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STABILITY ANALYSIS OF OVERBURDEN DUMP SLOPE

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ABSTRACT

Coal mining activities are increasing daily to meet the rapidly rising demand of power plant generation industry. As the coal mine is dug deeper below the current ground level, more quality minerals are being mined. Therefore, waste material stability is given significant attention in slope analysis for an economic and safety standpoint, and its instability is brought on by over-burden dump slopes, which puts people's lives at risk. This paper presents a case study on the slope stability analysis using Midas GTS-NX using the three types of soil, namely weathered soil, weathered rock, and bedrock. The study describes variation of factor of safety with various factors, such as slope height, soil friction angle, and diameter of the reinforcement bar using the Strength Reduction Method. The factor of safety increased after the dump was reinforced using the soil nailing technique, significantly affecting the dump's stability.

Keywords: Slope Stability, Factor Of Safety, Coal Mining, Reinforcement, Midas GTS-NX.

I. INTRODUCTION

The Civil engineering's evaluation of slope stability in soil is important, intriguing, and difficult. Some of the most significant developments in our knowledge of the intricate behavior of soils have been motivated by concerns about slope stability. A solid set of soil mechanics principles is available thanks to many engineering and research investigations conducted over the past 80 years, which can be used to tackle real-world slope stability issues.

In recent decades, experiences with slope behavior, and frequently with their failure, have enhanced understanding of the potential changes in soil properties over time. Recognizing the requirements and restrictions of in-lab and on-site testing to assess soil strengths, creating novel and deeper, recognizing the requirements and restrictions of in-lab and on-site testing to assess soil strengths, creating novel and deeper understanding of the soil mechanics ideas connecting soil reactivity to slope stability, and more efficient methods of instrumentation to study slope behavior, and more efficient methods of instrumentation to study slope behavior. Enhanced analytical techniques combined with a thorough analysis of the mechanics of slope stability assessments, comparisons with field behavior in detail, and the use of computers to do in-depth studies. These improvements have led to the growth of the talent for judging slope stability. To increase the amount of reliability that can be reached through careful conclusion, evaluation, and research, knowledge, and judgement—which continue to be of the utmost importance—are joined with a more thorough understanding of soil behavior and scientific methods of analysis.

Issues with slope stability are prevalent and ubiquitous in many civil engineering projects. (Shiferaw 2021). Slope collapses brought on by earthquakes may result in significant disruptions to transportation and life support systems. They may result in fatalities when they happen in densely populated areas. It is vital to establish logical techniques to evaluate the seismic stability of slopes. (Daddazio, et al.1987). This study discusses historical trends in slope stability analysis along with the development of each approach. Along with a quick summary of the approaches that are now in use, this article also lists their benefits and drawbacks. (Kaur and Sharma 2016). To calculate the time-history curve of the slope safety factor under earthquake action, the method takes into account the strength parameter elements of a rock-soil volume at various points and works together in the vector summation technique, which improves the accuracy and reliability of the evaluation result for slope stability. (Zhang, et al. 2022) The relatively quiet boundary, which can completely absorb seismic waves, is implemented in the simulation to prevent boundary effects in dynamics analysis. The conventional pseudo-static (PS) method, which substitutes an equivalent static force for earthquake impacts in the study of seismic slope stability, is still commonly used. (Zhang, et al. 2019). For calculating the factor of safety (FOS) against slope failure of soil with no moisture slopes, basic equilibrium limit analysis may be used. (Gavin, 2010). The process of "soil nailing" is commonly used to reinforce slopes. Additionally, there has been more research on the design of slopes reinforced with nails. (Zhangn, et al. 2014). For years, steep cut slopes have been stabilized and excavations kept in place with soil nails. (Liping et al. 2010). Under vertical surface loading circumstances, an array of centrifugal model experiments was performed on a slope reinforced with nails while taking various slope grades and nail heights into consideration. (Zhangn, 2013). Appreciation of the transitory factors that cause slope failure requires an understanding of the role of water infiltration in soil and the consequent pore pressure reaction at depth. (Sung Eun Cho 2016). Several small-scale experimental plate load studies have been conducted to examine the load-settlement behaviour of CFC. (Anand and Sarkar 2021). Using an effective factor analysis technique, it was determined how various input variables affect the bearing behavior of CFC in relation to one another. (Anand and Sarkar 2020). Applying the fitting variables to the water retention characteristic curve (WRCC), unsaturated shear strength could be calculated (Anand and Sarkar 2022). Axial load capacity of clay deposit increases with the use of stone columns made up of OBD (Amit and Ran Vijay 2021).

