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Dump Slope Stability Analysis based on Rainfall and Soil Characteristics - A Case Study

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Abstract: ***A case study dealing with the stability of dump slopes of an opencast mine at Nagpur, Maharashtra, India is presented in this paper. The study is based on determination of the shear strength parameters viz. cohesion and angle of internal friction of soil samples and stability analysis of slope by finding out the factor of safety, using numerical modeling software: OASYS by varying slope angle. Stability analysis has also been done by considering pore water pressure distribution in mine slopes. The outcome of the paper can be effectively applied in designing manageable dump heights.***
Keywords: Angle of Internal Friction, Cohesion, Factor of Safety, OASYS, Slope stability

I. INTRODUCTION

Opencast mine waste dump is becoming very crucial issue to be evaluated for mining industry. As there is need to make a stable slope for dumping process, it is also needed to design the required stable and cost effective slope for performing smooth operation of mine waste dump. Various studies have been taken out to find the stability of slopes as well as the safety factor for design considering various geotechnical parameters such as bearing capacity of strata, water condition, cohesion and angle of internal friction. It can be observed that for more safety purpose dump has to place at lower grade and at lesser height but it may be partially ineffective as economy of the project hampers. Hence for performing well and make optimum use of land efficient proper design needs to be done.

In the Vidarbha region of the Indian state of Maharashtra, Kamptee Coalfield covering an area of about 1344.78 sq.km located in Nagpur district . It lies in north of Kanhan railway station in Nagpur district. The total coalfield area is about 1344.78 sq. km. This Coalfield holds a premier position in India for having the considerable share of reserve of thermal grades non-coking coal for catering the demand of coal in the western part of country.

The primary purpose of the slope stability analysis is to contribute to the safe and economic design of mine overburden dump. Dump Slope stability evaluation are concerned with identifying critical geological, material, environmental and economic parameters that will affect project. Therefore, the aim of this research is to study the stability of dump slope with various geometry using geo-mechanical properties of dump forming material through numerical modeling software OASYS 9.1.

II. BASIC CONCEPT OF DUMP SLOPE STABILITY

Three principle stresses, namely, σ1, σ2 and σ3 are considered at any point in a saturated soil mass. Slope materials have tendency to slide due to shearing stresses created in the soil by gravitational and other forces like water flow, tectonic stresses, seismic activity, etc. This tendency is resisted by the shear strength of slope materials expressed by Mohr Coulomb theory as given below:

$$S = c + \sigma n \tan \varphi \qquad (1.1)$$

Where,
S= Total shear strength of the soil.
c= Total cohesion of soil.
σn= Total Normal stress.
φ= Total angle of internal friction
From the equation below:

$$\tau = \frac{S}{FOS} \qquad (1.2)$$

Where,
τ= Shearing stress along the assumed failure surface.

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S= shear strength of the soil.

FOS= Factor of safety.

Therefore from above equation we can say that: $FOS = \frac{c + \sigma n tan a}{\tau}$ (1.3)

$$FOS = \frac{Resisting\ Force}{Driving\ Force} \quad (1.4)$$

So, factor of safety can be defined as resistance force divided by driving force. If the safety factor is greater than 1 then the slope is assumed to be stable. However, for long term stability it must be 1.2 to 1.4 in open cast mine.

III. RESULT AND DISCUSSION

Analysis by adopting standard proctor test, direct shear test were carried out for determining maximum dry density and Optimum moisture content, cohesion and angle of internal friction. These parameters were used for calculating factor of safety and consequently the slope stability using OASYS 9.1 Slope software by varying slope angle and pore water pressure values. Designing the models in OASYS can gives reliable results about stability of existing slopes in mine area. If result found below the required level i.e., the safety is below 1.0, suitable measures have to take for increasing the dump slope stability. For considering the rainfall effect in soil dump material, pore water pressure has taken into account. Total of 4 samples have taken out from different locations in field.

