Experimental and Finite Element Analysis of Laterally Loaded Pile

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Abstract--- Piles have been widely used for supporting axial and lateral loads for a variety of civil engineering structures such as high rise buildings, transmission lines, bridge piers and port structures. In many cases, lateral loads govern the design of piles. Piles are commonly used to support bridge structures, tall buildings, transmission line towers etc. where poor subsoil conditions are encountered. To suit the various types of structures and their loading conditions, piles of different types, shapes and sizes are being used in practice, the safety of these structures mainly depends on the ability of supporting piles to resist large amount of lateral forces. These lateral forces may be due to the action of wind in case of onshore structures and due to combination of wind and wave action in case of offshore structures. In case of coastal structures, there are additional berthing forces.

Keywords: lateral loads, subsoil, lateral forces, wind and wave action

I. INTRODUCTION

The analysis of pile under lateral loading is complicated by the fact that the soil reaction is dependent on the pile movement; on the other hand it is dependent on the soil response. Thus, the problem is one of soil-structure interaction .Piles are columnar elements in a foundation which have the function of transferring load from the superstructure through weak compressible strata or through water, onto stiffer or more compact and less compressible soils or onto rock.

Fig: 1.2 Structure subjected to lateral load

Fig: 3.3 Sieve analysis setup

II. PROCEDURE

Weigh 0.1 g, each sieve which is to be used, make sure that each sieve is clean before weighing it.Obtain 200-300 g of oven dry soil as a representative sample from the bag of material or as provided to you weigh the sample to 0.1g pass the sample through 4.75mm IS sieve to find percent gravel, if any sieve remaining soil through a set of sieve by hand shaking .the sieve should be accompanied by lateral and vertical movements together with slighting jolting.use mechanical shaker ,if available, sieving should with slighting jolting .use mechanical shaker ,if available, sieving should continue at least for 10 minutes and take care to ensure that sieving is complete.Weigh to 0.1g each sieve and the pan with soil. Retained on them. Find by subtraction the weight of soil retained on each sieve by dividing the weight retained on each sieve by the original sample weight. Compute the percentage passing (or percentage finer) by starting with 100 percent and subtracting the percent retain on each sieve as a cumulative procedure

Table 3.2 Sieve analysis table

IS sieve designation	Weight of soil retained in 'gm'	Percentage of soil retained	Cumulative percentage of soil retained	Percentage finer
4.75 mm	0	0	0	100
2.36 mm	0	0	0	100
1.18 mm	111	22.2	22.2	77.8
600 micron	130	26	48.2	51.8
300 micron	221	44.2	92.4	7.6
150 micron	32	6.4	98.8	1.2
75 micron	4	0.8	99.6	0.4
Pan	2	0.4	100	0

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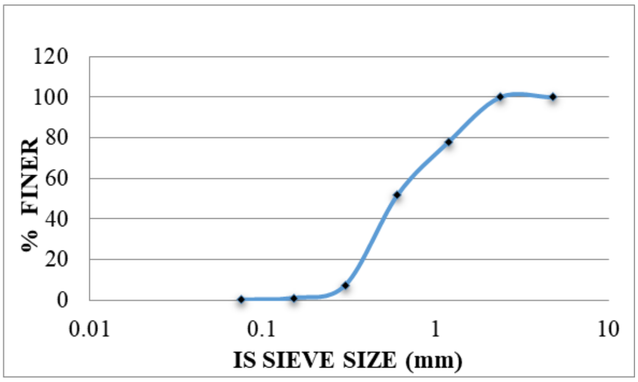

Fig: 3.4 Grain size distribution curve

Table 3.3 Index property of sand

S.No	Parameter	Symbol	Values
1	Gravel	%	0
2	Coarse sand	%	3
3	Medium sand	%	74
4	Fine sand	%	22
5	Silt and clay	%	Trace
5	Effective Size	D_{10}	0.25
6	Uniformity coefficient	C_u	2.08
7	Coefficient of Curvature	C_c	1.63
8	Specific Gravity	G_s	2.63
9	Classification	SP	Poorly graded

