per ECA-2010 (Rs.)	Ex-gratia (Rs 5 lacs as per MIPL)	Ex-gratia (Rs 5 lacs as per MoC)
1	Hari Kishore Yadav, Cont. Operator	30.12.2016	861120.00	500000.00	500000.00
2	Javed Akhtar, Cont. Operator	30.12.2016	896000.00	500000.00	500000.00
3	Rajendra Yadav, Cont. Operator	30.12.2016	847160.00	500000.00	500000.00
4	Brijesh Yadav, Cont.Operator	30.12.2016	879800.00	500000.00	500000.00
5	Sanjay Kr. Sahi, Cont. Driver	30.12.2016	778560.00	500000.00	500000.00
6	Md. Nurul, Cont.	30.12.2016	861120.00	500000.00	500000.00
7	Jai Prakash Rai, Cont. Driver	'30.12.2016	758240.00	500000.00	500000.00
8	Nageshwar Paswan, Cont. Driver	30.12.2016	839680.00	500000.00	500000.00
9	Ajit Patel, Cont. Operator	30.12.2016	854280.00	500000.00	500000.00
10	Sakil Khan,	30.12.2016	861120.00	500000.00	500000.00
11	Vikash Patel, Cont. Driver	30.12.2016	839680.00	500000.00	500000.00
12	Sunil Vhengra, Cont. Driver	31.12.2016	839680.00	500000.00	500000.00
13	Ajay Kumar Kushwaha, Cont.	31.12.2016	896000.00	500000.00	500000.00
14	Md. Julfkar, Cont. Driver	31.12.2016	867640.00	500000.00	500000.00
15	Md. Jamir, Cont. Driver	31.12.2016	847160.00	500000.00	500000.00
16	Raj Kamal Goswami, Cont. Driver	31.12.2016	867640.00	500000.00	500000.00
17	Sanjit Viswakarma, Cont. Driver	01.01.2017	867640.00	500000.00	500000.00
18	Laddu Yadav,	01.01.2017	831920.00	500000.00	500000.00

CHAPTER V

INVESTIGATION

5.1 Meetings and visits of the committee

i) On 30th December 2016 i.e. next day of the accident Sri P.K. Sinha, D(T/P&P), SECL, a member of the committee, reached Rajmahal Project and joined officials of Rajmahal area, ISO and other senior officials from ECL HQ, DGMS, State Govt. etc. for supervising the rescue and recovery operation, being done there by ECL Rescue teams, NDRF teams, Contractor's and departmental employees. An inspection note was submitted by DDG(HQ), DGMS, Dhanbad (copy enclosed at ***Annexure-9***), in which advice of experts was sought for ensuring safety of persons who were to be engaged in rescue and recovery operations.

ii) On 3rd January 2017 Professor P. Sen, Dr. V. K. Singh and Mr. A. K. Nath visited the accident site. On 4th January 2017 Professor P. Sen, Dr. V. K. Singh, Dr. I. Roy and Mr. A K Nath with others visited the accident site. On 5th January 2017 Mr. Shekhar Saran, Dr. I Roy and Mr. A K Nath visited the accident site.

iii) The Expert Committee after their inspection on 4th January'17, submitted an advisory regarding the mode of rescue & recovery and future course of action at the site of accident. Copy of advisory is enclosed at ***Annexure- 10***

iv) Copy of Manager's diary, SOPs, Minutes of Safety Committee meetings, training records and proposal notes for OB outsourcing contracts, geo-technical study & procurement of slope stability radar were collected by the members of the Committee during their inspection, which is enclosed at ***Annexure- 11 to 17***

v) Recovery operation therefore had to be suspended to ensure safety of the rescue personnel on account of significant strata movement with effect from 05.01.2017. Subsequently a meeting of DGMS officials and Expert Committee members with Area officials was held on the same day i.e. 5th January, to decide about further course of action. To ensure safety of all those involved in recovery operation it was decided first to prepare an action plan for removal of debris from the affected OB dump, which was to be vetted by ISO and Expert Committee members and then was to be submitted to DGMS officials for approval of the same. Recovery operation were to start only after the permission was accorded by the DGMS.

vi) Accordingly action plan along with plan and section was prepared by Rajmahal Area which was then vetted by ISO, ECL and members of Expert committee. The action plan was subsequently approved by the DGMS on 09.02.2017 with certain conditions.

vii) The 1st meeting of the High Power Committee was held on 18th January 2017 at CIL, Kolkata, in which, Shri S. Saran; Sri P. K. Sinha; Dr. V. K. Singh, Prof. I. Roy and Sri A. K. Nath were present. Matters pertaining to the Rajmahal accident were discussed in detail. Lists of the persons, whose statements were to be recorded, and documents to be collected, were prepared.

viii) 2nd meeting of HPC was held on 01.02.2017 at CMPDI, HQ Ranchi. Details of plans and section along with related documents were studied. Statements of officials recorded for investigation into accidents by ISO officials of ECL HQ were also studied.

ix) 3rd meeting of HPC was held on 3.3.2017 and 4.3.2017 at CMPDI,RI-I Asansol. The statements of the executives, staff and contractor workers concerned were recorded and cross-examination took place.

Statements of staff, officials, executives, contractor workers and others are enclosed at ***Annexure - 18***

x) 4th Meeting of HPC was held at CIL HQ on 27.03.2017. Sri Pramod Kumar, Manager and Sri Dhibar, Area Survey Officer of Rajmahal OCP were cross examined. Sri Ghosh, Survey officer from RI-1, CMPDI was also asked to clarify the calculation of volume of OB and rock displaced during the dump failure.

xi) 5th Meeting of HPC was held at CMPDIL HQ on 02.04.2017. All members discussed on the various aspects, analysed the statements and evidences, and prepared the 1st draft report for further consideration and deliberations.

5.2 Creation OB Dump (over Kaveri sump) at Rajmahal OCP

i) Part of the OB which failed from the existing OB dump, was approximately 140 meters high from the floor of the quarry, where entire coal was extracted about 10 years back. Coal extraction was completed at this place and face did not move further due to presence of a 60 meters down throw fault towards the south side. This area was also being used as a sump, which was known as 'Kaveri Sump. The coal extraction from seam III and seam II at Deep Mining Zone was being done towards the south side of this dump by M/s MIPL – NKAS (JV). As stated earlier the said dump was created from 2007 onwards.

ii) As the final expected depth of the workings of Deep Mining Zone were to be about 60 m below the base of the OB dump, a batter of about 150 to 200 meters was initially left and the access roads were made for extraction of coal and overburden partings.

iii) The year-wise record of dumping quantity was not made available to the Committee by the Project authorities.

iv) Year wise height of the dump available from CMPDI records are given below:
(Spot levels considered are between 188500E and 189000E at 244500N)

Year	Spot Level	Water Level at Kaveri	Increase of Dump Height	Remark
2007	36.6	5.85	OB Dumped in and around Kaveri sump	Dumping done outside Kaveri sump
2008	28.6	5.85	(-) 8 M increase in one year	Dumping done over Kaveri sump
2010	28.6	5.85	No increase in Two year	Dumping done over Kaveri sump
2011	28.6	5.85	No increase in one year	Dumping done over Kaveri sump
2012	72.0	No water found	43.4 M in one year	Dumping done over Kaveri sump
2013	72.0	No water found	No increase in one year	Dumping not done at Kaveri sump
2014	88.0	No water found	16 M in one year	Dumping done over Kaveri sump
2015	88.4	No water found	0.4 M in one year	Not much dumping done over Kaveri
2016	146 M	No water found	57.6 M in one year	Dumping done over Kaveri sump

5.3 Details of award of Work and Modification /Deviation, thereafter, at Dahernangi Patch Deep Zone Mining with reasons and remark..

