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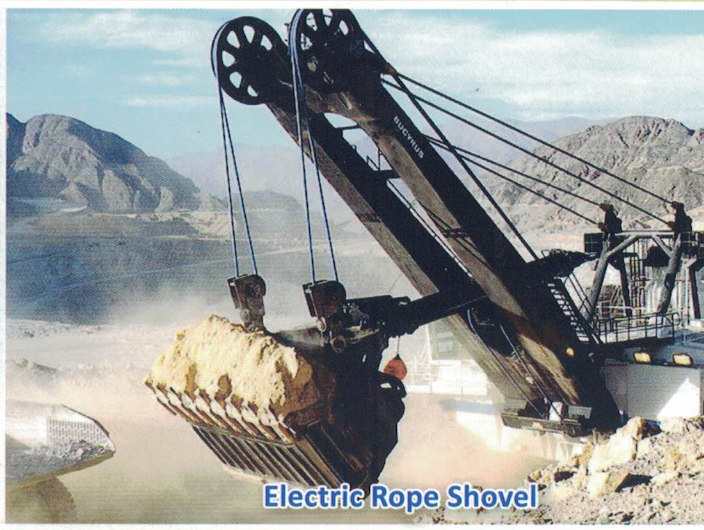
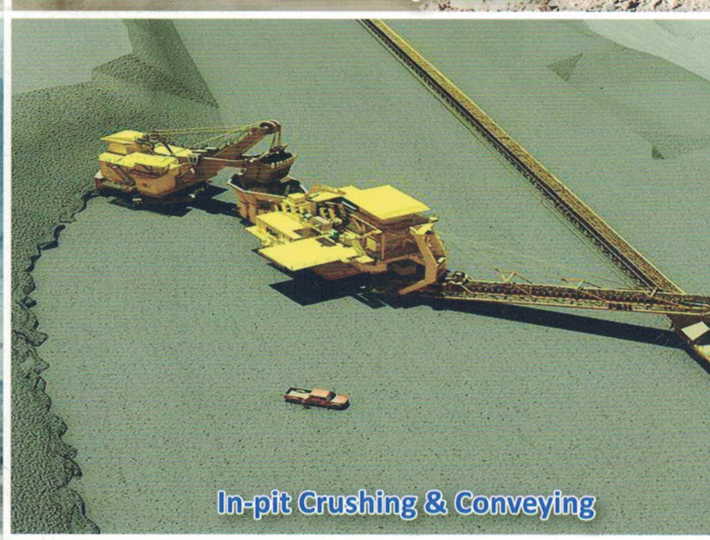
Special issue on "Opencast Mining"


Dragline


Electric Rope Shovel


Opencast Mine


In-pit Crushing & Conveying

शेखर सरन
अध्यक्ष–सह–प्रबंध निदेशक

Shekhar Saran
Chairman-cum-Managing Director

सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी/भारत सरकार का एक लोक उपक्रम)
गोन्दवाना प्लेस, काँके रोड, राँची –834 008, झारखण्ड (भारत)

Central Mine Planning & Design Institute Limited
(A Subsidiary of Coal India Limited/Govt. of India Public Sector Undertaking)
Gondwana Place , Kanke Road , Ranchi -834 008, Jharkhand (India)

MESSAGE

It gives me immense pleasure to know that CMPDI is publishing a special issue of ‘Minetech’ on the subject of ‘Opencast Mining’.

Opencast Mining is the predominant mining method worldwide. In India, the share of Coal production through Opencast mining has rocketed from 25% at the time of nationalisation to around 90% today. Lesser cost of production, high productivity, higher recovery, less hazard, less geo-mining difficulties, more mechanization, etc. have led to more thrust on opencast mining over UG mining.

For achieving the twin objective of meeting nation’s energy security and promoting economic growth, CIL has a long term vision of achieving coal output of 1 BT by 2025-26. It is gearing up for more than 50% increase in production. The majority of increase in production will come from opencast mine. Against this backdrop, a modern, technologically advanced, safe and sustainable approach for Opencast Mining is not only a technological imperative but also an economic necessity.

In this context, this Minetech issue comes at an opportune time and I am confident that various issues pertaining to Opencast Mining viz. technological up gradation and modernization, productivity, safety, Social & Environmental issues etc. have been dealt with and will prove beneficial to the industry for making our opencast mining operations technologically advanced, efficient, environmentally sustainable and socially tenable.

I wish all the success to this special issue of Minetech.

(Shekhar Saran)

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के.के. मिश्रा
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Director (Technical /Engg. Services)

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MESSAGE

I am very much pleased with the idea of bringing out special issue of our in-house technical journal ‘Minetech’ focussed on ‘Opencast mining’.

India is the second largest producer of coal globally and almost more than 90% of current production is through opencast technology. To meet the country’s growing demand it is not a question of choice or option but to increase the level of production significantly in coming years. To bridge the demand-supply gap, it is necessary to emphasise on opencast technology.

I am confident that this special issue of Minetech will serve the purpose of disseminating knowledge of recent technology and methods applicable to opencast mining and act as a useful reference point for all the stakeholders in understanding and emulating best practices in opencast mining operations for making it safer, efficient and eco- friendly.

On the occasion, I extend my greetings and felicitations to all those associated with the publication of this special issue and wish them all success in future endeavours.

(K.K. Mishra)

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MESSAGE

I am glad to present the special issue of our in-house journal 'MINETECH' focused upon 'Opencast Mining'.

The Opencast Mining in Coal India Limited has witnessed a sea-change after nationalization. It has contributed to raise the overall coal production of CIL from 79.03 Mt in 1974-75 to 606.89 Mt in 2018-19 with the production of individual mine to reach as high as 42.25 Mt.

The unprecedented growth is a testimony of successful planning and execution of high capital projects that involve state-of-the-art Heavy Earth Moving Machinery. With an emphasis on bulk coal production with the Opencast Mining during this period, the Underground Mining played a supportive role.

The Shovel-Dumper system remains the pre-dominant technology. A wide scale application of Surface Miners at several projects is extremely encouraging both from the point of view of selective mining as well as enhanced output.

At Opencast Mines, employees' productivity has reportedly improved steadily in the post nationalization period.

I hope, the technical papers incorporated in this issue of Minetech would be of immense help to the engineers engaged in the field of 'Opencast Mining' and discuss various issues pertinent from the industry point of view.

(R. N. Jha)

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अनिल कुमार राना
निदेशक पी एण्ड डी

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Director P & D

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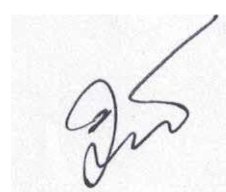
MESSAGE

The idea of bringing out a special issue of our in-house technical journal 'Minetech' is highly appreciable.

Due to population growth, economy expansion and improved quality of life, energy usage is expected to rise. As about 55% of the country's energy need is met by coal, coal requirement is expected to rise in the future. A major portion (about 95% in the year 2018-19) of coal produced by CIL is by opencast method. Efforts made in the past towards increasing share of coal production from underground mining have not yielded desired results for various reasons. So, the onus of meeting the increasing coal requirement is on opencast. In the present scenario of stringent Environmental rules, stringent rehab and resettlement rules, increased depth of mining, etc., augmentation of coal production to meet the coal requirement pose a great challenge. Thrust is on planning larger mines with larger capacity equipments, reduction in cost of production, enhanced safety, and environment friendly technology to achieve a sustainable growth within the statutory framework.

I am sure that the technical papers in this special issue of Minetech would address all the relevant areas of 'Opencast Mining' that would benefit the industry for desired production.



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Contents

Opencast Mine Planning

Devendra Pratap Singh[1]*, Arun Kumar Bal*[2]*,*
Dipankar Bhattacharjee[3]

INTRODUCTION

Increased demand of minerals has led to increase in size and depth of opencast (OC) mines all over the world. In the coal mining sector, it has been found beneficial to open large OC coal mines for reasons of economy of scales.

Underground mining being more hazardous and less economic compared to opencast operations, there has been continuous endeavor to operate larger and deeper OC mines. There has been a continuous increase in the size of the opencast mining machinery facilitating larger and deeper opencast mines to be operated profitably.

Depth of operations in India has been gradually increasing which currently stands at a maximum of about 270m. Many mines have been planned upto depths of 300m and above. The deeper deposits have to be mined at high stripping ratios involving large scale movement of overburden.

The scale of operation in India has increased considerably with some mines producing more than 30 Million Tonnes of coal per year (with the largest mine producing over 42.00 Mty) by using large capacity heavy earth moving machineries (HEMM).

Needless to say that operation of larger size of the OC mines requires suitable state of the art technology, which demands meticulous planning of the mines using latest techniques, making the planning of such mines very challenging.

OBJECTIVE

The objective of opencast mine planning is to extract the optimum quantity of coal for:

- Higher Percentage of Recovery: In UG operation recovery is of the order of 40 to 50 %, whereas OC operation permits more than 90% recovery
- Better Economy: Better economy due to higher production capacity, early return on investment etc.
- Better Safety: Opencast mining operations are relatively safer compared to UG operations
- Higher Capacity of Production: In opencast mines rated capacities of production are generally high due to less constraints in

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deployment of excavating machines in free and open spaces of OC mines.

- More Amenable to Efficient Mechanization: Constraint free open spaces allow better mechanization.

BASIC CONSIDERATIONS

Planning starts with the process of taking some important decisions at the very outset. Based on these decisions the details of planning is done by a team of planners of multiple disciplines. Considerable time and efforts are put to shape the planning process, which is finally brought out as a report comprising of text, economic appendices and plans & sections. It may clearly be understood that planning may end up with painstaking rework of the entire process in case the basics are not considered with due diligence. Provided below are the basic considerations in brief.

THE BLOCK

Block area, adjacent blocks, borehole density, evacuation arrangement, availability of power, land use, degree of habitation, greenfield/brown-field etc. are important particulars of a geological block and deciding factors for various techno-economic parameters of an opencast project (OCP).

Block area is one of the influencing basics for fixing size, target capacity, degree of mechanization, size of the HEMM, etc. of the OCP.

Adjacent block dispositions are responsible for deciding location and quantity of external dump, location of infrastructure, size of the quarry (in case of non-availability of land for external dumping outside the block), etc.

Borehole density imparts degree of confidence about the reserves i.e. Proved, Indicated and Inferred reserves.

Evacuation arrangement i.e. Road, Rail, Water way etc. influences design of the "load out arrangement", location of the access of the mine, location of the surface infrastructure of the mine, etc.

Availability of power influences type of mechanization, i.e. Diesel or Electric.

Land use and surface features e.g. (i) presence of forest land influences the shape and size of the project. Generally no infrastructure and external dumping is allowed in forest lands (ii) presence of villages influences the shape and size of the quarry. (iii) presence of habitation restricts blasting leading to selection of blast free equipment (iv) presence of rivers influences shape and size of the quarry, decides requirement of safety provisioning e.g. embankment etc., it may provide evacuation of mineral through water way.

Degree of habitation influences R&R, land acquisition, economy, infrastructure cost, workers availability and requirement of residential houses for workers.

Greenfield or Brownfield may influence in deciding quarry sequencing, Technology selection if already worked by underground method, etc., manpower provisioning, equipment provisioning, investment on land, investment on infrastructure, mine economics, quarry plans and sections, safety provisioning etc.

SURFACE FEATURES

Surface features include presence of river, presence of important roads, railway lines, presence of high tension power lines, topographical undulations like hills, valleys, etc.

River often influences number of important considerations e.g. shape and size of the quarry, number of quarries, safety provisioning i.e. embankment etc. Most importantly river provides the option of evacuation of mineral through water way, presumably the best transport route for material.

Rail, Road & Power Lines also like river may influence shape and size of the quarry, number of quarries, provisioning of additional infrastructure like flyover etc. This provides the option of rail and road transport.

Presence of hills & valleys may govern the shape and size of the quarry, location of entry to the quarry, number of quarries, sequence of mining operation etc.

NATURE OF DEPOSIT

Nature of coal deposits is the most important consideration for determining geometry, equipment provisioning, infrastructure requirement, capital provisioning etc. for an OCP. This comprises thickness of seams, number of seams, initial depth and depth of occurrence of seams, stripping ratio, geological disturbances, gradient of seams and strata, geotechnical parameters of strata, hydrogeology of the area and finally the grade of coal.

Thickness of seams influences estimation of rated capacity, selection of type, size and number of equipment, mine scheduling, percentage of extraction, etc.

Number of seams influences selection of type, size and number of mining equipment, elements of mining system i.e. bench parameters etc.

Initial depth and depth of occurrence of the seams influences parameters like extent of the quarry, external waste dump quantity & area, selection of technology, e.g. high angle conveyors, crushing conveying and spreading etc.

Stripping Ratio (SR) is the quantity of waste material needs to be removed before mining of a unit of revenue mineral. It can be clearly understood from the definition that higher the requirement of quantity of waste removal per unit of revenue mineral, higher the cost of production. Mine economics is primarily dependent on SR. It is the major deciding factor for limiting the size and shape of the quarry.

Geological disturbances, such as presence of faults, etc. influences decisions on selection of technology i.e. Surface miner, Dragline, etc. It also influences calculation of quarriable reserves, shape and orientation of the quarry etc.

Gradient of seams influences mining system i.e. incline slicing or horizontal slicing, direction of operation i.e. whether advance of the quarry in the dip direction or strike direction, terrace mining, size of the quarry, selection of technology e.g. Dragline, Surface miner etc.

Geo-technical parameters influences again selection of technology e.g. Bucket wheel excavator, ripper, rock breaker etc., design of the slopes of the mine, blast- hole design and selection of explosive etc.

Hydrogeology influences selection of pumps, design of the slopes of the quarry and internal dumps etc.

Grade of coal is a major consideration for deciding the cut off stripping ratio of the quarry, which ultimately decides the depth of operation.

PLANNING PROCESS

Inputs from geological reports

Following inputs required for opencast mine planning are taken from Geological Report:

Borehole Data: The location of the boreholes along with disposition of the seams within the boreholes serve the purpose of modeling of the deposit in 3D platform before undertaking the quarry planning.

Seam structures: This is a major input requirement for 3D modeling.

Seam Quality Data: This input is also modelled along with seam modelling for determining predictive quality of coal while mining.

Location Plan: It shows the location of the Block.

Surface Plan: For understating the surface features & topography and finally taking them into account in the planning process.

Geological Plan: An important input for proposing the extent of quarry, mine entry and sequence of mining etc.

Floor Contour Plan of each Seam: Required when these are used for 3D modeling instead of bore-hole data. Usually for modeling of old GRs, this technique is followed.

Seam Folio Plan of each Seam: Required when these are used for 3D modeling instead of bore-hole data.

Seam-wise Geological Reserves, etc.

Geological Modelling

Geological Model of the deposit in 3D is developed by Geologists through software with the help of Borehole Database or Geometry Data i.e. surface contours and floor contour, iso-chore & iso-grade plans of seams.

Geological Reserves

Geological Reserves of the Geological Block are estimated through the software, which works on algorithms, developed for estimation of reserves by different statistical techniques.

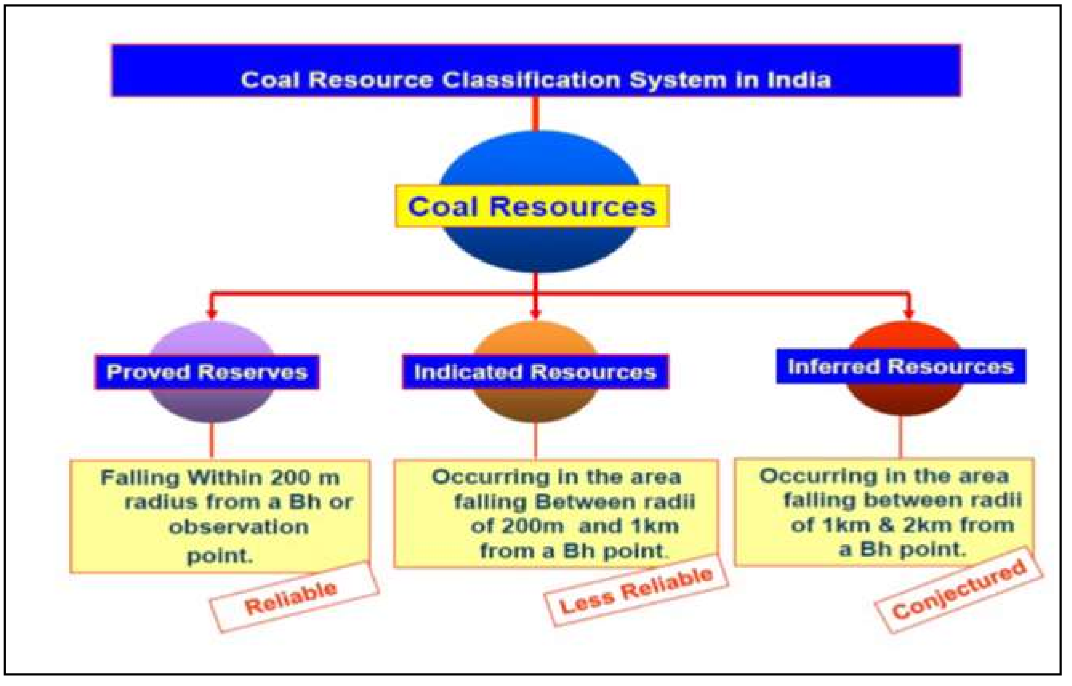
As per ISP (Indian Standard Procedure) reserves can be classified as follows:

As per statute [Coal Mines Regulation(CMR) 1917], barriers of required size should be left in all directions against river, nala, other water bodies, road, rail-line, powerline, underground workings, other block/mine boundary, other surface features etc.

Maximum depth of working should be decided on techno-economic considerations.

Mining Model

After fixing the mine boundary, Mining Model is developed through software from the Geological Model. The mining model of the proposed quarry is developed in 3D platform and eventually dividing the final quarry into strips & blocks or staged pits.



Delineation of Quarry Boundary

Mine boundary is delineated taking into account the basic considerations as explained above. In case there are no constraints, the dip side limit of the quarry may be delineated initially by cut off ratio line, which will be adjusted by stripping ratio.

Cut-off ratio line is basically the line drawn based on ratio of total waste thickness to total seam column thickness. The selection of cut-off ratio line varies for different grades of coal.

Reserve Estimation

Geological Reserves of the quarry are estimated through the software using the mining model. Geological and mining losses due to geological disturbances and due to dilution at the roof and floor of coal seams are taken into account as per standards for arriving at Mineable Reserves of the quarry. If there is any underground working in the block, %age of underground extraction is estimated and deducted from the Mineable Reserves to arrive at Extractable Reserves.

Selection of Mining Equipment

The following selection criteria are considered for selection of type, size and number of equipment:

Strike length of mine, seam gradient, geo-mining condition, total volume of coal & overburden (OB) to be handled annually, life of the mine, productivity of equipment, quality of coal, thickness of coal seams & partings, depth of working, whether seams are virgin or worked by underground, cost of equipment & operating cost, mine economics, etc.