CALCULATION

Coefficient of uniformity (C_u) = D_{60} / D_{10}
From graph D_{60} =0.74
D_{10} = 0.33
C_u =0.74/0.33=2.24micron
Co efficient of curvature (C_c)= $D_{30^\wedge 2}$/(D_{60} D_{10})
From graph, D_{30} =0.47
Therefore Cc=0.47^2/0.74x0.33=0.9045
C_c>1, it is poorly graded

3.3.1.1 SPECIFIC GRAVITY TEST

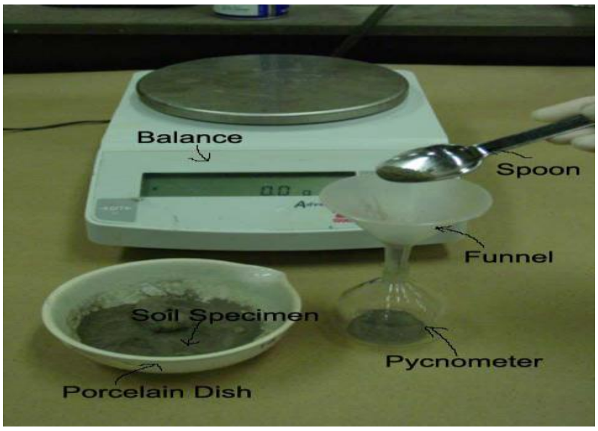

Fig 3.5 Specific gravity test setup

Table 3.4 specific gravity table

Weight of empty pycnometer , W_1	546 gm
Weight of sand + pycnometer, W_2	946 gm
Weight of sand, W	400 gm
Weight of sand + pycnometer + water , W_3	1620 gm
Weight of pycnometer +full water , W_4	1372 gm
Weight of equivalent weight of water ($W\omega = W + W_4 - W_3$)g	152 gm
Specific gravity of soil at t˚C, G=W/Wω	2.631 gm
Specific gravity of soil at standard temperature 27˚C, G	2.631 gm

III. RESULTS AND DISCUSSIONS

The results of laboratory tests on model piles embedded in dry sand bed of loose density to find the performance of pile due to ground movement are presented and discussed in this chapter. The performance of pile was studied under the following aspects,

- Piles of different L/D ratios

The results obtained from the test on piles of different L/D ratios are discussed in the following sequence.

IV. EXPERIMENTAL RESULTS

- Pile head deflection of short pile
- Pile head deflection of intermediate pile
- Pile head deflection of long pile
- Relation between δ_{max}/L_pvs lateral load capacity

V. NUMERICAL RESULTS

- Pile head deflection
- Comparision of experimental and numerical results

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Pile head deflection of short pile.

Fig 4.1 shows the variation of pile head deflection with lateral load for pile of L/D ratio 20 embedded in loose sand. It can be observed that the pile head deflection increases with applied load. For the lateral load more than 60 N, the slope of the pile head deflection curve is changed and rate of increase in deflection of pile head is also decreased on further increase in lateral load. The allowable lateral deflection of the pile is taken as 20% of the pile diameter (NarasimhaRao et al., 1998) and hence the load corresponding to deflection 2.5 mm, in this case, is taken as the lateral load capacity of the piles. The comparisons for various cases are made for this lateral load corresponding to deflection of the pile. The lateral load capacity is found to be 18 N.

