

# Lateral Performance for Long Pile Subjected to Simultaneous Axial and Lateral Loads in Dense Sand: An Experimental Study

Jasim M. Abbas, Qasim I. Hussain  
Department of Civil Engineering, College of Engineering, University of Diyala,  
jasimalshamary@yahoo.com  
qasim.ibrahim2015@gmail.com

## Abstract

The present study focus on the investigation of the response of single pile when subjected to both axial and lateral loads simultaneously in dense sand. To study this issue, laboratory model was locally improved to examine the piles under this kind of loading. The dense sand provided using raining technique. The slenderness ratio of the tested pile is ( $L/D=45$ ). On the other hand, the vertical and horizontal loads are divided into 5 stages to assess the influence of load intensities on the lateral pile response. It can be concluded that the lateral pile response is affected by changing the load intensities

**Keywords:** Piles; Lateral response; Sand.

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## 1. Introduction

In fact, piles foundation are structural member which made from timber, steel, or concrete, used to support the structures and to transfer the load to the deep layers of soil that have adequate bearing capacity to support the structures. Always piles were subjected to vertical loads which result from the weight of the structures and to lateral loads result from wave, wind or earth quake especially when the piles used in the offshore structures. Actually, piles are subjected to both vertical and lateral loads in the same time, so it is important to know the

response and the behavior of piles in such cases especially when the studies are limited in such way.

A number of previous study takes into account the effect of pure lateral load on piles, these studies were early reported by (Broms 1964, Reese et al. 1974), and continuously improved until present (Awad 1999; Prasad and Chari 1999; Janoyan et al. 2001; Bouafia 2007; Abbas et al. 2008 and 2014; Ozden and Akdag 2009; Rahman et al. 2009; Fatahi et al. 2014; Abdrabbo and El Wakil 2016, and others). While, there are little works take into account the effect of both axial and lateral load on piles (Banerjee 1978; Karthigeyan et al. 2006 and 2007; Lee et al. 2011; Khodair and Abdel-Mohti 2014, Park et al. 2016).

Based on the mentioned study it can be shown that the study about the pile behavior under combined loads is limited, therefore this study included experimental tests for lateral pile performance with the effect of the presence of the vertical load in the same time in dense sand.

## 2. Materials Used

### 2.1 Sand

The sand used in the present study was brought from Karbalaa governorate, Iraq. The laboratory tests were conducted on it to explain its physical properties according to the ASTM specification. Figure (1) and Table (1), explain the physical properties of the sand used.

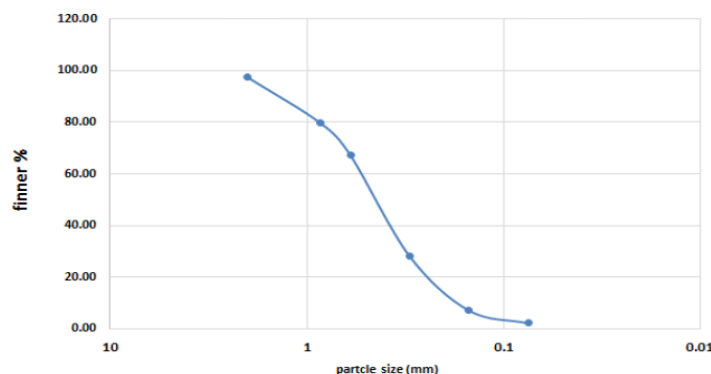


Figure 1: Particle size distribution of the used sand

**Table 1,** The physical properties of the used sand

Physical properties	Amount
D <sub>50</sub>	0.45
D <sub>10</sub>	0.191
D <sub>30</sub>	0.32
D <sub>60</sub>	0.55
Coefficient of uniformity, $C_u$	2.88
Coefficient of curvature, $C_C$	0.98
Classification based on USCS	SP
Specific gravity, $G_s$	2.67
Dry unit weight, $\gamma_d$ (kN/m <sup>3</sup> )	14.703
Angle of internal friction, $\phi$	36.8

