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Scientific Study and Advice on Mitigation of Silt Generation and Boulders & Debris Flow in the Coal Mine Overburden

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Abstract: ***Slope Stability is one of the major problems faced in open cast mining. Due to more recent technological advancements stripping ratio is getting increased and it has now become possible to extract coal from greater depths. Extraction of coal from greater depths results in heavy volume of overburden removal. This overburden is dumped either internally or externally and is called over burden (OB) dumps. Stability of these OB dumps needs utmost care from silts and rain cuts. A Rain cut of OB dumps is one of the most dangerous problems in open cast mines. Due to rain cuts soil gets eroded, OB slope stability may reduce and as a result slope failure may occur. Deep rain cuts in external dumps and huge formation of silt and spreading of silt/sludge over a large area surrounding the dumps generally effect coal production as well as reduce the stability of dumps. This paper deals with the study of OB dumps in Amlohri project of Northern Coalfields Limited giving a solution or advice for Water Management of dumps of Amlohri Project for minimization of rain cuts, minimization of silt/sludge formation and flow with minimization of associated damage to mining activities.***

Keywords: Slope stability; Rain cuts; boulders and silt formation; water management; OB dumps

1. Introduction

Amlohri Opencast Coal mining project is located in Moher basin of Singrauli district of Northern Coalfields Limited (A subsidiary of Coal India Limited) and lies between latitude 24^{0}7'30" to 24^{0}9'30" N and longitude 82^{0}34'30" to 82^{0}36'30" E. It is covered under Topo sheet no.63-L/12. It is located west of Nigahi OCP. The area is undulating and hilly terrain. The elevation varies from 140m to 470m above MSL (mean sea level). The average annual rainfall is generally 1000mm out of which 95% precipitation is during rainy season. The drainage of the area occurs through Amjharnallah on the west and a seasonal nallah in the east which joins the river kachani on the south. The mine is working since 1983-84 and it is planned to meet a targeted coal production of 10Mtpa. The project is being worked by combined mining system deploying dragline and shovel dumper combination. The ultimately working depth has been estimated as 165m. The total overburden during the mine life has been estimated as 1314.87Mm^3, out of which only 185Mm^3 is proposed to dump externally and balanced as backfill internally. The overall dump slope will be kept at 28^{0} to prevent dump slide.

Figure 1: Location map of study area

2. Stratigraphic Sequence of Lithology

The coal bearing rocks of Amlohri block belongs to Barakar formation of Damuda sub group. The generalized sequence of the block as established by the geological survey of India and the Indian Bureau of Mines. There are four coal seams occurring in the area viz. kota, turra, purewa bottom and purewa top seams in the ascending order. The purewa top and purewa bottom seams combine to-gethere in the south central part of the area to form a composite seam representing pure wamarged seam. The kota (thin and impersistent seam) has been encountered in few boreholes within the area and as such its description is not dealt with separately.

Table 1: Stratigraphic Sequence of Amlohri Block

Sl. No.	Lithology	Thickness
1	Soil and Sub-Soil	0-6
2	Sandstone & Shale	20.15-182.90
3	Purewa Top Seam	0.50-7.64
4	Sandstone	0-17.15
5	Purewa Bottom Seam	10.33-15.00
6	Sandstone	54.40-66.20
7	Turra Seam	11.50-17.90
8	Sandstone	18.44-23.65
9	Turra 'A' Seam	0.22-1.20
10	Sanstone	38.92-49.20
11	Kota Seam	0.12-1.39

3. Overburden Characteristics

Major part of OB is sandstone which amounts to about 94% of the total OB thickness. Compressive strength of fine grained sandstone varies from 125 to 200 kg/cm^2 and that of medium to coarse grained sandstone is in the range 40 to 150 kg/cm^2. Prevailing sandstone is medium to coarse grained. Strength of rock material of OB is quite low (one of the lowest in sandstone category).Volume weight of sandstone is 1.9 to 2.2 tons/m^3. The in-situ rock mass is competent with presence of little joint sets, however the blasted material dumped on the dump breaks into silt and sand particles easily due to low compressive strength.

Figure 2: A view of Amlohri Coal Mine OB dump

4. Observation of OB DUMP

Amlohri opencast mine has experienced severe problems related to deep rain cuts mostly near Nigahi-Amlohri Joint Dump Site, and near Old CHP and New CHP area. Some problems has been faced in this OCP in coursing rain water out of mine without pumping, water management of dumps, stability of dumps, and problems related to huge amount of silt generation and flow from dumps. The magnitude of the problem was such that the about 700m long 2.5m high retaining wall of RRM has been almost completely filled with silt accumulation but still there is no significant damage to this RRM wall has been noticed. The occasional gap in the continuity of the wall is allowing sand and silt flow with water from higher elevation to lower elevation. Similarly the Old CHP and New CHP area has also experienced severe problem related to sand silt and boulder movement into the existing cemented/ RCC drains.

