A Project Report on

EXPERIMENTAL AND NUMERICAL STUDY ON LATERALLY LOADED PILE IN SAND.

Submitted in partial fulfilment of the requirements

For the degree of

Bachelor of Engineering

by

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2018-2019

CERTIFICATE

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2018-2019

This is to certify that the project entitled **"EXPERIMENTAL AND NUMERICAL STUDY ON LATERALLY LOADED PILE IN SAND"** is a bonafide work of **Rizvi Md Muntazar, Sayyed Umar Javed, Shah Shahnawaz Irshad Ali** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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This dissertation report entitled **"EXPERIMENTAl AND NUMERICAL STUDY ON LATERALLY LOADED PILE IN SAND"** by **Rizvi Md Muntazar, Sayyed Umar Javed, Shah Shahnawaz Irshad Ali** is approved for the degree of "Civil Engineering"

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Place: Panvel

DECLARATION

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We take this opportunity to thank all our Professors and non-teaching staff who have directly or indirectly helped our project, we pay our respects and love to our parents and all other family members for their love and encouragement throughout our career. Last but not the least we express our thanks to our friends for their cooperation and support.

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ABSTRACT

In the present study an attempt is made to evaluate the lateral load carrying capacity of single and group of model piles embedded in loose and medium dense sand. The size of the model box used in the present study is 100mm length, 100mm width and 100mm height. A series of experiments were conducted on single and group of piles subjected to lateral load. All the tests were carried out on cohesionless soil with a relative density of 35.55% and 80% respectively was adopted to prepare the sample in the model box to achieve the desired density. It was found that as density of sand increases the lateral load was found to increase. In the present study the group efficiency was found which is defined as ultimate lateral resistance of a pile group to that of a single pile. The group efficiency was found to increase with increase in spacing to diameter ratio. The increase in group efficiency was attributed due to decrease in pile-soil interaction effects with increase in spacing between the piles.

Keywords: Group of Piles, Sand, Lateral Load, Group Efficiency, Relative Density

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Chapter 1

Introduction

1.1 General

One of the most important aspects of civil engineering project is the foundation system. Designing the foundation system carefully and properly, will not only leads to a safe and efficient structure but also an overall economy of the project.

Superstructure are supported by pile foundations so that it had its origin in prehistoric time this foundation may be subjected to significant horizontal loads such as dynamic and static loadings. Many methods have been presented within the area of foundation engineering to determine optimal lateral load carrying capacity of piles. One of the principal and most complicated issues faced in this field is measuring the reaction of pile group and individual pile to outwardly applied lateral load.

Pile foundations of many structures such as retaining wall, support of bridge abutment, piers, transmission tower, anchor for bulkheads and offshore structures, are frequently subjected lateral loads such as wind loading or earth quakes these lateral force are sometimes much greater than the weight of the structure itself. Therefore, the foundation system must be design to resist the both axial forces and lateral forces. Generally, vertical pile resists the lateral load or the moment by deflecting laterally until the necessary reaction in the surrounding soil mobilized. The behaviour of individual pile in group pile is controlled to a major extent by its location in the pile group and its pile head fixity condition.

Often piles are also constructed on sloping ground where the pile behaviour is not as like horizontal ground due to reduced passive resistance and initial confining pressure the study of laterally loaded pile response requires a proper assessment of soil-structure interaction phenomenon involving the interaction between the piles and the surrounding soil. Pile deflection and the corresponding bending moment is an important factor to be considered in the behaviour of laterally loaded piles A finned has been defined by Lee and Gilbert as a pile with four plates that is welded at 90° to a top of tradition mono pile. By measuring the lateral resistance against the displacement of pile head the rise in lateral resistance when the fins are applied to the pile can be revealed, and the numerical analysis demonstrates that an increase in fin length leads to an increase in lateral resistance.

In practice piles are used in groups and are connected by a cap at the pile heads. The spacing between the piles, arrangement of piles, their batter, and direction of load has an important role in the assessment of load deformation behavior of pile groups under lateral loads. The present study the group efficiency was found which is defined as ultimate lateral resistance of a pile group to that of a single pile. The group efficiency was found to increase with increase in spacing to diameter ratio. The increase in group efficiency was attributed due to decrease in pile-soil interaction effects with increase in spacing between the piles. However, the response of a laterally loaded pile group is much more complicated and still remains a fruitful research area. The behavior of an individual pile in group piles is controlled to a major extent by its location within a pile group and its pile head fixity condition. It is well known that the lateral resistance of a pile in a pile group is strongly influenced by the “shadowing effects instance, both the lateral subgrade modulus for piles and the ultimate lateral resistance within a pile group are reduced because of the overlapping of the stress zones in the surrounding soil given the same pile head fixity, the pile group will undergo significantly more displacement for a given load per pile than a single isolated pile does

1.2 Objectives

The response single pile and group of pile subjected to lateral load. In this project, an experimental programme on piles embedded in soils undergoing lateral load was outlined and aims to:

- To study the behaviour of Laterally loaded Single pile and Group of pile (with different configurations) in sand.
- To study the Load vs. Deflection curve.
- Establish guidelines for estimating lateral load carrying capacity of pile subjected to lateral load.
- Establish guidelines for the selection of modes of failure to be used in analysis on pile flexibility, boundary condition, soil movement profiles.
- Identify possible modes of soil movement and pile failure.
- Establish appropriate guidelines for modulus of sub grade reaction of piles under lateral load.

1.3 Aim of study

To study the response of vertical piles to lateral forces and Lateral movements of pile. The specific aims are:

1. To study the behaviour of single piles in progressively applied lateral load with focus on the impact of distance from the free lateral movement source and pile location, variation in lateral load level, soil movement profiles, magnitude of soil movement on the responses of piles.
2. To investigate the response of laterally loaded pile groups, lateral movement of pile for various pile spacing configuration and different length.
3. To develop simple solutions for preliminary evaluation of the internal forces and deformations in piles imposed by horizontal loading.
4. To verify the relationship between the maximum bending moment and lateral load, which is used in solutions for passive piles and active piles; and
5. To obtain the design parameters for laterally loaded rigid piles in sand and to identify any difference between active and passive piles.

The logic behind the proposed study is to fulfil the objectives, literatures on laterally loaded piles and piles subjected to lateral load have been reviewed. Model tests have been conducted to investigate the behaviour of single piles (aim 1) and pile groups (aim 2) subjected to lateral load. The results from pile group tests were compared with those of the single pile tests to study the pile-soil pile interactions and coupling effects in pile groups subjected to lateral load. Therefore, static and cyclic laterally loaded pile tests were also conducted in the same sand using the same apparatus as the tests on piles subjected to lateral load to gain the relationship between the maximum bending moment and applied lateral load. This study will promote a better understanding of the responses of pile foundation due to lateral loading.

1.4 Advantages

1) Pile are commonly used to support bridge structure, tall building and transmission line tower which usually subjected to overturning moment due to wind, wave pressure, earthquake these overturning moment transferred to the foundation in the form of horizontal and vertical loads. Pile foundation of the structure must be capable of resisting these horizontal or lateral load.
2) Piles maintain their shapes during load applications.
3) They do not deflect in different ground condition.
4) A pile driven into the granular soils and compacts the adjacent soil mass and as a result, the lateral resistance capacity of pile is increased.

Chapter 2

Literature review

2.1 General

The work is done by various investigators and it is referred and summarised in this chapter from the various journals and conference papers.
The following are the literature we had studied

2.2 Review of literature

k. Muthukkumaran et. al (2015) have used single model pile for investigation of model pile subjected to a lateral load in sloping ground. They have concluded that the maximum bending moment and the depth of fixity of the pile is significantly increases with the increase in ground slope, the increase in relative density of soil increases the pile-soil relative stiffness which cause to reduce the depth of fixity**.**

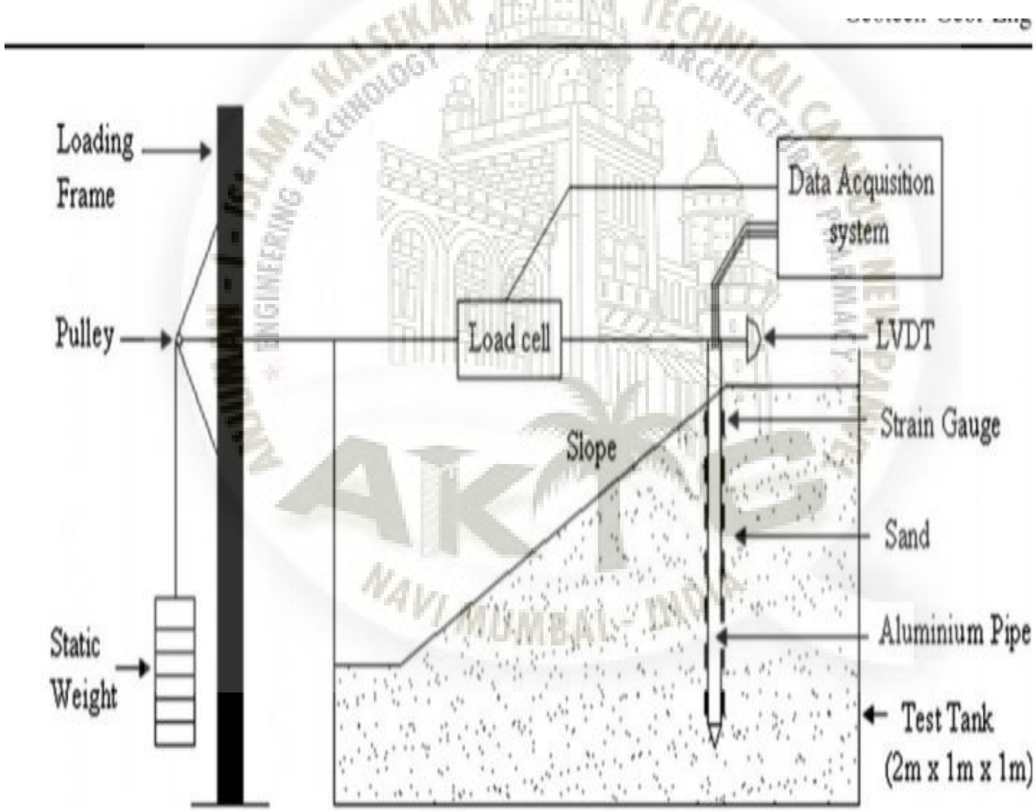

Fig 2.1 Experimental setup

Yenumula V.S.N. Prasad et al (1999) have used rigid pile to investigate lateral capacity of model rigid pile in cohesionless soil. They found that for circular pile the pressure distribution across the diameter is not uniform but it is maximum at the centre and it almost zero at their two ages. Taking this into account a method is proposed in the paper to predict soil pressure distribution.