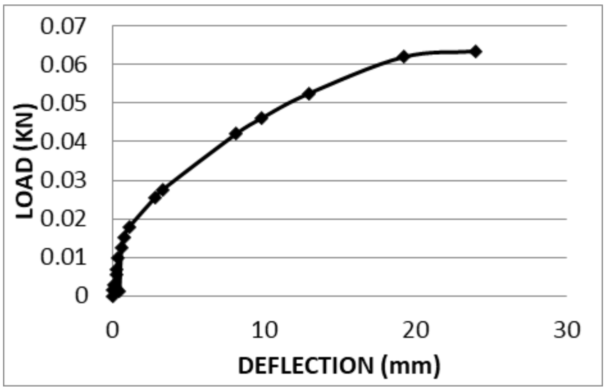

Fig: 4.1Pile head deflection of short pile obtain from experimental result

4.3.2 Pile head deflection of intermediate pile.

Fig 4.2 shows the variation of pile head deflection with lateral load for pile of L/D ratio 30 embedded in loose sand. It can be observed that the pile head deflection increases with applied load. For the lateral load more than 62 N, the slope of the pile head deflection curve is changed and rate of increase in deflection of pile head is also decreased on further increase in lateral load. The lateral load capacity of the intermediate pile is observed to be 22 N which is slightly higher than that of the short pile whose L/D ratio is 20.

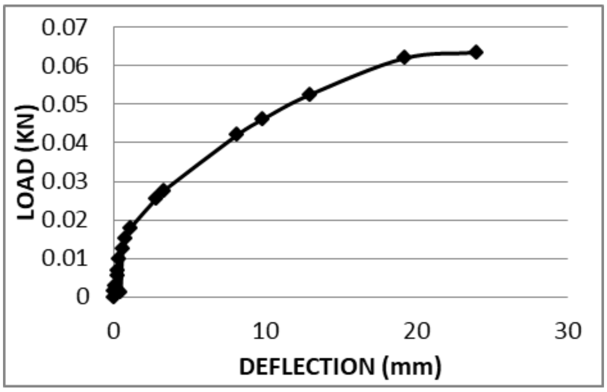

Fig: 4.2 Pile head deflection of intermediate pile obtained from experimentalresult

Pile head deflection of Long pile.

Fig 4.3 shows the variation of pile head deflection with lateral load for pile of L/D ratio 40 embedded in loose sand. It can be observed that the pile head deflection increases with applied load. For the lateral load more than 62 N, the slope of the pile head deflection curve is changed and rate of increase in deflection of pile head is also decreased on further increase in lateral load. The lateral load capacity of the long pile is observed to be 25 N which is higher than both short and intermediate pile.

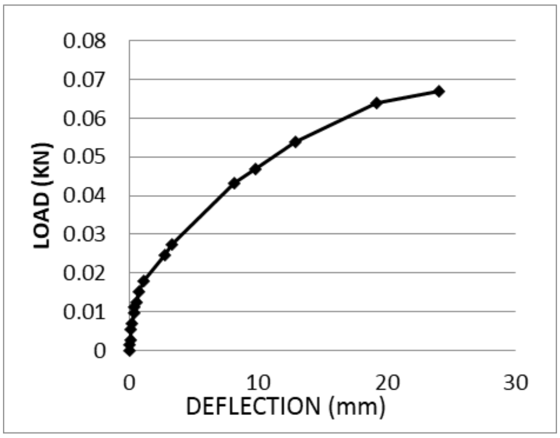

Fig: 4.3 graph of pile head deflection of long pile obtain from experimentalresult

4.3.4 Relation between Deflection/Total length and lateral load

Fig 4.36 shows the relationship between Deflection/Total length and lateral loadfor piles of embedded in loose sand bed respectively. The response is reduced almost linear.

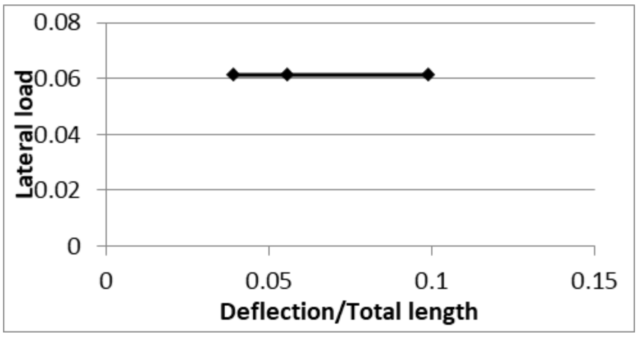

Fig: 4.4 Graph between Deflection/Total length and lateral load

Lateral load capacity of piles of different length

Table 4.1 lateral load capacity of pile of different length

Length(mm)	*Ultimate Lateral Load(N)*
230	15.24
340	16.25
460	17.52

From the results, it can be seen that lateral load capacity increases with increase in length of the pile. This is because the passive resistance is mobilized on increased embedment of pile, i.e. when the embedment length of pile increases.

