SLOPE STABILITY ANALYSIS USING PLAXIS 2D

Alex Jacob[1], Ammu Anna Thomas[1], Aparna G Nath[1], Arshiq MP[1]

[1]*Student, Dept. of Civil Engineering, M A College of Engineering, Kothamangalam, Kerala, India*

Abstract *In the earlier times, the problematic sites were usually ignored as there were abundant areas consisting of good quality soil. But now-a-days, rapid urbanization and industrialisation are urging people to make use of these problematic sites. Laterite soils have the characteristics of losing its shear strength with time and are highly erosive. Excavated slopes in such lateritic formations pose serious erosion and slope stability problems, especially due to seepage pressure from stagnated water at top. This study is basically conducted to analyse slopes- both failed slopes and existing slopes. Study of slope failures or investigation of recent landslides will be conducted, and the causes of failure and remedial measures which could have been taken will be suggested. Similarly, stability check for existing slopes will be done and then factor of safety and failure slip circle will be computed using plaxis (2D).*

Key Words: Slopes, Seepage, Factor of safety, failure slip circle, Plaxis.

1. INTRODUCTION

Slopes either occur naturally or are engineered by humans. Slope stability problems have been faced throughout history whenever the delicate balance of nature has been disturbed by any kind of internal or external forces. The forces with in nature like heavy rainfall leading to erosion and landslides constitute an important example of internal disruptive forces while the external forces mainly human activities such as excavation and filling of slopes have also caused the slide. The scope of this study is to analyse the slope stability problems for varying cut slope angles. Unexpected landslides in thickly populates areas can cause huge losses to life and property. For already existing slopes, the factor of safety will be calculated and thus the stability check for the slope is done. Also, the potential failure surface under assumed conditions of loading can be found out. If the slope is found to be unstable under varying amounts of precipitation or loading conditions, suitable remedial measures like natural vegetation cover, use of geogrids, anchoring etc can be suggested. In the case of failed slopes, the exact reason for failure could be identified by studying various properties of the soil. Suggestion of remedial measures to prevent further erosion could be done using the software plaxis.

2. MATERIALS AND METHODS

The project work was broadly divided into two phases. The initial phase was the experimental part in which soil samples from selected sites were collected. Five different slopes were analysed. Tests were conducted to determine the engineering properties of the soil such as cohesion, angle of internal friction, Young's modulus etc.Other input parameters for numerical analysis such as slope angle and geometry of the area were found out by theodolite surveying.

The second phase was the numerical analysis part, which were done by using an FEM based software, Plaxis (2D). The slip circle and factor of safety of existing slopes were obtained. In the case of failed slopes, reanalysis using geogrids, anchors etc. were done.

Table -1: Test Results

Sample	Water content [%]	Field Density [KN/m³]	Cohesion [KN/m²]	Angle of internal friction	Young's Modulus [KN/m²]
Slope 1	28.65	15.4	4.905	19.6°	16350
Slope 2	19.83	17.6	44.14	27.85°	11445.33
Slope 3	48.5	15.7	22.56	21°	4051.53
Slope 4	24.55	18.7	66.2	13.7°	9074.25
Slope 5	26.75	20.9	77	16.7°	8720

Sample Graphs

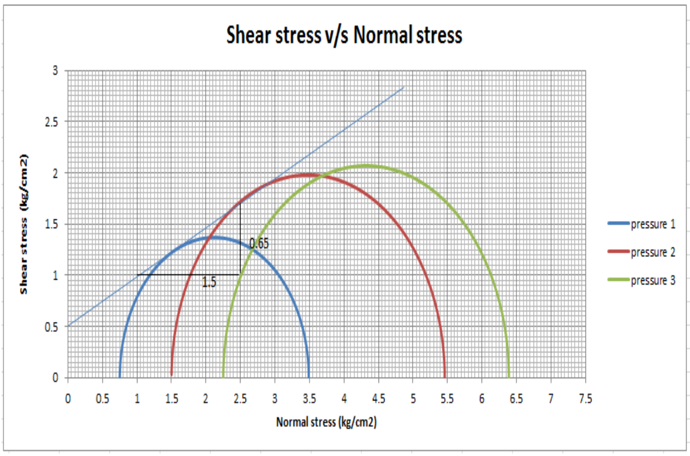


Chart -1 Variation of shear stress v/s normal stress (Triaxial Test)

