BEHAVIOUR OF COMPOSITE PILES UNDER LATERAL LOAD

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ABSTRACT: Piles have been extensively used for supporting axial and lateral loads for a variety of structures including heavy buildings, transmission lines, power stations and highway structures. These structures may be subjected to large lateral loads such as violent winds and earthquakes. The present investigation is to study the behaviour of composite piles under lateral loading in soil by conducting experiments. The materials chosen are Aluminium and Poly Vinyl Chloride (PVC) whose properties were studied by conducting tests in the laboratory. Based on the properties of the materials and theoretical studies, the various influence factors such as relative density of the soil, rigidity modulus and embedment length of the long elastic pile were analyzed. For the experimental study clean river sand at 30% relative density was used as the soil medium. The maximum allowable load carrying capacity was noted for a deflection of 5 mm at the top of the piles. It was observed that the load carrying capacity of the composite pile with Aluminium at the top and PVC at the bottom is 80% the load carrying capacity of the 1 m Aluminium pile. By using composite piles to obtain the required load carrying capacity, we can cut down on cost while maintaining the efficiency of the pile. It was thus found that the usage of Composite piles is more economical and efficient.

1. INTRODUCTION

Piles subjected to horizontal load due to wind pressure, water pressure, earth pressure, earth quakes, wave and current forces on offshore structures are termed as laterally loaded piles. Pile foundations are usually used when heavy super-structural loads have to be transmitted through weaker subsoil. Pile foundations may be required to resist significant lateral forces induced by earthquakes, waves, winds, earth pressures and ship impacts. In marine structures, lateral forces are caused by impact of berthing and mooring of ships, pressure of winds, currents, waves and floating ice. Piles are also subjected to significant amounts of lateral loads and overturning moments besides axial loads when used under tall chimneys, high-rise structures, and coastal and offshore structures. Lateral loads are in the order of 10–15% of the vertical loads in the case of onshore structures, and in the case of coastal and offshore structures, these lateral loads can exceed 30% of the vertical loads. The most commonly used pile materials are steel, concrete, and wood. These materials can degrade, and the degradation rate can be relatively rapid in harsh marine environments. The corrosion of steel, deterioration of concrete, and vulnerability of timber piles along with the high cost involved in repair and replacement of waterfront piling systems has spurred interest in alternative composite pile. They are designed mainly with the intent to produce piles that have lower maintenance costs and longer service lives than conventional piles. However, the widespread engineering use of composite piles will require further site testing and full-scale experiment to establish a relevant performance database for the development and evaluation of reliable testing procedure and design methods.

Roberto Lopez-Anido, presented in this paper after thorough surveying, the available methods for wood pile protection and structural restoration with the intent of developing an effective method. In addition to reviewing the available repair methods, he carried out a field inspection of a harbor in Maine to assess existing technologies. A wood pile repair method that utilizes bonded Fiber-Reinforced Polymer (FRP) composite shells and a grouting material was proposed. C. Dale Buckner, in his book wrote about Composite Construction in Steel and Concrete. Composite steel-concrete systems are used extensively for buildings, bridges, and other civil engineering structures. Research and development related to composite construction are in progress throughout the world. Gary Henderson, in his report studied two types of composite piles, a fiber-reinforced polymer (FRP) concrete-filled shell, and a plastic pile reinforced with a welded steel cage. Both axial and lateral short-term load displacement behavior was studied, as well as interfaced mechanical properties. Axial and lateral load-displacement behavior was similar for the concrete control pile and the FRP pile, and the plastic pile was significantly less stiff in both loading modes.
2. EXPERIMENTAL WORKS

2.1 Test Setup

The schematic diagram of test setup is shown in Figure 1. All the tests were conducted in a rectangular tank of size 2000 mm × 1000 mm × 1000 mm. Based on influence zone for pile and soil properties the test tank dimension was fixed (To avoid the size effect of wall). A wooden block of 50 mm thick covered by thin steel plate is used as a pile cap. The spacing between the piles is 3D (D-diameter of the pile). A model piles made of aluminium pipe of outer diameter 25.4 mm and pile embedment to depth ratio 30 is used in this investigation. The lateral load was applied to the test piles by using a motor pulling approximately mid depth of the pile cap. The force applied to the pile cap was monitored using a load cell (capacity of 5kN) placed between the motor and pile cap. The load deflection of pile head was measured using LVDT placed at the pile head.

