

# Stability Analysis of Earth Slopes using Plaxis Software

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**Abstract:** Analysis of stability of slopes is of utmost importance as its failure may lead to loss of lives and great economic losses. Failure of a mass located below the slope is called a slide. It involves downward and outward movement of entire mass of soil that participates in failure. Slides may occur in almost any conceivable manner slowly or suddenly, with or without apparent provocation. In the present day lots of methods are available to the modern engineer to obtain the stability of slopes. Some are quite rigorous, while some are expensive. In this project a comparative of study of such methods has been done with special stress on the application of PLAXIS Software in the analysis of slope stability.

**Keywords:** Finite element method, Factor of safety, Slope stability, Plaxis.

## 1. Introduction

In the earlier times, the problematical sites were usually overlooked as there were abundant areas consisting of good quality soil. But now-a-days, rapid urbanization and industrialization are urging people to make use of these challenging sites. When the shear stress goes above the shear strength, slope tends to fail due to sliding movements of materials. Hence the factors that will increase the shear stress or reduces the shear strength, will have a high possibility of creating the slope failure. Landslides are one among the slope failure which causes high destruction in environment and also it's a natural phenomenon.

### A. Types of slopes

1. Natural Slopes
2. Engineered Slopes

### B. Types of failures

1. Face failure
2. Toe failure
3. Base failure

### C. Types of LEM Methods

1. Swedish slip circle method
2. Log-Spiral procedure
3. Ordinary method of slices
4. Bishop method
5. The friction circle procedure
6. Janbu's simplified method

### D. Types of FEM Methods

1. SLOPE/W
2. GALENA
3. GEO5
4. PLAXIS

### E. Objectives

1. To determine the factor of safety and slip surface of the earthen slopes using plaxis software for various slopes.
2. To determine the results of above stated slopes and practical implementation of the same.

## 2. About Plaxis

This software is basically used by the geotechnical engineers, it is generally the finite element software used for the analyses for rock and soil. The software came in existence in the year 1987 by the Technical University of Delft to analyze the soft soil of the low lands of Holland.

After this the software extended to cover all the aspects and application of geotechnical engineering model using a user friendly interface with power of finite element. The first version of plaxis was commercially available in 1998.

The plaxis consist of different soil models which are incorporated within it with a versatile library of structural elements. The creation of model is easy, and the mesh is generated by the 6-nodes and 15-nodes triangular elements available. It also consists four sub routines such as plaxis input, plaxis output, plaxis calculation and plaxis curves.

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generated by the 6-nodes and 15-nodes triangular elements available. It also consists four sub routines such as plaxis input, plaxis output, plaxis calculation and plaxis curves.

### 3. Methodology

The stability of homogeneous slopes of varying cohesive strength and frictional angle is determined by the plaxis software. In which the plaxis generally involves four sub routine, they are plaxis input, plaxis calculation, plaxis output and curves.

Firstly, a homogeneous soil slopes with slope height-20m, Top-15m, Right-50m. [Common for all data set]. The density, elastic modulus, Poisson's ratio and along with the other parameters are default kept constant for all the variable data set respectively in all the stage of analysis here.

The values of other parameters which are constant for all the set are shown in the below table.

Table 1  
Parameters

Parameter	Name	Value	Unit
Material model	<i>Model</i>	Mohr's coulomb	
Type of behavior	<i>Type</i>	Undrained	
Soil unit weight above phreatic level	$\gamma_{unsat}$	16	kN/m <sup>3</sup>
Soil unit weight below phreatic level	$\gamma_{sat}$	20	kN/m <sup>3</sup>
Horizontal permeability	$k_x$	0.001	m/day
Vertical permeability	$k_y$	0.001	m/day
Young's modulus	$E_{ref}$	13000	kN/m <sup>2</sup>
Poisson's ratio	$\nu$	0.350	—
Cohesion	$c_{ref}$	Varying	°
Friction angle	$\phi$	Varying	°
Dilatancy angle	$\psi$	0.0	

The slopes with variation of C and Phi values are tabulated in the below table. The table shows the combination of C and Phi value for slope of inclination 1:2.

### 4. Steps to be followed

1. Whenever starting the new project at first the name of the project has to be entered along with the dimension and units of the slopes or embankment has to be entered. Since we are dealing with the stability of slopes the elements should be of 15 nodes and the model is in plane strain as shown in the below figure.