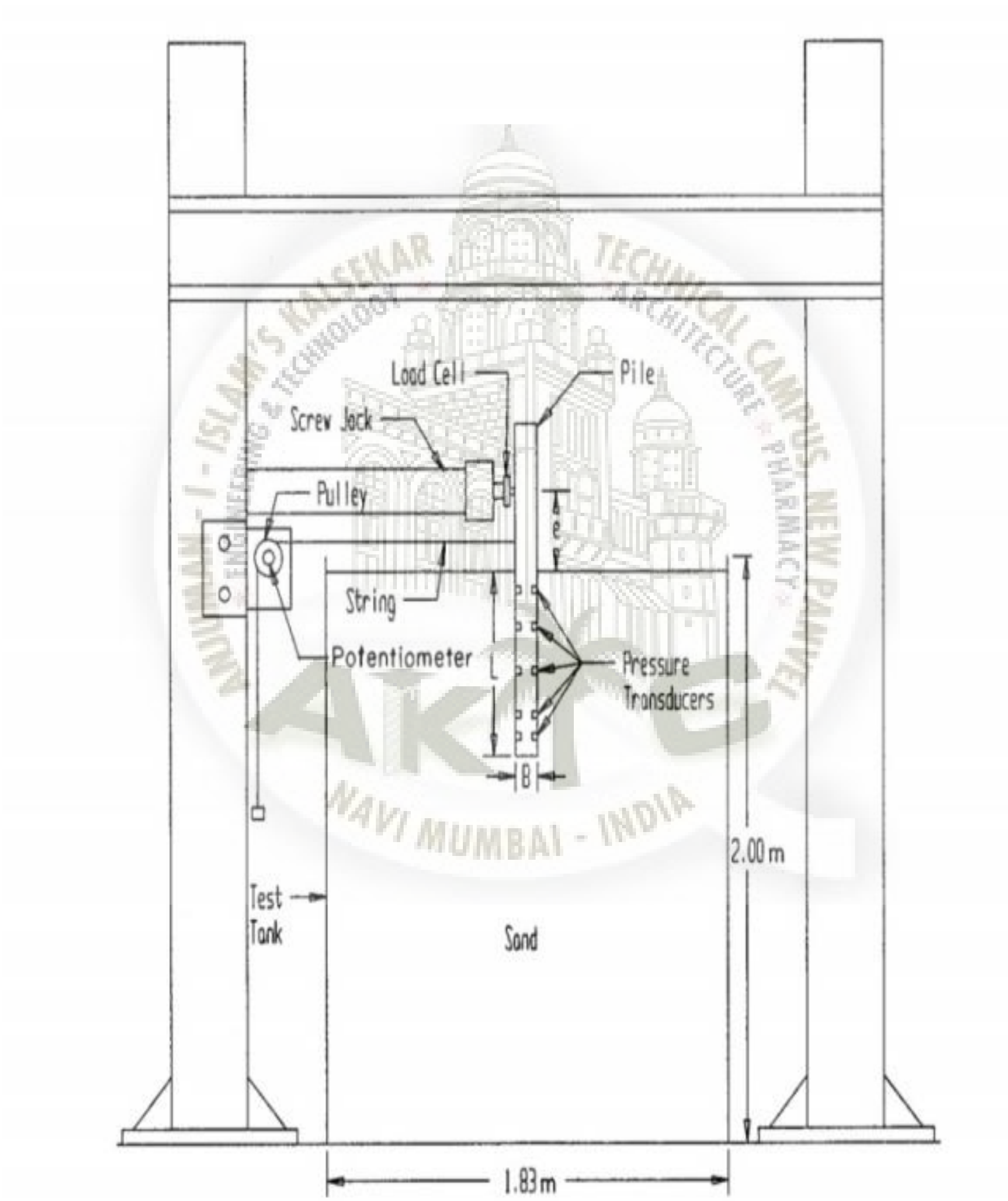

Fig 2.2 Schematic diagram of experimental setup

M.A. EL Sawwaf et al (2006) have used single pile for investigating its behaviour under reinforced sand under lateral load. They found that stabilising the earth slope using geogrid reinforcement has a significant effect on improving the lateral load carrying capacity of vertical pile located near the slope. Based on test result critical values are discussed and recommended.

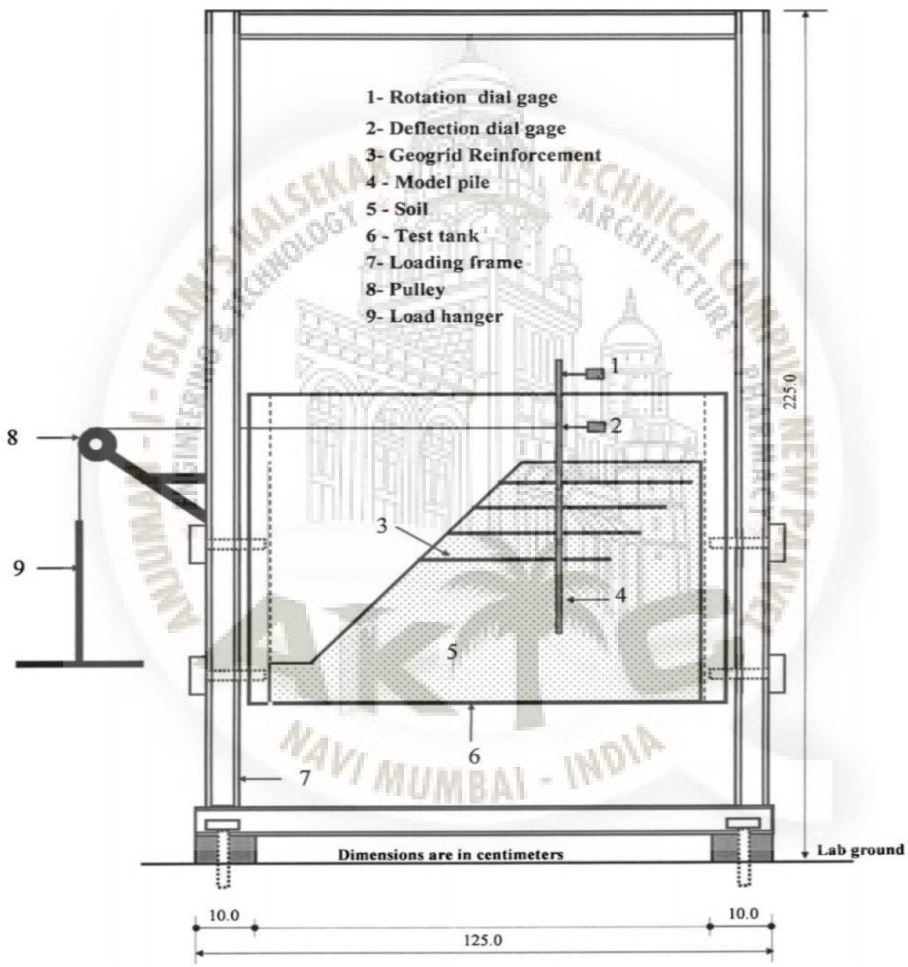

Fig 2.3 Schematic view of experimental apparatus

Ahmed M.A. Nasr (2013) used Finn pile for investigate theoretical and experimental studies of laterally loaded finned pile in sand. He found that the lateral resistance increases with the increase in length of fin until the fins length is equal to 0.4 of pile length. Result reveals that there is a significant increase lateral resistance of pile after mounting the fins close to the pile head. Based on the result of the laboratory model and numerical analysis, critical values of fin parameters for maximum improvements are suggested.

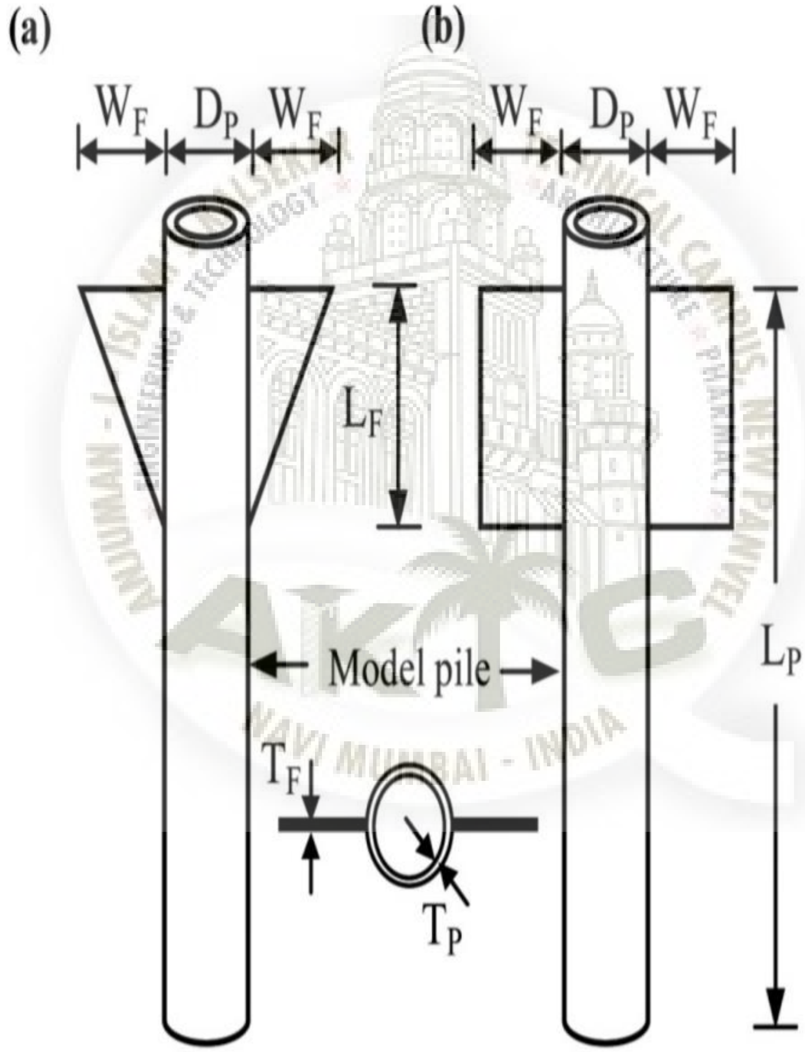

Fig 2.4 Schematic dimension of fin pile: triangular fin pile, rectangular fin pile

Mahdy Khari et al (2013) they have done an experimental study on piles spacing effect under the laterally loading sand. A series of test were carried out on pile group under lateral static loading in sandy soil. They have found that the ultimate lateral load carrying capacity increased by 53% due to increase in s/d ratio. The ratio of s/d more than 6d was large enough to eliminate the pile-pile interaction and the group effects. The increase of the no. of piles in group decreased group efficiency owing to the increased overlapping zones and active wedges**.**

