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ADOPTION OF OPTIMUM SLOPE STABILIZATION TECHNIQUES TO PREVENT FAILURE OF SLOPE IN NANDHI HILLS

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ABSTRACT

To increase the performance and stability of the slope, the soil structure is optimized, either by strengthening the material or by supplying reinforcement. Using digital elevation models and slope stabilization software, statistical experiment design and analysis methods have been designed expressly for the aim of optimal strength and durability conditions. Because the performance of a slope (soil structure) varies with changes in climatic circumstances (particularly during the rainy season), it is required to develop an optimal reinforcement for soil stabilization in response to climatic variations.

Keywords*: Optimize, reinforcement, Stabilization.*

1. INTRODUCTION

Landslides can be caused by a variety of circumstances, including mild slopes and high gradients. Landslides happen when a specific event occurs, such as an earthquake, strong rainfall, or slope cutting to build a new road. Despite the fact that the cause of most landslides is unknown, the goal of this research is to identify, analyse, and implement mitigation measures against the failure regions. The process of selecting suitable material replacement for soil stability and determining their properties that would produce the best strength characteristics, as economically as possible, reinforcements or the soil replacement that satisfies the job requirements, that is slope having certain minimum compressive strength, is known as slope stabilization.

2. METHODOLODY

a) Literature survey.
b) In-situ material sampling.
c) Performance analysis through laboratory testing.
d) Studying and selection of stabilization techniques.
e) Digital elevation modelling (DEM).
f) Optimal slope stabilization by numerical simulation.

3. STUDY AREA

Failure location was located and a brief reconnaissance survey was done. The co-ordinates of the location were, longitude (east) 77°40'21" and the latitude (north) 13°21'42" at the 10th curve of Nandi hills and the place was locally known as 'Brahmagiri hill' which was primarily situated in 'Nandi hills' comes within the borders of 'Chikkaballapur district'.

The failure of the slope occurred on '25th of August 2021' due to heavy torrential rainfall on the onset of 'south west monsoon winds. Tourism was highly affected in the surrounding areas due to the slope failure occurring in the main access way of the 'Nandi hills.

Figure 1: Failure location.

4. PROPERTIES OF SOIL

Soil samples were collected from the failure location and laboratory tests were conducted for various properties of the soil and the results are tabulated below.

SL NO	PROPERTY NAME	PROPERTY
1	Specific Gravity	2.037
2	Field Density	
	a) Moisture content of soil sample	8.41%
	b) Bulk density	1.629 g/cm3
	c)Dry density	1.502 g/cm3
3	Plastic limit	15.29%
	Plasticity index	23.21%
	Liquidity index	63.37%
	Consistency index	36.23%
	Toughness index	9.28%
	Soil classification based on plasticity chart	Medium compressible clayey soil
4	Shrinkage limit	39.42%
5	Liquid limit	
6	Sieve analysis	
	a) Uniformity coefficient (Cu)	15.306
	b) Coefficient of curvature (Cc)	4.914
	c) Gradation	Well graded
7	Coefficient of permeability (Cp)	9.98*10-3 cm/sec
8	Direct shear	
	a) Cohesion	18kpa
	b) Friction angle (Ø)	26°

5. ELEVATION DATA

The elevation data of the failure location was analyzed by the public works department of Chikkaballapur district. This data was physically collected for the purposes of this project which was thoroughly verified using 'ArcGIS' software. The verified data were taken for further modelling of the slope as shown in figure 2.

