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Project report

2020-21

VIT
UNIVERSITY

Vellore Institute of Technology

Project Report On

"SLOPE STABILITY USING GEOSLOPE SOFTWARE"

Winter semester 2020-21

GROUND IMPROVEMENT TECHNIQUES
(CLE2010)

Guided By: Prof. MUTHUKUMAR M

CERTIFICATE

This is to certify, that the mini project entitled "SLOPE STABILITY USING GEOSLOPE SOFTWARE" submitted by the following students, B. Tech, VIT University, Vellore for the partial fulfilment of the B. Tech- Ground Improvement Techniques course, is a record of bonafide carried out by the students under my supervision, as per VIT regulation of academic.

The J-COMPONENT project carried by the following students have not been submitted anywhere in the University.

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This project has provided us with the knowledge and to understand theoretical concepts in more depth. We are very thankful to all those who have helped us directly or indirectly in successful completion of this project.

Finally, we would like to thank the “Think Tank” of VIT University for introducing CAL system and giving us a chance to progress in our lives by doing such projects.

CONTENTS

OBJECTIVE

- The main objective of the project was to create a ground profile by considering all the necessary factors that are involved using Geoslope software.
- To define the properties of the embankment soil as well as the foundation soil. Also, to define the Pore-Water pressure for the ground profile.
- To check the soil stability at the ground. It involves finding out whether the soil would fail at certain conditions.
- To find if the stability of slope is compromised if cut from a certain slip surface.
- The remedies to be adopted to ensure the strength and the safety of the soil in case of failure.

INTRODUCTION

Slope is an angular inclination of region between crests and base of the valley. Geological structure, climate, vegetation cover, drainage network, drainage texture and frequency, bifurcation ration, absolute relief, relative relief, dissection index, and erosion are the causative factors which combination is developing the slope.

Slope is upward or downward inclination of ground between mountain and valley. The shape of the slope is concave, convex, free face and rectilinear which are known as morphology of slope. The convex element originates in the crest, free face element is found in steep inclination of slope and is shown like a wall which is resting on the sedimentary cover.

SLOPE STABILITY ANALYSIS

Slope stability analysis is a static or dynamic, analytical or empirical method to evaluate the stability of earth and rock-fill dams, embankments, excavated slopes, and natural slopes in soil and rock. Slope stability refers to the condition of inclined soil or rock slopes to withstand or undergo movement. The stability condition of slopes is a subject of study and research in soil mechanics, geotechnical engineering and engineering geology.

Identification of a slope on a region is very important from civil engineering point of view because we need to take certain measures way before we construct a structure on a slope and here comes in the importance of analyzing the stability of slope.

We always need to consider the factors that affect the instability of slope, because it can lead to severe natural disasters such as landslides.

A previously stable slope can be affected by a number of predisposing factors or processes that make the safety factor decrease - either by increasing the shear stress or by decreasing the shear strength - and can ultimately result in slope failure. Factors that can trigger slope failure include hydrologic events (such as intense or prolonged rainfall, rapid snowmelt, progressive soil saturation, increase of water pressure within slope), earthquakes (including aftershocks), internal erosion (piping), surface or toe erosion, artificial slope loading (for instance due to the construction of a building), slope cutting (for instance to make space for roadways, railways or buildings), or slope flooding.

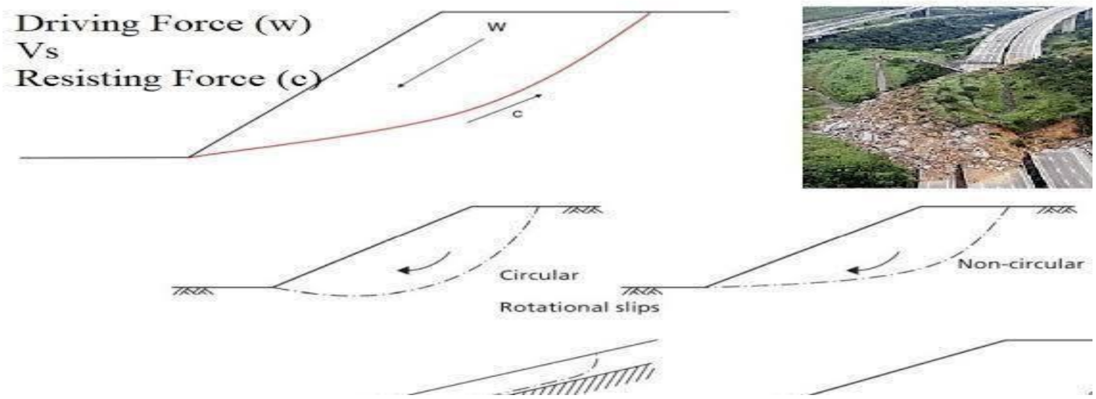
One of the advantages of analysis of slope stability is that, Stability analyses of two-dimensional slope geometries using simple analytical approaches can provide important insights into the initial design and risk assessment of slopes. Limit equilibrium methods investigate the equilibrium of a soil mass tending to slide down under the influence of gravity.

