A REVIEW on Slope Stabilization by Using PLAXIS 2D

Gwasikoti Saurabh[1], Sharma S.K.[2],
PG Scholar (Department of civil engineering, G.B.P.U.A.T. Pantnagar, Uttarakhand, India.)[1]
Assistant Professor (Department of civil engineering, G.B.P.U.A.T. Pantnagar, Uttarakhand India)[2]
Saurabhgwasikoti33@gmail.com[1]
subirksharma.civil@gbpuat-tech.ac.in[2]

Abstract
One of the most significant areas that need to be appropriately addressed in the field of geo-technical engineering is slope stability. The reasons of slope collapses or investigations of recent landslides will be done, the impact of various slip surface search algorithms on the safety-related factors and corrective actions that may have been taken will be recommended. The major goal of this study was to calculate the soil slope factor and displacement in both the vertical and horizontal directions. Here, the Finite Element Method has been used to analyse the slope's stability while utilizing PLAXIS-2D.

***Key Words*:** Slope, factor of safety, slip Circle, failure slip circle, Plaxis 2D

Introduction

A soil slope is an inclined portion of the soil mass. Slopes can be created artificially or naturally. In order to prevent slope failure, it is crucial to keep an eye on the stability, shear strength, and resistance to movement of soil slopes. Landslides are one of the important types of slope collapse. Illegal hill cutting, a lot of rain, natural weathering, seismic activity, and poor geotechnical soil qualities are the main causes of landslides. Numerous human activities, such as clearing forests for development, building in the hills, and haphazard farming, make slopes unstable and cause landslides. Because there were so many regions with acceptable soil quality in the past, the problematic sites were typically overlooked. However, today's rising industrialization and urbanization are pushing people to use these dangerous areas.

As more loads are placed on the soil slope in recent years, this has been observed. Geotechnical engineers are currently dealing with several frequent issues such significant settlement and slope instability.

This study's focus is on analyzing slope stability issues for various cut slope angles. For slopes that currently exist, the safety factor will be computed by using software plaxis and the slope's stability will then be examined.

Methodology

Chakrabarti, B., Shivananda, P., & Scholar, P. D.(2017). The Finite Element approach has been used to analyse the stability of the soil slope using PLAXIS-2D. The topic under consideration was analysed using the Mohr-Coulomb model. The Displacement and Safety Factor, as well as their relationship to one another, are taken into consideration here along with various slope heights, slope angles, and combinations of both for the entire variable data set. The length and top is taken same for every set. The density, permeability co-efficient, elastic modulus, Poisson's ratio, and cohesive strength (C), which are referred to as the stiffness factors of soil properties, are among the parameters used in this PLAXIS-2D modelling. These parameters are kept constant for each variable data set, respectively, at each stage of these analyses.

In this investigation, a homogenous soil with dimensions of 25 m in height, 50 m in breadth, and 7 m, 12 m, and 17 m in slope height was examined. Here, the water level was constant or assumed to be constant

despite the varied soil slope. And the slope angles are taken as 250, 300 380, 420 respectively.

Khan, M. S., Sahadat Hossain, ; M D, Ahmed, ; Asif, Greenwood, K., & Shishani, A. (n.d.).(2017). Took three slope ratios (4H:1V, 3H:1V, and 2H:1V) for Expansive clay soil in the North Texas region and, six slope heights (1.52 m increments from 4.57 m to 12.19 m), three recycled plastic pin(RPP) lengths (2.44 m, 3.05 m, and 3.66 m), and five RPP spacing configurations were for a parametric analysis (0.91 m, 1.22 m, 1.52 m, 1.83 m, and 2.13 m). For each combination of the aforementioned characteristics, the factor of safety (FS) was calculated using PLAXIS 2D's strength reduction technique. The FS values that were obtained ranged from 1.51 to 3.76. According to regression analysis, the soil strength and RPP spacing had the biggest effects on the reinforced slope's FS. The fill slope over US 287 in Midlothian, Texas, was chosen as the roadway slope under inquiry.

Islam, A.,& Islam, M. S.(2020). Took samples from the CHT of Bangladesh from four separate areas, both disturbed and undisturbed. To find out these soils' physical and engineering characteristics, studies in the lab were done. After examining these findings, PLAXIS 2D's numerical analysis will make use of the soil characteristics of CHT. The chosen location's existing hill slopes were discovered to vary between 10-15 meters, and their slope angles are between 70 and 80 degrees. The increased cohesion offered by roots in this work simulates the behaviour of slopes that are rooted. Tensile strength, root area ratio (RAR), and added apparent cohesion were obtained from Voottipruex after calculating the diameter of the vetiver plant's roots (2008).