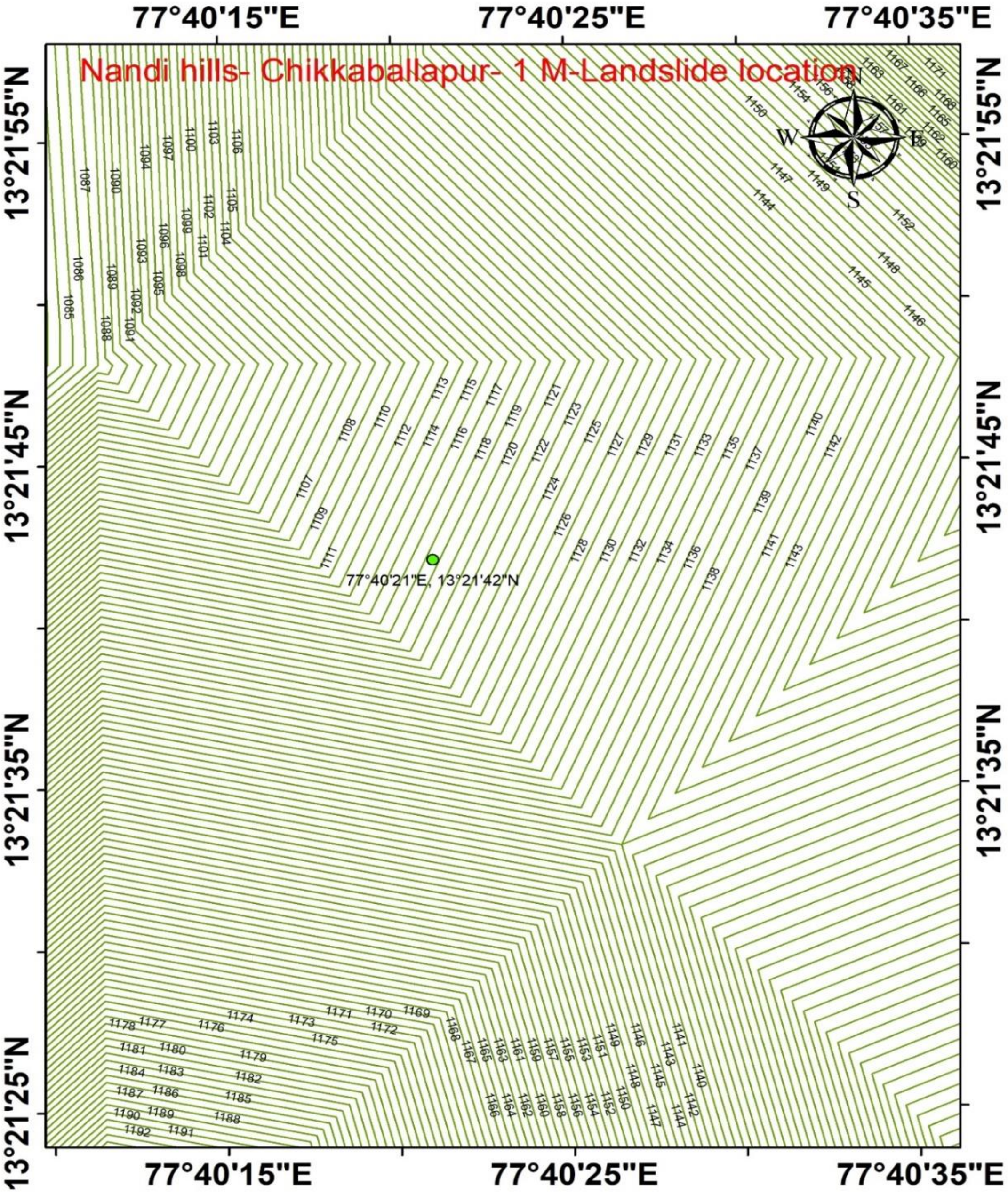

Figure 2: Digital Elevation data from ArcGIS software

6. MODELLING

The slope at the failure location was modelled and analyzed using 'GEOSTUDIO' software using the Slope/W function. The factor of safety of the corresponding slope is derived using Ordinary or Fellenius method. This method is also referred to as Swedish method of slices. This is the first method of slicing that has been created and published. Because of the method's simplicity, it was feasible to calculate safety factors by hand.

All interslice forces are neglected in this manner. Forces parallel and perpendicular to the slice base are resolved from the slice weight. The base normal force, which is perpendicular to the slice base, is utilized to determine the available shear strength. The gravitational driving force is the weight component parallel to the slice base. The factor of safety is calculated using the sum of moments around a point, which is used to characterize the trial slip surface. The factor of safety is equal to the sum of the gravitational driving forces divided by the entire available shear strength along the slip surface (mobilized shear).

