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STUDY OF FINITE SLOPES STABILITY VARIATIONS IN DIFFERENT SOILS USING FINITE ELEMENT ANALYSIS BASED SOFTWARE

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Abstract -*Rapid urbanization and increasing population have made the scientists and engineers to make use of the so called unfavourable sites for construction. Modern civil engineering have many more such examples. Slopes are also a example of such sites and finding stability of finite slopes has always been a complex and important task for engineers, also from the safety point of view. This study is basically conducted to study the variations in stability of slopes with different soil conditions. Finding stability of slopes means calculating its factor of safety(FOS). If FOS comes greater than 1 then only the slope is stable, otherwise it is in critical condition (FOS = 1) or unstable (FOS <1). This study is mainly concerned with finite slopes and give variation in FOS with different soil conditions. The study has been done on Finite Element Analysis by making use of PLAXIS 2D software. It can be divided into two phases, in first one we have collected the soil samples and data and in second phase FOS of all these data is calculated. The study has been done on 24 different models/soil samples to give accurate results.*

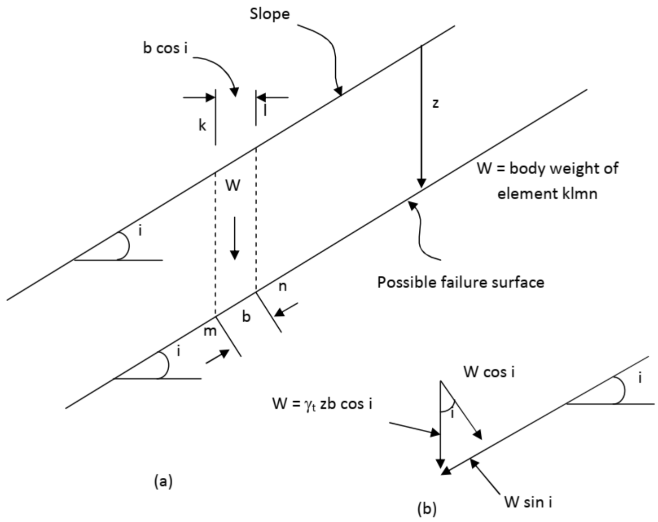
Key Words: Finite Slopes, Factor of Safety, Finite Element Analysis, PLAXIS, Cohesion, Internal Friction, Slope angle.

1. INTRODUCTION

A slope in a soil mass is encountered when elevation of ground surface gradually changes from a lower layer to higher one. For Geo-technical constructions, it is important for the engineers to have a knowledge of slope stability and types and causes of slope failure. Some causes of slope failure are Erosion, Rainfall, Earthquakes, External loading, Construction activities, Rapid Draw-down etc. Slopes can be categorized as Infinite slopes and Finite slopes.

1.1 Infinite Slopes

Slopes having their ends unbounded are infinite slopes. They have same soil properties at same depth in the length e.g. slopes found naturally in hilly or mountainous areas. They generally fails by sliding, when upper layer of soil slides down on the lower layer. The failure plane is parallel to the surface of the slope. Analysis of infinite slopes can be done by simple manual methods, by finding the ratio of shear strength and shear stress at failure plane. The figure below shows a typical element below infinite slope and the forces acting upon it.



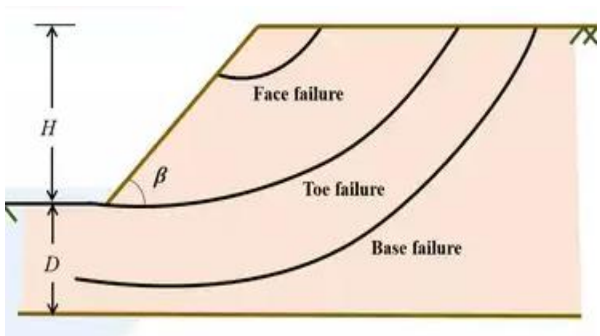
1.2 FINITE SLOPES

Slopes having their ends bounded are finite slopes. They can have different soil properties at same depth in length e.g. cross section of a canal. There are three types of failure for finite slopes.

