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Studies on Pile Subjected To Axial and Lateral Loading

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Abstract:- **Offshore structures, namely, oil drilling platforms, jetties, tension leg platforms etc. are mostly supported on pile foundation. Apart from the usual super structure load (dead load, live load, etc.), these piles are subjected to continuous lateral loading resulting from ocean waves. The combined type of loading induces progressive degradation of the foundation capacity associated with increased pile head displacement. In connection with the above, a total of 18 model pile load tests have been conducted in a model tank filled by sand and clay to examine the behavior of single pile under vertical and lateral loading. Pile is subjected to axial compressive loads and lateral load, for varying type of soil, combinations of loading and L/D ratio. Result indicate that the vertical load capacity of pile increases with L/D ratio and for sand bed compared to clay bed. The effect of L/D ratio and type of soil is less felt on the lateral load capacity of pile unlike vertical load capacity. In the case of vertical and lateral loading combination, at constant vertical load the lateral load carrying capacity of pile is lesser than that of the lateral load carrying capacity of pile without vertical load.**

1. INTRODUCTION

Pile foundations are frequently used to support various structures built on loose/soft soils, where shallow foundations would undergo excessive settlements or shear failure. These piles are used to support vertical loads, lateral loads and combinations of vertical and lateral loads. However, in view of the complexity involved in analyzing the piles under combined loading, the current practice is to analyze the piles independently for vertical loads to determine their bearing and settlement and for the lateral load to determine their flexural behavior. Since the piles are not often adequately designed to resist lateral loads, the response of piles under lateral load in the presence of vertical loads is more critical and interesting for the design engineers. The methods of analysis commonly used in predicting the behavior of piles and pile groups under pure axial loads could be categorized into: (i) sub grade reaction method (ii) elastic continuum approaches (Xu and Poulos 2000), and (iii) finite element methods (Desai 1974). Similarly, the methods to study the behavior of piles and pile groups under pure lateral loads could be categorized into: (i) limit state method (Broms 1964); (ii) p-y method (Reese et al. 1974) and (iii) finite element methods. The present investigation focuses on the effect of L/D ratio, number of piles and various soil type on the load carrying capacity of driven pile and pile group under vertical and lateral loading combination.

2. MATERIALS

The soil selected for this study was collected from Kishkinta, Chennai. The collected soil samples are sand and

clay. The soil is classified as high plastic clay (CH) as per the Indian standard soil classification system. The index properties of clay is given in Table 1.

Table 1 Physical properties of Clay used

Property	Value
Specific gravity (Gs)	2.68
Liquid limit (WL)	77%
Plastic limit (WP)	33%
Plasticity index (IP)	45%
Shrinkage limit (Ws)	8%
Clay	64%
Silt	16%
Sand	20%
Soil classification (group symbol)	CH

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The another soil is classified as poorly graded sand (SP) as per the Indian standard soil classification system. The index properties of Sand is given in Table 2.

Table 2 Physical properties of Sand used

Property	Value
Specific gravity, (Gs)	2.67
Sand	93 %
Silt	5 %
Clay	2 %
Soil classification (group symbol)	SP

Experiments were carried out using single pile, each pile being circular hollow aluminium rod having 10 mm outer diameter with 1.5mm thickness. The depth of embedment was 120 mm (L/D = 12) and 240 mm (L/D = 24). Aluminium plate of 3mm thick and size 45mmx45mm is used as pile cap. A steel square tank of 50 cm x 50 cm and height 70 cm was used to prepare the soil bed for conducting experiments.

3. METHODS

The main parameters involved are vertical load, lateral load and combinations of Vertical load and lateral load, Type of soil (clay, sand and clay-sand) and L/D ratio of pile (12 & 24). The pile was subjected to vertical load alone, in the prepared soil bed; the ultimate failure load was established from load-settlement curve. The pile was subjected to lateral load alone and the lateral capacity was arrived without any vertical load. In order to identify the effect of vertical load on lateral capacity of pile, a set of experiments are conducted by applying a vertical load equal to the ultimate vertical capacity of pile for the given condition. For laterally loaded pile, the two widely used criterions are suggested by Broms (1964) and Meyerhof method. As per Broms (1964), ultimate capacity is taken as the load corresponding to a deflection equal to 20% of the diameter of the pile. As per Meyerhof method ultimate lateral capacity is that one at which the portion of load-deflection curve becomes straight. For vertically loaded pile the graph shall be plotted between the load applied on the pile and corresponding settlement of the pile. The safe or working load on the pile shall be 50% of load causing settlement of 10% of pile diameter, Vertical ultimate capacity is taken as the load corresponding to a deflection equal to10% of the diameter of the pile.

