STABILITY ANALYSIS OF RIVER EMBANKMENT AT KATHAUTIA OPENCAST MINE

Prepared for

HINDALCO INDUSTRIES LIMITED

Consultants

Prof Pratik Dutta

INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR

Howrah-711103

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INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR

Department of Mining Engineering

CERTIFICATE

27/11/2020

This is to certify that the Department of Mining Engineering at Indian Institute of Engineering Science and Technology carried out the scientific study for analyzing the stability embankment on river Durgawati at Kathautia Opencast Coal Mine of HINDALCO Industries Limited. This report is the outcome of the scientific study.

It is certified that best possible scientific judgements were exercised in carrying out the study based on information available from the mine, assessments made during site visit, laboratory analysis of rock samples, and subsequent stability modelling study.

(Pratik Dutta)

Professor

P.O. Botanic Garden. Howrah 711103. West Bengal. India

Ph. (91-33) 2668-4561 Fax. (91-33) 2668-2916

Website: www.iiests.ac.in

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1 INTRODUCTION

1.1 Scope of Work

HINDALCO Industries Limited (HINDALCO) issued Work Order in favour of Indian Institute of Engineering Science and Technology, Shibpur (IIEST) for stability analysis of an old river embankment at Kathautia opencast mine (OCM). The scope of work, as indicated by IIEST in its project proposal and accepted by HINDALCO is as follows:

The scope of work will include collection of relevant field data from the mine officials, collection of soil/rock samples, laboratory testing for assessment of relevant geotechnical parameters, and detailed analysis of stability of the embankment following the best scientific practices. Specifically, the consultants would assess the stability of the embankment and recommend precautionary measures to be undertaken, if any, for consolidation of the embankment.

Prof Pratik Dutta from IIEST visited the mine to see the condition of the embankment and collect relevant information for the study. Detailed discussions were held with the mine officials for requirement of relevant information. He also guided mine officials about the process of or rock samples collection from the embankment. Subsequently, upon receipt of the required information and the samples from the mine, detailed scientific analysis was then carried out pertaining to the scope of the study. The report contains findings of the scientific study along with specific recommendations.

1.2 Kathautia Opencast Mine and the Embankment

Kathautia Opencast Coal Mine (KOCCM) is situated near Daltonganj, in Palamu District of Jharkhand. M/S Usha Martin Ltd operated the mine from 20th May 2005 to 31st March, 2015. Subsequently, it was allotted to HINDALCO on 1st April, 2015. Coal production under HINDALCO started from April, 2017 with annual production capacity of 0.80 Million tonnes. The mine is spread over an area of 938.27 Hectares (9.38 Km^2). The location detail of the mine is given in Figure 1. The nearest major habitat on is at Kathautia Village. Geographical Limits of “Kathautia Coal Block” is described as:

Direction	Boundary
North	Durgawati River and Lohari Block
East	Sika, Naudiha and Golhna Villages
South	Daltonganj-Patan Road and Meral Block
West	Daltonganj-Aurangabad Road (SH 48)