I) Face failure; which occurs when soil of upper part is weaker than soil of lower part.

II) Toe failure; which occurs when soil of upper and lower part is homogeneous and it fails.

III) Base failure; which occurs when lower part is weaker than the upper soil part.



2. FINITE ELEMENT ANALYSIS BY SOFTWARE FOR FINITE SLOPES

The manual methods for stability analysis for finite slopes includes methods like Mass procedure and Method of slices. These methods are generally complex methods and require time for result description. So for our analysis we have used PLAXIS software based on Finite Element Analysis.The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM).Engineers use FEA software to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster while saving on expenses.PLAXIS is a finite element program for Geo technical applications in which soil models are used to simulate the soil behavior.

The whole study can be divided in two phases. Phase 1 contains collection of different soil samples having different values of cohesion, internal friction etc. These values can be determined from the soil samples by various tests on them. Since our basic concern here is variation of slope stability with change in properties of soil so here we are taking calculated and observed values of the various properties of soil after basic tests of soil samples.

3. COLLECTED DATA AND MATERIAL SETS

Here, the samples/models and the values of soil properties are shown which are used in our study.

DATA SET 1 - Variation in values of Cohesion only

General Properties of Soil samples(Drained)	Values
Material Model	Mohr-Coulomb
Unsaturated Soil weight	18.70 kN/m3
Saturated Soil weight	19.25 kN/m3
Young's Modulus	6720 MPa
Friction Angle(Φ)	33°
Slope Angle(i)	63.43°

Cohesion values are taken as -

MODEL NO.	COHESION(kN/m2)
1.	14.00
2.	17.12
3.	20.23
4.	23.29
5.	26.28
6.	30.11
7.	35.27
8.	39.28

DATA SET 2 - Variation in values of angle of internal friction only.

General Properties of Soil samples(Drained)	Values
Material Model	Mohr-Coulomb
Unsaturated Soil weight	16.78 kN/m3
Saturated Soil weight	18.25 kN/m3
Young's Modulus	8720 MPa
Cohesion	27°
Slope Angle	63.43°

Angle of internal friction values are taken as -

Model No.	Friction Angle(Φ)
9.	18.25°
10.	20.00°
11.	23.50°
12.	27.50°
13.	32.27°
14.	36.27°
15.	40.00°
16.	47.00°

DATA SET 3 - Variation in values of slope angle only

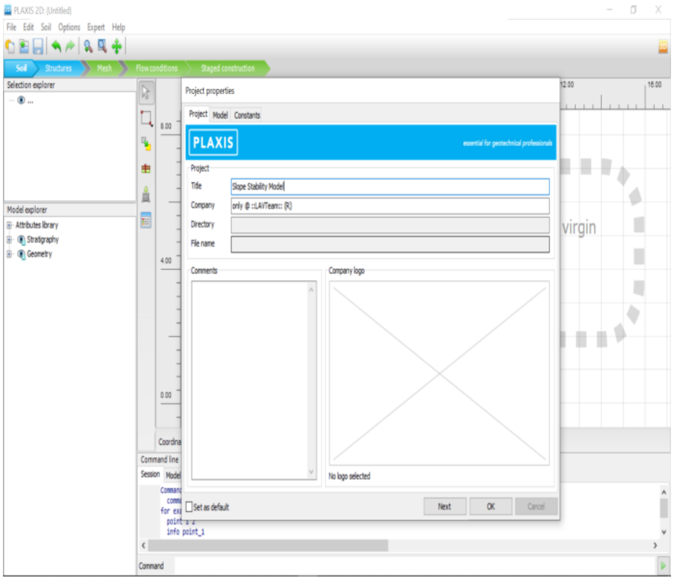
General Properties of soil samples(Drained)	Values
Material Model	Mohr-Coulomb
Unsaturated Soil weight	17.50 kN/m3
Saturated Soil weight	18.00 kN/m3
Young's Modulus	16350 MPa
Cohesion (c)	27 kN/m2
Friction Angle(Φ)	35°

