Experimental and Numerical Study of Compression and Tension Test on Pile

Submitted in partial fulfilment of the requirements
for the degree of

Bachelor of Engineering

By

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This is to certify that, **Shaikh MD Rehan MD Azam (15CES50), Shaikh MD Faisal MD Nisar (15CES48), Hashmi Aadil Naushad (15CES16)** and **Shaikh MD Waquas MD Hamja (15CES47)** has satisfactorily completed and delivered a Project report entitled, **"Experimental And Numerical Study Of Compression And Tension Test On Piles"** in partial fulfillment for the completion of the **B.E.** in **Civil Engineering** Course conducted by the University of Mumbai in Anjuman-I-Islam's Kalsekar Technical Campus, New Panvel, Navi Mumbai, during the academic year 2017-18.

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Project Report Approval for B.E.

This B. E. Project entitled **"Experimental And Numerical Study Of Compression And Tension Test On Piles"** by **Mr. Shaikh Rehan, Mr. Shaikh Faisal, Mr. Hashmi Aadil** and **Mr. Shaikh Waquas** is approved for the degree of ***"Bachelor of Engineering"*** in ***"Department of Civil Engineering".***

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DECLARATION

We declare that this written submission represents my ideas in our own words and where others ideas or words have been included; we have adequately cited and referenced the original sources. We also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

In this study, eighteen tests on mild steel piles, rough piles & smooth piles embedded in a cohesionless soil were carried out in the laboratory to assess the effect of compression and tension capacity of piles & group of piles considering various parameters. The model piles were of 50mm outside diameter, 2mm wall thickness and 600mm length whereas smooth and rough piles dimensions were 40,50,60mm in diameter and 600mm length. Subsequently, group of piles of 10mm dia of different length and spacing values were carried out for compression test and tension test was carried out only on single pile. The pile was embedded in sand for embedment length/diameter ratios of 500mm inside a model tank.

They were subjected to a static compressive and tensile load with respect to settlement values which was measured through displacement dial gauges & proving ring arrangement. A logical approach based on the experimental results, will give suggestion to predict the future site testing results by enlarging the dimensions of piles, increasing the loading values and various parameters respectively.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

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 leads to safe and efficient structure but also an overall economy of the project.

Now days pile is introduced in the foundation where there is a weak strata available beneath the ground surface. Pile is basically a long cylinder of a strong material such as concrete that IS pushed into the ground to act as a steady support for structure built on top of it. There are many types of piles like Anchor pile, Bored pile, Batter pile, Micro pile, etc.

History of construction buildings on pile is followed starting from ancient times, when people used piles for constructing foundations on weak peat soils near rivers. The concept of pile for construction is credited to a Neolithic tribe called the “Swiss Lake Dwellers” who lived about 6,000 years ago. They used piling not only for support but also for elevation to protect themselves from wildlife. The Roman often used piles, and built many structures including buildings, roads and viaducts on piling. The Roman built the first bridge across the Tiber River in Rome on timber piles in B.C. 1620. Homes in the cities of Venice and Ravenna were built on piles from B.C. 100 to A.D. 400. The Romans also built the first bridge across Thames River in London in A.D. 60 on timber piling.

A different approach, involving the use of piles as settlement reducers has been, reported by AL-Qaissy et. al (2013), Basouny El-Garhy et. al(2003), Jaymin Patil et. al(2015). The basic concepts of these approaches were that the foundation comprises only a number of piles that are necessary to reduce settlements to a tolerable amount and the loads from the structures are transmitted via piles.

Pile foundations are adopted generally in the following situations:-

- Low bearing capacity of soil
- Non availability of proper bearing stratum at shallow depths
- Heavy loads from the superstructure for which shallow foundation may not be economical or feasible

1.2 Classification of piles

1) Based on material:-
   a) Concrete
   b) Steel
   c) Timber
2) Based on method of construction/installation:-
   a) Driven/displacement pre cast piles
   b) Driven/displacement cast in situ piles
   c) Bored/replacement cast in situ piles
   d) Bored/replacement pre cast piles
3) Based on load transfer mechanism:-
   a) Friction/Floating piles

b) Bearing cum friction piles

c) End bearing piles

4) Based on sectional area:-

a) Circular

b) Square

c) H shape

d) Octagonal

e) Tubular

5) Based on size:-

a) Micro piles dia. <150 mm

b) Small dia. Pile dia.> 150mm and <600mm

c) Large dia. piles>600mm

6) Based on inclination:-

a) Vertical piles

b) Inclined/ Raker piles

The analysis of this works can also be done on software like abaqus plaxis 3D which works on the concept of finite element method

1.3 Load carrying mechanisms of piles

End bearing cum friction piles carry vertical compressive loads partly by means of resistance offered by the hard stratum at the tip of the pile and partly by the friction developed between the pile shaft and soil.

Pure friction piles carry the major parts of loads only by means of friction developed between the pile shaft and soil, and pure end bearing piles only by means of bearing resistance at the tip of the pile.

In both the above cases lateral loads are carried by the lateral resistance offered by the surrounding soil.

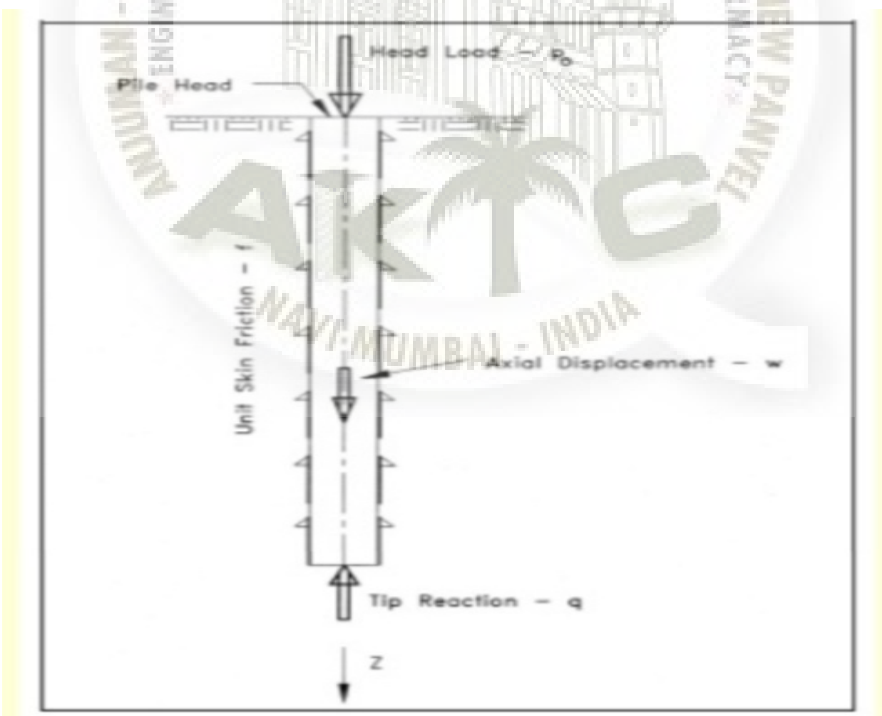


Fig 1.1 Schematic showing axial load carrying mechanism

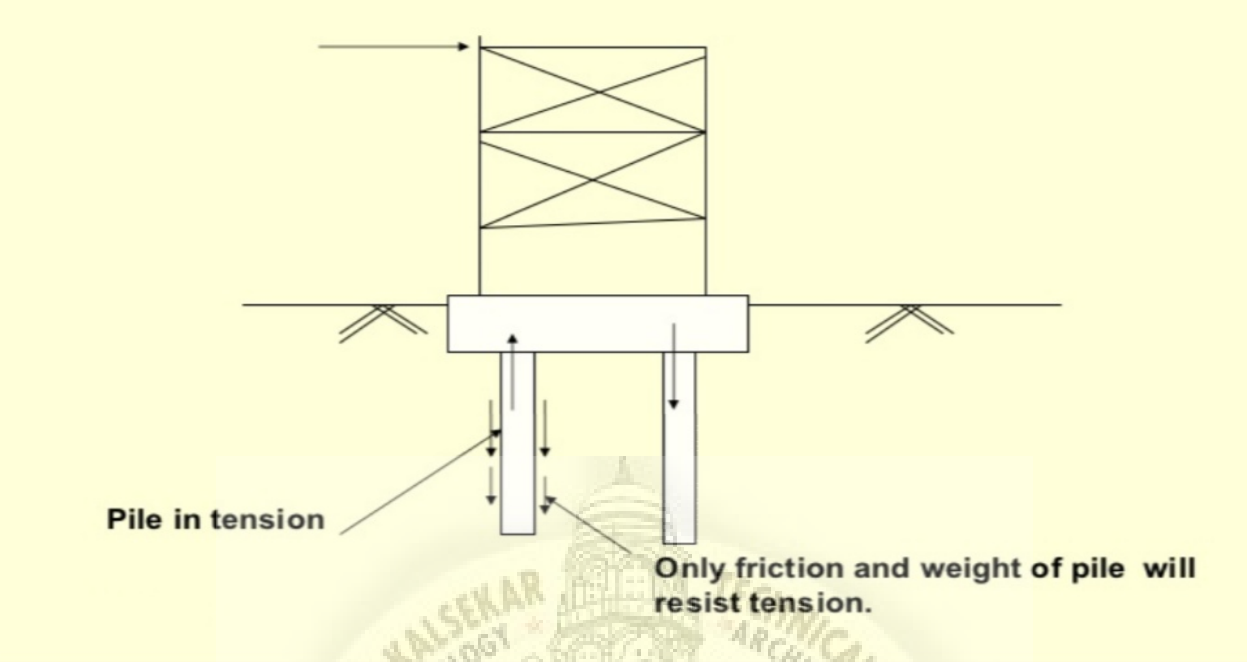


Fig 1.2 Load carrying mechanism of pile subjected to tension/Pullout

1.4 Group of pile

The interactions amongst the bearing elements in a pile groups are complex. When piles and a cap within a group are closely spaced, the induced stresses and strains in the surrounding soil overlap, and their bearing behaviour becomes different from that of an isolated pile and cap. The interactions in a pile group can be classified into two categories: the interaction amongst piles (pile-soil-pile) and the interaction between cap and pile (cap-soil-pile). In a free standing pile group, where the cap is not in contact with the soil, only the pile-soil-pile interaction is important. In a piled footing, where the cap is in direct contact with the soil, the cap-soil-pile interaction is also involved. These interactions can either increase or decrease the bearing capacity of the group, and thus two opposite effects of the interactions in a pile group have been reported.

An unfavourable interaction, which induces additional settlement of piles and cap or negative frictions in piles, can be caused by the increase of vertical stress and strain in the surrounding soil due to the applied load on the adjacent pile or cap. In the analysis of pile group, these interactions have been well recognized and generally taken into account by the method of

"Superposition of displacement fields" on the other hand, the interactions may have favourable influences on the behaviour of pile group. The loads applied on the neighbouring piles or the contact pressure between cap and soil increase the lateral normal pressure on the pile shaft and consequently, increase the pile capacity and the load on the inner piles in the group.

The change in the soil properties caused by the pile installation is an important factor affecting the behaviour of a pile group. Hence, the precise interaction characteristics of a pile group cannot be understood by simply comparing the behaviour of an isolated single pile with that of piles in a group. In this paper, based on model tests, the effects of interactions amongst bearing elements and pile installation on vertically loaded pile groups in sand are investigated. Using the same standard testing procedure and soil conditions, we carried out loading tests on an isolated single pile, and group of different combinations of piles. From the results of such a model test program, the effect of pile installation, interaction amongst piles and interaction between cap and piles were identified. The influence of pile spacing on the interaction characteristics is studied in detail.