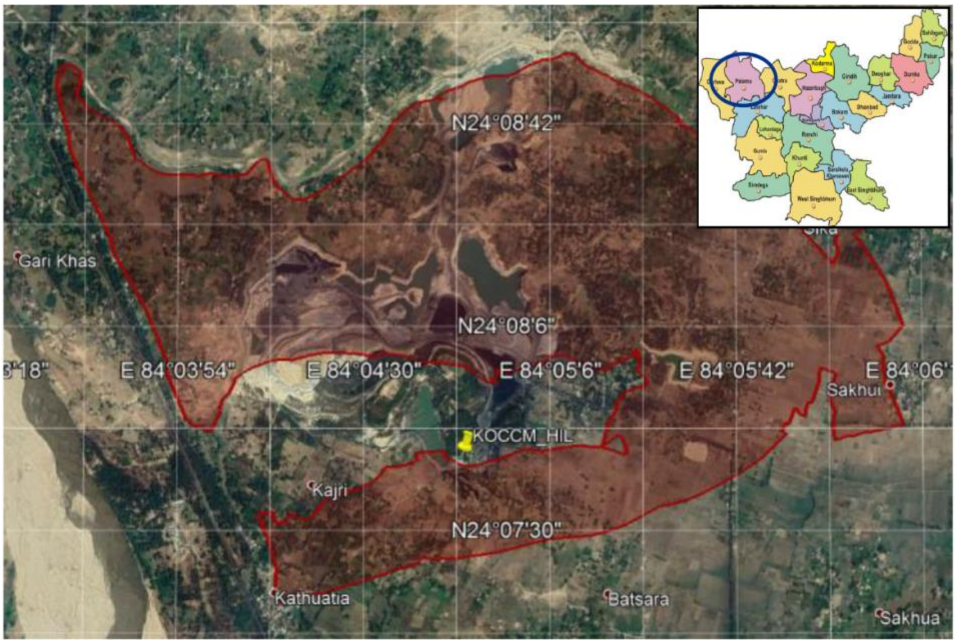


Figure 1: Location details of Kathautia Opencast Mine

Durgawati, a seasonal river flows on the northern boundary of the mine. M/S Usha Martin Ltd, the prior operator of the mine, constructed a 1.5 km long embankment beside the river bed to prevent accidental inrush of water into the mine in case of sudden flooding in the river. The embankment was constructed 6 meter above the High Flood Level (HFL). However, HINDALCO, current operator of the mine, wanted to assess the stability of this embankment along with measures for its consolidation to minimize the mine flooding risk.

2 FIELD OBSERVATIONS

Prof Pratik Dutta, the Consultant from IIEST visited Kathautia opencast mine to see the condition of the embankment. The following photographs, presented in Figure 2 to Figure 5, captured during the visit, depict the current condition of the embankment and the Durgwati river bed. Being a seasonal river and the visit being in winter, the river bed appeared completely dry. The embankment height remained more or less same throughout its length- 6 meter above the HFL. Southern side of the embankment was in better condition compared to the northern side. Signs of clear erosion were clearly visible on the northern side of the embankment. Other than this, no other issue of concern was apparently visible. It was informed that the embankment was constructed from overburden material. In some places, boulders were also visible below the top layer. In order to carry out the complete stability assessment, the mine management was requested to conduct a survey of the embankment to get the complete sectional profile and also collect material from the embankment and transport it to IIEST for geotechnical testing in the laboratory.

Figure 2: General view of the embankment top from the northern end, visible on the right is the dry river bed

Figure 3: View of the embankment from the river bed

Figure 4: Embankment was on the mine site as seen from the northern end. Erosion of the wall is clearly visible.

Figure 5: The complete river bed

3 STUDY APPROACH AND METHODOLOGY OF STABILITY ASSESSMENT

3.1 Survey Sections of the embankment

The mine management provided the complete plan of the embankment, which is shown in Figure 6.

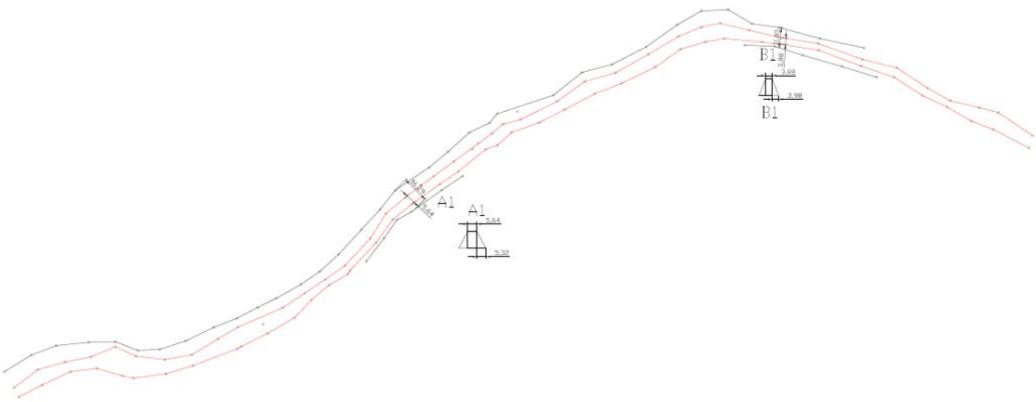


Figure 6: The complete plan of the embankment

Along with the plan, two survey sections, A-A1 and B-B1, on the southern and northern side, respectively, were also provided. These sections, presented in Figure 7, formed the basis of further Limit Equilibrium Analysis (LEA) of the embankment.

