# RESPONSE OF LATERALLY LOADED SINGLE PILE IN SANDY SOIL

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## Abstract

*Pile foundations are often required to resist lateral loading. Lateral loads come from a variety of sources including wind, earthquakes, waves, and ship impacts. The lateral capacity of a pile is usually much smaller than the axial capacity and as a result groups of piles are often installed to increase the lateral capacity of the entire foundation system. When vertical or plumb pile groups do not provide sufficient lateral resistance the piles can be battered in order to mobilize some of the higher axial capacity to resist the lateral load. Several methods are available for predicting the ultimate lateral resistance to piles in sandy soil. However, these methods often produce significantly different ultimate resistance values. This makes it difficult for practicing engineers to effectively select the appropriate method when designing laterally loaded piles in sandy soil. In this paper, lateral load behavior of single piles in sandy soil was studied, for different L/D ratio by changing the diameter and length of pile. The analysis was carried out considering long free-head pile. The influence of soil type, effect of pile length and pile diameter on the pile response was observed and the results obtained by IS2911Part1 (sec2) and Matlock & Reese were presented.*

***Keywords:*** *Pile, Cohesionless soil, Lateral load, Matlock & Reese, IS2911Part1 (sec2), Free head pile.*

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## 1. INTRODUCTION

Piles are structural members that are made of steel, concrete or timber. They are used to build deep foundations and which cost more than shallow foundations. Despite the cost, the use of pile often is necessary to ensure structural safety. Some time piles are subjected to lateral load, for example piles used in quay and harbor structure. Offshore structures have been built for oil production and for many other reasons in many parts of the world. Their design involves the consideration of unusually large ratios of lateral to vertical load, particularly in areas where severe storms occur. The exact effect of the cyclic wave loading on the soil response conducted in analytical fashion is very complex. It would be unrealistic to precisely follow in continuous fashion the path of this response. The sources of lateral load on harbor structure are impact of ship and wave action and off shore structures are also subjected to wind and wave. High rise building, tower are subjected to lateral load due to wind and earth quake forces. So, it is important to know the lateral load resistance capacity of pile foundation. Several methods are available for predicting the ultimate lateral resistance to piles in cohesionless soils. However, these methods often produce significantly different ultimate resistance values. This makes it difficult for practicing engineers to effectively select the appropriate method when designing laterally loaded piles in cohesionless soils. Reese and Matlock (1956) were the first who assumed that the soil modulus increases with depth and developed solutions for laterally loaded piles in a non-dimensional form. For stiff clays, they assumed a parabolic variation in subgrade reaction modulus with depth. Matlock and Reese (1960) developed general solutions for laterally loaded piles supported by an elastic medium. According to them, the expressions could be developed for shear force, bending moment, soil reaction and deflection. Bowles (1974) produced a computer program to analyze the problem of laterally loaded piles with ability of applying axial loads on the pile. This program processed general cases of a pile, fully or partially embedded and for vertical and battered piles. Reese (1975) presented a computer program using the finite difference approach to solve the deflection and bending moment of pile under lateral as well as axial loads as a function of depth. The soil properties define by a set of nonlinear “p-y” curves. Prakash and Kumar (1996) developed a method to predict the load deflection relationship for single piles embedded in sand and subjected to lateral load, considering soil nonlinearity based on the results of 14 full-scale lateral pile load tests. Phanikanth et al. (2010) studied the behaviour of single pile in cohesion less soils subjected to lateral loads. The modulus of subgrade reaction approach using finite difference technique is used and the same was coded in MATLAB for the analysis.

## 2. OBJECTIVES

The objectives of this paper were

- To find the lateral load carrying capacity of single pile in sandy soil.
- To compare the load carrying capacity of pile by IS 2911 part 1(sec2) with Matlock & Reese method.
- To find the effect of diameter of the pile on lateral load capacity.
- To find the effect of length of the pile on lateral load capacity.

## 3. METHODOLOGY

The various methods employed in this paper were discussed with the results in the following topics.