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4.4 INTRODUCTION AND VALIDATION OF PLAXIS

Table 4.2 Represent the finite element results

Parameter Unit	*Name*	*Soil1*	*Soil2*	*Pile*
Unsaturated Soil Weight KN/m³	Υ_{unsat}	18	19	25
Saturated Soil KN/m³	Υ_{sat}	18	19	_
Young's Modulus KPa	E	13000	13000	2000000000
Poisson ratio	v	0.3	0.3	0.15
Cohesion intercept KPa	C'	20	1	_
Friction angle	φ	35	45	_

Soil 1: Medium dense cemented silty sand layer

Soil 2: Medium dense to very dense silty sand with cemented lumps

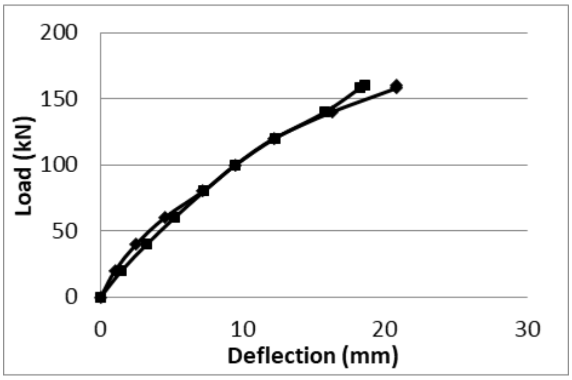

Fig: 4.5 Comparison between the finite element result and field test data

The comparison between the finite element results and field test data is shown in Fig.4.16

Also the numerical simulation is reasonably accurate for the problem of laterally loaded piles and pile – soil interaction over a wide range of deformation

4.5 NUMERICAL ANALYSIS

4.5.1 Generation of Mesh

Finite element analyses were performed using the software PLAXIS 3D FOUNDATION version 1.1. In the finite element method a continuum is divided into a number of (volume) elements. Each element consists of a number of nodes. Each node has a number of degrees of freedom that correspond to discrete values of the unknowns in the boundary value problem to be solved. In order to perform the finite element calculations, the geometry has to be divided into elements. A composition of finite elements is called finite element mesh. The basic soil elements of a 3D finite element mesh are represented by the 15-node wedge elements .These elements are generated from the 6-node triangular elements. The 15-node wedge element is composed of 6-node triangles in horizontal direction and 8-node quadrilaterals in vertical direction. Fig 1 and 2 shows the 2D and 3D mesh generated for the analyses.

