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Research Article

Slope Stability Analysis Of Internal Dump Of Rajrappa Mines

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Abstract:
Mining of coal basically deals with the excavation of coal in a well-organized manner considering the People Security as well as safety. Mismanagement of the over burden leads to instability of slope and may cause a Greater loss of lives. The present paper mainly inspects the permanence of dump of a coal mine at Rajrappa Coal Mine, Ramgarh district, Jharkhand, by Analyzing various Geotechnical aspects of dumps and mineralogy of the slope. In 2016, a disaster due to *dump failure* in Rajmahal coalfield of Eastern Coalfield Limited, killed 23 workers. Even though all such accidents are being analyzed and recommendations made in each case, similar accidents are not prevented. Failure of the dump mainly occurs due to the pore water pressure. In order to satisfy the minimum factor of safety usingfellenious method, finally, an economical, sustainable, overall slope angle and height has been recommended so that maximum over burden can be dumped in a smaller area.

INTRODUCTION

Along with the Coal Production in 2019-20, the Overburden raised upto 20%, due to insufficient area for dumping the rocks or for dumping Materials it is mandatory to maintain the standards of existing dumps in a mine throughout the life of respective mine. Basically, Overburden are the Materials which come out in the process of excavating Coal, the ratio of Overburden with respect to coal is around double that is number of overburdens produced is twice the coal production in a corresponding year.Only Coal producing companyCentral Coalfields Limited generated for fiscal year 2018-2019 generating 606.9 million tonne (mt) of coal and removed a overburden of 100 million tonne (mt). There are numerous experiences came across in India where dump failurehas been occurred due to which many people lost their lives. The Concerns regarding overburden dumps came into picture after systematic accidents and due to huge losses of life. All the mines or maximum number of mines are working on a dragline principle, generally due to insufficiency of land thetransporting of enormous quantities of dumping material are done outside the mine or backfilling is done. In current years the unparalleled rise in number of dumping materials challenged the environmental safety as well as the safety of mine workers and the local villagers. Dump continuously needs to be monitored and always maintained the safety standards.

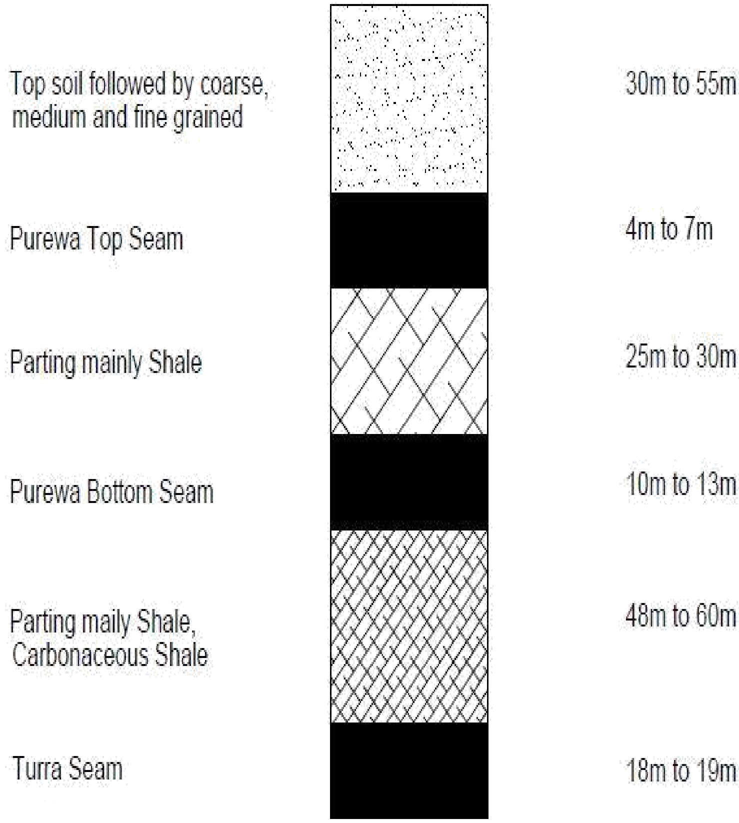

Figure 1 Different streams of soil

Method of work of Dragline

Working of Dragline (working in vertical tandom) in Rajrappa

Figure 2 Different streams of Dump

Figure 3. Closer view of Layers of internal dump

Figure 4 Lower Stream of dumps

The various streams indicate various parametersof the fine particles of coal , dust and the water below it.