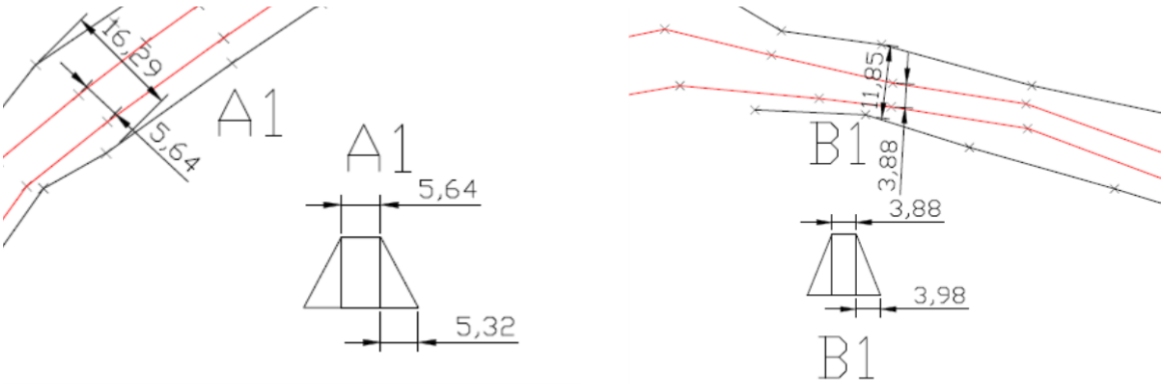


Figure 7: Survey sections of the embankment A-A1 and B-B1 on the southern and northern sides of the embankment, respectively

3.2 Methodology

A 2-dimenstional Limit Equilibrium (LE) Analysis was undertaken with the aim of considering the stability of embankment. Industry-standard software*, RocScience's SLIDE 2,* was used for the analysis. An LEA considers vertical slices of ground bounded by ground level and failure slip surfaces and calculates the Factor of Safety (FoS) based on the resisting and driving forces acting upon that slice of ground. After defining the slip surface by auto-refine search, the LEA was carried out using two rigorous analysis methods- Spencer, and Morgenstern-Price (GLE).

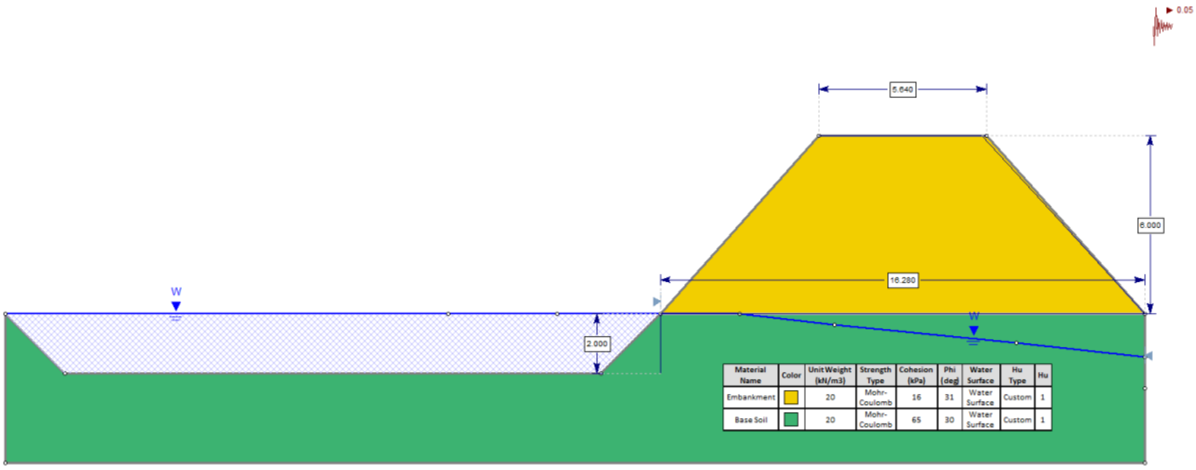
Following two modelling situations were considered for the analysis:

A. *The most likely situation*- water level in the river rises up to HFL and the embankment stays 6 meter above the water level (Figure 8).

