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Experimental Study on Uplift Load Carrying Capacity of Steel Pile in Sand

Parthipan N[1], Dr. M. Kumar[2]

[1]PG Scholar, Government College of Technology, Coimbatore-641013, Tamil Nadu, India

[2]Assistant Professor, Government College of Technology, Coimbatore-641013, Tamil Nadu, India

Abstract: ***Understanding the pile behaviour and predicting the capacity of piles under uplift loading are important topics in foundation design. Experimental model tests have been conducted on single pile and pile groups embedded in cohesionless soil and subjected to pure uplift loading. The experimental test were conducted on solid straight vertical steel piles with an diameter of 0.8cm and the length of the pile is 15cm.The sand bed is prepared at two different condition of relative density of medium and very dense sand condition. Single pile and group piles containing one and nine piles embedded in sandy soil were tested, and the results are presented and discussed in this paper. The influence of pile embedment depth, relative density of soil and arrangement in a group on the uplift capacity of piles are investigated. The study revealed that the behaviour of single pile under uplift loading depends on embedment depth and soil properties and relative density of soil. The group efficiency under uplift loading improved slightly with an increase in the relative density of soil. It is believed that the experimental results presented in this study would be beneficial to the professional understanding of the soil-pile-uplift interaction problem.***

Keywords: Steel piles, Relative Density, Uplift load, Axial displacement

1. Introduction

Pile foundations are frequently used to transmit the superstructure loads to deeper strata if the subsurface soil is of inadequate strength. In cohesionless soils, the shaft resistance is an important source of pile capacity under axial loading, especially when the pile is subjected to uplift loading. Uplift forces act on the supporting piles if structures such as dry docks, basements, and pumping stations are constructed below the water table. Additionally, transmission line towers, tall chimneys, submerged platforms, jetting structures, masts, and similar constructions on pile foundations are usually subjected to overturning moments due to wind effects, seismic events, wave actions or ship impacts. In such structures, the induced overturning moments are transferred to the piles supporting the structure in the form of compression in some piles and pull out on others. Moreover, uplift forces may be exerted on piles due to swelling of the surrounding soils. Therefore, studying the behavior of piles under uplift forces as well as the parameters affecting the uplift capacity of piles is one of the most important and interesting areas of research in geotechnical engineering.

In straight solid shafted piles, the applied uplift load is resisted by shaft resistance developed between the pile and the soil. Research on shaft resistance of piles has progressed during the last five decades. Most previous studies were directed toward the shaft capacity of piles subjected to axial compressive loads, while little research was conducted on pile response under uplift forces.Several studies have concluded that shaft resistance is about the same for uplift and compression loads Some studies were conducted on the behavior of a single pile under uplift loads, such as those by Vesic , Das and Seeley, Levacher and Sieffert, Rao and Venkatesh , Chattopadhyay and Pise , and Shanker et al.Properly conducted laboratory tests, with known parameters affecting the soil–pile response under uplift loading, would provide information on qualitative contributions of such parameters on the ultimate resistance of piles. At the same time, the increasing use of piles to resist and sustain uplift loads necessitates accurate assessment of uplift resistance to achieve economy and safety. Therefore, it is hoped that the current study may lead to a better understanding of the response of single piles and pile groups under pure uplift loads.

2. About the Study

In the present study, model testing has been preferred to field testing due to cost aspect and time constraint. To establish the relationship between pile-soil-uplift load behavior of piles, experimental investigation is done. Tests under axial uplift have been carried out on smooth solid mild-steel model piles having in the form of single and group of piles. All the piles used were truly vertical. Tests were conducted in a model tank of size 30cm × 30cm × 30 cm. Dry Sand collected from Palar river which is located between latitude 12º41'2.38"N, longitude 79º59'0.05"E having properties as G = 2.67, Uniformity Coefficient (Cu) = 3.23, Maximum density of sand (γmax) = 14.74 kN/m³ and Minimum density of sand (γmin) = 16.77 kN/m³ is used as a foundation medium. The effect of embedment length and diameter are investigated in medium and very dense sand condition.

