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Stability Analysis of an Embankment subjected to a Landslide

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ABSTRACT: Slope stability analysis is one of the most important topics in geotechnical engineering. For the construction of railways, embankments, canal, road embankments, earth dams etc. we go for different slopes with different geometric conditions. If the slope is naturally made, the kind of problem is to check the sustainability of slope. If it is manmade type, the problem is to choose the soil type with required stability. Evaluation of the stability analysis for road embankment is not only a problem but also a challenge for geotechnical engineering. In manmade slope, the problem of choosing soil has an important role for stability condition. The main purpose of this study is to determine the stability of road fill embankment according to the factor of safety and deformation. Finite Element Method by Plaxis 3D is used in numerical analysis of slope. The present study is to conduct the stability analysis of embankments using Plaxis-3D for soils found in Koottickal, Kottayam, where heavy landslides occurred in 2021 and to suggest some remedial measures.

KEYWORDS: Deformations, Embankment, Factor of Safety, Slope Stability

I. INTRODUCTION

The road network plays a major role in the development of the country hence the design and construction of road sub-grade plays a crucial role in the stability of highway. Often these roads are constructed on Embankments of different heights and inclinations with various soils. Hence the stability of such embankments plays a major role in the durability of the roads. In stability analysis calculation of safety factor (SF) is the primary design criteria which can be calculated by numerous methods such as limit equilibrium method (LEM) and finite element method (FEM). In recent years FEM has been used in the study of stability related problems. Stability analysis has an important role not only in the construction of transportation facilities such as highways, railroads, and canals; but also the development of natural resources such as surface mining, refuse disposal, and earth dams; as well as many other human activities involving buildingconstruction and excavation. Failures of slope in these applications may be caused by movements within the human created cut or fill, in the natural slope, or a combination of both. In manmade slope, stability is greatly affected by properties of subsoil and fill soils. The present study is focused on the stability analysis of Embankments using Plaxis-3D for lateritic clay found in Koottickal, Kottayam region.

II. OBJECTIVES

The objectives of this work are (1) To conduct stability analysis of soil affected with slope failure at Koottickal, Kottayam. (2) To study the effective stresses, effective strain and total displacement of soils using Plaxis 3D software. (3) Effect of slope stability in embankment.

III. METHODOLOGY

The main purpose of this study is to determine the stability of road fill embankment according to the factor of safety and deformation. Finite Element Method by Plaxis 3D is used in numerical analysis of slope. The present study is focused on the stability analysis of embankments for soils found in Koottickal, Kottayam, so that effective methods of stabilization can be identified. The software was first validated and then sample collection was carried out followed by testing the properties of soil after which modelling and analysis was done.

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Table 1 : Material Properties

Properties	**Value**
Specific Gravity	2.66
Water content	33.7 %
Liquid Limit	51 %
Plastic Limit	20 %
Plasticity Index	31
Optimum moisture content	15.7 %
Max dry density	1.34
Cohesion	52 kPa
Friction angle	3.2
Young's modulus	$3.2x10^4$kPa

IV. VALIDATION STUDY

The total deformation, effective principal stresses and effective principal strain characteristics from the journal [4] and numerical analysis on PLAXIS 3D are compared using their respective graphs and tables for the same model. The maximum variation of 3.8 % was found.

Table 2: Comparison between Journal and Plaxis 3D results

	Journal	Plaxis 3D
Mesh	Medium Mesh	Medium Mesh
Deformed Mesh	2.52 x 10^{-3}m	2.617 x 10^{-3} m
Effective Principal Stresses	53.4 x 10^{-3} kN/m^2	51.5 x 10^{-3} kN/m^2
Effective Principal Strain	1.35 x 10^{-3} kN/m^2	1.315x 10^{-3} kN/m^2

V. EMBANKMENT STUDY

For the present study an embankment model is considered of width 4.5m, height 5m and various toe angles of 30, 45 and 60 degrees respectively. In the modelling a wheel load of 5.2kN is applied over the pavement constructed on the embankment. Consider shoulder as 3.5m, top width as 0.5m and carriage way as 0.5m. A total of three models were developed in order to accomplish the objectives of the study. The models were developed with varying the toe angles to 300, 450 and 600.The properties of soils are given in the table 3 below.

Table 3 : Properties of soil

Properties	**Values**
Type of soil	Clay
Material Model	Mohr-Coulomb
Drainage Type	Undrained
γ_{unsat} (kN/m^3)	16
γ_{sat} (kN/m^3)	18
E (kN/m^2)	$3.2x10^4$
ν	0.3
C (kN/m^2)	52
φ	3.2^0
ψ	0^0

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VI. RESULTS AND DISCUSSIONS

In this section, the results of analyses are presented and discussed. The figures showing deformed mesh,effective principal stresses, effective principal strain and factor of safety for toe angle 30^0 are given below.