Causes of Dump Failure

To know the root cause of any failure one should know the ingredients behind it. Specially in case of dump miscarriage occurs due to both internal and external factors. Normally miscarriage of dumps happens due to internal factors. External factors include the rise in the shearing stresses or shearing forces due to waves and tidal impact results in the steepened of slope which is the major factor for failure of dump.

Internal factors includes the sliding of dump in constant surface conditions. This type of circumstances occur due to the rise in pore water pressure, breaking of bonds and ion exchange. It consists of two types slope and Toe Failure. The slope failure deals with the arc of rupture and the slope above the toe, when both curves meet that is if slope angle rises and the toe near dump gives greater strength then this type of failure arises. While in the case of toe failure it depends on the profile of the soil, if the soil beneath the surface of the dam and beyond the surface of the dam is similar and also if the base surface angle is much low and the dump material beneath the base surface behaves as a plastic the failure occurs.

In the slope failure, the arc of rupture surface meets the slope above the toe. This can happen when the slope angle is quite high and the soil close to the toe possesses high strength. Toe failure occurs when the soil mass of the dam above the base and below the base is homogeneous. The base failure occurs particularly when the base angle - is low and the soil below the base is softer and more plastic than the soil above the base.High variation in temperature can cause dump material to spall due to the accompanying dilation. Water freezing in voids may causes damage by further loosening the slope material. Repeated freeze/thaw cycles may result in gradual loss of strength. Except for periodic maintenance requirements, temperature effects are a surface phenomenon and are most likely of little concern for final waste dump slopes.