Badhon, F. F., Islam, M. S., & Islam, M. A.(2021). In this investigation, four different types of soil—Pubail clay, Dredged sand, Buriganga clay, and Sylhet sand—were gathered and employed. Several laboratory experiments, including the tests for grain size distribution, specific gravity, moisture content, and Atterberg limits, were used to determine the index properties of all the soil samples. The index characteristics of Sylhet sand, Buriganga clay, Dredged sand, and Pubail clay.

A numerical analysis was undertaken to assess the stability of bare and vegetated slopes using the laboratory test results from the direct shear test performed on undisturbed bare and rooted soil samples.

The finite element programme PLAXIS 2D was used for the numerical analysis. The effects of vegetation on slopes with four distinct slope angles (β= 18.40, 26.60, 450, and 64.40) were examined. In PLAXIS 2D,

the plain strain model was used for the investigation, and the soil was modeled utilizing the Mohr-Coulomb model. The 15-node triangular element was chosen, and the boundary's standard fixities were applied. At the bottom of the slope, on drained soil, the phreatic surface was applied.

Index properties of the soils used for laboratory investigations-

Table 1

Properties	**Pubail Clay**	**Dredged sand**	**Buriganga Clay**	**Sylhet sand**
Soil classification (USCS)	Clay of low plasticity	Poorly graded sand(SP)	Clay of low plasticity	Poorly graded sand
Specific gravity	2.68	2.74	2.65	2.68
Natural moisture content (%)	16	12	28	9
Liquid limit (%)	44	--	42	--
Plasticity index (%)	23	--	19	--
Uniformity Coefficient (C_u)	--	2.0	--	2.37
Coefficient of curvature (C_c)	--	0.92	--	0.89

Acharjee Jeet, A. (n.d.).(2021) Took Two slopes with heights of 10 and 15 meters each and an angle of 500 were taken into consideration for the stability analysis in order to imitate the typical slope characteristics of our nation. PLAXIS 2D has been used to simulate the bare slopes and the Recycled Plastic Pin (RPP) installed slopes in a Finite Element Model (FEM) analysis. The Factors of Safety (FOS) for bare slopes were below 1.3, indicating their unstable character.

Five input parameters were taken for the Mohr-Coulomb model to mimic soil behaviour. The elasticity modulus (E), Poisson's ratio (v), cohesion (c), friction angle (φ), and dilatancy angle (λ) are these. The base's displacement in the x and y directions is zero (full fixity) when standard fixities are used as boundary conditions, but roller conditions are assumed on the vertical sides.

A built-in feature in PLAXIS that enables the calculation of safety factors is the phi-c reduction method. The soil strength parameters (c and tan) are continuously decreased in this manner until failure occurs. This computation is done using the "load advancement number of steps" process, which defines the soil strength parameters at a specific stage of the analysis using the multiplier "Msf."

Sivakumar Babu, G. L. (n.d.). A standard Soil-Nail wall system was created using the Federal Highway Administration's (FHWA, 2003) recommendations. To evaluate the in-situ soil conditions, a comprehensive geotechnical investigation was conducted. A finite element code called PLAXIS was used to numerically simulate the full soil-nail wall system. Different design factors were investigated and contrasted. In particular, the impact of nailing on deformations and the overall safety factor are stressed.

A residual soil layer that has moderately weathered makes up the in-situ ground. In the influence zone, there is no groundwater to be discovered. The soil weighs around 18 kN/m3 per cubic metre. Undrained shear measurements on saturated, undisturbed samples show that the cohesiveness is between 10 and 20 kPa, and the large-strain total friction angle is 25o.