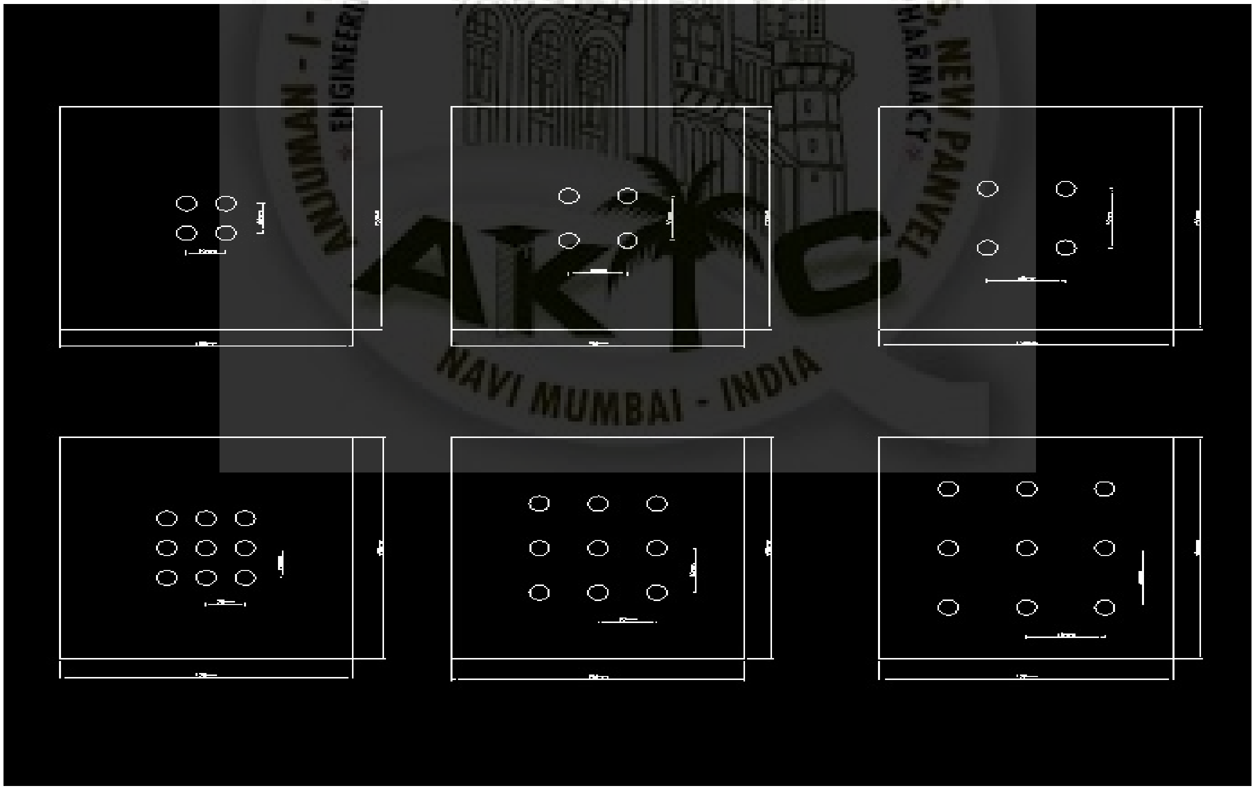


Fig 1.3 Configuration of piles

1.5 Advantages

1) Piles can be precast to the required specifications.

2) Piles of various size, length, and shape can be made in advance and used at the site. As a result, the progress of work will be rapid

3) A pile driven into the granular soils compacts the adjacent soil mass and as a result, the bearing capacity of pile is increased.

4) The work is neat and clean and creates no soil arising's.

5) Driven piles maintain their shapes during installation. They do not bulge in soft ground conditions and are typically not susceptible to damage.

1.6 Aim

To investigate an experimental and numerical study on compression and tension test on piles

1.7 Objectives

- To study the behaviour of piles by conducting compression and tension tests in laboratory
- To validate laboratory results using numerical modelling (PLAXIS 3D)

Chapter 2

Literature Review

2.1 General

Jie Han and Shu-Lin Ye (2005) have used micro piles for underpinning existing foundation on problematic soils. In this study, they have performed two compressions and two tension test on pile with quick loading and slow loading test methods. They concluded, quick loading test data indicated that ultimate shaft capacities of micro piles under tension were about 60% of those under tension, and measured skin friction value of under compression was higher than bored piles. However, the relationship between tip resistance and tip displacement is independent of the rate of loading.

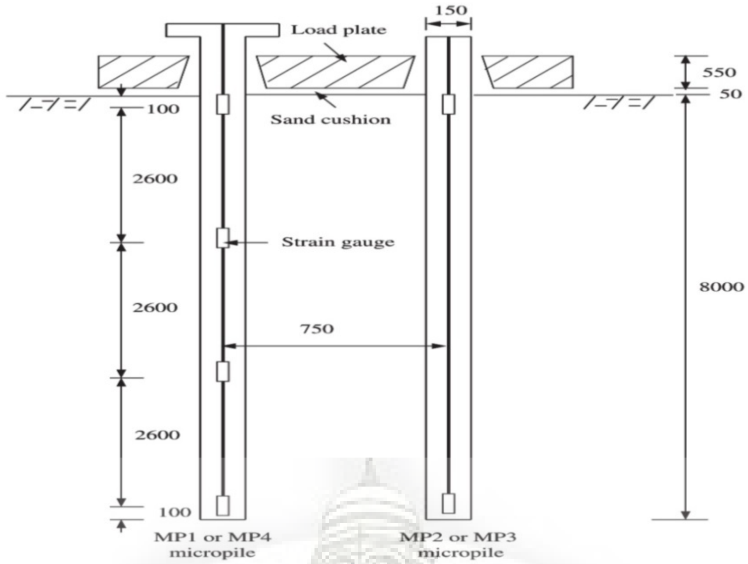


Fig 2.1 Cross section of Instrumentation setup

Zhong miao et al (2010) have used cast in situ bored piles for destructive field study under compression and tension. They found that the measured skin friction for piles under compression is about 6% to 42% higher than estimated values whereas the uplift cases are 16% to 50% smaller than estimated. The ratio of mobilized base load to applied load increases from 10% to 39% unlike the applied load-mobilized base load decreases because of the punching failure.

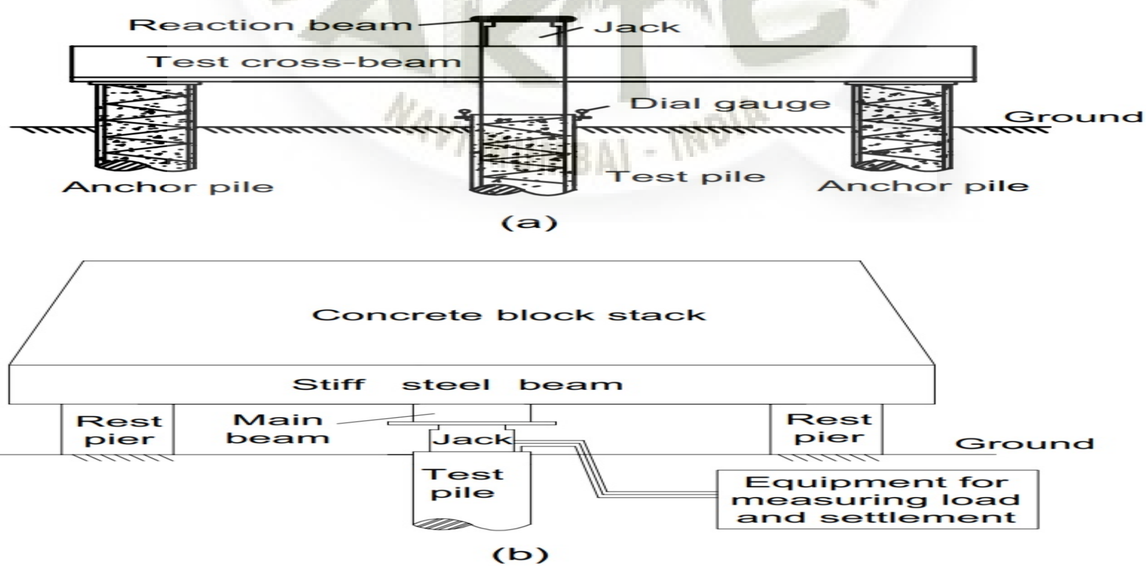


Fig 2.2 Tension (a) and compressive load test (b) setup

Nabil F. Ismael et .al(1994) have done tension test on bored piles in cemented desert sands.In this literature bored piles in medium dense cemented sands was examined by field tests at two sites.At first site two bored piles were tested in axial tension to failure in meduim dense and very dense cemented sand.at second site tension test was carried out in uncemented sand.The average shaft resistance measured is 84 KN/m^2 for short pile in medium dense cemented sand.For very dense cemented sands the average resistance is exceeds 100KN/m^2.Cementation leads to the presence of a cohesion inter-cept which increse the shaft friction along the piles.

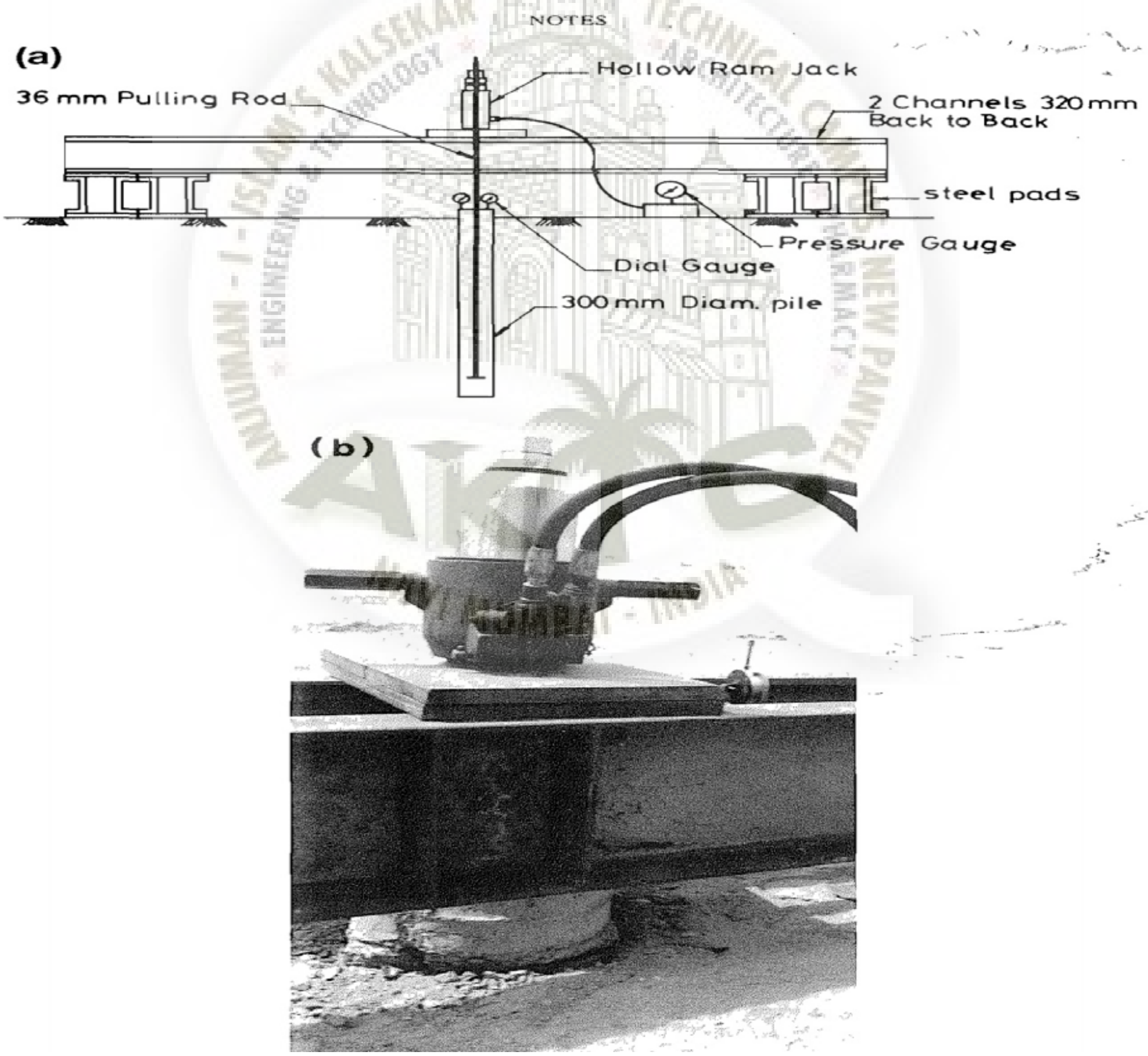


Fig2.3 a) Tension test setup. b) after failure view of 3.3m long pile

Hossein moayedi, et al(2june 2017) done test on Uplift resistance of Belled and Multi-Belled piles in Loose sand.In this literature The load displacement behaviours of belled and multi belled piles with various hells locations are recorded and compared with one from the straight piles. For the belled and multi belled piles they experienced greater uplift force when wings installed at deeper depth.