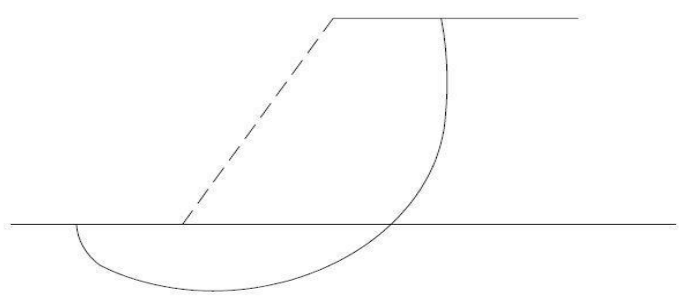

Figure 6 Slope Failure

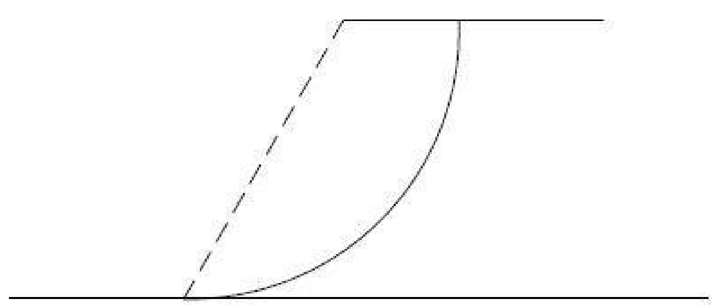

Figure 5 Toe Failure

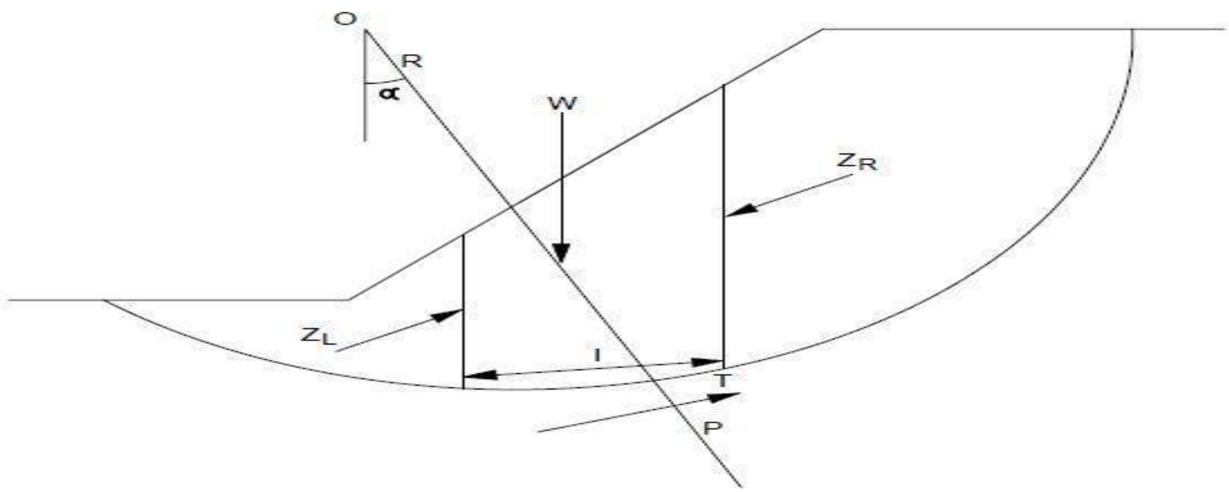

Figure 7 Fellenious Method of Analysis

The ordinary method is considered the simplest of the methods of slices since it is the only procedure that results in a linear factor of safety equation. It is generally stated that inter slice forces can be neglected because they are parallel to the base of each slice. For slice shown - total normal stress 'σ', shear stress 'T', pore pressure 'u'Also the Dump Profile is similar to Jayant, so we are considering same dump profile.

Overall moment equilibrium about O: $\Sigma WR\ sin\alpha = \Sigma TR$

(Note that inter-slice forces are internal and their net moment is zero).

Hence, F = $\dfrac{\sum\{c'l+(p-ul)\tan\phi\}}{\sum W\sin a}$

Fellenious Method of Slip Circle

Failure criterion: $s = c` + (\sigma\text{-}u)\ tan\phi`$

Mobilized shear strength $T = S/F$ where F is Factor of Safety

$$F = \frac{\{c'l+(P-ul)\tan\phi'\}}{F}$$

Under seismic condition the Factor of safety equation becomes

$$F = \frac{\sum\{c'l+(w-wv\cos\alpha-wh\sin\alpha-ul)\tan\alpha\}}{\sum\{(W-Wv)\sin\alpha+wh\cos\alpha\}}$$

Where Wh and Wv are the horizontal and vertical component of earthquake force

Assume that the resultant of the inter-slice forces Q is parallel to the base of slice. Resolving normal to base of slice $P = W\ cos\alpha$