DRAGLINE MINING

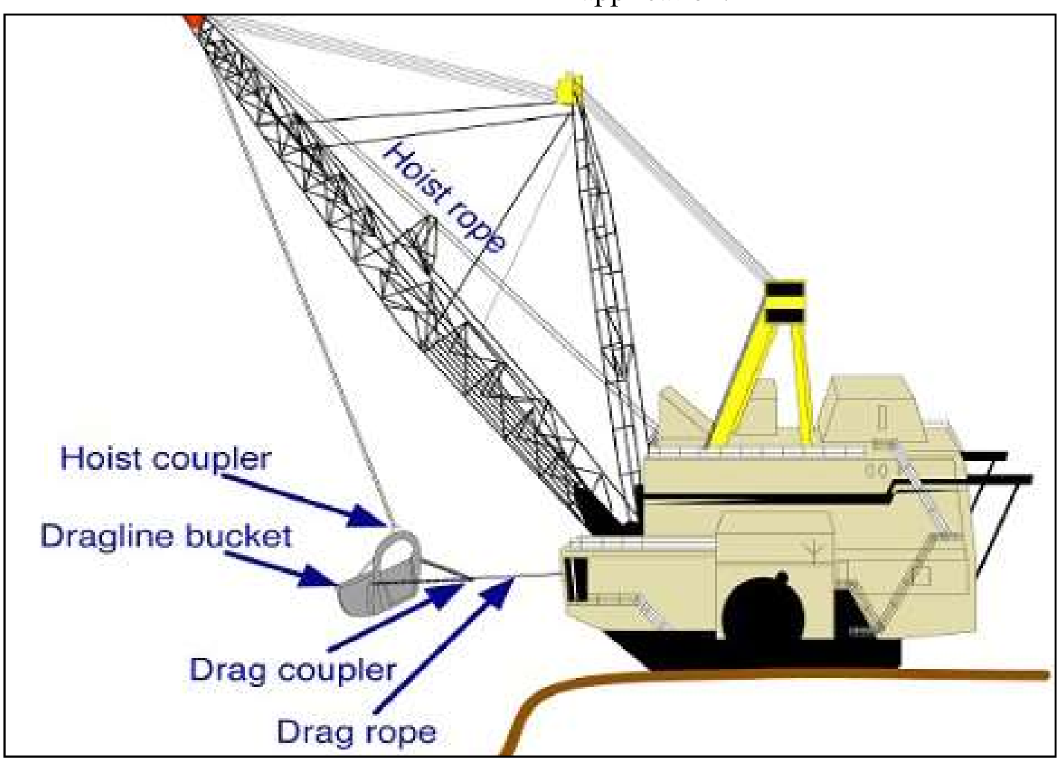
- Dragline mining is the most cost effective, very efficient and most reliable technology for the bedded deposits and is the first-choice technology for large opencast mining, where applicable.
- Draglines do not require dumpers for transport of the mine waste as the overburden stripped by the draglines is directly cast into de-coaled area.
- Common sizes of draglines used in CIL are 10/70, 15/90, 20/90, 24/96 & 30/88.
- Largest draglines operating in the country are 61 cum bucket capacity with boom length of 100 m.
- The commitment to deploy dragline(s) has to be a long term strategy.
- Outsourcing options is not very favorable for dragline application since the durations of the outsourcing contracts are generally for limited period (2-3 years) only. Even the extended contract periods are not more than 8/9 years in general.
- The way out for the projects attracting dragline deployment could be:

–Draglines are purchased departmentally and are given out on operation & maintenance contracts.

–Alternatively, the dragline(s) can be purchased by the outsourcing agency with arrangements to transfer the same to the coal producing subsidiary at the end of the initial contract period at pre-determined price.

Applicability

- Flat deposits, gradients preferably not more than 7 degrees to permit back dumping of OB in de-coaled area.
- Thick bottom most parting to suit dragline application.



- Seam thickness should not be more than 25m so that it can be worked in maximum two benches and allow the Dragline OB back dump clear of the bottom Coal.
- The property should be free from geological structural disturbances like occurrence of faults, uniformities, undulation & swing of the floor contour etc.
- Dragline is used for removing soft or well fragmented overburden above the coal.
- The property should be large enough ensuring life of 25 years or more, so that impact of heavy capital investment can be diluted.
- Strike length of the deposit should be preferably 1.5 to 2 km & more to avoid its frequent shifting.

SHOVEL- DUMPER MINING

Rope Shovels

- Low operation & maintenance cost of rope shovels make them ideally suited for stripping overburden in large quantities.
- Common sizes of Rope Shovels used in CIL are 5cum, 10cum, 20cum & 42cum.

Applicability

- Life of the mine should be long enough to match the Rope Shovel life.
- Rope shovels are generally used for OB removal.
- It can be used in any geo-mining conditions.

Hydraulic Shovels

- Hydraulic Shovels are ideally suited for selective mining and for operation in low bank heights in medium hard strata conditions.
- Popular bucket ranges used in CIL are 0.8 to 2.6cum, 2.7 to 4.2cum, 5 to 6cum, 10 to 12cum & and many other ranges.
- Currently, 34 cum bucket capacity hydraulic shovels are the biggest hydraulic excavators deployed in the country.

Applicability

- It is the most flexible excavator used in opencast mines.
- It can be used in any geo-mining conditions.

Transport Equipment

- Dumpers offer the most flexible means of transporting the mined coal or overburden to the designated areas.
- Popular sizes of dumpers used in CIL are 35T, 60T, 100T, 120T & 240T
- The major problems associated with dumpers are:
  – Availability of Diesel in Long Term.
  – Global shortage of tyres for dumpers.

Rope Shovel

Hydraulic Shovel

- The alternative modes of transport can be conveyor belts associated with in-pit crushing arrangement especially when the long hauls are involved to external dumps and the pit size & the scale of mining operations permit application of such technology.

CONTINUOUS MINING TECHNOLOGY

Bucket Wheel Excavators (BWE)

- Finds application in relatively softer strata.
- The current deployment of Bucket Wheel Excavators in India is limited to 700L and 1400L size unit.
- Conveyor systems of 1600 mm, 2000 mm & 2400 mm are in operation in the mines of NLC.
- Tripper cars and Spreader systems of 11000TPH & 20000TPH are already in operation in NLC.
- There is a need to explore the possibility of deploying Compact Bucket Wheel Excavators along with Belt Wagons / Mobile Transfer Car (MTC), wherever applicable, to reduce the cost of these systems.
- The Conveyor Bridges, though capital intensive, can considerably reduce the cost of mining when used in appropriate conditions.

Applicability

- It is applicable in relatively softer strata e.g. lose/sandy soil & lignite deposits.
- It is suitable for flat deposits.
- Free from geological structural disturbances like occurrence of faults, uniformities, undulation & swing of the floor contour etc.
- Life of the mine should be long enough to match the BWE life.
- Strike length of the mine should not be less than 1 km.
- Economy of the mine must be such as to permit the use of costly BWE.

OTHER MINING TECHNOLOGIES

In-Pit Crushing & Conveying

- As mines go deeper, increased excavation would warrant higher capacity equipment and adoption of alternative technologies in specific cases.
- Mobile in-pit crushing and conveying technology

Bucket Wheel Excavator

Bucket Wheel Excavator

In-pit Crusher

for coal is in operation at the Piparwar opencast mine of CCL.

- Shiftable in-pit crushing & conveying system for overburden is in operation at the Ramagundem-II mine of SCCL.
- These technologies have, however, been associated with high initial capital & and have been found to be economical in specific conditions.
- Introduction of crushing and conveying technology in mines may provide an alternate solution for opencast mining, under specific conditions.

SURFACE MINER

- Some of the opencast coal mines of ECL, CCL, SECL, NCL and MCL are using surface miners for extraction of coal.
- Presently surface miner is used as cutting machine only and pay loader has been added for loading the coal into the tipping trucks.
- Advantages of Surface Miner technology:

  - Elimination of drilling & blasting
  - Environmental problems of blasting like fly rock, ground vibration etc. are eliminated.
  - Selective mining.
  - Less coal loss.
  - No primary crushing required.
  - Good fragmentation.

- The surface miner-payloader-tipping truck/ dumper combination increases the cycle time of operation.
- Surface miners performance :

  - 750 to 3400 TPH in soft strata
  - Upto 475 TPH in hard strata
  - Upto 100 TPH in very hard strata

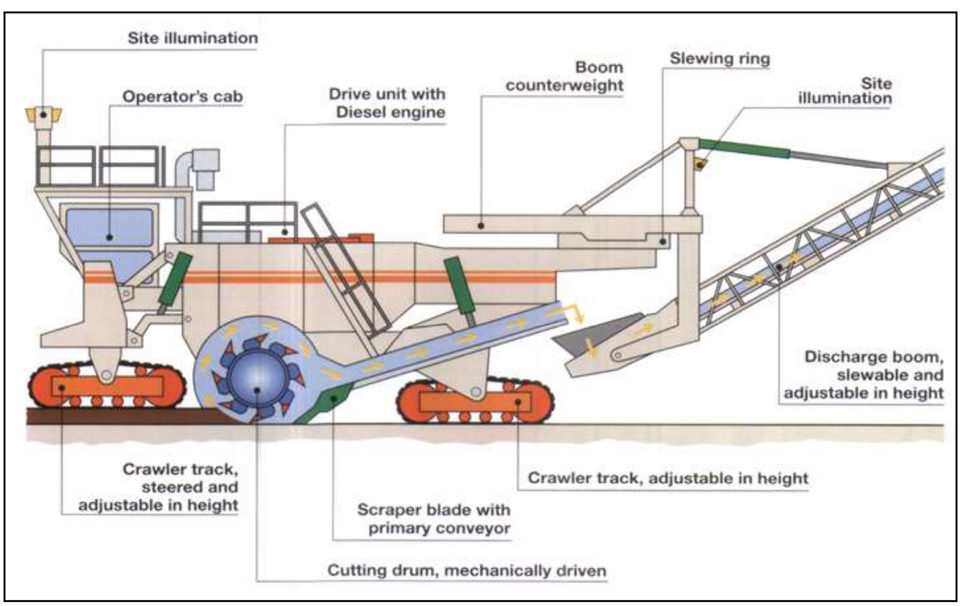
- Performance in hard to very hard strata still to be proven in Indian scenario.

Applicability

- It is suitable for flat deposits.
- It is suitable for deposits free from geological structural disturbances like occurrence of faults, uniformities, undulation & swing of the floor contour etc.
- It is suitable for virgin deposits.

HIGH ANGLE CONVEYOR (HAC)

With the increase in depth of opencast mines and under suitable geo-mining conditions, High Angle Conveyor (HAC) may be favored for better economy, better productivity, eco-friendly, traffic -friendly and space & energy saving solution for transporting coal/mineral from quarry floor to surface and also to load silos.



Surface Miner

Present Proposals for High Angle Conveyor:

High Angle Conveyor has been proposed in the following opencast coal mines of India:

- A Pilot Project in Gevra OCP (SECL).
- 3 sets in Gare Palma Sector-I OCP (GSECL)
- 2 sets in Kotre Basantpur OCP (CCL)
- 1 Set in Kalyaneshwari OCP (BCCL)

After detailed deliberations and discussions with manufacturers of HAC, two types of structural designs are approved for a feasible application in a mine: (i) Single Run System & (ii) Modular System.

Following are major factors governing a HAC structure for conveying material in a mine:

- Depth of working (for higher depth Modular System is used).
- Whether the dip of the seam permits internal dumping
- Rate of advance of coal face and internal dump
- Rate of deepening the pit
- Whether a Dump truck can pass underneath
- Ease of maintenance in a pit environment
- Mine Safety, Blasting parameters, Fire, Slope stability, material rolling back etc.
- Dependability to handle large quantities, break-down analysis/unscheduled maintenance.

Applicability

Type of material (Lump size & Density)

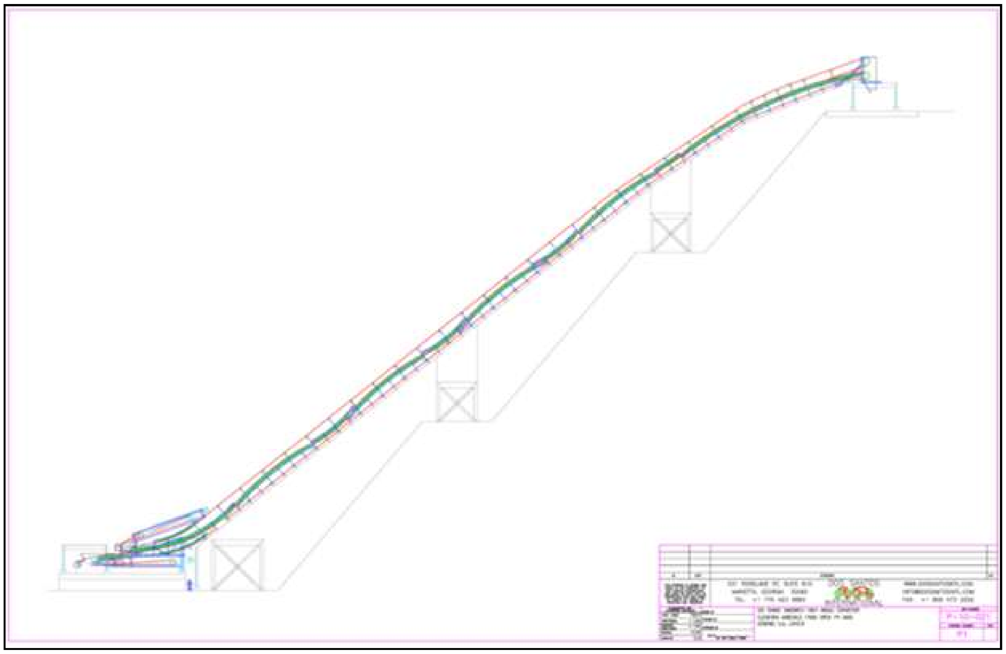
Coal with a lump size of preferably < 200 mm and density-wise suitable for all types of coal & for OB, it is suitable upto 2.4 t/cum. Coal must be evenly distributed for effective sandwiching and to avoid material falling back within the sandwich region.

Conveying Capacity (Tonnes per hour)

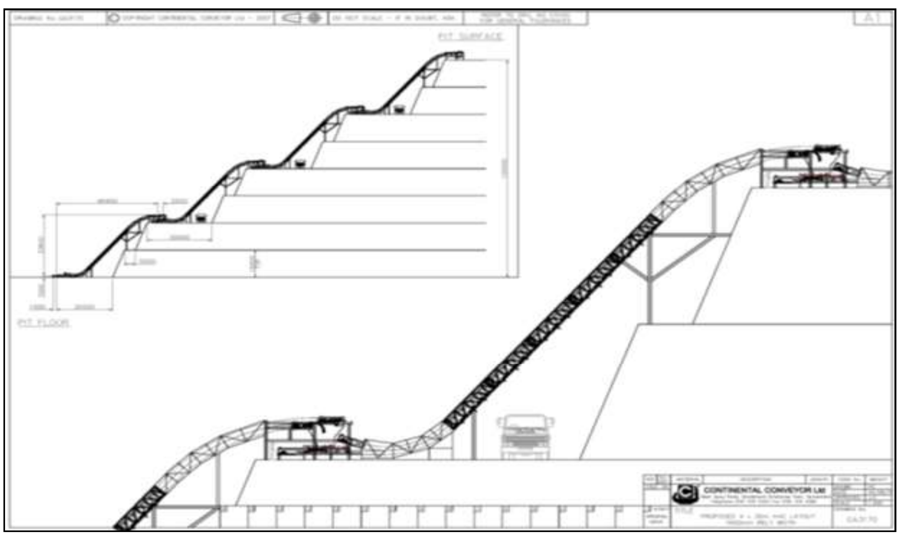
The system can be efficiently used up to a capacity of 4000 TPH, however, it is always recommended to use two sets of 2000 TPH each to take care of unforeseen circumstances. The system has not been tested for a capacity beyond 4000 TPH despite popular claim of capacities up to 10000 TPH.

Positioning of HAC unit

After testing no. of positions for HAC unit, it is decided to put it on side batter for most practical purpose. As a coal mine is typically multilayered, coal can be brought to the bottom most seam floor



Single run snake conveyor with mobile crusher



Modular Sandwich Conveyor in a deep Pit

if the parting is in between 30 to 50 meters, or a separate HAC unit can be planned for upper seams for greater parting thickness. Each project must be thoroughly examined for exact requirement.

Angle of lift

The belt is capable of carrying load up to 70^0.

Depth of working

For higher depth Modular System is used.

Temperature and Moisture

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

Other relevant information which may impact upon the application

- Mobile/Semi-mobile crusher of matching capacity will also be required inside the pit if the pit is not workable with Surface Miner.
- Crusher/ Reclaim Feeder will be fed by Dumpers carrying coal from different load zones.
- In some cases coal will be carried down the road and all precautions must be taken to avoid uncontrolled rolling of trucks.

- Further structural engineering studies need to be carried out to favorably accommodate the HAC system on the side batter and to ensure smooth mobility of HAC modules as the pit advances. Largest Dumper size is to be considered for passing underneath the structure where internal dumping is proposed.

TRUCK DESPATCH SYSTEM (TDS)

TDS offers a viable solution to improve communication, monitoring, dynamic allocation of trucks to shovels avoiding idle times of shovels and dumpers both and helps to achieve maximum utilization of shovel-dumper combination system working in the mine.

ANNUAL PRODUCTIVITY

Annual productivity of selected Mining Technologies are derived considering multiple parameters e.g. rock quality, distance of travel, equipment capacity, gradient of mining, specific gravity of the material to be handled, etc.

TARGETED ANNUAL CAPACITY

Generally targeted annual capacity of the mine is decided based on coal packet thickness, strike length of the quarry, rate of annual advance, specific gravity of the material to be handled, etc. The demand scenario is also an influencing factor for determining annual capacity of the mine.