S.N.	Proposal	Justification of the Proposal and salient features	Remarks
1	ECL Board in 225th Meeting on 29.01.2009 approved the proposal of "Outsourcing of Deep Mining Zone OC Patch at Rajmahal OCP by hiring HEMM at Rajmahal" for 9 Yrs for extraction of 21.8 MT of Coal and 49.6 MCum of OB.	As per approved work schedule of the conceptual report prepared by CMPDI on Dec-2008	
2	Initially ECL Board in its 230th Meeting approved work with outsourcing for extraction of 11.8 MT Coal and 27.96 MCum of OB in 1st Phase for 5 Yrs on 04.09.2009. Work awarded to M/s Saumya Mining Pvt Ltd.	Standard escalation clause of only diesel component was taken care of but many other elements involved in contractual cost expected to undergo escalation during a period of 9 Yrs was not considered.	Proposal was not vetted by ISO. M/s Saumya Mining stopped working since 8.2.2014 on administrative ground.
3	New Proposal for outsourcing of Dahernangi Patch in Deep Mining Zone was floated on 23/04/2014 for 7 MT coal and 20 MCum of OB. Work awarded to MIPL vide Order no: ECL/HQ/CMC/WO/Dahernangi OC patch/ 502 dated 10.6.2015 with scheduled date of completion: 2 Yrs . The work started by MIPL from April 2015	HOE of Dahernangi patch was required because: (i) M/s Saumya Pvt Ltd discontinued working in Deep mining Zone on 08/02/2014, hence replacement was required. (ii) Coal in down throw side of F-8 fault at large depth, highly watery due to aquifer. (iii) To make shortfall of RCML patch (working since 1-7-2013)	i) Space for OB dump not specified depicting Grid, RL etc. (ii) The impact of silt present in Kaveri sump in the northern part was not assessed. (iii) Changes in floor configuration of existing old dump from stability point of view was not assessed.

		(iv) No Re-handling of OB required. (v) OB to be backfilled in de-coaled area (Lead 2-3km, 3-4 km for OB and 4-5 km for coal) (v) Departmental equipment continued till 31.03.2016 thereafter shifted to RCML patch phase wise.	(iii) Geo-technical study and dangers from dump failure were not assessed by the Area or ISO departments.
4	1st Modification of the above proposal: dated 18/02/2016 Approved by ECL Board in its 286th Meeting on 23.02.2016	(i)An incident of dump failure took place on 04.01.2016, when a large volume of OB slid down towards the south slope of Kaveri dump. A team of senior officials from ECL Headquarters visited the site on 06.01.2016 and recommended for removal of Loose OB (re-handling of dump) (ii). Strata movement and cracks were observed along F-8 fault plane endangering man and machinery deployed / passing through the haul road. Widening of Cracks were also observed. (ii) Tendency of flow of silt from Kaveri Sump (situated on the upthrow side) towards south side, was apprehended. (iii) A safe barrier between sump and fault line was felt necessary from safety point of view. (iv)A safe barrier for old dump yard located in de-coaled area for working in down throw side	(i)Specific recommendation by ISO, HQ or Area Safety Dept regarding close monitoring of Strata movement was not made during vetting. (ii) The assessment of safe width of barrier (batter) against old dump created over Kaveri Sump was necessary, but neither strength assessment was done nor proposal for getting the study done by any expert agency initiated.

		was also felt necessary. (v)Modification of pit limit due to geo-mining condition with no change in quantity of OB and coal for the patch was required. (vi) 2.5 Ha area to be left and 9.4 Ha area to be added; 2.68 lakh cum to be removed departmentally for keeping the quantity within awarded limit as per the proposal note.	
	2nd Modification and 2nd Deviation of Pit limit: Proposal dated 16/06/2016 OB :16.5 Mcum ,Coal: 8 MT Approved by ECL Board in its 291th Meeting on 29th and 30th July 2017	(i) Quantity of OB to be removed was reduced and the quantity of coal to be mined was increased as the coal seams were found in upper horizon, due to two nos. of up throw faults with throw of 29m and 12 m respectively, which were not marked in Geological plan (ii)Approach road to this workings was to be diverted after removal of OB in departmental patch and modifying the pit limit. (iii) Approach road and exposed coal in lower benches got submerged due to recent rains and area left for working is only 35m×250m at +50m RL iv) Departmental HEMM were to be deployed in the above working area, but these are deployed in RCML patch. As deployment of HEMM in this area was thought to be unsafe, as it would have required plying	(i)The depth of coal seams in 20 M CuM patch were quite deep for 750m wide patch. (ii)Due to high depth of workings, the road for reaching bottom most seam might have come under water, even during normal rain fall situation. (iii)Instead of increasing length of patch for mining the dip most seam, the proposal aimed at extracting coal from up throw part and thus reducing the barrier part (batter) of old OB dump. (iv)The assessment of safe width of barrier (batter) against old dump created over Kaveri Sump was necessary, but neither strength assessment was

		of 170/100T dumpers and contractor's tippers simultaneously. (v) Modification sought in Departmental area with 1.153 MCum OB and 1.021 MT coal. As per the proposal note, It would help in early exposure of coal (at 25-30 m depth) available for extraction in monsoon, additional 1 million te of coal and safe approach for working in MPIL-NKAS (JV) patch. Progress of contractual work would not depend on departmental progress by this deviation. (vi) Lead for OB and coal to remain unchanged.	done internally nor proposed for getting the study done by any expert agency.
6	Re-handling of OB 1.344m cum by MIPL, through separate tender to MIPL Work order issued on 05.08.2016	(i)Work completed by reducing height from 146 m to 30 m. As per records, work completed on 09.08.2016.	(i)1.344 MCuM OB re-handling was insufficient to reduce the height of the dump from 146m RL to 30m RL. (ii)The stability of benches on OB dump could have been worsened by plying of a number of equipment at such height.
7	3rd Deviation and 3rd Modification for Re-handling of 1.73 million cum (loose OB), along F-8 fault on North side of Dahernangi patch proposed on 31/10/2016	(i) On 9/8/2016, dump failure occurred between 188925E and 189025E after formation of benches. (ii) Deep cracks were observed in OB dump top surface. (iii) ECL HQ team visited site on	(i)Again, Re- handlin quantity was not arrive at by true assessment in the stressed area by scientific method. (ii)Area of Re-handli was not exclusiv

	Approved in 294th ECL board meeting held on 27.12.16	24/08/2016. The committee report is enclosed at ***Annexure 19*** (iv) It was decided to form benches in OB dump as per DGMS permission regarding dump design by Re-handling 1.73 million cum of OB. (v) In line with permission, benches of size 15m×10m from 30m RL to 50m RL were to be formed. OB Re-handling was further justified on following grounds: (i)Dump contains clay and have water retention capacity. (ii) slide has already occurred earlier, and one shovel was trapped (iii)If re-handling is not done, 2.20 MTe of coal (650m ×50m ×1.7m) will be blocked and profit shall be reduced by Rs. 300/Te approx. iii) Dept HEMM cannot be deployed in re-handling as contractual and departmental dumpers shall not ply on the same haul road. iv) Slope of dump is required to be maintained at 36 degrees.	identified from safety perspective. (iii)Once again, the assessment of safe width of barrier (batter) against old dump created over Kaveri sump was necessary, but neither strength assessment was done internally nor proposed for getting the study done by any expert agency.

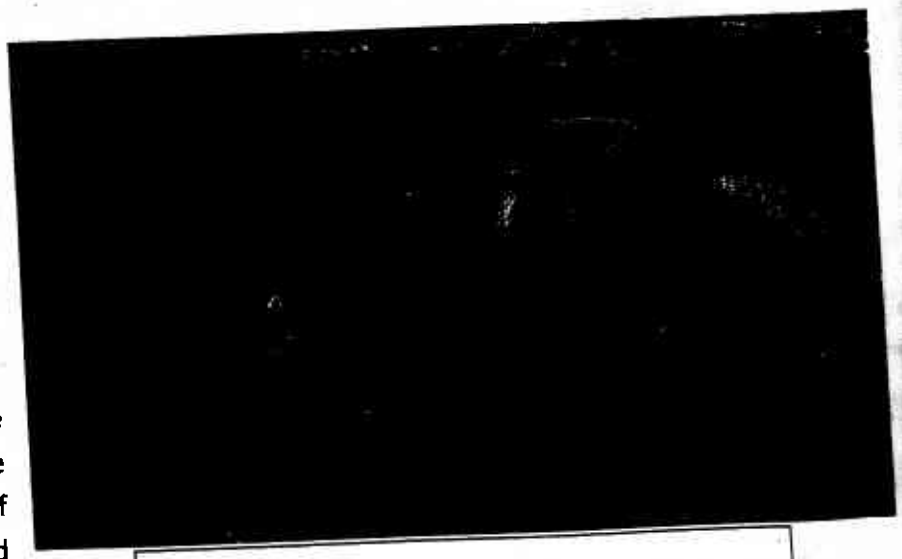
5.4 Survey of the Dump slide patch in Rajmahal using 3D Terrestrial Laser Scanner

CMPDI, RI-I survey team was earlier engaged at Rajmahal OC Project on 29.12.2016 for routine measurement of OB rehanding work at Daharnangi OC patch. Which was carried out by them using 3D TLS (Terrestrial Lesser Scanner). Incidence of OB/bench failure occurred on the same day in the evening few hours after their departure.