Slope Angle values are taken as -

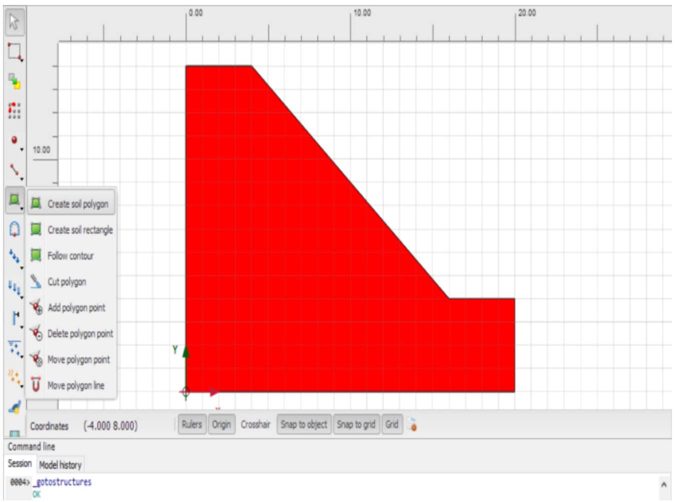
Model No.	Slope Angle(i)(°)
17.	30.25°

18.	39.80°
19.	45.00°
20.	51.30°
21.	56.39°
22.	60.25°
23.	64.79°
24.	66.03°

4. STEP BY STEP PROCESS WORKFLOW FOR A SINGLE MODEL IN PLAXIS 2D SOFTWARE

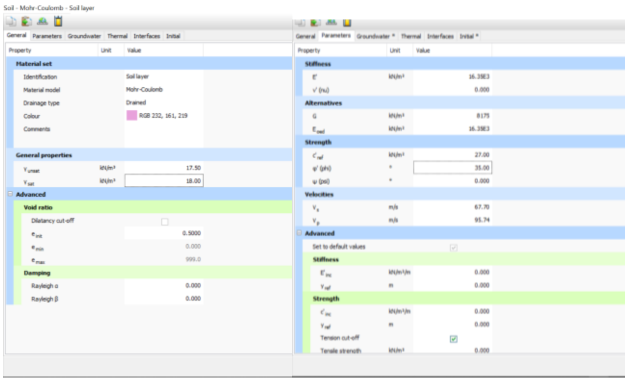


STEP1: INTERFACE OF SOFTWARE AND ADJUSTING DIMENSION LIMITS

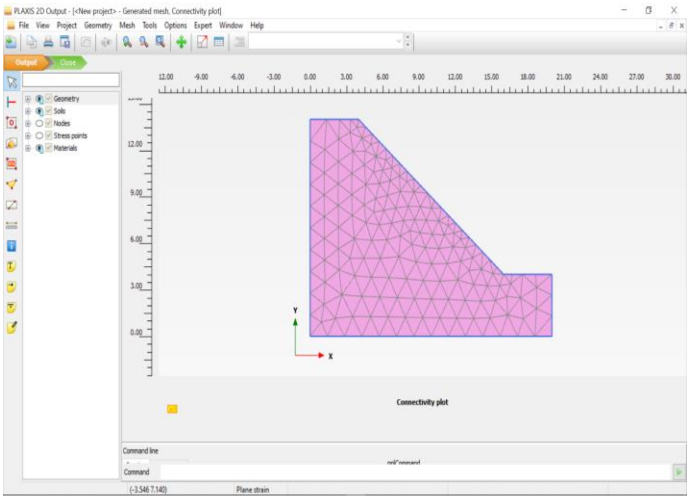


STEP 2: MAKING THE MODEL IN SOFTWARE WITH PROPER DIMENSIONS

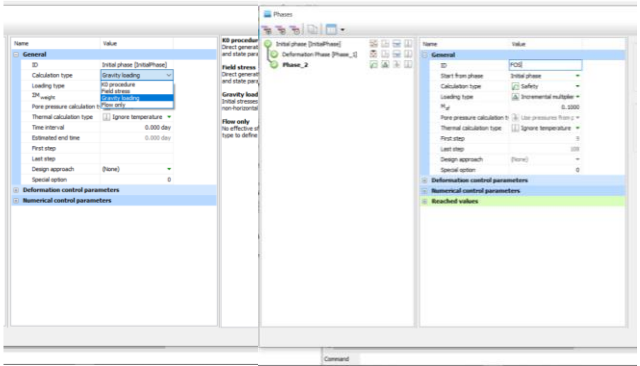
(For this model Angle of slope is 39.8° with a vertical height of 10m and horizontal span of 12m)