From mohr's circle obtained,

Cohesion, c = .45 kg/cm² = 44.14 KN/m²

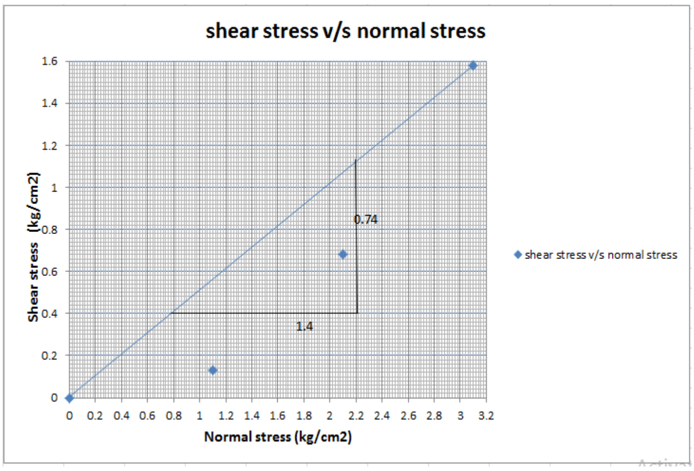


Chart -2 Variation of shear stress v/s normal stress (Direct Shear Test)

From the graph,

Angle of internal friction, Φ = 27.85˚

3. PLAXIS ANALYSIS RESULTS

The total displcement profile and factor of safety are obtained from software analysis. Finite element models may be either Plane strain or Axisymmetric. The slope is analyzed as a plane strain model. Displacements and strains in z – direction are assumed to be zero. However, normal stresses in z-direction are fully taken into account.15 –node triangular elements are selected for modelling soil layers and volume clusters. The 15-node triangle is a very accurate and can produce high quality stress results for difficult problems. The units for length, force and time used are m, KN and day respectively. The first step in every analysis is to set the basic parameters of the finite element model. This is done in the General settings window. These settings include the description of the problem, the type of analysis, the basic type of elements, the basic units and the size of the draw area. The standard fixities is used to define the boundary conditions or this is considered as the default boundary condition in new PLAXIS version

In PLAXIS, soil properties are stored in the material data set. Mohr-Columb model was selected as the material model and the soil properties obtained from the tests(Table 4.1) were given as input parameters. Poisson's ratio of 0.3 was considered. The initial phase is defined with the excavated slope geometry. Initial stresses are generated in this phase using the gravity loading. Safety analysis was done in the next phase. Medium coarseness was chosen for mesh generation.

Total deformation of first three slopes (stable) is negligible while that of the failed slopes are very high. Total displacement profile and factor of safety calculation of slope 1 (stable) and slope 4 (failed) are as shown.

Slope 1

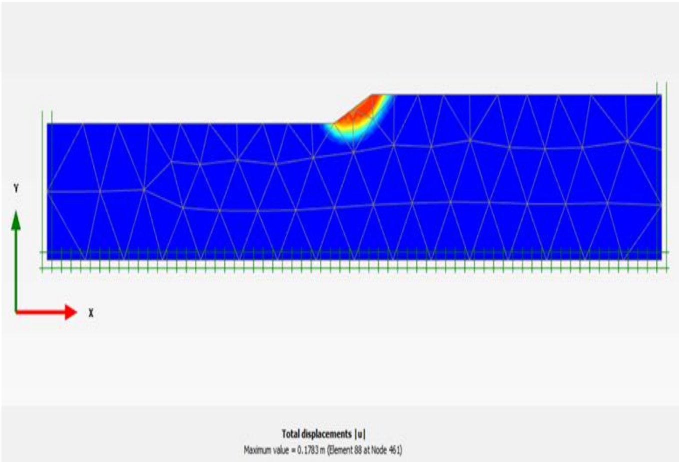
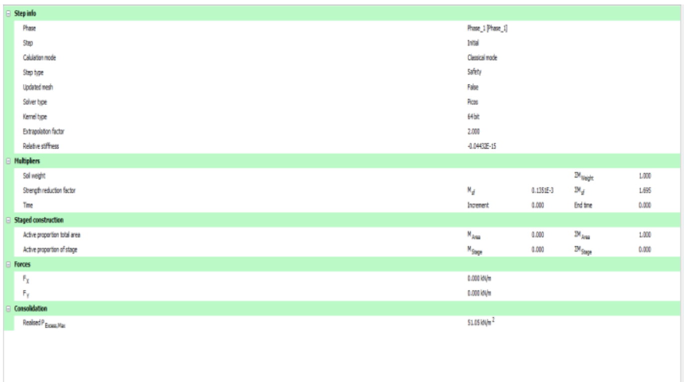


Fig -1: Total displacement profile of slope 1



Step info				
Phase	Phase_1 [Phase_1]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	2.000			
Relative stiffness	-0.04432E-15			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	0.1351E-3	ΣM_{sf}	1.695
Time	Increment	0.000	End time	0.000
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	1.000
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	51.05 kN/m^2			

