Slope Stability Analysis for Soil Erosion - A Case Study on Nadukani Hills

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Abstract

In Kerala majority of the hilly or steep sloped regions are under the elevated risk of soil erosion. It is one form of soil degradation induced mainly by the actions of wind or rain. The factors affecting erosion includes land use, geology, geomorphology, climate, soil texture, soil structure, vegetation etc. Soil erosion may be a slow process that continues relatively unnoticed causing loss of fertile top layer soil, which is good for plant growth, and it may reduce the soils ability to absorb and store water, which is in increased rate results in landslides, debris flows, rock fall etc., in the sloped regions. So it is essential to put as much as effort as possible into actions especially in slopes along with highway that will stop the soil from washing away by suggesting methods to control it after the analysis of the stability of that slopes. 'Nadukani Hills' is one of the frequent land slide region in Kerala. The stability analysis on that region is necessary. One of the method for stability analysis of slopes is by using the software GEO5. Using this software, we can solve most geotechnical tasks. By using the software's output, factor of safety and comparing it with the standards, we can analyze the stability of slope against sliding. The stability analysis on Nadukani Hills shows that the areas are highly susceptible for erosion. The control measure using reinforcements and anchors also suggested based on the analysis.

Keywords - *factor of safety, mitigation, soil erosion, slope Stability, slope stability analysis.*

I. INTRODUCTION

Soil erosion is one of the major environmental problems especially in the case of hilly regions or slopes. Erosion is the natural process induced mainly by the wind or rain. It causes the loss of fertile top layer soil, which is good for plant growth, and it may reduce the soil's ability to absorb and store water, which is in increased rate causes rock fall, debris fall etc. The determinant factor for erosion is water content in the soil. Other factors that induce soil degradation are rainfall and rainwater runoff, agricultural activities, vegetative cover, slope of the land etc. Therefore, it is necessary to analyze the slopes for stability. Slope stability is the resistance of inclined surface to failure by sliding or collapsing. The increasing demand for engineered cut and fill slopes on construction projects has only increased the need to understand analytical methods, investigative tools, and stabilization methods to solve slope stability problems. The need of slope stability in the slopes along with highway is more than other slopes. It is because the chances of the failure of the slopes and unexpected accidents are high. Slope stabilization methods involve special construction techniques that must be understood and modeled in realistic ways. An understanding of geology, hydrology, and soil properties is central to applying slope stability principles properly [1].

In older times, the stability analysis is done by using graphs or hands. The conventional methods used for the analysis are limit equilibrium methods. The method is mainly three types. Swedish circle method, Friction circle method and Bishop's method. Nowadays all analysis can be done through software. GEO5 is such an advanced software suitable for solving geotechnical problems based on traditional analytical method and Finite Element Method. Basic geotechnical approaches implemented in the GEO5 programs are applicable all over the world. GEO5 offers a unique way of applying standards, which significantly simplifies the work of a designer and at the same time, allows for complying with all required approaches. It is an accurate and easy to use tool in all geotechnical problems. The output of the GEO5 analysis is factor of safety, defined as the ratio of the shear strength to the shear stress required for equilibrium. The factor of safety is determined for different slopes. If the value of factor of safety is less than 1.5, the slope is unstable. For the safe standing of slopes, it is necessary to maintain the factor of safety [2].

II. METHODS OF SOIL STABILIZATION

Soil erosion is one of the major land degradation in the hill eco systems. Soil erosion is in the form of gully, rill and sheet erosions leading to rock falls and debris falls. If there is more compactive effort on the soil, then the resisting against erosion is also high. Like that, the methods in practice are revegetation, sand dune stabilization, chemical stabilization, grouting, fertilizer practices, stabilization using coir, geo textiles, geo grids, geo cells, soil nails, reinforcements, anchoring, retaining walls, gabion walls, etc. [3, 4]. In the present study the areas of soil erosion were identified, properties and factors were detected and on the basis of analysis a combination of anchors and reinforcement is selected for the stabilization. The results are shown in the analysis section.

III. METHODOLOGY

The main steps of the project is listed below:

1. Site selection and sample and data collection from the site.
2. Contour map preparation using LISCAD.
3. Laboratory experiments and analysis.
4. Analysis using GEO5

These are explained in detail in the following sections.

A. Site selection

In view of continues failures of slope occurred in recent times, we selected the site Nilambur Nadukani Churam in Malappuram district in Kerala, for doing this project. Two different slopes from this region is considered for the analysis.

