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Numerical Analysis Of Stability Of Slope Reinforced With Soil Nail

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ABSTRACT: An earth or soil slope is a surface of soil mass which is inclined. Slopes can both occur naturally and be man made. It is important to monitor earth slopes, such as their balance, shear strength and ability to withstand movement to ensure slope failure does not occur. Slope stability analysis is performed to assess the safe design of a human-made or natural slopes and the equilibrium conditions. In this work, Geostudio software is used . Geostudio is an integrated software suited for modelling slope stability, ground deformation, heat and mass transfer in soil and rock.Geostudio is software by Geoslope. Here, the limit equilibrium method is used which is the most common approach for analyzing slope stability in both two and three dimensions. This method identifies potential failure mechanisms and derives factors of safety for a particulargeotechnical situation. Factor of Safety determines stability of slopes. In order to improve slope stability, reinforcement is provided. Slope can be stabilized using soil nails, piles, geosynthetics etc. Soil nails are structural reinforcing elements installed to stabilize steep slopes and vertical faces created during excavations. The effect of length, spacing and angle of inclination of soil nail on factor of safety is found.

KEYWORDS: Geostudio, Soil nail, SLOPE/W.

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INTRODUCTION

Soil Slope is a surface of soil mass which is inclined. It can be natural or engineered slopes. Slope must be stable. It is important to analyse slopes such s their balance , shear strength and ability to withstand movement to ensure slope failure does not occur. Slope stability analysis is done to assess the safe design of engineered or natural slopes and the equilibrium conditions. The stability of a slope is essentially controlled by the ratio between the available shear strength and the acting shear stress, which can be expressed in termsof a safety factor. A slope can be globally stable if the safety factor, computed along any potential sliding surface running from the top of the slope to its toe, is always larger than one. The smallest value of the safety factor will be taken as representing the global stability condition of the slope. Similarly, a slope can be locally stable if a safety factor larger than one is computed along any potential sliding surface running through a limited portion of the slope. Values of the global or local safety factors close to one indicate marginally stable slopes that require attention, monitoring or an engineering intervention (slope stabilization) to increase the safety factor and reduce the probabilityof a slope movement. Slope stabilization refers to any implemented technique that aims to improve the strength of an unstable or inadequately stable slope.

The purpose of slope stabilization techniques is to increase the Factor of Safety of a slope to a level that is considered adequate. Soil Nailing is a slope stabilization technique by inserting soil nails into slopes. Soil nails are slender reinforcement bars. The soil nails are inserted into predrilled holes and it is grouted. Soil nail provide horizontal restraint to guard against active failure. The installation of soil nails help to defer the original failure planes of slope to greater depth inside the slope which is high stability condition. It is also economical and ecofriendly technique. In this work, effect of length of soil nail on stability of reinforced slope is studied. Geostudio software is used in this work. Geostudio is an integrated software suited for modelling slope stability, ground deformation, heat and mass transfer in soil and rock. Geostudio is software by Geoslope. Here, the limit equilibrium method is used which is the most common approach for analyzing slope stability in both two and three dimensions. This method identifies potential failure mechanisms and derives factors of safety for a particular geotechnical situation. Geostudio combine analysesand geometries in a single integrated project. This software has multi view modeling environment. Geostudio defines geometry using drawing tools or by importing CAD files. It also supports multiple geometries. It is an efficient software and allows parallel solving. It interpret results with powerful graphing, visualization data management, and data interpretation.

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Farzin Elmasi et al (2019) studied slope stability depends on factor of safety and also factor of safety depends on cohesion, angle of internal friction and unit weight. Talha Nalgire et al (2020) studied the effect of angle of slope on factor of safety..Poulami Ghosh et al(2012) studied inclusion of reinforcement increases factor of safety by 12-30%.The study of V Rotte et al (2013) shows with horizontal back slopes, optimum nail inclination increases with decrease in slope inclination but increases with increase in back slope inclination. Robert M Koerner et al (2015) studied stabilization of soil slopes using nail or anchor connected with geosynthetics. Md Akhtar Hossain et al(2016) studied effect of soil nail on stability of slopes and concluded optimum nail angle as 300. Felipe A etal (2020) studied the effect of nail spacing on soil slopes and concluded that as spacing increases, factor of safety decreases.