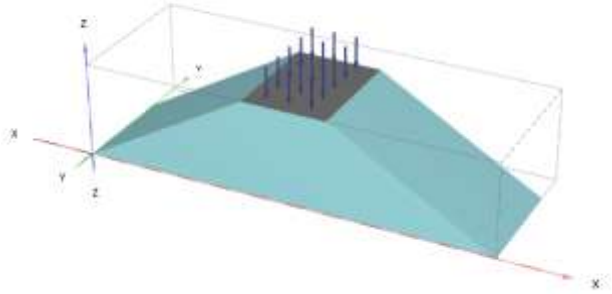

Fig 1 : Geometry for 30^0

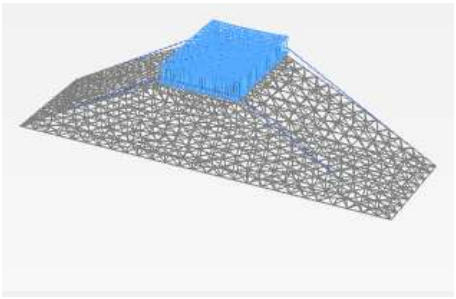

Fig 2 : Deformed Mesh

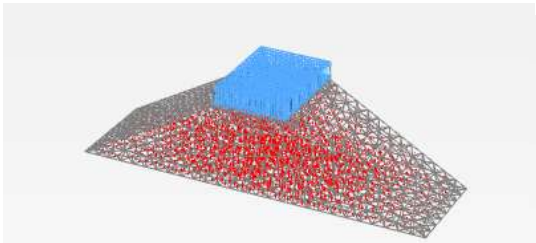

Fig 3 : Effective principal stresses

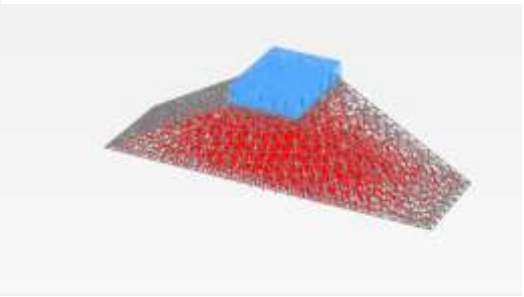

Fig 4 : Effective principal strain

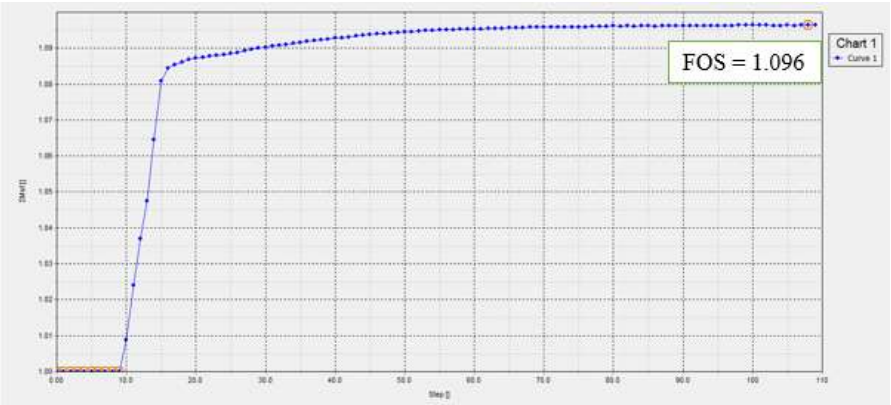

Fig 5 : FOS for 30^0

Table 4 shows a comparison of results for toe angles 30^0,45^0 and 60^0.

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Table4: Result Summary

	30^0	45^0	60^0
Deformed Mesh	5.302×10^{-3} m	5.304×10^{-3} m	5.302×10^{-3} m
Eff. Principal Stresses	77.79×10^{-3} kN/m^2	77.00×10^{-3} kN/m^2	77.58×10^{-3} kN/m^2
Eff. Principal Stain	1.817×10^{-3} kN/m^2	1.790×10^{-3} kN/m^2	1.798×10^{-3} kN/m^2
Factor of Safety	1.096	1.181	1.121

From the table it is observed that, when the toe angle is 45^0, the value of eff. principal stresses and eff. Principal strain were found to be the least and when the toe angle is 30^0, the value ofeff. principal stressesand eff. Principal strain were found to be the maximum.

VII. CONCLUSIONS

1. The stability of embankment increases as the toe angle varies from 30^0 to 45^0.
2. When the toe angle is further increased to 60^0, the factor of safety reduces by 5.08%.
3. The values of effective principal stresses and effective principal strain are also found to be maximum when the toe angle is 45^0.
4. From the study it is concluded that the toe angle of embankment at Koottickal,Kottayam varied considerably from 45^0.

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