MINING SCHEDULE

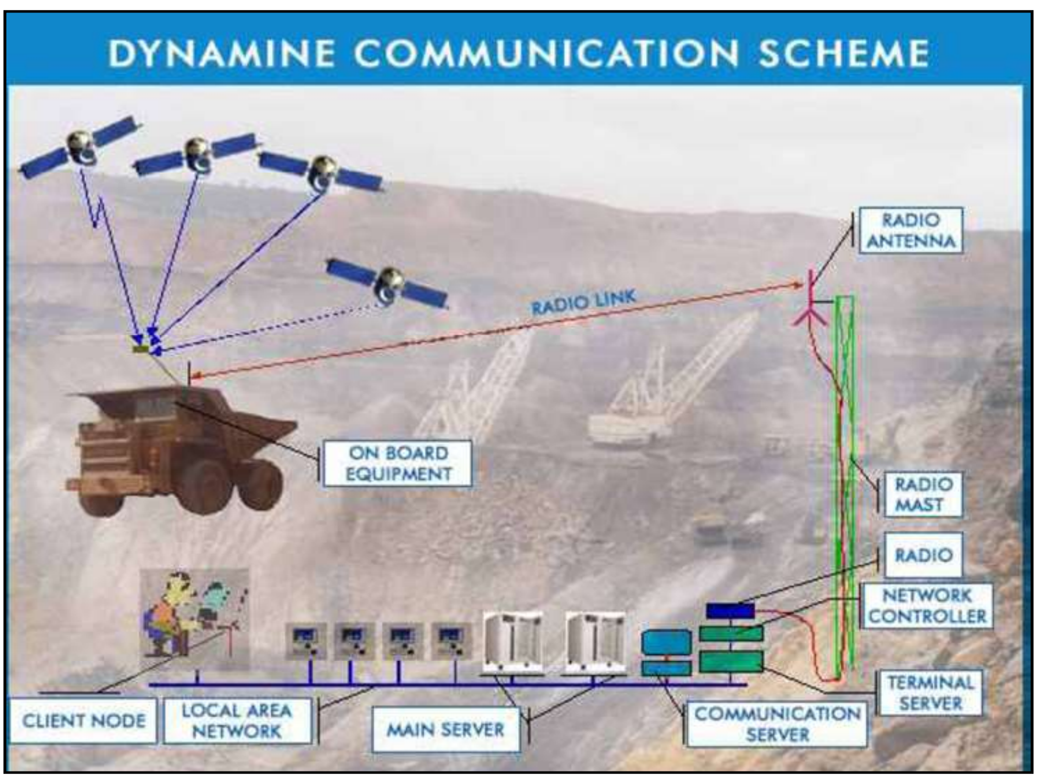
Year-wise schedule of coal/mineral production and OB removal is prepared based on the above derived mine capacity, annual productivity of selected Mining Equipment, sectorial mineable reserves, stripping ratios etc.

Scheduling is basically dividing the final pit into strips & blocks/staged pits/sectors, Formulating mining schedule of each sector by deriving annual coal production and OB removal and finally preparation of a combined schedule of the quarry out of the sectoral schedules. Sectors are strategically decided based on sequence of advance of the quarry, normally from lower stripping ratio zone to higher stripping ratio zone.

Sectors are strips and blocks in case of scheduling through software.

MINE LIFE

A Mining Schedule gives the clear picture of



Mine Life. It comprises of:

Construction Period: It is taken generally 2 to 4 years for a greenfield project for clearances, land acquisition and for development of infrastructure like construction of approach road, workshop, railway siding, CHP, office building etc.

Production Build-up Period: From the start of coal production or OB removal or both upto the target year.

Production Period: Period upto which targeted capacity of coal production is achieved.

Tapering Period: Period from which coal production reduces from the rated capacity till the exhaustion of mineable reserves.

Total Mine Life: Addition of no. of years of all the above periods will give total mine life.

POPULATION OF HEMM

The population of major HEMM are arrived after considering the following:

- Size of HEMM
- Workload for different HEMM based on Mining Schedule.
- General deployment pattern of different HEMM.
- Prevalent Productivity norms for different HEMM.
- Transportation lead for coal and OB dumpers.

EQUIPMENT PHASING

Procurement of equipment is done in a phased manner as per requirement for year-wise matching coal production and OB removal targets as per Mining Schedule. Phasing is done for systematic capital investment on HEMM.

PREPARATION OF PLANS AND SECTIONS

Based on the above Mining Schedule, stage plans of various stages e.g. Initial Mine Cut Plan/ 1st Year Stage Plan, 5th Year Stage Plan, 10th Year Stage Plan, 20th Year Stage Plan, Ultimate Quarry Plan, Final stage dump plan, seam & quarry sections with elements of mining system etc. are prepared. Along with these stage plans, location plan, surface feature plan, geological plan, floor contour & folio plans of all the seams, underground working plan in case of developed underground workings, pre-mining land-use plan, reclamation/post mining land-use plan are also prepared. These are prepared with the help of the mining and CAD software's.

DUMPING SCHEDULE AND DUMP DESIGN

With the help of mining software, the quantities of OB to be accommodated internally and externally at different stages of the mine are estimated. Based on it, year-wise and dump-wise Dumping Schedule is prepared.

Based on the above Dumping Schedule, external and internal OB dumps at various stages are designed with the help of mining and CAD software.

LAND REQUIREMENT

Land in the project area is broadly available in different categories i.e Tenancy, Government and Forest categories. Land rates are different for different categories. Estimation for capital investment on land is made accordingly.

MANPOWER REQUIREMENT

Requirement of manpower can be broadly divided under the heads of operation, maintenance, dispatch, supervision and others. Operation manpower is required for operation of the HEMM in the mine, whereas maintenance manpower looks after the maintenance of these HEMM. Supervisors are required for supervision of mining activity, operation and maintenance of HEMM and other activities of the mine. Safety is an important aspect of mining and requires statutory supervisory manpower for its strict assurance. Dispatch section of the mine requires separate set of manpower. Stores, survey department, personnel & welfare, finance, planning, security, magazine, pumping, substations & other electrical sections, civil, dispensary, environment, reclamation etc. are the other sections where there is need of separate set of manpower.

COAL HANDLING & DISPATCH ARRANGEMENT

Based on annual targeted capacity and

customer, output size of the crushed coal/mineral, coal handling arrangement, mode of dispatch, etc. of the OCP is proposed. It comprises of primary and secondary crushers for crushing ROM coal to desired size. Series of conveyors for handling this crushed coal to bunker and finally to a hopper, silo or any other suitable load out arrangement for final dispatch to the end user/customer either through rail, road, conveyor or water ways.

COAL BENEFICIATION / WASHERY

- Non Coking Coal

  Proposal for Washeries will be done in Projects having Ash% more than 34% & Coal Production of 2.5Mty or more and coal is transported for a distance more than Govt. approved distance.

- Coking Coal

  Washeries may be proposed in Projects having Ash% more than 18%.

ELECTRIC POWER

On the basis of estimated power demand, installed capacity of the substation is determined. The maximum power demand is the cumulative of the individual load on electric HEMM, CHP, Workshop & store, Illumination of the mine, office & colony etc. The power lines to the sub-station is drawn from the nearest available source of supply. Provisioning is also made on electronics and telecommunication for the purpose of communication in the project and the mine.

CIVIL CONSTRUCTIONS

Provisioning on civil constructions are made for the project, the extent of which depends on the size of the project, location, manpower provisioning etc. Civil constructions include service & residential buildings, roads & culverts, Water Supply & Sewerage, nala diversion, embankment, garland drains, fencings, R&R welfare amenities, magazine, township amenities including community building, statutory infrastructure e.g. pit head bath, canteen, crèche etc.

MINE ECONOMICS

The technical provisioning for the OC mine is followed by economic evaluation of the project based on DCF (Discounted cash flow) method for a life of 25 years or mine life whichever is less and calculate the IRR of the project for management decision making purpose. If IRR of the project is more than Hurdle rate/desired rate, then accept the project otherwise reject the project. In the case of projects in which IRR is less than hurdle rate and customer available in the market to purchase the coal at desired selling price at desired/hurdle rate then also the project may be accepted by the management.

The cash flow consists of cash out flow and cash inflow, in which cash outflow consists of Capital expenditure, Replacement capital expenditure, operating expenditure and cash inflow consists of Sales realization of coal and residual value of the assets at the end of the life or 25 years whichever is less.

Capital Expenditure:

The capital expenditure estimation consists of following heads:

1. Land
2. Service buildings & residential buildings
3. Plant & Machinery
   a. HEMM
   b. Other than HEMM
      i. Electrical P&M
      ii. Workshop
      iii. Pumps & Pipe fittings
      iv. CHP
      v. Telecommunication
      vi. Other P&M (Survey, Surveillance, Pollution control equipment etc.)
4. Furniture and fittings
5. Railway siding
6. Vehicles
7. Prospecting & boring
8. Mine development
   a. Capital outlay in the mines including R&R cost of Land
   b. Roads and culverts
   c. Water supply & Sewerage
   d. PR & EMP preparation
   e. Scientific research

9. Revenue expenditure capitalized

Replacement Capital Expenditure:

The replacement capital is estimated based on the survey-off norms published by CIL and life of the assets.

Operating Expenditure:

The operating expenditure estimation consists of following major heads:

1. Salaries & wages
2. Stores cost
   a. Diesel cost
   b. Lubricant cost
   c. Repair & maintenance cost
   d. Explosives cost
   e. Other Misc. Costs
3. Power cost
4. Miscellaneous cost
   a. Provision for TA/DA, Stationary etc.
   b. Workshop
   c. Repair & Maintenance of civil, railway siding, vehicles etc.
   d. Environment related cost
   e. Hire charges of Manpower & vehicles
   f. Other Misc. Costs
5. Mine closure cost
6. Administrative cost
7. Outsourcing cost of outsourcing activities
8. Interest on working capital
9. Depreciation/Amortization(if any)
10. Interest on loan capital (if Loan capital invested in the project)

Note: - The year wise cash flow of the above heads estimated and shown in the separate appendix in the PR at 100% capacity utilization & 85% capacity utilization. Cost per tonne under above specified heads calculated and shown in the project report as separate appendix for management decision making purpose.

Sales realization:

The sales realization of the project based on the geological grade/declared grade of the coal and notified selling price of CIL for the respective grades, in which deduction of 5% as a coal quality deterioration/ grade slippage.

The other charges like Sizing charges, Rapid loading system charges, Surface transportation charges, evacuation charges and other charges if any added to the sale price for estimation of cash inflow of the project.

Based on the above estimations we calculate the Net cash flow of the project and derive the internal rate of return for decision making purpose.

CONCLUSION

It may clearly be understood from the above that opencast mine planning is a multidisciplinary exercise with the involvement of very experienced, knowledgeable and hardworking planners. The correct decision making in the planning process, taking into account various parameters for the purpose, has far reaching effect on the success of the opencast project in achieving excellence in areas of production, safety, environment, return on investment and above all in the growth of the country.

Over the years Indian coal mining industry has gradually shifted to opencast mining method from underground mining method mainly due ever increasing demand of this fossil fuel in the society. There has been continuous change in type and degree of mechanisation with the change in size of quarry and structural needs of the deposits. Many of the issues related to opencast mining have been and are being resolved in the past or continually with application of either new technology or better techniques. However, the recent slope failure accidents at some of the OCPs of ECL has brought in the challenge of making opencast mining safer, which used to be considered as less affected by perils of mine accidents. Taking cognigence of this accident, DGMS has come up with newer regulations in its Coal Mine Regulation 2017, where many precautions have been suggested for safe working of OC mines. In coming years, more and more design aspects are to be addressed while planning of opencast projects for making this method of mining safer. Undoubtedly, this will be a new challenge to the planners in future.

Technology Used in Opencast Mines of Coal India Limited

Amar Kant Mishra[1]

INTRODUCTION

The opencast mining in Coal India Limited (CIL) has witnessed a sea-change in 21st century. It has contributed to raise the overall coal production of CIL from 268.14 Mt in 2000-01 to 606.89 Mt. in 2018-19 with the production of individual mine to reach as high as 42.25 Mt.(Gevra,SECL). It registered India as the 2nd largest coal producer in the World.

The unprecedented growth is a testimony of successful planning and execution of high capital projects that involve state-of-the-art heavy mining machinery. With an emphasis on bulk coal production with the opencast mining during this period, the underground mining played a supportive role.

Coal mining methods can be broadly classified as the opencast or strip mining and the underground mining. The choice of technologies available for these two methods is guided by geological, technical, economic and environmental considerations. Seam characteristics such as thickness, depth,

Coal production & OB removal of Coal India Limited for last 10 years:

Year	Production of Raw Coal (Million Tonnes)			Overburden Removal (Million Cum
	Opencast	Underground	Total	
2018-19	576.404	30.483	606.887	1164.680
2017-18	536.823	30.542	567.365	1178.120
2016-17	522.663	31.477	554.140	1156.377
2015-16	504.968	33.786	538.754	1148.908
2014-15	459.196	35.042	494.238	886.528
2013-14	426.310	36.110	462.420	806.540
2012-13	414.435	37.776	452.211	746.702
2011-12	397.450	38.390	435.840	735.140
2010-11	391.300	40.020	431.320	732.130
2009-10	388.010	43.250	431.260	682.030

[1]*CM (Excv.), OC Division, CMPDI (HQ), Ranchi- 834 008.*

ratio of coal to overburden, inclination or dip of the seams, strata conditions, volume of coal that can be recovered, multiplicity of seams, etc. all these earmark possible methods and technologies that are geologically feasible.

TECHNOLOGY IN OPENCAST MINING

High demand of coal can be admirably met with a phenomenal increase in the coal production that may result from the opencast mines to meet the ever growing needs of the economy. Phenomenal growth can be attained in coal production with greater emphasis on the opencast mining technology. Both from the considerations of volume of production as well as cost of production, the opencast mining prove its supremacy. Additionally, conservation with greater recovery of coal makes the opencast mining more acceptable to mine operators.

Coal India Limited has succeeded in adopting and absorbing the state-of-the art technology in the opencast mining. The Shovel-dumper system remains the pre-dominant technology. A wide range of hydraulic excavators prove successful for selective mining in medium hard strata condition. A number of mines deploy walking draglines for OB stripping operations. Mobile crushing and conveying system has added another feather to the value of this technology up-gradation. A wide scale application of Surface Miners at several projects is extremely encouraging both from the point of view of selective mining as well as enhanced output.

TECHNICAL MILESTONES IN OPENCAST MINING OF CIL

High capacity mining equipment inducted for the first time in opencast mines of CIL are as following:

Year	Equipment	Size	Project	Company
1981-82	Electric Rope Shovel	$10m^3$	Rajrappa	CCL
1981-82	Rear Dumper	85T	Rajrappa Kusmunda	CCL SECL
1983-84	Walking Dragline	24/96	Jayant	NCL
1983-84	RBH Drill	311mm	Jayant	NCL
1983-84	Rear Dumper	120T	Kusmunda	SECL
1988-89	Electric Rope Shovel	20 m^3	Amlohri	NCL
1988-89	Rear Dumper	170T	Amlohri	NCL
1991-92	Hydraulic Excavator	20 m^3	Rajmahal	ECL
1992-93	Dozer	770 hp	Piparwar	CCL
1993-94	Electric Rope Shovel	25 m^3	Piparwar	CCL
2006-07	Hydraulic Excavator	13/13.5 m^3	Rajmahal	ECL
2008-09	Dozer	860 hp	Jayant	NCL
2009-10	Electric Rope Shovel	42 m^3	Gevra	SECL
2009-10	Rear Dumper	240T	Gevra	SECL
2009-10	Water Sprinkler	70 Kl	Gevra	SECL
2009-10	RBH Drill	381 mm	Gevra	SECL
2009-10	Surface Miner	50 T Class	Belpahar	MCL
2010-11	Hydraulic Excavator	15 m^3	Gevra	SECL
2018-19	Rear Dumper	150T	Gevra	SECL
2018-19	Rear Dumper	205T	Amlohri	NCL

SELECTION OF EQUIPMENT FOR OPENCAST MINING

Walking Draglines

Dragline mining is the most cost effective technology for the bedded deposits and is the first-choice technology for large opencast mining, where applicable. Draglines have the advantage of being used as stand-alone equipment and do not require diesel guzzling dumpers for transport of the mine waste as the overburden stripped by the draglines is directly cast into de-coaled pit. Effort is made at the project formulation stage to suggest dragline application wherever feasible. Largest dragline operating in Coal India is of 33 m^3 bucket capacity with boom length of 72.5 m.

Population of Draglines in CIL as on 1.4.2019- 27 nos.

Electric Rope Shovels

Shovel-dumper mining is the most common technology in opencast coal mines due to inherent flexibility of its application. The past three decades have witnessed considerable up-gradation in the size of equipment as well as introduction of newer types of equipment. Low operating & maintenance cost of rope shovels make them ideally suited for stripping overburden in large quantities. Currently, 42 m^3 bucket capacity rope shovels are the biggest shovels deployed in Gevra, Dipka and Kusmunda opencast mines of SECL. It is expected that more and more nos. of 20 m^3 & 42 m^3 rope shovels will be deployed in the large coal mines of CIL. Rope Shovels deployment in Coal India Limited is moving towards global trends.

Population of Electric Rope Shovels in CIL as on 1.4.2019-240 nos.

Hydraulic Excavators

A wide range of hydraulic excavators prove successful for selective mining and for operation in low bank heights in medium hard strata conditions. In recent years, hydraulic excavators of larger size gain wider acceptance in opencast mines.

Currently, 15 m^3 bucket capacity hydraulic shovels are the biggest hydraulic excavators deployed in Gevra opencast mine of SECL. It is expected that more & more high capacity hydraulic excavators will be deployed in the large coal mines of CIL.

Population of Hydraulic Excavators as on 1.4.2019- 413 nos.

Rear Dumpers

Rear Dumpers offer the most flexible means of transporting the mined coal or overburden to the designated areas. Progressive advancement in design of new diesel engines, truck tyres and transmission systems has led to continuous increase in the size of rear dumpers. Currently, 240T capacity rear dumpers are the biggest off-highway trucks deployed in Gevra, Dipka and Kusmuda opencast mines of SECL. A worldwide trend of surface coal mining shows preference for dumpers with higher payload. Rear dumpers deployment in Coal India Limited is approaching international standards.

Population of Rear Dumpers as on 1.4.2019- 2655 nos.

Dozers

320 hp & 410 hp capacity dozers are commonly used in most of the opencast mines of CIL. High capacity dozers of 860 hp are also operating successfully in some of the big opencast mines of CIL.

Population of Dozers as on 1.4.2019 - 947 nos.

RBH Drills

RBH Drills of 160mm & 250mm size are widely used in opencast mines of CIL. 311mm RBH Drills are also deployed in some of the mines for drilling in overburden. Currently, 381mm drills are the largest size of RBH drills working in Gevra and Dipka opencast mine of SECL.

Population of RBH Drills as on 1.4.2019- 688 nos.

In-pit Crusher

The Piparwar opencast mine of CCL where

mobile crushing and conveying system is successfully operating has added another feather to the value of the technology up-gradation in opencast mines of CIL.

Surface Miners

A wide scale application of Surface Miners for wining of coal at several opencast mines of CIL is extremely encouraging both from the point of view of selective mining as well as enhanced output. This state-of-the-art technology is now proved to be a revolutionary technology in the present era. The Surface Miner technology eliminates drilling & blasting operation and also crushing installation. Compressive strength of rock is a major parameter that determines the suitability and efficiency of the surface miner technology.

Coal production from Surface Mines in CIL has been increasing over the years. Total Coal production from Surface Mines in last 6 years is as below:

Year	Coal Production by Surface Miners (Mt)
2013-14	170.82
2014-15	197.91
2015-16	233.84
2016-17	255.87
2017-18	265.76
2018-19	280.74

Population of Surface Miners as on 1.4.2019- 24 nos.

High Angle Conveyor

Developments in conveyor capability and improved performance has enabled coal mining technology to advance at an accelerated pace with it. Improvement in belt and drive technologies also allow longer flights and higher lifts. Scientific study for application of high angle conveying technology in coal mining has been being carried out at CMPDI.