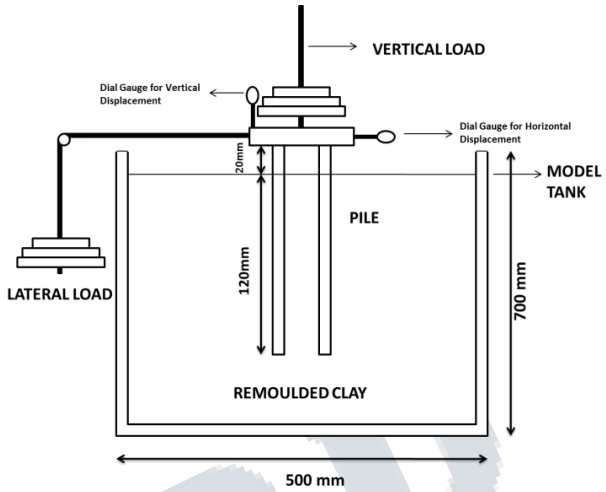

Figure 1 Schematic View of Vertical and Lateral Load Test in Model Tank

3.1 Experimental procedure

The clay sample was air-dried and water content equal to medium stiff consistency was added to the dry weight of soil. This moist clay was mixed thoroughly and then stored in air-tight plastic bags. It was sealed in plastic wrap to avoid loss in moisture content. It was allowed to cure at room temperature for 24 hours for uniform distribution of moisture content. The bottom of the model tank was filled with sand at a relative density of 60% upto the required depth, then model pile was placed in the required position. After placing the model pile in position, the uniformly mixed clay at a consistency of 0.2 was packed in the tank by using kneeding compaction technique till the required depth in order to achieve non displacement method of pile installation. To facilitate lateral loading, pile is connected to loading frame using high tension wire. The lateral and vertical displacements at pile head is measured using dial gauges. The load and pile head displacement are recorded at the regular interval up to failure for both vertical and lateral loaded pile and pile group. For each test separate soil bed was prepared. Figure 1 shows the schematic representation of experimental setup.

4. RESULTS AND DISCUSSION

4.1 Effect of soil type and L/D ratio on vertical load carrying capacity of pile

The variation of vertical load carrying capacity of pile founded in clay bed alone, sand bed alone and clay- sand bed with top layer clay followed by sand layer is shown in figure 2. From figure 2 it is observed that as L/D ratio increases the

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vertical load carrying capacity also increases. Further it is noticed that vertical load carrying capacity is higher for pile founded in sand layer than that for clay layer and clay – sand bed. The vertical load carrying capacity for pile in sand layer is 116 N, clay layer is 53 N and clay – sand layer is 95 N for L/D ratio 12 and the vertical load carrying capacity of pile with L/D ratio 24 founded in sand layer is 149 N, clay layer is 87 N and clay – sand layer is 121 N. The vertical load carrying capacity of pile with L/D ratio 24 embedded in sand bed, clay bed and clay – sand bed respectively is 1.3 times, 1.4 times and 1.3 times as that for pile with L/D ratio of 12.

The vertical load carrying capacity of pile founded in sand is 1.9 times and 1.8 times as that for pile founded in clay for L/D ratio 12 and 24 respectively. Further for pile founded in clay- sand bed the vertical load carrying capacity is 1.7 times and 1.5 times as that for pile founded in clay for L/D ratio 12 and 24. From this it is observed that the vertical load carrying capacity is influenced by the type of soil and presence of clay layer reduces the vertical load carrying capacity.