Riegl VZ-4000 Terrestrial Laser Scanner

ECL authorities again requested RI-I survey team on 31.12.2017 to do the survey of the accident site using the same 3D Laser Scanner to assess the accurate quantity of OB which had slid down. The survey team again went to Rajmahal the same day. The team conducted this exercise at intervals from 31.12.2016 to 06.01.2017. The team again took the observations of the patch from different angles from 09.01.2017 to 12.01.2017 on the request of project authorities.

RIEGL VZ 4000 Terrestrial Laser Scanner was used for data acquisition under this measurement. TLS is an active remote sensing sensor working on the principle of LiDAR. The scanner emits laser rays, which hits the object to be captured and comes back to the scanner. The scanner consists of an emitter and receiver. Depending upon the total travelling time, the scanner calculates the point distance in X, Y & Z in respect to



Post dump slide point cloud data as on

the position of the scanner, which is determined either by ETS. Laser scanner enables the surveyor to collect the data at faster speed with accurate 3D survey data (called point-cloud). This point cloud data can be used to create 3D models for a wide variety of spatial and volumetric tasks.

Data acquisition and processing is carried out using RiSCAN PRO Software. Point cloud data acquired by the scanner were used to create the 3D model for volume computation and analysis.

The volume of slid OB was estimated as 4.31 million cubic meter and the collapsed span was 600 meter. The volume was calculated as per the survey data before and after collapse and making cross-section at 50 Mtr interval. Measurement details of loose OB, hard rock dislodged and total volume is as under:

CALCULATION OF OB SLIDE ON 29.12.2016

Sec.No.	Area	X-Sec Interval	Volume in Cu.M.
188700	778.388		
188750	3611.425	50	109745.320
188800	7895.722	50	287678.693
188850	10253.734	50	453736.398
188900	10702.891	50	523915.613
188950	12097.810	50	570017.518
189000	12348.476	50	611157.135
189050	12690.469	50	625973.628
189100	7583.685	50	506853.863
189150	4692.858	50	306913.568
189200	2824.723	50	187939.515
189250	2338.035	50	129068.950
	87818.215		4313000.198
Total Volume 43,13,000 Cu.M.			

CALCULATION OF OB SLIDED ON 29.12.2016 AT RAJMAHAL OCP

Sec. No.	Area	X-Sec Interval	Volume in Cu.M
188700	789.457		
188750	1504.959	50	57360.405
188800	3253.611	50	118964.243
188850	4305.753	50	188984.098
188900	5121.590	50	235683.585
188950	4008.809	50	228259.975
189000	2628.264	50	165926.813
189050	2664.234	50	132312.450
189100	1476.193	50	103510.693
189150	831.713	50	57697.670
189200	609.378	50	36027.290
189250	697.885	50	32681.583
			1357408.803
Total Solid			**1357408**
Total Volume			**43,13,000.198**
Solid			**13,57,408.803**
Loose			**29,55,591.395**

The detail report submitted by the geomatics department of CMPDIL headquarter, regarding the above survey is enclosed at ***Annexure -20***

5.5 Observations of the Committee based on Administrative, Statutory and Technical evidences.

5.5.1 Administrative Analysis (Organizational Aspects):

i) The proposal for Dahernangi patch was not adequately backed by Operational plan viz. layout of haul road for extraction of bottom most seam and removal of overlying OB. The position of dumping place was also not exactly earmarked.

ii) Selection of the small patch just in the down throw part of fault with huge old OB dump in the northern part should have been examined for dangers due to excavation and subsequent stress unbalance of the dump which was resting on Fault -8.

iii) The Officials from Area, and ECL HQ overlooked the geology and overall impact on the adjoining huge OB dump by allowing successive modifications of the plan. Comments of geological experts were not sought from GM (Geology) posted at ECL HQ.

iv) The reasons for 1st modification and 1st deviation of the patch on the ground that strata movement was observed on the haul road along fault F-8 was a significant indication. The proposed modification was approved without putting any clause on the monitoring aspects of those cracks and compatibility of barriers. Only coal availability, OB quantity and terms of contract with MIPL were examined at all levels. The layout of modified area with respect to the adjacent overlying OB dump was worth assessment from safety point of view. The estimate was not examined in detail by the ISO of the HQ.

v) The reasons for **Second modification and 2nd deviation** was again the more quantity of coal at reduced height due to presence of an up-throw fault in the southern part of Deep Mining Zone. How the working in the rise part could have affected the working of old OB dump was not deliberated despite getting indications of cracks during the first modification. As the lower most exposed coal and haul road of the patch had earlier drowned in water, the proposing projects official have deliberated about the non-availability of space for contractual work. It appears that mining activities in area near the foot of old huge OB dump have taken place for movement of contractor's equipment resulting in the de-stabilization of the batter and the dump.

vi) Further MIPL has undertaken the re-handling of 1.344 million cum of OB from the old dump and was completed on 09.08.2016.

vii) By **2nd re-handling of OB of quantity 1.730 MCum** was sought for approval to make the OB dump benches to comply the provisions of the permission of DGMS. The mine permission was accorded in July 2012 and the mine management had sought permission for removal of OB after a dump slide took place only on 09.08.2016. No query has been put forth at any level of management regarding violation of the dump design parameters.

viii) Even after the slide of 08.08.2016, intimation to DGMS under CMR 9(1)(a)(viii) of CMR and DGMS permission was not given.

ix) The proposal for removal of 1.33 M cum of OB from the dump did not have any scientific study.

x) The old dump, as reported, was located in the de-coaled area and factors affecting stability of dump were required to be assessed considering floor condition, presence of aquifer, silt etc. before undertaking any work of de-capping. Any activity of OB removal might change the centre of gravity of the dump body. The centre of mass also changes during monsoon due to presence of water in the dump floor. Additionally, removal of 1.344 million cum of OB from dump might have been changed the centre of mass of the dump body.

xi) Despite experiencing couple of OB dump slides, the proposal for removing further 1.730 million cum of OB without any scientific investigation cannot be understood.

xii) In that area two activities were going on simultaneously, first extraction of coal and parting from the Deep Mining Area and second, re-handling of OB from the old OB dump using dumpers and excavators. These simultaneous activities have probably caused de-stabilization of the batter and the OB dump. Even the explosive consumption records, indicated substantial production from the barrier (in-situ OB strata) in the MIPL patch. These overall activities were weakening the stability and underlying fault might have compounded the trigger that lead to failure.

xiii) As per the note for modification during the 2nd proposal, the presence of 10 and 10A fault was not evident in the geological plan but was evident during mining of the patch. However, in the geological plan these faults were clearly shown.

xiv) The safety clearance of the working patch was not obtained by the ISO, ECL.

Specific SOP for the working in the dump was not framed.

5.5.2 Statutory Mechanism:

i) Violation of statutory provisions were noted as there was no scientific investigation through geo-technical study, for determining the methodology to be adopted for designing, control and monitoring of pit and dump slope in the disturbed zone, which would have helped in choosing of effective controls for stabilization of working and prevented sliding of OB dump which resulted into this accident. Based on the incidences on 20.12.2013 the manager had moved a proposal for scientific study which was forwarded to ECL HQ. However, no outcome of the proposal was found.

ii) The basic safety status monitoring statutory mechanism in a mine, apart from deployment of statutory personnel, to supervise the day to day operation, is Workmen

Inspector and Safety committee of the mine under the Mines Rules 1955. They are to note the deficiencies that may endanger safety of persons working therein, suggest corrective measures and ensure their execution. While going through the report of aforesaid statutory bodies for Rajmahal OCP, it appears that inspections lacked quality and objectivity. There is no mention of inspecting the cracks, dump slide and related records e.g. Diaries & deliberation in safety committee meetings etc.

iii) Slope stability was never discussed in any SC Meeting or at any other safety forums.

iv) Intra Area Safety Audit done in the year 2015 and 2016, wherein no recommendations for stability of Dump or High-wall slope and its monitoring were made.

v) There was no provision of 24 x 7 real time monitoring of the dump slopes /High wall, in spite of the visible movement in the past and the statutory provisions in this regard. No monitoring records was provided by the project which were in place over the dump. It has already been stated that no scientific study of stability of dump was carried out although it was mentioned in the permission.

vi) DGMS circular issued in the year 2001 for taking precaution while working near the fault plane in Open cast mines has not been complied with.

