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A Case Study on Coal Pit & Dump Slope Stability of Gondudih Khas Kusunda Open Cast Project of Kusunda Area of BCCL, Dhanbad

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ABSTRACT: Slope stability is a critical aspect of open-cast mining to ensure safe and productive operations. Poor slope design can lead to slope failures, risking worker safety, damaging equipment, and causing production delays. This study evaluates the stability of pit and dump slopes at the Gondudih Khas Kusunda Open-Cast Project (GKK OCP) in the Kusunda Area of Bharat Coking Coal Limited (BCCL), located in Dhanbad, Jharkhand. The main aim is to assess current slope designs, identify potential risks, and suggest improvements that balance safety, efficiency, and cost. The GKK OCP lies in the eastern part of the Jharia coalfield, with terrain gently sloping between 207 and 219 meters above sea level. The region experiences a sub-humid tropical climate with annual rainfall between 1,200 and 1,380 mm. The mine site is geologically part of the Barakar Formation, underlain by Talcher strata. Fieldwork was conducted at eight representative points, and soil samples were collected at depths of 0.6–0.9 meters. Laboratory tests, including the core-cutter method and triaxial testing, were used to determine properties such as bulk density, dry density, cohesion, and angle of internal friction. These parameters were then analyzed using FLAC/Slope software to calculate the Factor of Safety (FOS) under different slope conditions.

Results showed that FOS decreases with increased bench height and slope angle but improves with greater bench width. The study recommends optimized bench parameters for pits: 10 m height, 12 m width, and 60° slope angle. Controlled blasting is also advised to reduce vibration and improve slope integrity. These findings meet DGMS guidelines and offer a safer design for future mining operations.

1. INTRODUCTION

The stability of mine slopes is a critical aspect of safe and productive open-cast mining operations. In mines like the Gondudih Khas Kusunda Open Cast Project (GKK OCP) in Dhanbad, slope stability is influenced by several complex and interrelated factors such as geological structures, slope geometry, groundwater presence, and the strength of slope materials. Slope failures in mines can cause serious accidents, including damage to expensive equipment, loss of production, and even loss of human life. One such incident occurred in the Basundhara mines in 2013, highlighting the urgent need for better slope design and monitoring strategies. This study focuses on evaluating the stability of both pit and dump slopes at GKK OCP, located in the Jharia coalfield in Jharkhand. The area is geologically complex, with multiple coal seams, different types of rock layers, fault zones, and increasing depth, which adds more stress to the slopes. The study uses a combination of field surveys, laboratory tests, and numerical modeling using FLAC/Slope 2D software. This software is widely used for slope stability analysis because it can simulate the behavior of slopes under different mining and geological conditions. Field data were collected through visits to the mine, where soil and rock samples were taken from key locations. Laboratory tests, including the core cutter method, oven drying, and triaxial testing (ASTM D2850), were carried out to determine key geotechnical parameters like cohesion, internal friction angle, bulk density, and dry density. The results from these tests were input into FLAC/Slope to calculate the

Factor of Safety (FOS), which indicates how stable a slope is. The study also examined how blasting activities affect slope stability. Uncontrolled blasting can create cracks and vibrations that weaken the slopes. To address this, the study suggests using controlled blasting techniques like pre-splitting and electronic detonators to reduce damage. Finally, the study provides recommendations for optimum bench height, width, and slope angles, along with suggestions for improved blasting practices and slope monitoring systems to ensure long-term safety and efficiency in mining operations.

2 METHODOLOGY & PROCEDURE

2.1 Study Area

Gondudih Khas Kusunda OCP is present in the north-eastern part of Jharia coalfield and comes under the area of Dhanbad district in Jharkhand state. The Gondudih Khas Kusunda OCP can be reached through Bhuli- Loyabad road. The distance from mine is 2.5 km from Bhuli and is situated between Bhuli & Tetulmari railway station. The mine is 1.75 km north west of Kusunda railway station and south of Grand Chord eastern railway line. it lies in the latitude from 23°47'30" to 23°48'30" and longitude from 86°21'30" to 86°22'30". A location map of Gondudih Khas Kusunda OCP is given in fig.1

