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# OPENCAST COAL MINING AT LARGE DEPTH IN INDIA-CHALLENGES AHEAD

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## ABSTRACT

In present review study authors, have tried to present a glimpse of the forthcoming constraints in deep seated opencast mining of coal deposits in India. With the increase in demand of coal in India in the power sector and other industries, open cast mining of deep seated coal deposits has increased. To increase the depth of existing opencast coal mines is the only easy and cost effective option to meet the demand supply gap of coal in India. Various problems and their feasible solutions have been dealt in brief which are likely to encounter while extraction of deep seated coal deposits through opencast mining.

**KEYWORDS:** Mining, opencast mining, coal mining, challenges of deep seated coal mining.

## INTRODUCTION

Coal remains the primary source of commercial energy in India on economic consideration over the last two decades. The Coal vision 2025 estimates that the total domestic coal production is projected to increase to 1086 MT in 2025, of which the opencast production will be 902 MT (83%).

Coal extraction through opencast mining method is the most efficient and economic method of coal mining in India because of high production and extraction rate, low cost of production, lower gestation period, potential of full scale mechanization and lower safety hazards. In India, around 92% of the coal is produced by opencast mining method (Table 1).

If domestic coal production continues at 5% increasing rate, the extractable reserve will last for 45 years. Opencast mining has been proved very economical for low grade coal lying at shallow depth and there are lots of scopes to increase the production. This factor alone has attracted coal companies to opt for opencast mining. In view of the future planning and taking into account the limitations of underground mining, it may be essential to have more number of opencast coal mines. But, in last few years, environmental issues have surfaced up posing threats to growth of opencast mining sector. Severity of this issue can be easily understood by verdict of Honorable Supreme Court of India over iron ore mines of Goa, India. Also, any opencast mining project requires a huge area of land whose acquisition has become very difficult task in now -a -days.

**Table 1: Production of coal and lignite by government and private sector in last 10 years by opencast mining (Source: Coal Controller Organization of India).**

| Year | Production (Million tonne) | % of total production |
|---|---|---|
| 2005-06 | 437 | 85 |
| 2006-07 | 461 | 86 |
| 2007-08 | 490 | 87 |
| 2008-09 | 524 | 88 |
| 2009-10 | 566 | 89 |
| 2010-11 | 569 | 89 |
| 2011-12 | 581 | 90 |
| 2012-13 | 602 | 90 |
| 2013-14 | 609 | 91 |
| 2014-15 | 660 | 92 |

At present, most of the opencast coal mines in India are working in the depth of less than 150 m. Keeping in view of future demands, South Eastern Coalfield Limited, India is planning some of its biggest opencast coal projects to go beyond 300 m like Dipika with 25mt per annum at 250 m depth, Gevra with 35 MT per annum at 318 m, Kusmunda with 50 Mt per annum at 300 m depth (Singh and Manna, 2015).

Proper planning of transport network, dumps and drainage, adequate lighting and ventilation are required for deep opencast coal mines. As the depth and stripping ratio increases, the percentage accommodation of dump within the quarry will be limited. It may so happen that dump may have to be planned outside throughout the life of the mine. The adverse impacts of deep opencast mining on environment may also increase substantially which needs to be mitigated with proper planning. This study is focused on various problems to be encountered in mining of deep coal deposits through open cast mining methods, various environmental issues and their mitigation measures.

**Constraints in deep opencast coal mine and their likely solutions**

Some of the important constraints which might occur during deep opencast coal mining are highlighted and discussed as follows.

**Stability of high benches**

Slope failures are one of the leading causes of fatalities in opencast mining operations. It is obvious that as the mine will go deeper, the benches, both in OB (Overburden) and coal, will face stability problem. This will be enhanced due to weight of upper benches and movement of HEMM (Heavy Earth Moving Machinery) as well. This problem may become worse if compressive strength of both coal and OB material is less. To overcome this situation the sides shall have to be kept sufficiently flat to avoid collapse. But, this will demand additional space at pit top owing to extension in pit size. Keeping in view the maximum recovery of coal together with stable benches, faster rate of extraction shall be ensured to avoid benches standing for longer period. Safe geotechnical designs of slope using some stabilization techniques for permanent slopes and installation of slope monitoring devices for these slopes are some of the ways to reduce the chances of slope failures. A stringent slope stability analysis and monitoring is must for a deep opencast mine involving high benches.