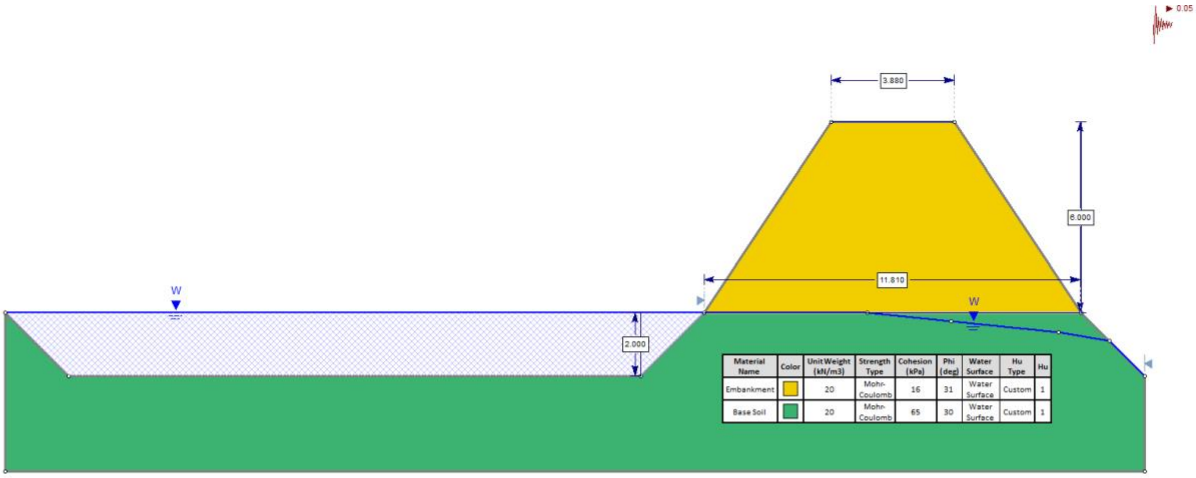
B. *An extremely severe episodic situation*- water level rises up 3 meter above the HFL (Figure 9). Although this is an extremely unlikely situation, for proper risk analysis, this hypothetical situation was also considered.

For both the situations, geotechnical parameters determined in the laboratory were utilized in building the models.

Pseudo-static analysis was carried out to factor in the dynamic loading induced by earthquake and blasting from the mine. Although earthquake is a rare phenomenon, the sudden loading induced by earthquake may have consequences on the stability of the embankment. Pseudo-static analysis is the preferred approach to analyze the seismic response of slopes. A horizontal seismic coefficient of 0.05 was considered for the analysis, which implies consideration of an additional load of 5 % of the vertical load working outwardly and continuously in the horizontal direction.