Benchmarking of mining operations

No two mines are identical, so as the mining operations. It is rather difficult to standardize the mining operation due to the varied operational parameters such as geo-mining, techno-economic, administrative and operational parameters. Thus, benchmarking of mining operation will have to be based on certain specific / generalized conditions or parameters.

The major areas, where benchmarking can be used as a tool for improving operational efficiency of the coal mining companies, are:

Man productivity, and
Machine Productivity.

Man Productivity

Unlike underground mines, output per manshift (OMS) as a measure of man productivity has little significance in highly mechanized opencast mines. Profitability is largely influenced by the performance of capital intensive heavy earth moving machinery (HEMM) in opencast mines. OMS in opencast mines are largely influenced by geo-mining conditions and should not be used as a comparative index of performance. The focus of planning and subsequent implementation of opencast coal mining projects is to offer least cost solutions, rather than high OMS.

Growth in Man Productivity

At opencast mines, employees' productivity has reportedly improved steadily in the post nationalization period. It is evident from the table below that there has been noticeable growth in the man productivity in last 10 years.

Year	Average per Man per Year (tonnes)	Output per Manshift (OMS)		
		Opencast (tonnes)	Underground (tonnes)	Overall (tonnes)
2018-19	2126	14.68	0.95	8.51
2017-18	1899	14.10	0.86	7.71
2016-17	1787	15.26	0.80	7.53
2015-16	1671	14.35	0.80	6.95
2014-15	1484	13.13	0.79	6.20
2013-14	1334	12.18	0.76	5.62
2012-13	1263	11.48	0.77	5.32
2011-12	1173	10.40	0.75	4.89
2010-11	1125.10	10.06	0.77	4.73
2009-10	1085.93	9.51	0.78	4.47

Machine Productivity

Availability & Utilization of HEMM: Based on the experience and the recommendations of the committee, benchmarking/ norms for Availability & Utilization of mining equipment is done in CIL. Every year actual achievement of HEMM deployed in opencast mines of CIL is compared with the benchmarked figures and efforts are made to improve the performance.

Annual Productivity Norms of HEMM: Benchmarking of annual productivity of the commonly used walking draglines & shovels (with dumper combination) under standard geo-mining conditions are done.

Standard geo-mining conditions can be considered as:

i. Standard bench height & width;
ii. Optimum drilling & blasting with proper fragmentation of rock material;
iii. Matching combination of shovels with transport equipment;
iv. Appropriate gradient of the working bench and haul road, etc.

Deviation from the standard geo-mining condition will influence the aforesaid benchmarks.

Adoption of state of art technology in opencast mines of CIL

In view of an increase in demand of coal production from opencast mines, the strategies being adopted are:

Big Opencast Projects:

Expansion of existing projects, amalgamation of small projects & opening of more green-field projects of high capacity to suit the deployment of higher size equipment.

High Capacity HEMM:

Replacement of small equipment (after surveyed-off) with higher capacity equipment that would reduce the cost of operation and maintenance.

Standardization/up-gradation of HEMM:

CIL has standardized/ upgraded the mining equipment.

Operator Independent Truck Despatch System (OITDS):

In a bid to benchmark itself against global best practices and also to ramp up productivity, Coal India Ltd has introduced latest satellite-based technology for improving the utilization of heavy earthmoving equipment at its opencast mines.

Operator Independent Truck Despatch System (OITDS), which draws on global positioning system (GPS) and satellite technology, allows critical equipment used in opencast mines like dumpers and shovels to be utilized better, so that there is little idling, thus improving productivity of the machinery and operational discipline. This helps to reduce costs and improve productivity of HEMM.

Use of Software in Mine Planning:

Latest mine- planning software, viz. Minex, Vulcan, Carlson, Datamine, AutoCad, etc. are used for OB & coal reserve calculation and mine planning so that in operation the optimum output is achieved economically.

Use of Information Technology:

Coal India Limited has initiated ambitious information technology (IT) programme through Enterprise Resource Planning (ERP). Through ERP the information services will be provided efficiently to all CIL subsidiaries and their remotely located mining areas. Recently, CIL has launched mdms (Mine Data Management System) portal. These will improve overall management efficiency as well as productivity.

Use of Simulator:

Coal India Limited has been imparting training to HEMM operators through Simulators. This improves the operating efficiency & ensures safety.

Slope Stability:

Advance technology such as TLS (laser profiler), GIS, GPS, Total Station and Slope Stability Radars are in use in opencast mines for monitoring dump slopes and for predicting the slope failure in advance.

Safety:

Safety aspects of all mines are being improved with introduction of new technology & devices such as anti-collision devices, use of global positioning system (GPS) & rear view digital cameras etc.

Selection, Deplyoment & Performance of Draglines Working in Opencast Mines of CIL: An Overview

D Bhattacharjee[1], R C Dutta [2], A K Mishra[3]

BACKGROUND

The dragline, invented over a century ago in 1904 by John W. Page (USA), is now widely used primarily for the removal of overburden in long-life opencast mines. Draglines have the advantage of being deployed as stand alone equipment and do not require diesel guzzling dumpers for transport of the mine waste as the overburden stripped by the draglines is directly cast into de-coaled pit. Since dragline is electrically operated so it is more environmental friendly, more reliable, efficient and cost effective equipment. Effort is made at the project formulation stage to select dragline application wherever technically feasible and economically viable.

Fig. -1: "Big Muskie" prior to demolition in Ohio, February 1999

[1] GM (Mining), [2] CM (Excv.) [3] CM (Excv.), OC Divn, CMPDI (HQ), Ranchi-834008

Table-1: List of big size Draglines

SL. NO.	MAKE	MODEL	BUCKET SIZE (cum)	BOOM LENGTH (m)
1	KOMATSU/ JOY GLOBAL	9010C	42-60	80-105
		9020C	55-90	90-125
		9020XPC	85-122	100-130
2	CATERPIL-LAR	8000	32	72
		8200	46- 61	100
		8750	76-116	109-132
3	URALMASH / OMZ (Russia)	ESH 30/110	30	110
		ESH 40/100	40	100
		ESH 65/100	65	100
		ESH 100/125	100	125
4	HEC	W-2000	24	96

Very large draglines are now available with huge bucket capacity and longer boom that go in line with an uprising productivity. Presently there are three major manufacturers of draglines, i.e. JoyGlobal (USA), Caterpillar (USA) and OMZ (Russia). In India, Heavy Engineering Corporation (HEC), Ranchi is manufacturing W-2000 model walking dragline indigenously in collaboration with Rapier and Ransom.

"Big Muskie", a Bucyrus-Erie make, 4250-W model, dragline recorded to be the largest dragline owned by Central Ohio Coal Company (USA) with 170cum bucket size & 94m boom length which operated from 1969 to 1991. During its 22 years of service, Big Muskie removed more than 465 Mcum of overburden.

DRAGLINES WORKING IN COAL INDIA LIMITED (CIL): STATUS

- In India, the use of large walking draglines for stripping the overburden in large opencast coal mines is growing steadily.
- The dragline mining was initially introduced in India in early 60's and the first walking dragline was commissioned at Kurasia on 05.04.1961 (Make: Page, 11.5cum). This dragline worked for about 45 years before it was grounded on 17.02.2006.
- Marion 7800E (30cum) is the oldest working dragline (commissioned on 03.11.1964) at Bisrampur opencast mine of SECL & it has worked for about 240802 Hours (as on 31.3.2018) in last 54 years.
- Presently (as on 31.3.2019), there are 27 nos. of draglines in operation to remove overburden in different subsidiary companies of CIL other than CCL, having bucket capacity in the range of 5cum-33cum. More than half of total draglines of CIL (19 nos.) are working open-cast mines of NCL. (Table -2)
- The life expectancy of a draglines to be eligible for Survey-off have been fixed by CIL as 25 - 30 years.
- Northern Coalfields Limited (NCL) is the only subsidiary company of CIL, where the entire coal production is mined by opencast mining method and draglines have been deployed in all the major opencast mines of NCL, namely, Amlohri, Bina, Dudhichua, Jayant, Khadia and Nigahi.
- Last dragline (W2000, 24/96) commissioned in CIL on 25.1.2016 at Amlohri opencast mine of NCL.

Table-2: Draglines in CIL as on 31.3.2019

COMPANY	PROJECT NAME	SIZE / CAPACITY	No.	CIL Plant Number	Date of Commissioning
ECL	Sonepur Bazari	24/96	1	EXC 1885	09.11.1996
BCCL	Block-II	24/96	1	EXC 1575	04.12.1988
	South Tisra	5/45	1	EXC 1686	08.12.1989
WCL	Sasti	20/90	1	EXC 2214	17.06.1992
	Mugoli	24/96	1	EXC 1610	08.12.1991
SECL	Bisrampur	30/88	1	EXC 052	03.11.1964
	Dhanpuri	20/90	1	EXC 1310	10.04.1990
NCL	Amlohri	24/96	1	EXC 1725	01.07.1993
	Amlohri	24/96	1	EXC 2905	09.05.2014
	Amlohri	24/96	1	EXC 2977	25.01.2016
	Bina	24/96	1	EXC 1454	10.03.1986
	Bina	24/96	1	EXC 1455	06.04.1987
	Dudhichua	24/96	1	EXC 1393	09.08.1991
	Dudhichua	24/96	1	EXC 1918	16.08.1995
	Dudhichua	24/96	1	EXC 2156	15.01.1999
	Dudhichua	24/96	1	EXC 2354	10.10.2001
	Jayant	24/96	1	EXC 655	03.03.1985
	Jayant	24/96	1	EXC 1065	21.02.1989
	Jayant	15/90	1	EXC 245	01.04.1979
	Khadia	33/72.5	1	EXC 2910	07.01.2015
	Khadia	20/90	1	EXC 1698	02.10.1992
	Khadia	20/90	1	EXC 1849	03.07.1995
	Nigahi	24/96	1	EXC 2233	13.04.2002
	Nigahi	24/96	1	EXC 2270	15.04.2003
	Nigahi	20/96	1	EXC 1727	01.04.1992
	Nigahi	20/96	1	EXC 1761	25.03.1994
MCL	Bharatpur	20/90	1	EXC 1280	01.05.1989
		TOTAL	**27**		

Apart from above, some surveyod off dragline have also worked during 2018-19

Table-3

Company-wise populaion of D/L

Company	Population of D/L
ECL	1
BCCL	2
WCL	2
SECL	2
NCL	19
MCL	1
TOTAL	**27**

Size wise population of D/L

Size	Population of D/L
5 cum	1
15 cum	1
20 cum	7
24 cum	16
30 cum	1
33 cum	1
TOTAL	**27**

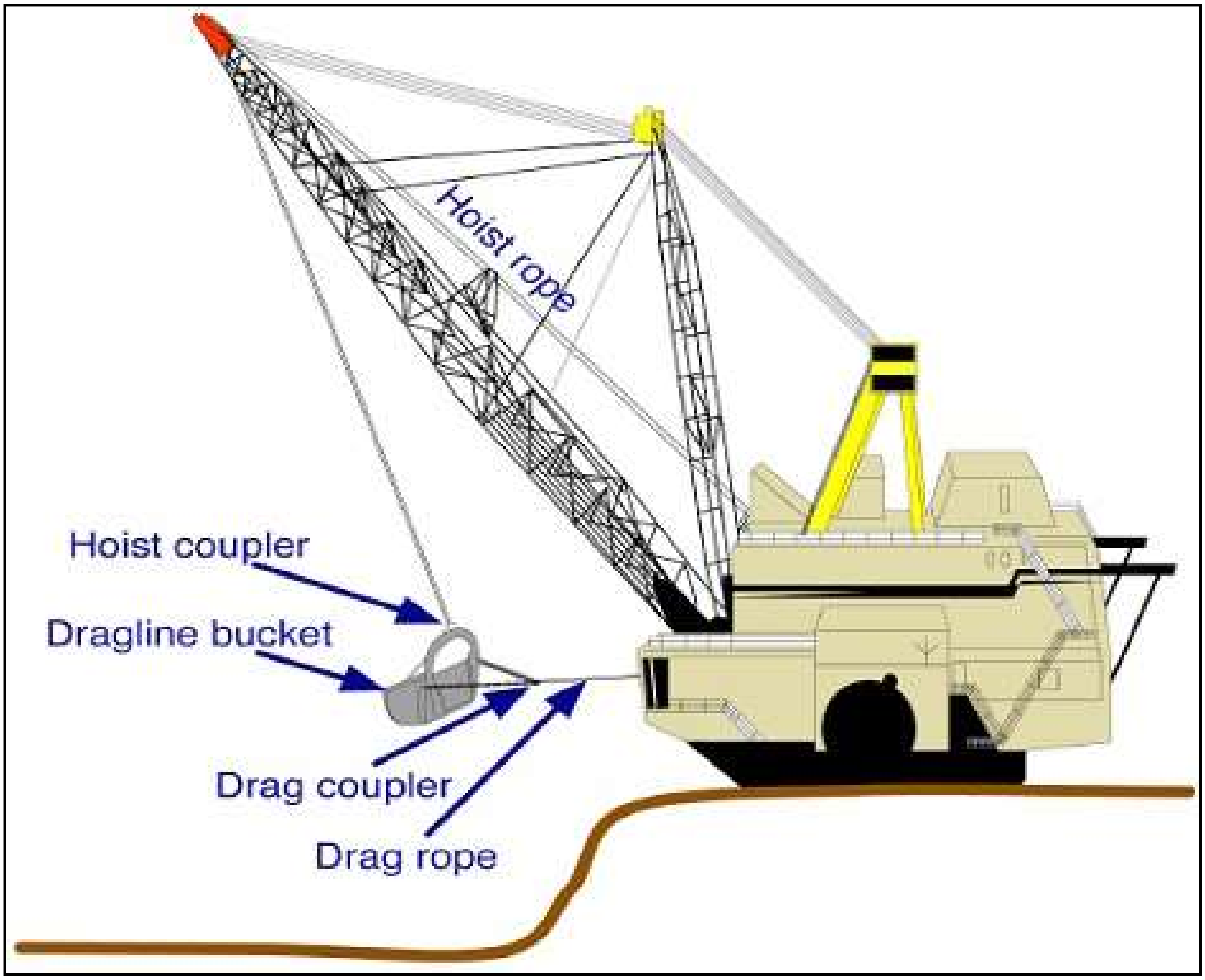


Fig. - 2: Line diagram of dragline

SELECTION OF DRAGLINE

Dragline stripping capabilities and its productivity are directly affected by the selection of digging method, strip layout and pit geometry. Selection of an optimal stripping method, strip layout and pit geometry for a given dragline must be considered with respect to the geological conditions of the mine. By drawing dragline balancing diagram with various OB cover / thickness & cut width, the optimal configuration is decided.

Ideally the digging method which results in optimal coal exposure with minimum re-handling of OB should be adopted for a particular operation. The choice of strip geometry is mainly governed by the selected stripping method and the size of dragline.

The nature of the coal deposit and geological conditions such as the number of seams, overburden/ inter-burden thickness and coal thickness are among the most important factors governing the choice of a digging method.

The general geo-mining characteristics for selection of dragline mining are as follows:

- Seams should have flat gradient (2 - 4^0)
- Adequate strike length of the quarry, should be more than 2 km
- Working zone should be free from major geological structural disturbances, like occurrence of faults, folds unconformities, undulation, swing of floor contour, fire & aquifer zone, etc.
- Overburden can easily be excavated after blasting
- Medium thickness of coal seam

Other factors such as soil stability, blasting techniques and material strengths are also important in the selection of a digging method.

SYSTEM OF WORKING

The operating cycle of the dragline consists of five basic steps:

- The empty bucket is positioned, ready to be filled.
- The bucket is dragged towards the dragline to fill it.
- The filled bucket is simultaneously hoisted and swung over to the spoil pile.
- The material is dumped on the spoil. (back-filled zone)
- The bucket is swung back to the cut while simultaneously being lowered and retrieved to the digging position.

The above operating cycle-time plays very important role in achieving desired productivity of any dragline.

DRAGLINE METHODS OF MINING

i. Simple side casting – applicable for single dragline deployed which is worked by direct side cast.

ii. Horse shoe method – less efficient & limited application.

iii. Extended bench method – widely used method.

iv. Tandem operation – applicable for two or more draglines together in tandem.

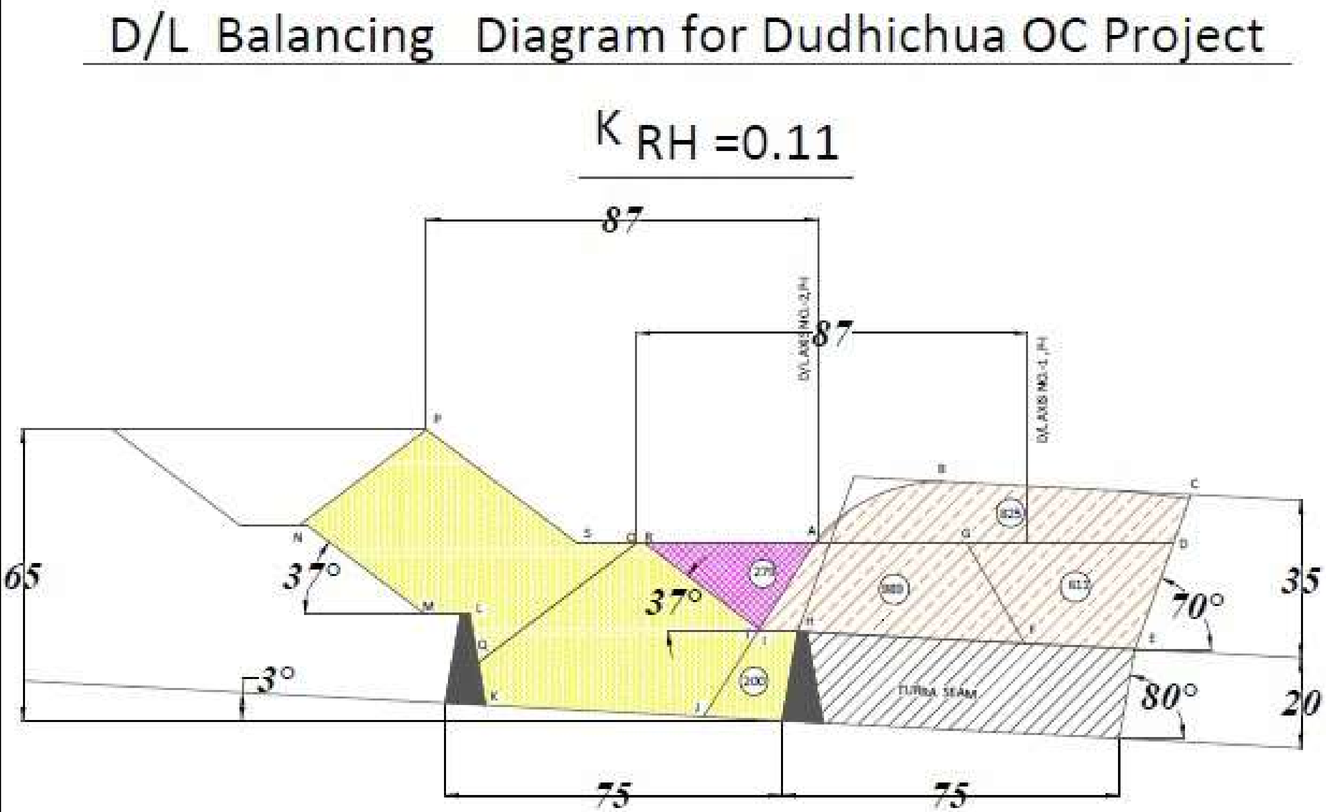
  a. Vertical Tandem
  b. Horizontal Tandem

DRAGLINE BALANCING DIAGRAM (Fig-3)

Balancing diagram is a graphical representation of the cross section of the dragline working. As the name suggests, the over burden to be removed by the dragline shall be balanced in the de-coaled void, of previous cut, such that the re- handling percentage is minimum, the internal dump is safe and stable, and least susceptible to failure. The balancing diagram is generally designed with variable OB thickness and cut width to be excavated by the dragline and swell factor is multiplied in OB dump volume.

