



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 9, Issue 11, November 2020

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 7.512

 9940 572 462

 6381 907 438

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# Performance of Steel Piles Driven in A Granular Soil Having Horizontal Profile Under Axial Compressive Load

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**ABSTRACT:** Pile foundations are widely used in the construction of transmission tower, high-rise buildings, bridges and other structures in soil having low bearing capacity. Experimental investigation of the behavior of piles as single and groups in sand under axial compression load is very much important in the study of settlement and group efficiency. This research work is carried out to study the behavior of single and group of piles under vertical loading with no surcharge. The pile is made up of steel with a hollow space and it is filled by concrete. The length of the pipe pile is 1.25m and the outer diameter is 34mm. The program consisted of installing test piles in dense compacted sand placed in a Mild steel soil chamber of size 2.50m X 1.50m X 1.50m, and subjected to compressive axial load. The spacing between piles is 2.5 times the pile diameters. The soil medium in which the piles are driven consists of soil having specific gravity 2.865, field density 1.86g/cc and the angle of internal friction as 38.6 degrees. On applying a vertical load on the pile, it causes settlement and also leads to an increase in shear stresses along the shaft of the pile, which increased the lateral resistance and subsequently leads to decreased lateral displacement under equivalent lateral loads. The calculation of the pile settlement is an important part of the pile foundation design. The load carrying capacity of the piles in different configuration is studied using Dynamic and Static formulae and is verified experimentally. In this project, the ultimate capacity of single and group piles are found out by allowing the pile to settle for 12mm and the settlement behavior of these piles are studied and the results are compared with the help of Load - Settlement curve and appropriate calculation methods. The ultimate load carrying capacity of single pile is found to be 49.5kg whereas it is 65.5kg for 2-pile group and 132.6 for 3-pile group.

**KEYWORDS:** Single pile, pile group, vertical load, ultimate load carrying capacity.

## I. INTRODUCTION

Piles can be driven, drilled or jacked into the ground and then connected to pile caps. Pile foundations are usually adopted, for large structures and in some situation where the soil at shallow depth is not suitable to resist excessive settlement.

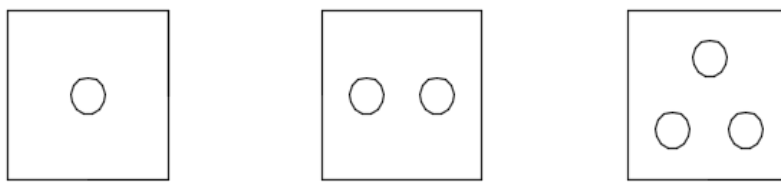
The main focus of this experiment was to determine the potential of driven steel piles in a granular soil medium subjected to vertical loads which has no surcharge over the horizontal profile. Piles are often used in groups, and the behavior of pile groups under the applied loads is generally different from that of a single pile due to the interaction of neighboring piles. By this experiment, we focused to investigate the behavior of driven single and group steel piles under vertical load by plotting the Load vs Settlement curves.

As there is interaction between piles when they are used in group, the bearing capacity of the piles in the group is different from a single pile, which causes the pile group effect. A study on the pile group effect for the proposed field condition and simulating it in the laboratory was done by Ismael (2011). The effect of piles when used in groups on the side friction, tip resistance and carrying capacity were studied by using pile groups in large scale in various soil condition (Liu, 2004). The bearing performance of pile groups under vertical loading is still not well-known. It is known that bearing behavior of group pile is substantially different from superposition of single pile loading in both clay sandy grounds when the pile spacing is narrower IkuoTowhata et al(2014). The greater the sand density, the higher the load capacity and pile stiffness. The increase in ultimate load capacity was smaller for medium dense sand Mauricio Martines Sales et al (2017). By allowing Slippage at pile soil boundary, interaction is bounded by the interface resistance that results in more realistic settlement profile compared to nonslip models Tirawat Boonyatee and Qui Van Lai (2017).

The ultimate capacity of single pile inside pile groups increases with increasing number of piles. However, the settlement of pile groups at the ultimate load was found to be more than the settlement of single pile Elsamny M K (2017). We used pile cap for single pile, group of 2-pile and group of 3-pile. A Pile of 34 mm diameter and 1.25m length was used and 0.8m of pile was cast into the tank. This pile had a tapered end at the bottom. The pile was painted to avoid environmental attacks. This was a steel pipe pile and the hollow space inside the pile was filled by a suitable grade of concrete.

**II.ASSUMPTIONS AND MATHEMATICAL MODELS**

The piles were drilled into the soil by inserting 0.8m length of pile. The piles were connected by pile cap. The spacing between the piles was 2.5 times the diameter of pile and it was done by pile caps.