In the absence of any pore-water pressures, the simplest form of the Ordinary factor of safety equation for a circular slip surface is:

$$FS = \frac{\Sigma[c\beta + N\ tan\O]}{\Sigma W\ sin\ \alpha} = \frac{\Sigma\, S_{resistance}}{\Sigma\, S_{mobilized}}$$

where:

c = cohesion,

β = slice base length,

N = base normal (W cos α),

Ø = friction angle,

W= slice weight, and

α = slice base inclination.

The modelling was done for the failure condition using the above-mentioned method in 'GEOSTUDIO' by using the results of the corresponding digital elevations and the soil properties which are pertaining to the study area. Two conditions were considered for further modelling and analysis. They are: -

1. No water table (fully dry)
2. Water table at top (fully saturated)

Figure 3: Modelled slope in GEOSTUDIO (side view).

7. SIMULATION AND RESULTS

7.1. WITHOUT REINFORCEMENT

The factor of safety was analyzed for the above two conditions without including reinforcements after modelling.

1. No water table (fully dry)

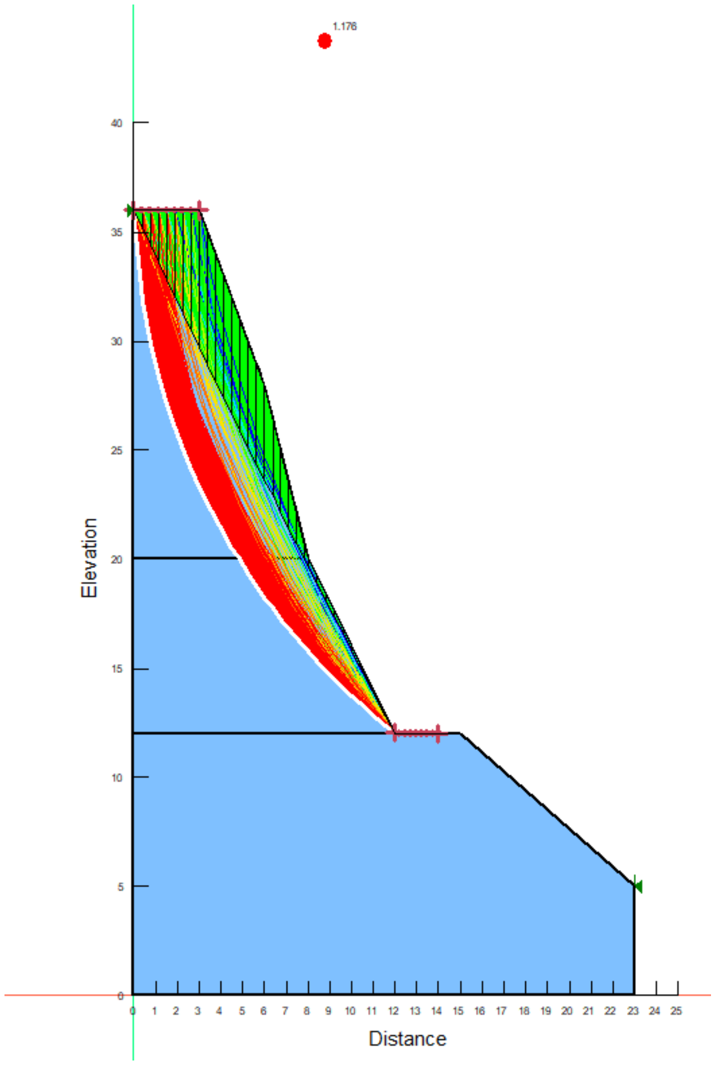

Figure 4: Modelled slope in GEOSTUDIO for no water table (side view).