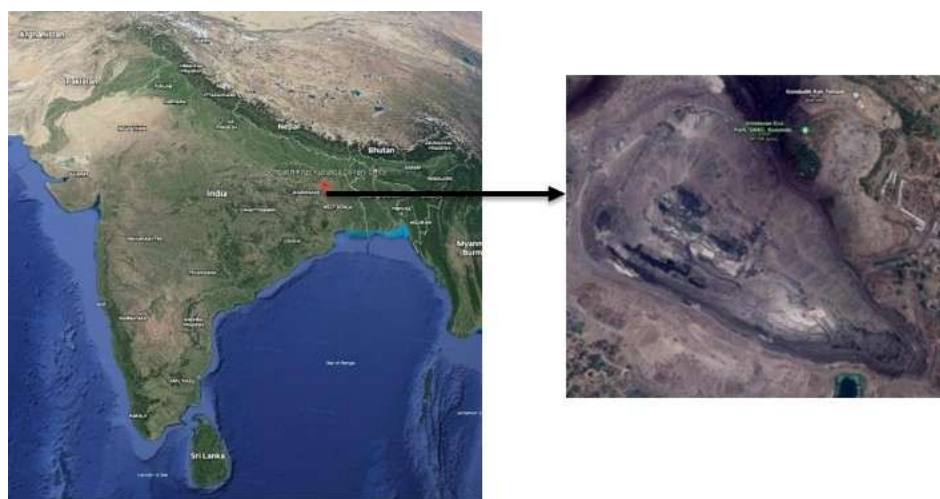


Figure 2.1 Study area

2.2 Sampling and Analysis

To ensure accurate representation of the study area, samples were collected from four different locations during the summer season. Samples were taken from a depth of approximately 2–3 feet and included topsoil, overburden, coal, and dump materials. For topsoil and dump, a cylindrical sampler was driven into the ground, while core samples were extracted from overburden and coal layers. The collected samples were carefully placed in sealed plastic gunny bags to prevent exposure to air and moisture. This process helped preserve the natural condition of the samples before laboratory testing.

2.3 Determination of Geotechnical Parameters

This method was used to determine the bulk and dry density, along with moisture content, of soil and rock samples. Samples were weighed, oven-dried at 105–110°C for 24 hours, then reweighed. Calculations were done using standard formulas. For topsoil, the bulk density was 1.904 g/cc, moisture content 12%, and dry density 1.70 g/cc (16.7 kN/m³). The same procedure was applied to overburden, coal, and dump samples for use in slope stability analysis. The result obtained is summarized in below table no. 2.1

Table no. 2.1 Calculation of Bulk and Dry density through core cutter and drying oven procedure

Material	Bulk density in (g/cc)	Moisture content	Dry density in (g/cc)	Dry density in (kN/m ³)
Top soil	1.904	0.12	1.70	16.7
Overburden rock	2.507	0.09	2.30	22.1

Coal	1.695	0.13	1.50	14.9
Dump	2.0184	0.16	1.74	17.1

2.4 Determination of Cohesion & Friction angle

Understanding the lithological units where slopes are formed is essential, as their engineering properties directly affect slope stability. Strength parameters used in the analysis at Gondudih Khas Kusunda OCP were determined through laboratory testing. Samples were taken from the pit and dump areas, and properties such as cohesion and friction angle were obtained using triaxial tests and plotting them in mohr's circle graph to determine cohesion and friction angle. Topsoil and dump samples were tested in the soil lab, while overburden and coal were analyzed in the rock lab. Results show overburden has the highest cohesion, while topsoil shows the weakest strength. Regular re-evaluation is recommended as conditions change. The values obtained are summarised in Table 2.2

Table 2.2 Geo-mechanical Properties

S.No	Lithology	Cohesion (kPa)	Friction angle (degree)	Density (kN/m ³)
1.	Top Soil	73	21	16.7
2.	OB/Parting Rock	285	29	22.1
3.	Coal	150	23	14.9
4.	Dump Material	80	23	17.1

