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Analysis of Effect of Anti Slide Pile on Stability of Slopes

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Abstract—*The slopes of weak soil are very unstable and can cause serious damage of life and property if not analyzed and reinforced properly. There are various methods of improving the stability of slopes, one such method is installing anti-slide piles. In this study anti-slide piles have been used to improve stability of considered soil-slope and analyzed variation of various parameters like pile spacing, length and pile position with respect to FOS of the slope. After analysis it was found that as pile length increases the FOS increases only upto a critical pile length, as pile spacing decreases the FOS increases and maximum FOS is obtained when pile is positioned somewhere between toe and heel of the slope.*

Keywords: *Soil Stability, Factor of Safety, Anti-Slide Pile, Pile position.*

1. INTRODUCTION

Anti-slide piles have been utilized in the treatment of very unstable soil-slopes, and have been proved to be an effective reinforcement method. It considerably increases the factor of safety of the slope. The piles are considered as passive piles in the upper unstable soil layer but active piles in the lower stable soil layer. For slopes with great depth between ground surface and stiff stratum, the solution is impractical to embed piles into bedrock or a stable layer (infinite pile length assumption). Thus, the embedded length of piles is an issue and attracts great attention. Griffiths et al. studied the influence of pile reinforcement on stability of slopes by numerical analysis, and presented the influences of pile length on stability and factor of safety of slope. But the analysis was carried out under two-dimensional plane strain, which could not reflect the actual pile-slope interaction. Qin and Guo conducted some model tests on vertically loaded single piles in sand subjected to either a uniform or a triangular profile of soil movement, and studied the effect of depth of soil movement on pile behavior. Yoon et al. introduced a simple chart for laterally loaded short piles in cohesion less soils to account for the effect of “finite slope”, and expressed the required pile length in a slope as a dimensionless ratio. In this study a soil slope case is considered for analysis and it is modelled in GE05 software. Anti-slide piles have been used I the slope model. Then the effect of parameters like pile spacing, pile position and pile spacing on the factor of safety of the slope have been analyzed to determine optimum pile parameters.

2. BISHOPS METHOD

In this study for the calculation of the factor of safety of the soil slope case considered bishop’s method of slices has been adopted. The analysis of the slope model for the FOS was carried out on GE05 2020 soil stability program. This program is used to perform slope stability analysis (embankments, earth cuts, anchored retaining structures, MSE walls, etc.). A slices method of slope stability analysis which involves a different procedure and gives different answers compared with the Ordinary Method of Slices has been proposed by Bishop (1955). This method, the analysis is carried out in terms of stresses instead of forces which were used with the Ordinary Method of Slices. The stresses and forces which act on a typical slice and which are taken into account in the analysis are shown in Fig. The major difference between the Bishop Method and the Ordinary Method of Slices is that resolution of forces takes place in the vertical direction instead of a direction normal to the arc (a direction which is different for each slice). In the simplified Bishop Method which is described here, it is assumed that the shear side forces X may be neglected without introducing serious error into the analysis.

3. NUMERICAL MODELLING

In this study slope case considered consist of 3 layers of soils and one weathered bedrock. The slope was modelled in the GE05 2020 software interface. The first step in the software is to select the limiting FOS which was considered as 1.5 in this study as shown in Fig. 1. Then, interface coordinates are entered either manually or textually as shown in Fig. 2.