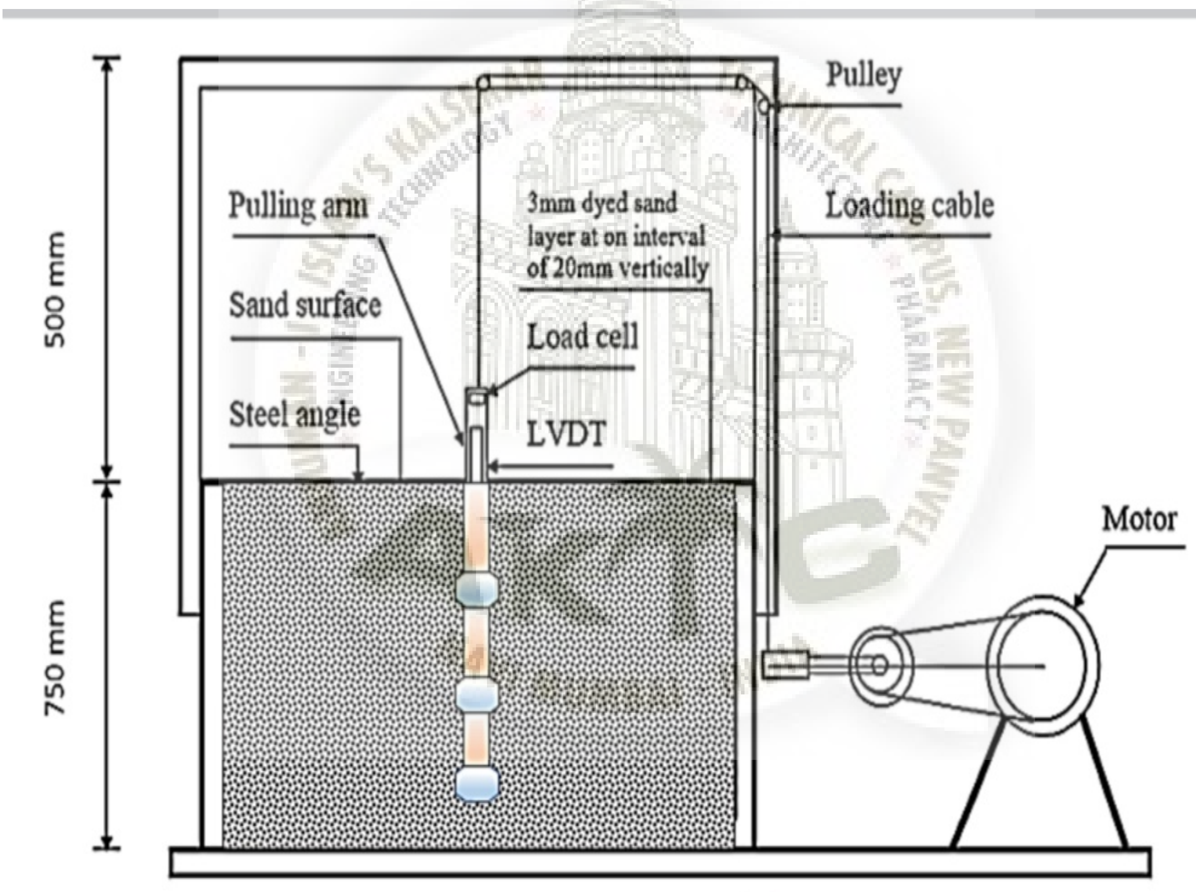
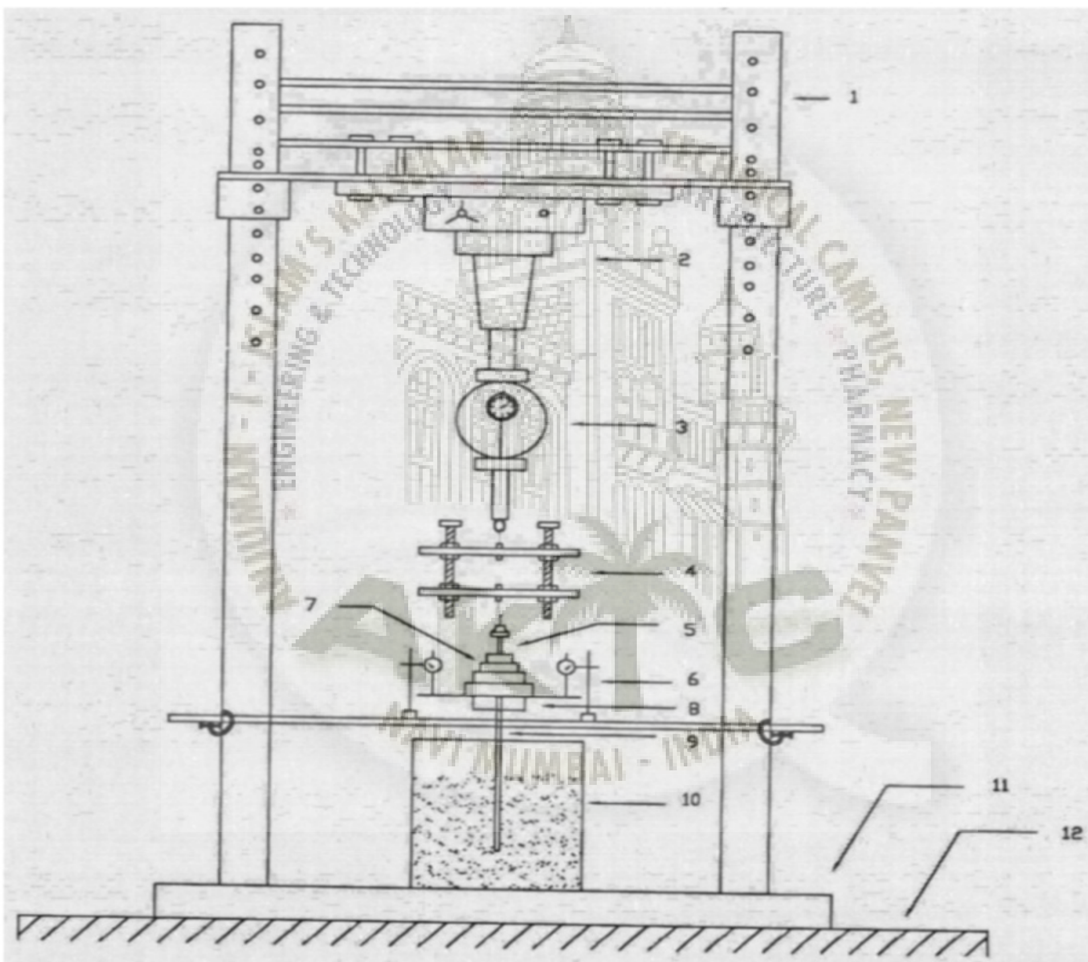


Fig 2.4 Schematic view of testing setup, belled pile, LVDT, 10KN S-type load cell

B.K. Dash and P.J. Pise (2january 2003) done test on Effect of compressive load on uplift capacity 0f model piles. In this literature 36 test on model tubular steel piles embedded in sand were carried out in the laboratory to access the effect of compressive load on uplift capacity of piles. They found that the net uplift capacity decreases with the increase in the stage of compressive loading.



1.Supporting Frame 2. Screw Jack 3. Proving Ring 4. Adjustable Threaded Arrangement 5. Extension 6. Dial Gauge 7. Static Compressive Load 8. Pile Cap 9. Model Pile 10. Model Tank with Sand 11. Concrete Pedestal 12. Concrete Floor.

Fig 2.5 Schematic diagram of experimental setup

Ashraf Nazir and Ahmed Nasr (3april 2012) done test on Pullout capacity of batter pile in sand. In this literature 62 Pullout tests were conducted on vertical and batter piles. They concluded that Pullout capacity increases with increase in a batter angle but at optimum value of angle (20) & then decreases. They also conclude that batter piles give 21-31% more capacity than vertical pile.

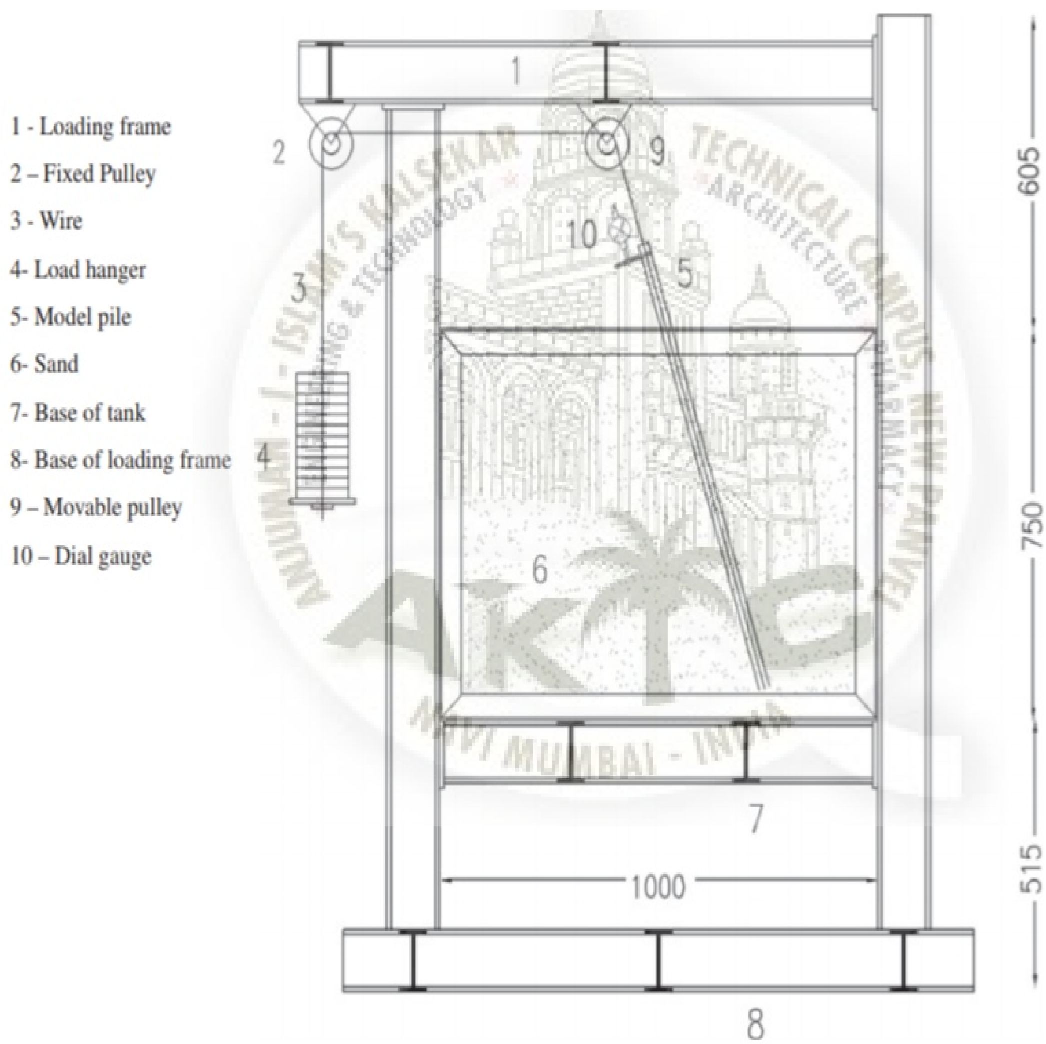


Fig 2.6 Schematic view of the experimental apparatus

Khalid E. Gaaver (1january 2013) done test on Uplift capacity of single piles and pile groups embedded in cohesionless soil. In this literature Experimental tests were conducted on single piles and pile groups containing two, four, and six piles under uplift loading. He found that behaviour of piles under uplift loading depends mainly on both the pile embedment depth to diameter ratio and the soil properties. The efficiency of a pile group under uplift loading decreases with an increase in the number of piles in the group and depth.

