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Numerical Analysis Of The Bearing Capacity For Inclined Sandy Soil Supported By A Pile Wall.

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Abstract
This paper presents a theoretical analysis of the strip footing behavior due to the existence of a pile wall to withstand the slope of sandy dense and medium soil under normally loading up to failure. The selection of the pile wall as a support in the current study refers to its ability to deep propagation through soil. The applications of the present study are used in; tunnels, swimming pools, bridges abutments, slopes of irrigation, roads and railways. PLAIX-2D ver. 8.2 was applied to solve numerically the present case study. The parameters studied are; slope angle, distant away from the slope crest, foundation depth, and the successive excavated layers on the other side of the pile wall. The study is directed towards the effect of the studied parameters on the bearing capacity for both dense and medium dense sandy soil. The results were validated by comparing them with previous studies with an acceptable uncertainty. At a slope of 30^0*, the more increase in the distant away from the crest up to the footing width results in an increase of about 13% in the bearing capacity. The bearing capacity reduces by about 14% due to the excavation thickness equal to the distant away from the crest, 35% reduction in the bearing capacity for an excavation equivalent to the double of the distant the crest, and 52% reduction for an excavation equivalent to three times of the distant from the crest. It was noted that the increase in the slope by* 5^0 *will result in more bearing capacity reduction by about 17%.*

Keywords: *Bearing capacity, Slope stability, Sand soil, pile wall, Numerical analysis.*

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I. Introduction

The introductory survey will provide a brief review of the previous works related to the current study as follows.

Salih Keskin, M. [1], Zerguine, S., et al. [2], Acharyya, R. and Dey, A. [3], Baah-Frempong, E. and Shukla, S.K., [4], Yang, S., et al, [5] investigated the ultimate bearing capacity on sandy slope to study the effect of different parameters such as setback distance of the footing to the slope crest, angle of slope, footing width and relative density of sand on the strip footing ultimate bearing capacity. This study demonstrated that the bearing capacity significantly affected by different parameters, where bearing capacity increasing with increase set back distance, footing width and relative density of sand and decrease with increase the angle of slope. El Sawwaf, M., [6],[7] studied using sheet pile wall in stabilizing soil sandy slope to study the effect of location, height and stiffness of sheet pile wall, set back distance of the footing to the slope crest and relative density of sand. The results indicated that the sheet pile wall has a significant effect in improving the bearing capacity of a strip footing, increasing sheet pile height lead to increasing the bearing capacity and the optimal location of sheet pile wall is at the slope crest.

The soil reinforced with piles and the effect of using pile and the optimal location of pile on the stability of slopes and bearing capacity improvement was investigated by Ausilio, E., Conte, E. and Dente, G., [8], Li, X., [9], Sharafi, H. and Sojoudi, Y., [10], Zhang, G., Wang, L. and Wang, Y., [11], Hajiazizi, M., Bavali, M. and Fakhimi, A.,[12], Sojoudi, Y. and Sharafi, H., [13]. The effect of stone columns and encased stone columns on improving the bearing capacity and stability of slopes was studied by Raee, E., [14], Nasiri, M. and Hajiazizi, M., [15]. Elsaied, A.E., [16], Induja, P.C. and Salinitha, K., [17] investigated the effect of micro piles on the bearing capacity and and micro pile location and depth on the bearing capacity. Zhang, G., Wang, L. and Wang, Y., [18] Studied pile reinforcement mechanism of soil slopes and its affected on the bearing capacity. The effect of geogrid reinforced earth slope on the bearing capacity behavior of a strip footing, effect of number of geogrid layers and location in the ground on the bearing capacity improvement was studied by Yoo, C.,[19]. Altalhe, E.B., Taha, M.R. and Abdrabbo, F.M., [20] investigated the effect of reinforced slope with geotextile and its effect in improving the bearing capacity and the slope.