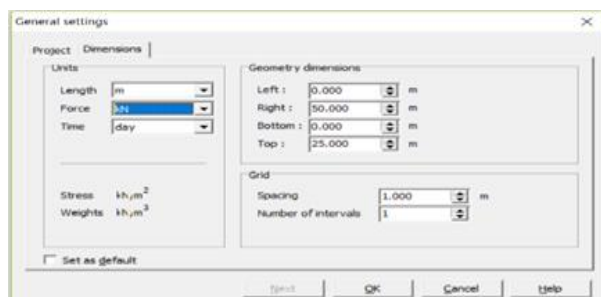


Fig. 1. Project tab sheet and Dimension tab sheet

2. After providing the necessary data in general settings the plaxis input sheet will be opened in which the model should be drawn as per the dimensions provided in the general settings. And the standard fixities should be applied to the model as shown in the below figure.

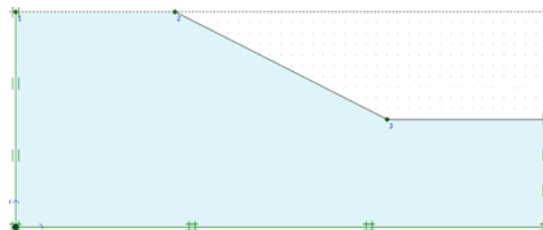


Fig. 2. Standard fixities model

3. When the standard fixities is assigned to the model, the material set is to be provided according to the requirements. The varying parameters and the constant parameters are provided in the material tab sheet and the material type and the material model should be selected.

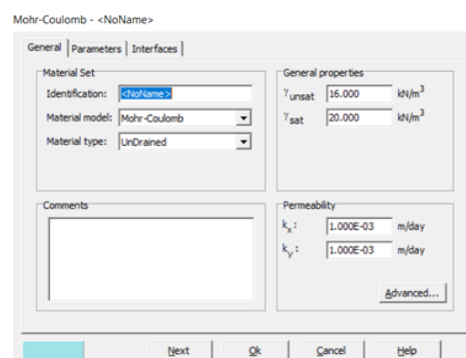


Fig. 3. Material set tab sheet

4. After applying the material set to the model, the mesh is generated in the mesh generation setup by keeping the element distribution as medium. And updated to the model as shown in the below figure.

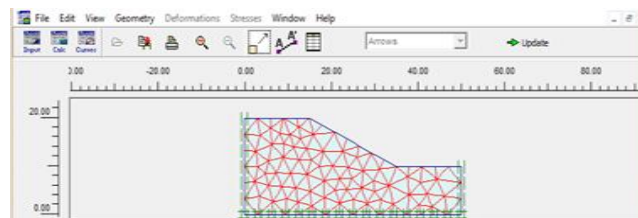


Fig. 4. Mesh generation setup

5. After generation of mesh go to the initial condition and provide the unit weight of water, water level, boundary condition for closed consolidation, generate water pressure by phreatic level, generate the initial stress and update it to the model. After generating the initial stresses the calculation process will be start in the calculation set.

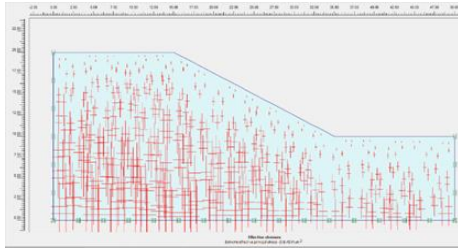


Fig. 5. Generated initial stresses

6. In the calculation page the general steps like phase name, number and flow of phase should be provided including the calculation type whether the calculation is based on plastic, consolidation, phi/c reduction or dynamic analysis. Further the calculation parameters like number of steps, time of intervals etc. should be given.

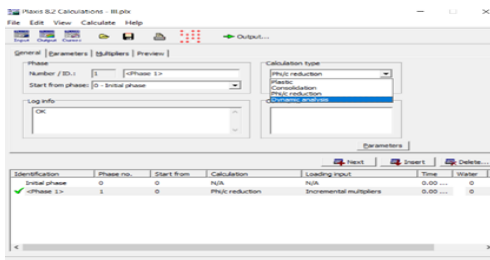


Fig. 6. General steps in calculation page

7. After general steps the points of curves has to be updated. After marking of points the calculation process starts and after some time the calculation process ends and the outputs are shown on the output page.

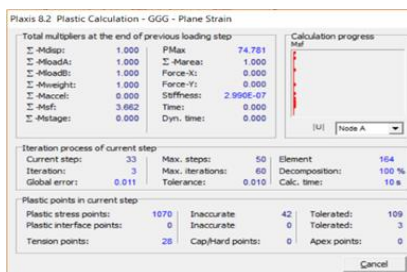


Fig. 7. Calculation process

8. The outputs of the model are given in two toolbars in which one consists of deformation and another one stresses. And the outputs may be seen in three modes they are shadings, arrows and counter lines as shown below.