Results:

Slip Surface: 1

Factor of Safety: 1.176

Volume: 30.81751o7 m³

Weight: 573.82216 kN

Resisting Moment: 3,43,353.23 kN·m

Activating Moment: 2,92,066.48 kN·m

Slip Rank: 26 of 405 slip surfaces

Exit: (11.9734, 12.0532) m

Entry: (0, 36) m

Radius: 567.14737 m

Center: (513.1174, 277.59195) m

1. Water table at top (fully saturated)

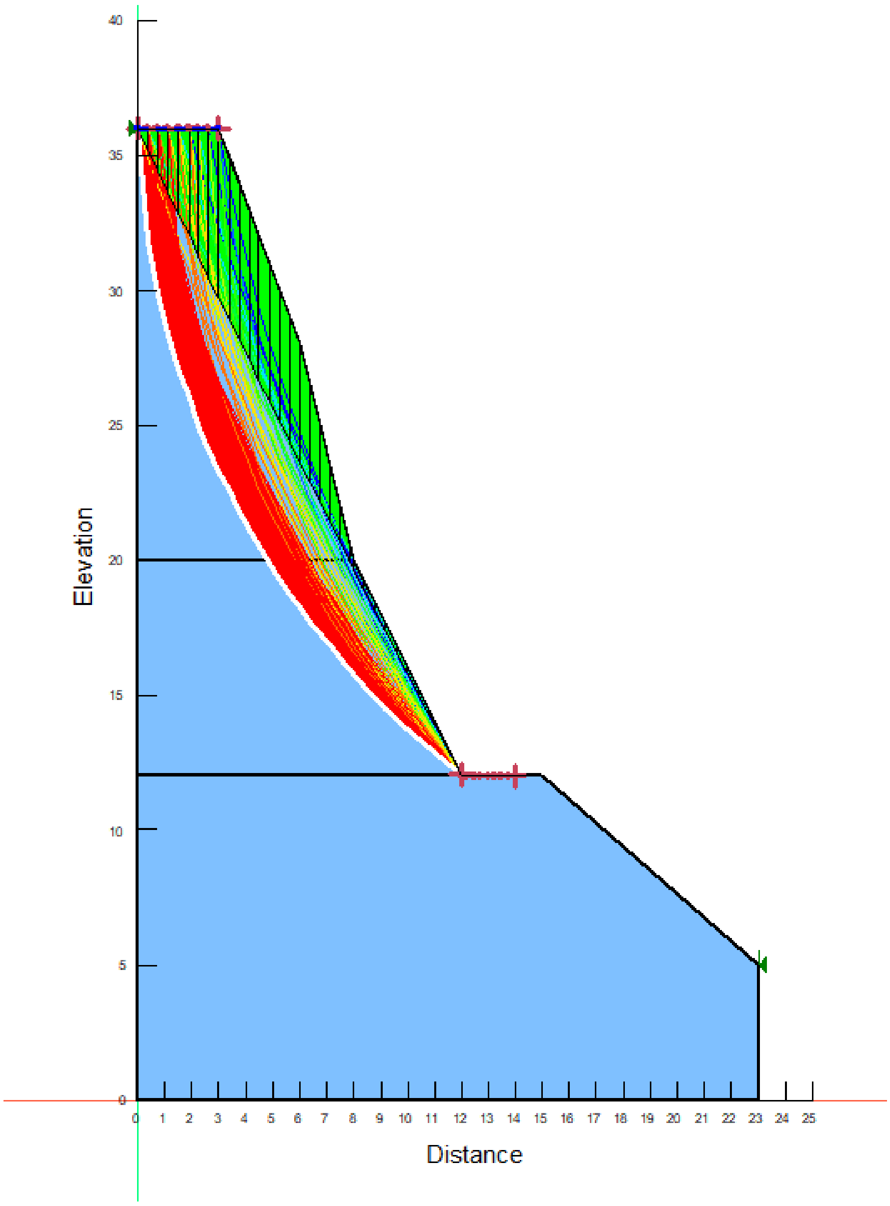

Figure 5: Modelled slope in GEOSTUDIO for water table at top (side view)

Results:

Slip Surface: 1

Factor of Safety: 1.138

Volume: 30.817517 m³

Weight: 573.82216 kN

Resisting Moment: 3,32,237.06 kN·m

Activating Moment: 2,92,066.48 kN·m

Slip Rank: 25 of 405 slip surfaces

Exit: (11.9734, 12.0532) m

Entry: (0, 36) m

Radius: 567.14737 m

Center: (513.1174, 277.59195) m

The factor of safety was analyzed for the above two conditions with including reinforcements using two stabilization techniques after modelling. Stabilization by piles and anchors is adopted. The comparative study was carried out between adopted two stabilization methods and the factor of safety was compared.