From the previous survey, and up to authors experiences, the present work deals with the studying of the bearing capacity of an inclined earth that was supported previously by a pile wall. The study was carried out numerically using PLAXIS 2-D 8.2 which was validated by previous published works at the same conditions. And as a consequence, one can formulate the aims of the present work as the following systemized items:

1- Study the effect the inclination angle of a supported sloping earth using pile wall on the bearing capacity of the soil.
2- Study the effect of the location of the footing with respect to the slope crest on the bearing capacity.
3- Study the effect of the foundation depth on the bearing capacity.
4- Study the effect of the existence of a single or multiple excavation layers that are adjacent to the pile wall on the bearing capacity taking into consideration keeping the effective depth of the pile.

Proposed model for study

The present work deals with a numerical simulation of the possibility of building construction in a safe manner over an inclined soil. The main geometrical specifications of the proposed model are conducted with a fixed height between the toe and the crest at one and half foundation width. However, the inclination angle differs. The proposed model considered the existence of a pile wall which its vertical end surface coincides on the toe. The model was directed towards to explore the bearing capacity of both medium and dense soil at different situations from the crest for different foundation depth, as well as how does the bearing capacity affect by excavation beside the other vertical end surface of the pile. Thus, one can summarize what is numerical simulation going on to be as follows; 2-D numerical modeling was performed for many series using plane strain system of footing slope by using PLAXIS, as the soil has homogeneous properties along its width. Each series was performed to investigate the effect of one variable while the other ones were kept constants. A footing of the proposed model was suggested to be located at different distances from the slope crest to investigate the effect of the distant apart of the footing from the crest on the bearing capacity. The distance between the footing and crest was varied from zero up to twice footing width and it was increased by a step equals footing width. The effect of the depth of the excavated soil layers in adjacent to the pile wall on the bearing capacity was monitored; as the depth of the excavated layers was varied from the footing width up to four times the footing width with a constant step equals footing width. The effect of foundation depth on the bearing capacity was investigated, the foundation depth was varied from zero up to one and half of the footing width, with a constant step equals half of the footing width. Also, different inclination angles; 30^0, 35^0 and 40^0 were suggested to investigate their effects on the bearing capacity, figure [1] show the geometry of the slope used in the study.

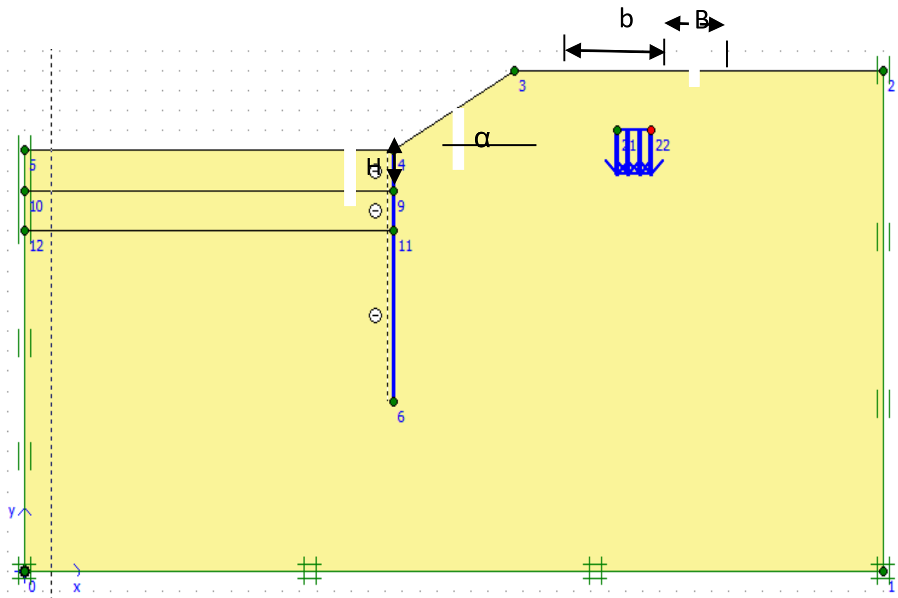

Figure 1 the geometry of the slope used in the study.