**Transport of material from pit**

As opencast mines get deeper, haul distances and cost of transportation will increase manifold, so standard size dumpers have to be replaced with larger trucks with payloads of up to 400 tons. Selection of suitable size and type of equipment can result in greater energy efficiency and productivity. Haul road optimization, dump configuration and optimization can minimize the overall transport cost.

For smooth running of dumpers and excavators and other HEMM and also to commensurate with The Coal Mines Regulations,1957 it is essential to provide adequate working space on the operational areas by way of increased bench width and wider haul roads. Eventually, this will again lead to demand of extra land at final pit top. The same difficulty will be raised while working at Pit bottom as the deeper parts will definitely have very narrow space for movement of dumpers. Owing to this, the rate of extraction may not be up to the desired level.

**Shovel Dumper/in-Pit Crusher/Conveyor Combination:** Shovel dumper combination is one of most proven technology used for removal of overburden and extraction of coal. Shovel with in-pit crushing and conveying technology using mobile/ semi-mobile crushers and conveyor combination can be more efficiently and economically used where production requirements are high and mine depth is large (Fig. 1 and 2). With this system, the materials transportation from the pit is continuous. This system, though, capital intensive, can give massive savings in operating cost with rapid payback period and environmental benefits in terms of reducing air borne dust and carbon emissions. This provides for reduction in manpower, fuel, infrastructure for maintenance of dumpers, better management of OB dumps at faster rate. For overburden, it is broadly assessed that if volume of overburden to be removed in a year is about 4 $Mm^3$ and distance of transport exceeds 4 km, it is advisable to install an in-pit crusher conveyor system and restrict movement of dumpers from shovel to crusher only.

**Figure 1: Large Rope shovel loading a mobilizing station (Dewangan et al, 2014).**

**Figure 2: Fully mobile crushing plant on face (Dewangan et al, 2014.**

In Ramagundam Opencast-II mine of Singareni Collieries Company Limited, India, In Pit Crushing and Conveying systems for both OB and coal are being practiced. Two systems of each 4 million cubic meters are being used for OB and one system of 4 mcm for coal. The mine is planned to produce 4 mtpa of coal and about 6.5-7 mcm of OB per annum. Coal is loaded by shovel into the hopper of 2800 t/hr. double roll mobile crusher. The crushed coal is conveyed from the crusher to a belt wagon and then to a shiftable conveyor running parallel to the face advance for onward transport to trunk conveyor. The system capacity is about 4 mtpa.

**Pipe Conveyors for Coal Transport**

The pipe conveyor is an enclosed curve going transportation system for all kinds of bulk materials. At the loading and discharging points, the conveyor system is identical with open troughed conveyors. The open belt passes through a series of transition idlers to form a pipe shape, which is maintained for the length of the conveyor (Fig. 3). Just before the discharge pulley, the belt opens again and allows the material to be discharged in the normal fashion. On the return side, the belt is again formed into a pipe shape.

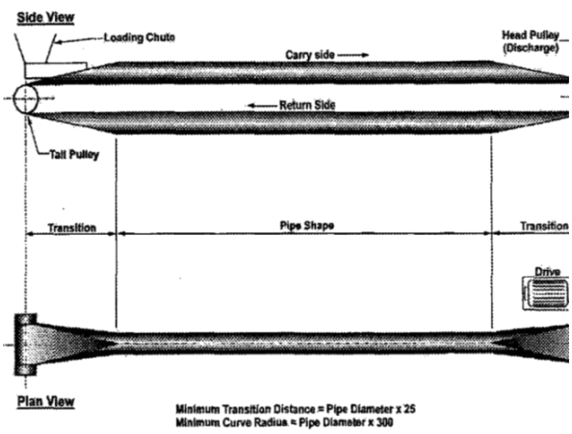


**Figure 3: Pipe Conveying Technology (http://www.tenovagroup.com/pdf/brochure/114-Pipe%20Conveyors.pdf).**


**Figure 4: BWE loading in to Belt Wagon (Dewangan et al, 2014).**

Due to its tubular shape, the conveyor is able to manage horizontal and vertical curves as well as high inclinations. The enclosed transportation system not only protects the conveyed material against external influences such as climatic conditions, it also avoids material loss and spillage and thus, protects the environment. The pipe conveyor is narrower than a conventional conveyor of the same capacity and uses less floor space. The pipe shape of the belt permits the conveyor to curve horizontally as well as vertically. Lump sizes up to 200 mm can be easily transported. Pipe conveyors are ideally suited to situations where transport by conventional conveyor systems would prove hazardous or costly due to environmental or population concerns.