To maximize the gainful utilization of dragline re-handling percentage has to be kept at minimum to the extent possible in a given situation.

Dragline balancing primarily means establishing relationship between the system capacity & its workload, advancement of Dragline and coal exposure. High capital outlay for dragline requires efficient operation to obtain low cost of OB removal. Since deployment and operation of a dragline in different modes affect its productivity, it will be necessary to study the effects on production and productivity of different operational schemes. A dragline-balancing diagram is prepared incorporating suitably selected equipment, design and geotechnical parameters of quarry. If a dragline is deployed as per the guideline balancing diagram, better safety, higher productivity and greater production can be achieved.



D/L Balancing Chart

SL.NO.	DRAGLINE	EXCAVATION	CUT	AREA (M2) (SOLID)	DUMP	UTILISATION	ANNUAL PRODUCTIVITY
1.	24m3/88mR	P I- TOP CHOPPING & KEY CUT	ABCDA DEFGD	825 611	OQKJAO	100%	4.10 M.Cum.
2.	24m3/88mR	P I- FIRST DIG REHANDLING	AGFIA RTAR + 10%	989 306.9	PNMLQOSP	100%	2.82 M.Cum. 0.96 M.Cum.
3.	COAL EXPOSURE	$= \frac{2.82}{989}$ x75x20x1.55x0.90x0.90 = 5.37 Mt				THROW BLAST =0.57 M.Cum.	

Fig-3: Dragline Balancing Diagram

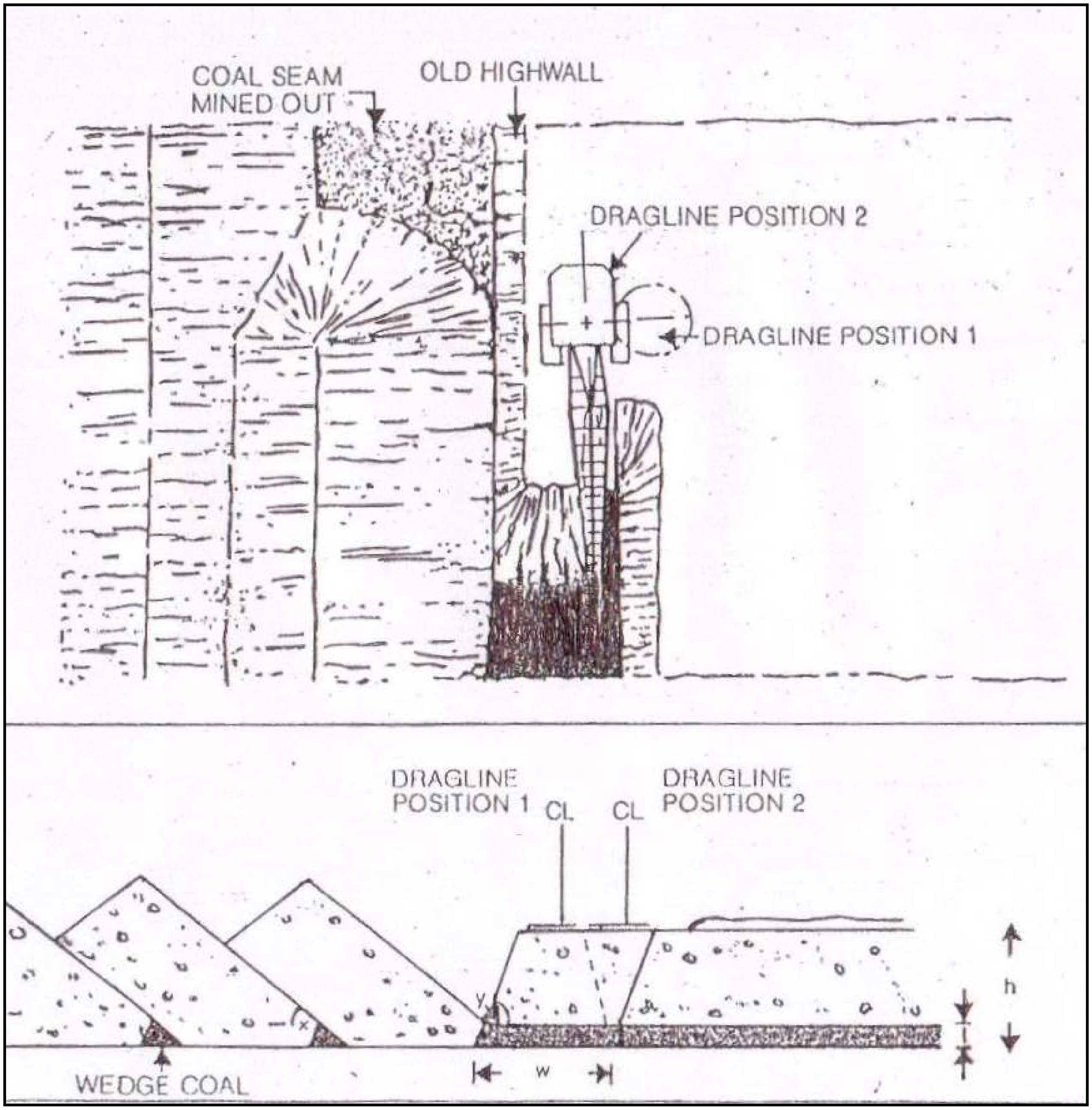


Fig-4: Dragling Stripping Method (Plan & Elevation X-Section)

PRODUCTIVITY OF DRAGLINES

Annual Productivity of Dragline (Mcum) =

$$\frac{B \times S \times F \times H \times M \times 60}{T \times 10^6}$$

B = Bucket capacity of dragline in cum

S = Swell factor of material to be excavated

F = Bucket fill factor of dragline

H = Normative annual working hours of dragline

M = Factor allowed for traveling, positioning, etc.

T = Bucket cycle time (in minutes) of dragline (depends on swing angle)

Table-4 : Annual Productivity of Dragline (330 Days)

Bucket Capacity in cum	Annual Productivity (Mcum)			
	50% cat-III + 50% Cat-IV		90% cat-III + 10% Cat-IV	
	90 degree swing	120 degree swing	90 degree swing	120 degree swing
10	1.30	1.18	1.41	1.27
20	3.13	2.83	3.37	3.04
24	3.81	3.45	4.09	3.70
30	4.87	4.42	5.24	4.73

AVAILABILITY AND UTILIZATION OF DRAGLINES

Looking into the merits and vast scope of application of the draglines in opencast mines on one hand and large capital investment incurred on procuring, operating and maintaining the equipment on the other hand, it becomes imperative to assess the performance of the equipment.

Availability (%) & Utilization (%) of HEMM are defined as:

- $$\text{Availability (\%)} = \frac{\text{Worked Hours + Idle Hours}}{\text{Worked Hrs. + Breakdown Hrs. + Maintenance Hrs. + Idle Hrs.}} \times 100$$

- $$\text{Utilization (\%)} = \frac{\text{Worked Hours}}{\text{Worked Hrs. + Breakdown Hrs. + Maintenance Hrs. + Idle Hrs.}} \times 100$$

Table-5: Company-wise availability & utilization of draglines during last 5 years

Company	2014-15		2015-16		2016-17		2017-18		2018-19	
	%Av.	%Ut.	%Av	%Ut.	%Av.	%Ut.	Av%	%Ut	Av%	%Ut
Norms	85	73	85	73	85	73	85	73	85	73
ECL	94	90	91	85	15	14	25	20	89	82
BCCL	82	48	76	37	79	42	81	29	83	22
WCL	73	59	81	64	88	34	80	56	82	68
SECL	76	50	87	31	80	41	74	33	69	42
NCL	65	53	71	58	70	53	67	56	64	54
MCL	82	46	70	26	93	5	100	0	98	0
Overall	72	53	75	51	73	45	69	48	69	51

Dragline availability and utilization are key issues for operators of large coal mines. It is observed that the availability & utilization achievement vis-à-vis norms of dragline is a matter of concern whose variation depends on availability of spares, maintenance and breakdown of equipment, working and idle hours as well as availability of working area & operators etc.

CIL NORMS RELATED TO DRAGLINES

i. CIL Norms for %Availability & % Utilization of Draglines:

% Availability	% Utilization
85	73

ii. Life expectancy of Draglines to be eligible for Survey-off

Sl. No.	Size	Years	Hours
1	5- 10 cum	25	100000
2	15-20 cum	30	140000
3	24 cum & above	30	150000

Life of dragline, both years & hours require to be completed to be eligible for survey-off.

CONCLUSION

- There are 27 nos. of draglines in operation to remove overburden in fourteen different open-cast mines of CIL, having bucket capacity in the range of 5cum-33cum.
- Out of total 27 nos. of draglines 19 nos. are deployed in different opencast mines of NCL.
- Under performance of draglines in almost all the subsidiary companies is a matter of concern which needs immediate attention for taking improvement measures.
- Performance of draglines can be improved by reducing scheduled & unscheduled downtime, reducing idle time and by increasing working hours.
- Improvement in operational parameters and safety aspects, such as, cut-width, OB thickness optimization, proper blasting and safer dumps design etc. will definitely ensure higher efficiency & better performance of draglines.
- Small increase in performance of dragline can translate into large gains in productivity and lower costs, higher revenue, and more profit.

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Solar Technology and Opencast Planning- An Integrated Approach

I D Narayan[1], Sanjeev M Singh[2], Badal Manna[3]

ABSTRACT

The coalfield areas are receiving comparatively higher solar irradiation and are quite potential for installation of solar power projects. Mining land mostly degraded due to mining activities and these degraded land can be made usable by installing solar power project. The solar power project can be integrated with opencast planning to implement with minimum time and it may improve project economics also. After the closure of mine, solar project would provide source of alternate employment generation for local people that will serve livelihood for surrounding people.

INTRODUCTION

Coal is the main source of energy contributes about 54.5% of overall power generation capacity of our country. Out of total coal produced by Coal India about 94% is being mined by opencast mining. The concept of clean and green energy are fast catching up. It is in the interest of environment that more green energy is to be produced. Coal India is having huge land bank in terms of land acquired under CBA Act. Land is the most crucial issue for generation of solar power. Effective and realistic planning are always keep focus on latest technology related to the industry and also latest requirement of the industry. In the same way, Opencast mine planning also should keep focus on latest opencast mining technology and latest requirement of mining industry. Over the passage of time many improvements took place in opencast mine planning to fulfil the latest requirement of time.

One such latest technology and current requirement of time is solar power technology which should be think off to include in the domain of opencast mine planning. It is time when opencast mine planning should expand its planning horizon by planning of solar power project during the planning stage. It will enable mine to use acquired degraded land to earn revenue for a long time after the closure of the mine with some additional cost. After the closure of mine the land remains under the possession

Fig-1: Laying of Solar panels in open ground

[1] Regional Director, [2] HOD (Mining), [3] Sr Manager (Mining), RI-V, CMPDIL, Bilaspur (C.G.)- 495 006.

of mine authority, so solar power project may be installed within minimum time.

Government of India has revised the National Solar Mission target of Grid connected Solar Power Projects to 100,000 MW by the year 2021-22. This capacity is proposed to be achieved through deployment of 40,000MW Rooftop Solar Projects and 60,000MW of Large and Medium Scale Solar Projects.The main benefit of solar PV is that it does not produce any pollution and it is one of the cleanest source of energy. It is easy to install and it requires low maintenance for its working. The other advantage is that once the solar PV project installed, it may generate revenue for next 25 years by spending little annual maintenance cost. The benefit of the solar power technology can be encashed by any mining industry – may it be coal mining, metal mining or any other mining industry.

SOLAR RESOURCES IN COALFIELD AREA

The generation of solar energy depends on solar irradiation of that area. Direct Normal Irradiation (DNI) is beam radiation measured on the earth surface directly from sun excluding diffuse solar radiation. DNI depends on solar elevation angle, cloud cover, moistures etc. Diffuse Horizontal Irradiation (DHI) is the radiation at surface of Earth from light scattered by atmosphere excluding radiation coming directly from sun. Global Horizontal Irradiation (GHI) is the total irradiation received on horizontal surface of Earth considering both Direct Normal Irradiation (after accounting solar zenith angle) and Diffuse Horizontal Irradiation. Solar Resource assessment is carried out using Global Horizontal Irradiation (GHI) receiving at the proposed sites.

$$GHI = DHI + DNI \cos(Z),$$

Z- solar zenith angle of the sun

NASA's Solar resource dataset is a monthly averaged values generated globally through satellite over the time span from July 1983 to Dec 2018 and contains monthly averaged values for each month in kWh/m^2. It holds satellite derived monthly data for a global coverage on a 0.5° latitude by 0.5° longitude grid. The data set is freely available on the website.

Indian solar resource map created using Global Horizontal Irradiation (GHI) and it is helpful to power generation in any location of India. For commercial use, site specific more detailed day wise, month wise solar irradiation data, sun path diagram, climatic parameters including temperature, wind and precipitation etc are analysed through computer software with different tilted angle of solar panel to assess generation of solar electricity.

The solar resources are different in different parts of India as shown in the Indian solar resource map. From the map it may be noted that Western, Southern and Central part of India is receiving higher solar irradiation in comparison to Northern and North Eastern part. The area which are receiving higher solar irradiation, it will generate more solar electricity with same number of solar panel.

Most of the coalfields are located in the eastern central part of our country. From solar resource map, it may noticed that most of the coalfields are receiving comparatively higher solar irradiation (Average about 5.0 to 5.5kwh/m^2/day). So, our coalfields areas are quite potential for installation of solar power projects.

ADVANTAGES OF SOLAR PROJECT IN MINE AREA

Land acquisition for opening of mine is being carried out under CBA Act 1957 in most of the cases. The land acquired under CBA Act is remains to mine authority after completion of mining activities. Major part of acquired land degraded due to mining activities and become un-usable for agricultural purposes. Those degraded un-usable land can be made usable by installing solar project.

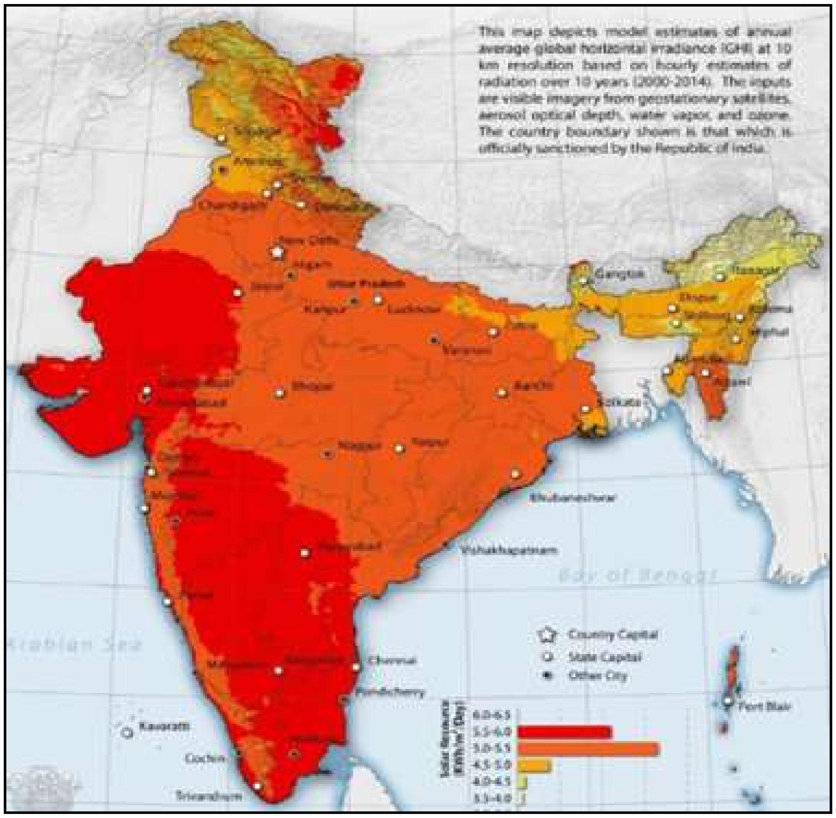

Fig-2: Estimate of Annual average global horizontal irradiance

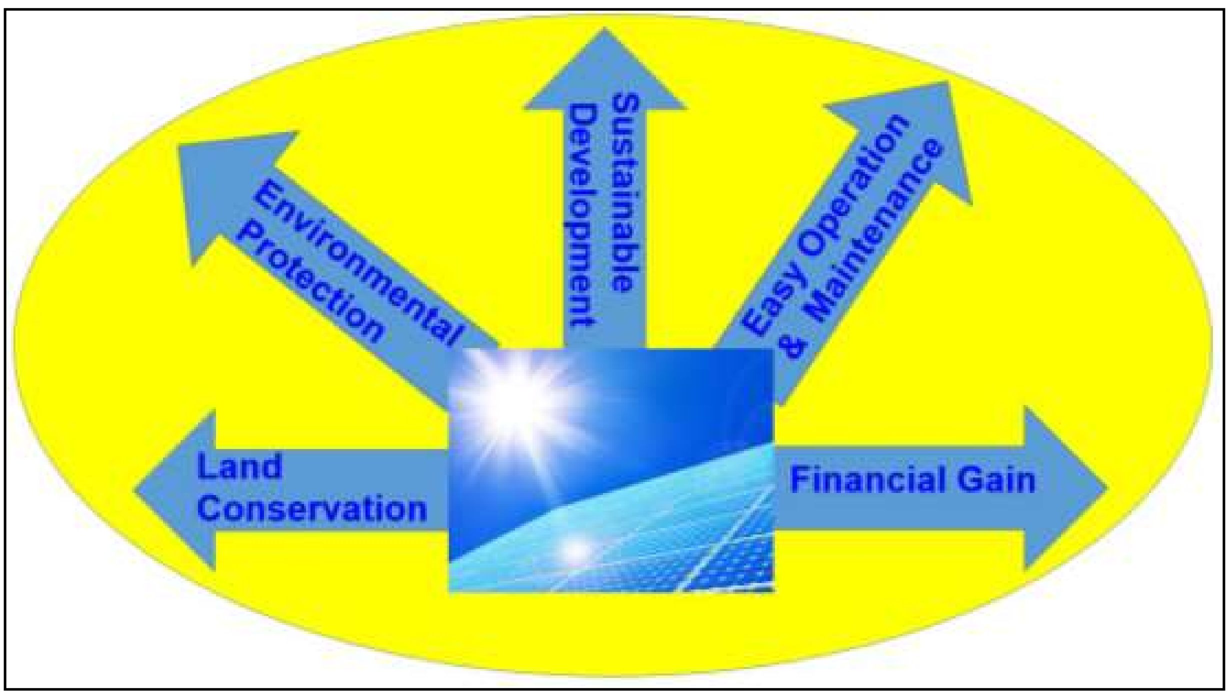

Fig-3: Advantages of solar technology

Some advantages of solar project at degraded/ backfilled site are:

Land conservation

1. The solar power project can be installed by gainful re-utilization of the acquired degraded land. Otherwise some additional land somewhere else will have to be used/sterilised for generation of such solar power.