SLOPE FAILURES

A slope failure is a phenomenon that a slope collapses abruptly due to weakened self-retainability of the earth under the influence of a rainfall or an earthquake. Because of sudden collapse of slope, many people fail to escape from it if it occurs near a residential area, thus resulting in a higher rate of fatalities.

It occur when driving forces overcome resisting forces. The driving force is typically gravity, and the resisting force is the slope material's shear strength.

Stability is determined by the balance of shear stress and shear strength. If the forces available to resist movement are greater than the forces driving movement, the slope is considered stable. A factor of safety is calculated by dividing the forces resisting movement by the forces driving movement.



GEOSLOPE SOFTWARE

- SLOPE STABILITY ANALYSIS is the software that we have used for our project.
- SLOPE/W is the leading slope stability software for soil and rock slopes. SLOPE/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, and loading conditions.
- With this comprehensive range of features, SLOPE/W can be used to analyze almost any slope stability problem that we will encounter in our project.

METHODOLOGY

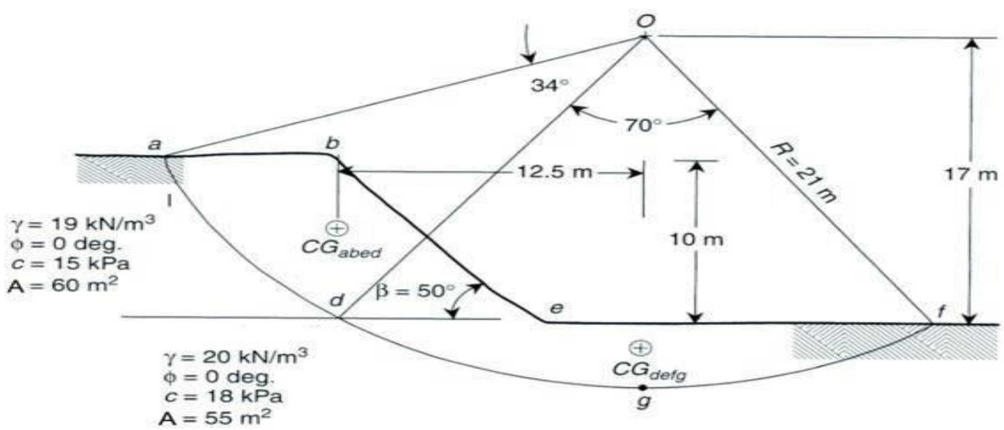
1. Setting up the profile of ground which is to be analyzed for shear failure.
2. Defining Material properties and Pore-Water pressure for the ground profile.
3. Introduction of Surcharge loads on the contour to simulate a pressure applied over a portion of the ground surface.

4. Establishing a set of trial slip surfaces which the software will use for computing a critical factor of safety.
5. Solving the multiple slip-surfaces and analysing the given solutions procured from the software.
6. Providing Improvement Solutions for improving slope stability.

GROUND PROFILE

The analysis was done on the contour given below:

- Embankment (10 m) rests on foundation soil(8 m) with soil properties as given in figure.
- Entry range of slip circle :(x,y)=(4.601,18) to (8.2301,18)
- Exit range of slip circle :(x,y)=(36.729,8) to (40.8,8)
- Centre of rotation of slip circle (x,y) (O) =(24.00,25.0)
- Water table was provided at the boundary of separation between foundation and embankment soil and hence whole of the foundation was submerged in water.
- The stability analysis was done using Morgenstern Price Method.



