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EXTENDED ABSTRACT

Investigating the Behavior of Single Pile and Adjacent Pile Group of Sandy Slope under Uplift Loading

Mohammad Ali Nejad Reza [a,*], Bayat Meysam [b]

[a] *Department of Civil Engineering, Ahwaz Branch, Islamic Azad University, Ahwaz, Iran*
[b] *Department of Civil Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran*

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1. Introduction

The pile is commonly adopted to transfer a part of the building and civil engineering structural loads into deeper layers with higher stiffness and thereby allow the reduction of total settlement and differential settlement of structures in a very economical way. Piles are often used in groups and the load transfer mechanism in group piles is generally different from that of a single pile due to the pile-soil and pile-pile interaction effects which has been described by previous researchers. Previous studies indicated that the interaction between soil and structure has a significant effect on the responses of foundation and structure.

In the past researches, various researchers investigated the effect of various factors such as relative density of soil, pile embedded length ratio, pile distance from each other on the uplift bearing capacity of the pile. The research results showed that the skin bearing capacity of the pile under compressive load is more than the uplift load, and this issue increases the importance of examining the uplift bearing capacity of the pile separately

No research has been done regarding the tensile load capacity of single piles and the group of piles adjacent to the slope, so investigating the behavior of the group of piles adjacent to the slope under uplift loading is of particular importance. The main purpose of this research is to investigate the uplift capacity and efficiency coefficient of the pile group adjacent to the dry sandy slope. In this investigation, the effect of various factors such as the effects of the direction of the linear pile group in relation to the slope and the arrangement of the pile group, the relative density of the soil and the embedded length of the pile on the uplift bearing capacity and the efficiency coefficient of the pile group adjacent to the dry sandy slope have been investigated. To achieve this goal, a series of laboratory tests have been conducted on the physical model of pile group near the dry sandy slope and the results have been discussed.

2. Materials and methods

2.1. Soil properties

In this work, fne, uniform sand having an average diameter (d_{50}) of 0.18 mm was collected from Ramhormoz, located in Khuzestan province in Iran. The sand was used to construct the slope models in a dry state. The sand has been classifed as poorly graded (SP) according to Unifed Soil Classifcation System.

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* Orcid Cod Corresponding Author: 0000-0002-2001-1765
E-mail addresses: reza@iaun.ir (Reza Mohammad Ali Nejad), bayat.m@pci.iaun.ac.ir (Meysam Bayat).

2.2. Experimental setup and testing program

A large-scale experimental setup was developed to study the response of axially loaded group of piles located on sloping ground. A box of inner dimensions 1.80m×0.90m×0.90m (length × width × height) was prepared for the present study. The model dimensions were chosen to minimize boundary effects and the interference between the walls of the sand.

Axial load was applied through a screw jack coupled to a steel rod attached to the loading frame. A steel box was used to attach the piles cap to the screw jack and force measurement was carried out using a load cell placed between the steel box and the pile cap. The axial load was applied at the center of the piles cap with a constant strain ratio of 1.5mm/min. Steel rods with an outer diameter of 18mm were used as end-closed piles. The pile groups subjected to axial loads using a steel pile cap of size 16m×16cm and thickness of 2cm which can be regarded as rigid. The upper 2cm of the piles were fixed in the rigid steel cap.

3. Results and discussion

In this study, a total of 126 model tests were carried out on single pile and pile groups near a sloping ground. The effect of edge distance from slope crest, relative density of soil, embedded length of pile on the axial load-uplift capacity and were obtained and efficiency coefficient of the pile group discussed.

3.1. Single pile

In this section, the effect of the distance from slope crest, the relative density and the embedded length of the pile on the uplift capacity of single piles was investigated.

The results show a decrease in the uplift bearing capacity of single pile when the single is placed in the near of slope. This is due to the reduction of the confing pressure surrounding the pile when placed in the near of slope. The results show that with the increase in the relative density, the reduction in the bearing capacity of individual piles decreases, so that with the increase in the relative density of the soil from 40% to 65% and 85%, the reduction in the uplift bearing capacity of the piles decreases from 40% to 29% and 22%, respectively. The results show that the critical distance of a single pile is greater than the horizontal distance of the theoretical failure surface.

