Indian Journal of Modern Research and Reviews

This Journal is a member of the *'Committee on Publication Ethics'*

Online ISSN:2584-184X

Research Article

Numerical Investigation of Overburden Dump Slope Stability Using Limit Equilibrium Methods: A Case Study of Lalmatia Opencast Coal Mine, India

Sumeet Kishore

Assistant professor, Department of Mining Engineering, Jharkhand Rai University Ranchi, Jharkhand, India

Corresponding Author: *Sumeet Kishore

DOI: https://doi.org/10.5281/zenodo.18847857

Abstract

Overburden (OB) dump stability is a critical geotechnical concern in opencast mining operations, directly influencing operational safety, production continuity, and environmental sustainability. Improper dump geometry, inadequate geotechnical characterisation, and simultaneous mining–dumping operations may significantly increase the risk of catastrophic slope failures. This study presents a comprehensive numerical evaluation of OB dump slope stability at the Lalmatia Opencast Project, Rajmahal Coalfields, India. A parametric analysis was performed using limit equilibrium techniques implemented in SLIDE software to evaluate the influence of slope angle, bench height, and bench width on factor of safety (FoS). The overburden material was modelled as homogeneous dry soil with experimentally determined shear strength parameters. Results indicate that slope angle is the most influential geometric parameter affecting stability. FoS decreases significantly beyond a slope angle of 30°, whereas bench width has a negligible influence within the investigated range. An optimum dump configuration was identified considering both safety and economic feasibility. The findings provide practical design recommendations for safe dump construction in similar geotechnical environments.

Manuscript Information

- **ISSN No:** 2584-184X
- **Received:** 01-12-2025
- **Accepted:** 28-01-2025
- **Published:** 30-01-2026
- **MRR:**4(1); 2026: 247-250

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Kishore S. Numerical Investigation of Overburden Dump Slope Stability Using Limit Equilibrium Methods: A Case Study of Lalmatia Opencast Coal Mine, India. Indian J Mod Res Rev. 2026;4(1):247-250.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Overburden dump, slope stability, limit equilibrium method, factor of safety, opencast mining, numerical modelling, Lalmatia mine.

1. INTRODUCTION

Opencast mining operations generate substantial volumes of overburden materials that must be systematically disposed of in designated dump yards. These dumps are typically constructed as engineered slopes or embankments. As mining depth increases and land availability decreases, dump heights tend to increase, thereby elevating the risk of slope instability.

Slope failures in overburden dumps can result in severe consequences, including equipment loss, production interruption, environmental damage, and fatalities. One such catastrophic failure occurred in December 2016 at the Lalmatia Coal Mine under Eastern Coalfields Limited, where a massive OB dump collapse caused significant loss of life and equipment.

The stability of OB dumps is influenced by:

- Shear strength parameters of dump material
- Dump geometry (slope angle, bench height, width)
- Groundwater conditions
- External loading and blasting vibrations
- Construction sequence

This study evaluates the stability of an overburden dump using numerical modelling based on limit equilibrium methods (LEM), with particular focus on the influence of geometric parameters.

2. OBJECTIVES

The main objective of this research is to evaluate the stability of overburden dump slopes using numerical modelling techniques.

Specific objectives include:

1. Determination of factor of safety under varying slope geometries
2. Parametric analysis of slope angle, bench height, and bench width
3. Identification of optimum dump design for safety and economy
4. Evaluation of the applicability of limit equilibrium methods for dump analysis

3. LITERATURE REVIEW

Slope failure refers to the uncontrolled movement of soil or rock mass under gravitational forces when driving stresses exceed resisting forces. In opencast mines, circular failures are most common due to the loose and fragmented nature of dumped materials.

3.1 Mechanisms of Slope Failure

Failure occurs when:

Driving Forces>Resisting Forces

The ratio of resisting to driving forces is expressed as the Factor of Safety (FoS):

$$FoS = \frac{\text{Available Shear Strength}}{\text{Mobilized Shear Stress}}$$

Failure condition occurs when FoS ≤ 1.

3.2 Types of Slope Failure

Common modes include:

- Plane failure
- Wedge failure
- Circular failure
- Toppling failure

In OB dumps, circular failure predominates due to homogeneous loose fill material.

3.3 Limit Equilibrium Methods

Limit equilibrium methods divide a potential sliding mass into slices and apply static equilibrium equations. Common methods include:

Method	Moment Equilibrium	Force Equilibrium
Fellenius	Yes	No
Bishop Simplified	Yes	No
Janbu Simplified	No	Yes
Spencer	Yes	Yes
Morgenstern-Price	Yes	Yes

In this study, Bishop's Simplified Method was adopted due to its reliability and computational efficiency.

4. CASE STUDY

4.1 Mine Description

The study area is located at the Lalmatia Coal Mine, approximately 34 km from Godda, Jharkhand, India. The mine operates under Eastern Coalfields Limited.

Mining method: Opencast semi-mechanised

Bench height: 10 m

Final pit slope: 45°

Transportation: Shovel-dumper combination

Dump dimensions:

- Available area: 375 m × 225 m
- Present height: ~32 m
- Dump distance from pit: ~1 km

5. METHODOLOGY

Slope stability analysis was carried out using SLIDE (2D Limit Equilibrium Software).

5.1 Material Properties

Parameter	Value
Cohesion (c)	1 kN/m²
Friction angle (φ)	35°
Unit weight (γ)	20 kN/m³
Water table	Absent
Tension cracks	Absent

Material is assumed homogeneous and dry.