7.2. STABILIZATION BY PILES

1. No water table (fully dry)

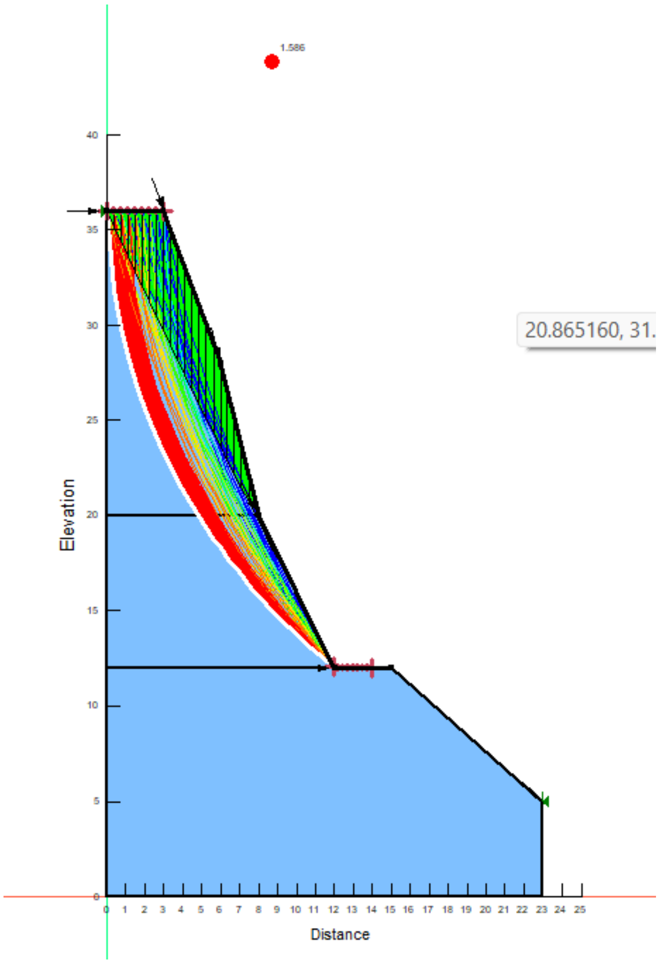

Figure 6: Modelled slope in GEOSTUDIO for no water table with piles (side view).