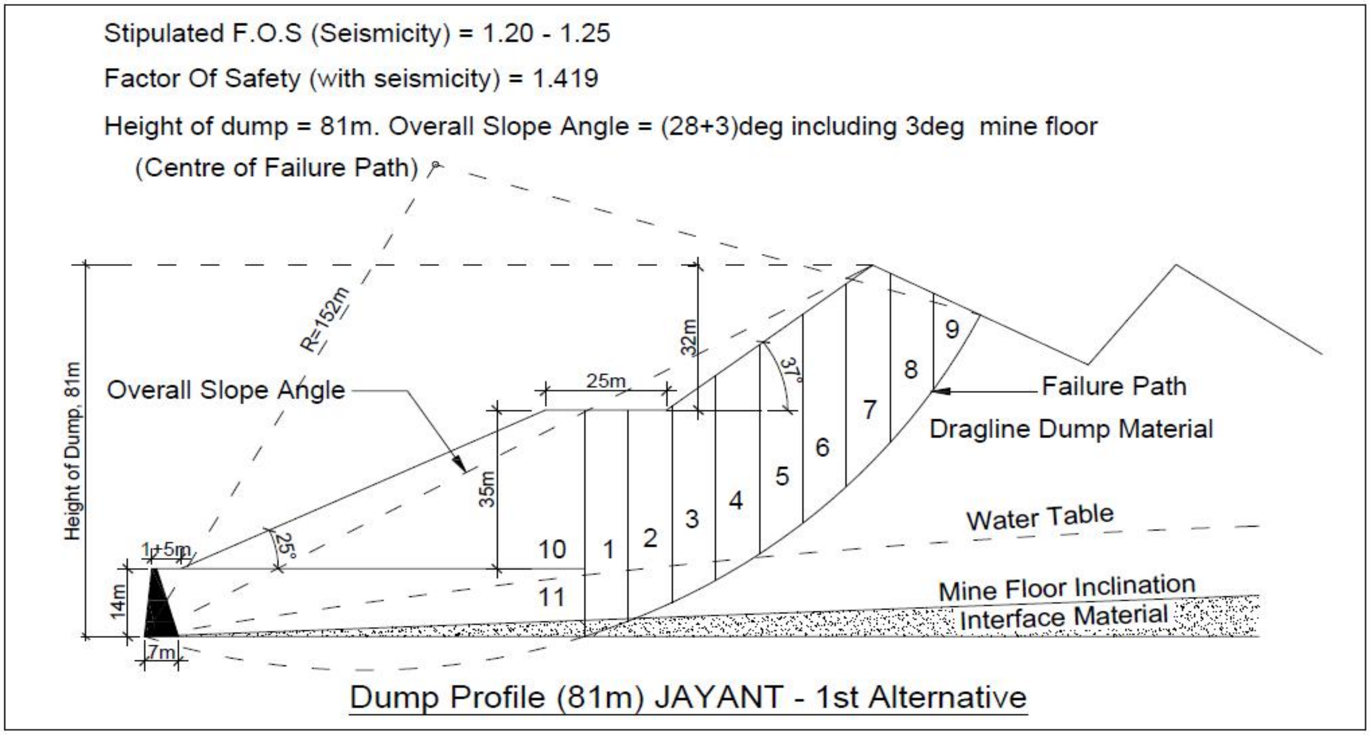

Figure 9 Dump Strucrture of Rajrappa Mines

Determination of FOS by Fellenius Method (with seismicity)

Frictional Force = $[W \sin\theta - sw\cos\theta]\tan\phi$

Where, S = Seismicity Factor, ϕ = Angle of Internal Friction

Slice 1

Friction Force=

$[80840 \times \sin 24 - 0.1 \times 80840 \times \cos 24] \times \tan 18$ = 8174.573136 KN

Slice 2

Frictional Force =

$[80840 \times \sin 30 - 0.1 \times 80840 \times \cos 30] \times \tan 18$ = 10652.35147KN

Slice 3

Frictional Force =

$[74260 \times \sin 32 - 0.1 \times 74260 \times \cos 32] \times \tan 18$ =10584.09958KN

Slice 4

Frictional Force =

$[65800 \times \sin 36 - 0.1 \times 65800 \times \cos 36] \times \tan 18$ =10668.12768KN

Slice 5

Frictional Force =

$[62040 \times \sin 40 - 0.1 \times 62040 \times \cos 40] \times \tan 18$ =11320.86067KN

Slice 6

Frictional Force =

$[61100 \times \sin 43 - 0.1 \times 61100 \times \cos 43] \times \tan 18$ =12081.74292KN

Slice 7

Frictional Force =

$[57340 \times \sin 50 - 0.1 \times 57340 \times \cos 50] \times \tan 18$ =12987.99166KN

Slice 8

Frictional Force =

$[51700 \times \sin 53 - 0.1 \times 51700 \times \cos 53] \times \tan 18$ 12291.73704KN

Slice 9

Frictional Force =

$[24440 \times \sin 57 - 0.1 \times 24440 \times \cos 57] \times \tan 18$ =6216.861456KN

Slice 10

Frictional Force =

$[163184 \times \sin 90 - 0.1 \times 163184 \times \cos 90] \times \tan 18$ =69190.016KN

Slice 11

Frictional Force =

$[128780 \times \sin 90 - 0.1 \times 128780 \times \cos 90] \times \tan 18$ =54602.72KN

Total Frictional Force with seismicity =

$\sum([w \sin \theta - sw \cos \theta] \times \tan \phi)$

=218771.0816KN

1. **Disturbing Force =**
   $[W \cos \theta + sw \sin \theta]$

Where, S = Seismicity Factor,

Slice 1

Disturbing Force=

$[80840 \times \cos 24 + 0.1 \times 80840 \times \sin 24]$

=78673.488KN

Slice 2

Disturbing Force =

$[80840 \times \cos 30 + 0.1 \times 80840 \times \sin 30]$=78317.792KN

Slice 3

Disturbing Force=

$[74260 \times \cos 32 + 0.1 \times 74260 \times \sin 32]$= 69529.638 KN

Slice 4

Disturbing Force =

$[65800 \times \cos 36 + 0.1 \times 65800 \times \sin 36]$60272.8 KN

Slice 5

Disturbing Force =

$[62040 \times \cos 40 + 0.1 \times \sin 40]$=52702.98 KN

Slice 6

Disturbing Force =

$[61100 \times \cos 43 + 0.1 \times \sin 43]$= 47517.47 kN

Slice 7

Disturbing Force =

$[57340 \times \cos 50 + 0.1 \times 57340 \times \sin 50]$=42620.822 KN

Slice 8

Disturbing Force =

$\left[51700 \times \cos 53 + 0.1 \times 51700 \times \sin 53\right]$=37151.62 KN