5.6 Technical Analysis:

5.6.1 Methodology of Investigation

A detailed investigation has been carried out to determine causes of failure of both OB dump and the batter, which is elucidated below:-

i) A number of representative cross-sections as recorded on 23.12.2016, prior to dump failure, between the grids 188500E to 189500E were studied along with geological maps of the region showing shear zones, fault zones (major and minor) and other geological discontinuities. Copy of part working plan prepared on 26.01.2017 along with the representative cross-sections have been enclosed at ***Annexure -21***

ii) The samples of dump and pit slope mass were collected from the field to determine the geotechnical parameters, which would be used during slope stability study.

iii) Back analysis of failed dump slope was done with the help of different parameters (cohesion, angle of internal friction, bulk unit weight, hydro-geological and seismicity of the area) (Fig 2).

iv) The geotechnical data of the pit slope mass were estimated and determined from the field photographs, geotechnical mapping of the nearby zone. The shear strength parameters of pit slope mass were also determined.

v) The load of back-filled internal dump on the pit slope was also taken into consideration for analysis.

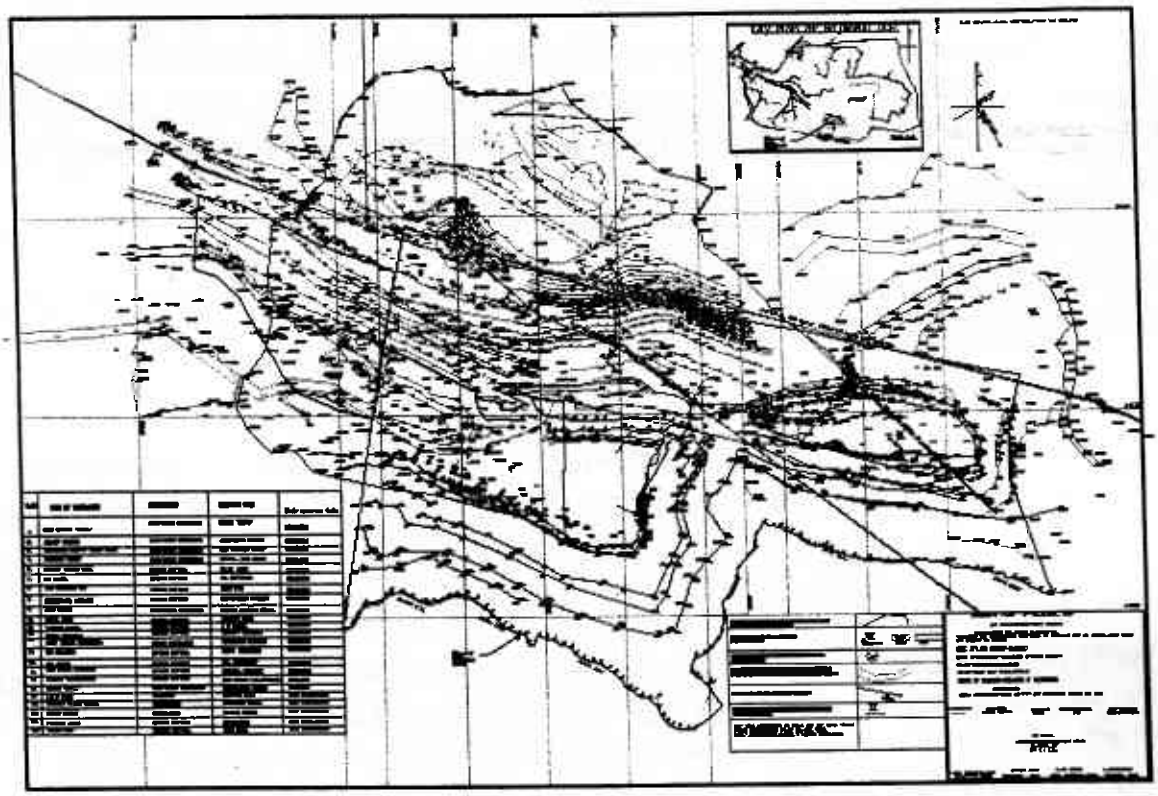


Fig 1 Working Plan as on 23.12.16

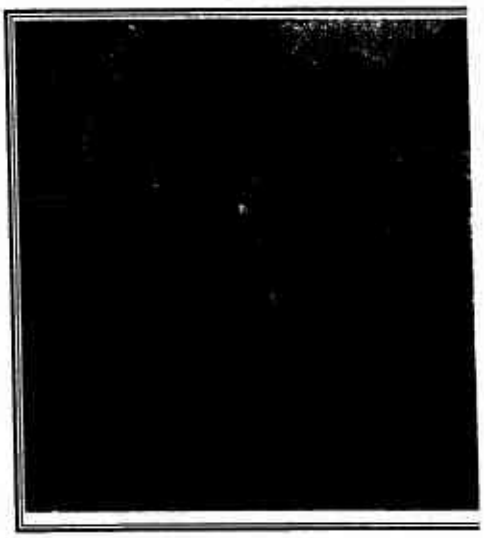


Fig 1a) Shear zones comprising of fault, joints and other structural discontinuities

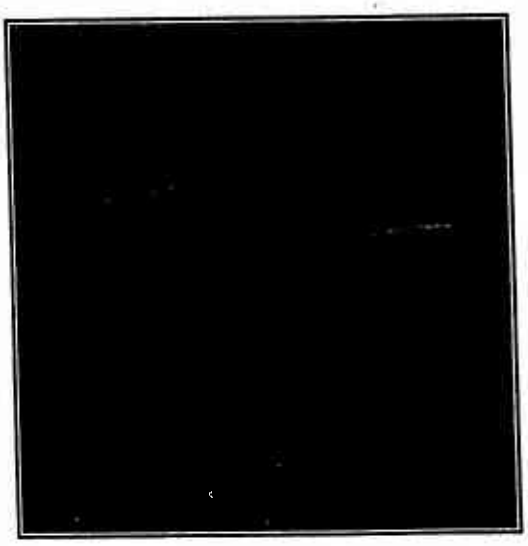


Fig 1b) Presence of minor fault planes and joints.

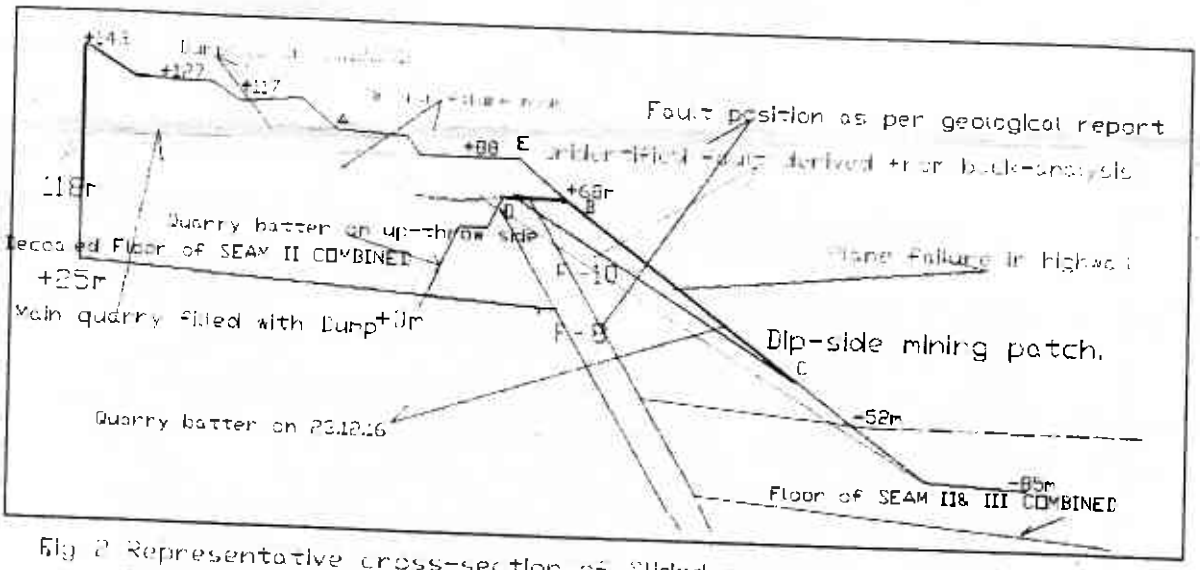


Fig 2 Representative cross-section of Slided zone as on 23.12.16

5.6.2 Stability Analysis of the batter :-

Different modes of failure in batter slope that can take place are as follows:-

i) Plane failure- It may occur when a geological discontinuity (such as major fault plane, bedding plane, minor faults) strikes parallel to the slope face at an angle flatter than the bench slope and steeper than the effective friction angle as shown in Fig.3. The weight of the sliding mass are calculated from the geometry of the slope and the failure plane. A tension crack running parallel to the crest of the slope, if any, can also be included in the calculation.

ii) Wedge failure - When two discontinuities strike obliquely across the slope face and their line of intersection daylights in the slope face at an angle more than the effective friction angle, the wedge of rock resting on these discontinuities may slide down the line of intersection . (Fig 4).