Results

Slip Surface: 1

Factor of Safety: 1.586

Volume: 81.858258 m³

Weight: 1,524.2008 kN

Resisting Moment: 27,150.076 kN·m

Activating Moment: 36,583.976 kN·m

Slip Rank: 1 of 405 slip surfaces

Exit: (11.9734, 12.0532) m

Entry: (0, 36) m

Radius: 31.346781 m

Center: (31.338904, 36.702702) m

1. Water table at top (fully saturated)

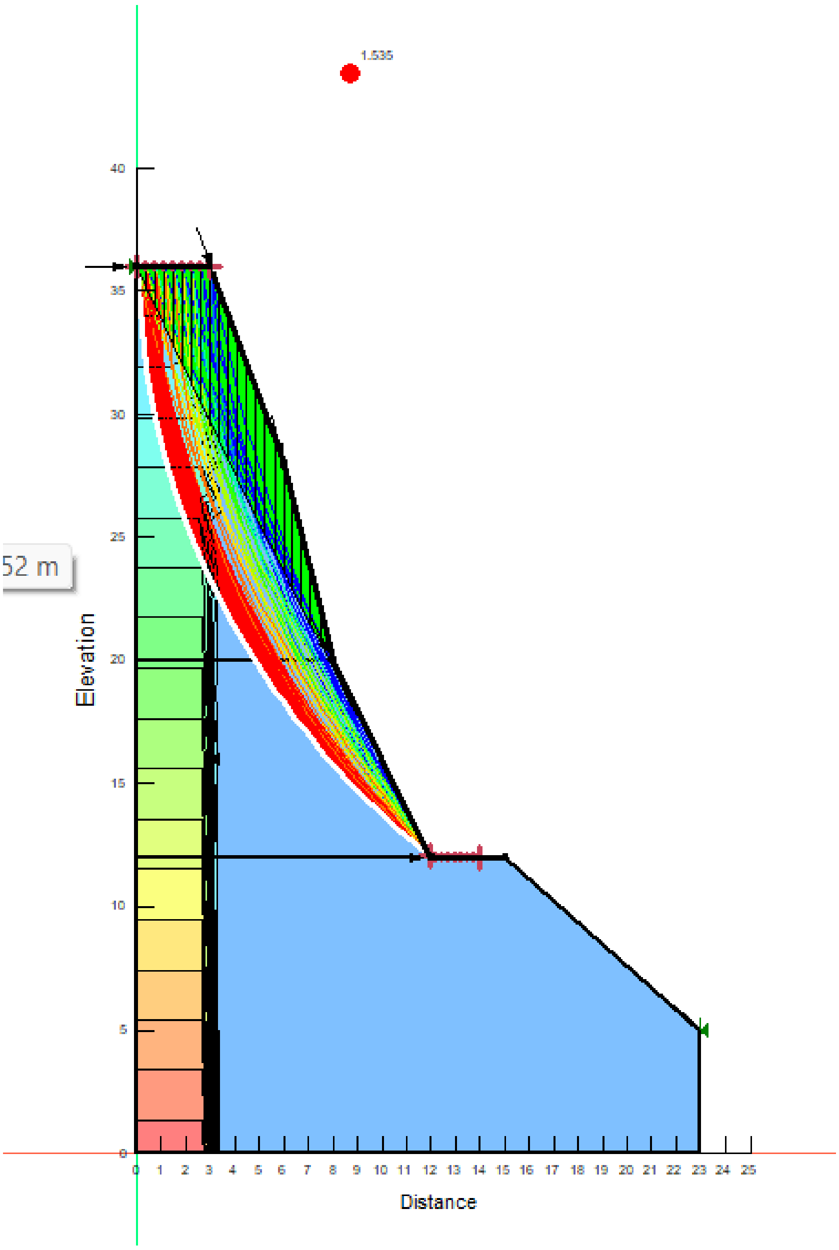

Figure 7: Modelled slope in GEOSTUDIO for water table at top with piles (side view).