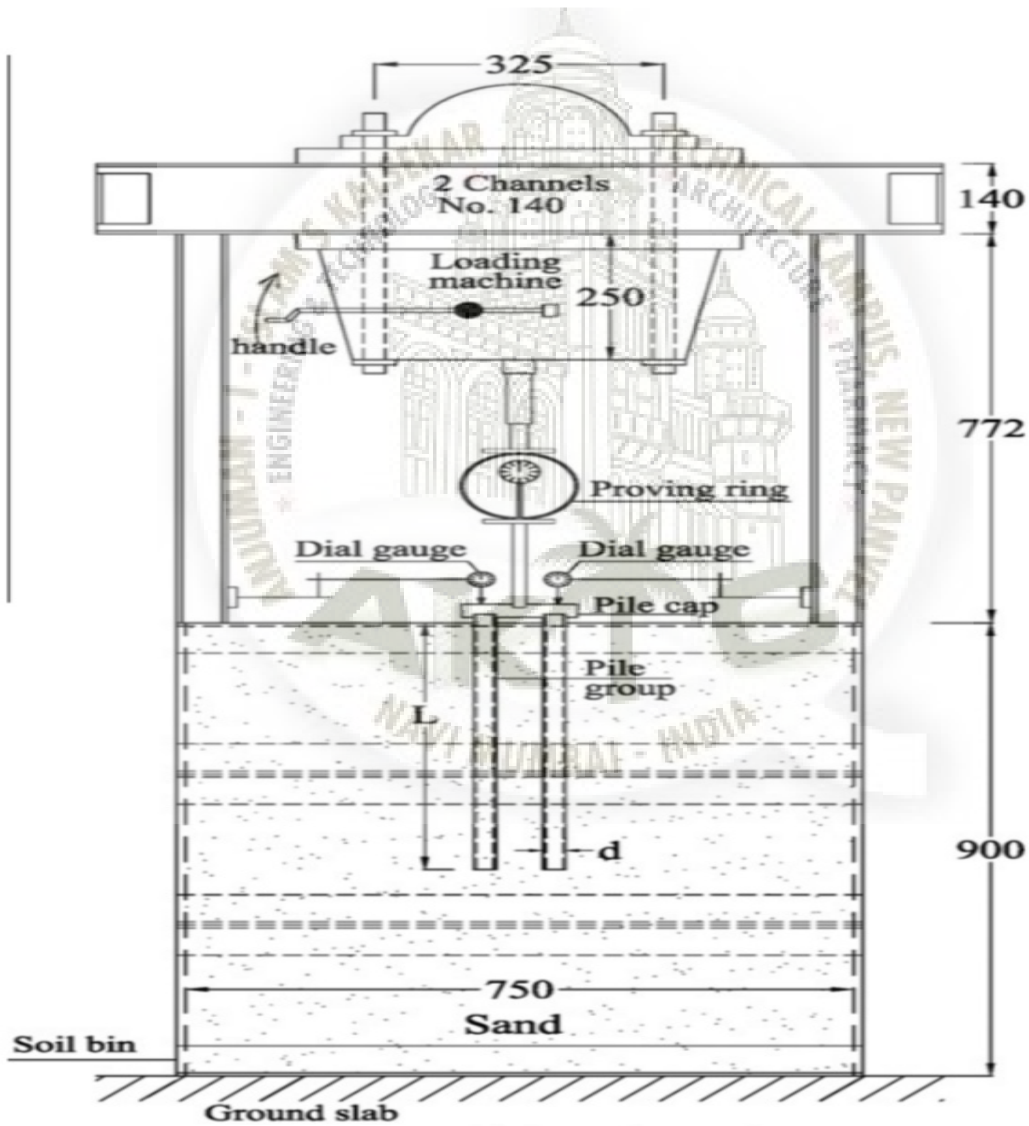


Fig 2.7 Schematic diagram of test setup

Paul Doherty et al(Oct 2015) have used novel mixed-in place piles for the estimation of compression and tension loads for offshore piles for oil & gas platform in silica and calcareous sand. In which they have found that this piling technology minimizes the number of offshore operations and it is quicker than D&G piles and therefore more cost effective. They conclude that silica and calcareous sand decreases the bearing capacity of normal piles which have been used in construction and contaminated the design criteria.

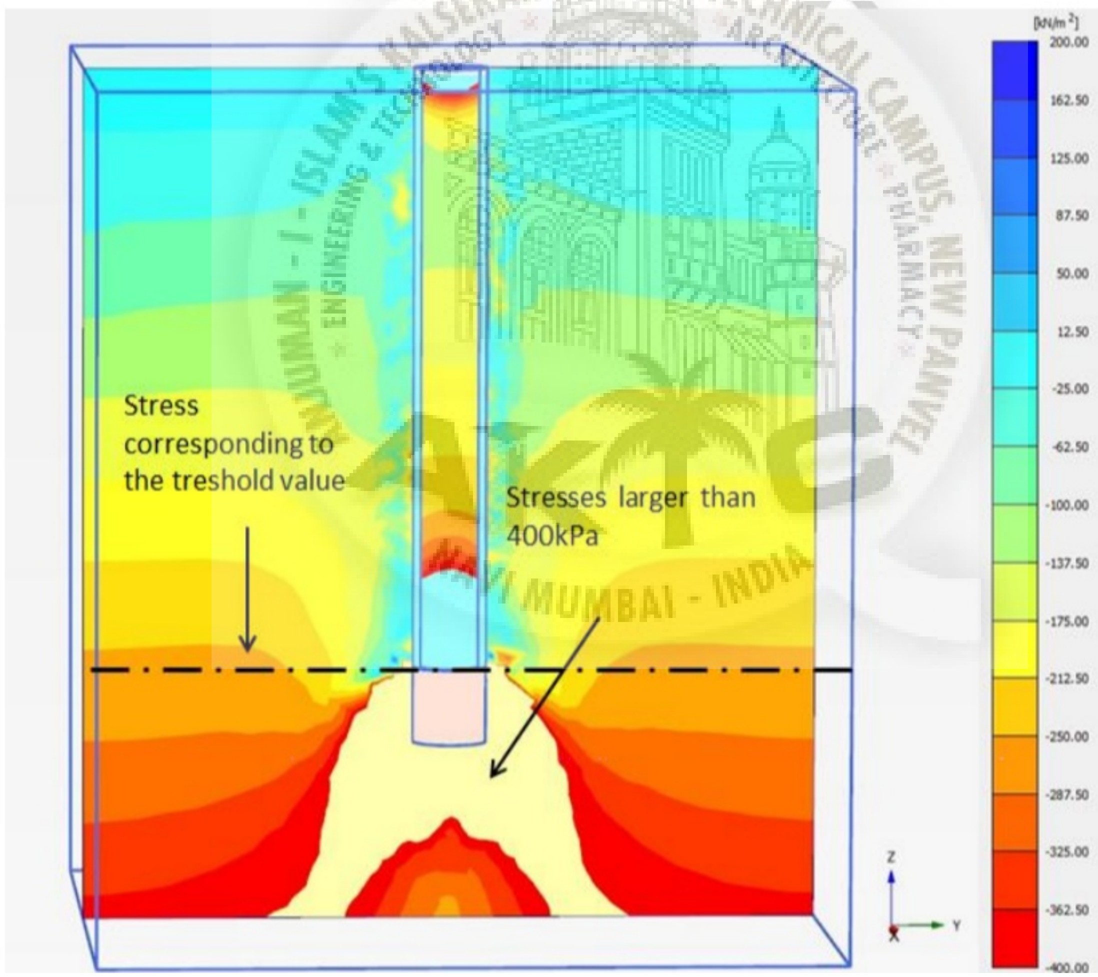


Fig 2.8 identifying the depth corresponding to stress threshold using an intact soil model analysis

Jin Bok Kim et al(2014) have tested short piles for determination of resistance and movement of short pile installed in sands under horizontal Pullout load. As a result, the horizontal Pullout resistance of a pile was dependent on the pile length, diameter, loading point, etc. the ultimate horizontal Pullout load tended to increase as the loading point(h/L) moved to bottom from the top of pile, regardless of the ratio between the pile length and diameter(L/D).

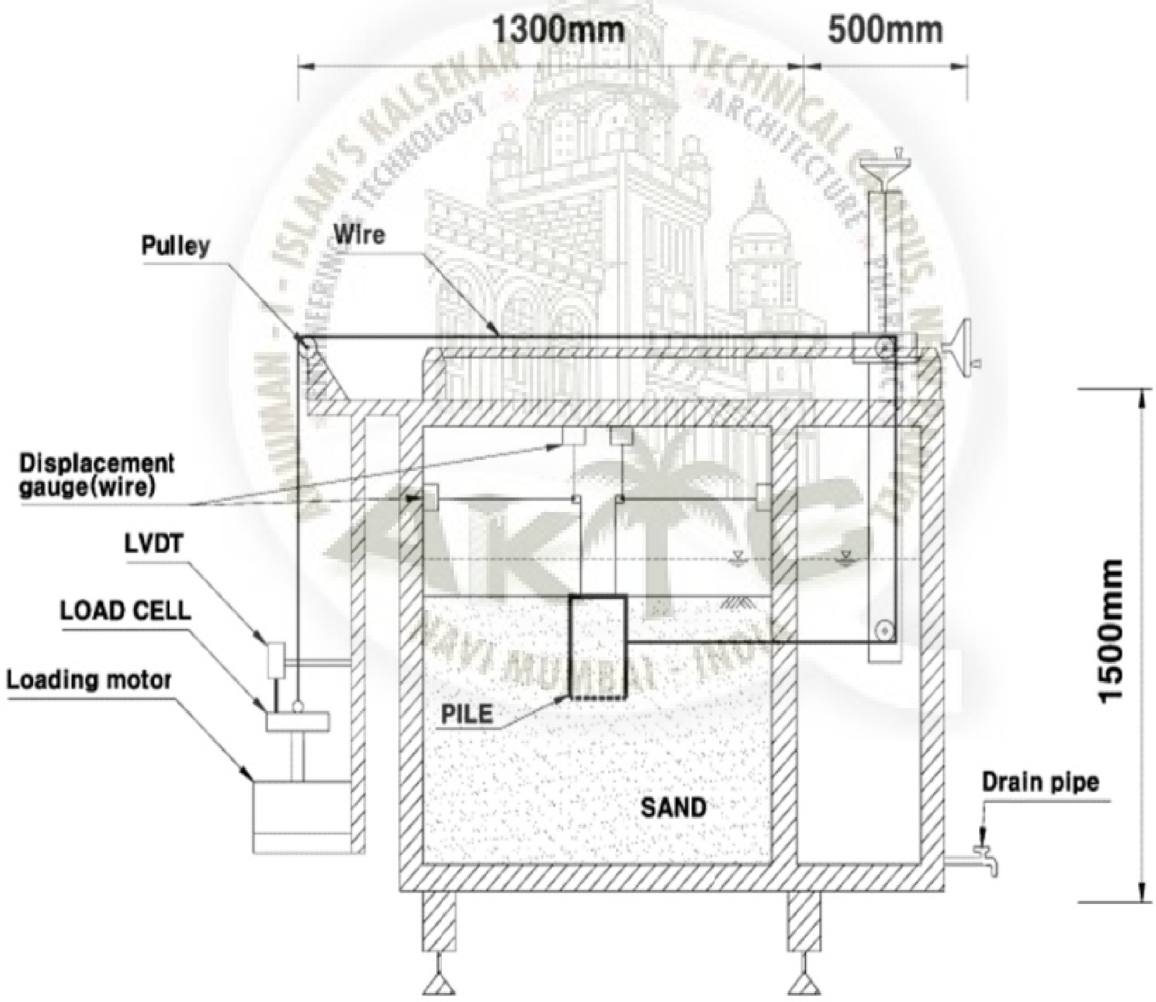


Fig 2.9 Picture of the model chamber

Masatoshi Wada et al (November 2016) have done a laboratory field test to investigate the bearing capacity and Pullout capacities of steel piles with a continuous helix wings during cyclic loading. They stated that both the laboratory and the field tests showed that the bearing and Pullout capacities of continuous helix pile under cyclic reversal loading decreases to approximately 60-80% of those of piles under monotonic loading.

