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Development of Guidelines for Safe Dragline Dump Profile under Geo-Engineering Conditions of Coal Mines in Coal India

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Abstract

The India ranks third in world coal production mainly due to 89% contribution from opencast mining or surface mining. Coal India (a major coal producing organization in India) produced 359.78 million tons of coal in the year 2008-09 from opencast mining or surface mining technology. It is pertinent here to mention that to mine out 359.78 million tons of coal from opencast mining, 645 million cubic meter of waste rock and soil was excavated in the year 2008-09. But a major hindrance in sustaining this level of coal production from open cast mining is area of land involved. This socio-environmental predicament requires a solution and the only possible way to reduce the area of land affected is to increase the slope angle of the waste dump embankments. However, this solution creates another problem in itself i.e. the stability of the waste rock dump. It is considered as one of the major issues faced in the open cast coal mining operation due to slope failures resulting in fatal accidents in some of the large opencast mines of India.

Keywords: *Fortan Language, Industrial Disaster, Handling Waste Rock, Slope Stability.*

1. Introduction

In Indian opencast mining scenario, dragline operated opencast mines with a share of 45% of total opencast coal production are considered to be the most efficient way of winning coal for opencast mines linked to power plants. However, the method of dragline operation involving excavation and simultaneous back-filling is associated with concurrent problems of slope stability of waste rock dumps formed by dragline. The difficulty in handling waste rock dumps in dragline operation is discussed in this paper through a case study of Sasti opencast coal mine located in central part of India.

2. Review of Literature

The Sasti opencast mine is covered by a thick blanket of black-cotton soil (0.5 to 23.0 metre) overlying a strata (10.1 to 14.25 metre thick) of red brown, yellow coloured, fine to coarse grained sandstone with clay bands followed by another strata (46 to 130 m thick) of grey to white, fine to medium grained sandstone with intercalation of shale (CMPDI, 2008) . It has maximum depth of 150 metre with quarry area at surface and at floor equal to 167 and 143 hectare respectively. [1 hectare = 10^4 square metre] The maximum strike length of the mine is 1525 metre.

The mine has experienced frequent dragline dump failures in recent years including a fatal accident involving two mine workers in June, 2009 with displacement of 0.2 million cu.m of waste rock dump formed by dragline(Roy, 2009).

2.1 Rationale behind Research Case Study

This research paper presents the causes of accident in dragline waste rock dump, methodology for stability analysis and recommended dragline dump profile to tackle stability problem, along with suggestions for preventive measures to eliminate any form of Industrial Disaster. Further the Dragline is world's third largest mining machinery. And a single hour's stoppage in operation of Dragline results into loss of millions of INR, which results into overall loss to Coal India Company Limited.

2.2 Geo-Engineering Parameters

Stability of dragline dump deals with geo-technical characteristics of both dump material and interface material (i.e. slushy material lying at the floor of the dragline dump). The dump material is comprised of both excavated black-cotton soil mass and fragmented argillaceous sandstone with clay bands in natural moisture condition, whereas interface material is comprised of both black-cotton soil and waste argillaceous sandstone in fragmented condition submerged under water. The dump and interface material has been tested in the laboratory of Birla Institute of Technology, Mesra.

Other than laboratory tested values (CMPDI, 2005), back analysis has been carried on the existing dragline dump (which is standing at limiting equilibrium) considering that the dump is standing at Factor of Safety equal to one. The dump and interface material is found to have high plasticity index (35.37%) with majority of Montmorillonite minerals which absorbs water, leading to expansion in volumes and abrupt reduction of shear strength properties.

As per hydro-geological study of this area, there is a steady seepage of water from nearby river during rainy season. Oozing of water to the length of 7 m is found to emerge from toe of dragline dump in rainy season.

Because a number of spoil dumps from successive strips had shown large instability in recent years in this mine, it was important to carry out a thorough geo-technical investigation with stability analysis of the existing spoil dumps so that future dump formation would not initiate further slope instability.