Fig -2: Calculation information of slope 1

Maximum value of displacement = 0.1783 m

Factor of safety = 1.695

Slope 4

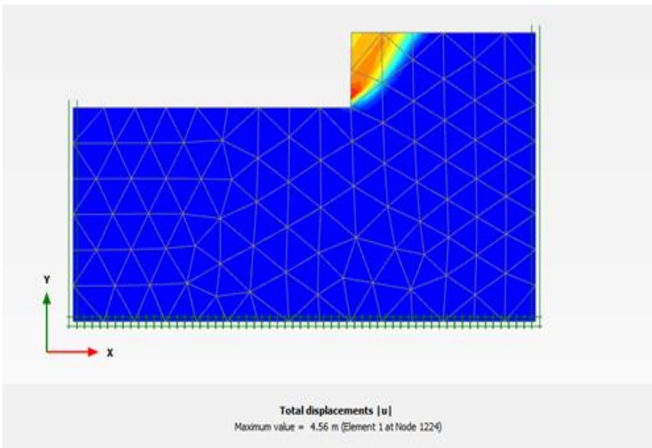
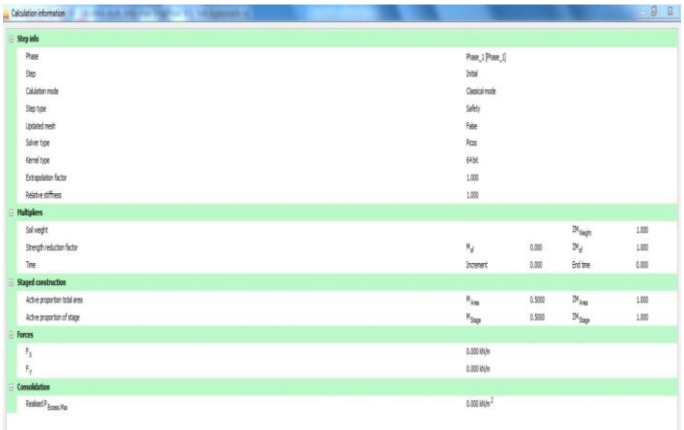


Fig -3: Total displacement profile of slope 4



Calculation information

Step info					
Phase	Phase_1 [Phase_1]				
Step	Initial				
Calculation mode	Classical mode				
Step type	Safety				
Updated mesh	False				
Solver type	Picos				
Kernel type	64 bit				
Extrapolation factor	1.000				
Relative stiffness	1.000				
Multipliers					
Soil weight			ΣM_{Weight}	1.000	
Strength reduction factor	M_{sf}	0.000	ΣM_{sf}	1.000	
Time	Increment	0.000	End time	0.000	
Staged construction					
Active proportion total area	M_{Area}	0.5000	ΣM_{Area}	1.000	
Active proportion of stage	M_{Stage}	0.5000	ΣM_{Stage}	1.000	
Forces					
F_X	0.000 kN/m				
F_Y	0.000 kN/m				
Consolidation					
Realised $P_{Excess,Max}$	0.000 kN/m^2				

Fig -4: Calculation information of slope 4

Maximum value of displacement = 4.56 m

Factor of safety = 1

4. CONCLUSION

Based on the analysis carried out, the conclusions of the study can be summarized as follows:

- Stability check for the existing slopes was carried out and was found stable with slight deformations under gravity loading.
- In the case of failed slopes, presence of fines could be a potential reason for the failure.
- The water table was assumed to be below the boundary considered for finite element analysis in line with the observations made at field. Any change of rise of water table, would result in a reduced factor of safety.
- Finite element analysis using Plaxis 2D with 15 noded element was found to capture the insitu stability condition.
- It can be predicted that the slopes near the failed slopes are prone to failure because of similar soil properties.
- Methods like geogrids, anchoring, stone coloums etc could be adopted to avoid failure of the existing slopes near the failed slopes.

REFERENCES

[1] Sarat Kumar Das, KanhuCharanPatra and Harishankar Jeevan Dash, "Slope Stability Analysis in Civil Engineering- A Review"

[2] Rongjian Li, Yuzhen Yu, Lijun Deng and Guangxi Li, 2014, "Stability Analysis Of Unsaturated Soil Slope by 3D Strength Reduction FEM".

[3] Kelvin Lim, An-Jui Li and Andrei Lyamin, 2014, "Slope Stability Analysis for Filled Slopes using Finite Element Limit Analysis Method"

[4] Pumia B.C,"Soil Mechanics and foundations", Laxmi publications, New Delhi.

[5] Arora K.R, "Soil Mechanics and Foundation Engineering", Standard publishers Distributors, Delhi.

[6] Fell, R., MacGregor, P., Stapledon, D., Bell, G., and Foster, M. (2015), "Geotechnical Engineering of Dams, 2nd Edition" Section 8.3.4.6, CRC press.

[7] Gidigasu, M.D. (1976). Laterite soil engineering: pedogenesis and engineering principles (Amsterdam ; New York: Elsevier Scientific Pub. Co).

[8] Valdiya, K.S. (2016), "The Making of India: Geodynamic Evolution" Section 23.5.3, Springer International Publishing.