EXPERIMENTATION

In this study, soil sample was collected from slope at place, Karikode, Ernakulam. The soil collected is laterite soil. Preliminary tests like Natural moisture content, specific gravity, sieve analysis and atterberg limit tests were carried out. Direct shear test was performed to know the value of cohesion and angle of internal friction. In this work, geostudio SLOPE/W has been applied.

Geostudio enables you to combine analysis using different products into a single modeling project, using the results from one as the starting point for another. Multiple geometries, including 1D, 2D and 3D geometries may also be included in a single file. Geostudio provides many tools to define the model domain including coordinate import, geometric item copy-paste, length and angle feedback, region merge and split, and DWG/DXF file import. BUILD3D, Geostudio's 3d geometry creation tool, offers a comprehensive suite of sketch features. Geostudio runs each analysis solver in parallel, allowing multiple analyses to be solved efficiently on computers with modern, multi- core processors. This saves substantial solve time especially for large 3D analyses. Geostudio provides powerful visualisation tools, including graphing, contour plots, isolines or isosurfaces, animations, interactive data queries and data exports to spreadsheets for further analysis. Limit Equilibrium method is used here. Mongenstern Price method is used for analysis. The effect of length, spacing and angle of inclination of soil nail is found. Firstly, the slope is modelled. Then, materials are assigned using cohesion, angle of internal friction and unit weight. Entry and exit slip surface is provided. Then reinforcement like soil nail is provided and factor of safety is found.

Soil nailing as an effective stabilization technique for the slopes, excavations, rail or road embankments, tunnels and retaining walls wherein, passive reinforcement is done by the insertion of slender elements (normally steel reinforcing bars) called soil nails. The soil nail can be installed horizontally or gently inclined parallel to the direction of tensile strain so that it develops 12 maximum tensile force. The function of soilnailing is to improve the strength or stabilize the existing steep slopes and excavations as construction proceeds from the top to bottom. Due to the ground deformation, tensile forces develop in soil nail and they develop their reinforcing action through soil-nail interaction. Due to development of axial force, major part of resistances comes which is basically a tension force. Conventionally, little contribution is provided by shear and bending in providing resistance. The effect of soil nailing is to improve the stability or strength of slope through; a) Increasing the normal force on shear plane and hence increase the shear resistance along slip plane in friction soil. b) Reducing the driving force along slip plane both in friction and cohesive soil. The soil nail system can be divided into active and passive region. Active region tends to deform during slope failure which results in an axial displacement along soil nails which are placed across the slip plane. This results in the development of tensile forces in soil nail in the passive zone which resists the deformation of active zone. This tension force results in increment of the normal force coming on slip plane and reduces the driving shear force. The soil nails are embedded in passive region through which it resists the pull-out of nail from slope through friction between nails and soil. The required amount of nail length should be placed in resistive zone based on the above two mechanisms. In addition, the combined effect of nail head strength and tension force generated in active zone must be adequate to provide the required nail tension at the slip surface.
The results are shown in below tables.

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Table 1 . Preliminary Tests Results

S No	Preliminary tests	Results
1	Wet Sieve analysis	Coarse-grained
2	Natural moisture content	17.60%
3	Specific gravity	2.64
4	Liquid limit	45%
5	Plastic limit	30%

The above table shows preliminary tests results. Soil is laterite. From wet sieve analysis, less than 50% soil retained in pan so soil can be classified as coarse grained.

Table 2. Effect of length of soil nail on factor of safety

S No	Length(m)	Factor of safety
1	0.8H	1.728
2	0.9H	1.827
3	1H	2.155
4	1.1H	2.473
5	1.2H	2.815

From table 2, it is clear that as the length of soil nail increases, factor of safety increases. Length is considered from range of 0.8 times height of slope (H) to 1.2 times height of slope. Maximum factor of safety is obtained for 1.2H.

Table 3. Effect of spacing of soil nail on factor of safety

S No	Spacing	Factor of safety
1	1	2.270
2	1.25	2.166
3	1.5	1.725
4	1.75	1.349
5	2	1.299

From table 3, it is clear that spacing of soil nail increases, factor of safety decreases. Maximum factor of safety is obtained for 1m spacing.

Table 4. Effect of angle of inclination of soil nail on factor of safety

S No	Angle(^{0})	Factor of safety
1	0	2.270
2	30	2.931
3	45	2.768
4	60	2.388
5	75	1.995

Table 4 shows optimum angle of inclination of soil nail is 30 with factor of safety of 2.931.