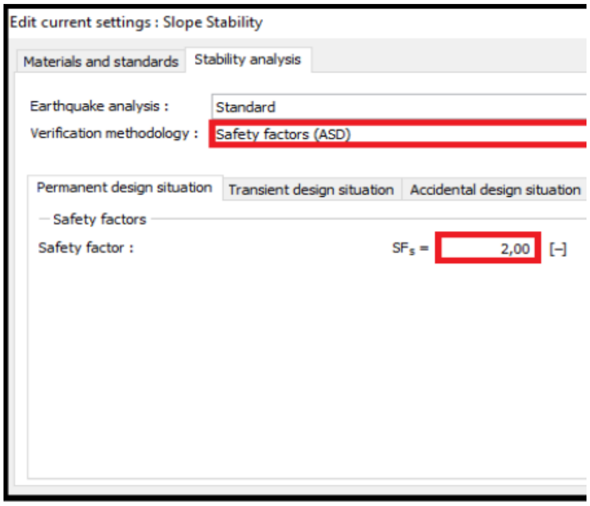
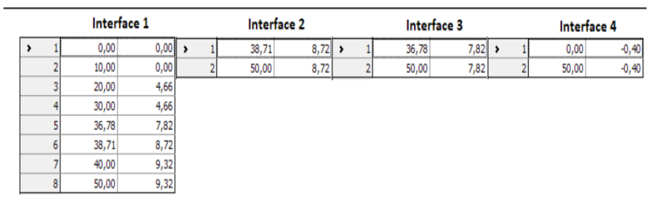


Fig. 1: Specifying limiting FOS



	Interface 1		Interface 2		Interface 3		Interface 4	
1	0,00	0,00	38,71	8,72	36,78	7,82	0,00	-0,40
2	10,00	0,00	50,00	8,72	50,00	7,82	50,00	-0,40
3	20,00	4,66						
4	30,00	4,66						
5	36,78	7,82						
6	38,71	8,72						
7	40,00	9,32						
8	50,00	9,32						

Fig. 2 Interface coordinates

After specifying the interface details soil parameters are entered, here in this slope case soil considered are silt with low plasticity, clayey sand, sandy clay, sandy clay and weathered slate as bedrock. The parameters are entered and soil are assigned on the interface. A surcharge is also assigned on the slope of 25 KN/m2 as shown in the Fig. 3. The Ground water table was also applied in the slope to introduce effects of pore water pressure and effective stress. The coordinates of GWT is shown in the Fig. 4.

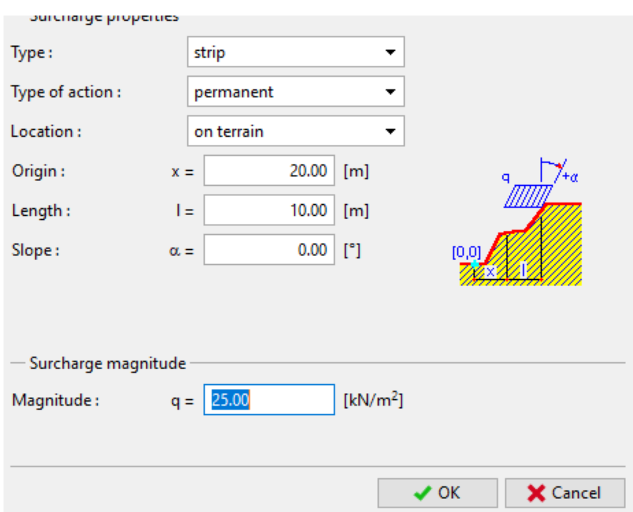
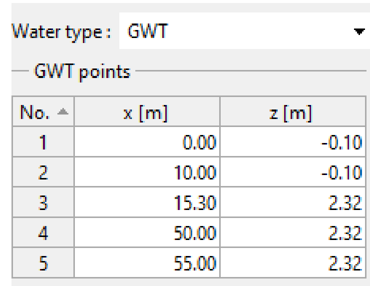


Fig. 3 Defining surcharge on the slope



No.	x [m]	z [m]
1	0.00	-0.10
2	10.00	-0.10
3	15.30	2.32
4	50.00	2.32
5	55.00	2.32

Fig. 4 Ground Water table coordinates

Now pile parameters are defined. Anti-slide pile defined is of circular cross section in one row. The diameter of the pile is 0.66 m and the initial length is 9 m. it is initially positioned at the toe of the slope. Usually we do not know the ideal position for inserting an anti-slide pile. The pile must always intersect a slip surface and it should go all the way into the geological layers with a greater bearing capacity. One of the major aim of the study is to determine the ideal position of the pile. Now, the slope interface can be seen in the figure-5.