3. Laboratory Investigation

The soil used as foundation medium was collected from Palar River, Chengalpattu. Which is located between latitude 12º41'2.38"N, longitude 79º59'0.05"E. The sample of soil was analyzed in laboratory for its specific gravity, particle size distribution, relative density and angle of shearing resistance.

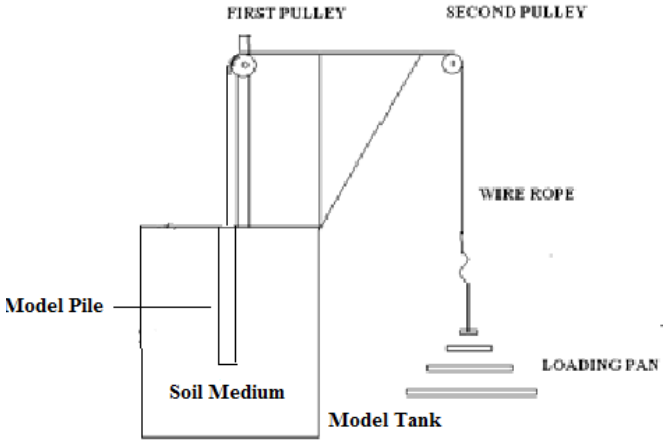
Table 1: Geotechnical properties of sand used in the tests

Properties	Value
Gravel	1.6%
Fine sand	18.2%
Coarse Sand	4.8%
Medium sand	75.4%
Silt	0%
Clay	0%
Effective Size , D_{10}	0.20mm
D_{30}	0.33mm
D_{60}	0.68mm
Uniformity coefficient of the sand,C_u	3.23(<6)
Coefficient of Curvature, C_c	0.76(<1-3)
Soil classification	Poorly graded sand(SP)
Specific Gravity	2.67
Maximum unit weight	16.77 kN/m³
Minimum unit weight	14.74 kN/m³
e_{max}	0.75
e_{min}	0.53

4. Experimental Program

The pile was tested under uplift loads by means of double pulley arrangement. The flexible non-extensible wire rope passing over the pulleys were connected to the top of the pile head through a hook and another end was attached to a loading pan. The position of first pulley was fixed according to the alignment of the wire rope and pile axis as per the vertical position of the pile.

Two dial gauges were fixed equidistant from pile axis on dial gauge fixture. The loads were applied by dead weights in the loading pan starting the smallest, with gradual increase in stages. Dial gauge readings were observed for both dial gauges for each increment of the pile corresponding to the pullout load applied.