2.5 Slope Stability Analysis Using FLAC/Slope 8.10 (Itasca)

The slope stability analysis for the Gondudih Khas Kusunda OCP was conducted using FLAC/Slope software, which applies the Finite Difference Method. This numerical technique solves differential equations to simulate large deformations and progressive failures in slopes. The Factor of Safety (FOS) was calculated using the shear strength reduction method, comparing mobilized stress with available shear strength. A minimum FOS of 1.5 was used, as per DGMS Circular No. 03, 2020, to ensure safe slope design. Strength parameters were derived from representative pit and dump sections provided by mine management, covering the deepest parts of the mine. Groundwater was considered negligible due to drainage measures, simplifying the slope as effectively dry. Minor slope instabilities, especially during monsoon, are expected and manageable. The design maintains bench widths suitable for equipment access. Sections analyzed included A1-A2, B1-B2, C1-C2, D1-D2, and C-D, as per the surface layout of the mining area.

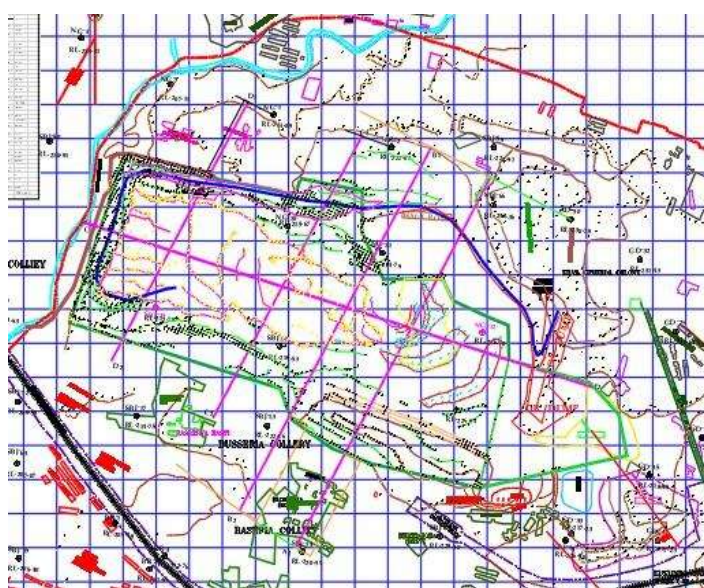


Figure 2.2 Location of section lines on surface plan of GKK OCP

3 RESULT & DISCUSSION

3.1 Results

Slope stability analysis of the existing pits and dumps at Gondudih Khas Kusunda OCP was carried out using FLAC/Slope software. The analysis was done along key sections A1-A2, B1-B2, C1-C2, D1-D2, and C-D, as provided by mine management. Results of these analyses are presented in Figures 5.7 to 5.15 and summarized in Table no. 3.1

Table no. 3.1 Stability analyses of existing pit and dumps of Gondudih Khas Kusunda OCP

Details of the slope	Factor of safety	Figure no.	Bench Height	Bench Width	Bench Slope Angle
Slope stability analysis of north side of existing pit & dump along section A1-A2 of Gondudih Khas Kusunda OCP	1.34	Fig 3.1	Dump 10m Pit 10m	Dump 14m Pit 12m	Dump 37° Pit 60°
Slope stability analysis of south side of existing pit along section A1-A2 of Gondudih Khas Kusunda OCP	1.70	Fig 3.2	10m	12m	60°
Slope stability analysis of north side of existing pit & dump along section B1-B2 of Gondudih Khas Kusunda OCP	1.35	Fig 3.3	Dump 15m Pit 10m	Dump 20m Pit 12m	Dump 27° Pit 50°
Slope stability analysis of south side of existing pit along section B1-B2 of Gondudih Khas Kusunda OCP	2.54	Fig 3.4	10m	10m	45°
Slope stability analysis of north side of existing pit & dump along section C1-C2 of Gondudih Khas Kusunda OCP	1.77	Fig 3.5	Dump 10m Pit 10m	Dump 12m Pit 12m	Dump 27° Pit 50°
Slope stability analysis of south side of existing pit along section C1-C2 of Gondudih Khas Kusunda OCP	2.33	Fig 3.6	10m	14m	45°
Slope stability analysis of north side of existing pit along section D1-D2 of Gondudih Khas Kusunda OCP	4.08	Fig 3.7	10m	15m	40°
Slope stability analysis of south side of existing pit along section D1-D2 of Gondudih Khas Kusunda OCP	4.52	Fig 3.8	10m	20m	50°
Slope stability analysis of existing internal dump along section C-D of Gondudih Khas Kusunda OCP	1.53	Fig 3.9	30m	30m	37°