**Fig 1 : Pile layout**

**2.1 Load carrying capacity of piles:**

The ultimate load carrying capacity, or ultimate bearing capacity of a pile is defined as the maximum load which can be carried by a pile, and at which the pile continues to sink without further increase of load.

**a)Dynamic formula:** Ultimate capacity of pile and pile group are calculated by Engineering News formula.

$$\text{Ultimate capacity} = \frac{WH\eta}{S+C} \tag{1}$$

Where W is weight of rammer = 2.5kg, H is height of fall = 30.5 cm  
 η is efficiency of pile = 100%, S is set of pile per blow = 6 cm  
 C is constant (for drop hammer) = 2.5cm

By applying known values,

$$Q_u = 8.97 \text{ kg}$$

**b)Static formula:** The static formula are based on assumption that the ultimate bearing capacity  $Q_{up}$  of a pile is the sum of the ultimate skin friction and total ultimate point end bearing resistance.

$$Q_u = A_s r_f + A_p r_p \tag{2}$$

The ultimate load carrying capacity,  $Q_u = 8.26 \text{ kg}$

**2.2 Group action in piles:**

According to Feld’s rule, the value of each pile is reduced by one-sixteenth on account of the effect of the nearest pile in each diagonal or straight row of which the pile in question in a member.

**Table 1:** Load carrying capacity of piles by Dynamic formula

Number of piles	Pile carrying capacity		
	Dynamic formula	Efficiency of pile by Feld’s rule	Dynamic formula incorporating Feld’s rule
Single pile	8.97	100%	8.97
2 piles group	17.94	93.5%	16.77
3 piles group	26.91	87.5%	23.55

**Table 2.** Comparison of Dynamic formula and Static formula

Number of piles	Dynamic formula	Dynamic formula incorporating Feld’s rule	Static formula
Single pile	8.97	8.97	8.26
2 piles roup	17.94	16.77	16.52
3 piles group	26.91	23.55	24.78

### III. TEST ON SOIL PROPERTIES

Soil samples were collected from the field to study the engineering properties of soil. The soil was classified as well graded fine sand according to IS 1498-1970.

It is important to determine soil moisture content in order to understand better on soil characteristics. The samples were collected throughout the depth of the soil in the tank using auger boring and moisture content of each soil sample was measured. The specific gravity of the soil sample was 2.865. The field density was found as 1.83 g/cc by adopting core cutter method. The angle of interface friction of 38.6° was obtained as a result direct shear test conducted on the sample material used to cast pile and the soil sample.

### IV. LOAD CARRYING CAPACITY OF PILE

Initially pile cap is placed on the pile and the drop hammer was placed over it. With a gravity drop hammer, the upper die is attached to a ram and is raised either by a board, belt, or air. It is then allowed to fall freely to strike the pile cap. The number of blows required for driving each 5cm length of pile was noted. The height of pile below ground level was 0.8 m. After driving the pile, dial gauge was installed by placing the tip near the pile cap. By applying load vertically downward on the pile cap, the settlement was noted. For each increment of load, the corresponding settlement was noted. The experiment continued till the settlement reaches 12mm.

The same procedure was followed for group of 2 piles and group of 3 piles.



**Fig 2 :** Setup of pile with dial gauge

Here single pile, pile group with 2 piles and pile group with 3 piles are subjected to vertical loads at a certain interval of time. We used a circular steel weight having a mass of 8.34 kg each for the application of vertical loads. Settlement of piles was observed and Load versus Settlement curve was drawn.

#### 4.1 Single pile under vertical load

After driving pile along with the cap, dial gauge was installed. The dial gauge reading was set to zero. Now vertical load of 8.34kg was applied and the dial gauge reading was noted until a same value of settlement noted for 30minutes. The settlement can be found out by multiplying dial gauge reading with its least count. The experiment continued till the settlement reached 12mm. The Load – settlement curve was drawn as in Fig 4..





Fig 3: Loading set up on a single pile

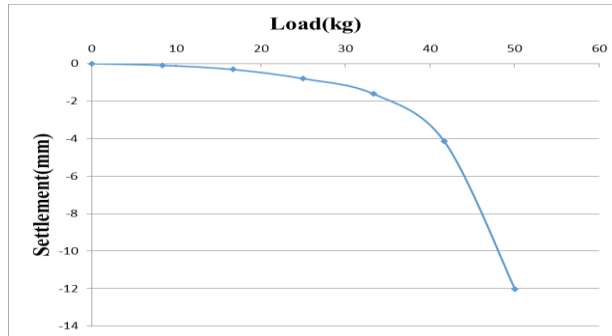


Fig 4: Load-settlement curve for a single pile

#### 4.2 Two piles in a group under vertical load

Two piles were driven simultaneously along with its cap. The spacing between the piles was 2.5 times the diameter of the pile. Initially, the dial gauge reading is set to zero. By applying the vertical compressive load as in single pile, settlement was tabulated till the settlement reached 12mm. Load – settlement graph was plotted.