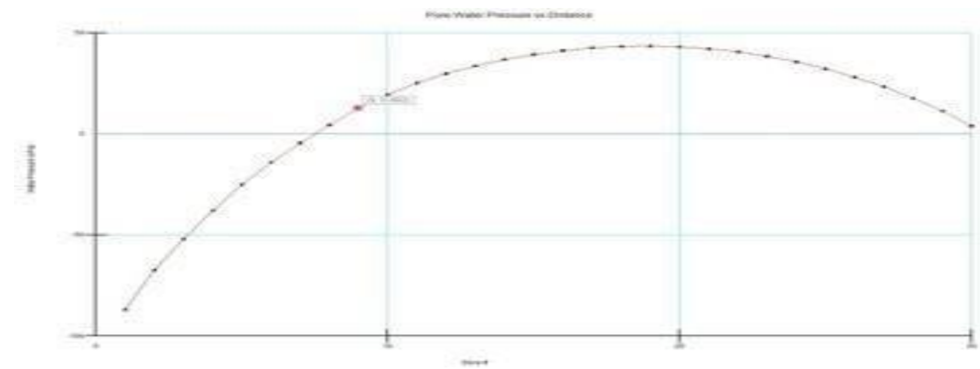
MATERIAL PROPERTIES

- For convenience in Analysis the section was divide into 2 zones namely Embankment Soil and Foundation Soil.
- Our Choice of soil was silty sand (SM) because:
    - ☐ It has a better water holding capacity.
    - ☐ It covers most of the area
- The parameters of SM category soil was found from http://geotechdata.info/

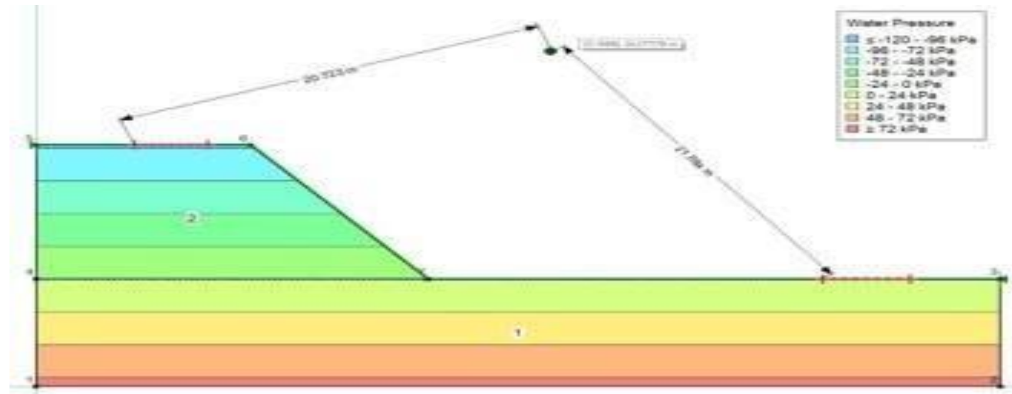
Colour	Name	Model	Unit Weight (kN/m2)	Cohesion (kPa)	Phi(°)	Piezometric Line	Include Ru in PWP
	Embankment Soil	Mohr-Coulomb	21.5	20	33.5	1	No
	Foundation Soil	Mohr-Coulomb	20.5	22	34	1	No

PORE-WATER PRESSURE

- Pore water pressure (pwp) refers to the pressure of groundwater held within a soil or rock, in gaps between particles (pores). Pore water pressures below the phreatic level of the groundwater are measured with piezometers.
- We assumed that the water table was in the line that separates the embankment soil and foundation soil. A piezometric line was drawn in the region for the very sole purpose.
- The pressure in each regions associated against the piezometric line has been illustrated in the provided figure.
- The pore-pressure was computed with the general formulae i.e. $\gamma_w.H$, where H denotes the height from the line.
- Furthermore, a graph portraying the pore water pressure along the slices cut for the recommended trial surface (FOS=1.285) is also given.