The Two types of slope failure are observed (Roy, 1998) are as follows:-

1. Circular failure (The Failure through dump material only).

2. Circular-Cum-Planar failure (The Failure through dump and interface failure).

2.3 The Stability Analysis

Stability of Slope of dragline dump of Sasti opencast mine is carried out by limit equilibrium method considering both Fellinius and Bishop's method (Roy, 1998) with the help of a site specific computer programme developed for the Sasti dragline dump. Though the cohesion and angle of internal friction of dump mass and interface material is determined in the laboratory by simulating the site condition considering different level of stresses and moisture levels actually existing in the site, it is still prudent to check the laboratory determined shear strength values with that of field values. This has been done by back analysis of existing dragline dump profile which is standing at limiting equilibrium i.e. at Factor of Safety equal to one.

Due to above, a scientific computer programme in ***Fortran language*** (Roy, 1998) is developed for ***back analysis of existing dump profile to calculate the average cohesion and angle of internal friction of dump mass corresponding to Factor of Safety equal to one***. The other geo-engineering parameters which are considered in this back analysis are as follows:-

1. Laboratory determined bulk density of saturated dump mass [The dump mass was compacted at average compacting stress equivalent to existing stress within dump i.e. if the height of dump is 70m and the bulk density is 20 kN/m^3,then the average compacting stress is estimated at 700(35×20) kN/m^2].

2. Laboratory determined cohesion of slushy material i.e. interface material [The interface material lies at the floor of the mine above which the dump is formed]. At the laboratory, the interface material was submerged under water for 24 hours and compacted at compacting stress

of 1400(70×20) kN/m^2 as the interface material is under full height of dump.

3. Similarly, angle of internal friction of interface material is determined by simulating the field condition as explained above.

4. Shearing resistance i.e. cohesive force and frictional force by coal rib against dump failure is calculated at the bedding plane between coal rib and mine floor.

5. Geometric dimensions of the existing Dragline dump profile which is standing at limit equilibrium is considered to be one of the prime parameters.

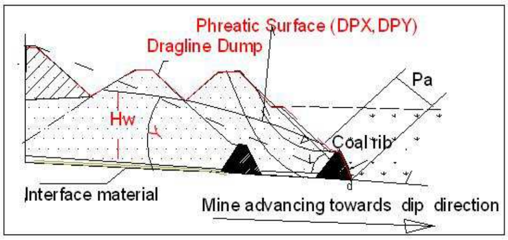
6. Height of water table (Hw) within dump mass at a distance of one cut width behind the toe of dump.

7. Height of water table outside the dump mass at toe of dump.

8. Inclination of dragline dump floor.

9. Height of interface material i.e. slushy material at the floor of the dump.

10. Ground acceleration generated due to maximum considered earthquake.



Schematic diagram of dragline dump

2.4 Principles of back analysis

A number of possible representative cohesive values of dump material are considered and corresponding values of angle of internal friction of dump mass is obtained by stability analysis for which the factor of safety becomes equal to one.

Similarly, a number of possible representative values of angle of internal friction are considered and corresponding cohesive values of dump is obtained for which the factor of safety becomes equal to one.

2.5 Steps for Stability Analysis Are As Follows:-

1. Factor of safety of 1st trial surface is determined by Fellinius method with assumed value of cohesion and angle of internal friction of dump material (nearer to the laboratory determined value) and other geo-engineering parameters stated above.