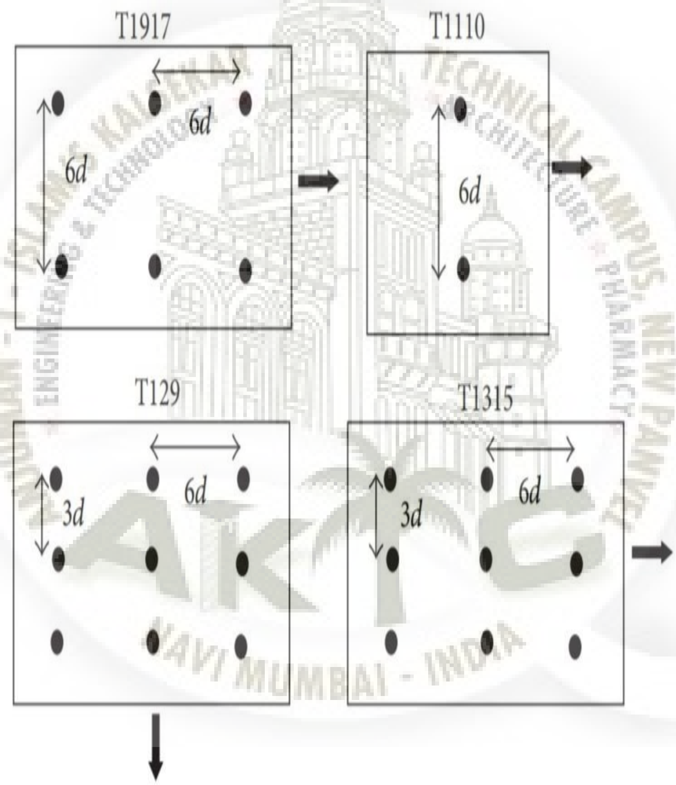

Fig 2.5 Pile group configuration and the pile spacing ratio (↑ is the lateral loading direction)

Chandrashekhara et al (2017) they have done a test on group of pile for investigating lateral load capacity of pile group in sand. They concluded that L/D ratio; density of sand increases, lateral load capacity is also increases and same for S/D ratio. Group efficiency of piles increases with increase in S/D ratio.

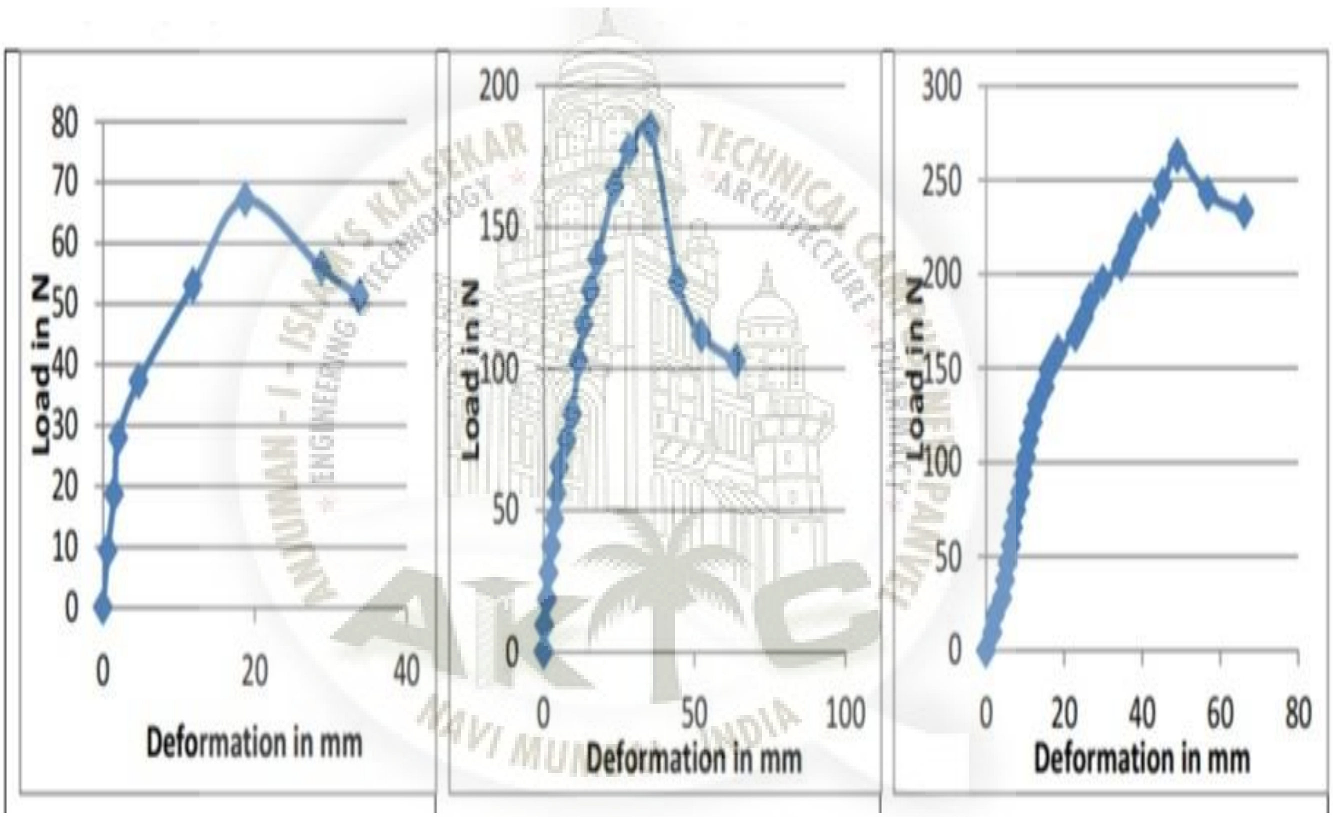

Fig 2.6 The variation of lateral load with displacement of single pile with (l/d) ratio= 10, 15, 20

Bushra S. Albusoda et al (2018) they have used regular and fin pile for investigating experimental and numerical modelling on laterally loaded regular & finned pile foundation in sandy soil. They found that fin pile increase lateral load carrying capacity by 67-76% than regular pile. For regular pile the ultimate lateral resistance of type G4S6 and G5S6 increase with 26 and 11& respectively as compared to G4S3. For finned pile group G4S6 and G5S6 ultimate lateral capacity show a significant increase compared to G4S4 and G5S4 by 15 & 26% respectively.

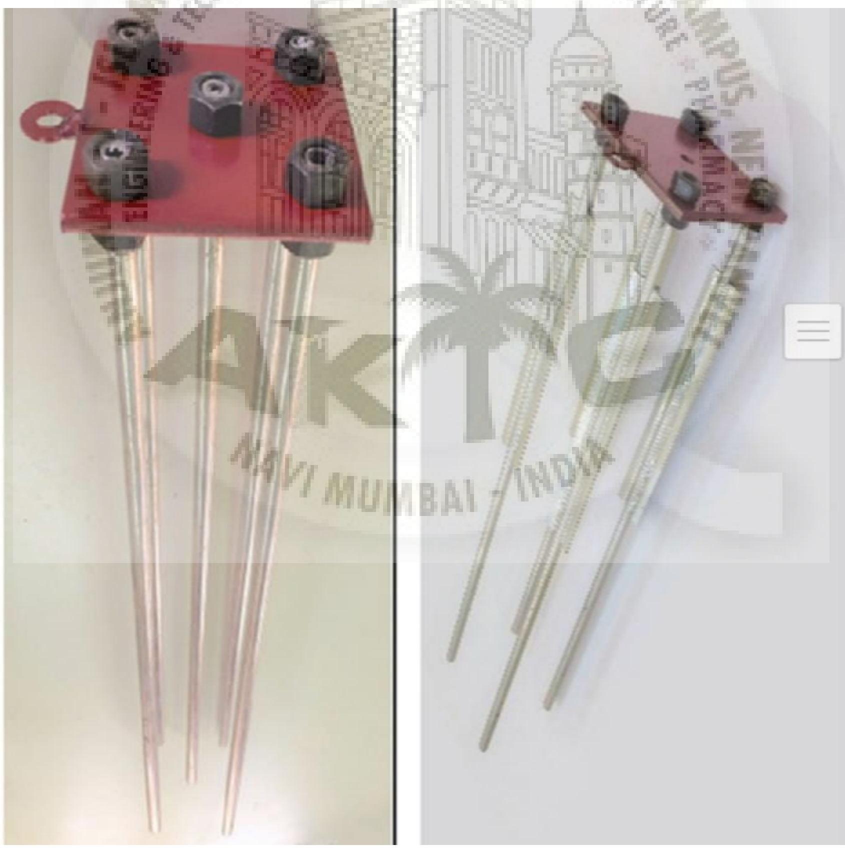

Fig 2.7 a) Model regular pile b) Model finned pile

Bingxiang Yaun et al(2016) they have used PIV tehnique to investigate deflection of laterally loaded pile and soil deformation. They have examined that PIV technique is way better than double integration method for finding displacement of laterally loaded piles. The result demonstrate that the PIV technique and the optical set up are suitable for solving soil-pile interaction problem.