2. This unused land may generate revenue for mine authority for next 25 years.

Environmental protection

1. The solar PV project does not create any environmental pollution. MoEF has already issued office memorandum that no environmental clearance is required for solar PV project vide letter no-J-11013/41/2006/-IA.II(I) dated 13.05.2011.

2. Land beneath the solar panel can be planted with grass plantation. It will reduce dust generation, increase soil conservation and provides green surroundings with oxygen.

Sustainable development for local people

1. The solar power project will generate employment for local people in the form of cleaning, monitoring, maintenance, security and supervision and other related activities.

2. At the time of closure of mine, it would provide source of alternate employment generation for local people that will serve livelihood for surrounding people.

Operation and maintenance

1. Selling or captive consumption of output energy is not difficult.

2. All major activities and expenditures are in first two years during installation of solar panel and evacuation infrastructure.

3. The running and maintenance of solar project do not involve much operations. The annual revenue expense for solar power project is also not very high.

POTENTIAL SITE OF SOLAR PROJECT IN MINE AREA

Land degraded due to mining activities are generally uneven in nature and are not suitable for installation of solar power project. But, the degraded land can be converted to potential site for solar project by levelling the site and developing sufficient soil strength to hold the mounting structure for solar panel In this way large degraded land can be converted to potential site for solar project in following locations.

1. Top of external OB dump
2. Top of internal OB dump
3. Un-used land in safety zone
4. Any un-used land in infrastructure area

Around 1.6 to 2.0 Ha of land is required for setting up a 1 MW Solar plant with crystalline Silicon technology. The generation of solar energy may vary from location to location depending on solar irradiation.

SUGGESTIVE STEPS TO INSTALL SOLAR PROJECT IN MINE AREA

The steps for installation of solar project in degraded land in mine area may vary from site to site depending on local conditions. However, generally there are four major steps for installation

Fig-2: Proposed site(OB dumps) in opencast mine for solar panels

and running of solar power project in mine area as enumerated in Table-1:

ESTIMATED TIME REQUIREMENT FOR SETTING UP SOLAR PROJECT

The estimated time requirement of each steps for installation of solar project also may vary from project to project depending on different factors. The general estimated time requirement for Preparatory Stage, Report Preparation and Approval Stage and Installation Stage of solar power project are as given in Table-2

ADVANTAGES OF PROPOSING SOLAR PROJECT IN PLANNING STAGE

The potential site that may proposed for solar project during opencast mine planning stage has been stated in para(4). Those sites may be proposed for installation of solar project after completion of mining activities and may be incorporated in the project report. The opencast project report integrated with solar project will be approved by company board. The estimated time requirement for preparatory steps will be reduced due to following reasons.

1) Formal approval of solar power project will done along with the approval of Opencast project report.

2) Land for solar project will be broadly identified during planning of PR.

3) Land will be acquired under CBA with noting that after completion of mining activities land will be used for solar power project, it may simplify land conversion from MoC.

4) Solar project will be incorporated in mine closure plan and modification of mine closure plan will not be required.

5)Solar project will be incorporated in the EMP report and clearances will not be required to avoid EC violations.

6)DGMS approval for installation of solar power project in mine area, if required, can be taken in minimum time.

7)The land will be levelled during dumping stage and no additional time & cost will be required to level the land.

8) Grass plantation will be done immediately after the dumping & levelling work is over. So stabilization of land and development of soil strength will not require any additional time.

9) The solar power project may be started partly before the closure of the mine and revenue can be earned by generation of solar electricity. In this way, the economics of the project may improve considering the revenue generated by solar power project.

The opencast mine planning integrated with solar power project may reduced the time requirement to few months or few days for completion of Preparatory stage.

CONCLUSION

The solar power technology is developed to provide green & clean energy and it may be accepted widely for our own benefit. For a long past, coal was being used to supply cheapest energy to mankind and still today it is being used. Now, solar PV is in a position to supply part of energy requirement without creating any pollution. Once the solar power project is integrated in the project report during the planning stage, it can be implemented with minimum time and minimum effort during closure of mine. After the closure of mine, it would provide source of alternate employment generation for local people that will serve livelihood for surrounding people. The opencast mine planning integrated with solar power project may pave the way to start solar project partly before the closure of the mine and it may improve project economics by generating additional revenue. So it is a time that solar power technology should be think off to include in the domain of opencast mine planning.

Inducting Solar technology at the planning stage of opencast mine may not only reduce the time for installation and improve in economics but will also revolutionalise the solar technology for

Table-1

Sl. No.	Particulars
A. Preparatory Stage	
1	Identification of land suitable for installation of solar power project
2	Land details finalization and marking the site on the plan
3	NoC from CMPDI for no future mining in the proposed land
4	Modification of mine closure plan to include solar project, if required
5	Approval of company board for installation of solar project.
6	Land conversion from MoC for the land acquired under CBA to be used for solar
7	Clearances to avoid EC violations, if required
8	DGMS approval for solar power project in mine area, if required
9	Freeing the land by shifting infrastructures, if required
10	Grass plantation for faster development of soil strength
11	Stabilization of soil by giving required settlement time
B. Report Preparation and Approval Stage	
1	Appointment of Solar consultant through JV or MoU
2	Solar power project report preparation
3	Approval of Solar project report by company board
4	PPA with DISCOM
5	Uploading solar power through evacuation infrastructure
C. Installation Stage	
1	Floating tender for developer selection
2	Setting up solar panel through developer
3	Installation of solar power evacuation infrastructure
4	Finalization of metering or net-metering system
5	Uploading solar power through evacuation infrastructure
D. Post Installation Stage	
1	Billing system establishment
2	Setting up for annual maintenance system

Table-2

Sl. No.	Particulars	Time Required without solar project proposed in planning stage	Time Required with solar project proposed in planning stage
1	Preparatory Stage	1 to 3 years or more	0 to 6 months
2	Report Preparation and Approval Stage	About 6 months	About 6 months
3	Installation Stage	6 to 12 months	6 to 12 months
	Total	2 to 5 years	1 to 2 years

the country and help in long way to achieve the Solar mission target set by Govt. of India.

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Optimization of Waste Dump in Opencast Coal Mines by Application of Steep Angle Conveyors

Pankaj Pandey[1], Vats Priyesh[2]

ABSTRACT

Mining being a site specific activity, land becomes the prime requirement for starting, running and closing of any mining project. Many strategic coal mining projects in India are not progressing as planned, due to unavailability of land and other environmental/social issues. The problem gets magnified in case of open-pit mining that requires large area for mining, dumping of waste and land for other mine facilities. Mine closure & post mining land use exercises, though funded generously may not achieve their objectives owing to uneven land profile post mining.

One of the feasible solutions to these issues is application of steep angle conveyors in large open pit mines that will result in more space for internal waste dumping (thus reducing external dump land requirement) and enhanced slope stability of the dump. Additionally, such applications will result in economic extraction of mineral in deep open pits. Land reclamation exercise may start concurrently during early years of mine development as mineral evacuation is limited to a specific part of the mine. The paper presented here attempts to address specific land related issues by developing suitable schemes and plans that can be practically implemented in open pit mines using advanced technology i.e. steep angle conveyors.

Keywords-*Open Pit, Coal Mining, Steep Angle Conveyor, Land Reclamation, Internal Waste Dump, Trucks.*

INTRODUCTION

In open pit mining methods, a large area of land is required, for mining, mine facilities and external dumping of waste material, in addition to initial mine cut and other infrastructure, like colonies etc. The issue becomes critical when the stripping ratio of an open pit mine is very high. As the stripping ratio increases, land requirement for external waste dumping also increases. Acquisition of land (especially in India), thus, becomes the most important activity which decides the fate of the open pit mine. The open pit mining process itself must

1. Optimize land requirement by maximizing back-filling/ internal dump of waste in the mined out area.
2. Produce a stable land form by concurrently reclaiming the back filled area.
3. Aesthetically blend reclaimed surfaces into adjacent undisturbed land.
4. Control reclamation cost by optimizing cut/fill balance.

One of the methods for achieving these objectives

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is by maximizing internal dumping of the waste in the mined out region of the mine by applying steep angle conveyors. Further, the internal dump in the mined out area may be merged with an external dump made in the initial years. This will result in reduction of land area requirement in open pit mines. The land reclamation exercise will also start concurrently, as a uniform profile of land could be made available during early years of mine development. By maximizing the internal dumping of the waste material, we can substantially reduce the land requirement for external dumping as well as haul distance for haulers as shown in our study. The above system will effectively be used in relatively flat deposits using shovel –truck and surface miners. Another important constraining factor in internal waste dumping is the creation of a large valley in the middle of the internal dump. This valley is created due to positioning of routes/ corridor in the middle of the property on the bottom most seam floor i.e. conveyors, truck routes and pipe lines from the sump etc (Figure-1).

This practice significantly reduces the total capacity and the stability of the internal waste dump and increases the land requirement for external waste dump.

This typical situation can be averted by the application of steep angle conveyors in side batter and shifting the coal transportation operations and other related activities from mid entry in bottom most seam floor as demonstrated here in this paper. This will lead to increased mined out area for internal waste dumping from the beginning and a uniform land mass for post mining land use planning (Figure-2).

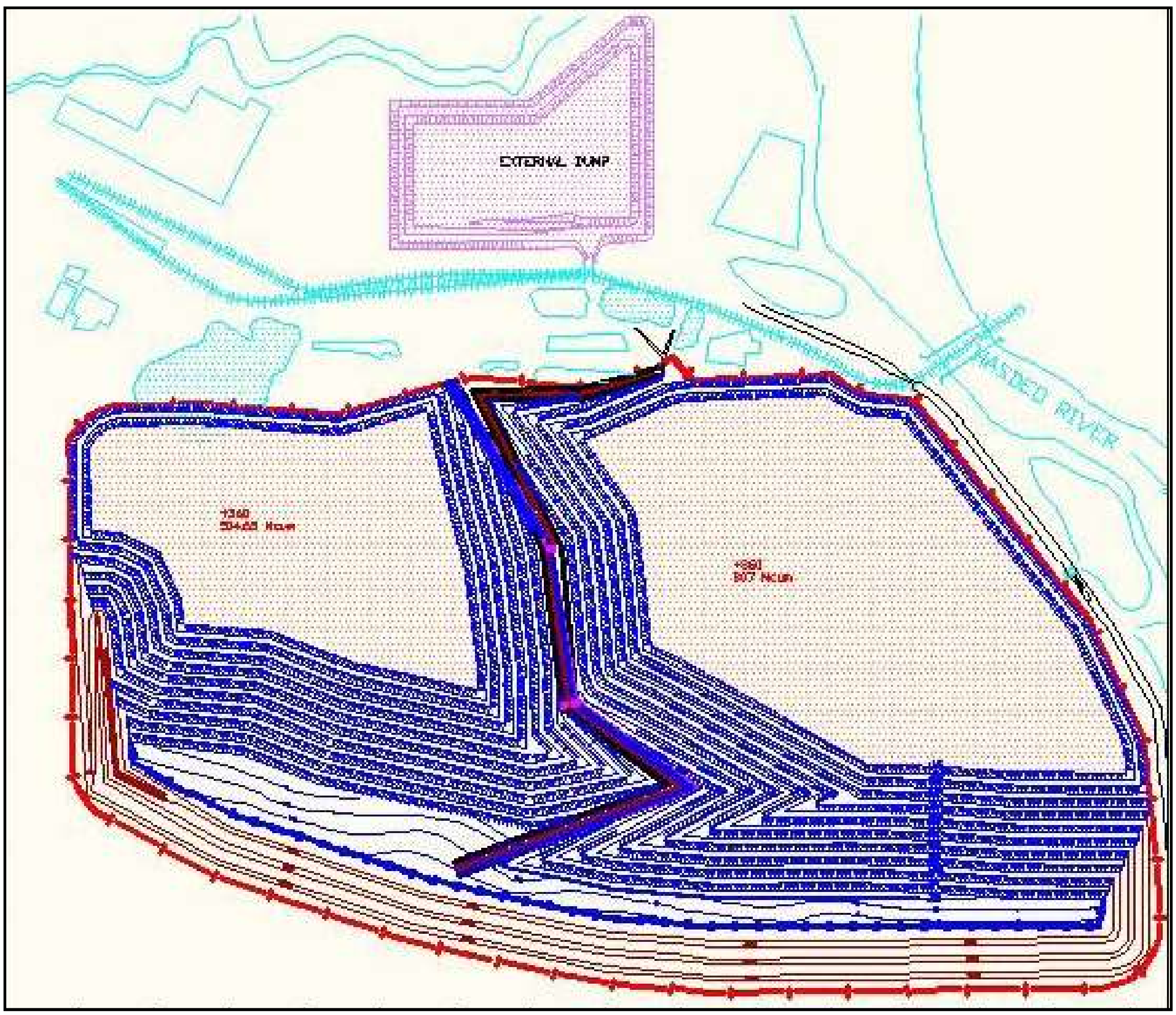

Fig.-1: Final pit with valley

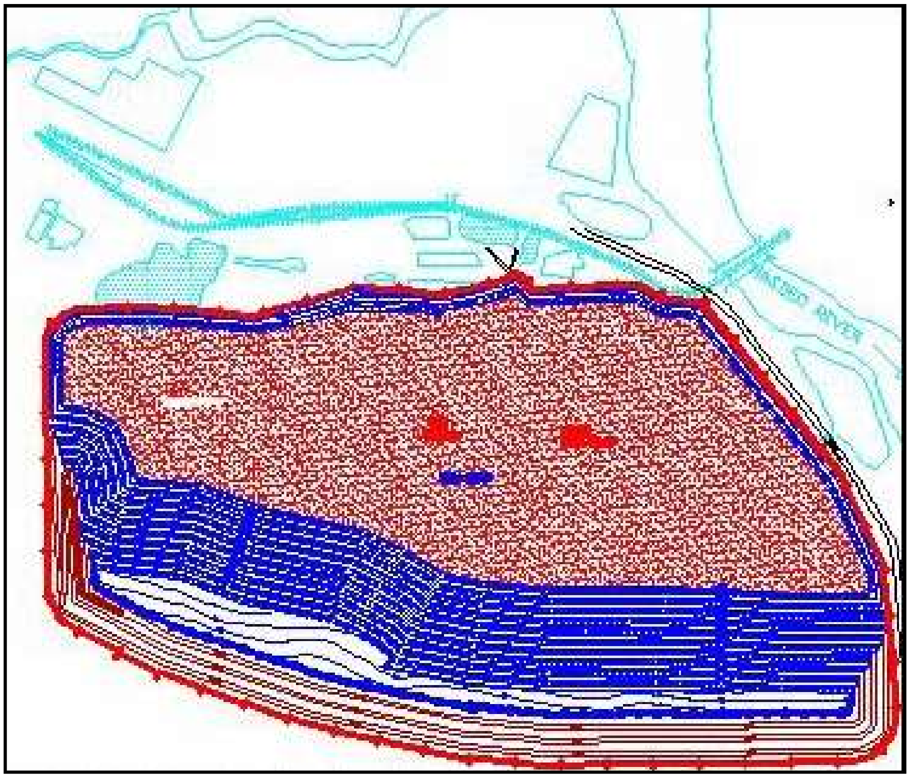

Figure-2: Final pit with steep angle conveyor

Mine Facilities located on the surface can also be advanced along with the pit by using modular/ portable structures. Application of steep angle conveyors will also result in economic extraction of mineral in deep open pits.

ESTIMATED SAVINGS IN LAND/AREA

Two large open pit coal mines of Coal India Limited with favorable geo mining and other conditions are studied in detail for the application of steep angle conveyors. In both the cases, different formats of steep angle conveyors have been proposed to be applied.

Case 1 - Block 'B' OCP (6.0Mtpa), Coal India Limited

Block 'B' OCP is an existing operating mine of Northern Coalfields Limited, a subsidiary of CIL. This mine is scheduled to produce 6.0Mty of coal with an average stripping ratio of 4.31m^3/t at a maximum depth of about 250m in future. There are two seams varying 15-25m thickness and having a parting thickness of 25-30m. The mine is planned to be worked in two pits due to presence of a fault (90m throw) in the middle of the property. 10m^3 hydraulic shovels with 100T trucks have been envisaged for mining coal as well as waste removal. Out of 715.45 Mm^3, 608.79 Mm^3 of waste have been proposed to be dumped externally in three external dumps requiring 1186.31 Ha of land for external waste dump (Figure-3, Table-1).

In our present study, a single run steep angle conveyor along with a semi mobile crusher have been proposed to be deployed in the bottom most seam floor. The semi mobile crusher will crush the run of mine coal to (-) 200 mm size and discharge into the steep angle conveyor. Coal from the upper seam will also be hauled to the bottom seam floor, crushed and discharged into the steep angle conveyor. Sized coal from the steep angle conveyor will be discharged into the surface conveyors for onward transportation to the coal handling plant. The single run steep angle conveyors will be shifted every 5-6 years as the mine progresses in the dip direction, and concurrently the de-coaled area will be backfilled and reclaimed.