Pore-Water Pressure vs Distance



Water Pressure
≤ -120 - -96 kPa
-96 - -72 kPa
-72 - -48 kPa
-48 - -24 kPa
-24 - 0 kPa
0 - 24 kPa
24 - 48 kPa
48 - 72 kPa
≥ 72 kPa
2
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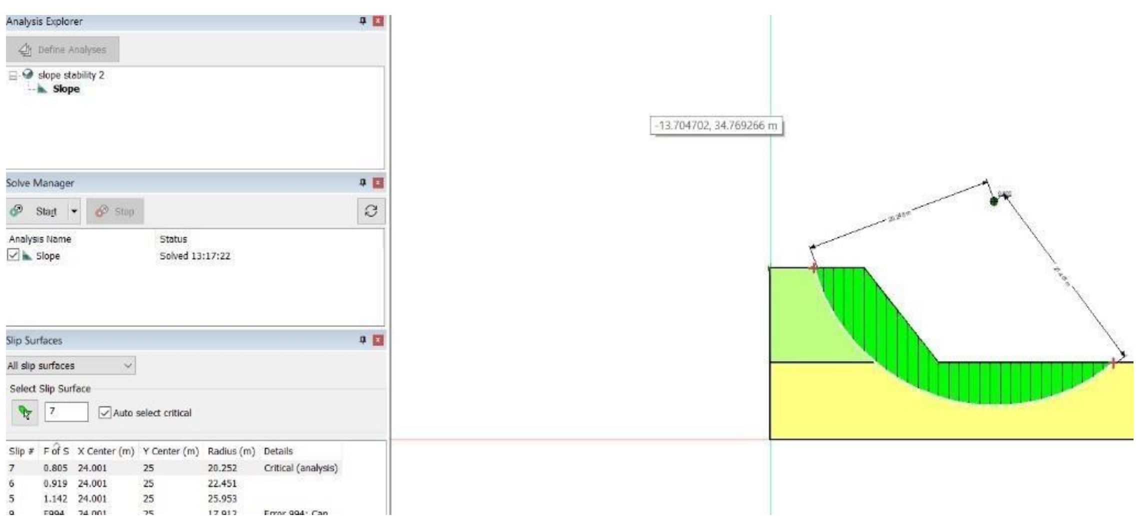

Analysis Explorer
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slope stability 2
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Solve Manager
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Stop
Analysis Name
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Slip Surfaces
All slip surfaces
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7
Auto select critical
Slip # F of S X Center (m) Y Center (m) Radius (m) Details
7 0.805 24.001 25 20.252 Critical (analysis)
6 0.919 24.001 25 22.451
5 1.142 24.001 25 25.953
-13.704702, 34.769266 m

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r rr	25	32	24.0	99	7
		12	24.0	99	6
r rr	35	2	24.0	99	5
		1	24.0	99	9
	23	1	24.0		8
	29	3	24.0		4
	16	4	24.0		3
	53	7	24.0		2

Va lid slip surfaces

Select Slip Surface

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Slip #	F of S	X Center (m)	Y Center (m)	Radius (m)	Detai
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D	o.9i9	zm.ooi	zs	xx. si	
s	i.i<x	zm.ooi	zs	xs.9sa	

Slip range to 2

Select Slip Surface

 5 Auto select critical

Slip #	F of S	X Center (m)	Y Center (m)	Radius (m)	details
5	1.142	24.001	25	25.953	Critical (c

RESULTS AND DISCUSSION

○ SLOPE STABILITY REPORT

- A computative analysis was done to the embankment to determine the radial slip-surfaces present throughout the profile.
- The slip surfaces were restricted between the entry and exit zones (illustrated as red lines at the top and bottom) so that all circular slip surfaces, with the slip axis (green dot) acted as the center, would pass through these points.
- The solution provided with about 897 slip surfaces between the specified entry and exit points.
- A safety map was procured with these slip surfaces as given in the picture .
- The red ones describes the slip surfaces with factor of safety <1 which are destined to fail.

OPTIMUM SLOPE FOR CUTTING

- The next main aim of our project was to calculate the best available slope if an excavation was to made along the embankment for routine cuts and fills
- As per the paper published by “DESIGN OF STABLE SLOPE FOR OPENCAST MINES” by department of mining engineering NIT Rourkela, the factor of safety stipulated for routine cuts and fills for roads was in the range of 1.25-1.4.
- Henceforth, we segregated the FOS within this range and examined the material properties for each slip surface within the scope.
- Amongst the other slip surfaces the slip surface with FOS of 1.142 was found out to be ergonomic and yielded the most quantity among the others.

