FEM ANALYSIS OF SLOPES IN IDUKKI USING GEO5

Diya Anna Varghese[1], Dipty Sarin Isaac[2]

[1]PG Student, Geomechanics & Structures, Department of Civil Engineering, Saintgits College of Engineering, Kottayam , Kerala, India
[2]Assistant Professor , Department of Civil Engineering, Saintgits College of Engineering, Kottayam ,Kerala, India

---***---

Abstract - *Due to the recent floods that had occurred in Kerala, it has resulted in various losses especially in many parts of the Idukki district. The major causes underlying such losses are the occurrence of landslides in the high terrain regions. Landslides are usually related to instabilities in slopes. To minimize the degree of instability in slopes, gabion structures are provided as a protective liner to slopes. Laboratory and numerical analysis is done to check the stability of slopes with and without gabions. FEM based softwares like PLAXIS and GEO5 is used for the numerical analysis.*

Keywords: *Gabion structures, FEM, Factor of safety*

1. INTRODUCTION

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope. The causes of landslides are usually related to instabilities in slopes. This slope instability results in loss of life, damages to infrastructure etc. Mostly landslides have hit in mountainous regions of Kerala due to the heavy rainfall that eventually lead to floods. It has caused a number of fatalities and infrastructure damages as reported. So to prevent further collateral damages, the slopes are to be analysed on trial and error basis. Experimental analysis are being done to reveal the given sample parameters like cohesion c, angle of internal friction, Young's Modulus and poissons ratio. Accordingly various preventive or remedial measures are taken to stabilize such slopes. Usually the stability of a slope is analyzed by the Limit Equilibrium Slope Analysis and the factor of safety of the so called critical slip surface is calculated. Here the main aim of a slope stability analysis involves

- Evaluating how safe a slope is/ to calculate the factor of safety for a slope before its failure.
- Finding out the failure mechanism if a slope has failed in order to propose the appropriate remedial measure and its design.

In this project we are dealing with the utilization of Gabions for slope stabilization. A Gabion is a cage or a cylinder or box filled with rocks, concrete, or sometimes sand and soil for use in civil engineering especially for geotechnical applications. Gabion walls are executed mainly in the purpose of soil stabilization behind the wall, but it can also be executed as a cover wall. Its walls are made from Gabion baskets or units stacked in one or more rows, depending on the height of the wall.

Before deciding the unit weight of rock/boulder used for gabion wall, the types of soil being retained and the foundation soil type should be identified by a soil investigation survey to ascertain the correct parameters to use in design. Gabion walls are designed with the drained soil parameters for the retained soils, but the undrained parameters can be considered for the computations for sliding. The gabion wall design can be made and analysed using another FEM based software named GEO5.

1.2 OBJECTIVES

- To analyze landslides and to understand failure mechanisms
- To assess the stability of slopes through numerical methods
- To design Gabion structures to unstable slopes
- To ensure the compatibility of gabions with slopes concerned

1.3 SCOPE

- Collect soil samples from the area of interest
- Experimental investigations to determine soil parameters(Direct shear test , UCC, Triaxial test)

- Stability analysis of slopes with and without Gabion structures using GEO5
- Comparison of slopes with and without gabions based on their factor of safety

2. LITERATURE SURVEY

Collins et al (2004) studied the Stability Analyses of Rainfall Induced Landslides and was investigated and presented. Specifically, the effect of both negative and positive pore water pressures on the stability of initially unsaturated slopes are carefully explained and coupled with infinite slope analysis methods in order to present a predictive formulation of slope failures that occur as a result of rainfall events.

Liang et al (2010) conducted a laboratory model test .Cyclic loading and unloading was imposed. Vertical earth pressure, lateral earth pressure, deformation behaviors of reinforcements, potential failure surface and deformation behaviors of wall face were studied. Results show that vertical earth pressure is less than theoretical value. Preventive measures were also studied as **Kostic et al (2016)** proposed an analytical model for the prediction of the slope safety factor as a function of basic geometrical parameters (slope height $H$and slope angle β) and soil factors (bulk density γ, cohesion c, angle of internal friction φ, and pore water pressure coefficient r_u)

Several Studies were adhered to improve wall resistance against falling of unstable soils. **Ramli .M et al (2013)** conducted a research undertaken to improve gabion resistance against lateral movement by means of an interlocking configuration instead of the conventional stack-and-pair system. The evolution of deformation observed suggested that the interlocking design exhibits better structural integrity than the conventional box gabion- based wall in resisting lateral movement and therefore warrants consideration for use as an appropriate scour-arresting device for earth retaining structures.