**Bucket Wheel Excavators:** These excavators are used to remove soft overburden and mine lignite and various soft minerals continuously in combination with belt wagons, or mobile transfer conveyors and form a flexible, adjustable, synchronized bridge between the bucket wheel excavator and the bench conveyor in order to ensure a continuous, uninterrupted flow of material from open pit mining operations. (Fig. 4)

**Truck Lift Systems:** To optimize transport while maintaining flexibility offered by truck transport, SIEMAG TECBERG has developed the Truck Lift slope hoisting system which considerably accelerates and cheapens transport from the mine (Fig. 6).

**Figure 6: Truck Lift Systems developed by Siemag Tecberg (http://www.siemag-tecberg.com/infocentre/technical-information/ti_27-trucklift.html).**

While the trucks move upwards at less than 3 m/s on a slope of 10 % at the maximum, a slope hoisting plant can overcome the mine's natural angle of repose of over even 50° at 8 m/s. This means that a truck is hoisted to surface in only 2 minutes while driving on the haul road incline takes some 20 minutes (from 300 m depth, time for driving on and off the Truck Lift platform included). Whereas one vehicle is on the slope with the Truck Lift plant at one time, conventional haulage requires large number of trucks only on the inclined part of the road for achieving the same transport volume. Thus, the truck fleet can correspondingly be reduced. The Truck Lift System transport capacity depends mostly on the truck size and hoisting depth. Capacity can be starting with 4,000 t/h and being at 2,000 t/h at the final depth. With a conservatively calculated annual operational time of 7,500 hours, this means a transport capacity of 15 million tons at the final depth. Depending on the depth, the saving in number of trucks in operation increases up to 12 or even more.

**High angle belt conveyor system**

The HAC (High Angle Conveyor) is a sandwich belt design which employs two ordinary rubber belts on top of each other sandwiching the material between them. HAC conveys properly sized material at very steep angles (up to and including 90° vertical), high lifts and capacities over 8,000 MTPH, saving up to 50% in material handling costs.

**Blasting of benches**

To have stable slopes, having large no. of small benches may be a good option. But, this will not facilitate blasting a large no. of holes with explosives having high shattering effect. To overcome this problem, blasting of less no. of holes with low explosives may be adopted. However, this will require more frequent blasting and shifting of HEMM during each blast. Transport of explosives, especially to deeper parts is an added problem. Site Mixed Slurry (SMS) system of blasting represents the most advanced and economical method to safely deliver high performance, water resistant bulk explosives to the borehole. The SMS Bulk Delivery Truck is a self-contained, mobile bulk emulsion manufacturing facility which produces bulk emulsion explosives and then delivers it to the bottom of the borehole. Here, for blasting at deeper parts of pit the truck can be placed right on the surface having a long hose pipes reaching up to the blasting site. However, it would be feasible to adopt continuous mining method, if physico-mechanical properties of the rock permit to avoid blasting.

**Ventilation**

Natural ventilation in deep open pits is of great concern as the mine will have inadequate ventilation having insufficient fresh air to breathe and affecting clearing away of dust, exhaust emission of dumpers and blasting fumes. General tendencies of open pits deepening, growth of pit vehicles efficiency lead to worsening of problem of natural ventilation of deep open pits. The parts of open pits, which are difficultly ventilated in re-circulated zone, are situated at tranches driving, ramps and working sites of benches at open pit bottom. According to this, air contamination level in face space of the given working sites considerably depends on direction of ventilating air flow. However, research of deep open pits' aerodynamics should be carried out, using the software, creating CFD-models (ANSYS, COMSOL etc.), 2D modelling of velocity fields' structure. Large vortex is clearly seen in the central part of open pits, formation of smaller vortexes is possible in deep part, reverse flows can occur at some parts of the open pit slopes, velocities at the open pit bottom are rather slow. Weakening of air flows on deep open pits bottom is more significant, in comparison with average-deep open pits. The vortex in the pit's upper part is formed, impeding removal of harmful impurities.