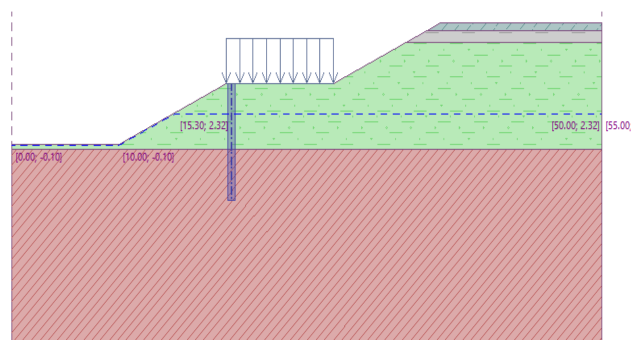


Fig. 5 Final slope model in the software

Thereafter finally defining all the necessary parameters the analysis for FOS is undertaken in this case by bishop's method of slices. The FOS obtained is compared to limiting FOS value for slope stability. A 3-dimensional view of the slope interface can be seen in the Fig. 6.

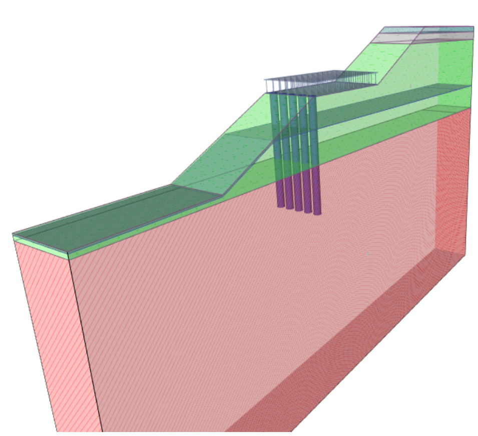


Fig. 6 A 3-D view of soil-slope model on GE045 2020 interface

4. RESULTS AND DISCUSSIONS

After undertaking the analysis of proposed soil slope reinforced with row of anti-slide piles various observations were made. The variation of soil slope was studied in reference to the change in length of piles, spacing of pile and position of pile.

4.1 Effect of length of the pile

When piles with an equivalent Young's modulus, Ep = 60 GPa, are installed in the middle of the slope with Lx =9 m. The effect of embedded pile length on the factor of safety of the slope reinforced with piles is shown in Fig.1 (where Ep = 200 GPa is given to study the effect of pile bending stiffness). As expected, the factor of safety of the slope reinforced with one row of piles tends to increase with increasing length of piles. When the embedded pile length exceeds a critical value, (in this case 15 m) namely, the critical pile length, which may be different for various pile spacing, the factor of safety of the slope will gradually approach to be a constant value.