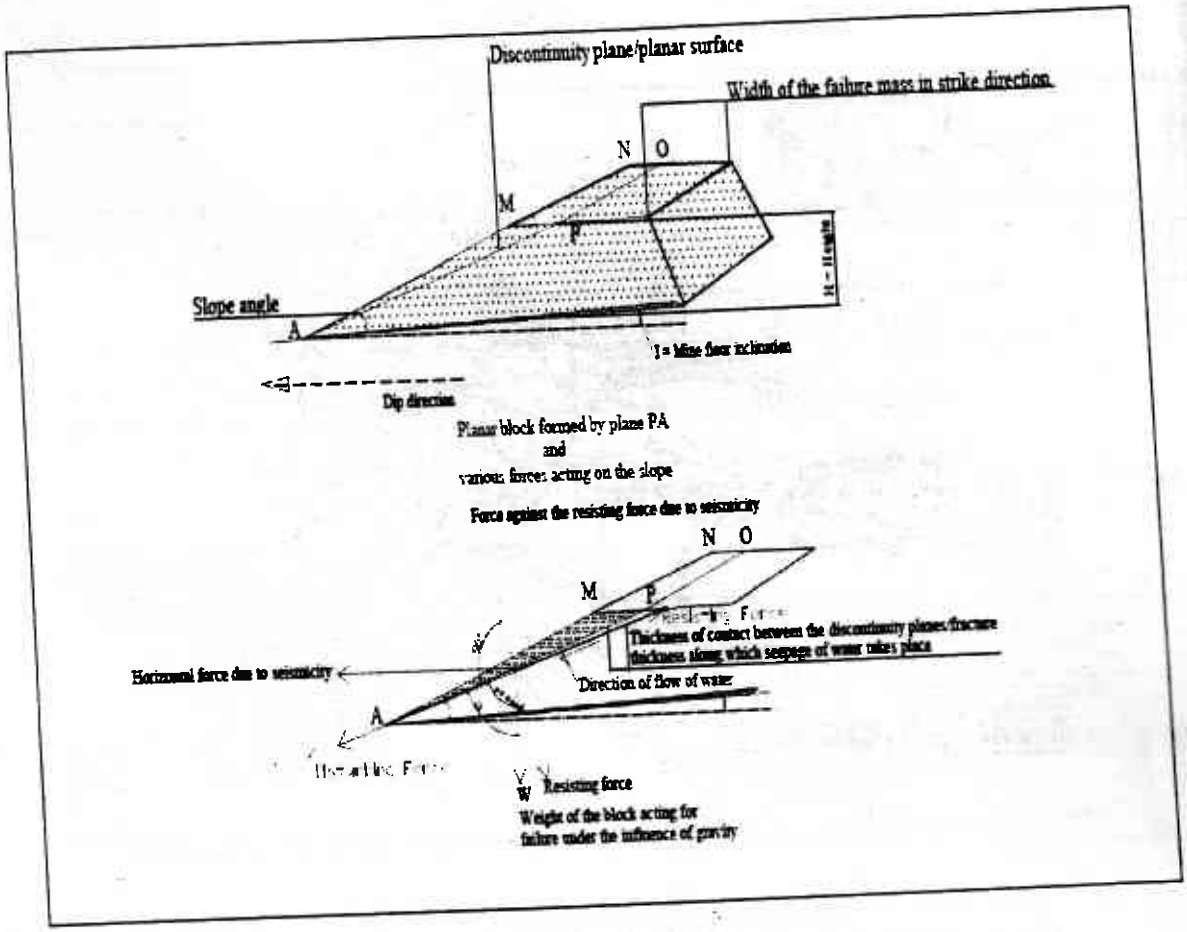


Fig 3 Free body diagram for plane failure analysis

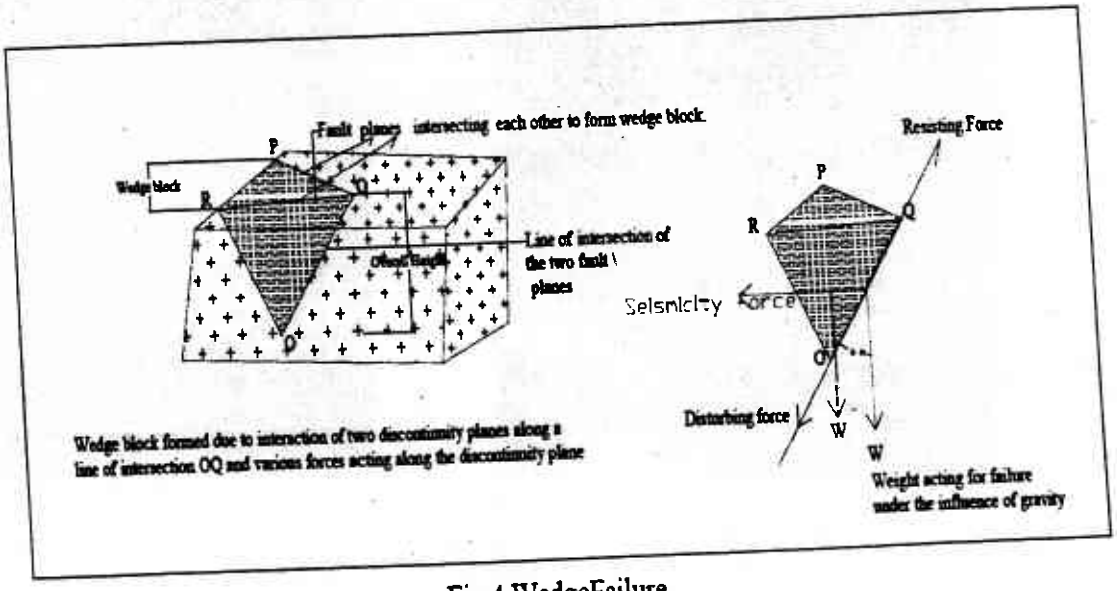


Fig 4 WedgeFailure

5.6.3 Values of cohesion and angle of internal friction for rock mass were estimated to be as follows :

i) Angle of internal friction = 33^0

ii) Cohesion = $157.5 kN/m^2$.

iii) Bulk unit weight of rock mass = $22 kN/m^3$

5.6.4 Back-analysis of failed batter slope reveals the following :-

i) The batter(intersected by unidentified Fault planes near section CC' and DD') in the failed zone seems to have suffered plane failure (Fig 3).

ii) Unidentified Fault planes might have also led to formation of potential wedge failure block within the failure zone (Fig 4) aggravating the failure condition.

5.6.5 Dump Stability analysis:

An analysis was performed using Fellenius Method and Bishop's Simplified Method for stability of overburden dumps. Overburden dumps in opencast coal mining operation generally experience one or combination of the following two types of failure surfaces;

a) Circular failure surface.
b) Circular-cum-planar failure surface.

The following sequence of calculations is envisaged in the stability analysis of this dump;

i) Determination of the factor of safety of the first trial surface by the Fellenius Method after considering all the geo-engineering parameters i.e. Geo-technical parameters, hydro-geological parameters, geo-mining parameters and effect of seismic vibration.