Case Studies have also been conducted to masculate soil resistance like **Tsige et al (2017)** who studied Geotechnical Conditions and Stability Analysis of Landslide Prone Area which was a case Study in Bonga Town, South-Western Ethiopia. **Sarma et al (2015)** based a study on the most occuring landslides in Guwahati area.

In compliance with measures to improve slope stability, it is therefore important to come up with economical measures. **Toprak et al (2016)** researched mainly about Gabion walls and their uses. Gabion type retaining structures constitute one of the most economical and efficient solutions for stabilization of natural ground slope. Gabion walls are also preferred for the efficiency of the drainage instead of gravity walls.

3. METHODOLOGY

3.1 MATERIALS

The soil sample was collected from Thodupuzha Idukki district. The sample was reddish brown coloured clay. Overall a total of four samples were taken from different points at the site .A PVC pipe of diameter 10cm and height 120cm was taken and the sample was collected and was covered with plastic covering at both ends in order to retain the existing water content of sample.

Samples were collected in their loose state from 4 selected slopes situated along road. The samples collected varied from reddish brown to brown in color. Various properties were studied to be given as input parameters for the Fem software GEO 5.

Triaxial Test was conducted to determine the shear parameters. It is seen that the sample starts to bulge outwards indicating that the sample has failed due to the stress σ_1.A total of 12 samples were made for this test for cell pressures 50,100,150 mpa.

Fig.1 Triaxial testing on sample before & after Loading

Table – 1: Basic Properties of Soil

Sl No	Properties	Slope 1	Slope 2	Slope 3	Slope 4
1	Water Content (%)	8.1	5.6	2	8
2	Dry Density (g/cc)	1.3	1.2	1.4	1.3
3	Specific Gravity	2.4	2.5	2.4	2.4
4	Liquid Limit	42	32	48	39
5	Plastic Limit	27	26	29	28
6	Cohesion (kN/m^2)	12	10	8	4
7	Friction Angle	24	15	11	18
8	Soil Classification	SW-ML	SW-ML	SW-ML	SW-ML

4. ANALYSIS OF SLOPES

4.1 GEO 5

Slopes to be considered are checked for stability by using FEM Based software called GEO 5. GEO5 is a powerful software suite for solving geotechnical problems based on traditional analytical methods and Finite Element Method (FEM). Individual programs verify a specific structure, which keeps them intuitive and easy to use. GEO5 is designed to solve most geotechnical tasks, from the basic ones (verification of foundations, walls, slope stability), up to highly specialized programs (analysis of tunnels, building damage due to tunneling, rock stability). Each GEO5 program solves definite structure type, so the customer can only select those he needs. Geotechnical methods applied in GEO5 software are used all around the world. GEO5 adopts a unique system of implementing standards and partial factors, which are separate from the structure input. GEO5 has a database of standards, however it is possible to create own settings.

The stability of slopes was analyzed in their dry state by using the GEO5 software. The input parameters for GEO5 includes,

- Geometry: slope, inclination & height

- Properties: soil parameters for soil in each zone.

Analysis was done in trial and error basis .Gabion structures were designed for the slopes by using the rigid body option and by assigning it to the structure. Analysis was done using Bishops slip circle method.

In this study, GEO5 "Slope Stability' program was used .The next step was to input the geometric coordinates of the terrain that is to be analyzed. Soil parameters mainly the unit weight, the angle of internal friction and cohesion (these are already determined from the experimental tests given before) was taken as input values to determine the type of soil classification given as per GEO5. The initial slip surface was inputted using the coordinates of the centre and the radius of the slip circle (x, y). Then the analysis was carried out using the Bishops circle method.

As per the analysis, the Sliding/Actuating moment (M_a) and the resisting moments (M_P) were found out and the factor of safety was calculated.

i.e. **Factor of Safety (SF) =** $\frac{\textit{Resisting Moment}}{\textit{Sliding Moment}}$

Finally the level of stability for the critical slip surface using the Bishop Evaluation method is decided by the factor of safety. With the FEM method using the standard safety factor of 1.5 ,the terrain was considered as unstable or stable depending on whether the SF value is less than or greater than 1.5.