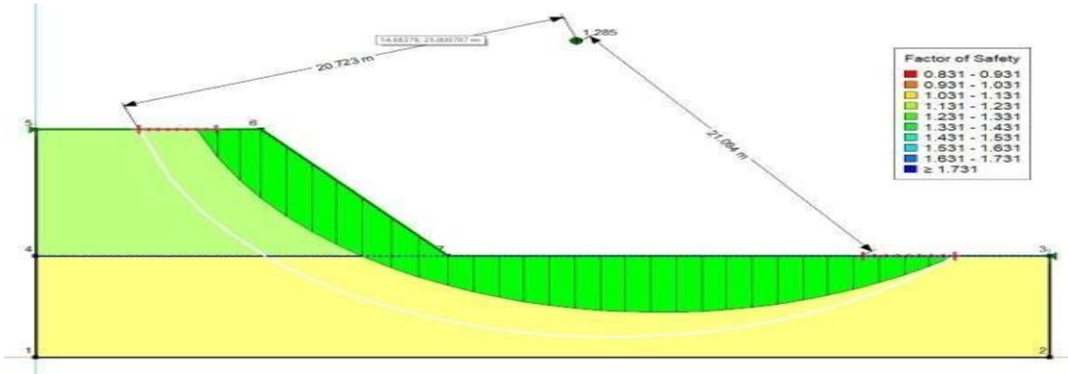


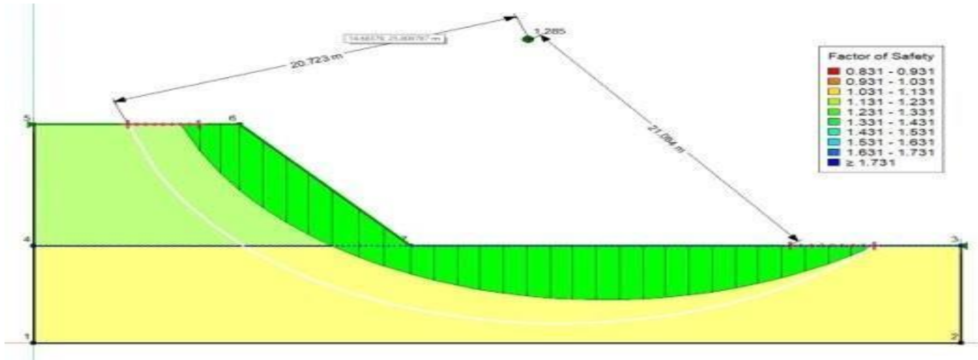
Table 2.1 Guidelines for equilibrium of a slope

Factor of Safety	Details of Slope
<1.0	Unsafe
1.0-1.25	Questionable safety
1.25-1.4	Satisfactory for routine cuts and fills, Questionable for dams, or where failure would be catastrophic
>1.4	Satisfactory for dams

PROPERTIES OF THE SUGGESTED SLOPE

The quantitative properties of the prescribed slope is given below:

- Method Morgenstern-Price
- Factor of Safety: 1.142
- Total Volume: 36.608 m³
- Total Weight: 719.76 kN
- Total Resisting Moment: 4,418.2 kN·m
- Total Activating Moment: 3,438.2 kN·m
- Total Resisting Force: 178.7 kN
- Total Activating Force : 139.13 Kn