Based on the techniques of Gassler and Gudehus (1981) and FHWA, the spacing and length of reinforcements were determined (1990). The safety factor against pullout was calculated to be 2.0, while the overall safety factor was 1.5. The excavated earth was nailed into place with 20 mm-diameter by 3500 mm-long ribbed mild steel bars. Direct shear experiments on typical soil samples that were compacted to the field density and moisture content were used to establish the interfacial friction angle between soil and nail, abbreviated as ju. 6% of the nail surface was covered in ribs or striations. A mild steel plate with similar striations at the interface measuring 60 mm x 60 mm and 2 mm served as a representation of this in the direct shear box test. The steel plate served as the bottom half of the sample and was fastened to a wooden plate (60 mm x 60 mm x 8 mm);

Results and Discussion

Chakrabarti, B., Shivananda, P., & Scholar, P. D.(2017). Found that When the slope angle and slope height were increased, the factor of safety on the estimated slope surface also fell. And on the other side, where the Displacement value is higher, the value of the height of the embankment is also higher in general. However, in some circumstances for some specific soil slopes, these trends or relationships between settlement and Factor of Safety didn't follow.

Input-

Table 2

DATA	SLOPE ANGLE	SLOPE HEIGHT
SET-1.1	25 degree	7 `METRE
SET-1.2	30 degree	
SET-1.3	38 degree	
SET-1.4	42 degree	

Output-

Table 3

PARAMETERS	SET1.1	SET1.2	SET1.3	SET1.4
1. EXTREME TOTAL DISPLACEMENT	2.58m	2.08m	1.26m	1.15m
2. FACTOR OF SAFETY	1.91	1.684	1.512	1.317

Khan, M. S., Sahadat Hossain, ; M D, Ahmed, ; Asif, Greenwood, K., & Shishani, A. (n.d.).(2017)
Found When an RPP length of 3.35 m (11 ft) was paired with a slope ratio larger than 0.41, FS reached its lowest value of 1.43. Additionally, FS varied between 2.12 and 2.89 in any combination with a slope ratio lower than 0.2917. A slope ratio more than 0.2917 and a slope height greater than 8.38 m (27.5 ft) were also necessary in order to achieve an FS of 2.24, provided that the RPP was 3.66 m (12 ft) in length. When RPP was larger than or equal to

3.05 m (10 ft), according to Khan at al. (2014), it behaved as a long pile because the soil provided enough anchoring for it to do so.

Table 4

Case No. (Kpa, degree)	**Critical Slope Ratio**	**Critical Slope Height**	**Critical RPP Length(m)**	**Critical Spacing (m)**	**Lowest FS**	**Highest**
1(4.55, 13)	0.2917	8.38	3.35	1.37	1.53	2.89
2(383,22)	0.2917	8.38	3.35	1.68	1.66	3.27
3(11.59,20)	0.4167	9.91	N/A	1.37	1.70	3.76
4(1.58,25)	0.2917	8.38	2.74	1.37	1.51	3.12
5(4.07,10)	0.2317	3.86	2.74	1.68	1.57	2.46

Islam, A.,& Islam, M. S.(2020) Took following data from CHT Bangladesh and got following results

Table 5

Parameter	**Unit**	**Soil-A**	**Soil-B**	**Soil-C**	**Soil-D**
Soil Classification(USCS)	--	SM	SC	CL	SM-SC
Moist unit weight	kN/m^3	16.4	16.7	15.1	14.5
Saturated unit weight	kN/m^3	18.5	19.0	19.0	16.8
Initial void ratio(e_{int})	--	0.60	0.58	0.75	0.85
Young's modulus (E)	kN/m^2	3.0×10^4	2.0×10^4	1.0×10^4	2.5×10^4
Poisson's ratio	--	0.3	0.3	0.3	0.3
Cohesion	kN/m^2	0.1	9	18	2
Friction angle (φ)	^{o}	40	37	-	30
Horizontal Permeability (k_x)	m/day	16.7×10^{-03}	4.6×10^{-03}	2.6×10^{-05}	4.5×10^{-03}
Vertical Permeability (k_y)	m/day	16.7×10^{-03}	4.6×10^{-03}	2.6×10^{-05}	4.5×10^{-03}

For Soil A, at all slope angles, FS rises as root zone depth rises. In the case of Soil A, FS rises by up to 15% when rooted soil is compared to bare soil. In contrast, the change in FS for rooted soil in Soil C is only 0.7%. Similar to the findings of this study, deep seated base failure occurs for clayey soil (like Soil-C), meaning that the failure surface is located at a greater depth. In comparison to bare slopes, FS for Soil-B increases by roughly 2-4% while

FS for Soil-D increases. This shows that vetiver is most effective for shallow slope failure because the increase in FS due to vegetation is greatest for Soil A, followed by Soil B and Soil D.