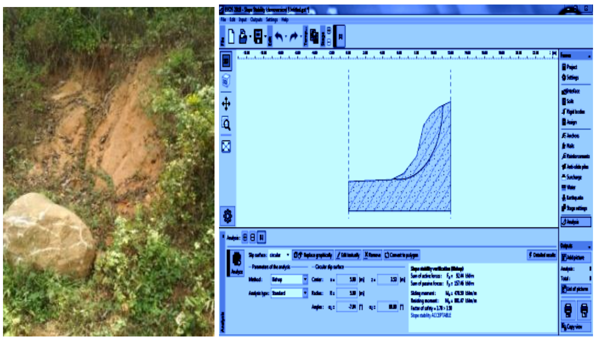

Fig -2: Analysis of slope 1 from FEM based software GEO 5

From Fig.2, It was found that the factor of safety is **1.7 > 1.5.**Hence the analysis is considered to be **acceptable** and stable against landslide.

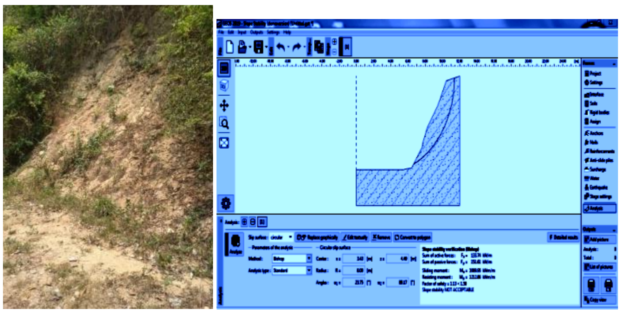

Fig -3: Analysis of slope 2 from FEM based software GEO 5

From Fig 3, the factor of safety was calculated as **1.13 <1.5**, the slope stability was considered as **unacceptable** and is unstable.

But When gabion structures were provided, the slope with the same slip circle was considered stable and safe with a factor of safety of **3.54 > 1.5.**This is shown as in Fig.4 below.

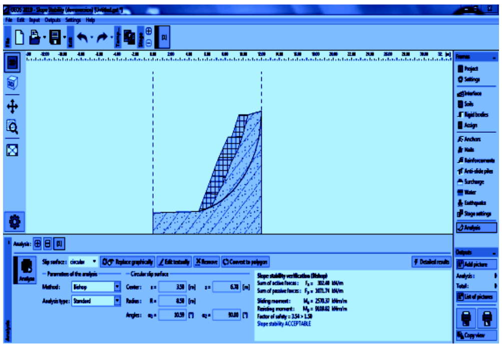

Fig.4: Analysis of slope 2 provided with gabion wall from GEO 5

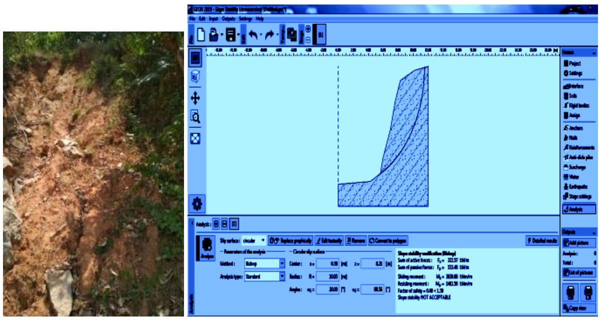

Fig.5: Analysis of slope 4 from FEM based software GEO 5

Similarly from the above figure , the factor of safety was calculated as **0.4 <1.5**, the slope stability was considered as unacceptable and is **unstable.**

When gabion structures were provided , the slope with the same slip circle was considered stable and safe with a factor of safety of **3.04 > 1.5**.Hence the slope stability was considered as a**cceptable** as per the software GEO 5. This is shown as given in Fig.6 below.