Modeling procedure

Mohr Coulomb modeling was used to analyze the suggested model in PLAXIS. The elasto – plastic Mohr Coulomb model includes five input parameters that describe the soil model; Young's modulus of soil (E), Poisson's ratio (ν), internal friction angle of the soil (φ), soil cohesion (C) and dilatancy angle (ψ). The pile wall was modeled as a plate which is having significant parameters; flexural rigidity (EI) and an axial stiffness (EA). Due to the difference between the materials of both pile wall and surrounding soil which results in a difference in friction factor at the interface, a correction factor was provided, (R_{inner}) value. After the geometry of the model was fully stated and the properties of each material were identified for all clusters and structural objects, the 15-node triangular element was selected to create a fine meshing for the frontal area of both the cluster and pile, figure (2), To check the mesh independence, a very fine mesh was performed once again for the same model at the same conditions and it was found a very slight difference between fine meshing and very fine meshing.

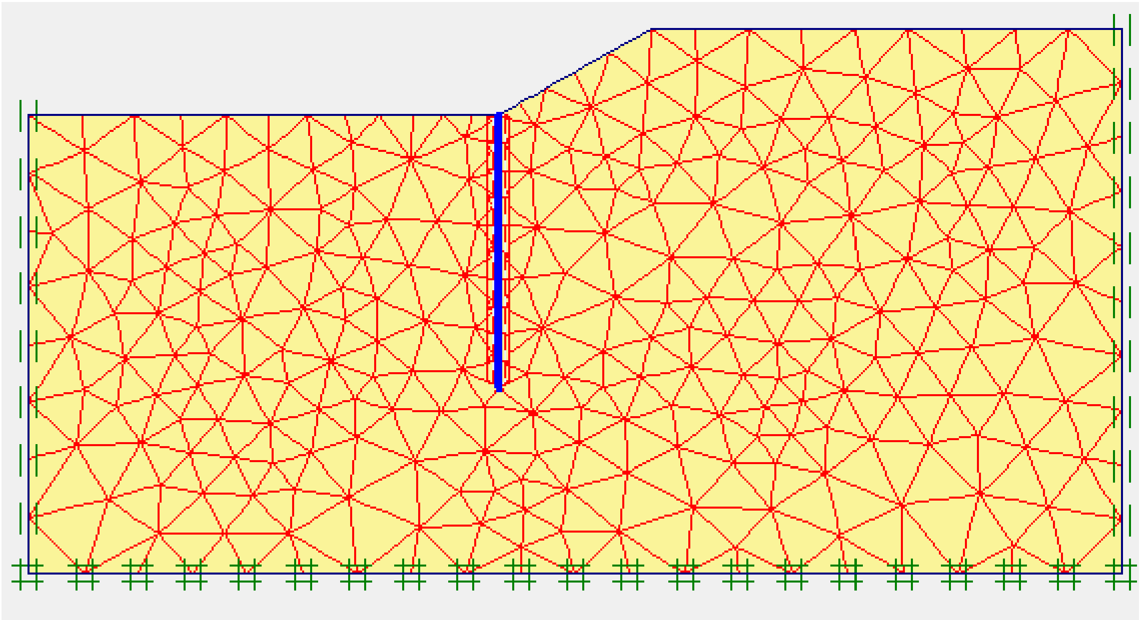

Figure 2 the model meshing and nodes.

II. Results And Discussion

Figure (3) shows the variation of bearing capacity versus both inclination angle and distant away from the slope crest as an area plot which itself repeats three times to show the effect of the excavated layer depth (H) at a constant foundation depth Df = 0.0. The lower area plots for H = 1B shows an increase in the bearing capacity as moving away from the slope crest for the same foundation depth. This is due to the more stability of the soil distant away from the crest, while, a slight decay in the bearing capacity was recorded as the inclination increase. The same trend is more noted for the three successive upper area plots at H=2B,3B,4B respectively.