B. Data Collection

Details obtained from Soil Survey Department, Malappuram, as secondary data, indicates that the soil of Nadukani region is deep, and excessively drained, brown to dark brown in colour, strongly acidic and moderately fine to fine textured. General pH of this soil is 5.5. These soils are developed over gneissic parent material occur on moderately steep to very steep side slopes of hills in the high lands (600 to 1200 m above MSL). Boulders and rock out crops are common on the surface. These soils are generally forest soils and are medium in general fertility status. The water table also follows the slope topography and it passes at a depth of 25-30 m from the surface. The soils of the region are suitable only for natural vegetation. The climate under this region is generally humid tropical.

C. Contour Map Preparation Using LISCAD Software

Data such as elevation, angle and gradient of the slopes were collected using total station. Data from total station is transfered to LISCAD Software and the corresponding contours of the slopes were drawn.

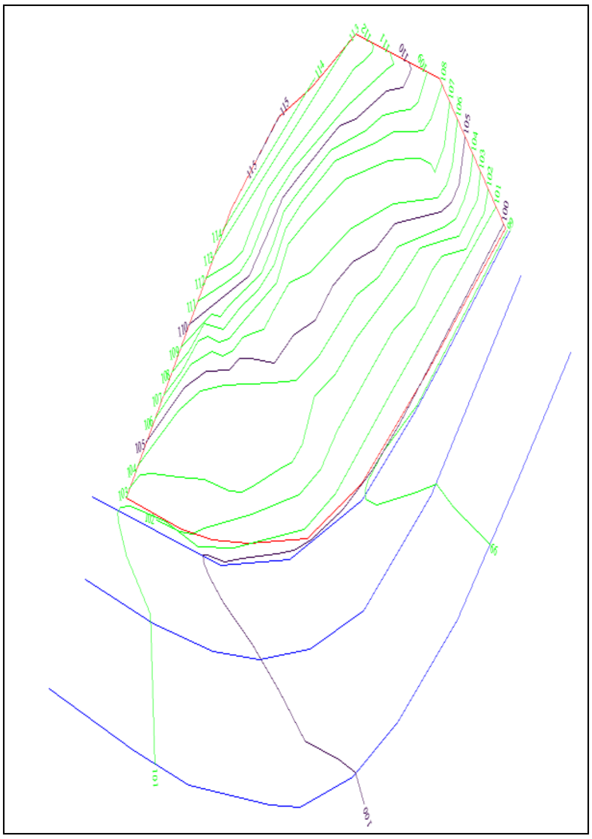

Fig.1: Contour Plan of Slope 1

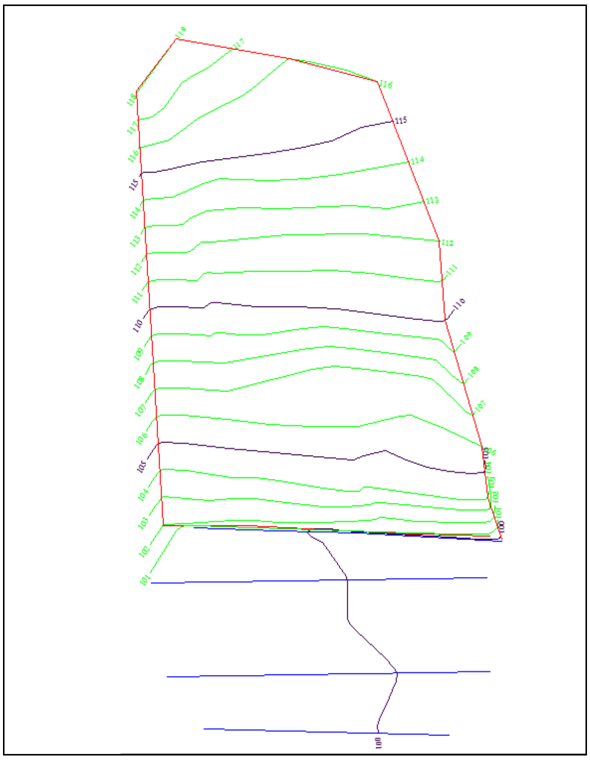

Fig.2: Contour Plan of Slope 2

Figure 1 and Figure 2 shows the corresponding contour maps of slope 1 and slope 2. In the red line boundary the green line indicates the 1m contour and violet line represents the 5m contour in the site. Blue line indicates the highway passes along with the slopes. Taking the reduced levels of the contour, the corresponding slopes can also be plotted in GE05 also.

D. Laboratory Experiments

The collected soil samples from both the slopes were oven dried and air-dried for the determination of the properties of soil [4]. Different laboratory tests on the soil samples were conducted according to Indian standard codes [5, 6, 7, 8]. The test results are shown in the Table 1.