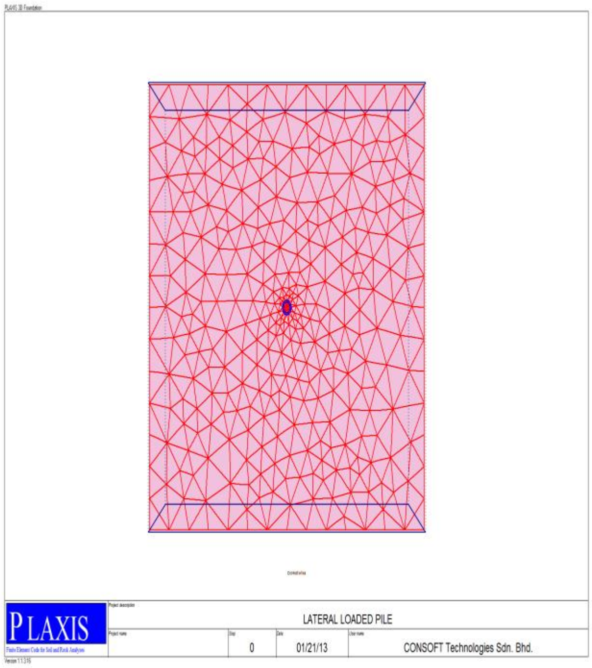

Fig: 4.6 2D Mesh

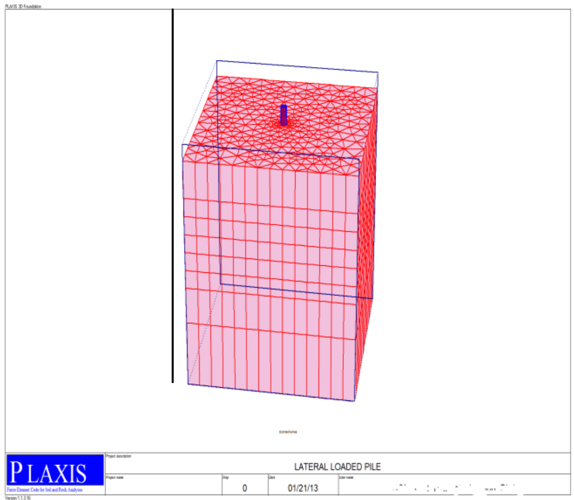

Fig: 4.7 3D Mesh

4.5.2 Pile Head Deflections

Figure 4.6, 4.7and 4.8 shows the Deflection vs Lateral Load Profile for L/D=20and 30 respectively. The observations shows that, Linear elastic model (perfect-plasticity) used to model the pile and Mohr-Coulomb model used to model the non-linear performance of surrounded soil which involves two main parameters, namely the cohesion intercept, c' and the friction angle, φ'and three additional parameters namely Young's modulus, E', Poisson's ratio, ν', and the dilatancy angle, ψ' needed to calculate the complete σ – ε behavior holds good.

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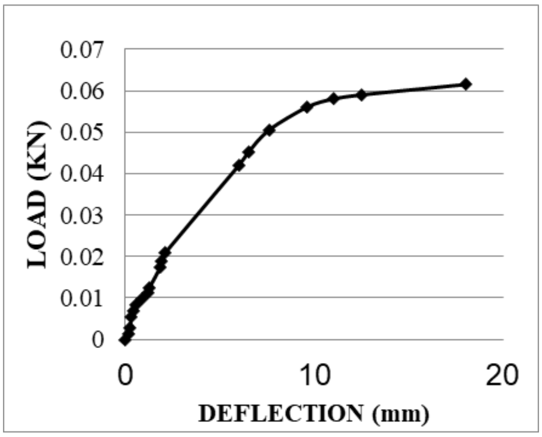

Fig: 4.8 Pile head deflection of SHORT pile obtained from Plaxis value

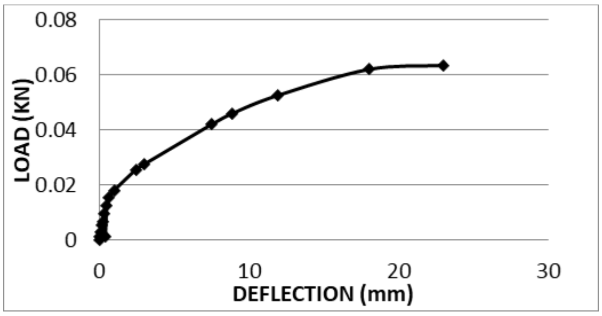

Fig: 4.9 Pile head deflection of INTERMIDIATE pile by using plaxis result

Figure 4.8 shows the load deflection profile for the pile of L/D ratio 40. The deflection of the long pile increases as the lateral load increases. The deflection starts decreasing after the pile reaches its ultimate resistant value.