TABLE I RESULTS OF SOIL SAMPLES

Sr. No.	Description	Standard Proctor Test			Direct shear Test	
		Bulk Density kN/m^3	Dry Density kN/m^3	Optimum Moisture Content %	Cohesion kN/m^2	Angle of Shearing Resistance (deg)
1	Sandstone	19.01	17.00	11.80	8	29.5
2	White Sandstone	19.13	17.30	10.60	3	32
3	Shale	19.35	17.40	11.20	0	33.5
4	Black Cotton soil	19.00	16.20	17.30	25	11

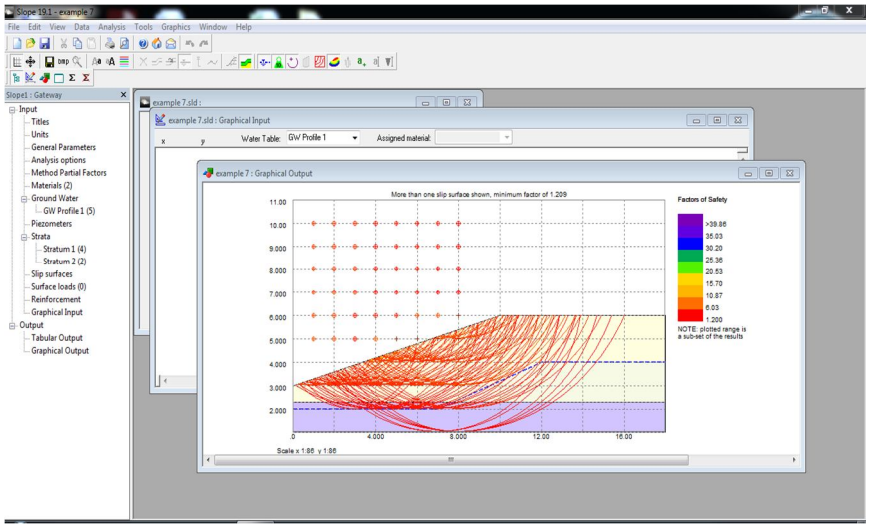

Fig. 1 Defining model in OASYS 9.1 SLOPE software

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TABLE II
RESULTS OBTAINED FROM VARYING SLOPE ANGLE

Sr. No.	Description	Cohesion	Φ (deg)	Slope Angle	FOS
1	Sandstone	8	29.5	18	1.50
				20	1.42
				22	1.35
				24	1.20
2	White Sandstone	3	32	18	1.56
				20	1.42
				22	1.35
				24	1.00
3	Shale	0	33.5	18	1.6
				20	1.52
				22	1.50
				24	0.9
4	Black Cotton soil	25	11	18	2.60
				20	2.24
				22	2.00
				24	1.60

Table III
Results obtained from varying ru value (pore pressure/overburden pressure)

Sr. No.	Description	Cohesion	Φ (deg)	Ru Value	FOS
1	Sandstone	8	29.5	0.2	1.20
				0.4	1.06
				0.6	0.76
				0.8	0.52
2	White Sandstone	3	32	0.2	0.84
				0.4	0.59
				0.6	0.46
				0.8	0.38
3	Shale	0	33.5	0.2	0.51
				0.4	0.40
				0.6	0.20
				0.8	0.16
4	Black Cotton soil	25	11	0.2	1.90
				0.4	1.79
				0.6	1.68
				0.8	1.58

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IV. CONCLUSION

The analysis results specify that the factor of safety changes with slope angle. Parametrical studies suggest that stability increases on increasing both cohesion & angle of internal friction. This happens because on increasing cohesion the binding property of the material increases which makes the slope stable. It can be concluded that by updating the search radius & angle of rotation in OASYS the factor of safety increases. Considering the effect of pore water pressure, the stability reduces with constant cohesion and angle of shearing resistance. Black cotton soil has maximum value of cohesion and found more safe considering geometric parameters and pore pressure distribution. Dump height and other bench parameters have not been taken into account and thus the study can be carried by considering these points. Shale and white sand stone is found to be most unsafe as it is cohesion less soil and pore water can easily affect the stability by entering into the void of soil mass.