Figure (4) clears the results that were plotted as area in figure (3) at foundation depth equal zero but at foundation depth equal half footing width. Also figure (5) explains the results that were plotted as area in figure (3) at foundation depth equal zero but at foundation depth equal footing width. And figure (6) leds to the results that were plotted as area in figure (3) at foundation depth equal zero but at foundation depth equal one and half footing width. These figures were plotted for dense soil. Figure (7) shows the variation of bearing capacity versus both inclination angle and distant away from the slope crest as an area plot which itself repeats three times to show the effect of the excavated layer depth (H) at a constant foundation depth Df = 0.0. The lower area plots for H = 0.5B shows an increase in the bearing capacity as moving away from the slope crest for the same foundation depth. This is due to the more stability of the soil distant away from the crest, while, a slight decay in the bearing capacity was recorded as the inclination increase. The same trend is more noted for the three successive upper area plots at H=2B, 3B, 4B respectively.

Figure (8) illustrates the results that were plotted as area in figure (7) at foundation depth equal zero but at foundation depth equal half footing width. Also figure (9) presents the results that were plotted as area in figure (7) at foundation depth equal zero but at foundation depth equal footing width. And figure (10) demonstrates the results that were plotted as area in figure (7) at foundation depth equal zero but at foundation depth equal one and half footing width. These figures were plotted for dense soil.

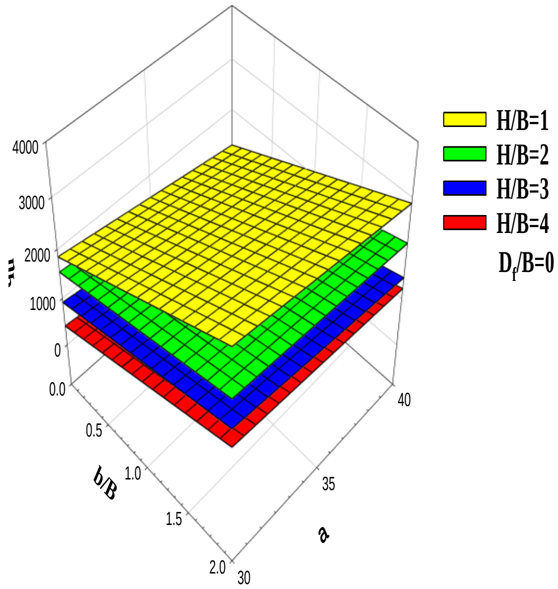

Figure (3) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth D_f = 0.0 for dense soil.

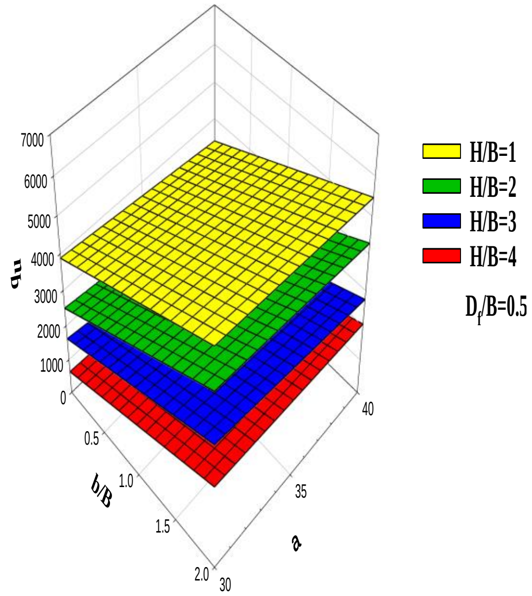

Figure (4) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth Df = 0.5 B for dense soil.