Badhon, F. F., Islam, M. S., & Islam, M. A.(2021). Analyze changes in root zone depth for sandy soil and the safety factor for vegetated slopes. The factor of safety is increasing with every slope angle and the depth of roots. (Fig 1)

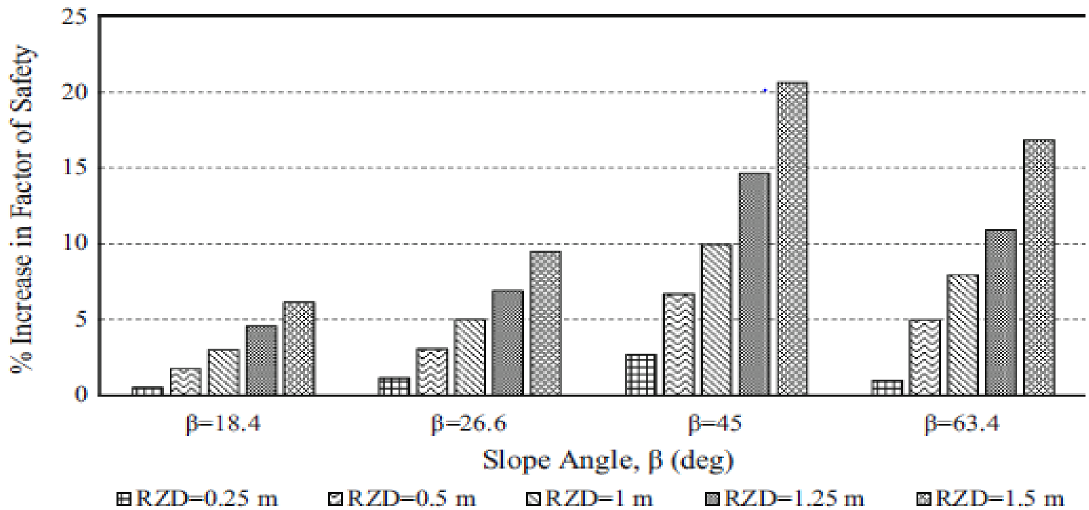

FIGURE 1

Fig2. Shown for all slope angles, the safety factor rises as the length of the root increases. Fig. shows the percentage rise in the factor of safety brought on by vetiver root. The findings demonstrate a favourable association between the depth of root penetration and the safety factor. The safety factor of a vegetated slope increases as root zone depth increases

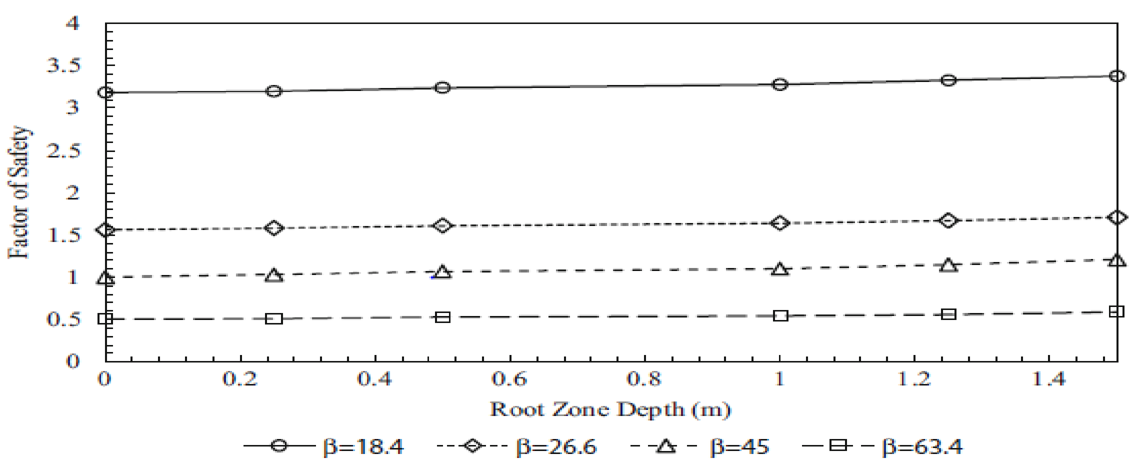

Figure 2

Acharjee Jeet, A. (n.d.).(2021). Found the slopes' numerical studies utilizing phi-c reduction demonstrate that the naked slopes are unstable and prone to failure. For slopes 1 (10 m) and 2, the Factors of Safety are found to be 1.292 and 1.092, respectively. The slope becomes increasingly unstable as it increases in height. As a result, the 15m slope has a lower FoS than the 10m slope, making it more susceptible to malfunctions.
Table displays the results of the safety analysis's phi-c reduction computation. The table shows that the FOS increased when the RPP was installed. Additionally, the FOS value has been impacted by the vertical spacing. Because the slopes' initial FOS values were less than 1.3, they were unstable. With the RPP installed, however, the FOS values increased, reaching 1.67 for slope 1 and 1.74 for slope 2.