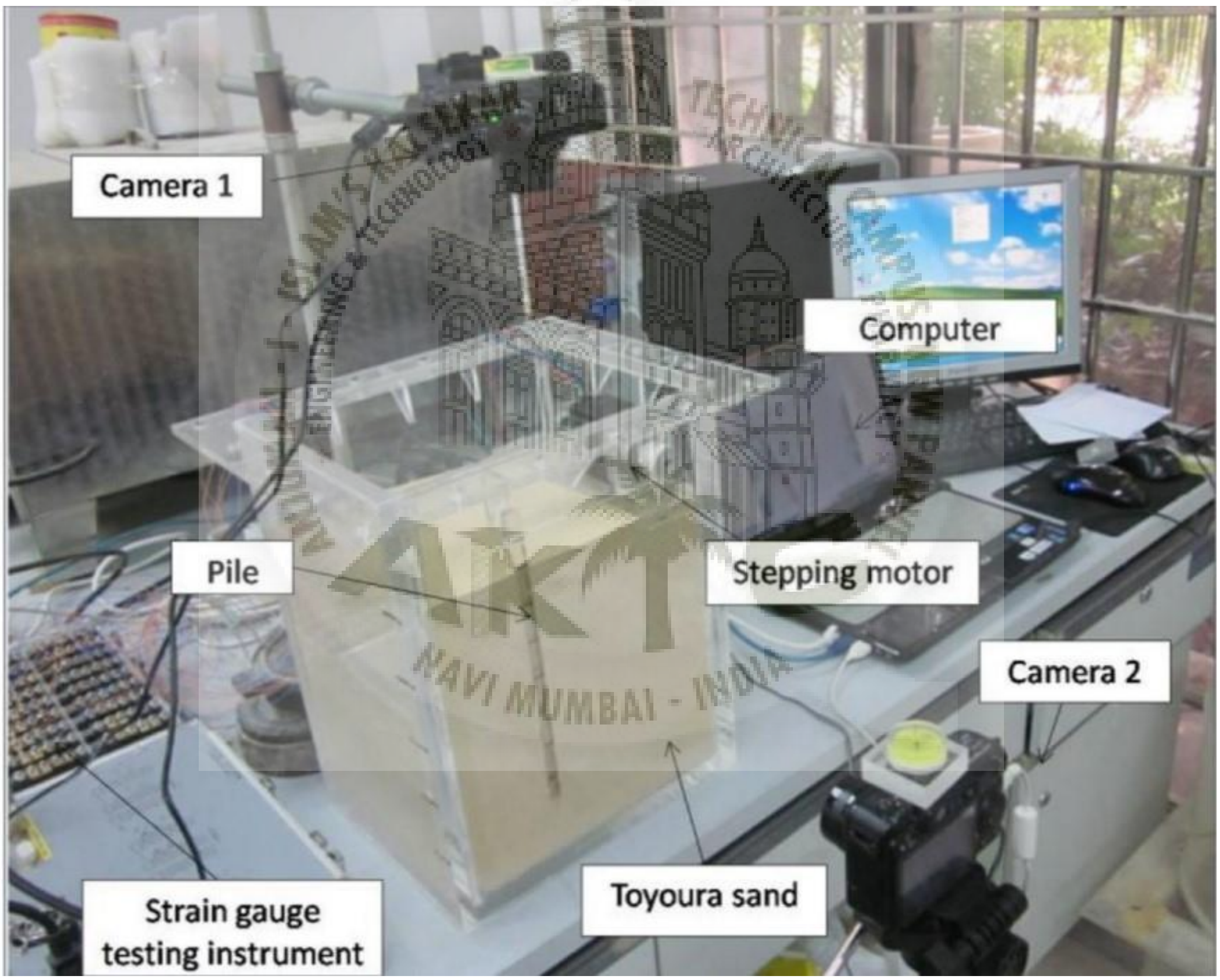

Fig 2.8 Experimental setup

Byung Tak Kim et al(2009) they have done the laboratory modeling of laterally loaded pile group in sand. A series of laterally loaded laboratory model pile group test where carried out to investigate the pile group effect in form loose to medium dense sand. The following conclusion are drawn from the experimental works. A pile spacing of more than 6d in group seems to be large enough to eliminate the group effects of the pile for both medium and loose sand, and in such case the individual pile in pile group behaves the same as a single pile.

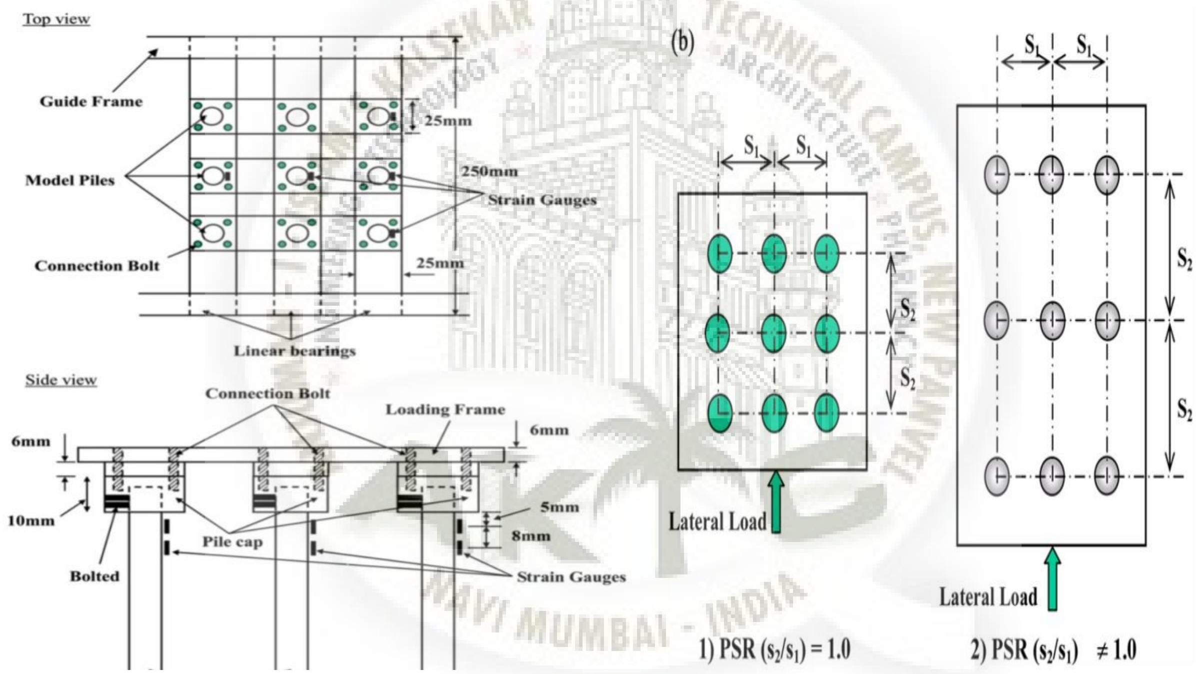

Fig 2.9 a) Systematic drawing of instrumental pile cap

b) Pile spacing ratio and the loading direction of pile group

M. Dehghan abnavi et al(2011) they have used sandy slope by randomly ditributed polymer as reinforcement to investigate the lateral resistance of single pile located near reinforced sandy slope by randomly distributed polymer wastes. They have found that increasing embedded length, the distance from the pile to the crest of slope, relative density and decreasing the slope angle and finally roughness of pile skin friction increases lateral resistance of pile in both reinforced and non reinforced conditions.

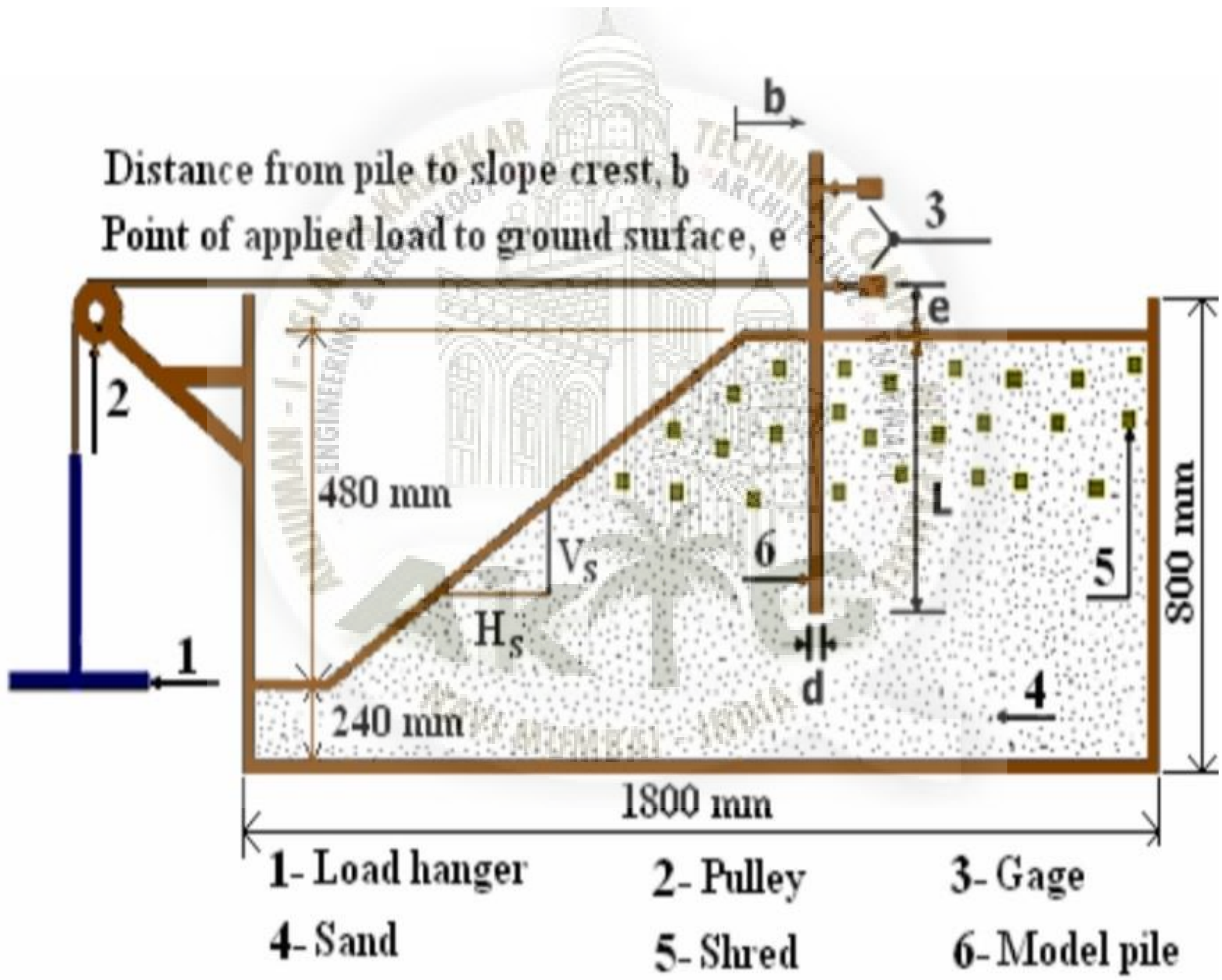

Fig 2.10 Schematic view of experimental setup

Chapter 3

Methodology

3.1 General

We had performed several experiments on single pile and group of pile with different configurations to study. The readings were generated by testing of pile under lateral load for different configurations in group of piles to study the load vs deflection curve and find the optimum result from the different configuration.

3.2 Details of Tank

The steel tank which is made up of mild steel material whose dimensions are 1000×1000×1000 mm. One side of tank is made up of acrylic glass whose thickness is 20mm. the glass side allow the sample to be seen during preparation and sand deformation to be observed during testing.

The inside walls of the tank are polished smooth by attaching fibre glass to minimize side friction with the sand as much as possible. The zone in which the soil will be affected either by installation of pile or loading varies with the soil density and pile installation method.