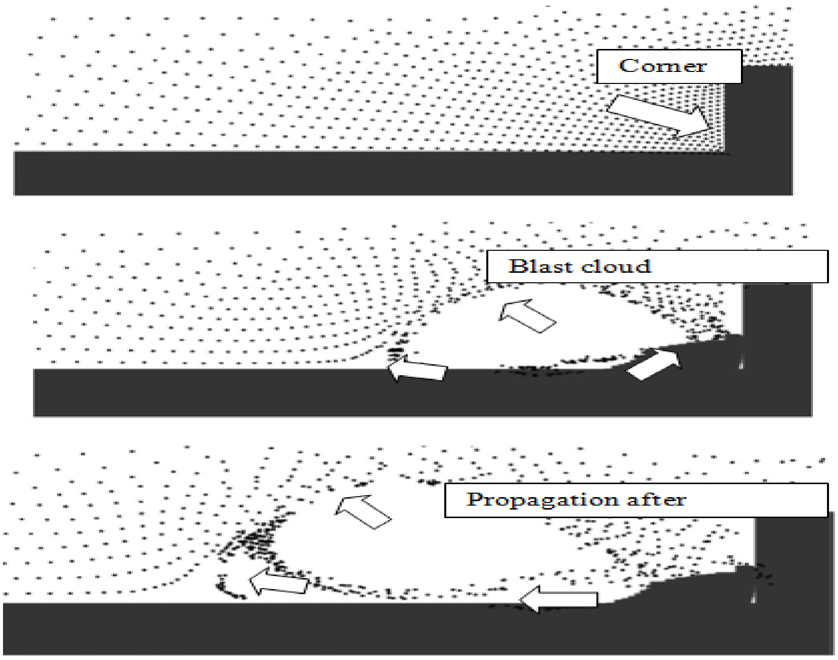


**Figure 7: Effect of local deflection on the dispersion of particulate plume (Appleton et al., 2006; Chinthala and Khare, 2011).**

The shape of the pit and slope present therein guides the wind flow. Also it play a major role in the reduction of the size of the primary eddies and results in increase in the wind speed. The bench faces and their elevation cause the local deflection of the plume affecting the direction of the dispersion. Moreover, the presence of corners enables the particulate matter to get confined to a region within the deep open pit till they reach a height where the effect of topography gets diminished and plume expansion is observed. This is called the venture effect. The sloping terrain may also result in katabatic and anabatic flows (i.e. drainage of air down or uphill sides in response to changing vertical temperature profiles). Further, the terrain elevation may either restrict or exacerbate aerial dispersion when the lower boundary layer heights confine the articulate plume closer to the terrain surface (Figure 7).

The only feasible solution to this problem is to install a heavy duty electrically operated Exhaust Fan system. It may be a multi impeller axial fans made of two or more fans in series, with ventilation ducts upto the surface. However, a detailed pre-installation study is essential before selecting any fan system.

**Drainage of mine**

The deeper the mine, the more will be accumulation of rain water. Intersection of ground water aquifer will also increase the influx of water. The quantity of water to be discharged may be so large that it may affect start of production from deeper parts as soon as rainy season recedes. Drainage of rain water and ground water may be difficult owing to long pipe range from sump to surface which may result in frictional losses, loss of head and finally less quantity of water discharged.

The different types of solutions to this situation are available of which having series of Intermediate sumps made at different benches at different levels to collect rain water may be best one. This will result in saving of head and power consumption.

Apart from this, a series of Garland drains shall be provided all around mine boundary to prevent In Rush of surface water into the mine. And, Toe drains shall be prepared at bottom of every bench and their gradient shall be such as to direct the flow of water to Intermediate sumps. This will help in reducing intake of rain water into Main sump.

**Backfilling in mined out lower sections**

Land degradation due to external dumping in India has assumed a significant dimension because loss of agricultural land, loss of ground water, etc., are very intensive. As such, it is essential to design environmentally sustainable backfilling plans for simultaneous backfilling of operational, highly inclined, and deep opencast mines. However, various constrains in backfilling also exist. When a coal seam dips at more than 28–30° backfilling becomes difficult or only partially possible. When the coal seam dips at a high angle (>30 with horizontal), backfilling is believed to be difficult or only partially possible (IBM, 1995).