Results

Slip Surface: 1

Factor of Safety: 1.535

Volume: 30.817517 m³

Weight: 573.82216 kN

Resisting Moment: 3,32,237.06 kN·m

Activating Moment: 2,16,446.86 kN·m

Slip Rank: 25 of 405 slip surfaces

Exit: (11.9734, 12.0532) m

Entry: (0, 36) m

Radius: 567.14737 m

Center: (513.1174, 277.59195) m

7.3. STABILIZATION BY ANCHORS

1. No water table (fully dry)

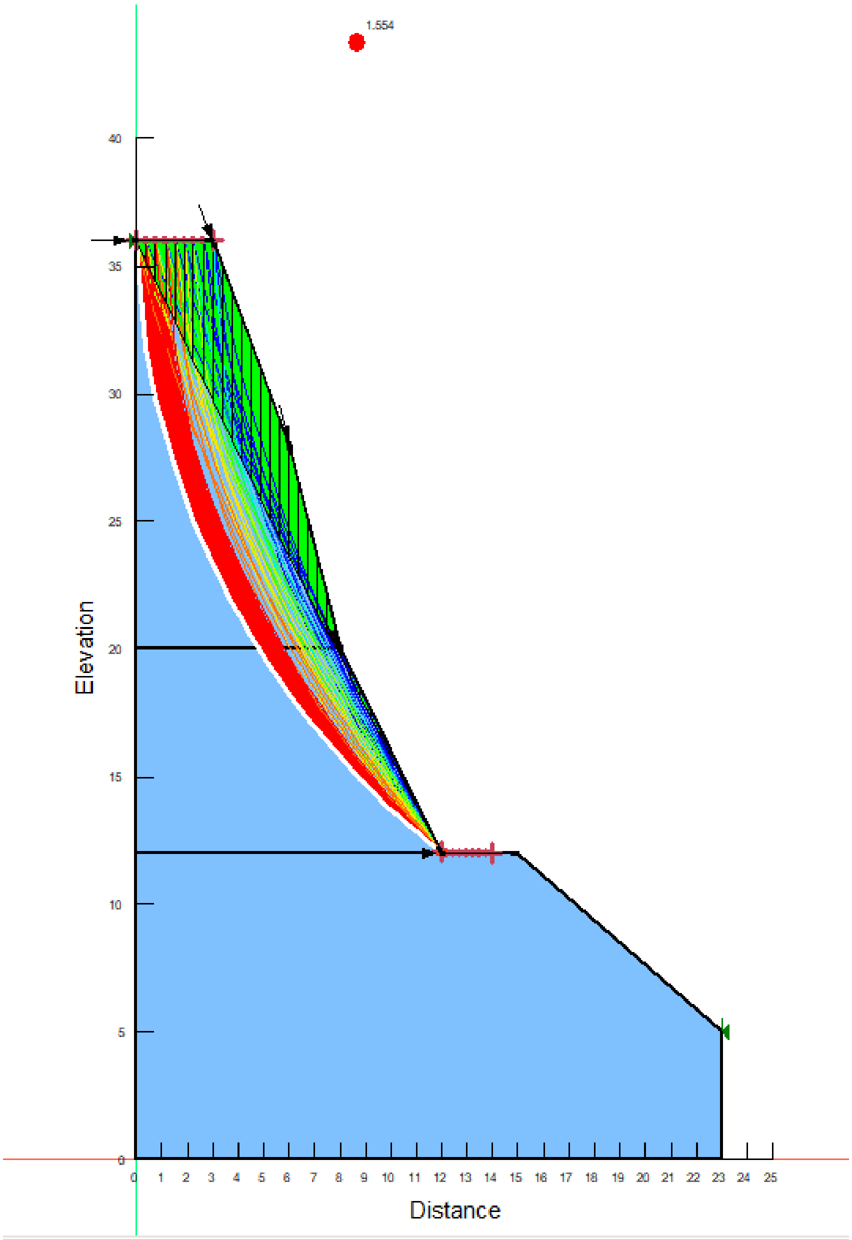

Figure 8: Modelled slope in GEOSTUDIO for no water table with anchors (side view).

Results:

Slip Surface: 1
Factor of Safety: 1.554
Volume: 30.817517 m³
Weight: 573.82216 kN
Resisting Moment: 3,43,388.44 kN·m
Activating Moment: 2,20,943.41 kN·m
Slip Rank: 25 of 405 slip surfaces

Exit: (11.9734, 12.0532) m
Entry: (0, 36) m
Radius: 567.14737 m
Center: (513.1174, 277.59195) m