2.2 Properties of Sand and Model Pile

Dry river sand was used as soil medium for the entire experimental programme. Based on the laboratory test results, the index and engineering properties of the sand are $D_{10} = 0.24$ mm, $C_{u} = 1.06$, $C_{c} = 2.36$, $\phi = 45^\circ$, $\gamma_{\text{max}} = 18.64$ kN/m$^3$, $\gamma_{\text{min}} = 14.62$ kN/m$^3$. As per IS (IS: 1498–1970), the soil classified as poorly graded angular sand. For test, the sand was placed with a relative density of 30% (for loose sand). To achieve uniform density in the test tank, a standard sand raining technique was adopted.

The flexural rigidity of the pile material was obtained by conducting simple bending test on a model pile. A model pile arranged on a simply supported beam and applied a concentric load at center, the deflection are measured at L/4 span from the both supports and center span by deflectometers. From the deflection test the flexural rigidity of the Aluminium pile was found to be $322.8 \times 10^6$ Nmm$^2$ and that of PVC pile was found to be $136.43 \times 10^6$ Nmm$^2$.

2.3 Pile Installation

An Aluminium pile and a PVC pile each of 1 m length were placed vertically in the tank filled with sand. The embedment length of each pile was 0.8 m. The tip of the pile was 10 mm above the surface of the tank and made to rest on a cushion of sand. A composite pile was fabricated using 0.5 m Aluminium and 0.5 m PVC and a bolted connection was given at the centre. It was assumed that 100% load transfer takes place at this point. The composite pile was placed in two different orientations – one with Aluminium at the top and PVC at the bottom and the other with PVC at the top and Aluminium at the bottom.

2.4 Test Carried Out

Sand is filled in the test tank, using sand raining device with the piles placed in the tank 10 mm above the tank bottom. Lateral loads were applied at the pile head using a pulley system. The load was incremented by 0.5 kg and the deflections were measured using dial gauge till the lateral deflection at the top of the pile reached 20% of pile diameter (5 mm). The corresponding load was taken as the allowable lateral capacity of the pile group. This was followed for four piles

1. Aluminium pile of 1.057 m total length and 0.8 m embedment length and outer diameter of 25.4 mm.
2. PVC pile of 1.067 m total length, 0.8 m embedment length and inner diameter of 25.4 mm.
3. Composite pile with 0.5 m Aluminium at the top and 0.5 m PVC at the bottom, 0.8 m embedded in the soil and connected by bolts at the center.
4. Composite pile with 0.5 m PVC at the top and 0.5 m Aluminium at the bottom, 0.8 m embedded in the soil and connected by bolts at the center.

3. RESULTS AND COMMENTS

The design of pile supported structure under lateral load is mainly governed by two factors. 1. Lateral load capacity 2. Allowable lateral deflection of the superstructure. For long flexible pile consideration of allowable deflection is important. The ultimate lateral load capacity of pile is taken at least of the following:

1. The lateral load corresponding to a lateral deflection equal to 0.2 times diameter of the pile (suggested by Brooms-1964)
2. Final load at which the total displacement corresponding to 5mm (As per IS2911 part 4-1985)

3.1 Aluminium and PVC Piles

A typical lateral load lateral deflection curve of Aluminium and PVC piles in soil of 30% relative density is shown in Figure 2. The figure shows that for 5 mm lateral displacement, (allowable) lateral load capacity of Aluminium pile is 180 N and that of PVC pile is 74 N. Lateral load capacity of the Aluminium pile is 58% more than that of the PVC pile for an increase of 87.5% in flexural rigidity.
4. CONCLUSIONS

The behaviour of laterally load homogeneous piles and composite piles were studied. The results are analysed and presented above. Based on the foregoing study, the following conclusions are drawn.

1. The allowable lateral load carrying capacity of the piles depends on the stiffness of the material. As the rigidity modulus of the material increases, the lateral load carrying capacity of the pile increases.
2. Lateral load capacity of the Aluminium pile is 58% more than that of the PVC pile for an increase of 87.5% in flexural rigidity.
3. The load carrying capacity of the composite pile with 0.5 m of Aluminium at the top is 80% the load carrying capacity of 1 m Aluminium pile for a decrease of 67.5% in flexural rigidity.
4. The composite pile with 0.5 m of Aluminium at the bottom gives only 25% more load carrying capacity for an increase of 61.5% in flexural rigidity.
5. The orientation of the composite pile has a major role to play in deciding the allowable lateral loading capacity. If the material with higher rigidity modulus is placed on the top, higher allowable lateral loading capacity can be achieved.
6. Thus, if the length of the material with higher rigidity can be suitably increased to reach optimum load carrying capacity, we can cut down on cost of the pile while maintaining the efficiency of the pile.

REFERENCES

Behaviour of Composite Piles under Lateral Load