Therefore, in the present test program, the dimension of the tank used provided a minimum lateral clearance of 11d and a clearance of10d below the bottom of the tank which satisfies the above requirements. The loading system consisted of 3mm diameter steel cable which are connected to the pile cap using eye bolt and place horizontally in the sand passing through the tank side wall and the column frame to the end vertically through pulley with a load hanger. The experimental setup as shown in below fig 3.1

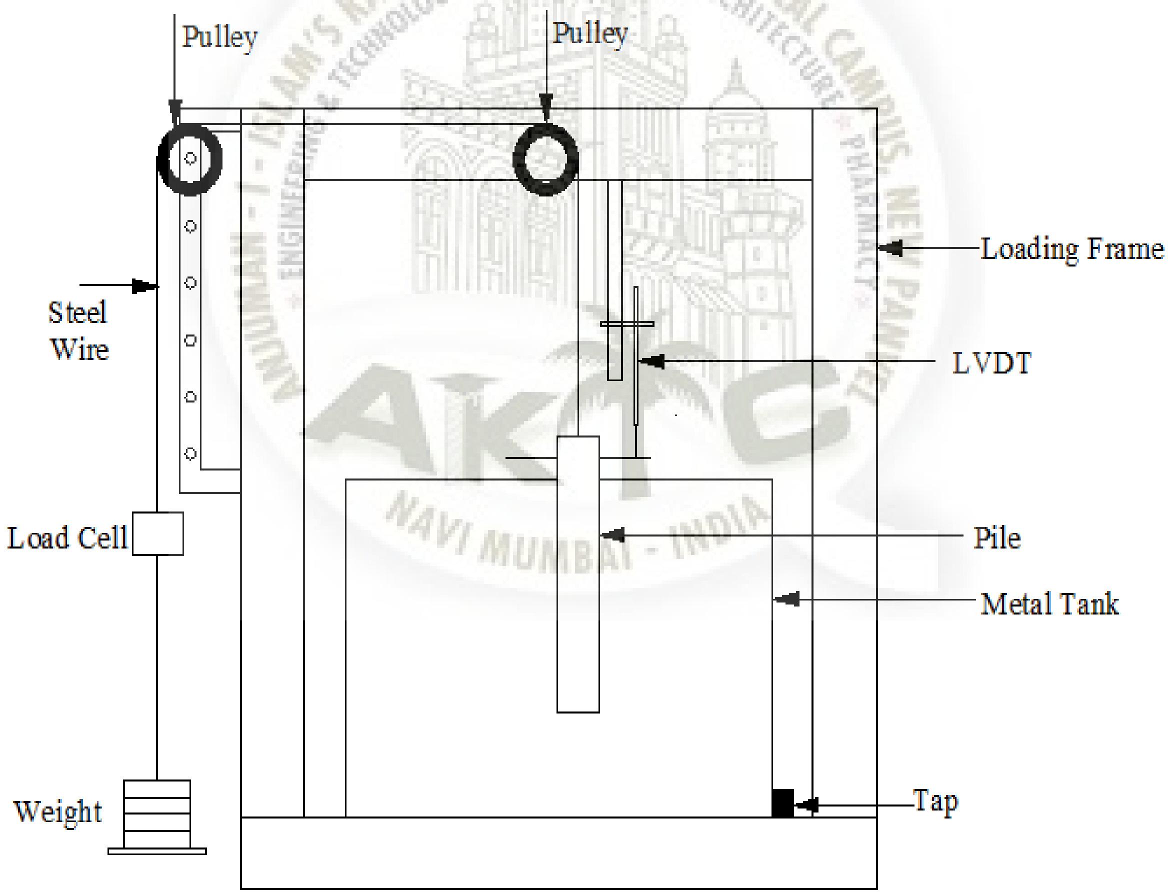

Fig 3.1 Experimental setup

3.3 Sand

Cohesionless soil were used for the experiment, the soil was washed, dried and sorted by a particle size. The specific gravity of soil was determined by the Jar Method. In order to achieve reasonable homogeneous sand bed of reproducible packing, controlled pouring and tamping techniques were used to deposit sand in 50mm thickness layer into the model tank. In this method, the quantity of sand in each layer, which was required to produce a specific relative density, was first weighed and placed in the tank and tamped until achieving the require layered height. The experimental test was conducted on sample prepared with an average unit weight of 17.44,18.15 and 19.10 kN/cubic meter representing loose, medium dense and dense condition respectively. The relative density of sample was 35.55 and 80% respectively. The estimated internal friction angle of sand determined from direct shear test using specimen prepared by dry tamping at the same relative density were 34, 37.5 and 43degree respectively.

3.4 Model Piles

The test was conducted in two parts one is conducted on single pile and series of test conducted on group of pile by applying lateral loading.

3.4.1 Single Pile

Diameter of pile is 50mm as outer Diameter and Length 600mm respectively which are made up of mild steel. The lateral load was transferred from the load hanger to the pile through a cable connected to a pile cap as shown in figure 3.2.

Fig 3.2 Experimental setup of Single pile

3.4.2 Group Piles

The tests were conducted in group pile by varying s/d ratio and l/d ratio. The total nine experiment performed by changing s/d ratio and l/d ratio as shown in below table 3.1 and Figure 3.2. One sample experimental setup of group of pile as shown in fig 3.3

Table no 3.1 pile configuration

Sr. No.	Pile Configuration	Pile Diameter (mm)	Spacing (mm)	Pile Length (mm)
1	2×2	10	2D	200
2	2×2	10	3D	200
3	2×2	10	4D	200
4	2×2	10	2D	400
5	2×2	10	3D	400
6	2×2	10	4D	400
7	2×2	10	2D	600
8	2×2	10	3D	600
9	2×2	10	4D	600

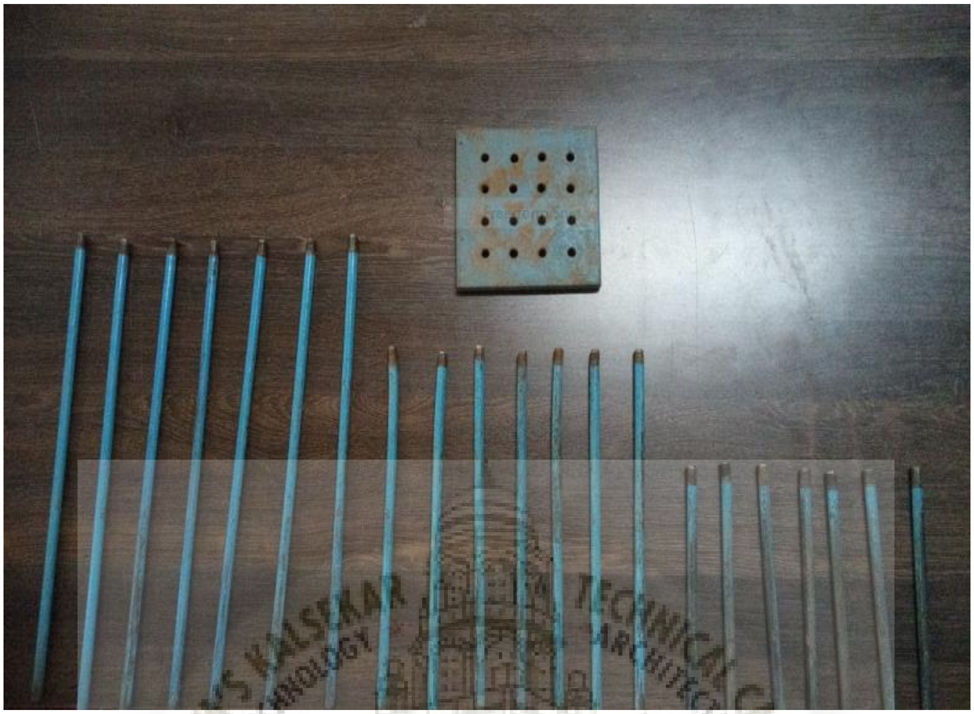

Fig 3.3 Different length of pile

Fig 3.4 Experimental setup of Group of Pile

3.5 Testing procedure on Single pile & Group pile

The total ten test were performed in which one test performed on single pile and nine test performed on group of pile. The testing procedure on single pile and group of pile are explained below

In the fabricated tank the soil sample were constructed in layers by controlled pouring and temping technique with the bed layer to be observed through the front glass wall. The minimum depth of sand below the base of the pile is 11D to minimize the influence of tank base. The inner face of the tank was marked at 50 mm interval to facilitate accurate preparation of sand bed in layer on reaching the level of pile base, the pile was placed on position and its held vertical using special clamp and layer of sand is poured. On reaching to every marked 50 mm position on tank the soil should be properly tempered, this is how the tank gets filled at each and every successive compacted layer. Lateral load is applied to the pile through flexible steel wire of 3mm diameter in which one end of the wire with a hook, it is connected to the pile cap and other end is connected to the load cell and this load cell is connected to load hanger. LVDT is mounted on a rigid L-shaped extension connect to the pile. The LVDT were used to measure horizontal displacement at a specific point in the pile portion above the ground line. The pile was loaded in an incremental manner until failure.

Testing procedure on group of pile:

The above procedure is carried out for the entire test i.e. for varying l/d ratios, varying spacing's, and also different pile groups configuration.

Tests were carried out on Single and Group of pile by varying length to diameter and spacing to diameter of piles. Graphical representation and list of table have been presented for both single pile and group of pile (with different configuration) as shown in below.

Table No 3.2 Lateral capacity of Single Pile length 600mm and Diameter 50mm.

Sr. No.	Load (KN)	Deflection (mm)
0	0.00	0.0
1	0.020	0.5
2	0.023	1.0
3	0.027	1.5
4	0.033	2.0
5	0.038	2.5
6	0.041	3.0
7	0.045	3.5
8	0.047	4.0
9	0.051	4.5
10	0.055	5.0
11	0.060	5.5
12	0.063	6.0
13	0.068	6.5
14	0.075	7.0
15	0.080	7.5
16	0.083	8.0
17	0.090	8.5
18	0.095	9.0
19	0.100	10
20	0.103	11
21	0.108	12
22	0.115	13
23	0.120	15

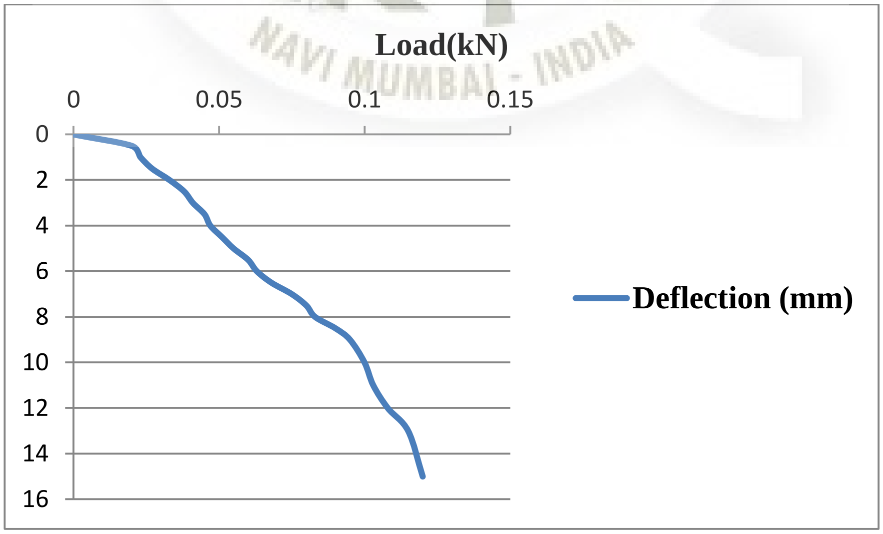

Fig 3.5 Load vs Deflection curve for Single Pile length 600mm and Diameter 50mm.