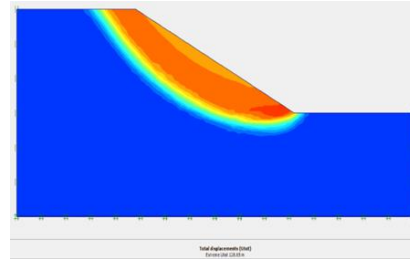


Fig. 8. Output in terms of Shadings

9. After tabulating the outputs, the curve tool is to be selected and the file name of the model on which the curves has to be plotted is to be selected and the parameters on x and y axis has to be selected and it should be applied.

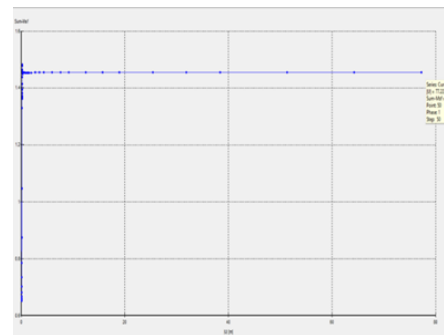


Fig. 9. Curve plotted

### 5. Results and discussions

The results obtained by the output are tabulated and the values obtained for both deformation and stress are noted. In deformation some of the main particulars like Total, Horizontal and vertical displacement are tabulated. Similarly, in the stresses the particulars like Total and Effective stress, Active and Excess pore pressure and Active ground head are tabulated. Factor of safety of the slope is given by the curve plotted in the curve phase.

Table 1  
 When Cohesive value is 10 and Phi value is varying for slope 1:2.

Particulars	Phi=10 & C=10, A <sub>11</sub>	Phi=20 & C=10, A <sub>21</sub>	Phi=30 & C=10, A <sub>31</sub>	Phi=40 & C=10, A <sub>41</sub>
<b>Deformation</b>				
Total Displacement (m)	1.30	128.65	1.49	2.12.83
Horizontal Displacement (m)	1.25	123.87	1.45	208.72
Vertical Displacement (m)	814.20e-3	86.48	1.04	146.16
<b>Stress</b>				
Total Stress (KN/m <sup>2</sup> )	-308.21	-310.89	-306.82	-310.81
Effective Stress (KN/m <sup>2</sup> )	-429.13	-340.22	-407.94	-289.59
Active Pore Pressure (KN/m <sup>2</sup> )	-122.37	-113.62	-103.29	-130.20
Excess Pore Pressure (KN/m <sup>2</sup> )	-122.37	-113.62	-103.29	-130.20
Active Ground Head (m)	19.49	19.40	19.76	19.76
Factor of Safety (FOS)	0.547	1.457	1.812	2.141
Multiplier (U)	1.061	9.36	1.341	139.33

Table 2  
 When Cohesive value is 20 and Phi value is varying for slope 1:2

Particulars	Phi=10 & C=20, A <sub>12</sub>	Phi=20 & C=20, A <sub>22</sub>	Phi=30 & C=20, A <sub>32</sub>	Phi=40 & C=20, A <sub>42</sub>
<b>Deformation</b>				
Total Displacement (m)	82.17	15.79	248.86	225.46
Horizontal Displacement (m)	77.21	15.15	72.37	153.93
Vertical Displacement (m)	59.28	11.15	172.37	153.93
<b>Stress</b>				
Total Stress (KN/m <sup>2</sup> )	-314.59	-313.13	-312.08	-310.93
Effective Stress (KN/m <sup>2</sup> )	-345.85	-323.53	-327.86	-273.47
Active Pore Pressure (KN/m <sup>2</sup> )	-148.08	-56.17	-90.79	-11.47
Excess Pore Pressure (KN/m <sup>2</sup> )	-148.08	-56.17	-90.79	-11.47
Active Ground Head(m)	20.78	20.59	20.32	20.21
Factor of Safety (FOS)	1.448	1.939	2.339	2.695
Multiplier (U)	68.56	14.29	201.83	185.69

Table 3  
 When Cohesive value is 30 and Phi value is varying for slope 1:2

Particulars	Phi=10 & C=30, A <sub>13</sub>	Phi=20 & C=30, A <sub>23</sub>	Phi=30 & C=30, A <sub>33</sub>	Phi=40 & C=30, A <sub>43</sub>
<b>Deformation</b>				
Total Displacement (m)	1.49	136.44	156.96	126.56e-3
Horizontal Displacement (m)	1.45	129.37	149.63	124.40e-3
Vertical Displacement(m)	1.04	99.43	111.65	98.71e-3
<b>Stress</b>				
Total Stress (KN/m <sup>2</sup> )	-306.82	-312.49	-334.35	-311.51
Effective Stress (KN/m <sup>2</sup> )	-407.94	-314.08	-288.40	-264.47
Active Pore Pressure (KN/m <sup>2</sup> )	-103.29	-109.14	-153.23	-68.56
Excess Pore Pressure (KN/m <sup>2</sup> )	-103.29	-109.14	-153.23	-68.56
Active Ground Head (m)	19.76	20.53	20.37	20.37
Factor of Safety (FOS)	0.015	2.38	2.814	1.577
Multiplier (U)	1.105	120.09	132.85	0.118