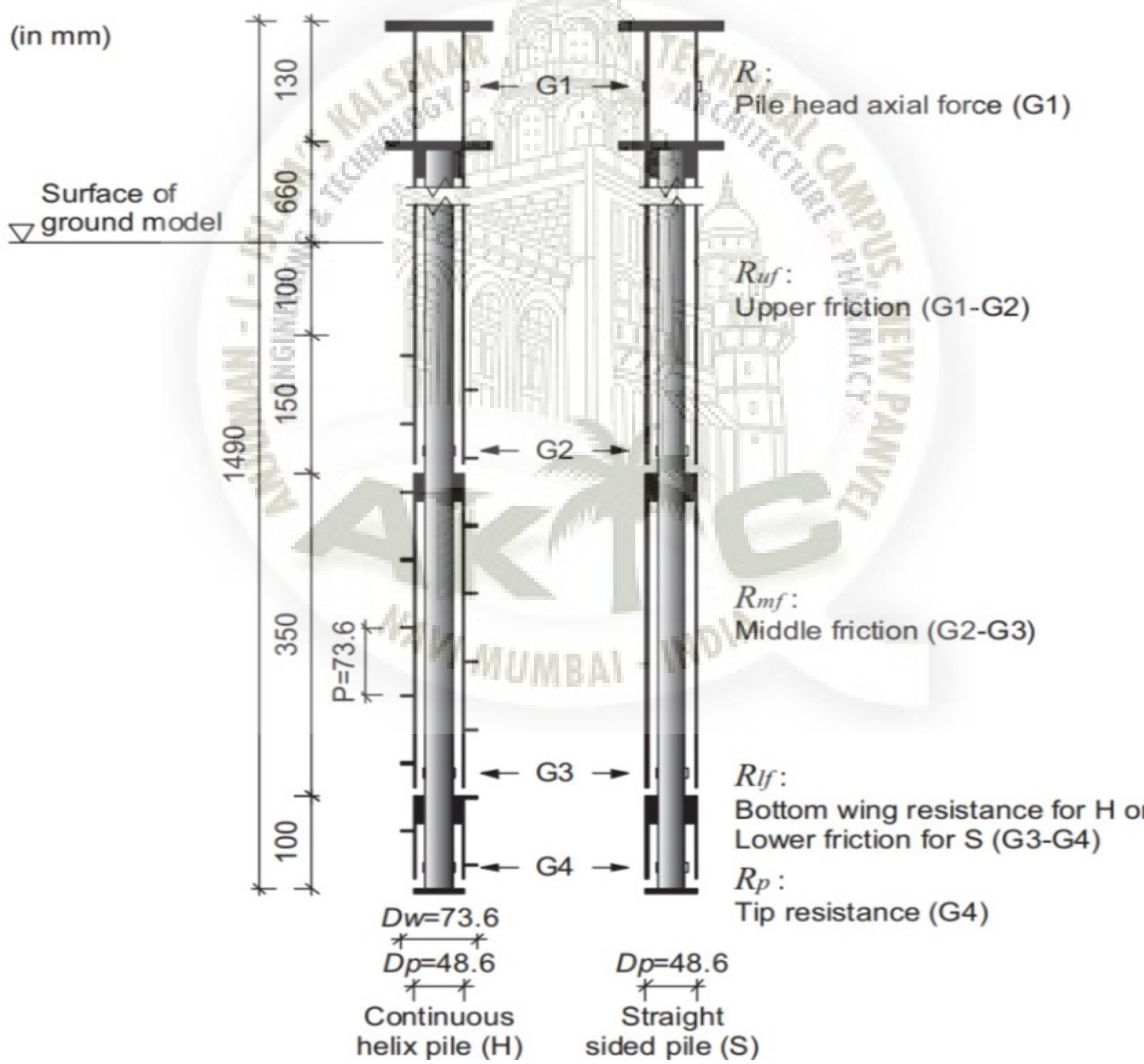


Fig 2.10 Cross section of steel piles

Chapter 3

Field Pile Load Test

3.1 General

Name of the project: Construction of elevated corridor from

a) Kurla to vakala flyover on santacruz chembur link road
b) MTNL Junction, BKC to LBS Flyover at Kurla

Site location: Hans Bhugra Marg Opposite Mumbai University

The most reliable method for determining the load carrying capacity of pile is the pile load test. The setup generally consists of two anchor piles provided with an anchor girder (plate) at their top. The test pile should be at least 3B or 2.5m clear from the anchor piles. The load is applied through a hydraulic jack resting on the reaction girder. The measurement of the pile movements are taken with respect to fixed reference mark or with the help of gauges.

3.2 Procedure:

1) The test is conducted after a rest period of 3days and after the installation in sandy soils and a period of one month in silt and soft clays.
2) The load is applied in equal increment of about 20% of the allowable load.
3) Settlement should be recorded with dial gauges.
4) Each stage of the loading is maintained till the rate of movement of the pile top is not more than 0.1mm per hour in sandy soils and 0.02mm per hour in case of clayey soils or a maximum of two hours (IS 2911-1979).
5) Under each load increment settlements are observed at 0.5,1,2,4,8,12,16,20,60,120, minutes.
6) The loading should be continued upto twice the safe load or the load at which the total settlement reaches a specified value (12mm).
7) The load is removed in the same decrements at 1hour interval and the final rebound is recorded 24hours after the entire load has been removed.

Fig 3.1 Practical setup of pile load test

In this loading the following dimensions of the pile has been taken.

Pile used in testing is cast in-situ type and the length of pile is 11.820m. The diameter of pile is 1000mm with the design load of 473 tons. The load applied for testing on pile is 1182.5 tons (2.5 times of dead load). The thickness of plate is 30mm with the diameter of 1500mm. The load transferring mechanism is done by hydraulic jack which has a diameter of 2826.5mm (4hydraulic jack is used) and the capacity of each jack is 500 tons. In this test 4 dial gauges are used which has a least count of 0.01mm and diameter of each dial gauges is 25mm. For tension releasing purpose Anchorage bars are used whose length is 32m and the diameter is 20mm.

Fig 3.2 Group photo at pile load testing site

Chapter 4

Methodology

4.1 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 sheet whose thickness is 20mm. the glass side allow the sample to be seen during preparation and sand deformation to be observed during testing. 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 of 10d below the bottom of the tank which satisfies the above requirements.

4.2 Sand

Cohesionless soil was 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 is 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 were 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. At the bottom of tank hardened concrete layer was used as Rock layer having a proportion of Cement=39.44Kg, Sand=147.90Kg, Water22.834Litre, POP=9.86Kg. The model piles were socketed into the rock and at the bottom of model pile, spongy material will be used to allow settlements during loading.

4.3 Model Piles

Mild steel tubes of 50mm outside diameter and 2mm wall thickness having one surface characteristic was used as model piles. The top portion of the pile was threaded to connect it to the pile cap and proving ring for compression and tension tests. The embedment length (L) to diameter (d) ratios of piles was 600mm maximum and 400mm minimum.

4.4 Material Testing

a) Cube Testing: - 7×7×7cm

We have casted equal numbers of cubes but with different proportions i.e, one with Cement-POP and other one is Cement-Bentonite. After the compressive testing of cubes we got to know that Cement-POP mixture has much higher strength than Cement-Bentonite. So we adopted Cement-POP mixture for the simulation of rock.

Fig 4.1 Pictorial view of Cement-POP & Cement-Bentonite cubes

Table 4.1 Cube testing with different proportions of mixtures

Sr no.	Proportions	Curing period	Peak load (KN)	Peak stress (Mpa)
1	80% - Cement 20% - POP	7	50.3	10.2
2	60% - Cement 40% - POP	7	24.8	5
3	80% - Cement 20% - POP	14	77.8	16.3
4	60% - Cement 40% - POP	14	33.7	7.3
5	80% - Cement 20% - POP	28	93.7	19.1
6	60% - Cement 40% - POP	28	44.1	9

Given values shows the variation as well as the highest or maximum value of strength of mix proportion. We wanted our rock layer to neither be much stronger nor be much stiffer so we went with an option no 1 i.e, 80% Cement & 20% POP as 10Mpa strength was more than enough for our experimental analysis part.

4.5 Compression Test

This series of tests was meant for the assessment of the ultimate load carrying capacity of single pile as well as group of piles in compression. In each test the single pile or group of pile was suspended centrally in an empty tank by the screw jack and proving ring arrangement. Sand was poured by the rainfall technique method to attain the required embedment length to diameter ratio L/d. the compressive load was applied by the hydraulic jack arrangements in suitable increments with respect to settlement. The corresponding values of load versus settlement were recorded from the displacement dial gauges and proving ring. The load-displacement curves were plotted for single as well as different combinations of group of piles.

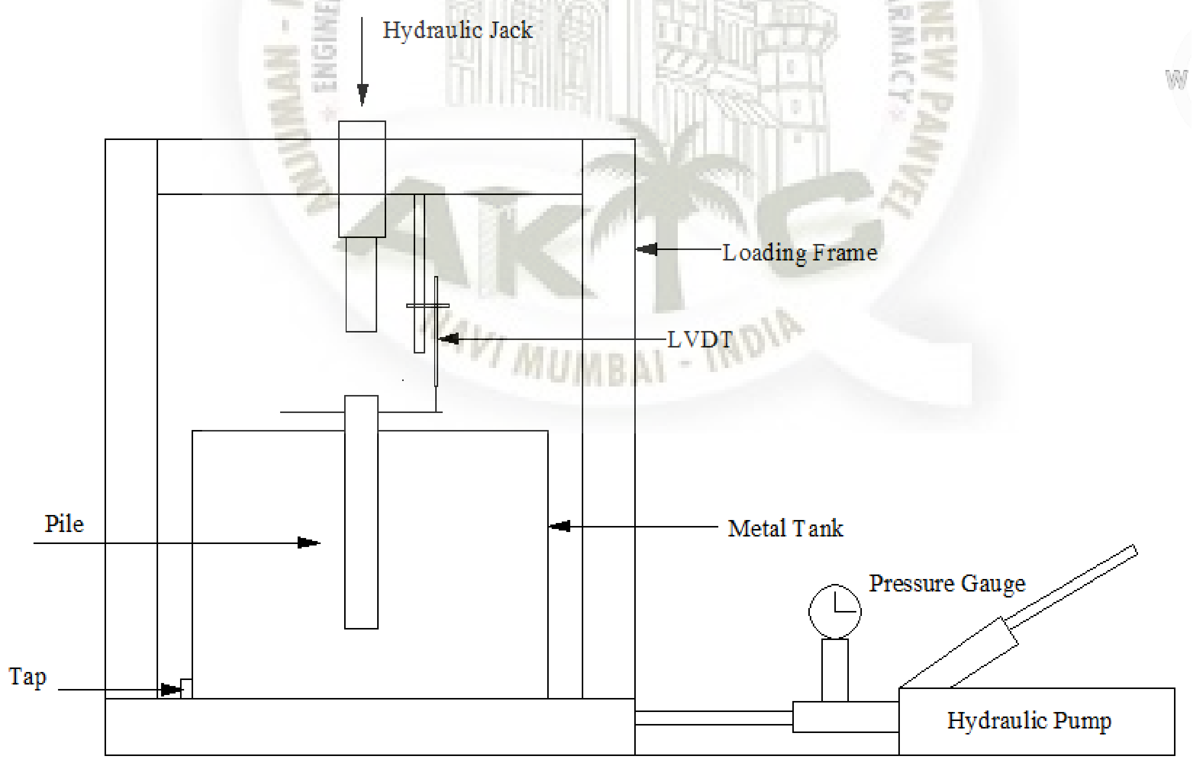


Fig 4.2 Compression test set up

4.6 Methods

1) The pile was driven to a maximum displacement of 20mm by a means of hydraulic jack and a reaction frame.
2) Sand was placed by rainfall technique to full width of tank in 50mm thick layers for 400mm.
3) This loose sand layer was lightly compacted with a wooden hammer in the tank until about 50mm thick.
4) To confirm the 50mm thickness, horizontal lines at 50mm intervals was drawn on the internal face of glass plate.
5) This process continued until the sand mass height reached 400mm.
6) And from then loading was given to the respective layer depth and settlement was recorded through dial gauge and strain gauges.
7) Lastly, scale effect was done i.e, predicting experimental result for an actual site pile load test.

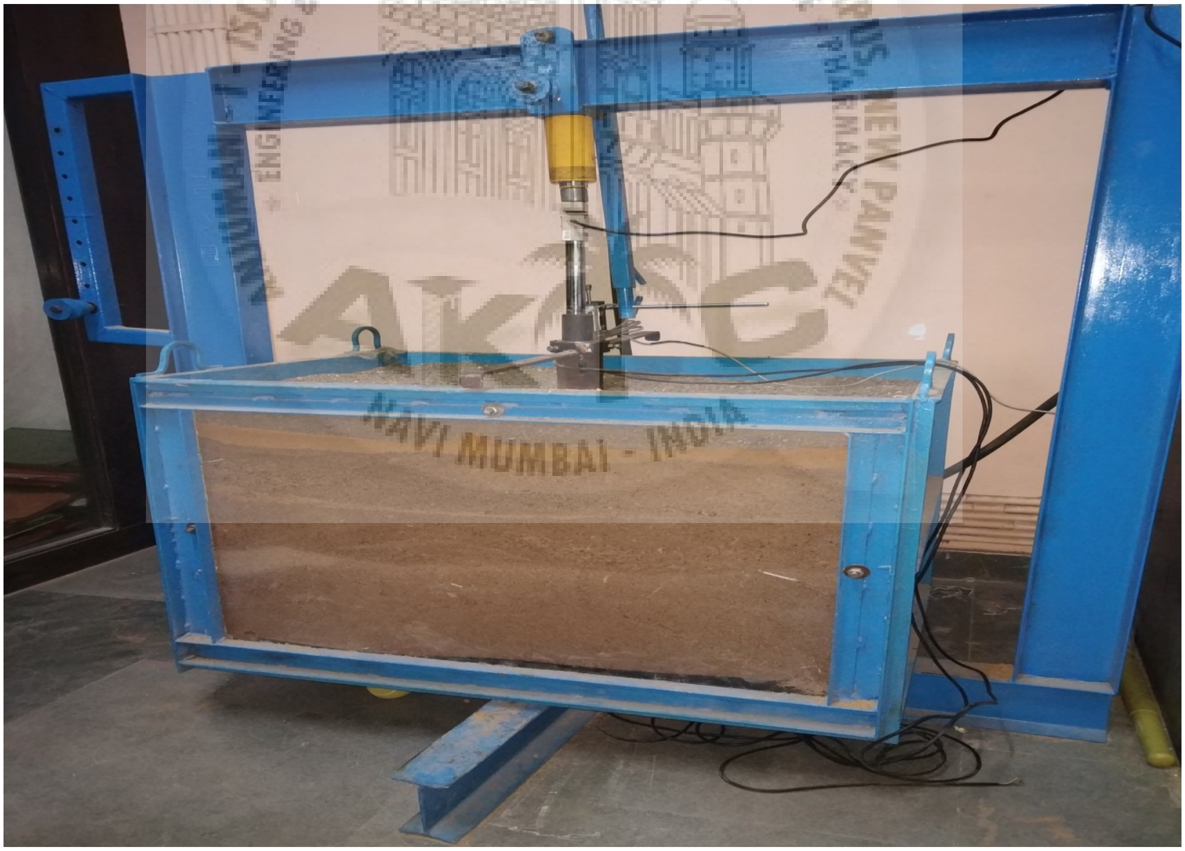


Fig 4.3 Experimental arrangement of compression test

Fig 4.4 Pile group of (2x2)