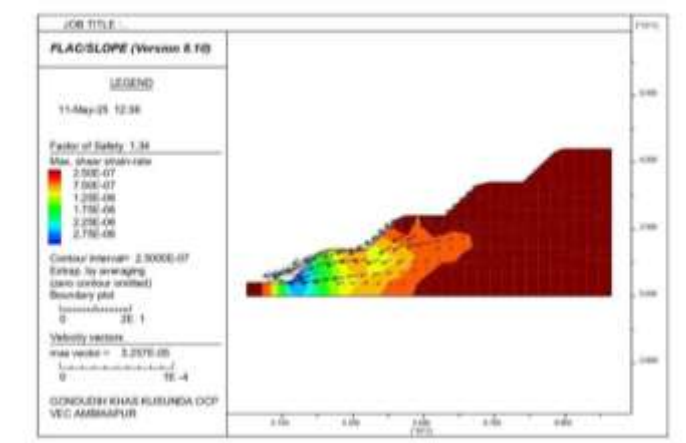


Figure 3.1 Slope stability analysis of north side of existing dump along section A1-A2 of GKK OCP, (FOS 1.34)

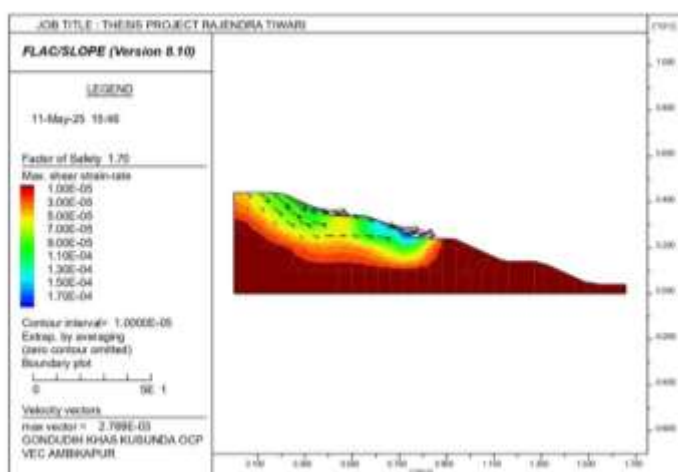


Figure 3.2 Slope stability analysis of south side of existing Pit along section A1-A2 of GKK OCP (FOS 1.70)

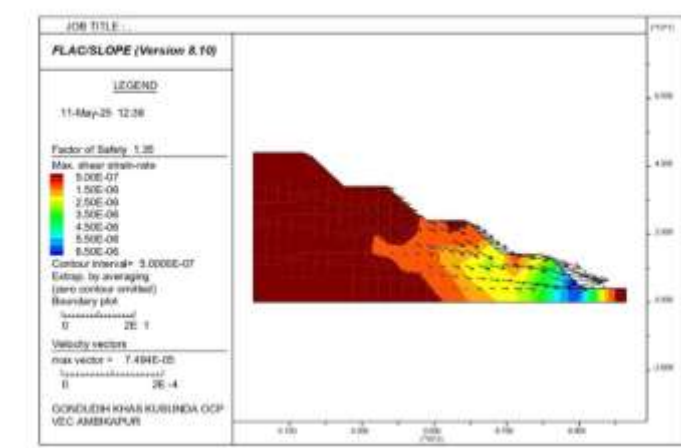


Figure 3.3 Slope stability analysis of north side of existing pit & dump along section B1-B2 of GKK OCP (FOS 1.35)