Table 4  
 When Cohesive value is 40 and Phi value is varying for slope 1:2

Particulars	Phi=10 & C=40, A <sub>14</sub>	Phi=20 & C=40, A <sub>24</sub>	Phi=30 & C=40, A <sub>34</sub>	Phi=40 & C=40, A <sub>44</sub>
<b>Deformation</b>				
Total Displacement(m)	1.42	44.84	111.09	105.68
Horizontal Displacement(m)	1.39	42.39	104.91	100.85
Vertical Displacement(m)	1.02	32.85	31.11	75.69
<b>Stress</b>				
Total Stress(KN/m <sup>2</sup> )	-307.3	-313.78	-313.25	-315.49
Effective Stress(KN/m <sup>2</sup> )	-400.23	-308.58	-282.07	-257.36
Active Pore Pressure(KN/m <sup>2</sup> )	-94.81	-167.96	-114.99	-153.01
Excess Pore Pressure(KN/m <sup>2</sup> )	-94.81	-167.96	-114.99	-153.01
Active Ground Head(m)	20.18	20.8	20.53	20.53
Factor of Safety(FOS)	0.020	2.82	3.27	3.66
Multiplier(U)	1.23	38.98	100.04	93.25

By referring table number 1, 2, 3 and 4 the graphs are plotted by taking Factor of safety and Effective stresses on y axis and varying C and Phi value.

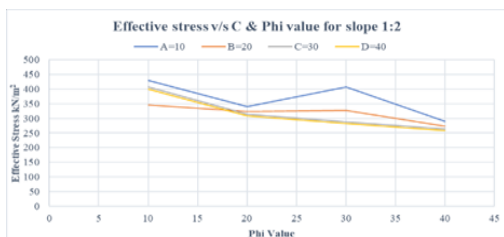


Fig. 10. Determination of Effective stresses for varying C and Phi values

By seeing the above figure, where the graph is plotted between Effective Stress verses Phi values the curves A, B, C

and D represents the cohesion(C) values as 10, 20, 30 and 40 respectively. we can state that as curve A is rapidly changing with the increasing value of phi. Both C and D curves run parallel to each other. And curve B, C, and D have the intersection point at phi value ranging from 15-20, whereas the curve A dose not intersect with any curve. Curve A has the maximum effective stress at phi value 30. Curve C and D will sudden fall with increase in phi value up to 20, and then there is gradually fall and these both curve run parallel to each other.

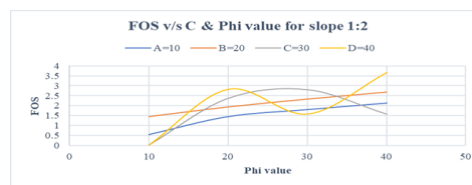


Fig. 11. Determination of FOS for varying C and Phi values.

By seeing the above figure, where the graph is plotted between FOS versus Phi values the curves A, B, C and D represents the cohesion(C) values as 10, 20, 30 and 40 respectively. The curve C and D are rapidly varying with the increasing phi value. The curves A and B are both having the same characteristic with changing phi value. We got the highest FOS for the curve D at phi value 40. Curve A, C and D should be neglected for the phi value 10 as it has FOS less than 1. Curve B gives the positive result for all the phi values.

### 6. Conclusions

After seeing the results of slopes for varying Cohesion and Phi values for the slope 1:2 the below conclusion are made from the study.

- The plaxis does not give the output for the cohesive less soil, that is when  $C=0$ .
- The plaxis does not give the desired output when Phi is equal to zero.
- When  $\Phi=0$  the desired factor of safety is not obtained, that is  $FOS=1e6$  which is fully stable, but the slip circle is obtained as desired.
- The water table was assumed to be below the boundary considered for finite element analysis. The increase of water table, would result in a reduction of FOS.
- For the outcome results we have been seen that different stresses values are increasing with the

increase of angle of friction value or some time decreasing also.

- For the slope 1:2, there is increase in the FOS with respect to increase in the cohesion and phi value.
- The effective stress decrease for the slope 1:2 with the increase in the cohesion and phi value.

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