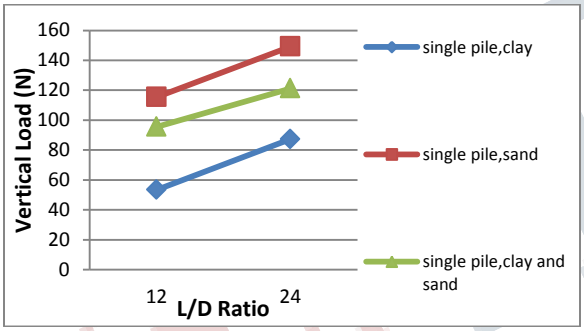

Figure 2 Vertical Load – L/D Ratio curve of single pile for different soil type

4.2 Effect of soil type and L/D ratio on lateral load carrying capacity of pile

The variation of lateral load carrying capacity of pile founded in clay bed alone, sand bed alone and clay- sand bed with top layer clay followed by sand layer is shown in figure 3. From figure 3 it is observed that as L/D ratio increases the lateral load carrying capacity also increases. Further it is noticed that lateral load carrying capacity is higher for pile founded in sand layer than that for clay layer and clay – sand bed. The lateral load carrying capacity for pile in sand layer is 57 N, clay layer is 43 N and clay – sand layer is 52 N for L/D ratio 12 and the lateral load carrying capacity of pile with L/D ratio 24 founded in sand layer is 164 N, clay layer is 76 N and clay – sand layer is 107 N. The lateral load carrying capacity of pile with L/D ratio 24 embedded in sand bed, clay bed and clay – sand bed respectively is 2.8 times, 1.8 times and 2 times as that for pile with L/D ratio of 12.

The lateral load carrying capacity of pile founded in sand is 1.3 times and 2.2 times as that for pile founded in clay for L/D ratio 12 and 24 respectively. Further for pile founded in clay- sand bed the lateral load carrying capacity is 1.1 times and 1.5 times as that for pile founded in clay for L/D ratio 12 and 24. From this it is observed that the lateral load carrying capacity is influenced by the type of soil and presence of clay layer reduces the lateral load carrying capacity.

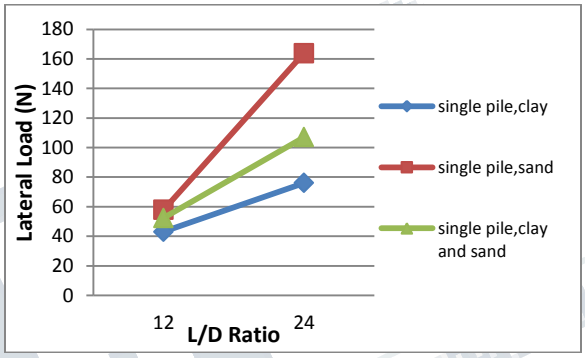

Figure 3 Lateral Load – L/D Ratio curve of single pile for different soil type

4.3 Effect of vertical load on lateral load carrying capacity of pile

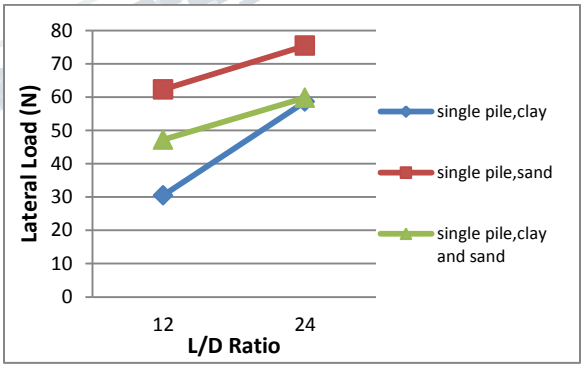

Figure 4 Lateral Load (with vertical load) – L/D Ratio curve of pile for different soil type

The variation of lateral load carrying capacity of pile with constant vertical ultimate load founded in clay bed alone, sand bed alone and clay- sand bed with top layer clay followed by sand layer is shown in figure 4. From figure 4 it is observed that as L/D ratio increases the lateral load carrying capacity also increases. Further it is noticed that lateral load carrying capacity is higher for pile founded in sand layer than that for clay layer and clay – sand bed. This trend of behaviour is similar to the same noticed for pile

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subjected to only vertical load and only lateral load. To bring out the effect of vertical load on lateral capacity of pile, the lateral load capacity of pile with and without vertical load is compared. The lateral load capacity of pile of L/D ratio 12 and 24 with vertical load founded in sand bed, clay bed and clay- sand bed is 0.5, 0.8 and 0.5 times as that of lateral load capacity of pile founded in identical condition without vertical load. From this it is realised that the lateral load capacity of pile is reduced if vertical load is acting on the pile. Further the effect is more pronounced for the pile founded in clay bed.

5. CONCLUSIONS

The following conclusions may be drawn from this study
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- The vertical load and lateral load carrying capacity of pile increases with L/D ratio.
- The lateral and vertical load capacity is higher for sand bed than clay – sand bed and clay bed.
- The lateral load carrying capacity of pile is lesser than that of the lateral load carrying capacity of pile under lateral load alone. The effect is more pronounced for the pile founded in clay bed

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