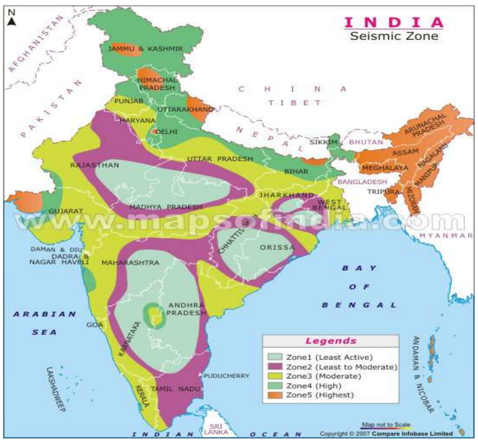
2. An iteration method is carried out to determine the most critical failure mode and corresponding absolute minimum Factor of Safety by Fellinius method.

3. As the Factor of Safety determined by Fellinius method is not absolutely accurate and underestimated, this value of Factor of Safety is again modified by Bishop Simplified method which gives fairly accurate results equivalent to other complex methods like Janbu's method, Morgestern-Price method and Spencer's method.

4. Then the above method is repeated till the combination of cohesion and angle of internal friction of dump mass is found for which Factor of Safety is equal to one.

2.6 Impact of Dynamic forces

Seismic forces are considered as per "Indian standard criteria for earth quake resistant design of structures (fifth revision) IS 1893:2002."



A Seismic zoning Map of India

The design horizontal seismic coefficient (A_h) for the dragline dump of Sasti opencast mine (located in central India) is determined by the following expression:-

$A_h = ZIS_a / 2Rg$

Where

1) Z = Zone factor for the maximum considered earthquake and service life of dragline dump in zone – 2. (Sasti opencast mine is situated in zone-2 as per Indian seismic map)

2) I =Importance factor depending upon the post earth quake functional needs, historical value or economic importance.

3) R = Response reduction factor depending on the perceived seismic damage performance of the dragline dump characterized by ductile or brittle deformation.

4) S_a /g = Average response acceleration coefficient for dump mass as given in the Indian seismic code.

The peak ground acceleration as determined above is 0.5886 m/sec^2 which covers both seismic and blast vibration effect as both blast vibration and earthquake does not occur simultaneously.

2.7 Hydro-geological parameters

Hydro-geological parameters influencing dump Slope Stability in determining stability of dump is as follows:-

Due to difficulty in assessing the water table within dragline dump mass through piezometer, height of water table (Hw) is determined by Casagrande's equation.

$Pa = Dp/Cosß - Sqrt[(Dp/ Cosß)^2 – (Hw/Sinß)^2]$.

Where

1) Pa = Length of oozing on dump toe.

2) ß = Slope angle of dump with horizontal.

3) Dp = 60 m.

Pheratic surface (DPY, DPX) is also determined by the following equation:

DPY(J)=SQRT{(DPX-Pa×Cosß/2)×2Pa ×Sinß×Tanß}(1)

Height of water table (Hw) is calculated as 15.3 metres.

Upward thrust of water - It is determined by the product of unit weight of water and volume of dragline dump mass under water table falling within the failure mass.

2.8 Geo-Engineering Parameters for Stability

The geo-engineering parameters considered for stability calculation is as follows:-

Cohesion of dump material= 65 kN/m^2

Cohesion of interface material= 30 kN/m^2

Angle of internal friction of dump material = 30 degree.

Angle of internal friction of interface material = 13 degree.

Bulk density of dump material = 20 kN/m^3

Bulk density of interface material = 18 kN/m^3

Height of water table (Hw) at 60m behind the toe of dragline dump = 15.3m

Cohesive and frictional force by the coal rib is taken as stated above.

2.9 Impact of Resisting Force by Rib

Cohesive force (for 10 m width) by the base of the rib against dump failure =120,000 kN.

Frictional force (for 10 m width) by the base of the rib against dump failure =12,390 kN.