STEP 3: ASSIGNING PROPERTIES TO THE SOIL

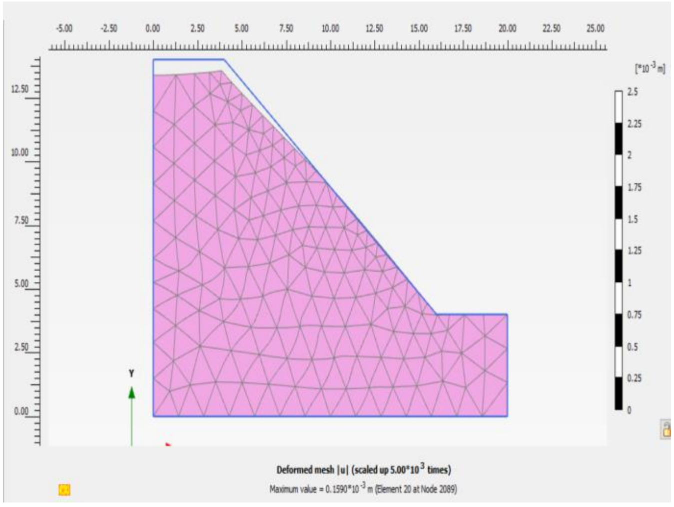


STEP 4: GENERATION OF MESH

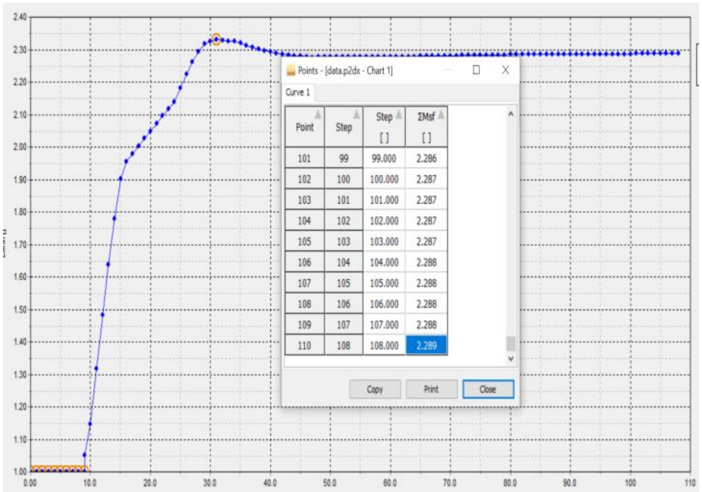


STEP 5 : ASSIGNING LOADING CONDITIONS

(Here we are considering deformations only due to gravity loading. Soil is in dry condition. Software analysis works in phases. In first phase we get deformations and in next phase we would get the factor of safety.)



STEP 6: GENERATION OF DEFORMED MESH
(displacement can also be seen from here)



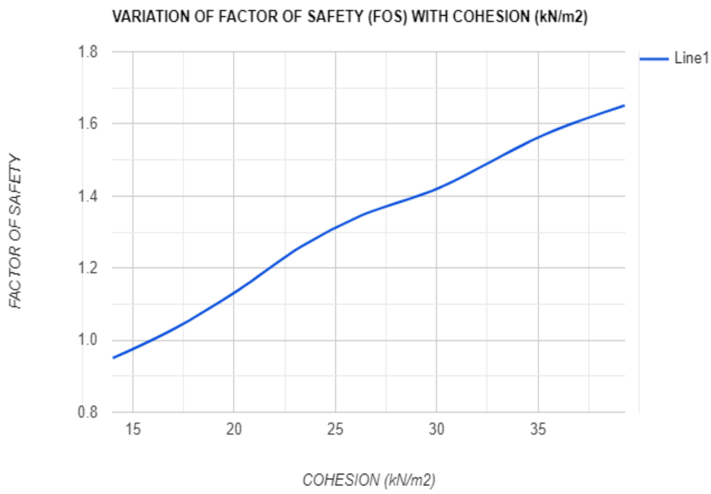
STEP 7 : GENERATION OF GRAPH OF FOS AT DIFFERENT NODES AND FINAL VALUE OF FOS
(here final FOS can be seen as 2.289)