Table No 3.3 Lateral capacity of Group of Pile length 200mm and Diameter 10mm for different configuration

Sr. No.	Deflection (mm)	2d	3d	4d
		Load(kN)	Load(kN)	Load(kN)
0	0	0	0	0
1	1	0.01	0.025	0.02
2	2	0.02	0.03	0.026
3	3	0.025	0.04	0.03
4	4	0.03	0.047	0.035
5	5	0.035	0.058	0.045
6	6	0.037	0.065	0.05
7	7	0.04	0.08	0.06
8	8	0.045	0.09	0.067
9	9	0.049	0.1	0.075
10	10	0.05	0.115	0.083
11	11	0.055	0.127	0.09
12	12	0.06	0.139	0.1
13	13	0.065	0.14	0.115
14	14	0.071	0.145	0.12
15	15	0.075	0.15	0.13

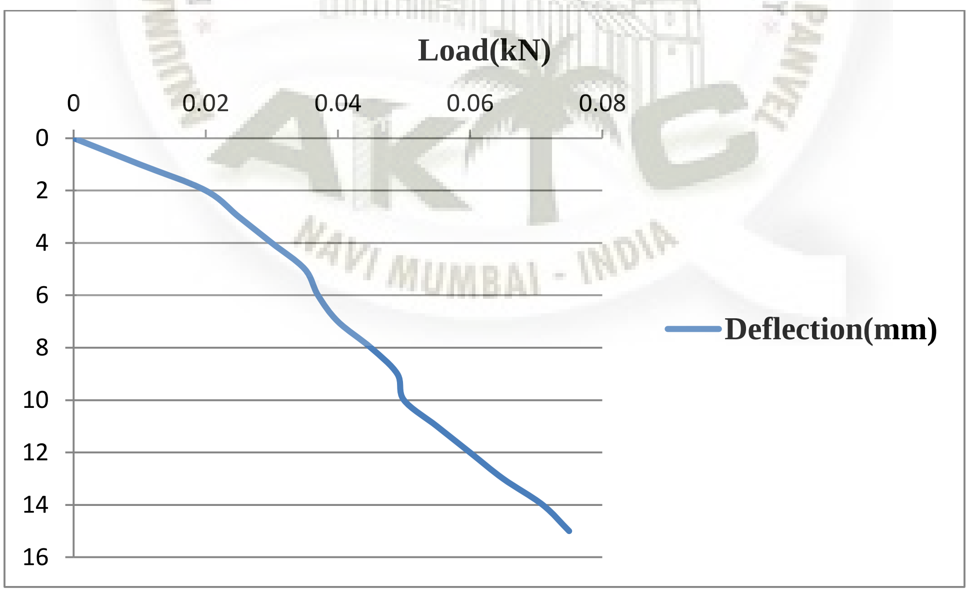

Fig 3.6 Load vs Deflection curve for Pile length 200mm and Diameter 10mm for spacing 2d

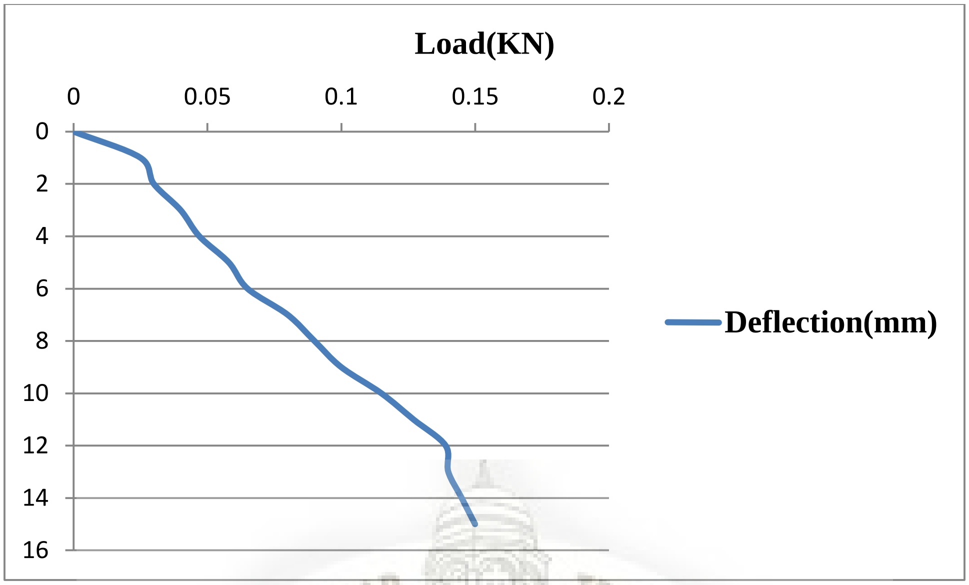

Fig 3.7 Load vs Deflection curve for Pile length 200mm and Diameter 10mm for spacing 3d

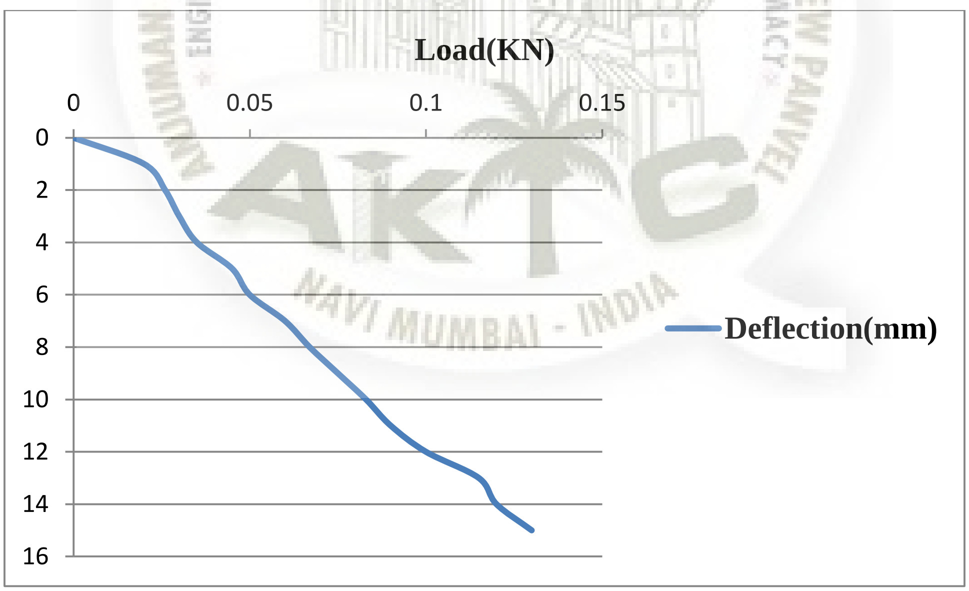

Fig 3.8 Load vs Deflection curve for Pile length 200mm and Diameter 10mm for spacing 4d

Table No 3.4 Lateral capacity of Group of Pile length 300mm and Diameter 10mm for different configuration

Sr. No.	Deflection (mm)	2d	3d	4d
		Load(kN)	Load(kN)	Load(kN0
0	0	0	0	0
1	1	0.02	0.04	0.03
2	2	0.04	0.05	0.03
3	3	0.045	0.06	0.04
4	4	0.05	0.07	0.05
5	5	0.055	0.08	0.06
6	6	0.057	0.09	0.07
7	7	0.06	0.1	0.082
8	8	0.063	0.11	0.089
9	9	0.067	0.12	0.096
10	10	0.07	0.13	0.105
11	11	0.071	0.14	0.111
12	12	0.074	0.145	0.118
13	13	0.077	0.155	0.12
14	14	0.079	0.155	0.13
15	15	0.082	0.16	0.15

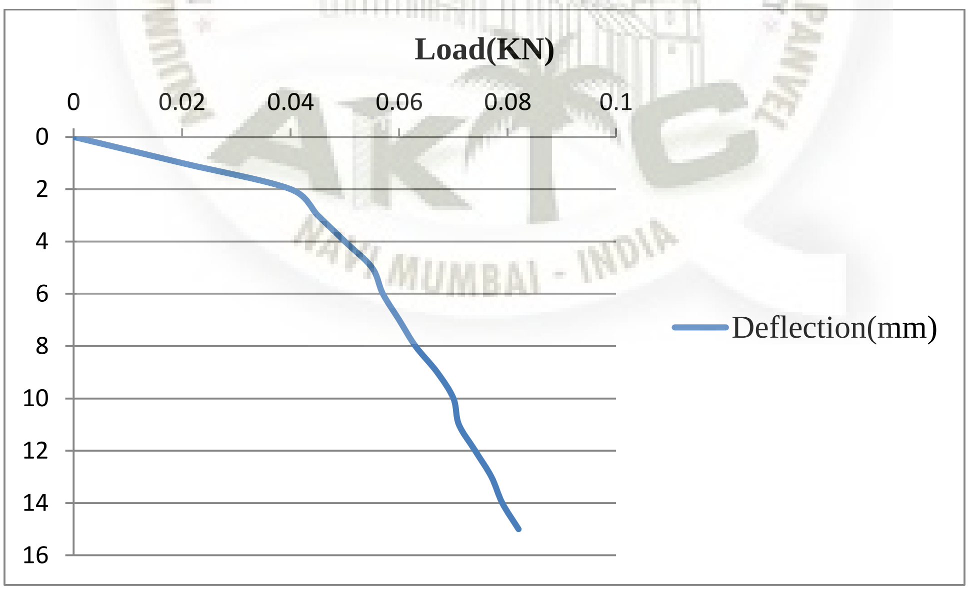

Fig 3.9 Load vs Deflection curve for Pile length 300mm and Dia 10mm for spacing 2d