Table 1: Properties of soil

Sl.No	Experiments	Sample 1	Sample 2
1	Average Water Content, W	21.48%	20.88%
2	Average Specific Gravity, G	2.350	2.310
3	Liquid Limit	61.00%	61.00%
4	Plastic Limit	28.90%	28.90%
5	Shrinkage Limit	18.00%	23.00%
6	Maximum Dry Density, MDD	1.75g/cc	1.80 g/cc
7	Optimum Water Content, OMC	12.00%	12.00%
8	Cohesion Intercept, C	0.025	0.025
9	Angle Of Internal Friction, Φ	1.400	1.400

E. Analysis

The stability of slopes was analyzed by using the GEO5 software. The input parameters for GEO5 includes [2],

- Geometry: slope, inclination & height.
- Properties: soil parameters for soil in each zone.
- Water levels: levels of water adjacent to the slope

*1) **Slope Stability Analysis:*** The stability of both the slopes from Nadukani Hills is analyzed with the help of slope stability tool in GEO5.

Slope 1:

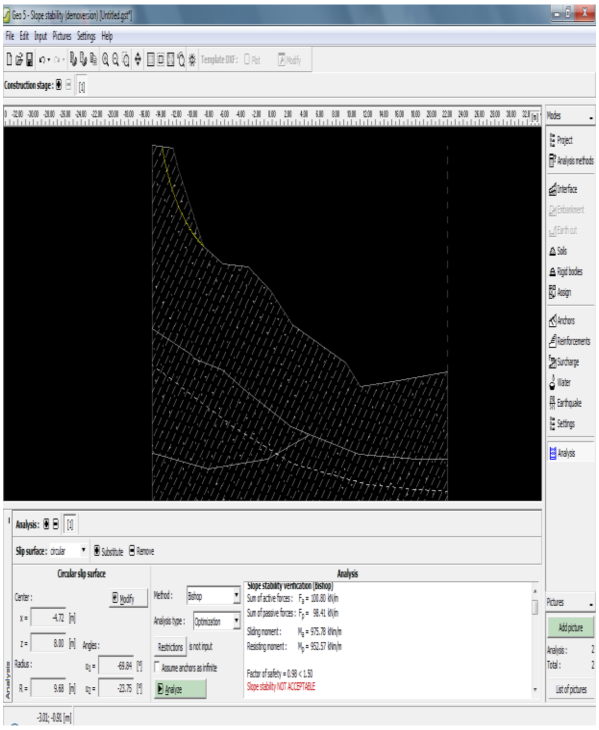

Fig 3: Stability analysis of Slope 1

The figure 3 shows the stability analysis for slope 1. Here the top line indicates the slope surface and the lines beneath it shows different strata. Dotted line represents the water table below the ground. Soil type is hatched in the figure. The slip surface obtained after the analysis in GEO5 is shown by yellow line in the figure. The factor of safety value for the slope is 0.98 which is less than 1.5 (FOS<1.5). The results show that the area is highly susceptible to soil erosion. Hence, the slope is not safe against erosion.

Slope 2:

The FOS value obtained for this slope is 1.42, which is also unsafe against erosion.

From the analysis, it is clear that the both slopes 1 and 2 are coming under the erosion susceptible areas. Therefore, as explained earlier, use of suitable method for erosion control is compulsory. It is done in the stabilization step.

*2) **Slope stabilization**:* Here the best method of providing anchors and reinforcements are chosen through trial and errors done on the stabilization checks. Stabilization of slopes with anchors and reinforcement is selected as best suited for the critical condition of the hills through as it gave high FOS values. Detailed analysis is given below;

Slope 1:

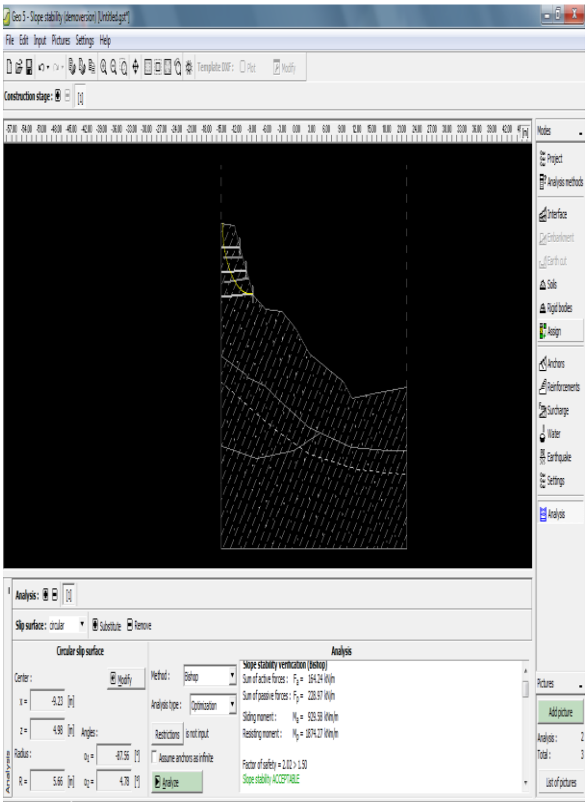

Fig 4: Stabilization of Slope 1

Figure 4 shows stabilization of slope 1. Here we are using three anchors and two reinforcements. The details of length, position, slope, angle etc., of the materials are given in the table 2 and table 3. After stabilizing with the combination of reinforcement and anchors, the FOS becomes 2.02. The FOS value greater than 1.5 shows that the slope becomes safe against the erosion action.