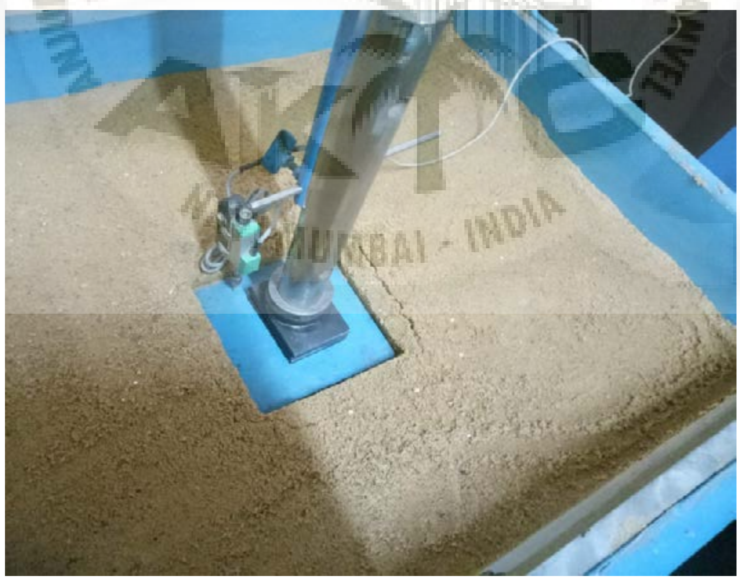


Fig 4.5 Cake shape settlement of pile group

Table 4.2 Experimental results values

Sr no	No Of Piles	L/D	Pu (N)	Load O %	Settlement (mm)	Load 25%	Settlement (mm)	Load 50%	Settlement (mm)	Load 75%	Settlement (mm)	Load 100%	Settlement (mm)
1)	Single Pile		0.79	0	0	0.32	5	0.47	10	0.62	15	0.79	20
2)													
	S2	20	4.05	0	0	2.06	5	2.56	10	3.2	15	4.05	20
	S3	20	6.96	0	0	4.09	5	5.42	10	6.13	15	6.96	20
	S4	20	4.63	0	0	3.5	5	4.03	10	4.38	15	4.63	20
	S2	30	4.16	0	0	2.15	5	2.85	10	3.3	15	4.16	20
	S3	30	7.21	0	0	4.3	5	5.6	10	6.41	15	7.21	20
	S4	30	5.11	0	0	3.62	5	4.2	10	4.61	15	5.11	20
	S2	40	4.18	0	0	2.14	5	2.9	10	3.35	15	4.18	20
	S3	40	7.22	0	0	4.33	5	5.63	10	6.44	15	7.22	20
	S4	40	5.2	0	0	3.61	5	4.23	10	4.64	15	5.2	20
3)													
	S2	20	6.86	0	0	3.22	5	4.27	10	5.28	15	6.86	20
	S3	30	11.8	0	0	6.66	5	8.4	10	10.5	15	11.89	20
	S4	40	8.43	0	0	5.43	5	6.3	10	7.6	15	8.43	20

Table 4.3 Spacing notations

Test denotation &description	Spacing	Figure
S2,S3,S4	2D,3D,4D	5.1

Table 4.4 Group of pile (2×2)-spacing 2D- Length 200mm

Sr no	Load(KN)	Settlement(mm)
1	0	0
2	0.86	1
3	1.45	2
4	1.76	3
5	1.89	4
6	2.06	5
7	2.23	6
8	2.47	7
9	2.5	8
10	2.52	9
11	2.56	10
12	2.7	11
13	2.8	12
14	2.9	13
15	3	14
16	3.2	15
17	3.4	16
18	3.6	17
19	3.8	18
20	3.9	19
21	4.05	20

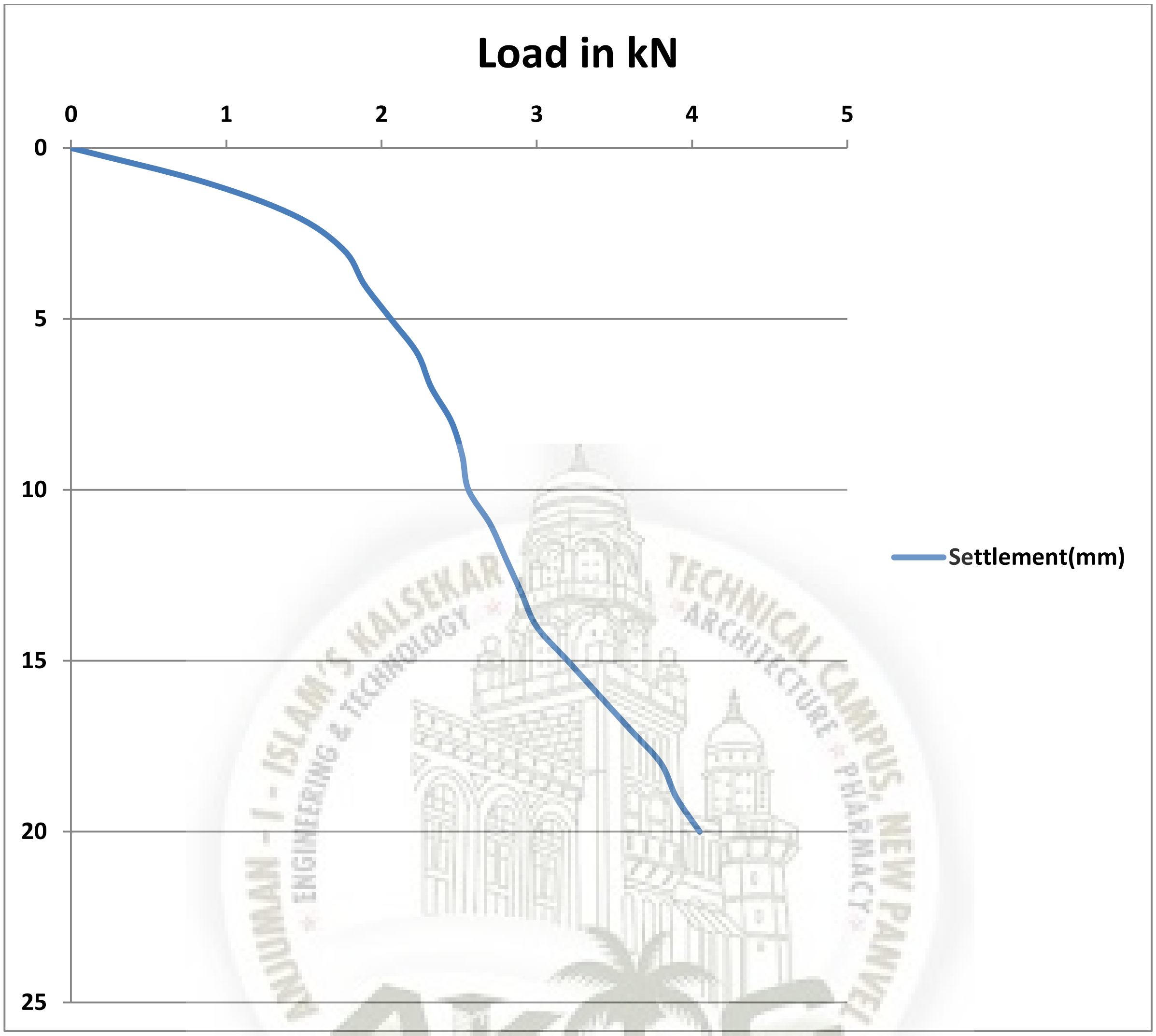


Fig 4.6 Load Vs Settlement of (2×2)-2D-200mm

Table 4.5 Group of pile (2×2)-spacing 3D- Length 200mm

Sr no.	Load (kN)	Settlement (mm)
1	0	0
2	2.9	1
3	3.3	2
4	3.5	3
5	3.75	4
6	4.09	5
7	4.57	6
8	4.84	7
9	5	8
10	5.25	9
11	5.42	10
12	5.54	11
13	5.69	12
14	5.9	13
15	6.03	14
16	6.16	15
17	6.33	16
18	6.42	17
19	6.54	18
20	6.68	19
21	6.96	20

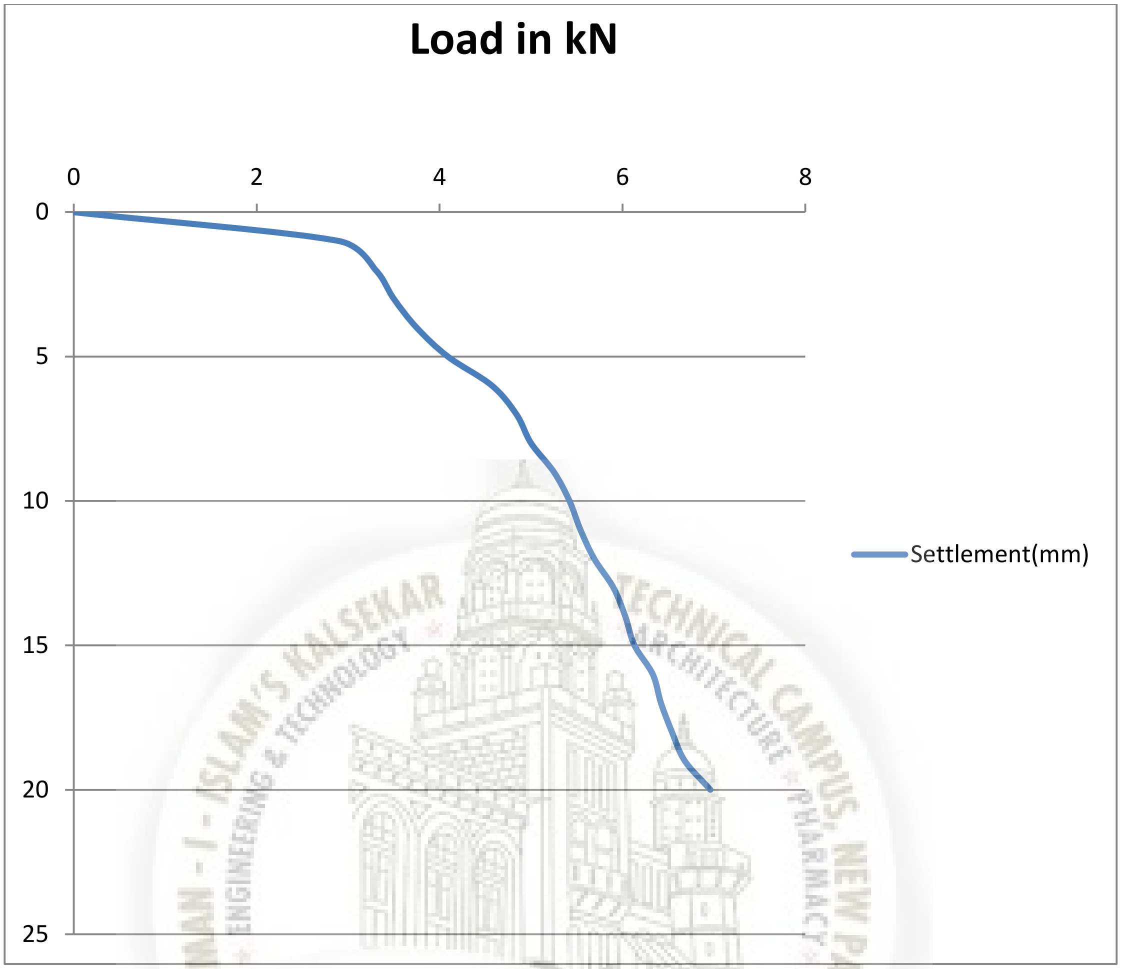


Fig 4.7 Load Vs Settlement of (2×2)-3D-200mm

Table 4.6 Group of pile (2×2)-spacing 4D- Length 200mm

Sr no.	Load (KN)	Settlement(mm)
1	0	0
2	2.9	1
3	3.3	2
4	3.5	3
5	3.75	4
6	4.09	5
7	4.57	6
8	4.84	7
9	5	8
10	5.25	9
11	5.42	10
12	5.54	11
13	5.69	12
14	5.9	13
15	6.03	14
16	6.13	15
17	6.33	16
18	6.42	17
19	6.54	18
20	6.68	19
21	6.96	20