### 3.1. Effect of Diameter of the Pile on Lateral Load Capacity

To study the effect of diameter on lateral load capacity, 20 m length of piles of different diameters such as 0.50 m, 0.60 m, 0.70 m, 0.80 m, 0.90 m, and 1.00 m were considered. The results aregiven in Table 1, which indicates that lateral load capacity increases with increasing diameter of the pile (Fig.1& 2). This was due to the increase in surface area. Also the pile stiffness, EI, increases withincrease in moment of inertia I which depends on the diameter of pile. The lateral load capacity of pile obtained from IS2911 Part1 (sec2) was significantly less when compared with Matlock & Reese method.

### 3.2. Effect of Length of the Pile on Lateral Load Capacity

To study the effect of length of the pile on lateral load capacity, 0.50 m diameter piles of different lengths such as 20 m, 16.7 m, 14.3 m, 12.5m , 11.1 m, and 10 m were considered. The results aregiven in Table2, which indicates there is no any considerable change in lateral load capacity with increase in length (Fig.3 & 4).

**Table 1:** Comparison of lateral load capacity &lateral deflection with increase in diameter

| Sl.No. | Length (m) | Diameter (m) | L/D Ratio | Lateral load capacity (KN) | | Lateral deflection (mm) | |
|---|---|---|---|---|---|---|---|
| | | | | As per IS 2911 | As per Matlock & Reese | As per IS2911 | As per Matlock & Reese |
| 1 | 20 | 0.50 | 40.00 | 1218 | 1557 | 3.5 | 4.2 |
| 2 | 20 | 0.60 | 33.33 | 1924 | 2164 | 2.5 | 2.9 |
| 3 | 20 | 0.70 | 28.57 | 2685 | 2847 | 2.0 | 2.3 |
| 4 | 20 | 0.80 | 25.00 | 3340 | 3674 | 1.5 | 1.7 |
| 5 | 20 | 0.90 | 22.22 | 4114 | 4525 | 1.2 | 1.4 |
| 6 | 20 | 1.00 | 20.00 | 5206 | 5768 | 1.0 | 1.15 |

**Table 2:** Comparison of lateral load capacity &lateral deflection with increase in Length

| Sl.No. | Length (m) | Diameter (m) | L/D Ratio | Lateral load capacity(KN) | | Lateral deflection (mm) | |
|---|---|---|---|---|---|---|---|
| | | | | As per IS 2911 | As per Matlock & Reese | As per IS 2911 | As per Matlock & Reese |
| 1 | 20.0 | 0.50 | 40.00 | 1218 | 1557 | 3.5 | 4.2 |
| 2 | 16.7 | 0.50 | 33.40 | 1169 | 1557 | 3.5 | 4.2 |
| 3 | 14.3 | 0.50 | 28.60 | 1108 | 1557 | 3.5 | 4.2 |
| 4 | 12.5 | 0.50 | 25.00 | 1069 | 1557 | 3.5 | 4.2 |
| 5 | 11.1 | 0.50 | 22.22 | 1040 | 1557 | 3.5 | 4.2 |
| 6 | 10.0 | 0.50 | 20.00 | 1008 | 1557 | 3.5 | 4.2 |