5. RESULTS AND ANALYSIS

When each of the 24 models are worked with PLAXIS 2D then FOS for each model is calculated. Models are categorized in three data sets, each one having one property varying. So the results are also expressed as for each of three data sets and we can see the variation of FOS with cohesion, angle of internal friction and slope angle respectively by the graphs.

DATA SET 1

Model No.	Cohesion(kN/m2)	FOS
1.	14.00	0.95
2.	17.12	1.034
3.	20.23	1.140
4.	23.29	1.259
5.	26.28	1.346
6.	30.11	1.422
7.	35.27	1.569
8.	39.28	1.651

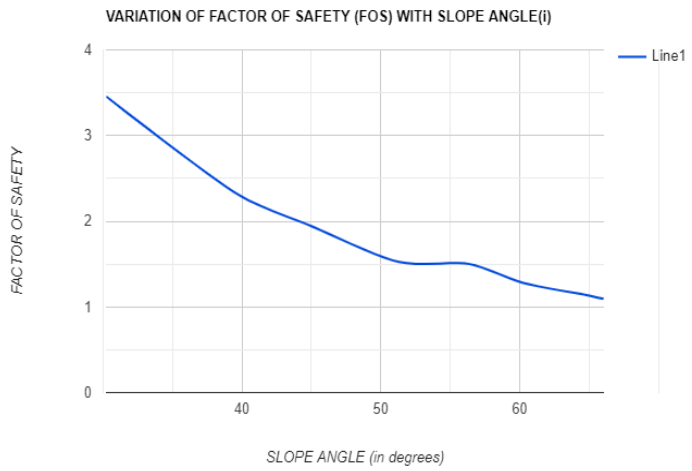


DATA SET 2

Model No.	Internal Friction(Φ)	FOS
9.	18.50°	1.027
10.	20.00°	1.060
11.	23.50°	1.135
12.	25.50°	1.223
13.	32.27°	1.339
14.	36.27°	1.415
15.	40.00°	1.533
16.	47.00°	1.727

DATA SET 3

Model No.	Slope Angle(i)	FOS
17.	30.25°	3.454
18.	39.80°	2.304
19.	45.00°	1.943
20.	51.30°	1.524
21.	56.39°	1.500
22.	60.25°	1.280
23.	64.79°	1.139
24.	68.19°	1.093



6. CONCLUSIONS

- ✓ FOS of slopes increases with increase in cohesion and internal friction but decreases with increase in slope angle. The variation of Factor of safety of slope with variation in cohesion, angle of internal friction and slope angle is know so we can use these results for designing stable slopes at different soil conditions.
- ✓ In different data sets, the slopes having FOS greater than 1 are stable slopes , those near to 1 are in critical condition. In the case of failed slopes, presence of fines could be a potential reason for the failure.
- ✓ In data set 3 , the slope was found to be collapsed when slope angle was larger than 68° so for this condition of soil , max value of slope is 68°
- ✓ Slopes are also found collapsed when cohesion is too low (i.e. Cohesion-less soil) or when internal friction is too low (i.e. max fraction of clay).
- ✓ 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.

7. REFERENCES

i. Dr. B.C. Punmia “Soil Mechanics and Foundation”.

ii. PLAXIS 2D Manual for General Information, Reference and Scientific Manaual.

iii. www.google.co.in/images

BIOGRAPHIES

Currently, as a B.Tech student of Civil Engineering from MITS Gwalior, I have pursued my research work in Geotechnical engineering studies. I also have a keen interest in civil based -software learning and in Enviroment impactstudy. Suggestions are always welcome from the readers and scholars.

- Rajan Pandey