II. METHODOLOGY

It is possible to implement a simple strain condition for geometry in MIDAS GTS NX 2D analysis to generate a "line" in the coordinate system. Absolute coordinates in the form of (x, y) are the starting position's input. As the finish line, the user can select [(Absolute (x, y))]: In the 2D work plane, type the coordinate value. The numerous forms of analysis, such as linear or non-linear static construction stage, slope stability, seepage, eigenvalue, seismic reaction spectrum, history of time and consolidation, load, and boundary analysis conditions, are also examined by GTS NX Software. Each analysis's circumstances are defined independently.

III. MODELING AND ANALYSIS

The present work examines the slope stability, unsaturated soil, and suitable requirements for an over-burden dump slopes using finite element modelling and MIDAS GTS NX software. The slope is modelled in 2D with dimensions of 50m in height and 55m in width. The properties of the soil layer for weathered soil, weathered rock, and bed rock, are defined with the general elastic model in Mohr's Coulomb; the material property is different for each layer.

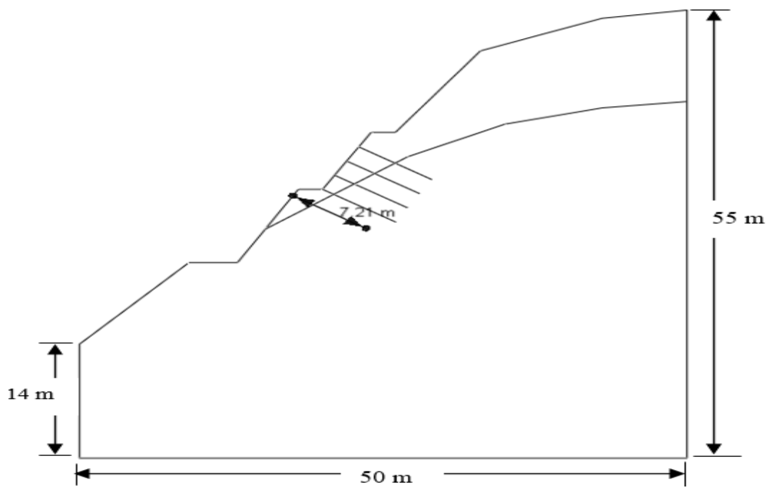

Fig. 1. Geometry of the problem considered in the present study.

Table 1: Slope Stability soil properties used in finite element analysis.

Parameter	Weathered Soil	Weathered Rock	Bed Rock	Nail
Model	Mohr coulomb	Mohr coulomb	Mohr coulomb	Elastic
Material	Isotropic	Isotropic	Isotropic	Isotropic
General Property				
∈	36500	150000	1850000	20000000

v	0.2	0.26	0.27	0.28
γ	19	22	24.5	78.5
K_0	1	1	1	1
General Property				
γ	19.8	23	24	-
$\in_\circ$	0.5	0.5	0.5	-
K_0	0.506	0.00254	0.0388	-
Non-Linear				
C	8	40	98	-
ϕ	20	25	37	-

Table 2: Slope Stability soil properties used in finite element analysis.

Name	Weathered Soil	Weathered Rock	Bed Rock	Nail
Model type	Plain Strain	Plain Strain	Plain Strain	Truss
Property	2D	2D	2D	1D

IV. RESULTS AND DISCUSSION

4.1 Factor of safety with slope height

To determine the factor of a safety of slopes, the first analysis is done by increasing the height of the slope from 25 m to 70 m gradually and varying with an interval of 5 m for the three different soil types, while all other variables kept constant. As the slope height grows, the safety factor declines, as demonstrated in Table 1 and Fig. 2

Table 3: Variation if FOS with hight of slope.

SI. No.	Slope Height (m)	Initial stress	Rain SRM 1	SRM with nails
1	25	4.4031	2.10391	3.10781
2	30	3.3375	2.15625	2.15234
3	35	2.8097	1.47734	2.03164
4	40	2.09687	1.40234	1.55313
5	45	1.1	1.03984	1.13242
6	50	1.11875	1.00625	1.20625
7	55	1.00625	1.00937	1.058
8	65	1.10469	1.01563	1.0125
9	70	1.13437	1.02109	1.1445

