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Stabilization of Slope with Piles – A Parametric Study on PLAXIS 3D

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ABSTRACT:
Failures of Unstable slopes have been a major disaster for the people of the world. It causes a lot of damage to public life as well as properties. Therefore proper analysis of the unstable slopes needs to be done with proper installation of piles to have adequate "factor of Safety" so that the slopes should not fail. The analysis and design of failing slopes and highway embankments requires an in-depth understanding of the failure mechanism in order to choose the right slope stability analysis method.

There are various methods available for the analysis of the existing slopes and to find the "Factor of safety". Some of the common methods used in this regard are the "Friction circle method", "Bishop's method" etc. But all these methods are tedious and time consuming. But with the use of "PLAXIS 3D" software, it has been possible to determine the "Factor of Safety" of the existing slope easily. Reinforcing piles are one of several options for improving the stability of failing slopes. The design and implementation of such a stabilizing scheme relies on traditional design methods based on limit equilibrium methods with a focus on the overall factor of safety and does not implicitly consider deformations.

In this paper, literature review has been done to study the theoretical background of the most widely used 3D slope stability method. Slope is analyzed to understand their mechanism by including pile using Finite Element Method [3]. The variation of safety factor for the slope stabilized with inclusion of vertical piles is analysed for a homogeneous slope of 1:1 slope angle. The variations are studied in terms of parametric analysis for clay and sandy slope by varying the pile parameters such as position, length and spacing of pile.

To gain a better understanding of slope behavior, a study was conducted to investigate the factor of safety of slopes with, and without, reinforcing piles with a goal of identifying the optimum design parameters. A finite element model consisting of pile was used in the analysis which was performed using the commercially available software PLAXIS 3D. Most of the research conducted so far focuses on the improvement in the overall factor of safety (FS) without investigating the actual influence of pile configurations. Finite element models were used to investigate pile spacing and the pile-row configuration. The deformation after pile stabilization is just as important as the actual overall factor of safety. This study investigated the effectiveness of the pile stabilization techniques in limiting deformations by considering: Spacing between piles installed in a row and variation of pile configuration: staggered pile rows.

KEYWORDS: Factor of Safety, FEM, Skin Resistance

INTRODUCTION:

Ground stability must be assured prior to consideration of other foundation related issues. Embankment foundation problems involve the support of the embankment by natural soil. Problems with embankments and structures occasionally occur that could be prevented by initial recognition of the problem and appropriate design. Stability problems most often occur when the embankment is to be built over soft soils such as low strength clays, silts, or peats. Once the soil profile, soil strengths and depth of ground water table have been determined by field explorations and/or field and laboratory testing, the stability of the embankment can be analyzed and a factor of safety estimated. If the embankment is found to be unstable, measures can then be taken to stabilize the foundation soils and/or embankment itself.

Insuring the stability of both natural and man- made slopes continues to be an important problem in geotechnical engineering. Slides account for many civil engineering failures and often result in extensive property damage and sometimes loss of human life.

There is no universally accepted method for the prevention and/or correction of landslides. Each slide is unique and should be considered on the basis of its own individual characteristics. Avoidance of a potential slide area can be a primary consideration when selecting a new site. Otherwise, corrective measures can be taken which include:

1. Improving the slope geometry by changing the slope angle, excavating the soil at the head, or increasing the load at the toe;
2. Constructing a compound slope; and
3. Providing surface and subsurface drainage.

However, where such corrective measures fail to insure stability or when their use is prohibited due to space limitations, retaining structures may be necessary. Piles carried across the active or potential failure surface can be used efficiently as the retaining element, since they can often be installed without disturbing significantly the equilibrium of the slope.

The analysis of a slope/pile system requires that the soil pressure acting on the piles, and the subsequent reaction that the piles provide to the slope, be known. There are several techniques which are currently used to estimate the pressures that act on active or passive piles. They include the coefficient of sub grade reaction method, methods based on the assumption of elastic soils and other empirical methods. Most of these techniques either consider the solution of a single pile or introduce corrective factors to analyze the row of piles, or treat the row of piles as a retaining wall. The first approach can lead to inaccurate answers in case of passive piles, while the second approach provides very conservative answers.

MODELING:

A 3D finite element solution has been obtained for a row of single pile installed in a homogeneous soil slope. The slope is 10 m high with the rigid base at 30 m below the ground surface. The analysis is carried out for various soil and pile properties using homogeneous soil slope of constant thickness 6 m with slope inclination of 1:1 and the piles are provided to improve the safety of the slope.