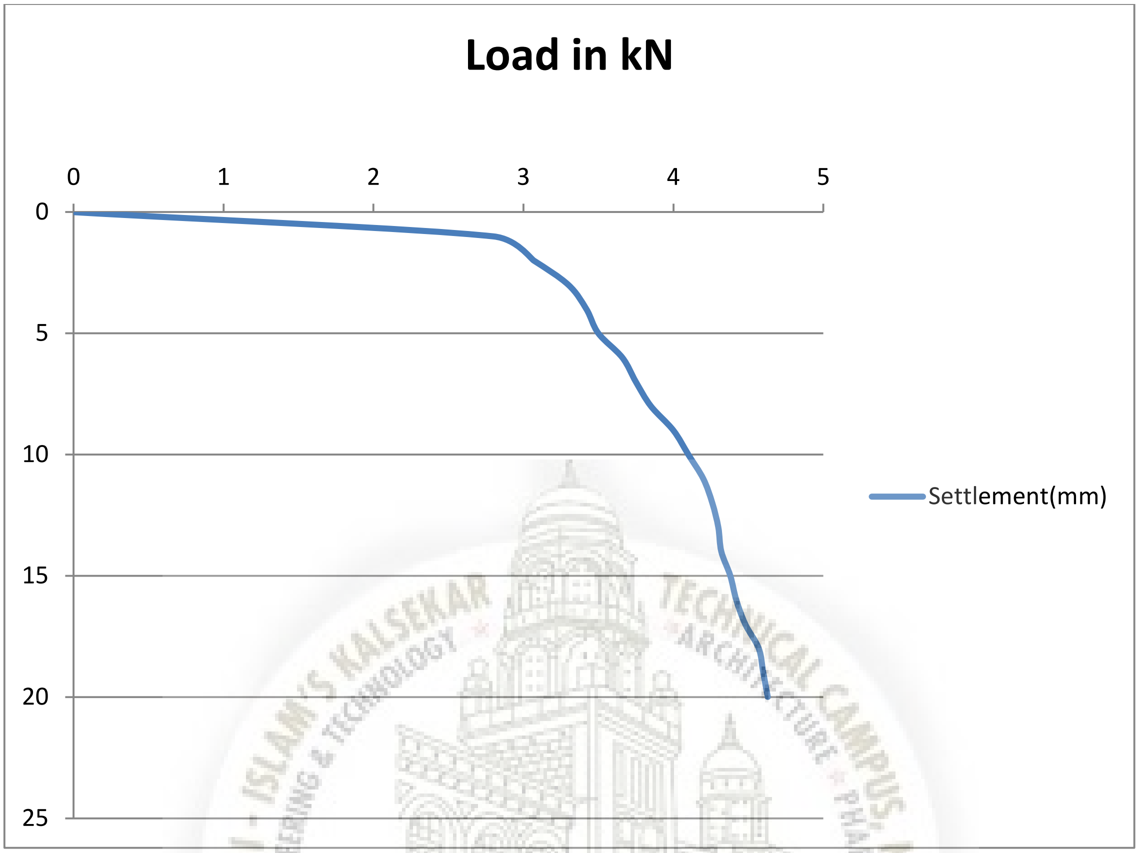


Fig 4.8 Load Vs Settlement of (2×2)-4D-200mm

Table 4.7 Group of pile (2×2)-Spacing 2D-Length 300mm

Sr no.	Load (KN)	Settlement(mm)
1	0	0
2	0.91	1
3	1.5	2
4	1.82	3
5	1.96	4
6	2.15	5
7	2.35	6
8	2.58	7
9	2.65	8
10	2.78	9
11	2.85	10
12	2.9	11
13	3.05	12
14	3.15	13
15	3.2	14
16	3.3	15
17	3.54	16
18	3.74	17
19	3.92	18
20	4.04	19
21	4.16	20

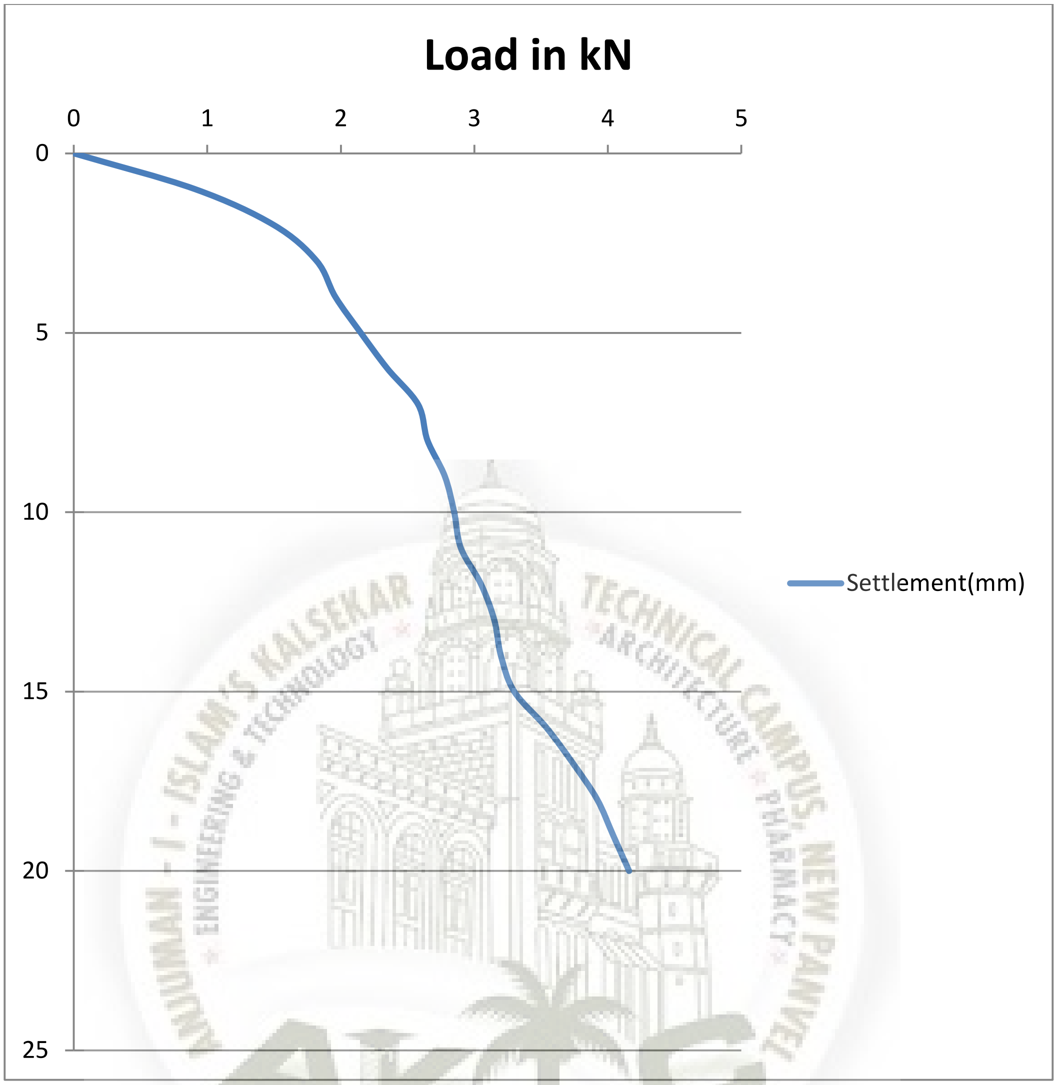


Fig 4.9 Load Vs Settlement of (2×2)-2D-300mm

Table 4.8 Group of pile (2×2)-Spacing 3D-Length 300mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	3	1
3	3.3	2
4	3.63	3
5	3.81	4
6	4.3	5
7	4.75	6
8	4.93	7
9	5.2	8
10	5.42	9
11	5.6	10
12	5.73	11
13	5.88	12
14	6.15	13
15	6.3	14
16	6.41	15
17	6.57	16
18	6.7	17
19	6.85	18
20	6.98	19
21	7.21	20

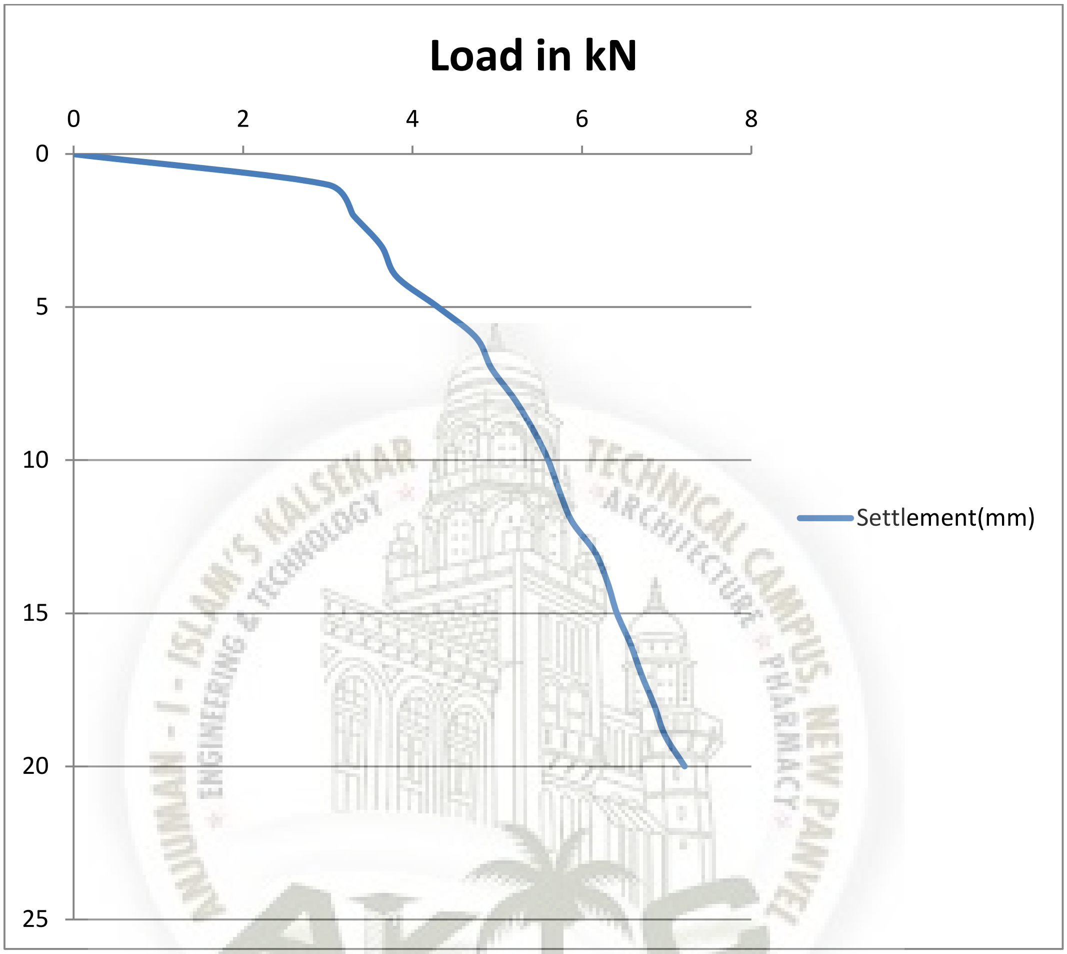


Fig 4.10 Load Vs Settlement of (2×2)-3D-300mm

Table 4.9 Group of pile (2×2)-Spacing 4D-Length 300mm

Sr. No	Load (KN)	Settlement (mm)
1	0	0
2	2.85	1
3	3.18	2
4	3.43	3
5	3.52	4
6	3.62	5
7	3.76	6
8	3.88	7
9	3.96	8
10	4.12	9
11	4.2	10
12	4.33	11
13	4.4	12
14	4.47	13
15	4.52	14
16	4.61	15
17	4.7	16
18	4.82	17
19	4.94	18
20	5.05	19
21	5.11	20

