HBRC Journal (2015) xxx, xxx–xxx

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

The effect of pile parameters on the factor of safety of piled-slopes using 3D numerical analysis

Ahmed Abdelaziz, Dahlia Hafez *, Ashraf Hussein

Civil Engineering Department, Cairo University, Cairo, Egypt

Received 11 September 2014; revised 13 February 2015; accepted 16 June 2015

KEYWORDS

Slope stability;
Piles;
Factor of safety of slopes;
3D finite element analysis

Abstract Slope stability can be achieved using different methods. Piles are commonly used to stabilize slopes or to improve slope stability. Stabilized slopes with piles are numerically studied in the current paper. A 3 dimensional (3D) finite element study is carried out to investigate the effect of different parameters on the stability of slopes stabilized with piles. A 3D finite element model was developed using the finite element program PLAXIS. The 3D model was verified using experimental data from the literature for a stabilized silty sand slope in a large-scale physical model. A parametric study was undertaken to study the effect of pile position, pile inclination, pile length and pile diameter on the factor of safety of the piled-slopes. The findings of the research were compared to other findings from the literature. The results show that using the 3D aspect gives more insight into the complicated slope stability problem. The study determines the optimum location of the pile and its optimum inclination to achieve the maximum stability. It shows that after a certain length of the pile, increasing the pile length becomes unnecessary and that the diameter of the pile has a relatively minor effect on the factor of safety of piled-slopes.

Introduction

Slopes can be stabilized using many methods including geotextiles, nails, piles, and pitching [1]. Stabilizing slopes with piles is one of the commonly used methods. The analysis of slopes stabilized with piles can be carried out using either an uncoupled or a coupled approach. Most common methods used to calculate the stability of piled-slopes use an uncoupled approach, where the limit soil pressure is obtained using an analytical, empirical or numerical method and, subsequently, the limit soil pressure obtained is used as an additional resistance in slope stability analysis using limit equilibrium methods. It is found that the loading on piles predicted using the currently available theories may differ significantly or may be similar depending on the investigated problem. The uncoupled approach was studied by many researchers [2–9].

On the other hand, coupled analysis approach is receiving more attention in the recent years where powerful numerical

* Corresponding author at: 3225 Dougall Ave, Windsor, Ontario N9E1S8, Canada. Tel.: +1 226 2464257.
E-mail addresses: eng.ahmadaziz@hotmail.com (A. Abdelaziz), dahliahafez@gmail.com (D. Hafez), ashrafkh07@gmail.com (A. Hussein).

Peer review under responsibility of Housing and Building National Research Center.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.hbrcj.2015.06.002

Please cite this article in press as: A. Abdelaziz et al., The effect of pile parameters on the factor of safety of piled-slopes using 3D numerical analysis, HBRC Journal (2015), http://dx.doi.org/10.1016/j.hbrcj.2015.06.002

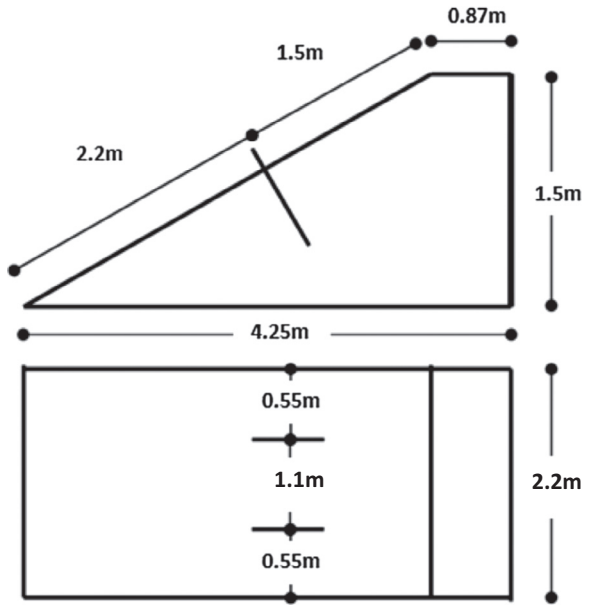

Fig. 1 Geometry of the experimental model by Bozok [14].

Table 1 Properties of soil material for the FE model.

Parameter	Value
E	34 MPa
v	0.25
Maximum dry unit weight	18 kN/m^3
Drained angle of internal friction	33°
Effective stress cohesion intercept	3.4 kPa
Model type	Mohr–Coulomb
Drainage type	Drained
Interface	Rigid

Table 2 Properties of pile material for the FE model.

Parameter	Value
E	2 * 10^8 kPa
Maximum dry unit weight	23 kN/m^3
Diameter	0.05 m
Length	0.89 m
Inclination	Perpendicular to surface (I = 40°)
Skin resistance	Linear

tools (2D and 3D finite element analyses) are becoming increasingly available [4,9–12]. In the coupled approach both the pile response and slope stability are considered simultaneously.

In the current study, coupled analysis is performed using a 3D finite element method to investigate the efficiency of stabilizing slopes with piles and to study the effect of different parameters on the slope stability. It is believed that the finite element method will provide good insight into the 3D nature of the complicated problem presented by slopes reinforced using structural members or piles.

In the following sections, the developed 3D finite element model is first presented and verified with an experimental large-scale model. The developed model is then used to perform the parametric study to investigate the effect of pile location, inclination, length and diameter on the factor of safety of slopes stabilized with piles. The results are compared with the literature results. Finally, conclusions giving insight to the optimum choice of parameters which have a direct application to engineers dealing with slope stability are presented.

Finite element modeling

A 3D numerical model is developed using the 3D finite element geotechnical program PLAXIS [13]. The model was verified with an experimental model obtained from the literature. The experimental model is presented followed by the verification of the finite element (FE) model. The 3D FE model to be used in the parametric study is finally presented in this section. More details of the model and its verification are available in the literature [14,15].

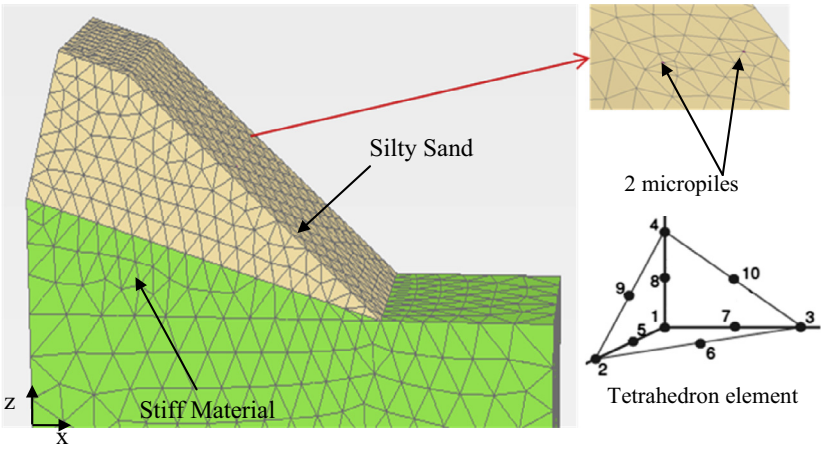

Fig. 2 Finite element mesh.