3. Recommendations

With the above geo-engineering parameters, stability analysis has been carried out by site specific computer programme written in Fortran language (developed for this purpose). The recommended guidelines for dragline dump profiles are documented below:-

3.1 Guidelines for dragline dump profile

1. Base width and top width of coal rib should not be less than 11 m and 5m respectively.

2. Total berm width at the coal rib level should not be less than 10 m.

3. Height of coal rib should not be less than 7 m.

4. The above mentioned coal rib section should be maintained during and after retreat of the cut.

5. Slope angle of the coal rib bench should not exceed 66 degree with respect to horizontal.

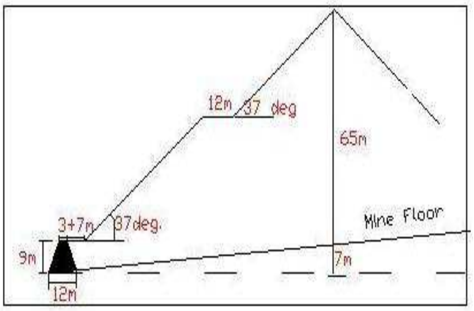
6. Slope angle between

(i) Roof of coal rib and dragline sitting level and

(ii) dragline sitting level and the peak of dragline dump should not be steeper than 37 degree with respect to horizontal.

7. Berm width on dump side at the dragline sitting level must not be less than 13 m.

8. Total height of dragline dump with respect to horizontal plane passing through toe of the dump should not exceed 72 m for above recommended slope angles.



Recommended dump profile

3.2 Preventive measures

Other than maintaining the above slope, following precautionary measures are recommended and implemented as far as possible to ensure stability of dragline dump:

1. Top soil is dumped separately as far as possible much away from the site of active dragline dumping.
2. No top soil is allowed to be dumped on the floor of de-coaled area to form the base of dragline dump.
3. There is minimum accumulation of water in the de-coaled floor of the quarry by ensuring natural gravitational drainage of water towards the sump.
4. Toe of shovel-dumper dump is formed at least 120 to 150 m away (i.e. more than two cuts) from the toe of dragline dump so that dragline dump gets adequate time to stabilize before fresh dumping by dumper.
5. The valley in the dragline dump is filled up by dozing to the extent possible.
6. Coal rib left at the toe of dump improves the stability of dragline dump to some extent. It may be noted that coal rib is prone to spontaneous heating and therefore, it is covered by dump material to the extent possible.
7. The interface layer i.e. debris of coal dust, fragmented rock, soil mixed with water is cleared as far as possible from the de-coaled floor before dumping by dragline.
8. Mine floor (which forms the base of dragline dump) is blasted to a depth of 1 to 2 m in a scattered way, if possible, before dumping by dragline to improve the frictional resistance at the base of the dump.
9. Minor blasting also facilitates the passage of water through the quarry floor down to the competent sandstone strata, thus preventing accumulation of water at the base of dump.
10. Regular monitoring of dragline dump is also carried out to observe any movement of dragline dump face which will indicate likely dump failure.

4. Conclusions

Interface material is a mixture of fragmented medium hard rock and top soil lying under water in slurry from. This interface material on an inclined floor of the quarry is the plane of weakness at the foundation of the dump, which is one of the major causes behind the failure of dump. Geo-technical parameters (Moisture contents, Grain Size Distribution, Atterberg Limits, Cohesion, Angle of internal friction and Bulk density) will be determined by collection of rock samples of size equal to or less than 6 cm from the dump mass, the samples will be pre-compacted to average stress within dump to simulate the actual stress conditions existing within dump mass.

References

[1] Central Mine Planning and Design Institute (CMPDI) (2005) Consultancy report on Slope Stability Study of Sasti Opencast Project – Ranchi, India.

[2] Central Mine Planning and Design Institute (CMPDI), (2008) Operational Plan of Sasti Opencast Project- Ranchi, India.

[3] Roy, I. (2009) Investigation Report on Causes and Remedies of Accident in the Sasti Opencast Project of Western Coalfield Limited - Birla Institute of Technology, Mesra, India

[4] Roy,I. (1998) Influence of Geo-Engineering Parameters on the Stability of Dumps, Ph.D Thesis, Indian Institute of Technology, India.