4.1 Comparison with single pile in medium and very dense sand condition

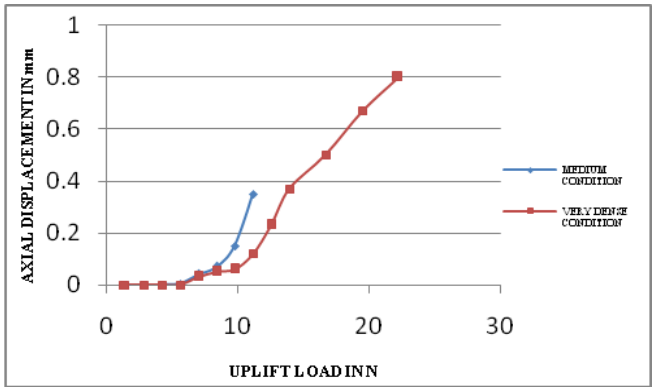


Figure 4.1: Uplift load-Axial displacement

4.2 Comparison with group pile in medium and very dense sand condition

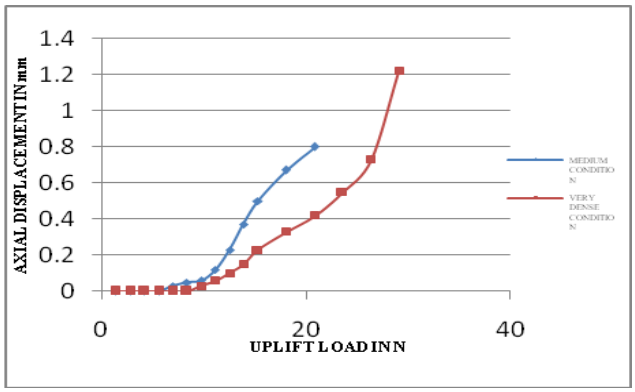


Figure 4.2: Uplift load-Axial displacement

4.3 Comparison with single and group piles in medium sand condition

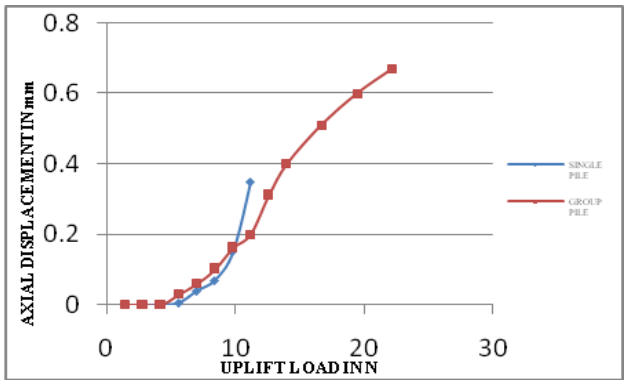


Figure 4.3: Uplift load-Axial displacement

4.4Comparison with single and group piles in very dense sand condition

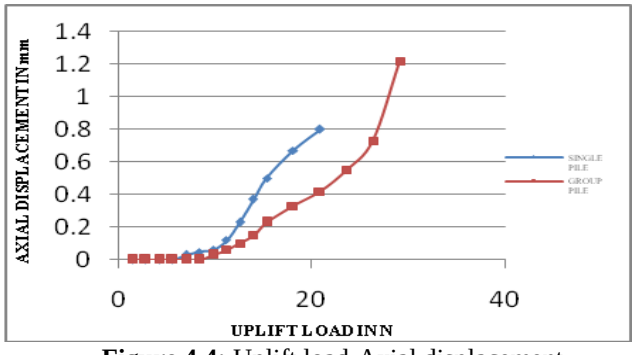


Figure 4.4: Uplift load-Axial displacement

5. Results and Discussion

The ultimate uplift capacity is higher for very dense sand condition than medium sand condition. The net uplift capacity of a single pile and group piles improves significantly with an increase the relative density of soil.

For Medium sand, the ultimate uplift capacity of single steel pile are 11.15N and 13.92N and group piles are 22.18N and 33.29N respectively.

For Very dense sand, the ultimate uplift capacity of single steel pile are 20.88N and 29.13N and group piles are 29.13N and 30.32N respectively.

In compare to uplift load capacity of group piles in medium sand condition is more than 1.2 times of the single pile in medium sand condition.

In compare to uplift load capacity of group piles in very dense sand condition is more than 1.42 times of the single pile in very dense sand condition.

6. Conclusion

The behavior of single pile under uplift loading depends mainly on the pile embedment depth , relative density of the soil and soil properties.The behavior of pile in a group under uplift loading mainly depends on the relative density of soil and arrangement of pile in a group.

For a net uplift load per pile in a group equal to a single pile load, the upward displacement of a closely spaced pile group increases due to interaction effects between the piles.

For a net uplift load per pile in a group equal to a single pile load, the upward displacement of a closely spaced pile group increases due to interaction effects b/w the piles.

The efficiency of a pile group under uplift loading increases slightly with an increase in the relative density of soil.

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Author Profile

Parthipan N currently pursuing the M.E. degree in Geotechnical Engineering from Government College of Technology in 2015-2017 and received in the B.E. degree in Civil Engineering from S.B.C Engineering College.

Dr. M. Kumar currently working as Assistant Professor in Civil Engineering (Geotechnical Division) in Government College of Technology, Coimbatore.