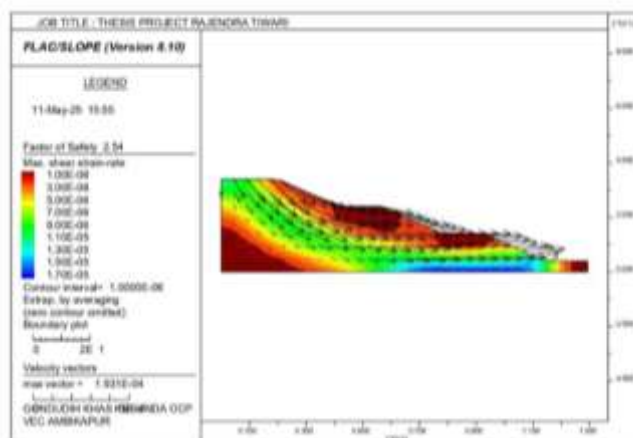


Figure 3.4 Slope stability analysis of south side of existing pit along section B1-B2 of GKK OCP (FOS 2.54)

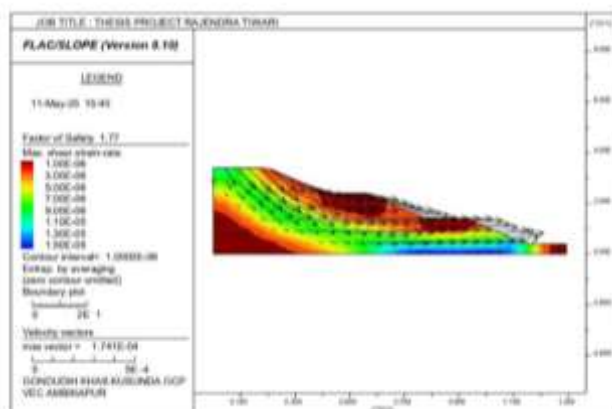


Figure 3.5 Slope stability analysis of north side of existing pit & dump along section C1-C2 of GKK OCP (FOS 1.77)

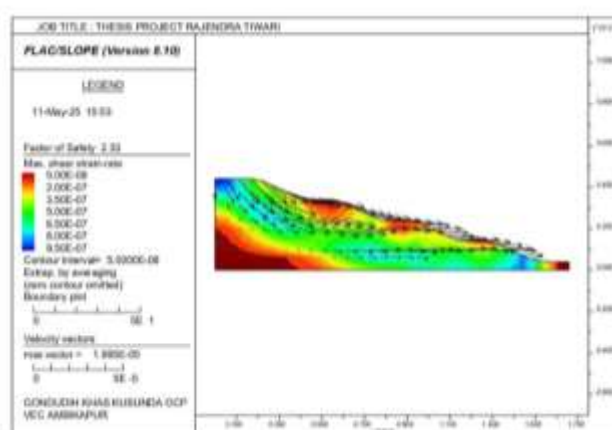


Figure 3.6 Slope stability analysis of south side of existing pit along section C1-C2 of GKK OCP (FOS 2.33)

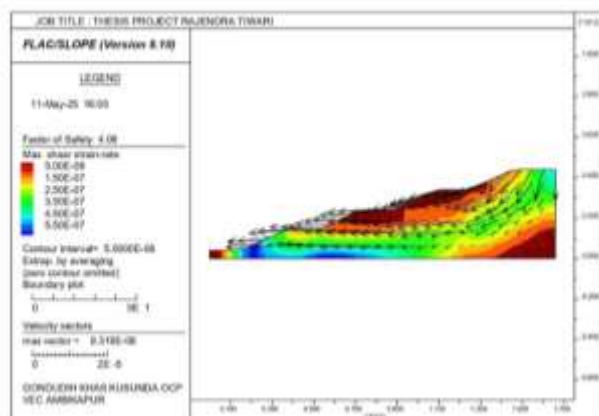


Figure 3.7 Slope stability analysis of north side of existing pit along section D1-D2 of GKK OCP (FOS 4.08)

