Geotechnical Investigation and Numerical Analysis of Slope Failure: A Case Study on Landslide Vulnerable Zone in Attapadi, Kerala

SARATH RAJEEV[1], DR. M. KUMAR[2]
[1]*PG Student, M.E. Geotechnical Engineering, Government College of Technology, Coimbatore.*
[2]*Professor, M.E. Geotechnical Engineering, Government College of Technology, Coimbatore*

Abstract*— The stability of slopes is always under severe threats in many parts of Western Ghats, especially in Attapadi during rainy season, causing disruption and loss of human life and economy. Slope instability is a common phenomenon with a high level of risk in living hoods. It is dangerous because the soil strata's shear strength is weakened by the slope-forming materials gradual migration. To minimize the instability of the soil slope, a critical evaluation of the slope section is required. The stability of the slope is measured by its factor of safety using geometric and shear strength parameters based on infinite slopes. The region of Attapadi in Kerala has been selected as the study area for the geotechnical investigations. Undisturbed soil samples were collected from seven different landslide's vulnerable locations were tested for their geotechnical properties. A detailed numerical analysis was carried out for the slope failure area. The slope stability depends on the soil shear strength parameters such as cohesion, angle of internal friction, unit weight of soil and slope geometry. From the soil sample analysis, the slope failure phenomena and factor of safety have been calculated using Rocscience software, which is a finite element software and suggests suitable remedial measures. The knowledge of slope behavior and productive measures in the study area is improved by this investigation.

***Index Terms*-Stability of slope, factor of safety, Rocscience software.**

I. INTRODUCTION

Slope failure also known as landslides, refers to the movement of a mass of soil, rock, or debris down a slope or hillside. It may be brought on by a variety of causes, including human activity, or it may be a naturally occurring geological process. Slope failures can be dangerous and could endanger human life in addition to seriously damaging property and infrastructure. Numerous concepts from geotechnics, soil science, rock mechanics, and engineering geology are used to slope stability. Slope behavioral case studies have improved our knowledge of slope stability mechanisms, complicated material models, the constraints of insitu and laboratory testing, and the creation of new instruments for evaluating slope reaction. The Attapadi region of Kerala state is one of the tourist spots located on the large mountain valley below the Nigiri Hills of the Western Ghats, at the headwaters of the Bhavani, which are the severe to very high landslide hazard-prone areas of India. The region is well known for its landslide threat. In recent times, causalities and damage due to landslides have increased in the Attapadi Terrain. The sliding can be classified into three type, Rotational failure, Block failure and transitional failure. It has become necessary in recent years to anticipate landslides and take precautions against them. However, the geotechnical instruments required to examine landslides have been enhanced. Both constitutive and numerical models can now be used to analyses a wide range of situations. Numerical simulations using a variety of techniques, including neural networks, the boundary element method (BEM), the finite element method (FEM), the finite difference method (FDM), and the limit equilibrium method (LEM), were used to comprehend the failure mechanism of slopes. Numerous pieces of software, including Transient Rainfall Infiltration and Grid-based Regional Slope Stability (TRIGRS), GeoStudio's (SEEP/W and SLOPE/W programmes) Roc Science RS2, PLAXIS, and FLAC (Fast Lagrangian Analysis of Continua), were used to analyze slope stability. The present study, around seven soil samples were collected in and around the Attapadi area in the Palakkad district. Laboratory tests were conducted and the geotechnical properties of the soil were determined. Numerical analysis of the stability of slopes in this study area

were done in Rocscience software and the Factor of Safety were Analyzed. Further the Recommendations were given to stabilize the slopes.

II. DESCRIPTION OF STUDY AREA

Attapadi is situated in the southeastern part of Palakkad district in the southern state of Kerala, India. It is geographically close to the state of Tamil Nadu. It is one of the most popular hill stations in India, situated in a valley of mountains nestled between two Western Ghats hills and the geographical location of the study area is shown in figure below. Attapadi is approximately 10.6184° N latitude and 76.7311° E longitude. The average elevation of Attapadi above mean sea level approximately ranges from 800 to 1400 meters, or 2625 feet to 4593 feet. This elevation can vary slightly depending on the specific location within Attapadi, as it is a hilly area.