There is basically two major problems faced by mine which are given blow-

- **Deep Rain Cut**

Due to the weathering and erosion action during heavy rains, sand and silt flows on high slope rapidly towards bottom of dump along with water creating rain cuts in the OB dump of mine.

Figure 3: Deep rain cuts in OB dump

- **Huge formation of silt and spreading of silt/sludge**

When the flow of water on the slope surface in uncontrolled and concentrated in a narrow zone then deep rain cuts occur with silt and large boulder flow on the slope surface. Huge formation of silt and spreading of silt/sludge over a large area surrounding the dumps have taken place affecting severely the mine access roads and mining activities. The coal production from the mines are also getting severely affected due to silt/sludge.

Figure 4: Silt formation and spreading on the roads

5. Mechanics of Silt Generation on Dump Surfaces

Initiation of channelized silt flow starts with heavy inrush of water during rains from a certain narrow location of crest part of dump slope. When the continuous inclined slope surface height is large (larger than 30m) the rain water attains high velocity and high kinetic energy to dislodge and transport good amount of silt material of slope. As the compressive strength of medium and coarse grained sandstone is quite low so that the sand and silt easily gets carried away along with high velocity of water. Overburden dump material is such that the silt and sand content is in the range 80 to 85%. The dump of Amlohri project behaves as if it is made up of very low compressive strength sand and silt. Silt is also generated and transported on haul road or along drains with water when water of a large catchment area flows through an area on roads or drains. Rate of silt generation and its flow increase with increase in catchment area and amount of rainfall within a small period of time. Where the drain type and size is not appropriate, the amount of silt generation is likely to be high. If the silt flow at appropriate locations and with appropriate design of arresting system is not done, it will flow through a long distance. When such transported silt meets a wide and relatively flat part of ground then sand and silt deposition takes place. There are many places where large scale of sand and silt deposition has taken place.

Figure- 5. Huge Silt Transportation Channel at mine

6. Mechanics of Debris and Boulders Flow with Rain Water

When the catchment area is large, slope is relatively high, rainfall is torrential (heavy rainfall within a few hours - a situation something like cloudburst) the sand and silt along with large size boulders of overburden material also flows along with water. Such boulders flow is associated with high kinetic energy which creates damage and havoc in mines.

Figure 6: Boulders flow with rain water

7. Recommendations for Mitigation of Silt Generation and Boulders & Debris Flow

In order to reduce the generation of boulders and silts and it flow and minimized the flow of channelized water from the crest part of slope for its downward journey on high slope, following steps should be adopted-

For protection and stabilization of fresh exposed dump surfaces which are more sensitive for silt generation, geotextiles should be used. Normal rainwater which falls directly on slope surface will have minimum rain cut effect if single slope height does not exceed 30m and overall slope does not exceed 28 degree. At suitable locations, boulders need to be arrested with RCC structural design coupled with wiremesh, iron rods, etc. A design for arresting system of boulders must be placed at appropriate locations to sustain the impact load. In selected areas of final dump re-technical reclamation and re-bio-reclamation will have to be done to achieve long term slope stability. In the process of technical reclamation some greeneries will have be sacrificed else long term stability will be difficult and costly to achieve. In the process of bio-reclamation more number of plants can be developed than sacrificed.

7.1 Non-Woven and Woven Geotextile

Geotextiles are permeable fabrics. They are used in association with soil because they have the ability to separate, filter, reinforce, protect or drain. They are typically made from polypropylene or polyester, geotextile fabrics come in three basic forms: woven (resembling mail bag sacking), non-woven needle punched (resembling felt), or heat bonded (resembling ironed felt). Non-woven geotextiles are having the property of soil retention and high water flow rate through fabrics. It is an excellent material for erosion control applications. It is also having adequate fabric strength and elongation properties.

Jute Geotextile

Jute Geotextile is a natural geosynthetics made from Jute fibers. Jute is a low cost, renewable, biodegradable and eco-friendly natural product. It has three basic functions-separation, filtration, and drainage. Amlohri Project should be used jute geotextiles because it possesses following advantages-

- It is much cheaper than synthetic geotextiles
- It is environment friendly and biodegradable
- It is easily available in abundance
- On gradual degradation, it adds fertility to the slope mass.

Jute geotextile also promote growth of vegetation. Cost of jute geotextile is low however the strength and durability is also low. It can be a cheap alternative to synthetic geotextiles if sincere effort is made to grow vegetation within a year or two.