With the proposed application of steep angle conveyors, the internal waste dump has been

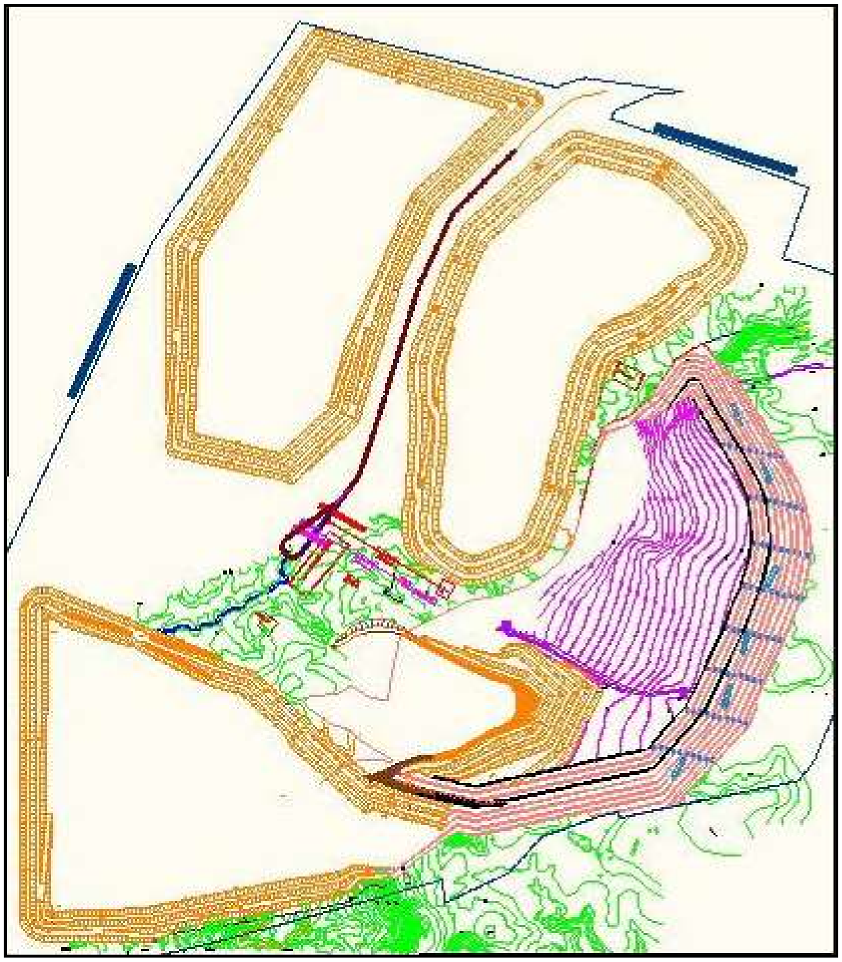

Figure-3: Block 'B' mine without steep angle conveyor

Table 1- Dump parameters of Block 'B' mine

OB from Quarry	Internal Dump (Mm^3)		External Dump (Mm^3)			Total OB
	V-I	V-II	OLD Ext. Dump	South Ext. Dump	North Ext. Dump	(Mm^3)
V-I	46.98	8.29	134.7	6.45	0	196.39
V-II	0	21.7	0	56.69	0	78.39
Vindhaya-I &II	46.98	29.99	152.6	63.14	0	274.78
B & C	0	29.69	0	145.54	265.5	440.68
Total OB (Mm^3)	46.98	59.68	152.6	208.68	265.5	715.46

optimized. Simultaneously, the internal waste dump has been proposed to be merged with an external waste dump. This process helped in increasing the waste dump material in the internal dumps from 106.96 Mm^3 to 401.53 Mm^3. As per initial estimates, this will save 6.19 Sq. km of land area from external waste dumping (Figure 4). Additionally, this will also reduce the total haul distance for haul trucks and further reduce the cost of production. A uniformly backfilled area will also be concurrently reclaimed in the early years of operations. (Figure-4, Table-2).

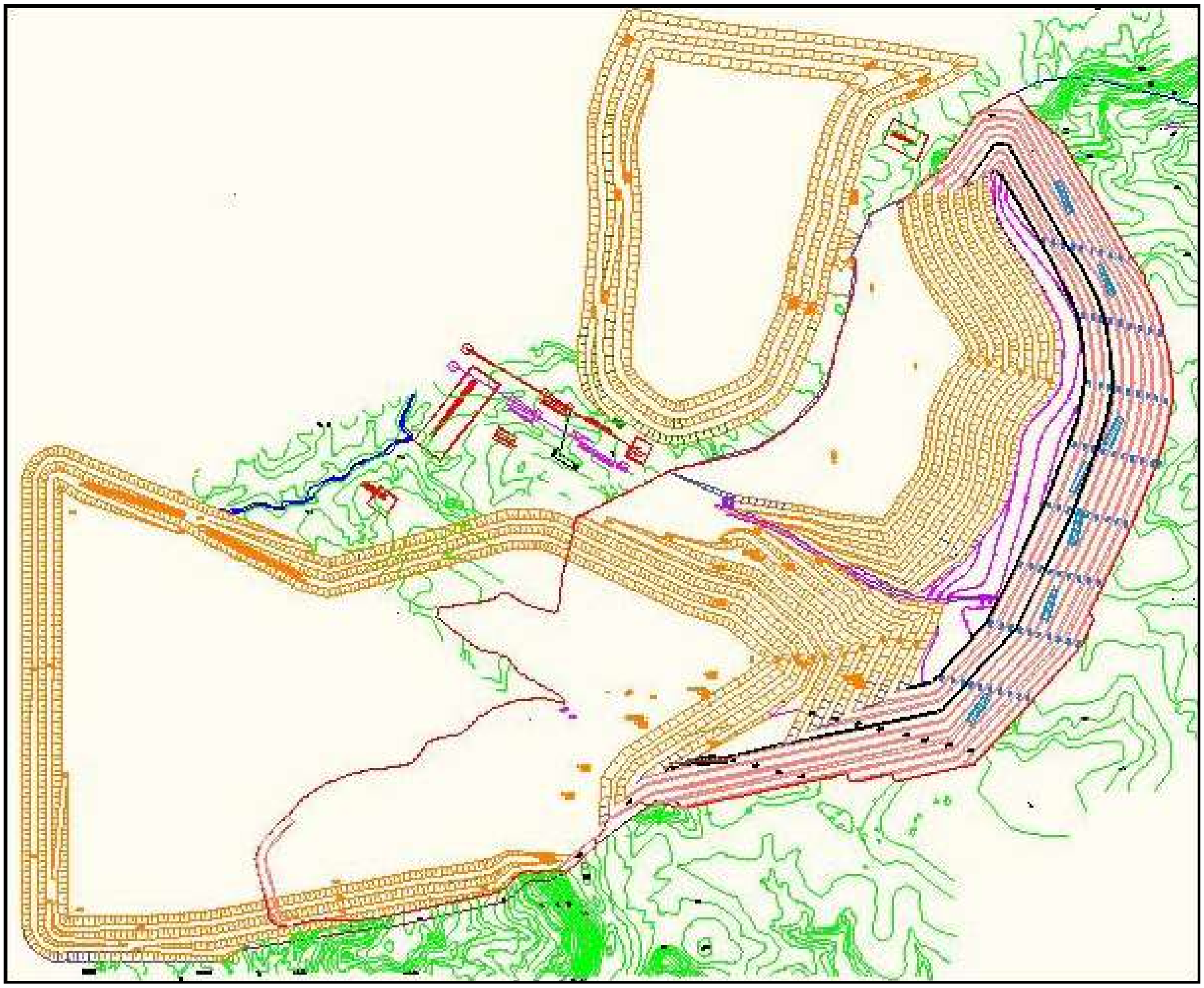

Figure-4: Proposed Block 'B' mine dump with steep angle conveyor

Table-2: Dump parameters of Block 'B' mine with steep angle conveyor

OB from Quarry	Internal Dump(Mm^3)		External Dump(Mm^3)		Total OB (Mm^3)
	Vindhya-I & II	B &C	OLD Ext. Dump	South Ext. Dump	
Vindhaya-I &II	106.38	0	59.98	108.36	274.72
B & C	190.64	104.53	0	145.57	440.74
Total OB (Mm^3)	297.02	104.53	59.98	253.93	715.46

Estimated saving in dump area (Sq. km) – 6.19

Case 2- Kusmunda OCP (50.0Mtpa), Coal India Limited

Kusmunda open pit mine is a very prestigious mine of Coal India Limited and is one of the largest coal mine of India in coming years. This mine has two thick seams (30-40 m) with an average parting thickness of 70-90 m. This mine has a total coal reserve of 1005.40 Mt with a waste volume of 1342.45 Mm^3 with an average stripping ratio of1.34 m^3/t. It is scheduled to produce 50.00 Mty of coal at a depth of about 300 m in future. Surface miners, front end loaders and trucks are to be deployed for coal winning, whereas a 42 m^3 electric rope shovel along with 240T trucks will be used for waste removal. Coal from the bottom seam (pit floor) has been proposed to be hauled to the surface by the conventional conveyors. Since, conveyors, supply roads and pipe lines are proposed to be located on the pit floor along the mid entry corridor, large channels or valleys will be left in the middle of the internal dump (Fig.- 1, Table- 3).

In our present study, the application of modular units of steep angle conveyor on the side batter along with a reclaim feeder will facilitate infilling of this valley with waste material. This will effectively increase the volume of the internal dump and will provide a level and uniform land mass for early reclamation. Since the parting between the two seams is not favorable for bringing the upper seam coal to the pit floor, additional units of the modular steep angle conveyors will be deployed in the upper seam for hauling the coal to the surface.

The proposed change in coal evacuation strategy will greatly assist in increasing internal waste dumping with volumes going up from 1321.70 Mm^3 to 1516.29 Mm^3 in the internal dump (Fig-2) As per initial estimate, 173.79 Mm^3 of additional waste will be accommodated in the internal waste dump (a net gain of 13.15 %) by applying steep angle conveyors. Further this land mass can be reclaimed by freshly excavated top soil from dip side of the mine. Approximately 3.59 Sq. km of additional land area is available for reclamation by filling the central channel. The external dump proposed in Kusmunda mine can also be placed on a coal bearing area on the dip side of the mine, to be re-handled in future.

This will result in saving of 1.25 Sq. km of land area. (Figure-2, Table 4).

Table-3 :Dump parameters Of Kusmunda mine

Sl.No	Particulars of working	Total
1	Coal reserve (Mt)	1005.4
2	Waste volume (Mm^3)	1342.5
3	Stripping ratio (m^3/t)	1.34
4	Excavated quarry area (Sq. km) Western internal dump (Mm^3)	15.91 694.55
5	Eastern internal dump (Mm^3) Total internal dump(Mm^3)	627.15 1321.7
6	External dump (Mm^3)	20.8
7	Total dump volume (Mm^3)	1342.5

Table 4 - Kusmunda mine dump parameters with steep angle conveyor

Sl. No.	Particulars of working	Final year
1	Coal Reserve (Mt)	1005.4
2	Waste Volume (Mm^3)	1342.5
3	Stripping Ratio (m^3/t)	1.34
4	Excavated Quarry area	15.91
5	Internal Dump (Mm^3)	1516.29
6	Additional Dump Capacity (Mm^3)	173.80
7	Re-handled Volume (Mm^3)	20.80
8	External Dump (Mm^3)	0.00
9	Additional Reclaimed Area (Sq. km)	3.59
10	Total Dump Volume (Mm^3)	1516.29
11	Estimated Saving In Dump Area (Sq. km)	1.25

DESIGN APPROACH

Following are some of the design approaches considered for the purpose of effectively utilizing steep angle conveying capabilities with different mining systems for optimizing waste dumping and concurrent land reclamation.

Steep angle conveyor installation along sides of the pit: (Figure-5 & 6)

The first option is to put the steep angle conveyor structures on the side batter in the base seam floor. Coal can be fed into the conveyor hopper through a pit bottom facility of crushers/ surface miners and face conveyors. Alternately flexibility of front end loader / truck transportation system can be used inside the pit for feeding into the conveyor. Coal from upper seams can be transported to the pit bottom, crushed and evacuated by steep angle conveyors. The modular structure of the steep angle conveyor mounted on crawler/skid can be periodically advanced laterally along with mine face in the dip direction, simultaneously allowing the backfilling of waste in the internal dump. In this case, trucks transporting waste into the internal dump must be able to pass beneath the conveyor structures with utmost safety.

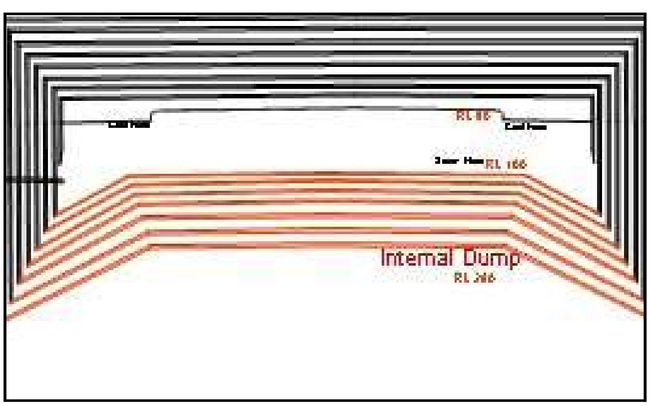

Fig.-5: Steep angle conveyor on side batter

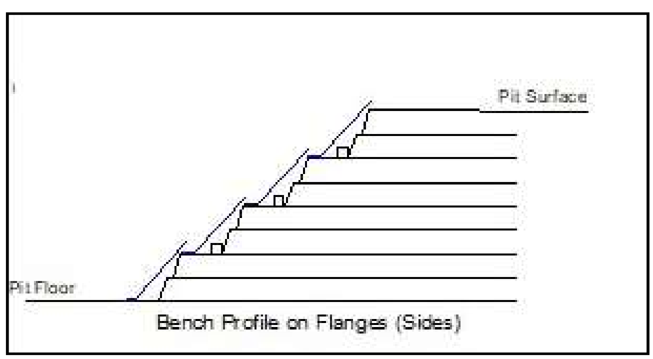

Fig.-6:Steep angle conveyor on side batter

Conveyor installation on top of the internal dump: (Figures-7 & 8)

Internal waste dump benches can also be used to place steep angle conveyor structures as shown in the picture. Here trucks need not pass beneath the conveyor but advancing the conveyor modules with the internal dump will require elaborate arrangements. Another important aspect in this case would be dump stability due to static and dynamic loading of conveyor modules.

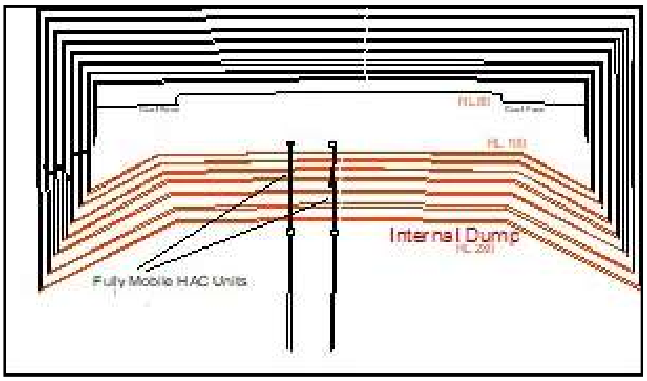

Fig.-7: Steep angle conveyor on top of dump

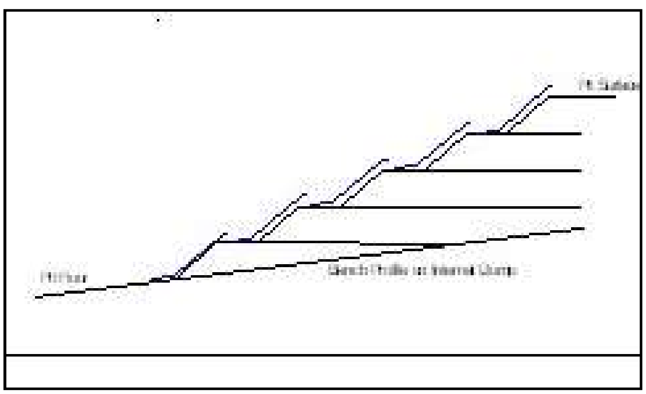

Fig.- 8 : Steep angle conveyor on top of dump

Conveyor installation without internal dumping: (Figure-9 & 10)

Here the basic idea is not to create internal dumping space but to realize savings in coal and waste transportation costs. As the depth of the pit increases, the cost of hauling material increases exponentially. At a certain depth the cost is equal for both the systems i.e. trucks and steep angle conveyors. It is advisable to install a steep angle conveying system after certain depth. Lateral shifting of conveyor structure is not required here. Conveyor length can be extended by adding modular structures as the depth increases. Trucks may or may not require passing beneath the conveyor structure.

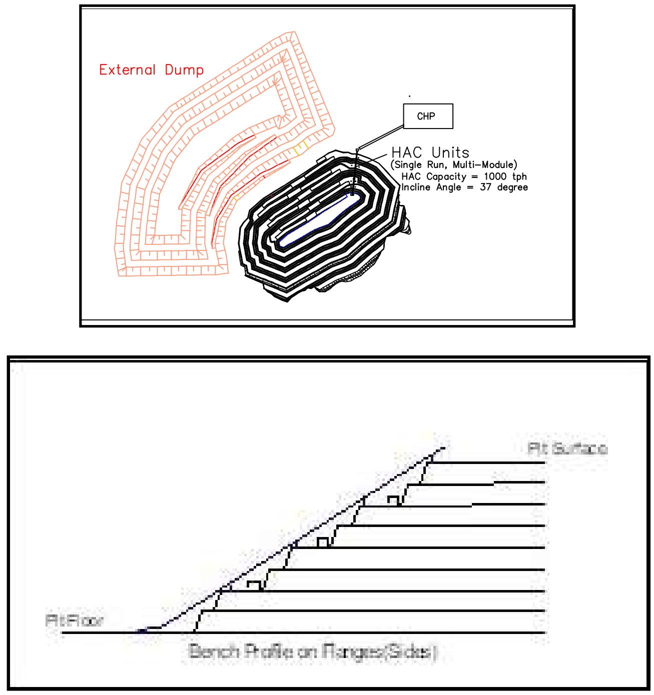

Figure-9-10: Steep angle conveyor in a deep pit

ADDITIONAL DESIGN REQUIREMENTS

Haul Road & Service Road for Pit floor

In the absence of a central corridor for laying conventional conveyor and truck routes on the base seam coal floor from surface to pit bottom, it becomes imperative to provide an alternate route for trucks and other maintenance vehicles, cranes etc to the pit floor. Long term and short term planning must be done to clearly mark the ramps and their periodic changing position on stage plans/layouts prepared for the purpose.

Stability of Internal Dump

A completely enclosed pit working with an internal dump on one side requires complex arrangements for safety of workmen and heavy earth moving machineries.

Safe distance from the active working faces must be maintained at all time. Any movement on dump faces or benches can be dynamically monitored with the help of GPS based tools. LASER/RADAR technology is also available to predict any movement on active faces of dumps. Early reclamation and re-vegetation of dump faces substantially helps in stabilizing slopes.

Pumping

Pipe lines from mine/pit sump to surface can be laid through batter or on top of internal dump by suitably anchoring the support structure. Other option is to lay the pipeline underneath the internal dump enclosed within concrete casing. These can be further advanced as the mine face progresses. To make the pipeline corrosion/erosion resistance underneath the internal dump, the metal can have nano-crystalline surface engineering treatments.

Emergency Evacuation System

An EES may be prepared at project planning stage and put into action as soon as the mine reaches a critical stage of operation. The system can be designed on the basis of preferred pit layout, mining system selected as well as local conditions prevailing in the region.

MODELING TOOLS

Computer modeling and simulation is a dependable and low cost method for developing insights, while studying a complex system such as material handling in all cases discussed so far.