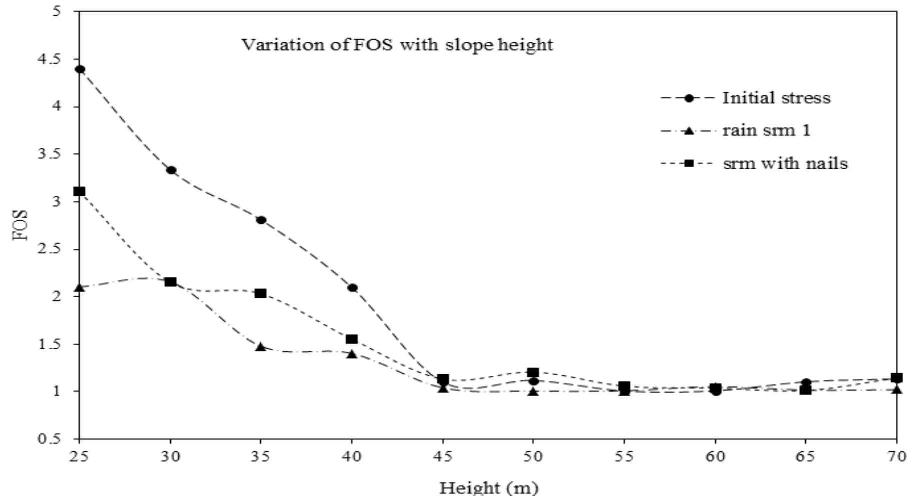

Fig. 2. Variation of FOS with Height of Slope.

4.2 Factor of safety and friction angle

To determine the factor of safety, a second analysis is carried out by keeping the slope height, reinforcement used, and soil parameter kept constant and increasing the slope gradually. By varying the friction angle of the soil. The factor of safety rises gradually at a small level from 20 degrees to 50 degrees, keeping between 3.06563 and 3.32969. A linear link exists concerning the friction angle and the factor of safety. Adopted values are shown in Table 3 and Fig. 3.

Table 3. Variation of FOS with Friction Angle.

SI. No.	Slope angle (ϕ)	Initial stress	Rain SRM 1	SRM with nails
1	20	3.06563	1.70234	2.60664
2	25	3.09688	1.90156	2.75938
3	30	3.15156	2.25078	2.88789
4	35	3.19141	2.4396	2.92734
5	40	3.24219	2.80313	2.92656
6	45	3.27695	2.93125	2.95
7	50	3.32969	2.95469	2.95626

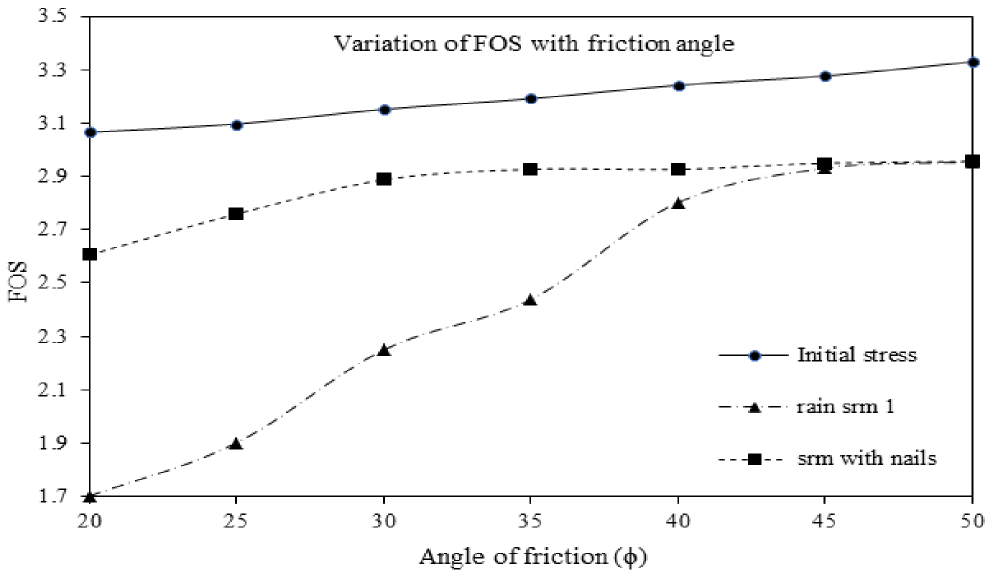

Fig. 3. Variation of FOS With Friction angle.

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4.3 FACTOR OF SAFETY AND DAIMETER OF NAIL REINFORCEMENT.

To determine the factor of safety, the third testing is carried out by variable the diameter of the nail from 0.012 m to 0.025 m. The factor of safety increases at the initial stage until the optimum diameter of nail reinforcement, which is 0.020 m, and then the factor of safety decreases, control other limits such as the height of the slope angle of friction and the soil parameter constant. Adopted values are shown in Table 4 and Fig. 4.

Table 4. Variation of FOS with Diameter of nail.