Application potential areas of geotextiles for Amlohri Projects are:

- For protection and stabilization of dump slopes of high vulnerability from erosion point of view such as freshly exposed dump surface sensitive to high silt generation.
- For control of erosion of water channel banks sensitive to silt erosion from banks.
- For promoting development of vegetation on slopes of dumps

Figure 7(a). Jute Geotextile for Erosion Control

Figure 7(b): jute geotextile with small plants

7.2 Construction of RCC Retaining Wall

A retaining wall is any constructed wall that restricts soil/silt or other material at locations having an abrupt change in elevation. After observing and analyzing the severity of the problems in the mine, it is recommended to go for RCC Retaining Wall at all high risk places. Such wall will be a bit costly compared to other type of walls but they will have high strength and long life. The construction must be done strictly as per these given designs ensuring quality. The chances of physical damage or breakage of RCC wall will be rare cases only, if properly constructed.

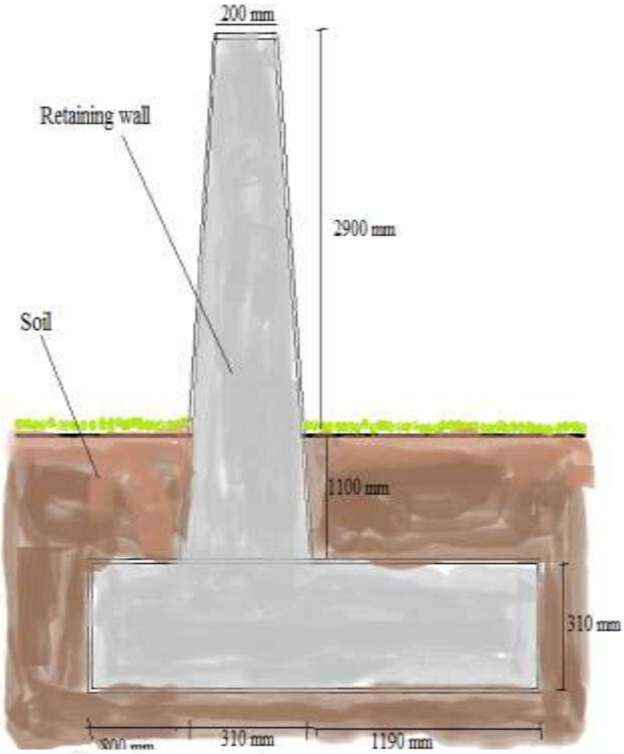

Figure 8(a). Design of Cantilever type RCC retaining wall of 4m tall stem

Figure 8(b). Photograph of a RCC Retaining wall

7.3 RCC Drain Design

RCC drains are also recommended in lower parts of mine dumps on toe side where water is required to be handled from a catchment area of more than 10 lakh m^2. Size of RCC drain should be adequate wide and deep. For handling received water from more than 20 lakh m^2 catchment area a bigger RCC drain is recommended. Design of such RCC drains are given in figures. Effectiveness of such kuchha drains must be ensured through machine cleaning before and during rainy season. Effectiveness of RCC drains should also be ensured before and during the monsoon period. A record of periodic inspection and action taken report for all kuccha drains, RCC drains, Hume pipes, and culverts should be maintained in a bound register or in any other form of record.

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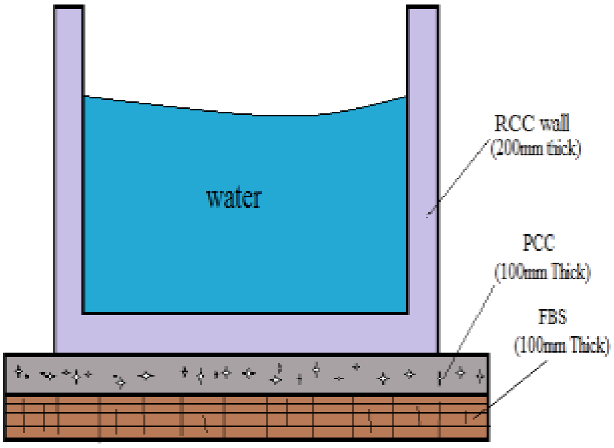

Figure 9(a): Cross section of RCC drainage

Figure 9(b): Photograph of a RCC drain

7.4 Water Management

- Water need to coursed out of the mine. For this kuccha drains and RCC drains as suggested should be used. All drainage system (kuchha drain, RCC drain, hume pipes, culverts) should be inspected and maintained properly and a record of such inspection and maintenance should be kept. Drains with design given in annexure should be used.
- Wherever necessarily required, water should be transported outside the mine through HDPE water pipeline on high slope parts of dumps. Pipe of appropriate size and pressure rating to be used for water transportation with adequate mouth protection at entry and exit points of water.
- In order to conserve water for future use of sprinkling or for use in plantation large or small water storage ponds can be created on suitable locations of dump surface using HDPE geomembrane or some other membrane of impervious and high strength values. This is likely to reduce rain cuts and silt generation and flow to a large extent. The cost involved in subsequent pumping will also reduce.