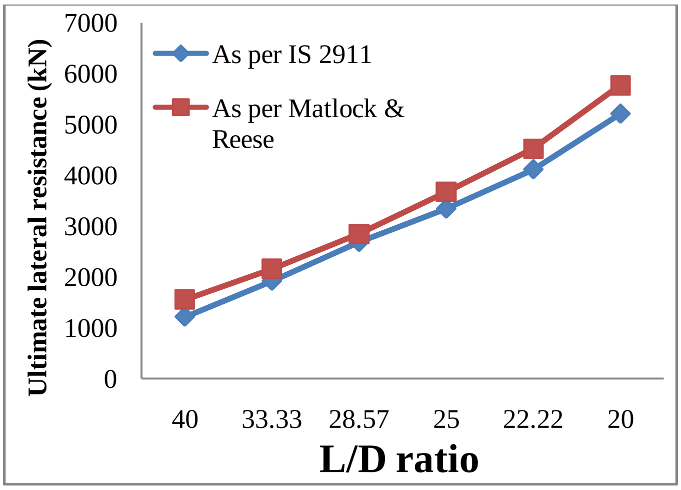


**Fig 1** Ultimate lateral resistance (Increase in diameter)

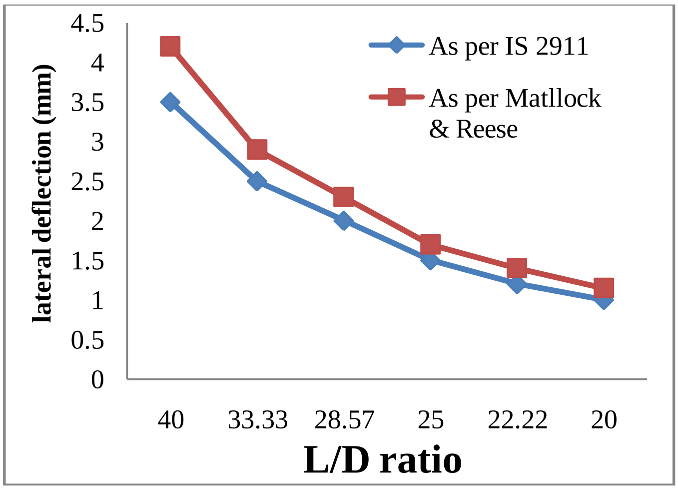


**Fig 2** Lateral deflection (Increase in diameter)

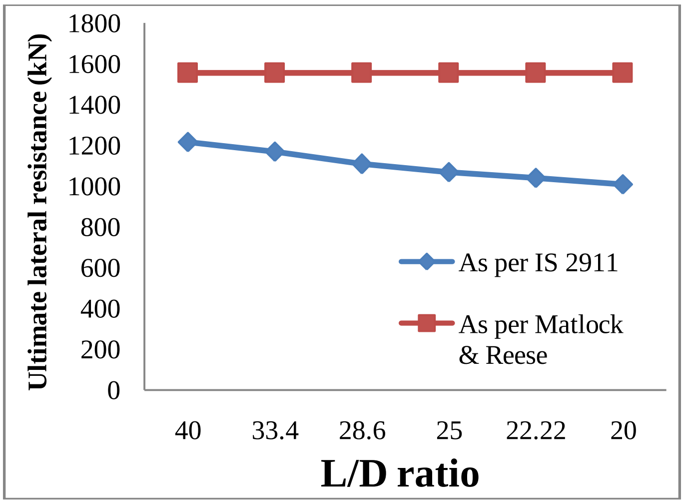


**Fig 3** Ultimate lateral resistance (Increase in length)

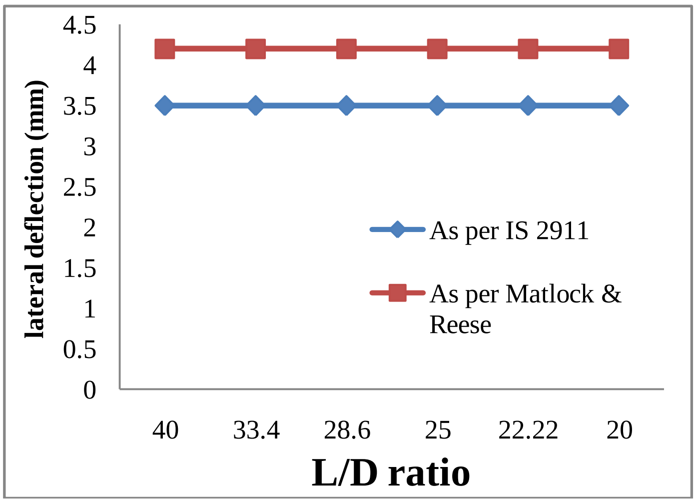


**Fig 4** Lateral deflection (Increase in length)

## 4. CONCLUSIONS

From the obtained data the following conclusions were made

- The effect of pile diameter was studied and it was concluded that lateral load capacity increases with increase in diameter of the pile for same length. This was due to the increase in surface area, pile stiffness, moment of inertia and young's modulus.
- The lateral load capacity of pile obtained from IS 2911 Part1 (sec2) was significantly less when compared with Matlock & Reese method.

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