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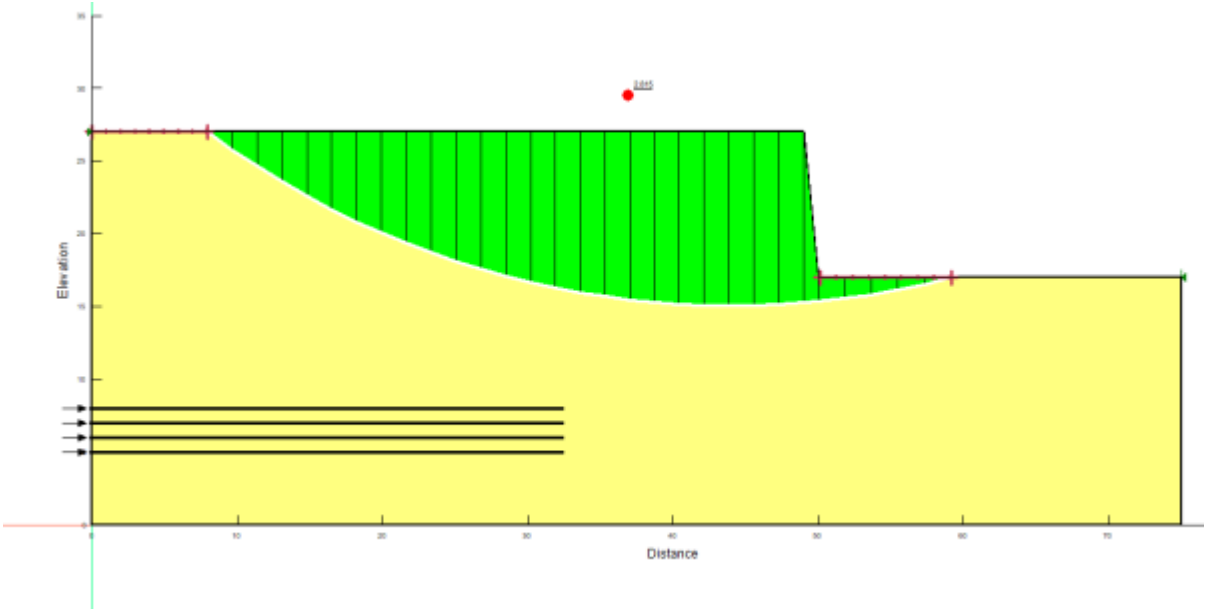