Table:1 Latitude and Longitude of sample location

SAMPLE LOCATION	LATITUDE	LONGITUDE
Attapadi Mountain Pass	11.040808	76.533398
Manarkkad-Anakkati Road	11.040629	76.7533476
Mukkali	11.059046	76.53861
Narasimukku	11.03253	76.642898
Chittoor	11.070217	76.653407
Sholayur	11.076627	76.712985
Agali	11.95340	76.641726

III. LABORATORY TESTS

A-Moisture Content Test

The test is conducted on the samples that are collected from the specified locations around the Nilgiris district. The tests are conducted as per IS: 2720 (Part-2) – 1973 specification.

B-Specific Gravity Test

Specific gravity is the ratio of the mass of soil solids to the mass of an equal volume of water. Using a pycnometer, three samples are tested, and the average result is taken as the specific gravity of the soil at each site. According to IS: 2720 (Part 3/Section 1) – 1980, the tests are carried out.

C-Atterberg Limits

The consistency of a fine-grained soil is largely influenced by the water content of the soil. A gradual decrease in water content of a fine- grained soil slurry causes the soil to pass from the liquid state to plastic state, from the plastic state to a semi-solid state and finally to solid state. The water contents at these changes of state are different for different soil. The water contents that correspond to these changes of state are called the Atterberg limits. As per IS 2720 (Part 5) The Atterberg limits of the soil is determined. The Atterberg limits are a set of tests used to determine the plasticity and moisture sensitivity of fine-grained soils

D-Unconfined Compressive Strength

The Unconfined Compressive Strength (UCS) test is a laboratory test used to determine the mechanical strength properties of cohesive soils. The tests are conducted as per IS: 2720 (Part-10).

IV. NUMERICAL ANALYSIS

The procedure for performing slope stability analysis using Rocscience Slide generally involves the following steps

A-Defining Geometry and Materials

Start by defining the geometry of the slope, including its dimensions, shape, and any surface irregularities. Specify the material properties of the soil, rock, and any other relevant layers. This includes parameters like unit weight, cohesion, friction angle, and groundwater conditions.

B-Model Creation

Create a digital model of the slope in the software. This involves defining different soil and rock layers, assigning appropriate material properties, and specifying any structural components or reinforcements.

C-Defining Analysis Method

Choose an appropriate analysis method. Rocscience Slide offers several methods such as Bishop's method,

Simplified Janbu's method, Morgenstern-Price method, etc.

D-Performing Analysis

Run the analysis using the chosen method. The software calculates factors of safety and evaluates the stability of the slope under the specified loading conditions.

E-Interpreting Results

Review the analysis results to determine the factor of safety, which indicates whether the slope is stable or not. A factor of safety less than 1 indicates potential instability, while a factor greater than 1 indicates stability.

V. RESULT AND DISCUSSION

Table:2 FOS obtained from numerical analysis

Sample No:	Slope Height (m)	Ru	FOS		
			30	45	60
1	15	0	2.825	2.153	1.752
2	15	0	2.589	1.936	1.553
3	15	0	2.537	1.916	1.543
4	15	0	2.370	1.742	1.381
5	15	0	1.879	1.382	1.095
6	15	0	3.103	2.348	1.899
7	15	0	2.687	2.047	1.667