	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength	Base Material
Slice 1	5.1399991 m	17.220588 m	-90.426306 kPa	-0.0021509376 kPa	-3.7540981e-06 kPa	15 kPa	0 kPa	Embankment soil
Slice 2	6.2199993 m	15.761753 m	-76.119514 kPa	22.695688 kPa	0.039611489 kPa	15 kPa	0 kPa	Embankment soil
Slice 3	7.2999996 m	14.481516 m	-63.564224 kPa	43.692244 kPa	0.076257429 kPa	15 kPa	0 kPa	Embankment soil
Slice 4	8.3799999 m	13.344426 m	-52.412791 kPa	63.169333 kPa	0.1102514 kPa	15 kPa	0 kPa	Embankment soil
Slice 5	9.4600002 m	12.326581 m	-42.430783 kPa	81.276213 kPa	0.1418539 kPa	15 kPa	0 kPa	Embankment soil
Slice 6	10.595001 m	11.369183 m	-33.041579 kPa	87.600427 kPa	0.15289174 kPa	15 kPa	0 kPa	Embankment soil
Slice 7	11.785001 m	10.468059 m	-24.204256 kPa	81.522933 kPa	0.1422845 kPa	15 kPa	0 kPa	Embankment soil
Slice 8	12.975001 m	9.6625505 m	-16.304633 kPa	73.406274 kPa	0.12811825 kPa	15 kPa	0 kPa	Embankment soil
Slice 9	14.165002 m	8.9429892 m	-9.247896 kPa	63.408269 kPa	0.11066842 kPa	15 kPa	0 kPa	Embankment soil
Slice 10	15.355002 m	8.3018199 m	-2.9599482 kPa	51.650243 kPa	0.090146772 kPa	15 kPa	0 kPa	Embankment soil
Slice 11	16.534502 m	7.737466 m	2.5746701 kPa	38.157777 kPa	0.062104301 kPa	18 kPa	0 kPa	Foundationsoil
Slice 12	17.703501 m	7.2439989 m	7.4141022 kPa	23.99884 kPa	0.028945857 kPa	18 kPa	0 kPa	Foundationsoil
Slice 13	18.885063 m	6.8080697 m	11.68926 kPa	20.701444 kPa	0.015729245 kPa	18 kPa	0 kPa	Foundationsoil
Slice 14	20.079188 m	6.4278805 m	15.417776 kPa	28.717012 kPa	0.023211569 kPa	18 kPa	0 kPa	Foundationsoil
Slice 15	21.273313 m	6.1061364 m	18.573119 kPa	35.780776 kPa	0.030033058 kPa	18 kPa	0 kPa	Foundationsoil
Slice 16	22.467438 m	5.8407532 m	21.175733 kPa	41.898684 kPa	0.036168409 kPa	18 kPa	0 kPa	Foundationsoil
Slice 17	23.661563 m	5.6300856 m	23.24175 kPa	47.071844 kPa	0.041591403 kPa	18 kPa	0 kPa	Foundationsoil
Slice 18	24.855688 m	5.4728734 m	24.78353 kPa	51.296492 kPa	0.046273894 kPa	18 kPa	0 kPa	Foundationsoil
Slice 19	26.049813 m	5.3682012 m	25.810051 kPa	54.563845 kPa	0.050184889 kPa	18 kPa	0 kPa	Foundationsoil
Slice 20	27.243938 m	5.3154711 m	26.327174 kPa	56.859835 kPa	0.053289599 kPa	18 kPa	0 kPa	Foundationsoil
Slice 21	28.438063 m	5.3143855 m	26.337821 kPa	58.164697 kPa	0.055548434 kPa	18 kPa	0 kPa	Foundationsoil
Slice 22	29.632188 m	5.3649383 m	25.84205 kPa	58.452389 kPa	0.056915837 kPa	18 kPa	0 kPa	Foundationsoil
Slice 23	30.826313 m	5.4674147 m	24.837063 kPa	57.689802 kPa	0.057338904 kPa	18 kPa	0 kPa	Foundationsoil
Slice 24	32.020438 m	5.6223998 m	23.317125 kPa	55.835693 kPa	0.056755666 kPa	18 kPa	0 kPa	Foundationsoil
Slice 25	33.214563 m	5.8307949 m	21.273394 kPa	52.83928 kPa	0.055092921 kPa	18 kPa	0 kPa	Foundationsoil
Slice 26	34.408688 m	6.0938453 m	18.693659 kPa	48.638357 kPa	0.052263411 kPa	18 kPa	0 kPa	Foundationsoil
Slice 27	35.602813 m	6.4131787 m	15.561956 kPa	43.156767 kPa	0.04816208 kPa	18 kPa	0 kPa	Foundationsoil
Slice 28	36.796938 m	6.79086 m	11.858036 kPa	36.300972 kPa	0.042661015 kPa	18 kPa	0 kPa	Foundationsoil
Slice 29	37.991063 m	7.2294641 m	7.5566447 kPa	27.955318 kPa	0.035602438 kPa	18 kPa	0 kPa	Foundationsoil
Slice 30	39.185188 m	7.7321767 m	2.6265429 kPa	17.97537 kPa	0.026788784 kPa	18 kPa	0 kPa	Foundationsoil

SLICE INFORMATION FOR THE SUGGESTED SLOPE

CONCLUSION

A clear analysis was done to the slope outline and the following conclusions were made:

- Any trial surface with FOS <1 is destined to fail.
- The optimum Factor of safety to be adopted for cutting slope for roads should be well within the range of 1.2-1.4. Any value less is susceptible to fail if exposed.

- Among the other slip surfaces in the optimum range the slip surface with FOS of 1.142 was found out to be ergonomic and yielded the most quantity among the others.
- Through the values and results obtained from the software used, it was clear that a safe slope was calculated in order to excavate an embankment.
- It was observed that the stability of the soil was getting weaker at certain slopes.

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