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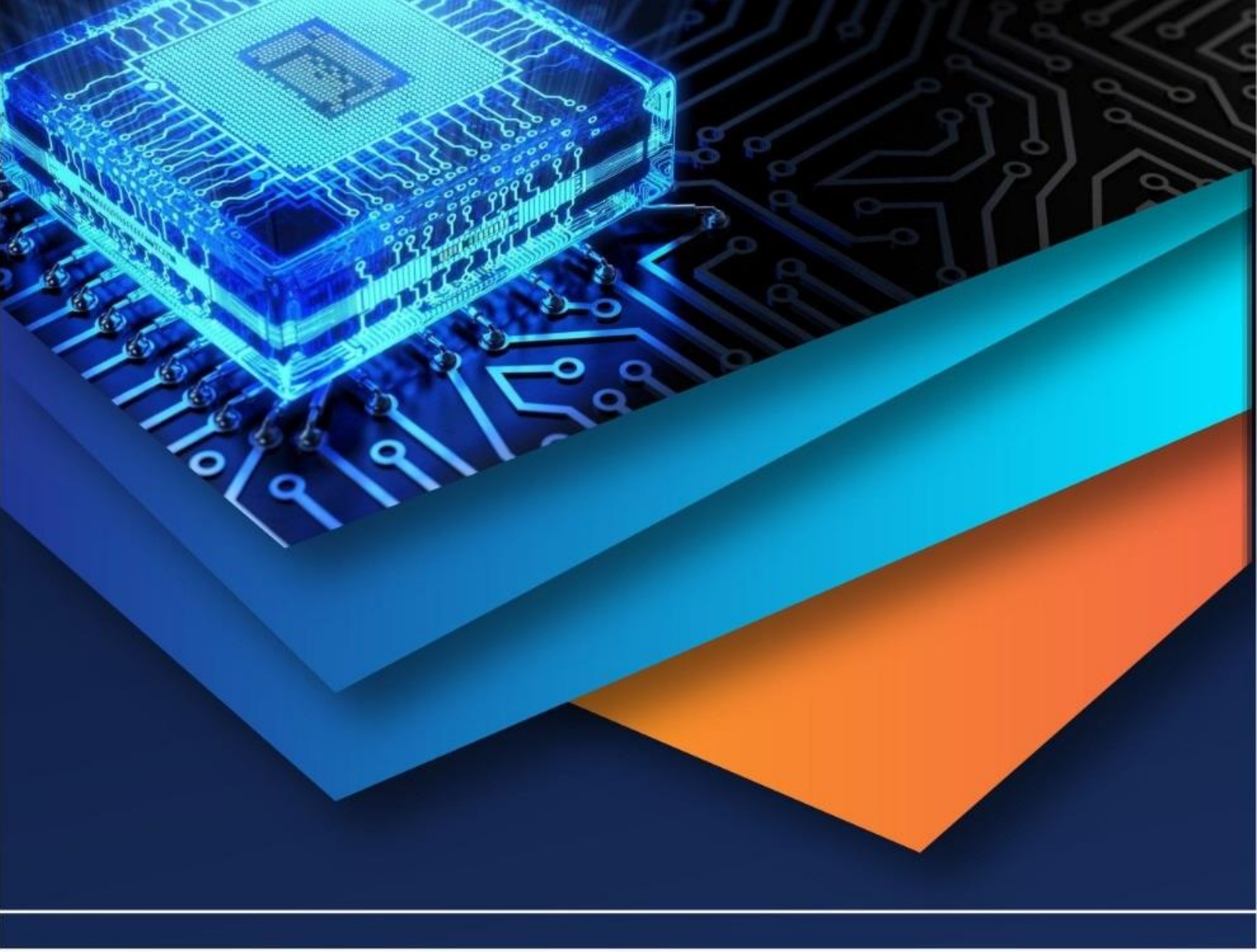

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