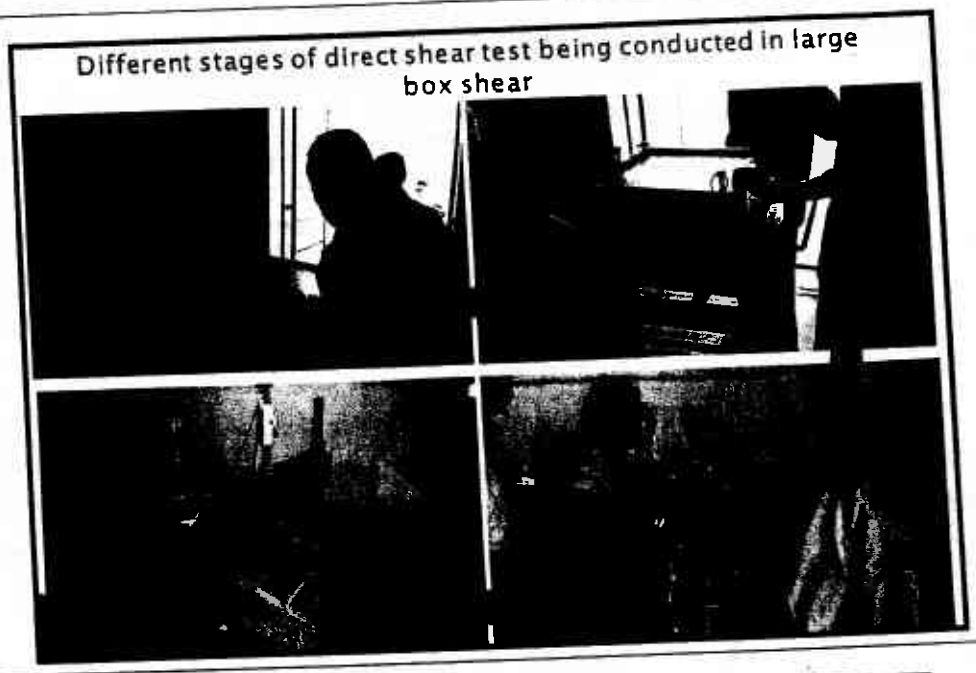
ii) An iteration method to locate the most critical failure surface corresponding to the absolute minimum factor of safety.

iii) Absolute minimum factor of safety corresponding to the most critical failure surface by the Fellenius Method is further modified by Bishop's Simplified Method.

5.6.6 Geo-technical data generation parameters:

Loose dump material was collected from the dump site and compacted at a stress equivalent to average compacting stress within the dump mass. If the bulk unit weight of dump material is $20kN/m^3$ with average dump height of 100m, then the average compacting stress will be equal to $20\times(100/4) = 500 kN/m^2$. The laboratory sample was prepared at moisture content equivalent to field condition. Then around 50kg dump sample(with particle size not more than 8cm) was tested in large box shear test apparatus(40cm X 40cm) (Fig 6) for determination of shear strength parameters.

For interface material, similar process was carried out for maintaining equivalent stress condition and moisture content. (After the mining of coal, a layer of crushed rock and coal dust submerged in water lies in the floor of the de-coaled area, which is termed here as interface material.] Other than laboratory tested values, **back analysis** has also been carried out for the existing dump profile which was standing at factor of safety equal to one i.e. at limiting equilibrium.



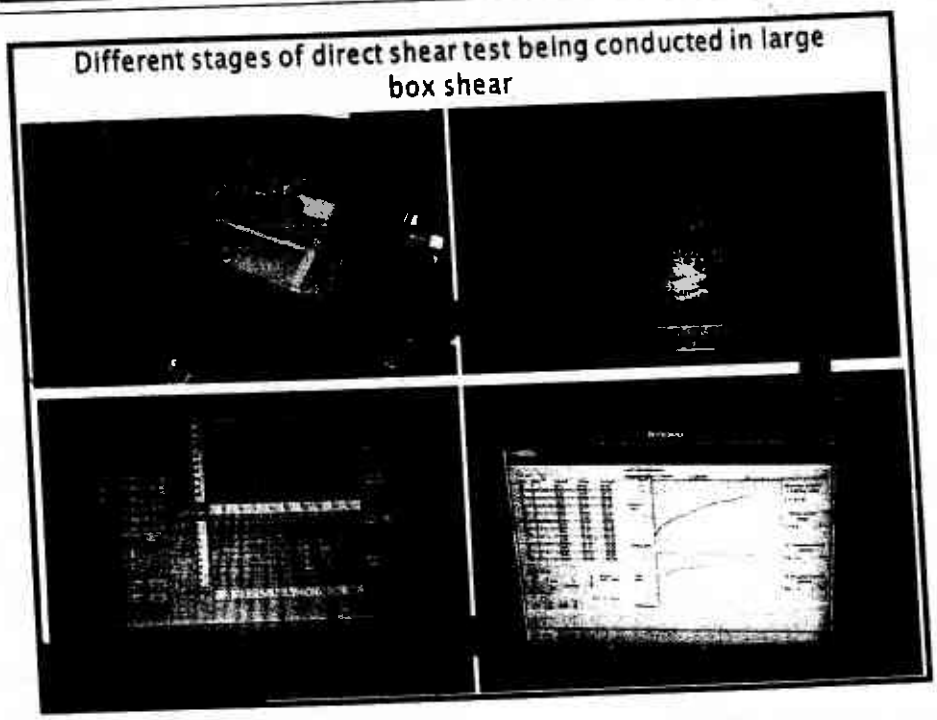


Fig 6) Geo-technical data generation of dump material by Large box shear test apparatus