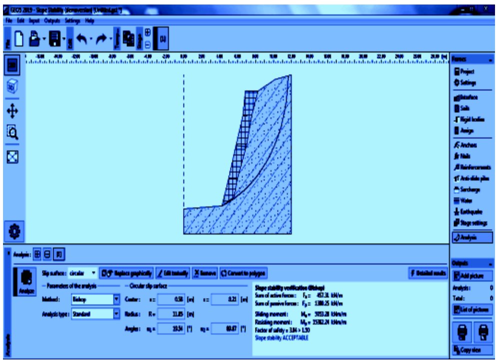

Fig.6: Analysis of slope 4 provided with gabion wall from GEO 5

From the below fig.7, the factor of safety was calculated as **0.47 <1.**5, the slope stability was considered as unacceptable and is **unstable.**

Fig.7: Analysis of slope 3 from GEO 5

But the slope with the same slip circle was considered **stable** and safe with a factor of safety of **4.94 > 1.5** when Gabion Structures were provided. This is similarly shown as in fig 8 below.

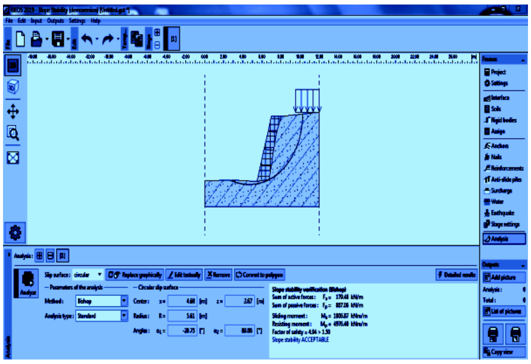

Fig.8: Analysis of slope 3 provided with gabion wall from GEO 5

5. CONCLUSIONS

The comparisons of resisting moments (obtained from GEO5) of respective slopes were studied for determining the slope efficiency. This is given as in Table 2.

Table 2: Efficiency of Gabions on Slopes

Sl No	Sample no	Resisting moments(kNm/m)		% increase
		without Gabion	with gabion	
1	Slope 1	801.47	-	-
2	Slope 2	1212.86	9109.82	87
3	Slope 3	366.56	4976	93
4	Slope 4	1461.58	15362.24	90.5

From the table, it is easily understood that, among the gabion supported slopes,

- Slope 3 gave an incredible increase in its efficiency to withstand even during the monsoon seasons.
- As per the analysis made by GEO 5, the % increase in resisting moment is very efficient as it contributes to increase in the slope stability
- Such slopes are more prone to translational landslide in their saturated state during monsoons
- To prevent such problems , it is more economical to provide gabions to such slopes
- Provision of such structures improves their stability against minor landslides.

- It is also known that Gabion structures enhance drainage during rainy seasons which then further widens the life span of such slopes.

REFERENCES

1. Maynord, S. T. (1995),'Gabion-Mattress Channel-Protection Design. Journal of Hydraulic Engineering', ASCE 121(7), 519–522.
2. Ramli, M., Karasu, T. J. r., & Dawood, E. T. (2013). The stability of gabion walls for earth retaining structures. Alexandria Engineering Journal, 52(4), 705–710.
3. P.M. Kandaris (2000), "Use of gabions for localized slope stabilization in difficult terrain", The 37th U.S. Symposium on Rock Mechanics (USRMS), pp 1221-1227.
4. Kostic, S., Vasovic, N., & Sunaric, D. (2016). 'Slope Stability Analysis Based on Experimental Design', ASCE Vol 16.
5. Arwan Apriyono, Sumiyanto, Yanto and Bogie Arif Hidayat(2018), 'Application of woven waste tires gabion wall as slope reinforcement for preventing landslide in laboratory' , ASCE Vol 20
6. Braja M. Das (2001), 'Principles of Geotechnical Engineering', Thomson Engg.
7. R Chitra, Manish Gupta (2016), 'Geotechnical Investigations and Slope Stability Analysis of a Landslide', IJERT Vol 5 Issue 2.
8. Sirazhum Monera Asha, Mehedi Ahmed Ansary (2018), 'Slope Stability Analysis of Embankments of Gaibandha Area, Bangladesh', ResearchGate.
9. Andrzeg Michalski (2014), 'Slope Stability Analysis with GEO 5 Software', Contemporary Trends in Geosciences Vol 2.
10. T. E. Elahi, M. A. Islam .et al (2018), 'Stability Analysis of Selected Hill slopes of Rangamati', ICACE 2018.

BIOGRAPHY

Diya Anna Varghese

PG Scholar in Geomechanics and Structures.