It helps in exploring "What if" scenarios with much ease. In a simulation model an attempt is made to compress time and space and bring processes close to reality. Real life uncertainties, problems, and issues are incorporated through probability distributions and other statistical tools. Change in object attributes, positions, layouts etc can be done with high speed. Different processes and entities/ objects of the system are shown with the help of animation and relevant data are collected, stored and presented by the software itself. Process optimization is also carried out by the software during run time. Success of the methodology entirely depends upon validity of the model and accuracy of the input data. In this study, 3D Auto CAD layouts of the pit dimensions are imported into the software and custom built objects such as load zone, digger, truck, conveyor etc. are located as per project plan. Dump zone etc are placed and connected to represent processes. These objects have real life attributes (capacity, speed, load time etc) which can be changed to create multiple scenarios. The simulation is run for a predetermined period, say one month, at an accelerated rate. Real time data are collected from the model for that duration, just like real life measurements. A simulation can be rerun with changed attributes and object positions to compare various scenarios. Results are displayed containing productivity, cost of operation, waiting time for equipment etc.

Provision for shift working, fuelling, breakdown and maintenance are also there. All the processes can be actually seen in 3D animation. Codes can be written to suit specific requirements of the project. This capability can be further extended to other areas of planning and operations by building new objects and models with customized logic.

CONCLUSION

Further field studies are suggested and data may be collected from different opencast mines in India and abroad to further establish efficacy of the system. Study will involve investigation in the field, implementation of a pilot project of this system in Indian mines and analysis of its performance in Indian coal mining context.

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Opencast Mining: An Environmental Eco-Friendly Engineering Activity in terms of Water Conservation Practices

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ABSTRACT

Coal mining industry has a significant bearing and impact on the economic, energy and water security of India, and thus playing an indispensable role in its development. To cater to the coal demand for even a nominal GDP growth of 8% p.a., 1267 MT coal is needed (Coal Vision 2025), whereas a real GDP growth rate of 8% p.a. is required for India to become a 5 trillion $ economy by 2024, as envisioned by the Govt. of India. Moreover, the water availability has also reduced from 1,816 cum to 1,544 cubic metres between the 2001 and 2011 (CWC, 2015), with NITI Aayog's Composite Water Management Index alarming that 21 major cities of India may reach to zero groundwater levels by 2020. Coal mining, especially Opencast, though considered a hazard for the environment for the time being, holds the potential to contribute to environmental sustainability of localities around them upon adoption of proper safeguard measures. Of these, the Overburden dumps created during and after cessation of mining can be restored and reclaimed for future use. However, a MoEF&CC notification mandates mixing of 25% fly ash in the backfilled overburden and which may release Potentially Toxic Trace Elements (PTEs) into the surrounding water environ and also cause a decline in permeability of the reclaimed overburden, thereby altering the hydrogeological regime of the area. This article proposes an alternative integrated approach so as to make opencast mining an environmental eco-friendly engineering activity in terms of water conservation practices. Under it, the reclaimed area can be developed into an eco-restoration park and the left out residual mine void can be turned into a pit lake. The pit lake will directly augment the replenishment of depleted groundwater regime in terms of both confined/semi-confined and unconfined aquifers, apart from catering to various water needs of local

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population such as domestic and irrigation after proper treatment. The eco-restoration park indirectly supports the groundwater recharge by enhancing infiltration and diminishing rainfall runoff, and most strikingly maintaining the flora and fauna in the study area besides adding aesthetic feature.

Keywords: *Opencast mining, Fly ash, Biological reclamation, Pit lake, Groundwater, Water conservation*

INTRODUCTION

Coal Mining is an indispensable part of India's development in general, and its power sector's development in particular. The dream for "New India' to become a 5-trillion $ economy by 2024 requires GDP real growth rate of 8% p.a. (Economic Survey, 2018-19). To cater to this, coal demand for even a nominal GDP growth of 8% p.a. is envisaged to be 1267 MT (Coal Vision 2025). Moreover, despite the huge proven coal resources in India (more than 300 BT), around 240 million people have no access to electricity due to the lack of infrastructure in the power sector (IEA 2015). This has been set to quadruple the current capacity of power system by 2040, in order to meet the needs of country. Hence, though the relative proportion of coal contribution in power generation is gradually declining, the absolute demand is set to grow in the future hence establishing the indispensability of coal mining.

Exacerbating this scenario is the fact that over time, there has been a reduction in per capita availability of groundwater resources globally. Precisely, the per capita annual availability of water in India has reduced from 1,816 cubic meters to 1,544 cubic metres between the 2001 and 2011 (CWC, 2015), mainly due to rapid population growth coupled with urbanization, industrialization and intensive agricultural activities which have enormously impacted groundwater quality as well as its quantity (Singh *et al.*, 2017a).

Alarmingly, NITI Aayog's *Composite Water Management Index* (CWMI-Report, 2018) has cautioned that 21 major cities (Bengaluru, Chennai, Delhi, Hyderabad and others) are trending to reach zero groundwater levels by 2020, affecting access for around 100 million people. The recycling of coal-mine water, and pit-lakes have been working to offset such trends by increasing water availability locally and replenishing the groundwater levels in the surrounding areas respectively.

It is, thus, notable that the coal mining industry has an impact on the economic, energy, and water - security of India. By virtue of this, the industry holds the potential to contribute constructively to the aforementioned aspects of the nation's development.

Opencast (OC) mines form a majority of the Indian coal mines and are set to form a lion's share of India's coal production in future in order to meet the exponentially rising demand. Specifically, CIL contributes around 90% of India's commercial coal production. But, the share of its production from underground mines (considered lesser hazard to the environment) has reduced from around 90% at the time of its formation to around 5% in the recent years. Hence, with greater adaption, OC mining needs special attention to ensure their environmental sustainability in the long-term. Measures can be taken especially at the post-mining stage. Select few of them are discussed in this article.

In OC Mining, every million ton of coal extraction requires the removal of a certain quantity of over-burden (OB) and hence leads to creation of OB dumps. These OB dumps need progressive biological reclamation, both during and at the end of the mine life (Singh *et al.*, 2017b). Such reclamation is necessary to take the area back to its original condition, and to avoid any damage to the ecology of the surrounding area. On the contrary, to promote 100% utilization of fly ash generated by Coal-based Thermal Power Plants (TPPs), the Ministry of Environment and Forest & Climate Change (Govt. of India) brought out a Gazette Notification to regulate fly ash utilization vide no. S.O. 763 (E) dated 14th September 1999 (amended subsequently in 2003 and 2009). *This mandates Opencast coal mines within fifty kilo-*

metres from coal or lignite based TPP shall undertake backfilling using at least 25% fly ash of the total materials used for external dump of overburden and same percentage in upper benches of backfilling and this shall be done under the guidance of the Director General of Mines Safety (DGMS).

As a consequence, Potentially Toxic Trace Elements (PTEs) associated with the fly ash may leach into the surrounding water environ (Verma *et al.,* 2016). Moreover, there is a possibility of fly ash mixing causing a significant decline in permeability of the reclaimed overburden. This may lead to the confining of *aquifers* from one another due to creation of aquicludes in the intermediate areas, or conversion of existing aquifers into *aquitards*, thus altering the natural hydrogeological characteristics of an area. Therefore, as no systematic scientific study has been undertaken so far to assess the impact of fly ash disposal in opencast coal mine voids in India, we hereby propose an alternative integrated approach to OB reclamation after cessation of the mine, so as to make the OC coal mining an environment & eco-friendly engineering activity.

INTEGRATED RECLAMATION APPROACH POST-MINING

The OB dump reclamation can be used not only as a means of mitigation, but also as an end in itself to take the mined-out area to the closest possible state to its pristine condition. One such way is to undertake reclamation with an integrated approach involving viz., creation of an Eco-restoration park, conversion of the residual mine-void into a pit-lake, and water harvesting and management thereof by adopting suitable treatment techniques (Figure-1). These components are mostly inter-related and feed into each other, ultimately leading to optimum water management (Figure- 2).

Pit-Lake from the residual mine void

It is suggested to convert the residual/ abandoned mine voids into “pit lakes” after cessation of the mine in order to augment the groundwater recharge in a sustainable manner. The infiltration of stored water into the ground-water would lead to a subsequent rejuvenation/ rise of the regional water table. The drinking water supply to the localities nearby may also be augmented by the establishment of the necessary treatment/ RO plant. This will help cater to the increasing sweet-water demands for both domestic and industrial uses.

Once established though, these pit lakes shall

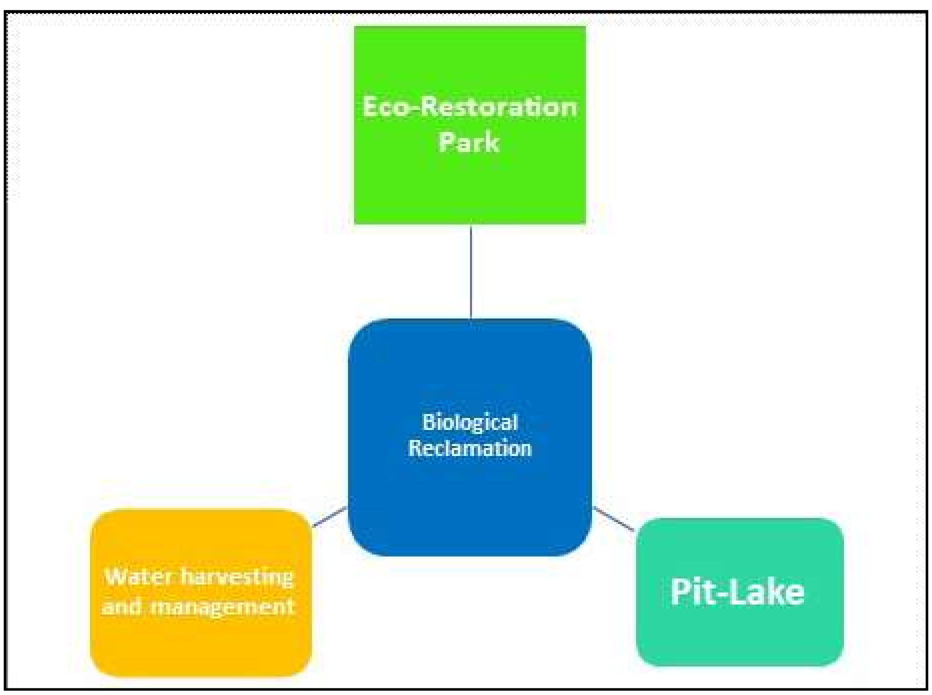

Figure-1: Components of Integrated biological reclamation approach

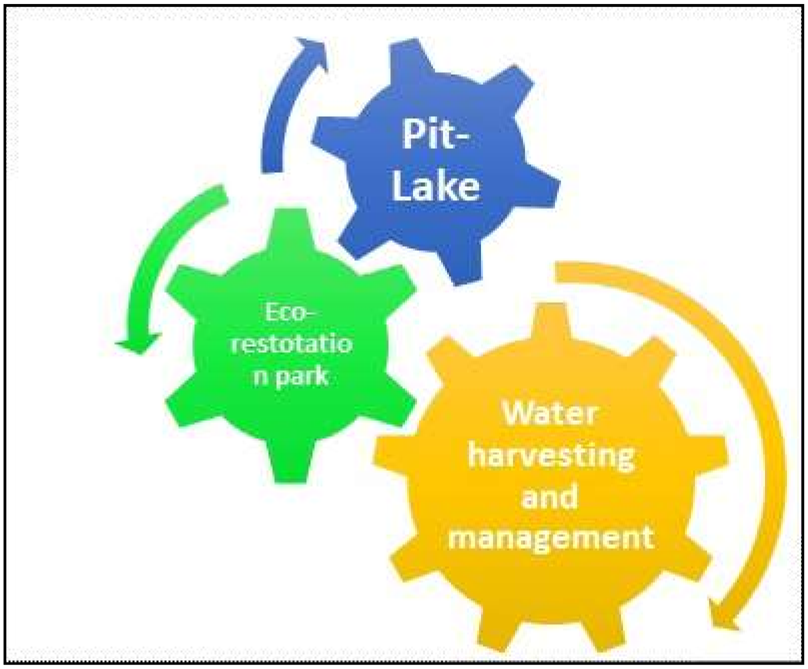

Figure-2: Inter-related components of biological reclamation leading to optimum water management

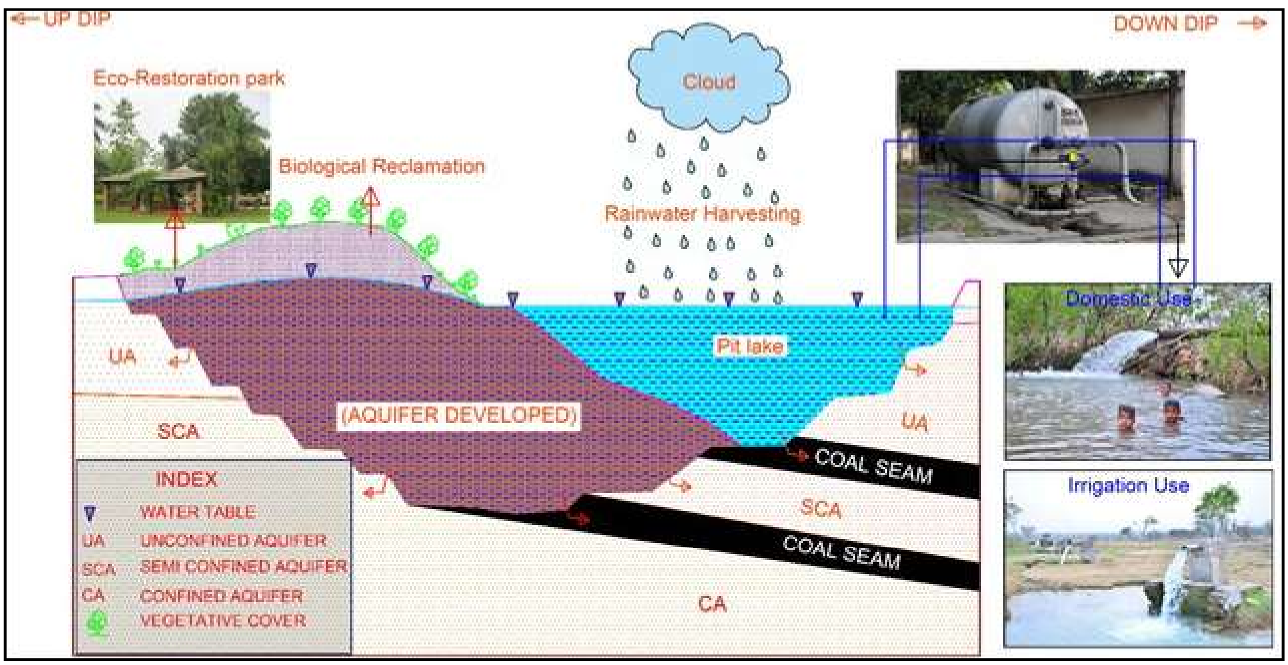

Figure-3: A schematic diagram depicting a pit lake and the aquifer developed in the backfilled and reclaimed area

be monitored periodically in terms of both quality and quantity of water resources in the proximity. To avoid occurrence of large-scale oxidation the pit lake, so developed after cessation of mining, shall be filled with water by connecting with local drainage, to restore the original course. A schematic diagram depicting the pit lake developed in the reclaimed area is given in Figure-3. Photographs of some pit lakes developed in SECL mines are given in Figure-4a and 4b.

Figure-4: Photographs of pit-lakes/ abandoned mine quarries filled with water at (a) Dola OC, Hasdeo Area, SECL and (b) Manikpur OC, Korba Area, SECL

Eco-restoration Park

A part of the reclaimed site could be converted into an Eco-Restoration park, wherein a garden can be built, with a (pit) lake facing view. Proper biological reclamation over the OB dump would allow reintroduction and flourishing of native species of flora and flora in the area. Asthetic features like a greenhouse, inhouse-nursery etc. can be built-up and tourism can be promoted in such parks by allowing public entry at fixed hours, thereby benefiting the local population. From a geo-technical perspective, the biological reclamation will lead to land and soil-stabilisation, and indirect groundwater recharge.

The *Ananya Vatika,* an Eco-restoration park, in Hasdeo Area (SECL) is a model case for such an effort and similar approach can be adopted for other mine areas as per their local conditions (Figure-5).

Water harvesting and management

The Pit-lake and Eco-restoration park help harvest rainwater, augment groundwater recharge and thus allow better water management in the area. The drinking water supply to the nearby localities can be augmented by the establishment of water treatment plant (like the Dola RO plant in Hasdeo Area) (Figure-6). Moreover the water from the pit-lake can be used for various purposes like irrigation (Figure-7).

The pit-lake also leads to significant ground-water recharge. The amount of possible recharge happening in the groundwater due to pit-lake created in the Hasdeo Area is estimated below:

$$\textbf{Recharge} = \textbf{Average Wetted Area * Infiltration factor}$$
$$= 0.6 * \text{Wetted Area} * 0.0014(\text{m/day})$$
$$= 0.6 * 50 * 4046.86\ (\text{m}^2) * 0.0014\ (\text{m/day})$$
$$= 169.97\ \text{m}^3/\text{day}$$
$$\mathbf{= 62{,}038.36\ m^3/yr = 0.062\ M\ m^3/\ year}$$

Figure-5: Photographs of an Eco-restoration park/ Garden-cum-Lake view created in the restored area, Hasdeo Area, SECL

Figure-6: Photograph of Dola RO Filter plant at Hasdeo Area

Figure-7: Photographs of water from pit-lake in Hasdeo Area, SECL for various purposes

The creation of an artificial reservoir elsewhere amounting to a similar value of groundwater recharge would involve significant costs. Hence, conversion of residual mine-voids into pit lakes should be adopted on a large scale for optimized water management.

CONCLUSION AND RECOMMENDATIONS

The reclaimed OB dump and the backfilled residual abandoned mine quarry hold a potential to be utilized for promoting environmental sustainability. It is suggested to convert the residual/ abandoned mine voids into "pit lakes" after cessation of the mine in order to augment the groundwater recharge in a sustainable manner. Once established, these pit lakes shall be monitored periodically in terms of both quality and quantity of water resources in the proximity.

Besides this, proper biological reclamation of the backfilled area shall also be undertaken for the eco-restoration of the mined out area through the creation of eco-restoration parks. For scaling up such efforts on a large scale, the best practices of successful cases like the *"Ananya Vatika"* in the Hasdeo Area, SECL may be adopted by other mines as well after feasibility assessment.

In essence, adoption of this integrated multi-pronged approach: i.e., development of the reclaimed area into an eco-restoration park and conversion of mine voids into Pit lake, thereby effective water harvesting and management practices will substantially augment the ground-water recharge and also cater the needs of the local populace upon reclamation of mine voids with pristine overburden/ interburden material rather than blending of OB material with fly ash for reclamation. Moreover, the creation of such capacity surface reservoirs will incur huge cost and land submergence and therefore, it is prudent to conclude that pit lakes formed after open cast mining will enlighten the policy makers and water auditors to adopt water security policies out of such reservoirs in the near future, besides augmenting the groundwater recharge of confined/semi-confined and unconfined aquifers.

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