Geo-technical Properties of dump material:-

a) Angle of internal friction = 32^0

b) Cohesion = 70 kN/m^2

c) Bulk unit weight = 20 kN/m^3

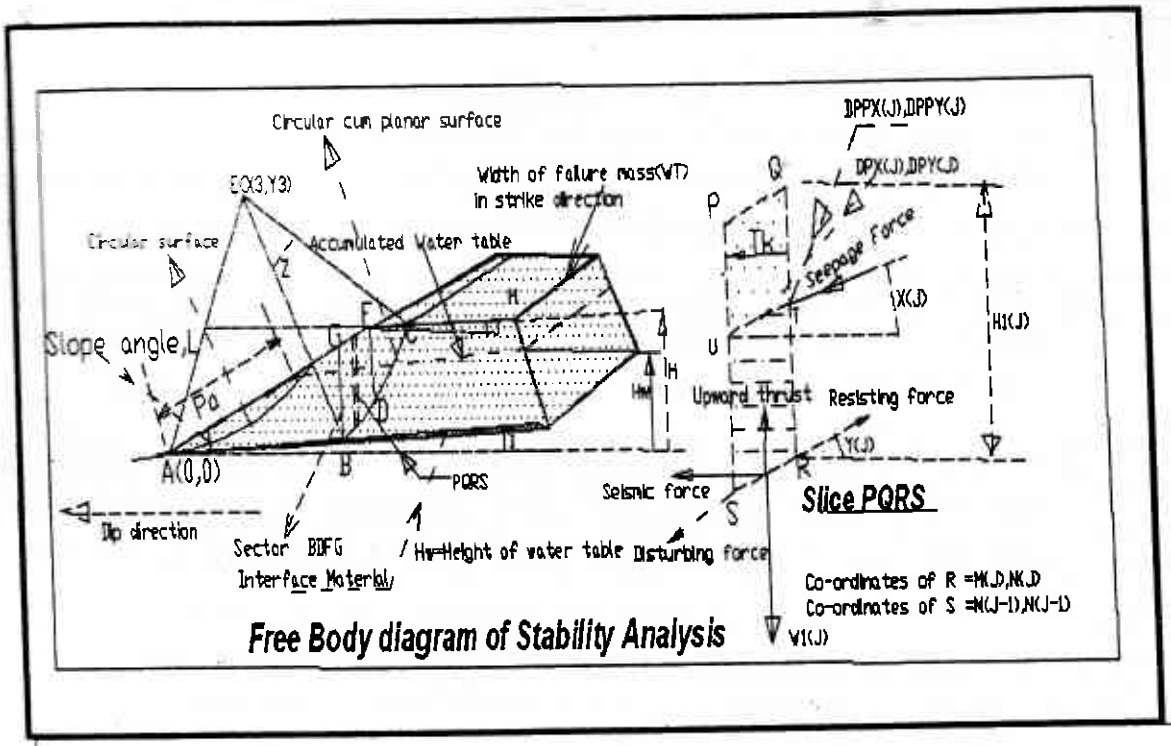


Fig 7: Free Body diagram of Stability Analysis

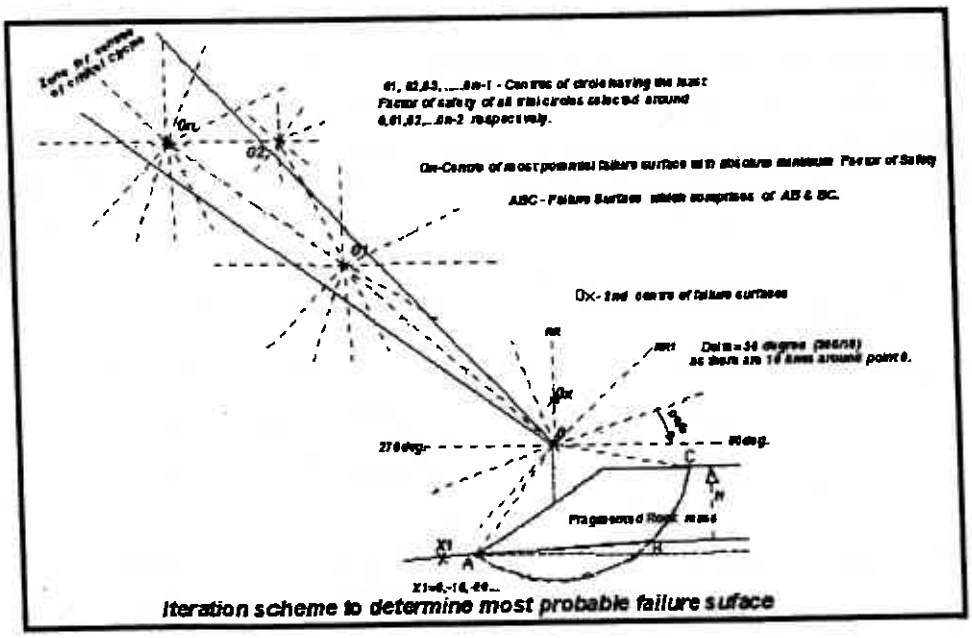


Fig 8: Iteration Scheme to Determine Most Probable Failure Surface

5.6.7 Back –analysis of failure mode of both batter and the OB dump reveals the following :-

i) It has been observed that a number of unidentified fault planes / shear zones were existing in the Deep Mining Zone.

ii) The attitude (i.e. strike direction, dip direction and dip amount) of unidentified fault plane was such that it intersected the batter on the down throw side of fault F8-F8 leading to potential plane failure block. The unidentified fault plane is shown in Fig 2 and the mechanisms of failure is shown in Fig 3.

iii) Other than the plane failure, formation of potential dangerous wedge due to presence of other fault planes on both ends of failure block might have added to the instability of the batter. This failure mechanism is explained in Fig 4.

iv) The above orientation, position and dip angle of unidentified fault planes/ zones intersecting batter forming both plane and wedge failure supplemented by surcharge load of 140 meters high dump may be responsible for failure in the batter.

v) The above mentioned batter failure has resulted in the dump failure (Fig2).

CHAPTER VI

FINDINGS OF THE COMMITTEE

6.1 Findings of the investigation (The Cause of accident)

After inspection of the site of accident, recording the statements of Rajmahal officials, supervisory staff, employees and the contractor employees, examining all the relevant records and by back–analysis of failure mode of both quarry batter and internal dump, the Committee has come to the following conclusions: -

i) It was well known for many years that the site of Rajmahal Project is traversed by a number of faults like F-8, F-9, F-10, F-11, F-12, F-13, F-14 and F-15 etc. with throw being as much as 60 m. Due to this reason, this area was not found suitable for working with high capacity departmental equipment and accordingly outsourcing agencies were engaged for OB and coal extraction.

ii) There was failure of high-wall (batter) slope, most likely along the fault planes, followed by dump failure. This resulted in movement of 4.31 M cum of both the OB dump and batter. Constraint of extending the mine towards south side on account of delay in land acquisition in the dip side of the mine, necessitated the extending of coal exposure in the north side (rise side), which ultimately resulted in reducing the width of batter against the fault zone. Failure of batter wall might also have been triggered due to blasting in coal and OB parting for exposing coal further or in the coal bench adjacent to the batter.

iii) The steeper mining at intermediate and lower level increased the stress at the toe of standing pit slope. It activated movement in the pit slope mass and also activated the movement along fault. The presence of fault is not a problem if working method near the fault is correct. Once any movement is activated due to steeper slopes at intermediate and/ or lower levels, the water flow/percolation also increases through the micro fractures of the instable slope mass. It leads to high hydrostatic pressure and causes failure in the lower steeply dipping slope mass, which results in failure of overhanging upper slope mass also.

iv) The presence of 140m high dump in close proximity of the pit slope added the dead weight over the standing 100m high pit slope mass. The pit slope yielded at lower level due to the dead weight of 140m high dump along with 100m high pit slope standing at steeper slope angle. The yielding of pit slope resulted in to the failure of the overlying dump also.

v) Initially the failure of pit slope before the dump could be manifested by the fact that the pit benches were observed to be bodily shifted towards southern highwall, as observed by the committee members during field visit. There was no cover of dump material on lower

moved pit benches. Had the dump failed first, all the pit benches would have been covered with dump material.

vi) Due to delay in land acquisition, the project was facing the problem of dumping space for many years. The top benches were not being advanced due to rehabilitation problems and management was using the space available inside the quarry for OB dumping, although the height of the dump created over the de-coaled area (north of the F8 fault at Kaveri sump) was about 140 m from the floor of the de-coaled quarry. The south side of this dump later failed resulting in the loss of life and machineries.

vii) Due to presence of unidentified faults/shear zones in Deep Mining Zone, appropriate scientific investigation for determining the method of working in the area and more intensive monitoring of bench movement of batter wall and internal dump was required. However, Committee did not find any serious attempt by area or HQ officials for considering the application of slope monitoring system.

viii) Actions which were required for compliance of statutory provisions with respect to working near faults and slope monitoring were not considered seriously by the mine officials. In spite of incidences of slope/dump failures in the past, the issue was not addressed in the Safety Committee Meetings or ISO inspections appropriately. Inspections by the statutory personnel of the mine, in the Deep Mining Zone, lacked quality and objectivity. Even the maintenance of inspection records were not proper. It was also observed that DGMS has not specifically pointed out these violations in their inspection reports. A copy of recent violations, given during inspection by DMS Sitarampur is enclosed at ***Annexure- 22***

ix) It has been observed by the Committee that the said outsourced patch was mostly supervised by contractual supervisors, who were not competent as per the provisions of CMR 1957. The cross examination also revealed that the charge handover on important statutory positions or competent level of management in the area, did not include the safety aspects of the mine.

x) The incidences of the dump/slope failures in the past as well as the statutory provisions necessitated the real time monitoring of the slopes, on 24 x 7 basis. It has been noted that the proposal was initiated for procurement of 3 slope stability monitoring system one each for Sonepur Bazari OCP, Rajmahal Project and SP Mines Area of ECL on 29.03.2011 but the same never materialized, citing the requirement of some clarification from DGMS. DGMS has, however vide their Technical Circular no. 8 of 2013, dated 23.09.2013 had clarified the issue. In spite of the clarification from DGMS, no further action was taken.

xi) Even the records of monitoring of cracks by conventional method, adopted in the mine, were not properly maintained.

Although the apparent lapses by the Project authorities have been deliberated above in detail, yet it would be important to mention here that Rajmahal Project alone was expected to contribute every year more than one third of ECL's production. ECL being a BIFR company, relies heavily on this project for improving its balance sheet. Also coal produced from this project is entirely earmarked for Farakka and Kahalgaon STPS of NTPC and any disruption in coal supply seriously affects the performance of these power stations. Management of this project was therefore under pressure to continue production. Also project was facing acute problems in land acquisition and R&R problems which was spoiling mine geometry. Top benches were not moving forward and there was inadequate space for external dumping. It was accepted by colliery officials when they recorded their statements before the High Power Committee.

6.2 Human Failures, if any

Observations of the Committee from the proceedings of the inquiry lead to the follo conclusions, with respect to Human failures:

6.2.1 Non-compliance of the stipulations in DGMS pe provisions: statutory

The committee found that status of compliance, in reference to the various stipulations of DGMS permission and other statutory provisions were n t comp with. The provisions regarding working near faults, scientifi the methodology to be adopted for designing, control and monitoring of dump slopes in opencast mines, development of safety management pla , real time monitoring of slope strata etc. were not complied. It was also obser + DGMS has not pointed out these violations in their inspection reports.

6.2.2 Height of internal OB dump

The committee observed from the available records tha ay in acquisition of land and rehabilitation villages required fo proje lay in acquisition & rehabilitation had forced the mine officials in difficult mining patch as an alternate option. This also resulted ck of dumping space for overburden removed from the mine & in turn resulted in dumping of OB in the muck/silt of erstwhile "Kavery sump" and heightening of the this dump up to an un-desirable height of 140m.

6.2.3 Overlooking the warning signs of impending danger of slide.

The plan and sections show that there had been a small scale dump failure in the past. First time, the cracks were observed in OB dump on 04-01-2016 which was followed by small scale failure. The second failure was on 09-08-2016. Further, crack was observed

on 08-12-2016, followed by small scale failure. Even then the concerned officials have not taken it seriously.