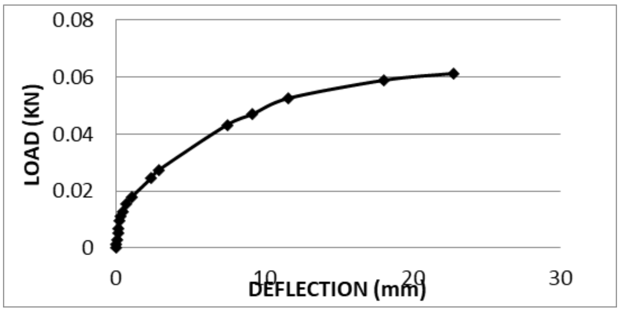

Fig: 4.10 Pile head deflection of LONG pile by using plaxis result

Fig 4.9 and 4.10 shows the pile head deflection and horizontal displacement of soil respectively. This confirms the behavior of long pile as mentioned by Poulos and Davis.

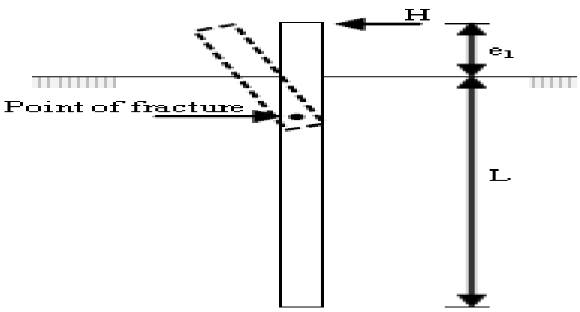

Fig: 4.11 sketch diagram of deflected pile head

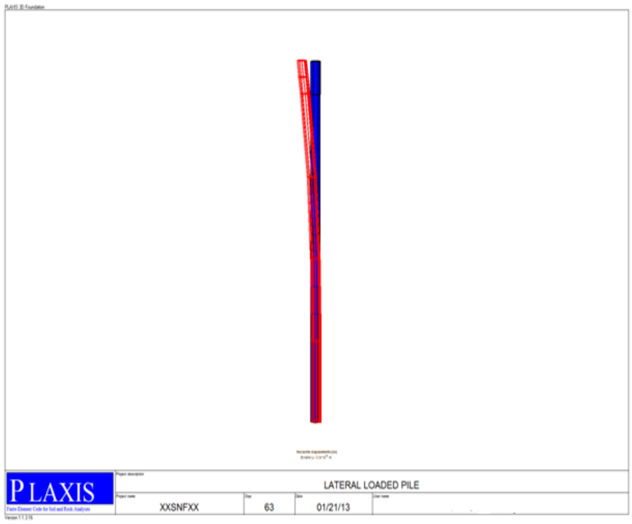

Fig: 4.12Deflection of pile obtained by plaxis-3D - foundation

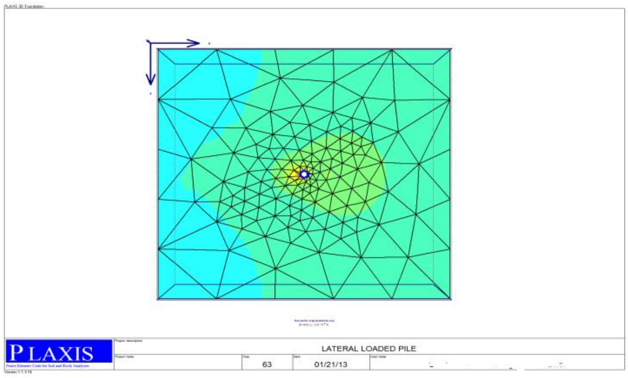

Fig: 4.13 lateral loaded pile obtained by Plaxis -3D - Foundation

4.6 COMPARISION OF EXPERIMENTAL AND NUMERICAL RESULTS

The experimental results are compared with the finite element analyses Plaxis 3D Foundation. The variation of deflection of pile with lateral load for a pile of L/D =10 embedded in loose sand are presented in the fig 4.12. The deflection presented in the figure is deflection of pile measured at the head of respective piles. The deflection of piles observed in the Plaxis show the trend as seen in the model tests on single piles. Deflection at the pile head increases with lateral load with increasing rate. However the slope of the curve is changed it direction for the lateral load of 60N in both experimental and numerical results