Table 6

Slope ID	**Condition**	**RPP Vertical Spacing**	**Factor of safety**
Slope 1 Height: 10m Angle 50^o	Bare	N/A	1.292
	With RPP	4m	1.423
		3m	1.445
		2m	1.542
		1m	1.674
Slope 2 Height: 15m Angle: 50^o	Bare	N/A	1.092
	With RPP	4m	1.535
		3m	1.621
		2m	1.72
		1m	1.742

Sivakumar Babu, G. L. (n.d.). Found after each stage of construction, the global factor of safety is determined using the strength reduction technique. Three sets of data were obtained, and the increase in the safety factor is seen. These observations correspond to cohesion values of 10 KPa, 15 KPa, and 20 KPa.
The obtained safety factors are shown in Table 2. On average, safety factor values have increased by 1.5 to 2.5 times. Additionally, a global factor of safety in the range of 1.20 to 1.53 is obtained for the entire depth of excavation (6.8 m) supported by nails, it can be shown. According to FHWA rules, this figure reasonably complies with the minimal range of 1.20 to 1.30 of recommended factor of safety for worldwide stability.
The graphic representation of factor variation is shown in Figure

Table 7

Depth of Excavation, m	Factor of safety					
	Without nailing			With nailing		
Cohesion, C, kPa	10	15	20	10	15	20
1.50	1.30(1.48)	1.87(2.22)	3.29(2.96)	3.40	4.48	5.17
3.00	0.74	1.06(1.11)	1.18(1.48)	2.03	2.43	2.86
4.50	--	0.74	0.96(0.98)	1.62	1.87	2.18
6.00	--	--	0.74	1.28	1.51	1.72
6.80	--	--	--	1.20	1.37	1.53

Conclusions

The review was over slope stabilization using plaxis 2d software. It is found that we can determine factor of safety of any slope using soil characteristics and can increase the stability of soil and its strength. Using plaxis 2d we can find the change in factor of safety. For increasing the stability of soil we can use different methods like

Chakrabarti, B., Shivananda, P., & Scholar, P. D.(2017). Found that we can increase the FOS of slope by changing the geometry (by decreasing angle of slope and decreasing the height of the slope

Islam, A.,& Islam, M. S. took sample of soil from Bangladesh and and increase its FOS upto 15% after growing grass over the soil slope

Badhon, F. F., Islam, M. S., & Islam, M. A.(2021). Found that the FOS can be increased by growing grass in slope and by changing the angle of roots of the grass.

Acharjee Jeet, A. (n.d.).(2021) Found that factor of safety can be increase by using Recycled Plastic Pin (RPP) in slopes. The FOS was increased from 1.092 to 1.742.

Khan, M. S., Sahadat Hossain, ; M D, Ahmed, ; Asif, Greenwood, K., & Shishani, A. (n.d.).

Also used Recycled Plastic Pin (RPP) in slopes of soil. And the FOS was increased from 1.53 to

2.89

Sivakumar Babu, G. L.(n.d.). Used nails in soil slopes and found that the FOS increased from 1.32 to 3.40.

So the conclusion was that we can increase the strength of the soil by using soil nailing method. Because soil nailing significantly raised the FOS.

Future Scopes

- As we have seen that by different types of methods we can increase the slope stability of the soil. However there are other methods to improve the soil stability without treating the soil such as making retaining wall against the slope. A retaining wall holds and protects the soil from sliding. Other ways of treating soil are using nails in slope with retaining wall against the slope so that not only the strength of the soil increases but also decreases the amount of the nails required for soil stabilization

- One of the most common causes of slope failure is Rainfall. Due to heavy rainfall the unit weight of the soil increases and pore water pressure also increases due to which the soil reaches to its liquid limit and starts flowing with water, causing landslide. We can grow grass on slope for stabilizing the slope and can make a good drainage system for removing the rainwater thus protecting the slope against any failure.

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