The indications of slope/dump slides were not taken seriously in spite of several incidences in the past. These incidences should have been deliberated in Safety Committee meetings, should have been acted upon by the Workman Inspector, Safety Officer, Manager, Agent, Area Safety Officer and other senior management of the Area. It was also not given serious importance by the ISO officials as well and teams visiting from the HQ. The circumstances necessitated a rigorous and advance level of monitoring of the dump slopes and prompt action, as the conditions were becoming dangerous. When the work of coal extraction was suspended due to falling of OB material in the Deep Mining Zone at about 4.30 PM on 29.12.2016, management should have taken decision to suspend the re-handling operation in the OB dump.

6.2.4 Not advising/apprising management about danger associated with the activity by Safety organization.

Inspections by the statutory personnel of the mine, deployed in the dip mining patch, and Internal Safety organization, lacked quality and objectivity. Even the maintenance of inspection records were not proper. Any indications of strata movement or the issue of impending danger by reducing the width of the batter (in situ OB strata) should have sent the alarm to the management and corrective action should have been taken accordingly.

6.2.5 Lapses during Conceptualization & Planning:

The area of proposed Dahernangi (Deep Mining Zone) patch was not only constrained by presence of fault/shear zones, a major fault F-8 (having throw of about 60m), but was also under surcharge load of about 140m high internal dump created over an old (Kaveri) sump. Both the impediments required careful planning supported by detailed geo-technical investigation and more intensive monitoring of bench movement of High-wall/batter wall. However, no appropriate scientific study appears to have been undertaken before the unfortunate incident. As per the details elaborated in point no. 5.3 (*Details of award of Work and Modification /Deviation, thereafter at DAHERNANGI PATCH Deep Zone Mining with reasons and remark)* of Chapter 5, it is evident that, at various stages, proper care has not been taken towards planning of working near major fault zone (in the Deep Mining Zone).

The area of proposed Dahernangi patch was not only constrained by major fault F-8 (having throw of about 60m) but was also under surcharge load of about 140m high internal dump. Both the impediments required careful planning supported by detailed geo-technical investigation.

It is worth to mention here that DGMS in its technical circular No. DGMS(Tech.)(S&T) Circular 2, dated 20/06/2001 has indicated that special care should be taken while working near the fault plane.

6.2.6 Lack of awareness of safety provisions:

There was lack of supervision because safety aspect of workings of OB dump and pit was found missing. The plan and sections of the accident site show clearly that the dump and pit benches were not formed systematically and the benches were of varying height and width not adhering to the basic principles of dump and open pit mining. The outsourced patch was mostly supervised by contractual supervisors, who were not competent as per CMR 1957. The Project management should have ensured proper supervision through competent persons.

6.2.7 Non-provision of Instrumentation for real time monitoring:

The circumstances in the past and with history of numerous occurrences of dump failures in the mines of CIL, real time round the clock monitoring of the slopes was required. However, no such mechanism was available at the project, which is the highest producing opencast coal project of ECL. Even the records of monitoring of cracks by conventional method were not properly maintained.

6.2.8 Non-reporting of violations during inspections by DGMS:

While going through the violations book maintained at the project, it was noted that excessive height and high angle of dump slope was not recorded by the officials of DGMS in recent past.

6.3 Whether the accident could have been avoided by taking identified corrective measures;

The accident might have been averted if:

1. The height of the dump and its slope would have been as specified in the permission granted by the DGMS and as per the norms. The dump and pit benches should have been formed properly from top to bottom, preferably based on any scientific study.
2. The minimum gap between the toe of the dump and crest of the pit should have been designed based on any scientific study to avoid transfer of the dead weight of the dump to underlying pit slope. Without any study this gap should never be less than 1.5 times the overall final proposed/ planned depth of the pit or final planned overall height of the dump, whichever is more. It would avoid the transfer of the dead weight of dump to the pit slope.
3. Dump slide was of such a magnitude that it could not have been averted by taking any short-term measures. Meticulous planning and scientific monitoring on a

continuous basis could have averted such type of accident.The dump area would have been monitored regularly (once in a day or week) for any sign of developing instability or stress concentration (e.g. formation of tension cracks, minor movement, etc.) and necessary corrective action would have been taken.

4. Widespread awareness regarding dump slope stability and safety among all the concerned.

5. A scientific study by any expert agency would have got done and actions recommended were implemented.

6.4 Measures to avoid recurrence of such accidents in future:

The Committee recommends that following actions should be taken to prevent such types of accidents in future:

1. In all large open cast projects there should always be a Geo-Technical cell equipped with proper instrumentation for slope monitoring like Laser profiler, Total Station, Slope Monitoring Radar etc. The cell should be headed by senior level officer and shall essentially include a geologist, mining engineer and sufficient no. of Surveyors. All operational planning must be routed through this cell to assess any unwanted surprises.
2. A detail scientific study of the mine is required for assessment of geological disturbances, analysis of strata parameters and recommendations thereof, for adopting an appropriate method of working.
3. While creating an internal dump, dip side of which is coal bearing and proposed to be extracted in future, extra precaution in respect of slope stability needs to be taken. Scientific study from the expert agency must be carried out in such cases.
4. Continuous slope monitoring is essential to detect any instability in advance to safeguard against possible slope failure. The dump shall be regularly surveyed to produce up-to date and accurate dump geometry.
5. Risk Management Plan shall be prepared and the mitigation measures suggested should be regularly reviewed.
6. Safety Audit guidelines should be prepared as per the international standards. Safe operating procedure should be prepared for all the activities and the same should be appropriately communicated to all the workers, including, contractual workers. Awareness of contractual workers shall be enhanced through regular interaction and training programmes.
7. Vetting of all coal and OB extraction proposals by ISO, with respect to mine safety, must be mandatory.

8. Adequate infrastructure to be provided for imparting training on slope stability to all concerned person employed in the large opencast mine.

9. Technical competence of the contractual supervisors shall be appropriately scrutinized before deploying them in the mine.

10. It is possible that any unfavorably oriented structural discontinuity (shear planes/ fault/s) may be present in the mining area, which could not be detected during exploratory drilling and it is detected during the ongoing excavation. It may create unsafe mining condition. The resident geologist should conduct field mapping to see the existence of faults in the fresh exposures of the pit. It will help to detect the impending failure along these undetected weak planes.

11. A few small-scale failures may subsequently cause a big failure. If two or three benches are made steeper at any level in any part/ depth of the pit/ dump then it may initiate failure. Although the overall slope angle may be quite low but the steeper slope angle of three benches may increase the stress at the toe of relatively steeper part of the slope, which may cause failure. Two or three such small failures may cause a big failure. So, benching should be done properly from top to bottom.

12. In case there are multiple fault planes, bench design should be such that they do not strike parallel to fault plane.

13. Presently, there is no dump classification system for the varying Indian geo-mining conditions. Hence it is recommended that a detail scientific study shall be carried out for the "development of a classification system for dump slopes in Indian geo-mining conditions".

Shri P K Sinha	Prof P Sen	Dr V K Singh	Prof I Roy	Shri A K Nath
DT(P&P),SECL	Prof. IIT(ISM)	HoD Slope Stability Div, CIMFR	Prof. BIT(Mesra)	GM/TS to DT, CIL

(Shri S. Saran)
CMD/CMPDI
Chairman of High Powered Committee

List of Annexures

Annexure No	Description of Annexure
1	OM regarding constitution of the High power committee
2	Location plan of Rajmahal OCP, Ultimate quarry plan & final stage dump plan
3	CIMFR report for highwall stability study
4	Safety audit report (2016 & 2016)
5	DGMS permission letter (1987 & 2012)
6	Geo physical survey report (magnetic survey after the accident)
7	NIT Rourkela observation report
8	Minutes of meeting held on 08.02.2017, under chairmanship of DDGMS (EZ)
9	Inspection note of DDG (HQ), DGMS-Dhanbad (after accident on 31.12.2016)
10	Advisory note issued by expert committee of HPC for further course of action towards Rescue and Recovery operation
11	Manager's and Workman Inspector's diary
12	SOPs for outsourcing workings
13	Minutes of safety committee meetings
14	Training and Mock Rehearsal Records
15	Relevant pages of the proposal note for OB/Coal outsourcing contracts
16	Proposal note for geo-technical (slope stability) study.
17	Proposal note for procurement of Slope Stability Radar
18	Statement of staff, officials, executives, contractor worker and others
19	Report submitted by ECL HQ team after inspection on 24.08.2016
20	3D Laser scanner Survey Report submitted by Geo-Matic department, CMPDIL
21	Part working plan and representative cross-sections (A-4 size)
22	Recent violation given during inspection by DMS Sitarampur
23	Observation of Prof P Sen, IIT(ISM)