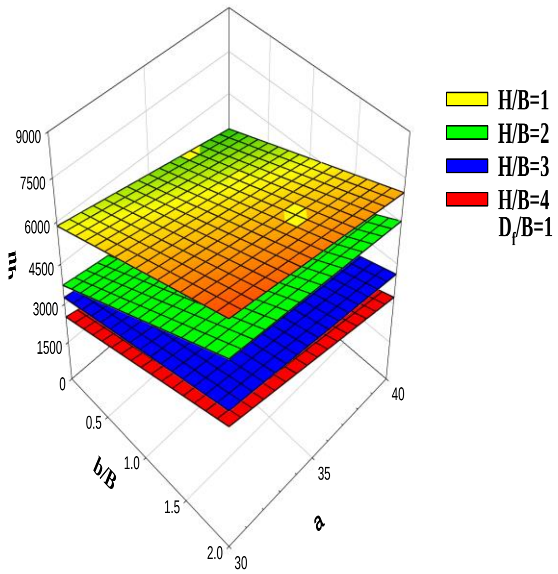

Figure (5) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth D_f = 1.0 B for dense soil.

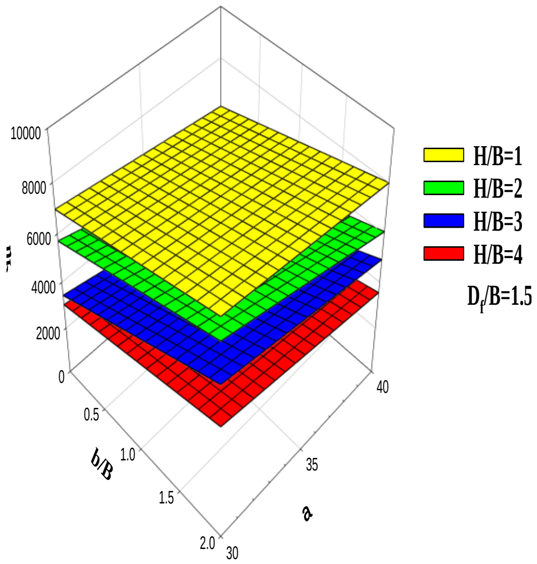

Figure (6) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth D_f = 1.5 B for dense soil.

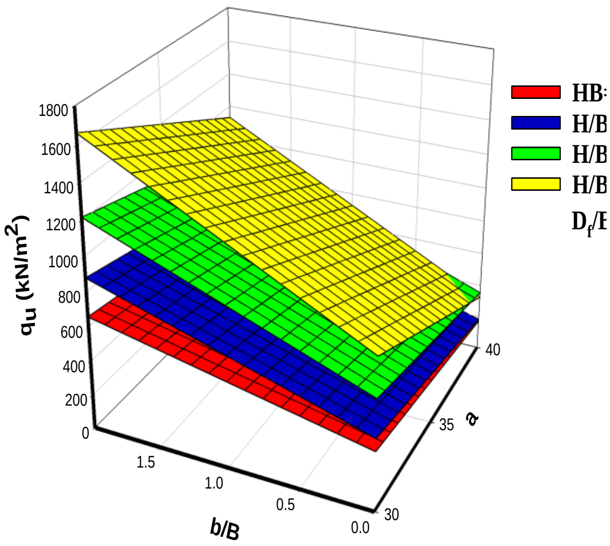

Figure (7) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth Df = 0.0 for medium soil.

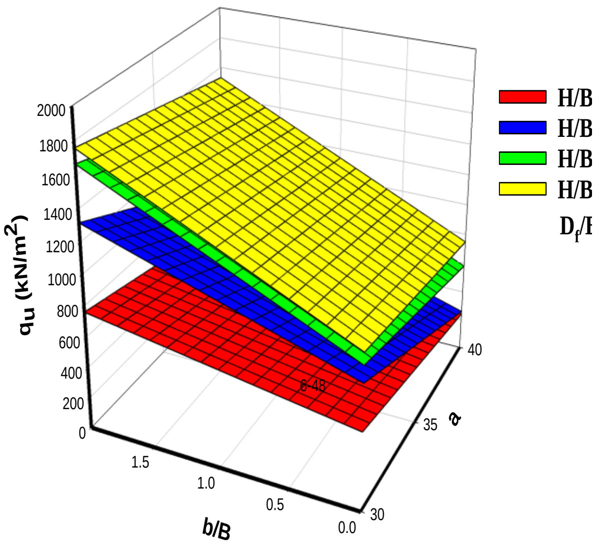

Figure (8) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth Df = 0.5B for medium soil.

