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Evaluation of Long Piles Horizontal Displacement Subjected to Lateral Loading in Sandy Soil

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1-Introduction

Almost all types of piles are subjected to lateral loads. In many cases, however, the applied lateral loads are comparable with gravity loads. Piles which are subject to lateral load are usually divided into two categories: long piles and short piles. The behavior of both short rigid piles and long flexible piles is based on the relative stiffness of the soil–pile system. The general methods to estimate lateral bearing capacity of piles are based on ultimate bearing capacity and allowable horizontal displacement for short and long piles, respectively.

Free-head short piles under lateral loading act as a rigid body and they are expected to rotate around a center of rotation while fixed-head piles move laterally in translation mode. Free and fixed-head long piles under lateral load form one or two joints, respectively and rotate from the joint point.

Several theoretical methods, including Hansen, Broms, Petrasovits, Meyerhof, Prasad and Chari, modulus of subgrade reaction, elastic approach and ultimate modulus of horizontal subgrade reaction (K_{hmax}) have been proposed to predict lateral bearing capacity of piles in cohesionless soils.

2-The Aim of the Study

There exist many theories to estimate ultimate bearing capacity of piles subject to lateral loads which have been proposed by various researchers. It is difficult for engineers to choose a suitable method due to the complexity of these theories. Experimental and theoretical efforts have been made to clarify the precision of these theories. In the present research study, laboratory tests have been conducted to evaluate the behavior of long piles under lateral loads. Also the point of bending, force-displacement phenomena and the effect of parameters such as soil bulk density, length and diameter of piles been have been investigated.

3-Equipment and Material Testing

To carry out an experimental study of the behavior of piles under lateral load, it is required to develop a set of devices such as to be able to apply horizontal force and also measure horizontal displacement of the pile at the soil surface and at different depths of the pile. For this purpose, an experimental apparatus was designed. The following sections describe the details of the apparatus, materials and equipment used in this research study.

A. Soil

Standard Firuzkooh sand with a specific gravity of 2.66

was used for the present investigation. The friction angle of sand, determined in a Direct Shear device, was 33o and 41.5o for loose (γ = 13.8 kN/m3) and medium dense (γ = 15 kN/m3) states, respectively

B. Pile

Galvanized and aluminum pipes were used as pile for the experimental tests. The embedded lengths of piles were 400, 600 and 800 mm. The outside diameters of the pipes were 21.7, 22, 24.8 and 27 mm, while their wall thicknesses were 1.4, 1.9 and 2.4 mm. Tensile tests were performed on these pipes and the results are shown in Table 1.

Table 1. CHARACTERISTICS OF PILES

No.	weight (kg/m)	Outside diameter (mm)	Wall thickness (mm)	Young's modulus (GPa)
1	1.00	21.7	2.4	196
2	1.31	27	2.4	196
3	0.25	22	1.9	68
4	0.36	24.8	1.4	68

C. Experimental Setup

When a pile is subjected to lateral loads, the lateral stress is distributed in the soil behind of the pile. The diameter and depth of the soil reservoir must be large enough to allow soil pressure to be freely distributed. If the diameter of the soil reservoir is 10 times that of the pile in the direction of lateral loading, this condition will be satisfied. Hence, the tests were conducted in a test tank having a diameter and height of 700 mm and 1000 mm, respectively. For measuring the horizontal displacement of the pile at various depths, small holes were made on the wall of the tank at intervals of 200 mm in the direction and opposite direction of.

The static lateral load was applied by means of dead weights placed on a hanger connected to a flexible steel wire, strung over a pulley supported by a frame. Before filling the reservoir with sand, thin wires were attached to the pile at regular intervals to measure the horizontal displacement in depth. The pile was then placed inside the tank. The reservoir was filled by slow raining of sand through air and was then compacted at 15 cm layer to get a uniform density. During the horizontal load application to the pile at the top surface of the sand, an LVDT was used to measure the horizontal movement of the pile. Each test is specified with a unique code such as

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"Ga-L*D*"or "Al-L*D*". "Ga" and "Al" to indicate that the substances of the pile is galvanized or aluminum, respectively. The letters "L" and"D" represent the embedment length (cm) and outer diameter (mm) of the pile, respectively. For example "Ga- L40D27" indicates that the pile is galvanized with 40 cm embedment length and outer diameter of 27 mm.

3-Test Result

The static lateral load was applied to different embended length piles in soil with density of 13.8 and 15 kN/m^3. During the test, the applied load and the horizontal displacement of the pile on the surface and in the depth of the soil were measured.

For example, the experimental test results of one pile (Ga-L80D27) are shown in Figures 1 to 3. Figure 3 shows the experimental result of galvanized pile with a diameter of 27 mm subjected to lateral loading in the soil with a density of 15 kN/m^3 that is compared with the modulus of subgrade reaction and elastic approach. In Figure 2,the experimental test results of pile are compared with the ultimate modulus of horizontal subgrade reaction (K_{hmax}). Four stages of the load are displayed in Figure 3 where the behavior of a long pile under lateral load is shown.

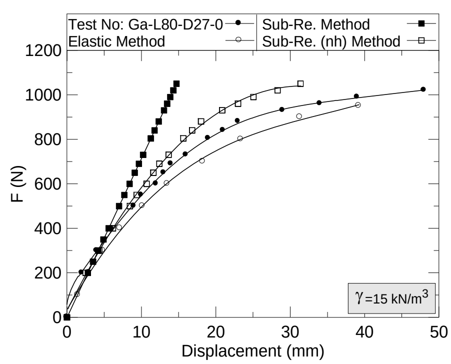

Fig.1 Comparison of experimental curve with the modulus of subgrade reaction and elastic approach

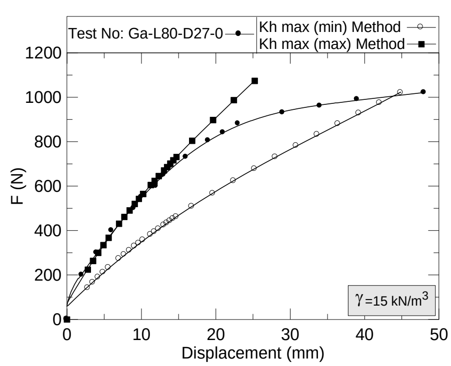

Fig.2 Comparison of the experimental curve with ultimate modulus of horizontal subgrade reaction (Khmax)

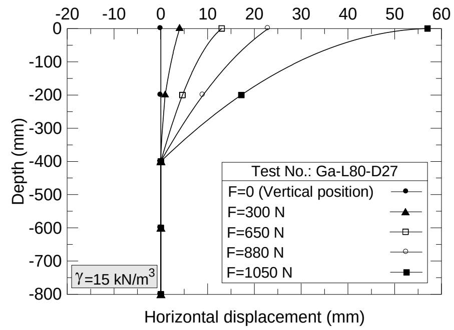

Fig.3 The horizontal displacement of the pile at different depths

4- Conclusions

In general the test results and comparisons show the following:

- The ultimate modulus of horizontal subgrade reaction is better than other theories for determine the bearing capacity of long piles
- Increasing the diameter of a long pile causes an increase in lateral load capacity
- Increasing the length of a long pile until it reaches a fixed length does not have any effect on the load-bearing capacity.
- In general, joint point in long pile with increasing stiffness of pile will be far from the soil’s surface.