HDPE Pipelines

High Density Polyethylene Pipes (HDPE) pipe's unique characteristics have made it the product of choice for numerous applications in the mining industry. It is a proven product in extreme climates, rugged terrains and changing site environments. Heat-fused joints create a monolithic structure that allows long lengths of pipe to be pulled from one area to another. HDPE pipe's flexibility, abrasion resistance and leak-free joints have helped the product prove itself long-term in demanding environments.

Proven advantages of HDPE pipe for mining applications include:

- Chemical and Abrasion Resistance
- Low Cost - Life for PE pipe to conservatively be 50-100 years, and has zero leakage through pipes. Coiled lengths over 1,000 feet are available depending on size providing low cost installations.
- Polyethylene pipe is produced in straight lengths up to 50 feet long and coiled in diameters up through 6-inch. Coiled lengths over 1,000 feet are available depending on size providing low cost installations.
- Light weight – HDPE pipe is about one-eighth the density of steel. It does not require the use of heavy lifting equipment for installation

Figure 10(a): Photograph of HDPE Pipes

Figure 10(b): Close View of HDPE Pipe

7.5 Bio-reclamation

Vegetation has as important role in conservation of soil surface from erosion and allowing accumulation of fine particles[2] (Tordoff et al., 2000; Conesa et al., 2007). They can reverse degradation process by stabilizing soils through development of extensive root systems. Once they will be established, plants will increase soil organic matter, lower soil bulk density, and moderate soil pH and also they will bring mineral nutrients to the surface and accumulate them in available form. The plants will accumulate these nutrients redeposit them on the soil surface in organic matter from which nutrients will much more readily available by microbial breakdown[3] (Li,2006; Conesa et al., 2007; Mendez and Maier, 2008). The vegetation of eroded ecosystem must be Carried out with plants selected on the basis of their ability to survive and regenerate or reproduced under severe conditions provided both by the nature of the dump material, the exposed situation on the dump surface and on their ability to stabilize the soil structure[4] (Madejon et al., 2006). The list of plant species recommended for afforestation of OB dumps of Amlohri project and its surrounded area are given in Table

Table 2: Various plants species for reclamation

Grasses	Herbaceous Legumes	Trees
Bothriochloa	Hamata	Acacia albida
Bothriochloa	Cajanus cajan	Acacia
Eragrostis pertus	Crotalaria juncia	auriculiformis
Brachiaria mutica	Crotalaria burhia	Albizia amara
Cenchrus setigerus	Desmodium	Acacia catechu
Chloris gayana	Triflorum	Acacia holosericea
Chryosopogon	Medicago sativa	Aracia nilotica
intermedia fulvus	Phaseolus mungo	Azadirachta indica
Cynodon	stylosanthes	Leucaena
Echinochloa colona		Dalbergia sissoo
cynosuroides		Eucalyptus hybrid
geminatum		Erythrina variegata
Heteropogon		Gliricidia sepium
contortus		Zizyphus
dactylon		Acacia senegal
Paspalidium		Grewia tenax
Sacharum		Hardwikhia
bengalense		Albizia lebbeck
Sehima nervosum		binata
Sporobolus airoides		latisiliqua
Sporobolus		Pithecellobium dulce
coromendelines		nummularia

Figure 11: Reclamation process of OB dumps

8. Other Observations and Recommendations

Observations and recommendations for this site are as follows:

- It is observed that the height of first bench above Amjhar Nalla is more than 30m. Pumped water of from mine sump is seen being discharged directly on the wall of dump slope at least 25m above amjhar nalla level. Such discharge may gradually increase the silt level of the Nalla. As far as possible, water discharge should have be done at much lower level.
- Bench height should be maintained at 15m height with overall slope angle not above 28 degree. This design itself will go a long way in controlling siltation of Amjhar Nalla.
- Some cleaning of central zone of Nalla may have to be taken up in order to stop accumulation of stagnant water inside Nalla.
- **N**o rain water should be allowed from dump top to enter into rain damaged (water flow damaged) area having undulating deep rain cut surfaces. Water should be coursed on toe side of dump top through kachha drain.

9. Acknowledgements

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