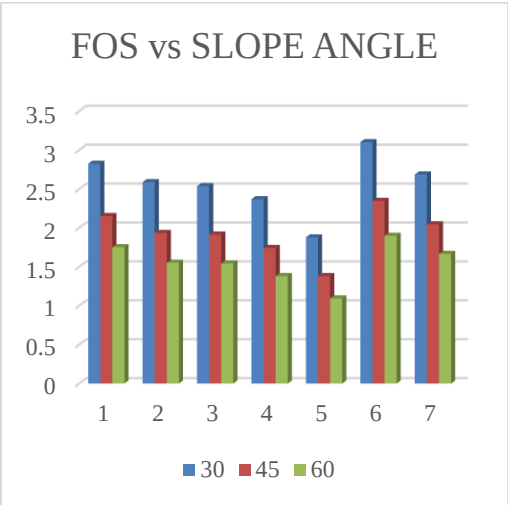

Figure:1 FOS vs Slope angle

1. Soil samples were collected from seven different locations within and around Attapadi, Kerala. The geotechnical characteristics of each sample were obtained.
2. Numerical analysis was done using Rocscience software and FOS is found out.
3. A numerical analysis shows that as the slope angle increases, the factor of safety decreases.
4. The characteristics of the soil, such as its cohesion, internal friction angle influence the factor of safety of slopes.
5. When comparing with all the 3 different slope the critical slope angle is found to be 60°.
6. When comparing the results of all the seven samples it is observed that soil sample in location 6 has highest factor of safety whereas soil sample in location 5 has the lowest factor of safety.

CONCLUSION

1. Slope stability is a critical aspect in geotechnical engineering and plays a significant role to ensure the safety and sustainability of various structures and natural formations. The slope's geometry plays a significant role in determining the stability of the slope and the potential for failure.
2. Understanding the interaction between slope geometry and geotechnical factors is essential for conducting accurate slope stability analyses and designing appropriate mitigation measures to ensure the safety and longevity of the slopes.
3. The steep slopes and undulating terrain of the study area to investigate slope stability and arrive the Factor of safety.
4. Geotechnical investigations of slope failures were conducted in the study area by collecting undisturbed and disturbed samples from eight locations.
5. The laboratory tests were conducted on the samples, it was found that the soil in the locations were mostly falls under fine grained soil category.
6. The results and findings of this study can help the planning and development of slope management and land-use planning. The geotechnical output is useful to carry out proper preventative and restorative measures to avoid occurrence of landslides in the future.
7. Remedial measures such as modification of slope

geometry, drainage control and retaining walls, anti-sliding pile are suggested for unstable slope sections.

REFERENCES

[1] A.R. Amashi, A.M. Hulagabali, C.H. Solanki, G.R. Dodagoudar, "Landslide risk assessment and mitigation- a case study," Springer Nature Singapore pte Ltd., pp.249-258.

[2] Aleotti, P. and Chowdhury, R. (1999), "Landslide Hazard Assessment: Summary Review and New Perspectives", Bulletins of Engineering Geology and the Environment, 58(1), pp 21-44.

[3] Ali Fawaxl,Eliad Farah,Fadi Hagechehade"Slope stability analysis using numerical modelling"Americal journal of civil engineering 2018;vol2,issue(3):pg no 60-67.

[4] Cheng,Y.M. Lansivaara, T. Wei, W.B. (2006) Two-dimensional slope stability analysis by limit equilibrium and strength reduction methods Computers and Geotechnics, Elsevier, Vol:34.,pp 137-150

[5] Diya Varghese, Dipty Issac, "FEM analysis of slope in Idukki using GEO5," International Research Journal of Engineering and Technology, 7(8), pp.4425-4430.

[6] Dr. Premlet B, "Proceedings of the symposium on landslides in Kerala 2018- held at Munnar on February 23, 2019."

[7] G. Sooraj, Dr. H.S. Kumara, Naveen, "Sustainable habitat plan for conservation of hilly areas: a case study of Kannur district, Kerala state," Journal of Xi'an University of Architecture and Technology, pp.733-741.

[8] Hymavathi Jampani, Navya Bhupathi, "Stability analysis of slope with different soil types & its stabilization techniques," Indian Geotechnical Conference, 14(16), pp.1-4.

[9] IS 2720-10 1991 Methods of test for soils, Part 10: Determination of unconfined compressive strength.

[10] IS 2720-2 1973 –Methods of test for soils, Part 2: Determination of water content.

[11] IS 2720-3-1 1980 Methods of test for soils, Part 3: Determination of specific gravity, Section 1: Fine grained soils.

[12] IS 2720-4 1985 Methods of test for soils, Part 4: Grain size analysis.

[13] IS 2720-5-1985 Methods of test for soils, Part 5: Determination of liquid and plastic limit.