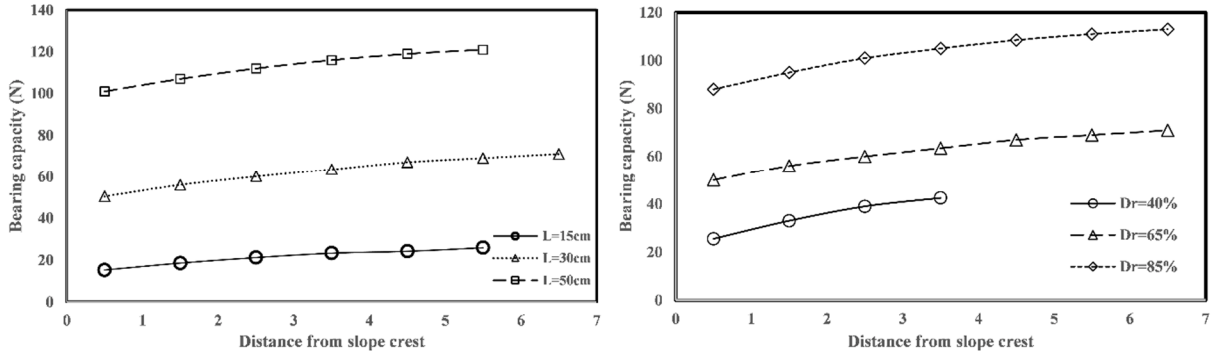

Fig. 1. Comparison of response of pile groups

3.2. Distance from slope crest

In this section, the effect of the distance of pile groups 1×2, 1×3, 2×2 and 3×3 from the slope crest on the bearing capacity of the pile group was investigated. The relative density of the soil was 65%, the buried length of the piles was 30cm, and the distance between the piles was 3 times the diameter of the pile. The results showed that the uplift bearing capacity of the pile group adjacent to the slope is lower than that of the Horizontal ground. The reduction of uplift capacity in linear pile groups (1×2 and 1×3) depends on the direction of the pile group with respect to crest slope. The amount of reduction in bearing capacity in the group of piles parallel to the crest slope is more than that of the group of piles perpendicular to the crest slope. The amount of reduction in the uplift capacity of pile group 1×2 and 1×3 is 33% and 39% respectively in the parallel state and 22% and 32% in the perpendicular state to the crest slope respectively. The results show that with the increase in the number of piles in the linear pile group, the load capacity reduction increases. The results showed that with the increase in the number of piles in the linear pile group, the decrease in the efficiency coefficient increases.