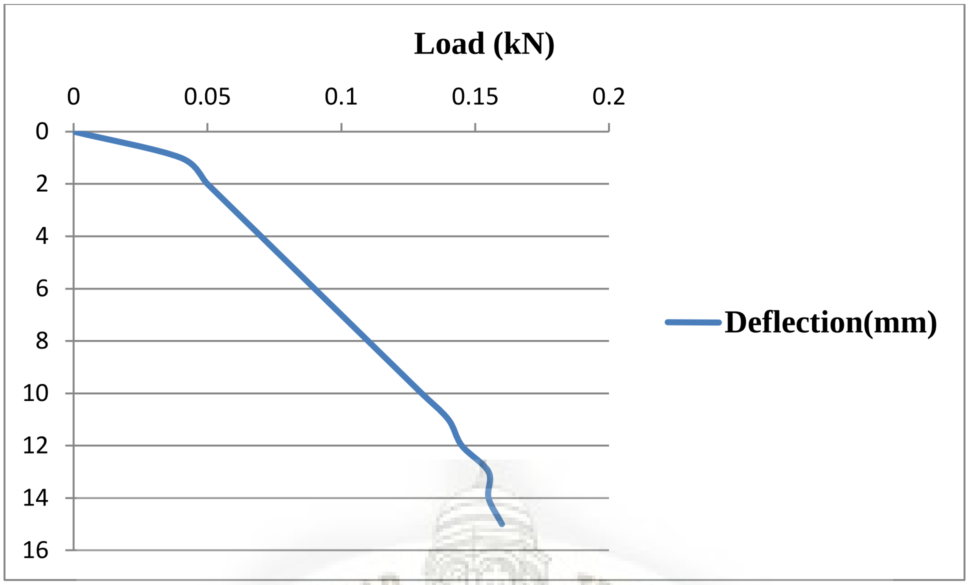

Fig 3.10 Load vs Deflection curve for Pile length 300mm and Diameter 10mm for spacing 4d

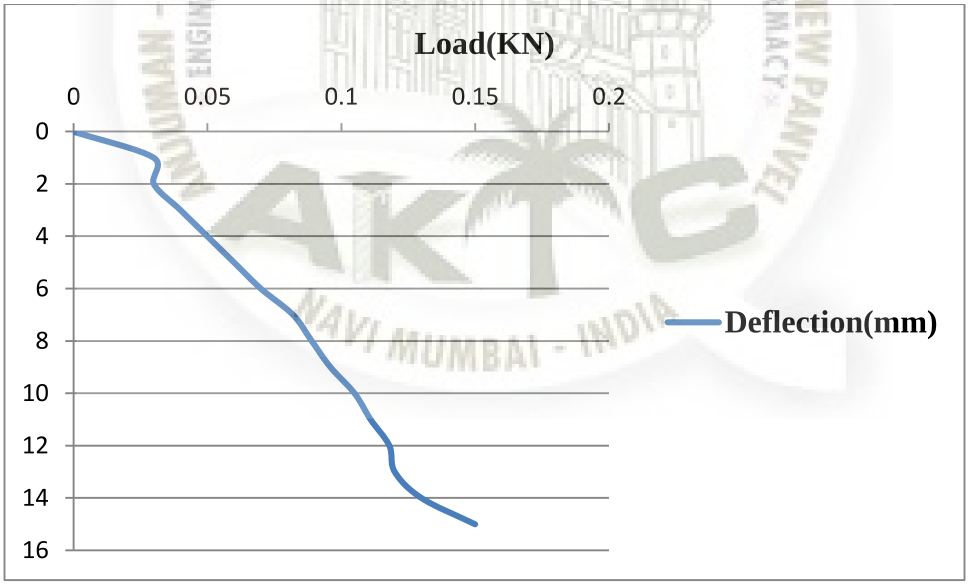

Fig 3.11 Load vs Deflection curve for Pile length 300mm and Diameter 10mm for spacing 6d

Table No 3.5 Lateral capacity of Group of Pile length 400mm and Diameter 50mm for different configuration

Sr. No	Deflection (mm)	2d	3d	4d
		Load(kN)	Load(kN)	Load(kN)
0	0	0	0	0
1	1	0.03	0.045	0.04
2	2	0.05	0.06	0.04
3	3	0.052	0.07	0.05
4	4	0.059	0.08	0.06
5	5	0.06	0.09	0.07
6	6	0.063	0.1	0.08
7	7	0.07	0.11	0.09
8	8	0.072	0.121	0.097
9	9	0.075	0.13	0.105
10	10	0.08	0.14	0.11
11	11	0.082	0.145	0.116
12	12	0.085	0.149	0.12
13	13	0.09	0.153	0.13
14	14	0.093	0.16	0.145
15	15	0.097	0.165	0.15

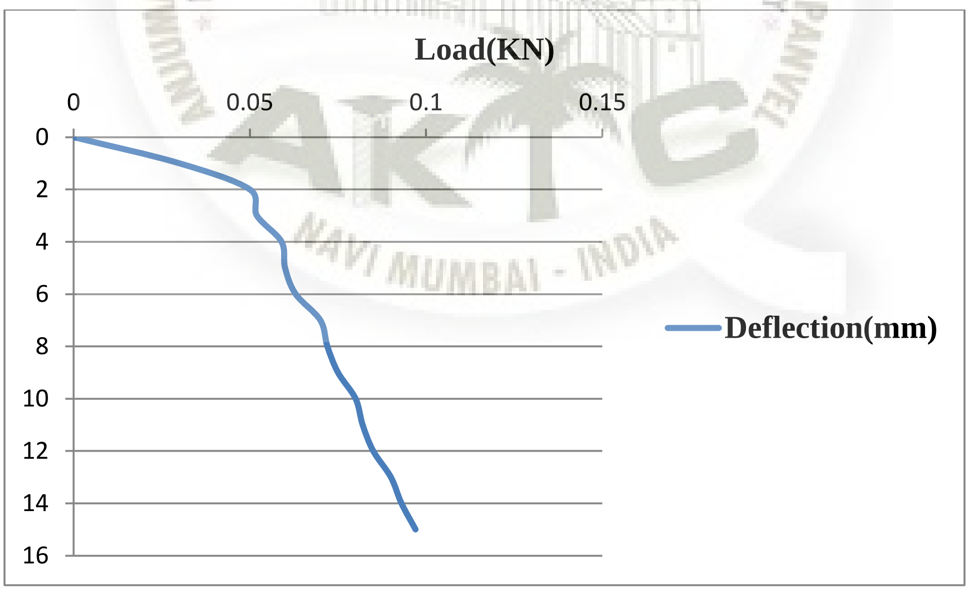

Fig 3.12 Load vs Deflection curve for Pile length 400mm and Diameter 10mm for spacing 2d

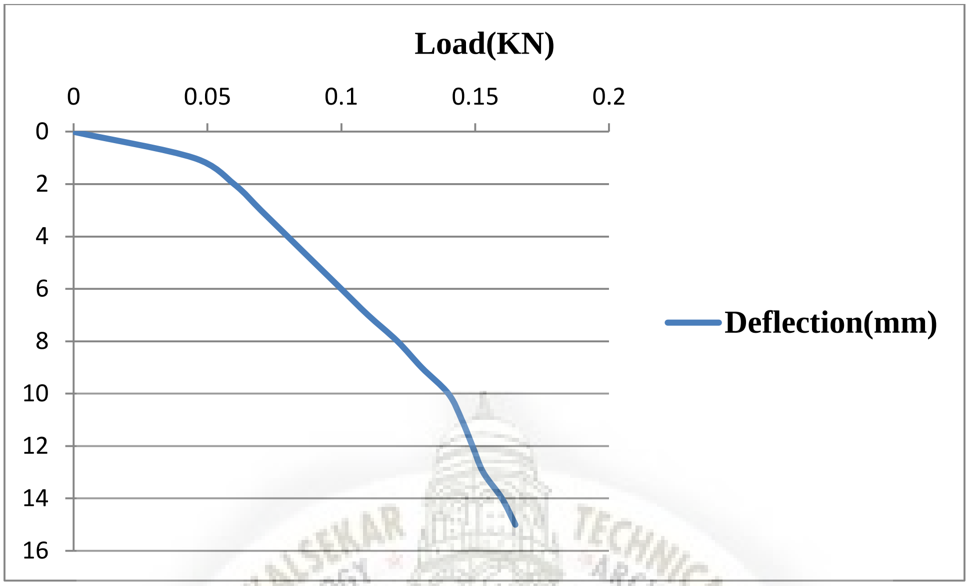

Fig 3.13 Load vs Deflection curve for Pile length 400mm and Diameter 10mm for spacing 4d

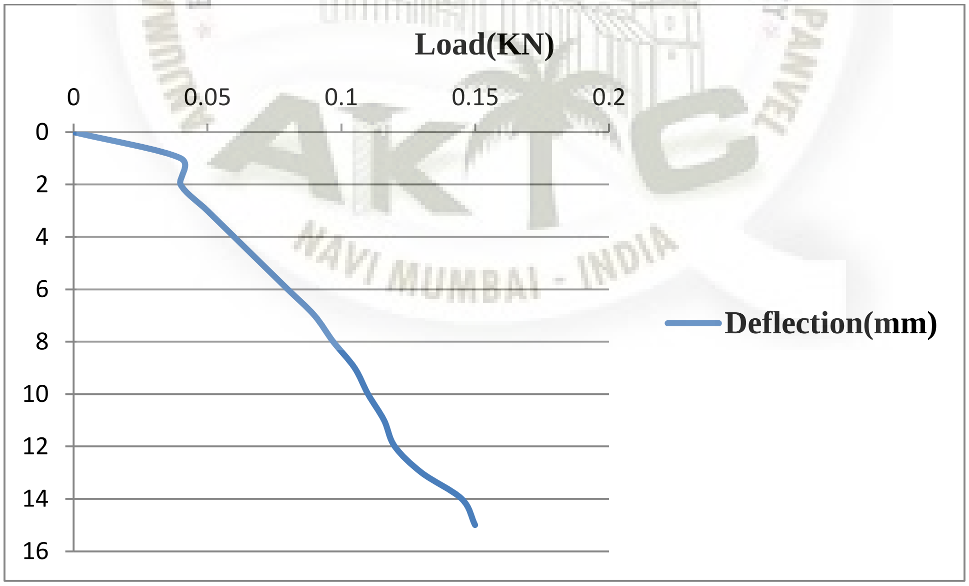

Fig 3.14 Load vs Deflection curve for Pile length 400mm and Diameter 10mm for spacing 6d

Chapter 4

NUMERICAL ANALYSIS FOR PILES

4.1 General

In the following sections, the Field Load Displacement curve are compared with the Plaxis curve to validate the program.

4.2 Material modelling for Numerical Analysis

Following Parameters are used for Modelling Plaxis model.