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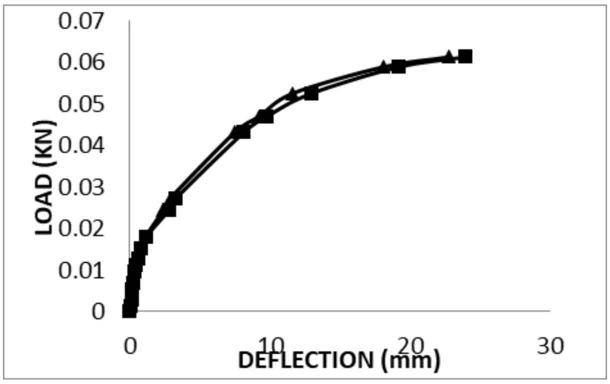

Fig: 4.14 Graph represent the comparison between experimental value and plaxis values for short pile

Figs 4.13 and 4.14show the comparisons of deflection vs lateral load for the L/D=30 and L/D=40 respectively. The finite element analysis slightly underestimates the deflection when compared with experimental results in case of pile groups.

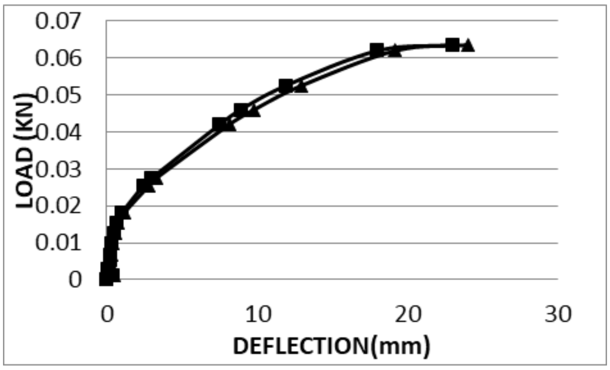

Fig: 4.15 Graph represent the comparison between experimental values and plaxis values for INTERMIDIATE pile

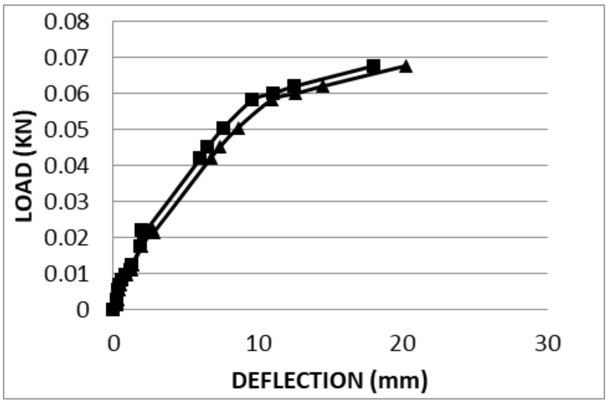

Fig: 4.16 Graph represents the comparison value for experimental result and plaxis result for LONG pile

CONCLUSION

An attempt was made in this research to study the behavior of pile subjected to lateral load. Piles of three L/D ratios such as 20, 30 and 40 were chosen for the study. The tests were carried out on sand beds of density via loose (γ=15.3kN/m^3). The following are the important conclusions derived from the tests conducted on piles.

- The pile head deflection for longer piles is more in case of loose sand when compared with intermediate and long piles.
- On comparing the behavior of piles, the percentage increase in maximum deflection is 3.3% for L/D of 30 and 13.3% for L/D of 40 in loose sand.
- The pile head deflection is found to increase exponentially with increasing lateral load.
- The lateral load capacity of short pile is observed to be 15.24 N and intermediate and long pile is 16.25 N and 17.52 N respectively.
- The lateral load capacity of longer pile is higher than shorter pile due to the passive resistance is mobilized on increased embedment of pile.
- The influence of on the lateral response of piles installed in sand is also analyzed through 3-dimensional finite element analyses and its compares reasonably with experimental results.

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