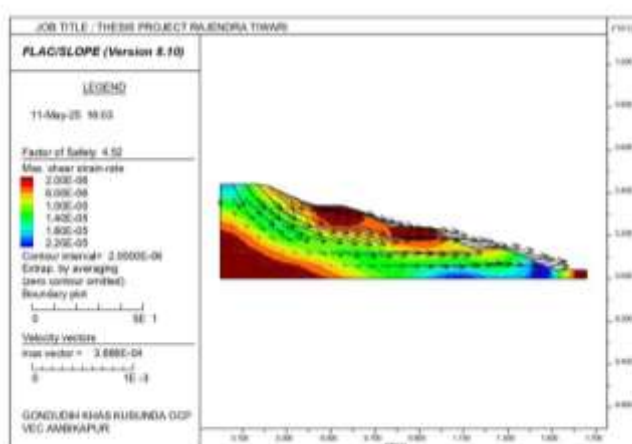


Figure 3.8 Slope stability analysis of south side of existing pit along section D1-D2 of GKK OCP (FOS 4.52)

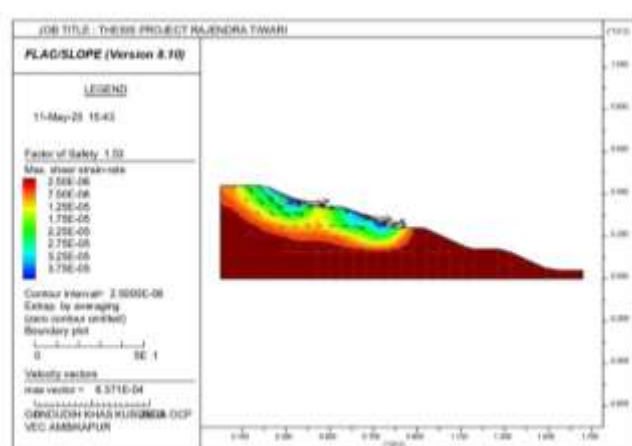


Figure 3.9 Slope stability analysis of existing Internal Dump along section C-D of GKK OCP (FOS 1.53)

3.2 Discussion

Table 3.1 and Figures 3.1 to 3.9 show that the Factor of Safety (FOS) for the existing pit sections of Gondudih Khas Kusunda OCP exceeds the minimum requirement of 1.50, ensuring long-term stability as per DGMS (Tech.) Circular No. 3 of 2020.

Similarly, the dumps show FOS values above 1.30, confirming short-term stability. Thus, both pit and dump are stable in their current state. As per CMR 2017 Regulation 106(5), bench width must be maintained. Wider benches help contain small-scale failures, and flatter operational slopes reduce the risk of major slope collapses during mining operations. It is also recommended for adoption of control blasting technique like pre-splitting and total station method for slope monitoring for further improvement of slope stability.

4 CONCLUSION

Stability analysis of slopes of existing pits of Gondudih Khas Kusunda OCP (GKK OCP) revealed that their factor of safety (FOS) is more than 1.50 as required under DGMS(Tech.) Circular No. 3 of 2020 dated 16.01.2020 for long term stability. Thus, existing pits of Gondudih Khas Kusunda OCP as per existing plans and sections may be considered to be stable. Stability analysis of slopes of existing dumps of Gondudih Khas Kusunda OCP revealed that their factor of safety (FOS) is more than 1.30 as required under DGMS(Tech.) Circular No. 3 of 2020 dated 16.01.2020 for short term stability. Based on the observation, following recommendation for optimum possible bench parameters of Gondudih Khas Kusunda OCP are as follows:

Table no 4.1 Recommendations for Possible Bench parameters for optimum FOS

Geo-mining conditions	Bench Parameters		
	Optimum Bench height(m)	Optimum Exposed Bench width(m)	Maximum Angle (deg.)
Benches in Coal seam/parting/overburden	10	12	60°
Benches in old stabilized overburden dump	10	14	37°
Benches in internal dump	30	30	37°

The above study can be extended for optimisation of Ultimate pit slope design in future. Further Regular surveys should update pit and dump geometry. Geotechnical conditions change over time, so a new study is advised every five years or with any mining plan change for better safety and design.

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