Soil Model	Value used
Identification = Fill material (debris)	
Material Model	Mohr- Coulomb
Material Type	Drained
ϒ	16 kN/m^3
ϒ sat	20 kN/m^3
Permeability	
Kx	1x10^{-3} cm/s
Ky	1x10^{-3} cm/s
Stiffness	
Young's Modulus (Eref)	10000 kN/m^2
Poisson's ratio (μ)	0.3
Strength	
φ	30 ^{0}
Ψ	0
Interface	
R inte	0.65
Identification = Clay	
Material Model	Mohr- Coulomb
Material Type	Drained
ϒ	16 kN/m^3
ϒ sat	18 kN/m^3
Permeability	
Kx	1x10 $^{-8}$ cm/s
Ky	1x10 $^{-8}$ cm/s
Stiffness	
Young's Modulus (Eref)	1x10 ^{4} kN/m^2
Poisson's ratio (μ)	0.350
Strength	
Friction Angle (φ)	25 ^{0}
Dilatancy Angle (Ψ)	0
Cohesion (C ref)	100 kN/m^2
Interface	
Strength reduction factor (R inte)	0.5
Pile	
Type of Behaviour	Elastic
Normal stiffness (EA)	12 x 10^6 kN/m
Flexural Rigidity (EI)	1 x 10^6 kNm^2/m
Diameter (D)	1 m
Poisson's ratio (μ)	0.15

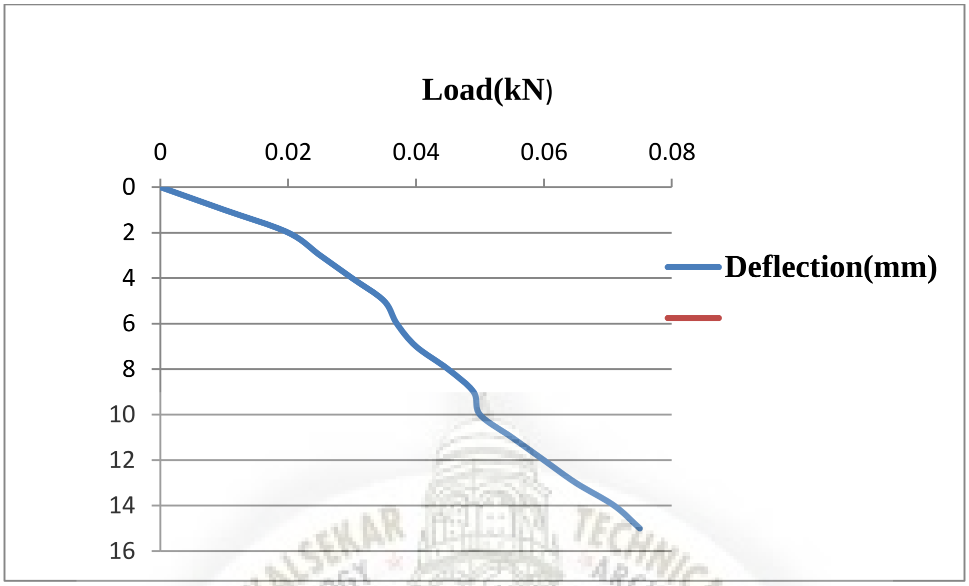

Fig.4.1 Experimental and Numerical Load Displacement Curve for 200mm and spacing 2D

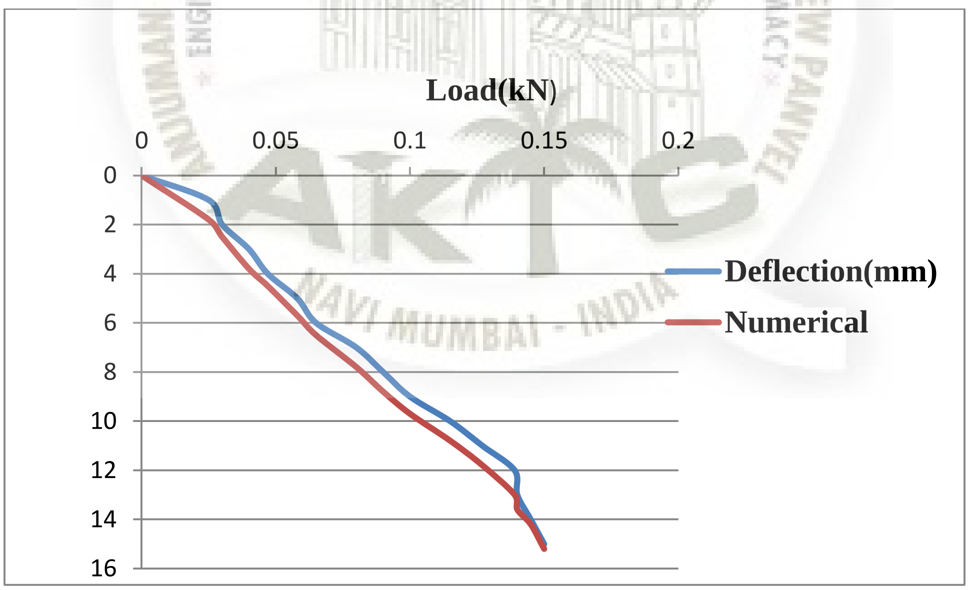

Fig.4.2 Experimental and Numerical Load Displacement Curve for 200mm and spacing 3D

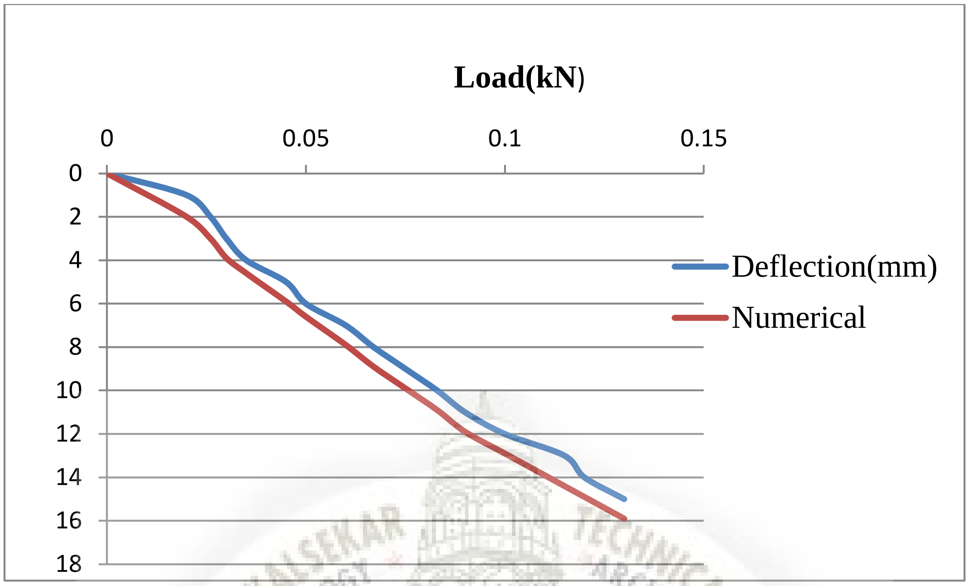

Fig.4.3 Experimental and Numerical Load Displacement Curve for 200mm and spacing 4D

From the above studies it has been seen that a close match between experimental and numerical stimulated curve is obtain by choosing appropriate values of the parameters

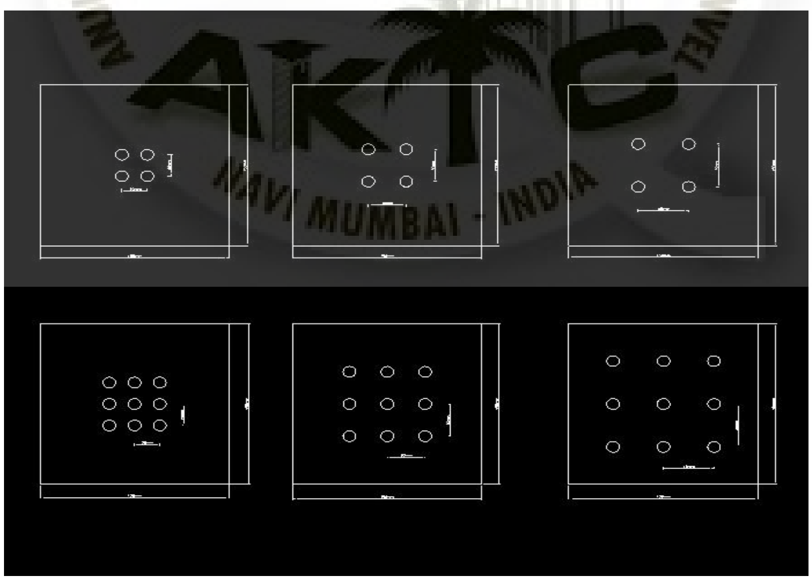

Fig 4.4 Pile configurations

Chapter 5

Result & Discussion

5.1 General

From the performed experiment we had studied the lateral load carrying capacity of single pile and group of pile (with different configurations) and the effect of changing the length and spacing of pile were studied. Test for each configuration are modelled and tested. Reading were noted and calculation done and results are interpreted.

5.2 Single pile

Lateral load carrying capacity of single pile for deflection 25%, 50%, 75% and 100% are 0.046kN, 0.080kN, 104kN and 0.120 respectively as shown in below table5.1.

Table No 5.1 Lateral load carrying capacity for single pile

Sr. No.	Deflection (%)	Load (kN)
1	25	0.046
2	50	0.080
3	75	0.104
4	100	0.120

5.3 Group of pile

Table no 5.2 Ultimate lateral load carrying capacity of group of piles for 15mm deflection

Sr. No.	Length of pile(mm)	Deflection (mm)	Ultimate lateral load carrying capacity of group of piles (kN)		
			2D	3D	4D
1	200	15	0.075	0.15	0.13
2	300		0.082	0.16	0.15
3	400		0.097	0.165	0.15

From above table no 4.2,

1. Lateral load resistance capacity of group of pile for length of pile 200mm and spacing 2D is 0.075 kN, for 3D is 0.15 kN and for 4D is 0.13 kN for 15mm deflection. From above reading we can conclude that 3D spacing give the maximum lateral resistance.
2. Lateral load resistance capacity of group of pile for length of pile 300mm and spacing 2D is 0.082 kN, for 3D is 0.16 kN and for 4D is 0.15 kN for 15mm deflection. From above reading we can conclude that 3D spacing give the maximum lateral resistance.
3. Lateral load resistance capacity of group of pile for length of pile 400mm and spacing 2D is 0.097 kN, for 3D is 0.165 kN and for 4D is 0.15 kN for 15mm deflection. From above reading we can conclude that 3D spacing give the maximum lateral resistance.
4. Lateral load resistance capacity of group of pile for length of pile 3D (300mm) for spacing 3D is 0.16 kN and it is adopted as most optimum case.

Chapter 6

Conclusion

- The deflection behaviour of pile depends upon the type of soil, length of pile and diameter of the pile.
- The ultimate lateral load pile group increases for a pile group then for a single.
- The lateral resistance capacity of group of piles increases up to 3D spacing between them.
- The optimum lateral resistance capacity of group of pile length gives 30D.

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