2. Water table at top (fully saturated)

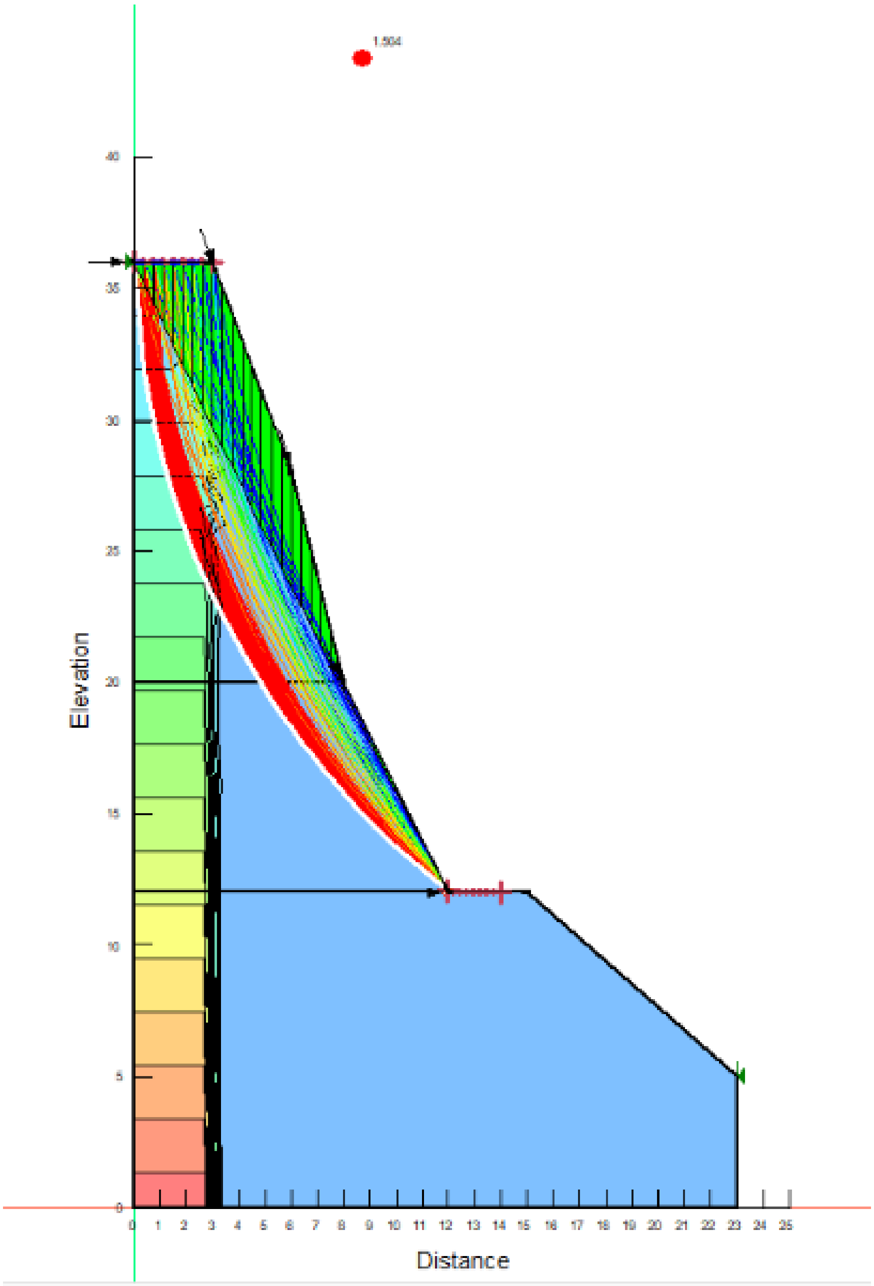

Figure 9: Modelled slope in GEOSTUDIO for water table at top with anchors (side view).

8. RESULTS

Slip Surface: 1

Factor of Safety: 1.504

Volume: 30.817517 m^3

Weight: 573.82216 kN

Resisting Moment: 3,32,272.27 kN·m

Activating Moment: 2,20,943.41 kN·m

Slip Rank: 25 of 405 slip surfaces

Exit: (11.9734, 12.0532) m

Entry: (0, 36) m

Radius: 567.14737 m

Center: (513.1174, 277.59195) m

9. CONCLUSION

Finally, we attempted to achieve slope stability to supplement previously used methods such as stabilization by piles and anchors by studying the site's soil conditions and elevations using a Digital elevation model, which simulates real-life situations in software format, saving time and money by extracting the required results and giving us an idea about the topography of the slope. We can provide an ideal strategy for improvising on supplying an optimal slope stabilizing measure by doing so.

As per the analysis and comparative study carried out for the study area piles are giving best results of factor of safety to counteract slope failure compared to anchors. But as per the market availability and cost, piles are costlier than anchors.

The primary goal of this initiative is to prevent future disasters in the Nandi Hills. The most recent disaster happened as a result of uncontrolled urbanization.

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