**2.2 Pile**

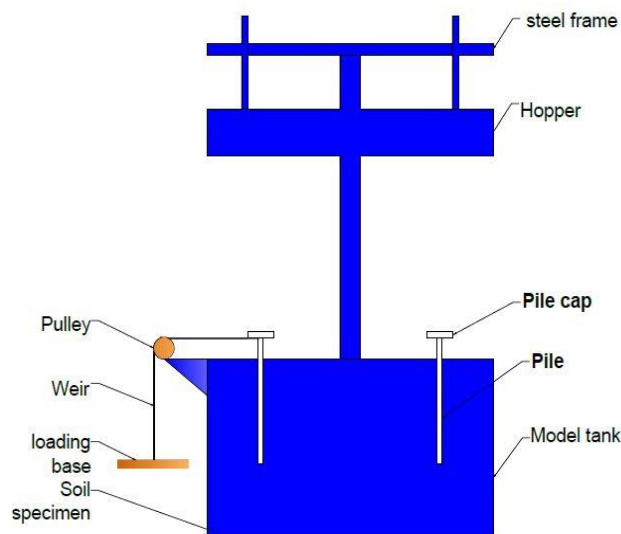
The pile used in the present study was made of steel material with diameter (D) of 1.5cm, wall thickness (t) 0.1 cm, and slenderness ratio (L/D) of 45.

**2.3 Model Tank**

The model tank that used in the present study was locally manufactured with dimensions of (100cm x 100cm x 100cm) to prevent any interface between the effective

zones of the piles used, and also to prevent the friction between the container wall and the soil used which may affect the obtained test results.

The laboratory model was made from steel plate of thickness equal to 4mm. All the sides of the model tank were fixed together via a number of screws as shown in the figure below. Figure 2 show the laboratory testing model that included all equipment's and the location for each part.

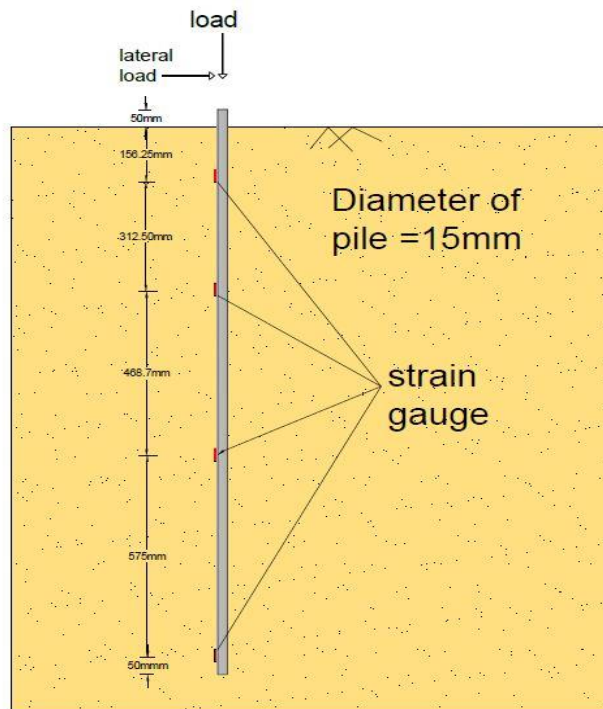


**Figure 2:** The laboratory model

**3. Experimental Work**

In the current study the pile used were subjected to both vertical and lateral loads. At initial stage the strain gauges were fixed at the pile side figure (3) to measure the lateral deflection of pile inside the soil. After that the pile model was placed in the laboratory model in the required depth by using steel mesh which fixed above the sides of model tank, the soil used (sand) was placed in the same tank from a required height (0.6m) for obtaining the

required placement density in the test via using the raining technique. The lateral load was applying on the pile by using a wire which attached by the cap of the pile from one direction and from the other it is related to the loading base via frictionless pulley. The lateral deflection of pile above the soil surface was measured by two dial gauges above the soil surface fixed at the pile cap and the lateral deflection along the pile inside the soil was measured by using the strain gauges.



**Figure 3:** The location of the strain gauges at the pile side

The amount of lateral load that used in the current study is equal to 20% of the allowable vertical load of the pile used and applies in five increments on pile. In each increment the lateral displacement was measured by using two dial gauges (sensitivity of 0.01 mm) which fixed on the pile cap and by strain gauges fixed along the pile. Vertical load is applied on the pile with the applied lateral load in five stages (0%, 20%, 40%, 60%, 80%, 100% from the allowable vertical load).

#### 4. Test Results and Discussion

The load-displacement curves were plotted for the pile used as shown in figure 4 to explain the effect of the presence of the vertical load on the lateral response of

pile. The lateral deflection of pile was measured by using dial gauge which is fixed on the pile head and for the embedded length of pile, the lateral deflection was measured by using strain gauges fixed at the pile side in the direction of load. From figure 4 it can be shown that when the vertical load is between 20% and 60% from the allowable vertical load, the lateral capacity of pile increases about 15.8% and 1.2% respectively, this is possibly due to the increase of pile stiffness due to increase of axial load. While, when the applied the vertical load more than 80% from the allowable vertical load, the lateral capacity of pile decreases to reach about 33.8%. This is possibly due to increase the effect of p-delta phenomena.