Table 2: Reinforcement Details

Sl. No	Points to the left		Points to the right		Length	Tensile strength
	X (m)	Z (m)	X (m)	Z (m)	(m)	(KN/m)
1	-14.62	2.04	-10.90	2.19	3.72	50.00
2	-14.44	0.23	-9.66	0.56	4.79	50.00

Table 3: Anchor Details

Sl. No	Origin		Length	Slope	Anchor spacing	Force
	X(m)	Z(m)	(m)	(degree)	(m)	(KN)
1	-11.40	2.94	3.00	178.00	1.00	50.00
2	-10.10	1.17	4.50	178.00	1.00	50.00
3	-8.75	-0.67	6.00	178.00	1.00	50.00

Slope 2:

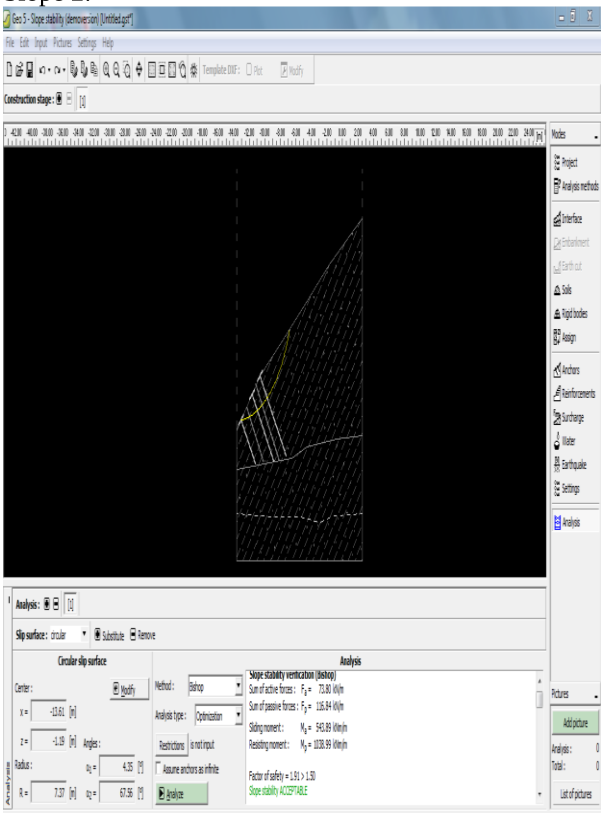

Fig 5: Stabilization of Slope 2

Figure 5 is the slope stabilization in slope 2. After the stabilization here, the FOS becomes 1.91, greater than 1.5. So the stability of the slope is safe. The details of reinforcement and anchors used in this slope is shown in the tables 4&5 below.

Table 4: Reinforcement Details

Sl. No	Points to the left		Points to the right		Length	Tensile strength
	X(m)	Z(m)	X(m)	Z(m)	(m)	(KN/m)
1	-12.29	-7.97	-10.16	-10.64	3.42	50.00
2	-11.12	-6.80	-8.14	-10.57	4.81	50.00

Table 5: Anchor Details

Sl. No	Origin		Length	Slope	Anchor spacing	Force
	X(m)	Z(m)	(m)	(degree)	(m)	(KN)
1	-13.06	-8.54	2.87	50.00	1.00	40.00
2	-11.63	-7.26	4.36	50.00	1.00	40.00
3	-10.62	-6.35	5.23	50.00	1.00	40.00

If stabilization arrangements are executed at site as per these details the erosion can be controlled to a large extent.

IV. CONCLUSIONS

The stability of slopes along with highway is an important factor for resisting soil erosion accidents. Two different erosion prone slopes from Nadukani Churam is selected for the study. The slope stability was analyzed using the GEO5 software. Control measures for the prevention of soil erosion in these locations were suggested on the basis of slope stabilization analysis. Anchors and reinforcement installations were tried in the analysis. Major findings in the study can be summarized as:

- The FOS values for both the slopes obtained as 0.98 and 1.42 indicating high susceptibility to erosion.
- Stabilization using anchors and reinforcements will result an increase in the FOS values to greater than 1.5 resulting in a greater control of erosion.

Through the practical application of the stabilization method simulated in the GEO5, as explained earlier, we can control the soil erosion in the region. Findings in this study can be extended for stability analysis of similar locations in future and can act as a great measure of safety to such erosion prone areas.

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