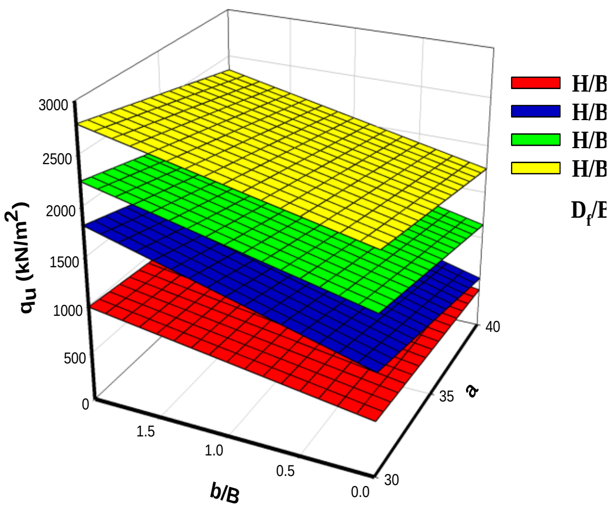

Figure (9) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth Df = 1.0B for medium soil.

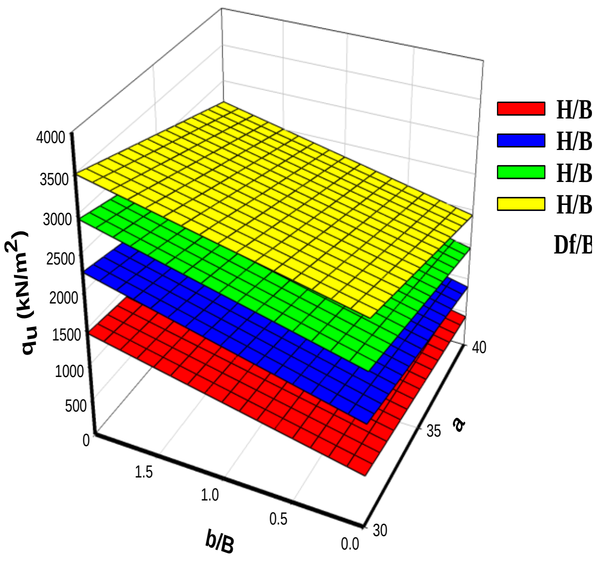

Figure (10) variation of the bearing capacity versus both inclination angle and distant away from the slope crest at different excavated layer depth (H) and a constant foundation depth Df = 1.5B for medium soil.

III. Conclusion

The present work explores a theoretical analysis of the strip footing behavior due to the existence of a pile wall to withstand the slope of sandy dense and medium dense soil under normally loading up to failure. The selection of the pile wall as a support in the current study refers to its ability to deep propagation through soil. PLAIX-2D ver. 8.2 was suggested to solve numerically the present case study. The parameters studied are; slope angle, distant away from the slope crest, foundation depth, and the successive excavated layers on the other side of the pile wall. The study is directed towards the effect of the studied parameters on the bearing capacity for both dense and medium dense sandy soil.

1- The more increase in the distant away from the crest up to the footing width results in an increase of about 13% in the bearing capacity.
2- The bearing capacity increase by about 33% with increase in the foundation depth from the half of foundation depth up to a depth equals the footing width. The more increase in the foundation depth will result in a reduction in the percentage increase of the bearing capacity.
3- At a slope of 30^0, the bearing capacity reduces by about 14% due to the excavation thickness equal to the distant away from the crest, 35% reduction in the bearing capacity for an excavation equivalent to the double of the distant the crest, and 52% reduction for an excavation equivalent to three times of the distant from the crest.
4- The increase in the slope by 5^0 will result in more bearing capacity reduction by about 17%.

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