SI. No.	Dia. of nail(m)	Initial stress	Rain SRM 1	SRM with nails
1	0.012	1.00625	1.0082	1.0082
2	0.016	1.0125	1.0125	1.0289
3	0.02	1.01563	1.05664	1.09375
4	0.025	1.0125	1.0125	1.01563

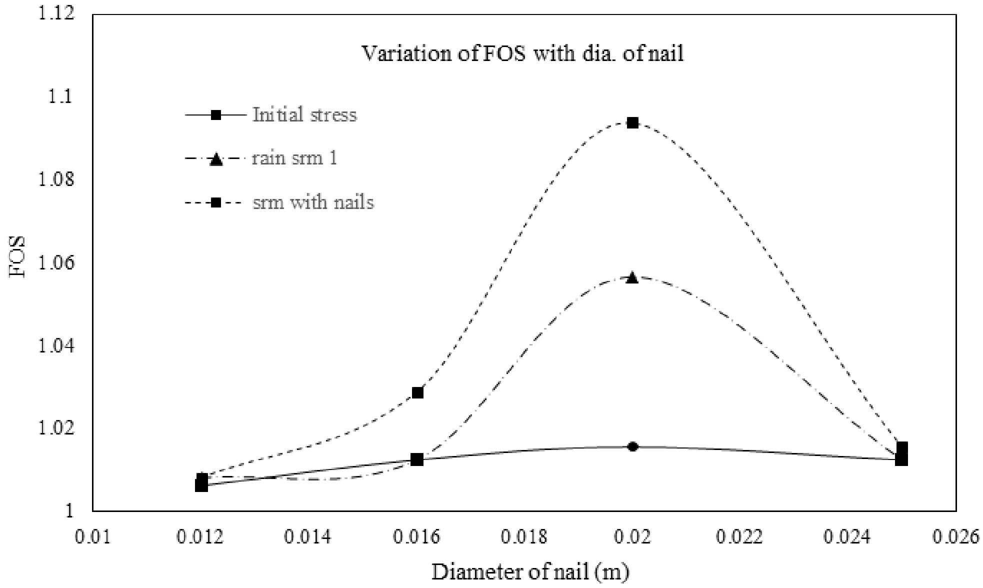
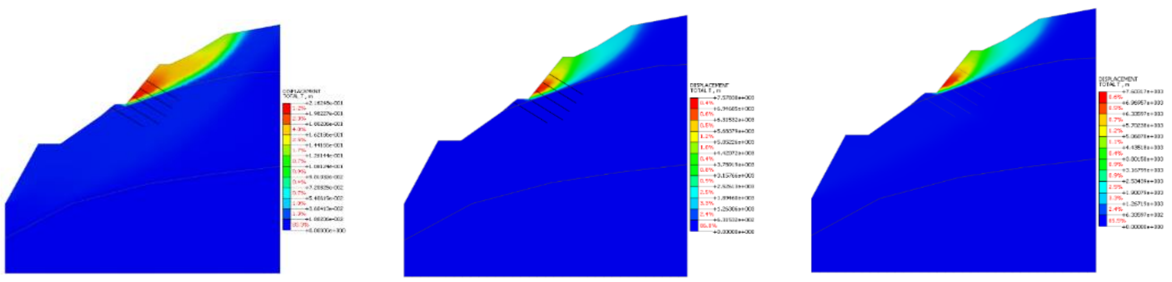


Fig. 4. Variation of FOS with Diameter of nail



(a) (b) (c)

Fig. 5. Static condition of slopes at 50m slope height (a). Initial stress SRM-Total displacement. (b). Rain SRM 1. (c). SRM with nail.

V. CONCLUSION

Through the use of meticulous numerical analysis methodologies, a thorough evaluation of the stability characteristics of soil slopes with nail reinforcement, slope height, and diameter of nail has been described in the current study. By contrasting the results with those obtained through a limit equilibrium method, it has been determined how well FELA works to solve slope stability concerns. The investigation's main findings are listed below.

• The factor of safety decreases rapidly with an increase in the height of slopes at the initial stages (i.e., from 20m to 45 m, the decrease in factor of safety is 4.4031 to 1.1), and on later stages, the variation is small as compared to the initial stages.

• Increasing the friction angle of the soil, increases the factor of safety gradually. There exists a linear relationship between factors of safety and the friction angle of slopes.

• Unreinforced soil of great height is more prone to slope failures. Therefore, slopes of such height can be made safe by reinforcing the slopes by providing a suitable diameter easily available. Thus, it can be concluded that increasing the reinforcing nail to optimum diameters increases the factor of safety and thereafter decreases.

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