5.2 Parametric Study

Three cases were analysed:

Case1: Variation in slope angle (20°–40°)

Case 2: Variation in bench height (10–40 m)

Case 3: Variation in bench width (40–90 m)

Bishop's Simplified Method was used for FoS computation.

6. RESULTS AND DISCUSSION

6.1 Effect of Slope Angle

Slope Angle (°)	FoS
20	2.307
25	1.606
30	1.315
35	1.098
37.5	1.009
40	0.942

FoS decreases sharply beyond 30°. At 40°, the slope becomes unstable (FoS < 1).
Observation: Slope angle is the most critical design parameter.

6.2 Effect of Bench Height

FoS decreases gradually with increasing bench height but stabilises beyond 25 m.
Optimum bench height: 20–25 m

6.3 Effect of Bench Width

FoS variation: 1.313–1.318
Bench width has a negligible influence within the studied range.

7. DISCUSSION

The analysis clearly demonstrates:

- Slope angle has dominant control over stability
- Bench height has a moderate influence
- Bench width has minimal effect
- Economic design must balance safety with land constraints

The Lalmatia failure likely resulted from excessive slope steepening and simultaneous dumping and excavation operations.

8. MITIGATION MEASURES

Recommended stability enhancement measures:

1. Controlled dump geometry (slope angle ≤ 30°)
2. Sequential dumping and excavation planning
3. Surface and subsurface drainage control
4. Toe buttressing where necessary
5. Vegetative stabilization
6. Monitoring using slope stability radar

9. CONCLUSIONS

1. Slope angle is the most significant factor affecting OB dump stability.
2. Stability reduces drastically beyond 30° slope inclination.
3. Optimum configuration for the studied site:

- **Slope angle:** 25°–30°
- **Bench height:** 20–25 m

4. Bench width has a negligible impact on FoS.
5. The limit equilibrium method provides reliable results for preliminary dump design.

This study provides practical design guidance for safe overburden dump construction in Indian opencast coal mines.

10. FUTURE SCOPE

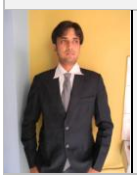
- Inclusion of groundwater and pore pressure effects
- Seismic stability analysis
- 3D numerical modelling
- Probabilistic slope stability assessment
- Instrumentation-based validation

REFERENCES

1. Spencer E. A method of analysis of the stability of embankments assuming parallel inter-slice forces. Geotechnique. 1967;17(1):11–26.
2. Duncan JM, Wright SG. Soil strength and slope stability. New York: John Wiley & Sons, 2005.
3. Hoek E, Bray JW. Rock slope engineering. London: Institution of Mining and Metallurgy; 1981.
4. Abramson LW, Lee TS, Sharma S, Boyce GM. Slope stability and stabilisation methods. New York: John Wiley & Sons; 2002.
5. Griffiths DV, Lane PA. Slope stability analysis by finite elements. Geotechnique. 1999;49(3):387–403.
6. Singh TN, Singh R. Stability analysis of mine waste dumps. Int J Surf Min Reclam Environ. 1997;11(2):81–86.
7. Sharma PK, Roy MP. Stability analysis of external dumps in opencast coal mines. J Geol Soc India. 2015;86(2):201–210.
8. Roy MP, Singh RB. Stability assessment of overburden dumps using numerical modelling. Min Technol. 2008;117(3):123–132.
9. Kainthola A, Verma D, Singh PK. Stability analysis of mine overburden dumps. Arab J Geosci. 2012;5(4):793–806.
10. Sarkar K, Singh TN. Determination of safe dump slope in open pit mining. Int J Rock Mech Min Sci. 2009;46(4):708–718.
11. Chugh YP. Sustainable overburden dump design in surface coal mines. Int J Min Sci Technol. 2018;28(3):349–356.
12. Kumar B, Ramamurthy T. Stability analysis of mine spoil dumps considering rainfall infiltration. Eng Geol. 2013; 159:1–12.
13. Ghosh R, Sinha S. Geotechnical characterisation of overburden dumps in Indian coalfields. J Mines Met Fuels. 2016;64(9):409–417.
14. Das SK, Mandal PK. Numerical modelling of dump slope failure using limit equilibrium and finite element methods. Environ Earth Sci. 2018;77(12):1–15.
15. Sahoo B, Pal SK. Influence of geometry on stability of overburden dumps. Geomech Eng. 2020;21(5):463–475.
16. Singh R, Murthy VMSR. Risk assessment of mine slope failure. Int J Min Miner Eng. 2010;2(4):299–313.
17. Kumar P, Bhasin RK. Stability assessment of coal mine dumps under seismic loading. Soil Dyn Earthq Eng. 2014;65:14–23.
18. Verma AK, Deb D. Three-dimensional slope stability analysis of mine dumps. Int J Geotech Eng. 2017;11(4):345–354.

19. Pradhan SP, Siddique T. Rainfall-induced failure analysis of mine waste dumps. Eng Fail Anal. 2019;101:128–140.
20. Central Mine Planning and Design Institute (CMPDI). Guidelines for the design of overburden dumps in opencast mines. Ranchi: CMPDI; 2015.
21. Directorate General of Mines Safety (DGMS). Technical circular on safe dumping practices in opencast mines. Dhanbad: DGMS; 2017.

About the corresponding author



Sumeet Kishore is an Assistant Professor in the Department of Mining Engineering at Jharkhand Rai University. He is engaged in teaching and research in mining engineering, contributing to academic development and technical training. His interests include mine planning, rock mechanics, and sustainable mining practices, with a focus on industry-oriented learning and innovation.