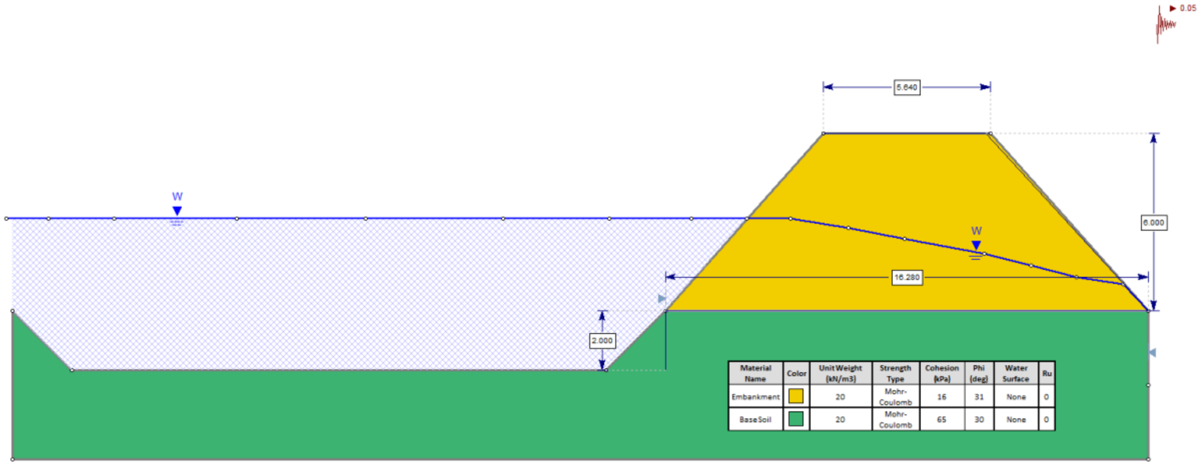


Section A-A1



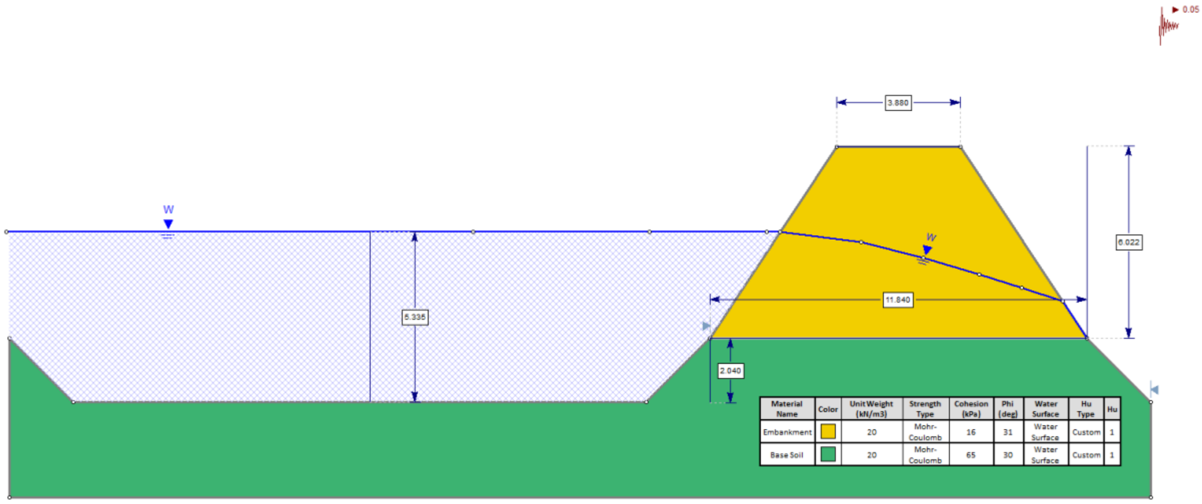
Section B-B1

Figure 8: Basic model with dimensions for situation A (water level up to HFL)



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Ru
Embankment		20	Mohr-Coulomb	16	31	None	0
Base Soil		20	Mohr-Coulomb	65	30	None	0

Section A-A1



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Embankment		20	Mohr-Coulomb	16	31	Water Surface	Custom	1
Base Soil		20	Mohr-Coulomb	65	30	Water Surface	Custom	1

Section B-B1

Figure 9: Basic model with dimensions for situation B (extremely severe episode with water level up to HFL plus 3 meter)

4 RESULTS OF ANALYSIS

Reults of Limit equilibrium Analysis for both the sections, A-A1 and B-B1, under the two situations, A and B, stated above are presented in Figure 10 to Figure 13. As can be seen from the figures, for situation A, which is the most probable situation under flooding condition, the Factor of Safety (FoS) obtained for section A-A1 using both the analysis methods, Spencer and Morgentern Price (GLE) are identical at 1.650. For section B-B1, the corresponding values for the two methods are 1.446 and 1.469, respectively. Any FoS value in pseudo-static analysis above 1.2 can be considered to be adequate. Therefore, the FoS values for both the sections in the most probable flooding situation are very high and no stability threat is envisaged.