When dip is high, less effective space is available for accommodating OB. In case of high dip excavation, as the excavation advances, the ratio of vertical dimension to horizontal dimension increases; consequently, effective space decreases as compared to a flat or near flat deposit excavation of similar quantity. As such, with high dip excavation, effective space for OB accommodation is less. The following is a rough observed estimate of backfilling feasibility in the Indian coal mining sector (Nand et al., 2015).

**Table 2: Backfilling feasibility (Nand et al., 2015).**

| Gradient of seam | Effectiveness of backfilling |
|---|---|
| 0–6° | Dip angle facilitates 100 per cent backfilling |
| 6–15° | Dip angle facilitates 100 per cent backfilling with 18 per cent rehandling of initial overburden (although rehandling is discouraged due to pressure on economics) |
| >15–25° | Dip angle makes possible 50–65 per cent backfilling |
| >25–30° | Dip angle makes possible 30 per cent backfilling |
| >30° | Dip angle makes backfilling impossible |

A concept of the retaining wall has been tried in Chasnalla Opencast mine, Jharia Coalfield, India. Retaining wall is a structure used to provide lateral support to vertical slopes of soil. Gravity walls, counter fort walls, cantilevered walls, and mechanically stabilized earth walls, concrete butters retaining wall, gabion wall are commonly used (Figure 8). Later two types have been applied in the above mine.

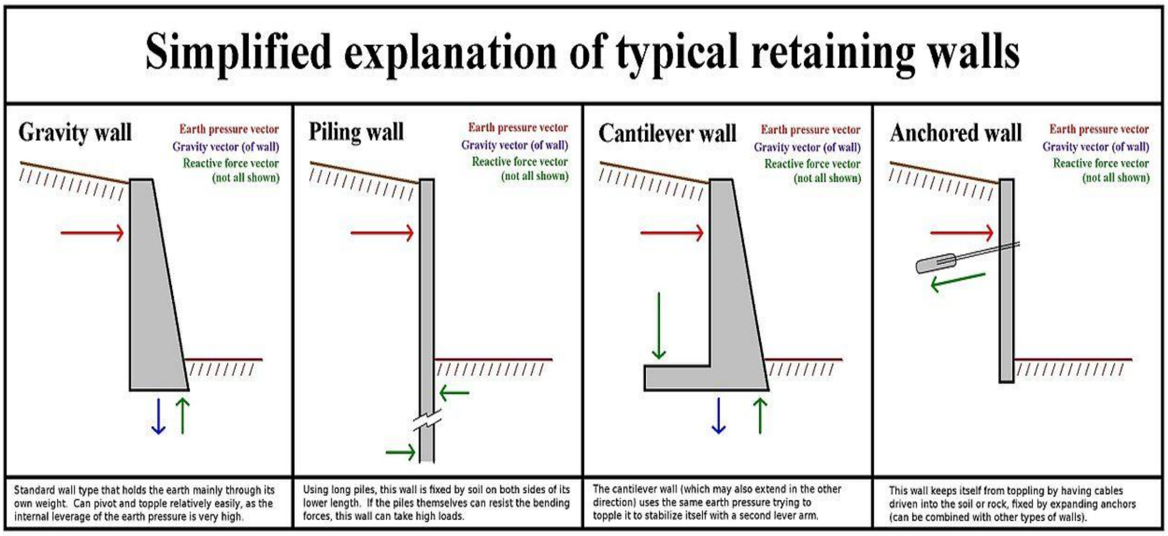


**Figure 8: Typical Butters retaining walls (http://www.aboutcivil.org/retaining-wall-definition-types-uses-retaining-walls.html).**

### Adverse impact on water regime

Open cast mining affects the hydrological regime of the region and quality of surrounding water. Lot of water is required in various mining activities. The water collecting into the mine sump is partly used up for these activities and the excess water is taken out and discharged into the surface. A deep mine is likely to have longer haul roads requiring more spraying water.

## CONCLUSIONS

Coal will continue to dominate other fossil fuels for energy generation in Indian scenario. The huge gap between demand and supply can only be filled up by extraction of deep seated coal deposit by opencast mining. Obviously, it has so many constraints which must be taken care of. The probable difficulties and their most probable and economical solutions have been discussed in the paper to provide a basic know how for the investors while exploiting deep seated coal deposit. However, an immense study is required before deploying any new technologies and innovations in deep opencast mining method to make it commensurate with the economics of mining.

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