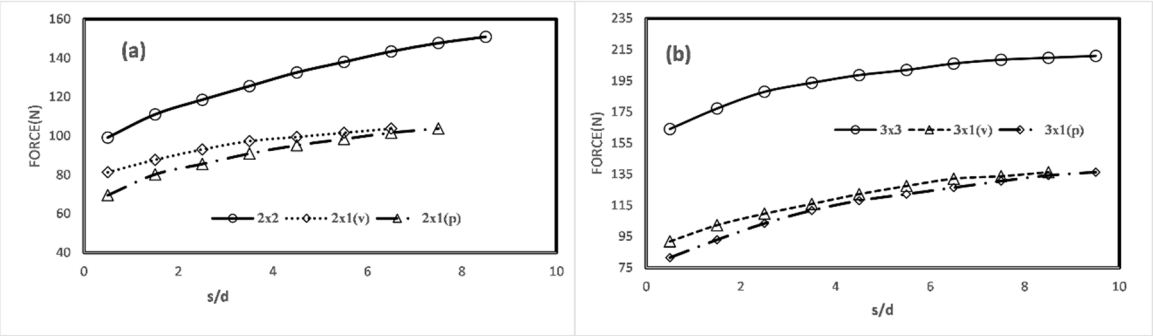

Fig. 2. Comparison of response of pile groups

3.3. Effect of relative density

In this section, the effect of relative density of soil on the bearing capacity and efficiency coefficient of the pile group located on the crest slope was investigated. The results showed that the amount of reduction in uplift capacity in linear pile groups (1×2 and 1×3) located at the crest slope with different relative densities depends on the direction of the pile group in relation to the crest slope, and the amount of load capacity reduction In the group of piles parallel to the top of the gable, it is more than in the group of piles perpendicular to the crest slope. The results showed that the increase in relative density increased the uplift capacity of 2×2 and 3×3 pile groups.

Table 1. Comparison of the uplift capacity of the pile group at the slope crest and horizontal ground

		2×1(p)	2×1(v)	3×1(p)	3×1(v)	2×2	3×3
Dr=40%	Crest slope	38	45	42	48	55	95
	Horizontal level	53	53	69	69	71.5	111
Dr=65%	Crest slope	69.5	81	83	92	99	164
	Horizontal level	104	104	136	136	151	211
Dr=85%	Crest slope	137	155	154	165	170	301
	Horizontal level	172	172	231	231	253	376

3.3. Effect of embedded length

In this section, the effect of the embedded length of the pile on the bearing capacity and efficiency coefficient of the pile group located on the crest slope was investigated.

The results showed that increasing the embedded length of the pile increased the uplift capacity of the 2×2 and 3x3 square pile groups. The effect of increasing the embedded length of the pile on increasing the uplift capacity in the 3×3 pile group was more than the 2×2 pile group.

The results showed that in 2 and 3 linear pile groups, the efficiency coefficient of the pile group depends on the direction of the pile group to the crest slope. The results showed that for every 3 embedded lengths of the pile, the efficiency coefficient of the pile group located at the top of the gable decreases with the increase in the number of piles.

Table 2. Comparison of the uplift capacity of the pile group at the slope crest and horizontal ground

		2×1(p)	2×1(v)	3×1(p)	3×1(v)	2×2	3×3
L_d=15cm	Crest slope	23	31	35	44	48	70
	Horizontal level	40	40	52	52	57	84
L_d=30cm	Crest slope	69.5	81.2	83	92	99	164
	Horizontal level	104	104	136	136	160	211
L_d=50cm	Crest slope	143	155	195	210	212	267
	Horizontal level	164	164	218	218	238	300

4. Conclusions

The results of this research can be summarized as follows:

1) As the relative density of the soil and the embedded length of the single pile increases, the influence of the slope on the tensile load capacity of a single pile located on crest slope decreases.
2) The direction of the linear pile group relative to the crest slope has an effect on the value of the efficiency coefficient and uplift capacity of the pile group. The pile group perpendicular to slope has a higher uplift capacity and efficiency factor than the pile group parallel to slope.
3) Increasing the relative density of the soil has a greater effect on increasing the uplift capacity of the linear pile parallel to the top of the slope than the group of piles perpendicular to the slope, and with the increase of the relative density of the soil, the effect of the direction of the linear pile relative to the crest slope decreases.
4) By increasing the number of piles from 4 to 9, the uplift capacity of the pile group located on the crest slope decreases, and at a distance of 6.5 times the diameter of the pile from crest slope, the difference in the percentage of the uplift capacity of pile groups 4 and 9 decreases. It is reduced and the effect of the number of piles in the pile group on the reduction of the uplift capacity of the pile adjacent to the slope can be ignored.
5) Increasing the length of the embedded pile has a greater effect on increasing the uplift capacity of the linear pile parallel to slope than the group of piles perpendicular to the slope, and with the increase of the embedded length of the pile, the effect of the direction of the linear pile relative to the ccrest slope decreases.
6) The increase in the length of the embedded pile is more due to the increase in the capacity of the 3x3 group located at the crest slope than the 2×2 pile group.