Fig 5: Arrangement of Pile group with 2-piles

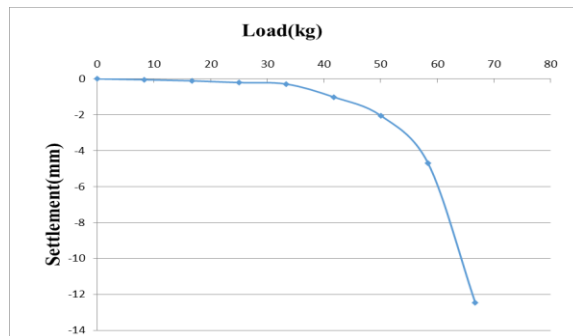


Fig 6: Load Settlement curve of 2-pile group

#### 4.3 Three piles in a group under vertical load

Three piles were driven along with its pile cap using drop hammer. The pile was driven to the depth of 0.8m. The spacing between each pile is 2.5 times the diameter of pile. The dial gauge was installed and the dial gauge reading is set to zero. Now vertical load is applied by using a circular disc having weight of 8.34kg each. Once the load is given, the dial gauge reading is noted. The dial gauge reading should be noted after the needle pointed out a steady values. The settlement can be found out by multiplying dial gauge reading with its least count. The experiment continues till the settlement reaches 12mm. The settlement values and its corresponding load values are plotted in a graph and the load-settlement curve will be drawn.



Fig 7: Arrangement of Pile group with 3-pile

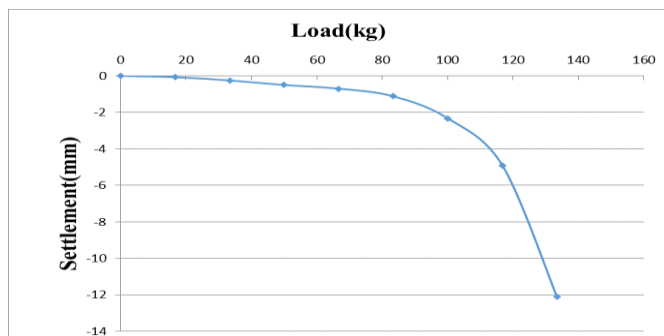


Fig 8: Load Settlement curve of 3-pile group

#### 4.4 Comparison of single pile with group piles

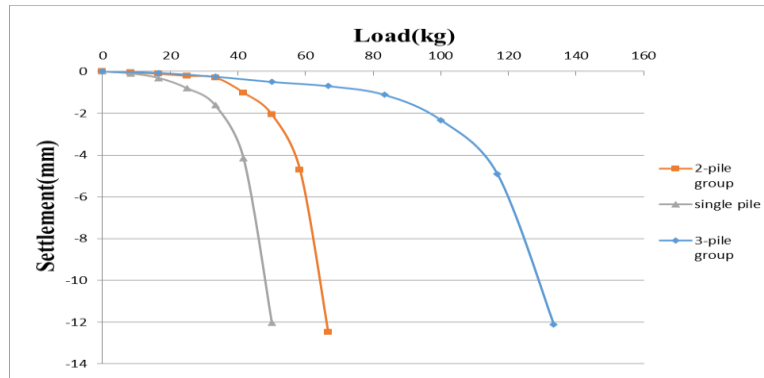


Fig 9: Load Settlement curve of single pile and pile group

By comparing the load-settlement curve of single pile and group pile, it was found that when the load increases the settlement also increases in case of single pile as well as group piles. The settlement will be more for single pile when compared with the group piles. And also settlement of 2-pile group will be more than 3-pile group.

The ultimate load carrying capacity of single pile is found to be 49.5kg. The ultimate load carrying capacity of 2-pile group and 3-pile group is found as 65.5 and 132.6 respectively. The ultimate load carrying capacity of group piles will be more than the ultimate load carrying capacity of single pile.

#### V. CONCLUSION

From this study we can able to understand the behavior of piles under vertical loadings. The settlement behavior of single pile and group piles were studied using load-settlement curve and the results were compared. From results, it was concluded that when the load increases the settlement also increases in case of single pile as well as group piles. The settlement will be more for single pile when compared to with the group piles. And also settlement of 2-pile group will be more than 3-pile group. The ultimate capacity is more for 2-pile group and 3-pile group when compared to single pile. The load carrying capacity of group pile is more than single pile. It is because when the pile is driven into the soil, the soil around the pile gets bulged. While driving group pile, the soil between the piles will get compacted, thus the load carrying capacity of piles will be increased. Thus the usage of group pile will be more efficient than single pile.

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