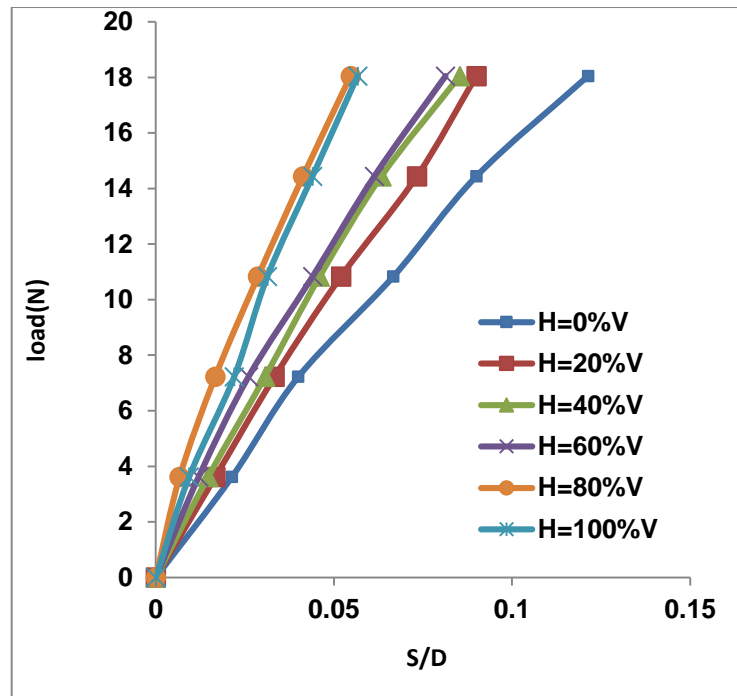


Figure 4: The load- displacement relationship for pile tip

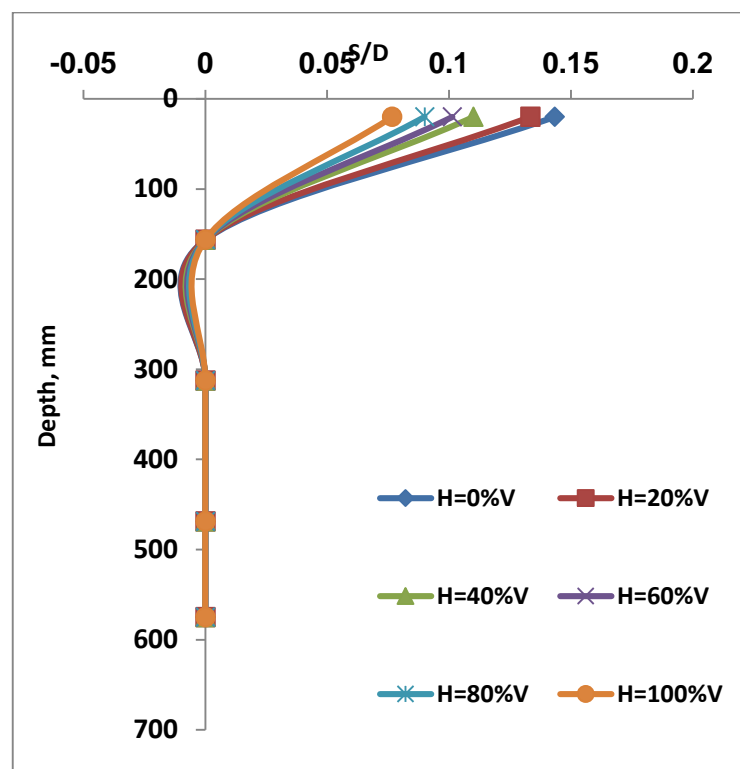


Figure 5: The lateral pile deformation with depth

Figure 5 explains the lateral pile deformation with depth that is obtained by strain gauges which are fixed at the pile side. From that curves it can be shown that the position of the flexural point is 156.25mm from the soil surface, flexural point is the point where the shear force is zero and the bending moment is in the maximum

value. Thus, the amount of load increases reduces the deformation value of the substrate

### 5. Conclusions

Based on the test result it can be shown that the presence of the vertical load affects the lateral response of the pile and the large effect of vertical load can be seen when

its amount it is 20 and 60% from the allowable vertical load of pile.

From the test results it can be shown that when the vertical loads applied on the pile is 20% and 60% from the allowable load then the lateral capacity of pile increases about 15.8% and 1.2% respectively and when the vertical load applied on the pile are 40%, 80%, and 100%, then the lateral capacity of pile decreases. The location of the flexural point is 156.25mm from the soil surface.

#### Acknowledgment

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