Slice 9

Disturbing Force =

$\left[24440 \times \cos 57 + 0.1 \times 24440 \times \sin 57\right]$=15001.272 KN

Slice 10

Disturbing Force =

$\left[163184 \times \cos 90 + 0.1 \times 163184 \times \sin 90\right]$

=69190.016KN

Slice 11

Disturbing Force =

$\left[128780 \times \cos 90 + 0.1 \times 128780 \times \sin 90\right]$ = 12878 KN

Total Disturbing Force with seismicity =

$\left[w \cos \theta + sw \sin \theta\right]$

= **510984.282 KN**

1. **Cohesive Force,**

   C = $\theta \times c \times R \times$ width of slice

   Where, θ = In Radian, c = Cohesion of Dump Material, R = Radius

   Slice 1

   Cohesive Force = $20 \times {}^{\wedge}\!/_{180} \times 40 \times 150 \times 10$

   = 25454.93 KN

   Slice 2

   Cohesive Force = $30 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 31818.66 KN

   Slice 3

   Cohesive Force = $32 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 33939.91 KN

   Slice 4

   Cohesive Force = $36 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 38182.4 KN

   Slice 5

   Cohesive Force = $40 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 42424.88 KN

   Slice 6

   Cohesive Force = $43 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 45606.75 KN

   Slice 7

   Cohesive Force = $50 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 53031.11 KN

   Slice 8

   Cohesive Force = $53 \times {}^{\wedge}\!/_{180} \times 40 \times 152 \times 10$

   = 56212.97 KN

Slice 9

Cohesive Force = $57 \times \pi/180 \times 40 \times 152 \times 10$

= 60455.46 KN

Slice 10

Cohesive Force = $90 \times \pi/180 \times 50 \times 152 \times 10$

= 119320 KN

Total Cohesive Force = 506447.11 KN

Factor of safety = $\dfrac{\text{Frictional force} + \text{cohesive force}}{\text{Disturbing Force}}$

F.O.S = 1.419

Results and Conclusion

The Factor of Safety (FOS) has been obtained vide different method.

The lowest Factor of Safety under seismic or blasting effect found 1.256. The Factor of Safety obtained by using departmentally developed software at BIT Mesra (Developed and validated for a decade ago in FORTRAN 77 for Research and Development and Industrial consultancy works). The synopsis result for the basic tests conducted and based on these factors FOS was

Recommended:-

Project Description	
Test Type	Direct Shear
Project Id	CIL
Project Site	RAJRAPPA
Soil Type	Dump
Bulk Density (g/cc)	1.88
Dry Density (g/cc)	1.74
Degree of Saturation (%)	0.02
100% Saturation	54949.99
Void Ratio	1099.00
Porosity (%)	99.91
SET No 1	
Specimen Description	
Specimen Id	Default
Specimen Length (cm)	40
Specimen Width (cm)	40
Specimen Thickness (cm)	15
Specimen Area (cm^2)	1600
Specimen Volume (cm^3)	24000
Specimen Weight (g)	47000
Water Content	10
Specific Gravity	2
Sigma n (kg/cm^2)	1

Figure 10 Results of Direct shear Tes

Considering RAJRAPPA Mines, the Factor of Safety of surviving dump in the nearby cut taking worst seismic stimulation advancement comprehened is 1.419 i.e. above 1.2. So, we can say that the surviving dump of RAJRAPPA mines are unadventurous or safe in today's framework and it is advised always to perpetuate FOS till the mines survive.

For keep an eye on these dumps, following initiatives are undertaken at the site-

a) Height of dragline dump is cramped to 82m.

b) Angle of Repose of dragline dump should not be steeper than 32° in any case. Continuous monitoring is highly commended.

c) The corridors of dragline sitting level should not be less than 15m and it should be watched in a time framework. Secondly at rib level should not be less than 13m..

d) If Possible Embankment is placed at the toe of the dump and also at the outer side of the roof corridor to restrict any type of Gibber stone from the slope.

e) In order to reduce the Permeability in dump, gradient of the flow is to be kept to ensure the gravitational flow of water.

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