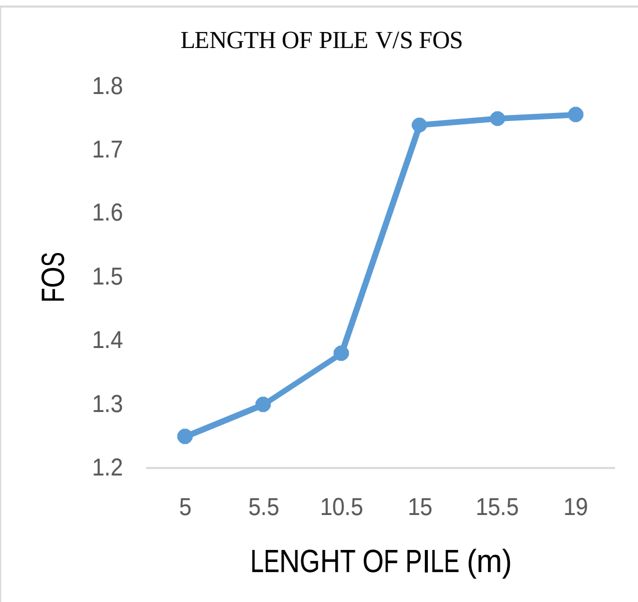


Fig. 1 Effect of length of pile on FOS of slope

4.2 Effect of spacing of piles

The effect of pile spacing on the factor of safety is shown in Fig.2. As the piles pacing decreases, the piles become more like a continuous pile wall and the stiffness of the soil and piles becomes greater, so the lateral bearing capacity of the slope has been greatly improved and the affected area, reflected by the critical pile length, has been expanded. This can be interpreted by the pile behaviors for various pile spacing, as shown in Fig.2.

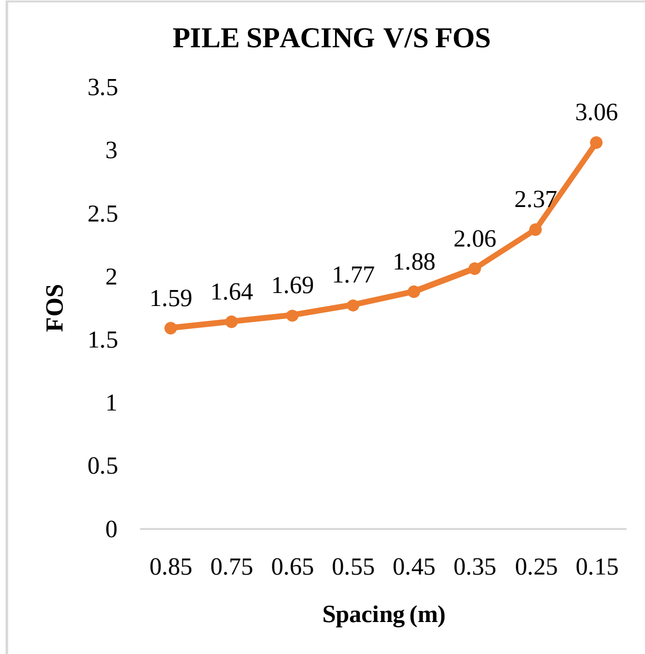


Fig. 2 Effect of Pile Spacing on FOS

4.3 Effect of Pile Position

The effect of pile position on FOS is shown in the Fig. 3. Initially pile was positioned at the toe of the slope where an FOS of 1.17 was observed. Then moving the pile position up away from the toe the FOS increases. And the FOS is maximum when the pile is 7m away from the toe then FOS decreases.

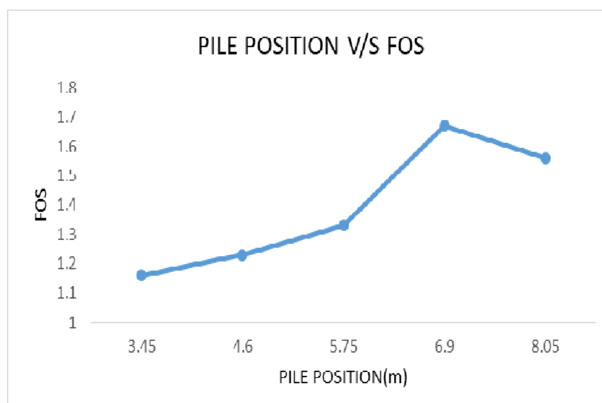


Fig. 3 Effect of Pile Position on FOS

5. CONCLUSION

The stability of a slope can be improved with anti-slide piles, and, the factor of safety increases with increasing pile length and tends to be a constant when the pile length exceeds the critical length. The critical length increases with decreasing pile spacing, and smaller pile spacing tends to increase the stiffness of reinforced slopes. Hence, optimum pile length would be around 10-15 m and optimum spacing for single row of pile for this case will be around 0.65-0.55 m. The pile position of anti-slide pile also has some influence on the stability of soil slope. With the increase of distance from anti-slide pile to toe of slope, safety factor of soil slope increased first and then decreases. The largest FOS is obtained when pile is about 7 m away from the toe.

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