Fig 1. Factor of safety when 1.2h=32.4m soil nail is provided

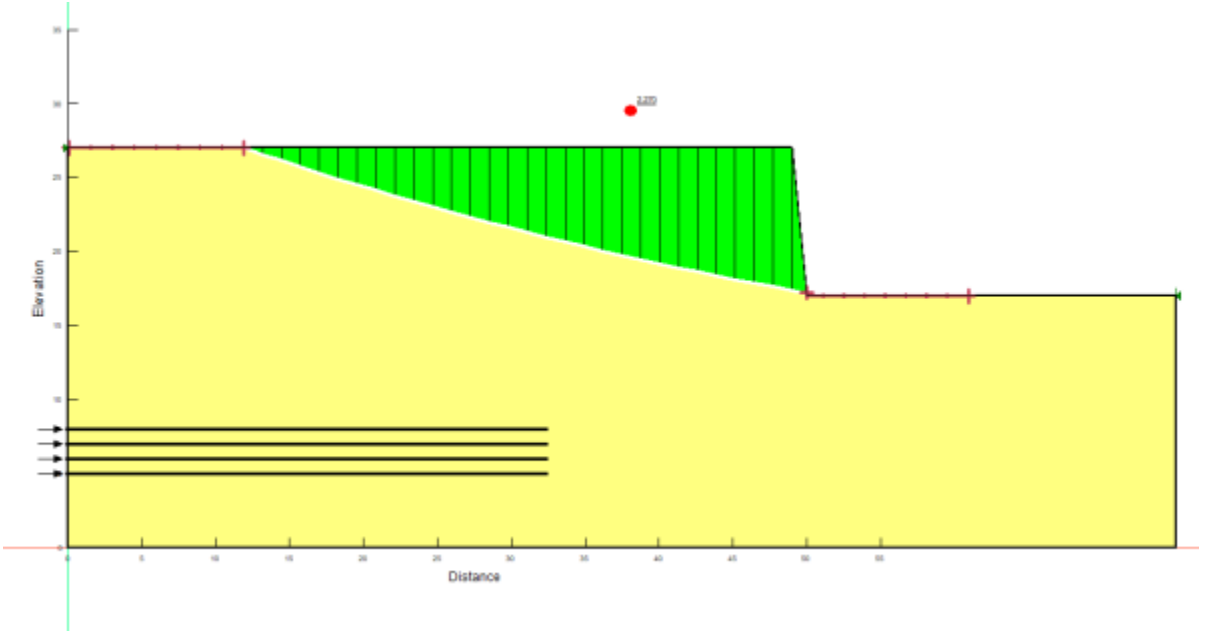

Fig 2. Factor of safety when soil nail is provide at1m spacing

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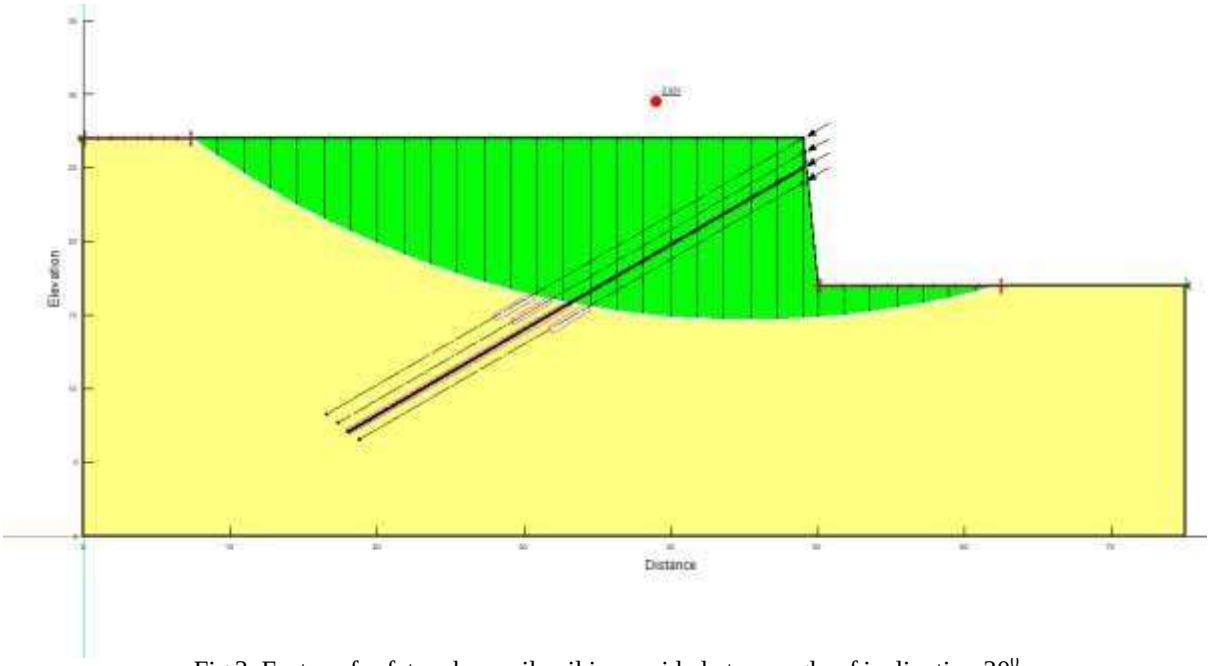

Fig 3. Factor of safety when soil nail is provided at an angle of inclination 30^{0}

CONCLUSION

Slope Stability is determined by factor of safety. Factor of safety is the ratio of actual strength to required strength. Allowable limit of factor of safety is one. Slope is stable if factor of safety is more than one. Slope is unstable if factor of safety is less than one. The slope taken for analysis is slope at Karikode, Ernakulam district. Factor of safety of the slope is found to be 1.10. As the factor of safety of slope considered is 1.10 which is close to allowable limit, reinforcement is provided to improve factor of safety. Reinforcement is provided in the form of soil nail. The effect of length, spacing and angle of inclination of soil nail on factor of safety is found. It is found that as the length of soil nail increases, factor of safety increases. As the spacing of soil nail increases, factor of safety decreases. More factor of safety is obtained for soil nail inclined at 30^{0}. Considering effect of length of soil nail, there is an increase of 155.9% of factor of safety. There is an increase of 106.4% of factor of safety when spacing is considered. There is 166.5% of increase of factor of safety when soil nail is provided at 30^{0}.

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