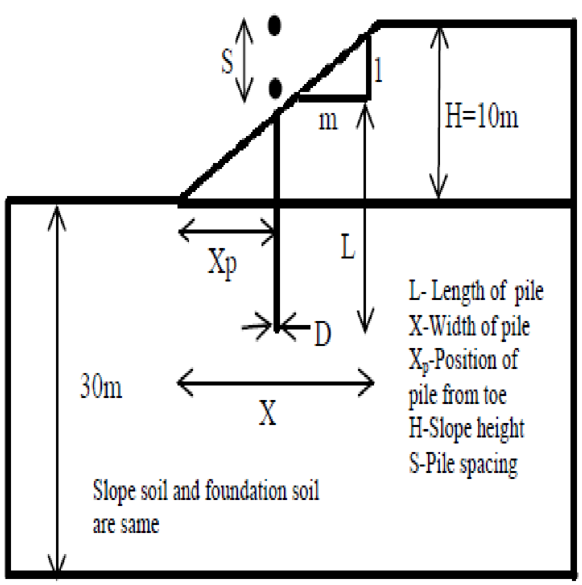

Figure 1 Geometry of the pile slope system

MATERIAL PROPERTIES:

The properties of the homogeneous soil and stabilizing pile are shown in Table.

Table 1 Material parameters for the soil

Input Parameter	soil	Unit
Young's modulus, E	20000	kN/m^2
Poisson's ration, ν	0.25	-
Saturated unit weight, γ_{sat}	20	kN/m^3
Unsaturated unit weight, γ_{unsat}	18	kN/m^3
Cohesion, C	25	kN/m^2
Friction angle, Φ	10	º

Table 2 Material parameters for the Pile

Input Parameter	Pile	Unit
Young's modulus, E	$30*10^6$	kN/m^2
unit weight, γ	25	kN/m^3
Pile type	Predefined	-
Predefined Pile type	Massive circular pile	-
Diameter, d	0.5	
Skin resistance	Linear	-
Maximum traction allowed at the top of the embedded pile	$T_{top, max}$	200
Maximum traction allowed at the bottom of the embedded pile	$T_{bottom, max}$	500
Base resistance	F_{max}	10000

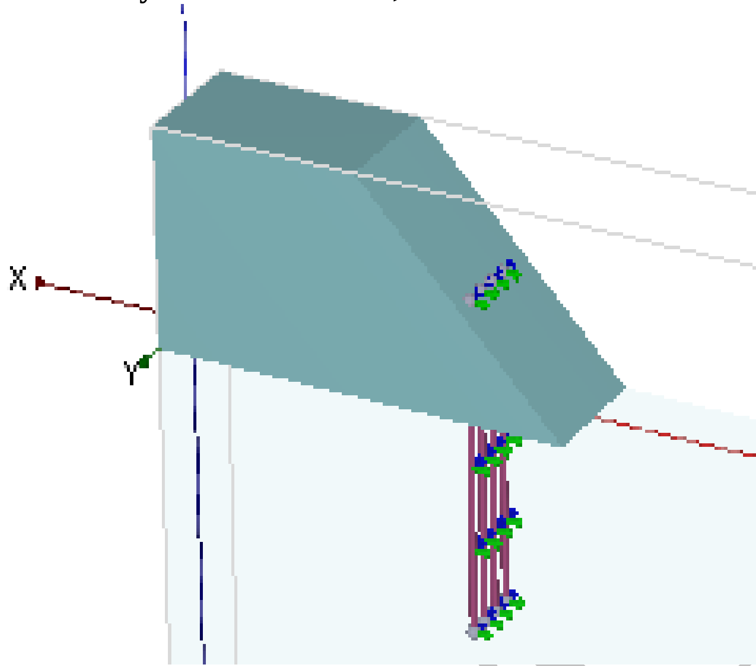

Figure 2 Slope model generated in PLAXIS 3D

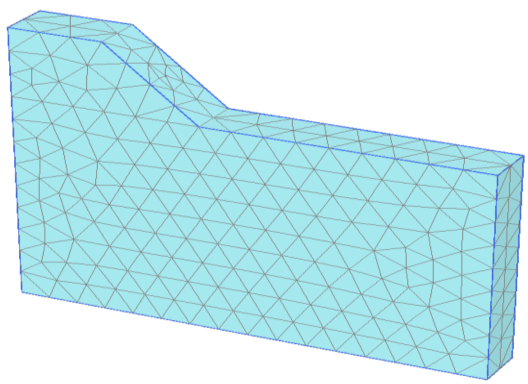

Figure 3 3D mesh generated in PLAXIS 3D

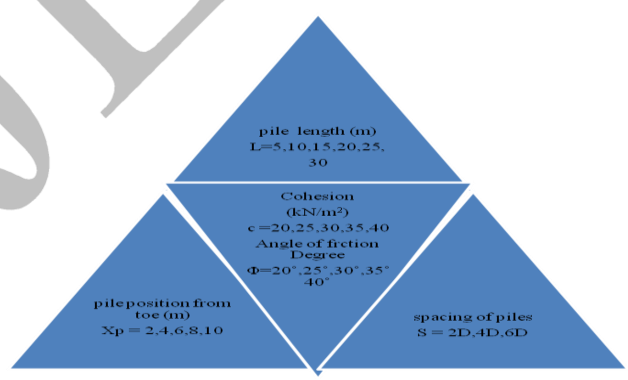

Figure 4 Variation of parameters for c and Φ

RESULTS:

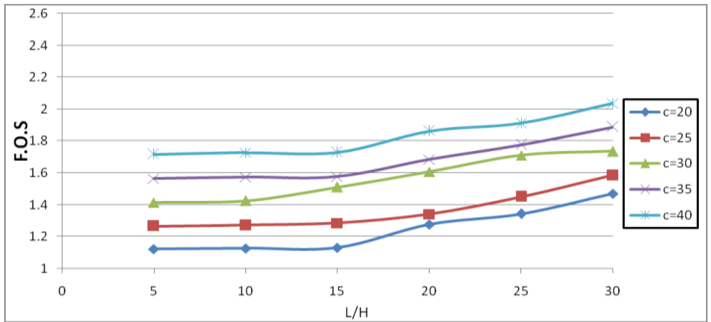

Figure 5 Variation of safety factor with respect to the length of the pile for clayey soil slope

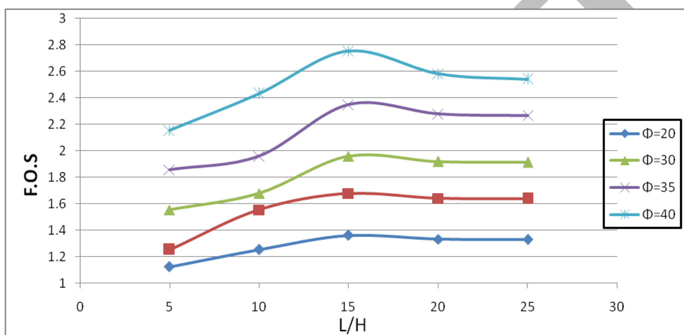

Figure 6 Variation of safety factor with respect to the length of the pile for sandy soil slope

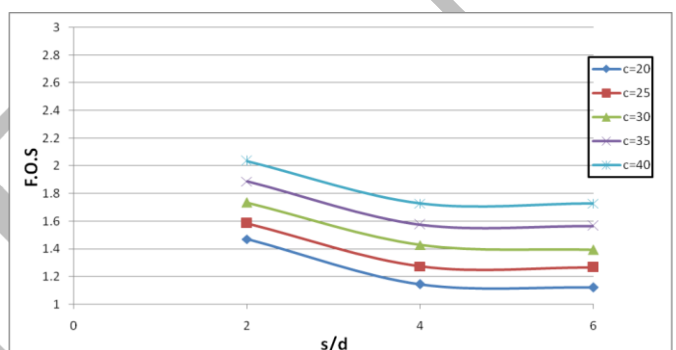

Figure 7 Variation of safety factor with respect to the s/d ratio for clayey soil slope

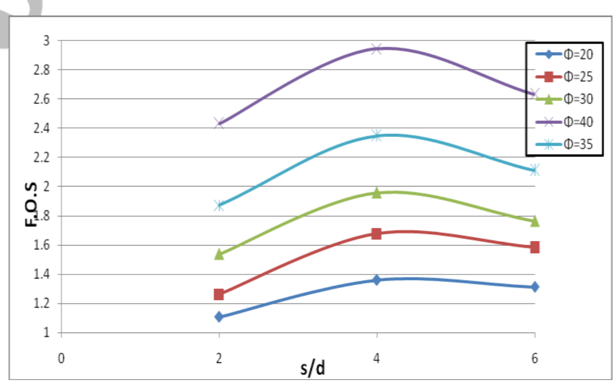

figure 8 variation of safety factor with respect to the s/d ratio for sandy soil slope

CONCLUSION:

From the result analysis it is found that in clayey soil slope and in sandy soil slope, the factor of safety is maximum when the pile is at the centre of the slope. The FOS increases with increase in length of the pile. It is found that there is marginal increase in FOS beyond certain length. The length is more effective when length to depth (depth of slope) ratio (L/H) lies between 1 and 1.5. The safety factor decreases with increase in pile spacing. The optimum spacing is 4D for the sandy slope of 1:1 and the spacing has marginal influence the case of clay slope.

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