Evaluation of results for the severly extreme episode, when the water level rises 3 meter above the HFL, the FoS falls to ~1.57 for the section A-A1 and ~1.36 for the section B-B1. Therefore, in this extreme situation also, the embankment is expected to remain quite stable.

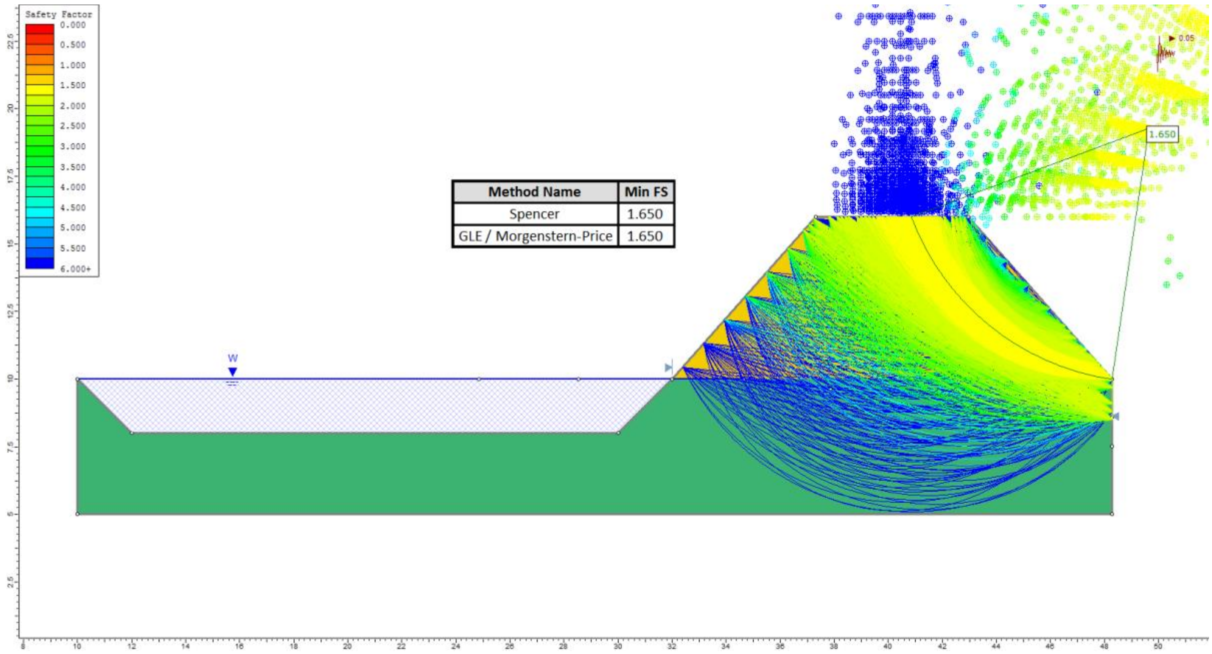


Figure 10: Results of LEA for section A-A1 under situation A

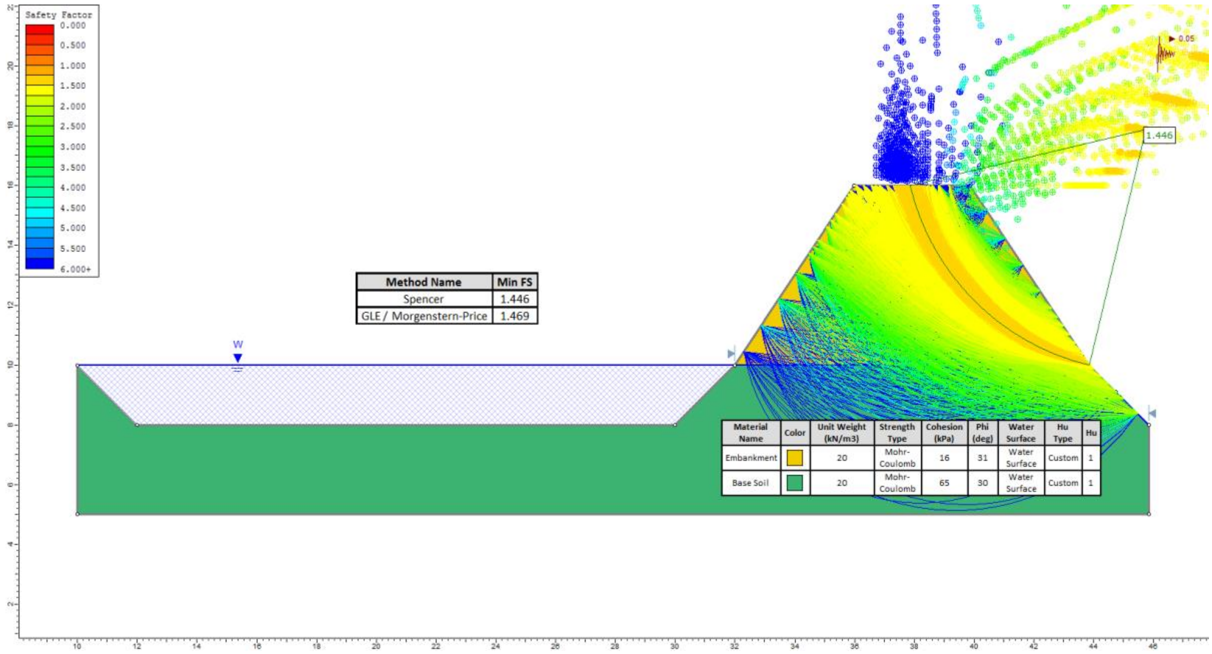


Figure 11: Results of LEA for section B-B1 under situation A

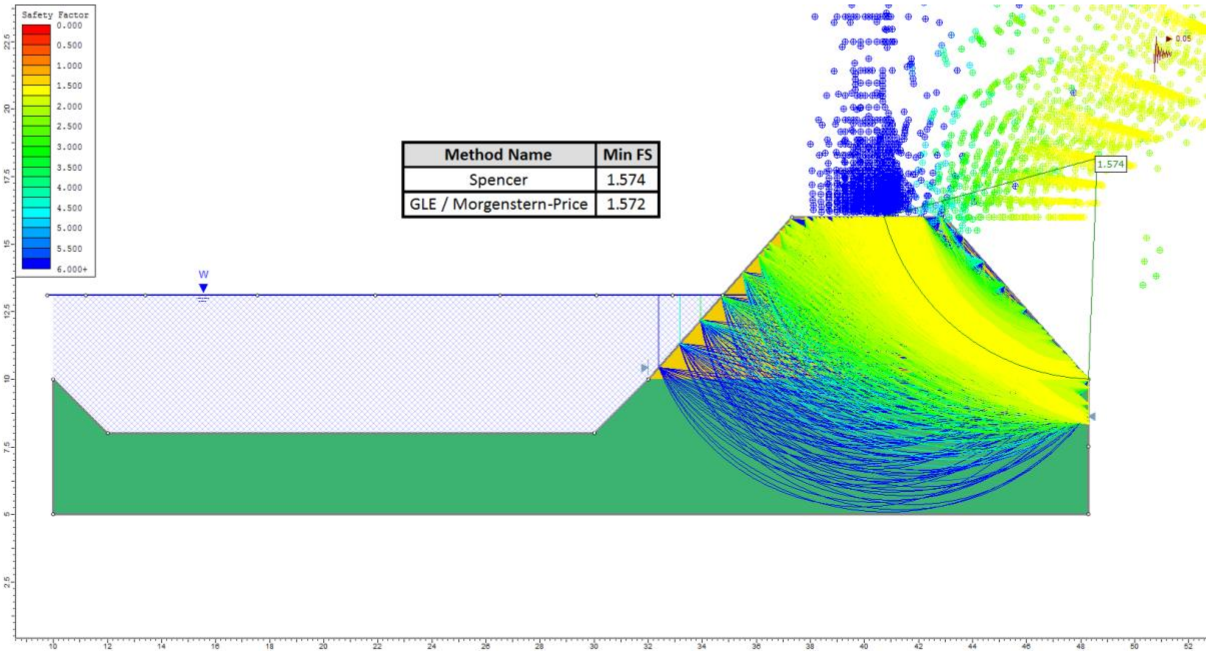


Figure 12: Results of LEA for section A-A1 under situation B

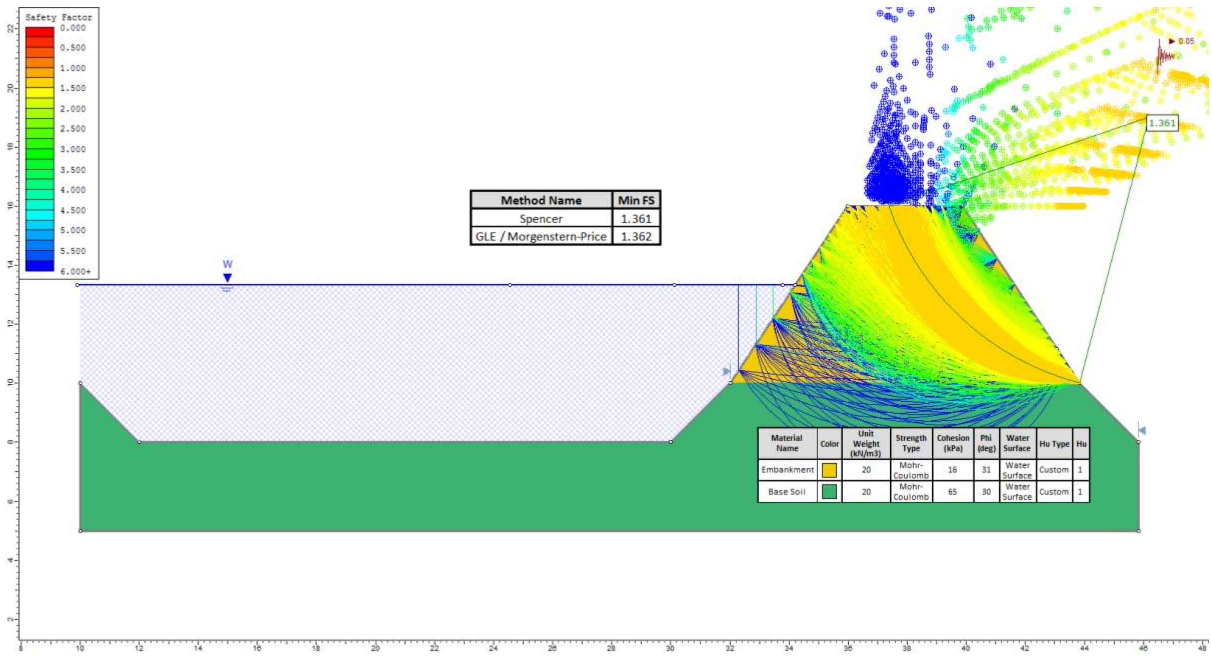


Figure 13: Results of LEA for section B-B1 under situation B

5 CONCLUSION AND RECOMMENDATIONS

The following conclusions and recommendations can be made from the stability analysis carried out on the river embankment at Kathautia opencast coal mine of HINDALCO:

A. Limit equilibrium analysis of the embankment at two sections of the embankment, provided by the survey sections, indicate that, under the most probable situation of water level in Durgawati river rising up to it HFL, is not likely to cause any instability to the structure

B. In case of an extremely severe episode of flooding, where the water level rises even up to 3 meter above the HFL, is also not likely to destabilize the embankment

C. To consolidate the embankment further, it is recommended that the walls of the embankment should be pitched with boulders especially at places where gully erosion or other such irregularities are visible

D. Although best scientific judgement has been incorporated into the study, the inherent uncertainties in such studies cannot be overlooked. Hence, it is recommended that, if water level ever rises above the HFL, continuous monitoring of water level should be done. If water level rises by one meter, all men and material should be temporarily withdrawn till the water level subsides

E. The value of physical inspection is emphasized here, which should be done at least once in every month under dry season and more frequently during the rainy season. Immediate corrective actions should be taken in case of any visible water seepage or other breach on the embankment