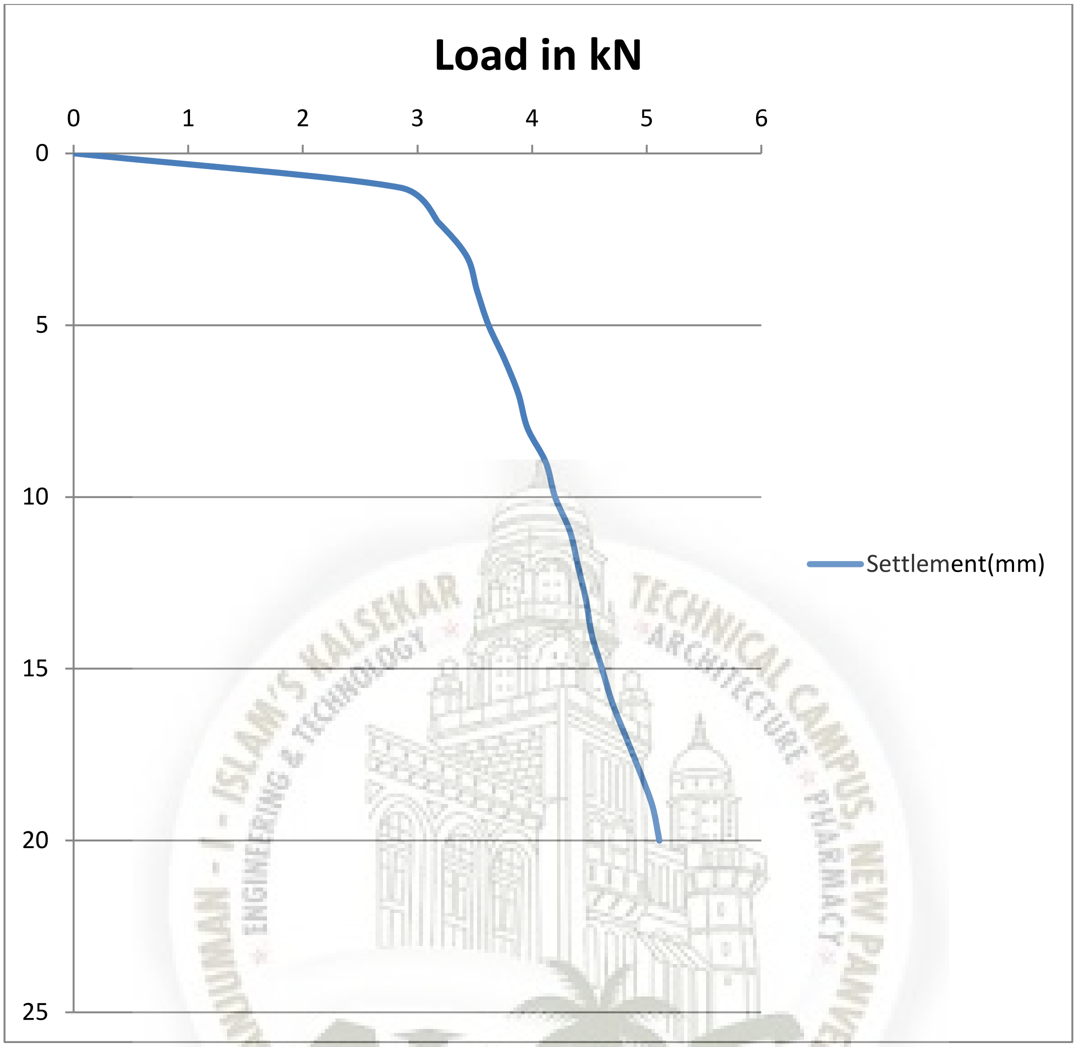


Fig 4.11 Load Vs Settlement of (2×2)-4D-300mm

Table 4.10 Group of pile (2×2)-Spacing 2D-Length 400mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	0.92	1
3	1.52	2
4	1.85	3
5	1.98	4
6	2.14	5
7	2.38	6
8	2.56	7
9	2.66	8
10	2.8	9
11	2.9	10
12	2.98	11
13	3.1	12
14	3.17	13
15	3.25	14
16	3.35	15
17	3.51	16
18	3.69	17
19	3.88	18
20	4.06	19
21	4.18	20

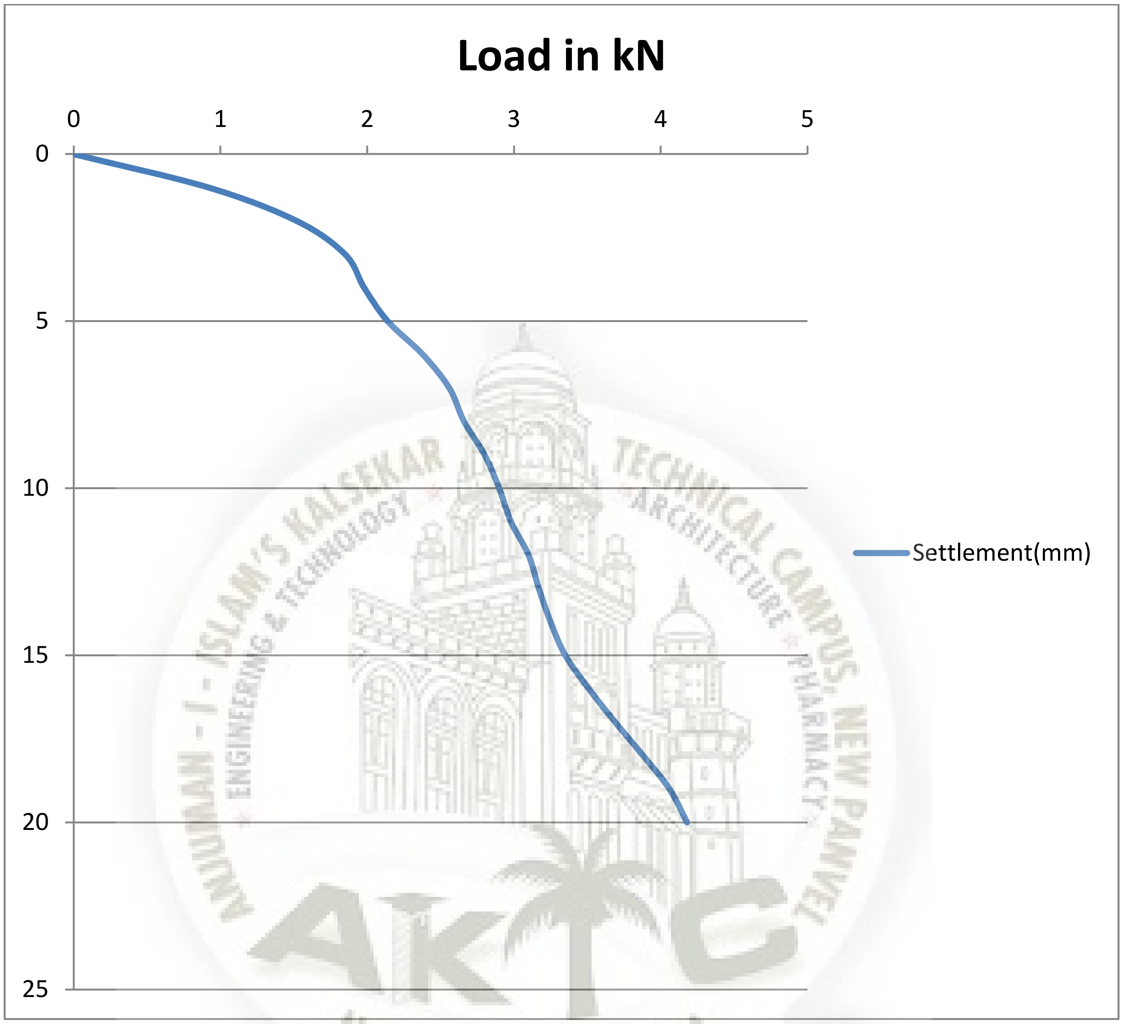


Fig 4.12 Load Vs Settlement of (2×2)-2D-400mm

Table 4.11Group of pile (2×2)-Spacing 3D-Length 400mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	3.1	1
3	3.38	2
4	3.65	3
5	3.9	4
6	4.33	5
7	4.77	6
8	4.96	7
9	5.18	8
10	5.39	9
11	5.63	10
12	5.76	11
13	5.9	12
14	6.18	13
15	6.33	14
16	6.44	15
17	6.57	16
18	6.71	17
19	6.85	18
20	6.99	19
21	7.22	20

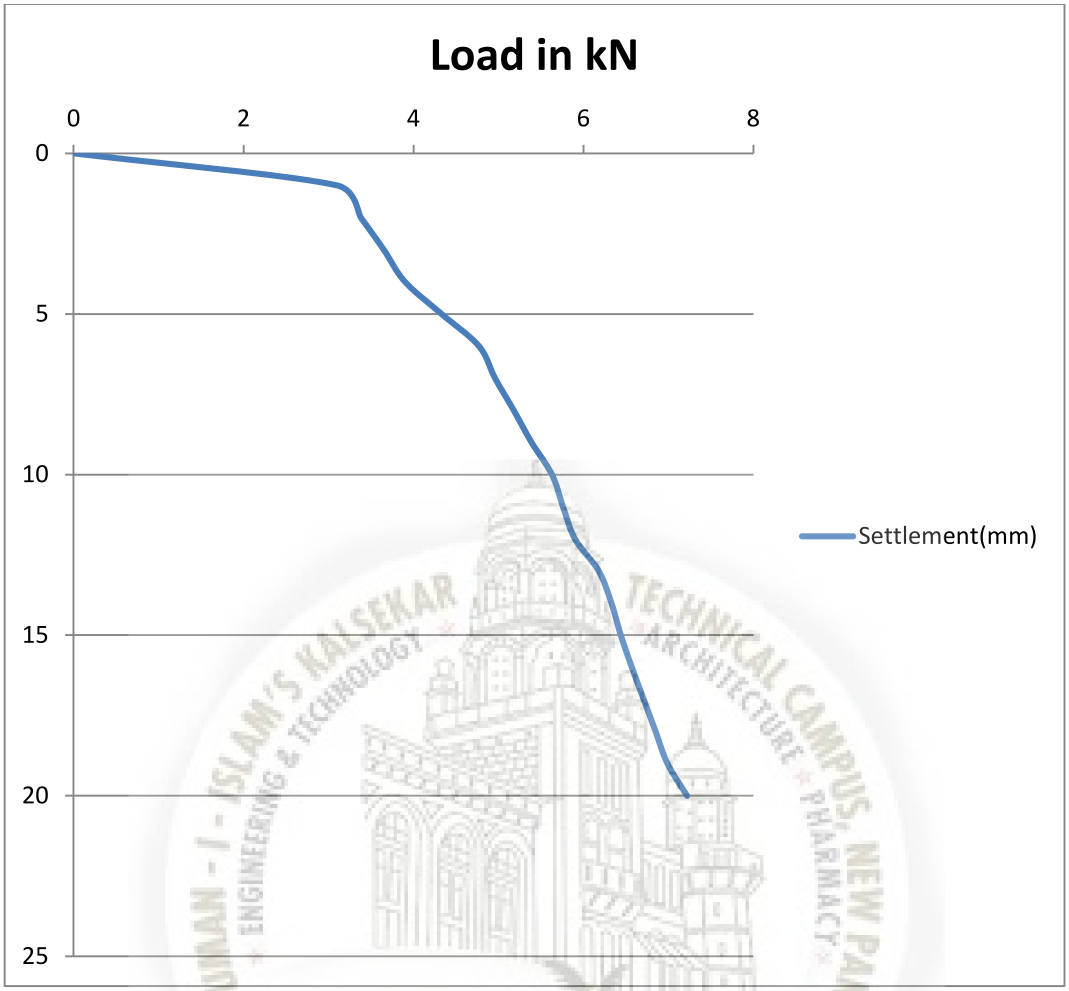


Fig 4.13 Load Vs Settlement of (2×2)-3D-400mm

Table 4.12 Group of pile (2×2)-Spacing 4D-Length 400mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	2.87	1
3	3.2	2
4	3.44	3
5	3.53	4
6	3.61	5
7	3.78	6
8	3.91	7
9	3.97	8
10	4.11	9
11	4.23	10
12	4.34	11
13	4.43	12
14	4.49	13
15	4.57	14
16	4.64	15
17	4.72	16
18	4.81	17
19	4.95	18
20	5.05	19
21	5.2	20

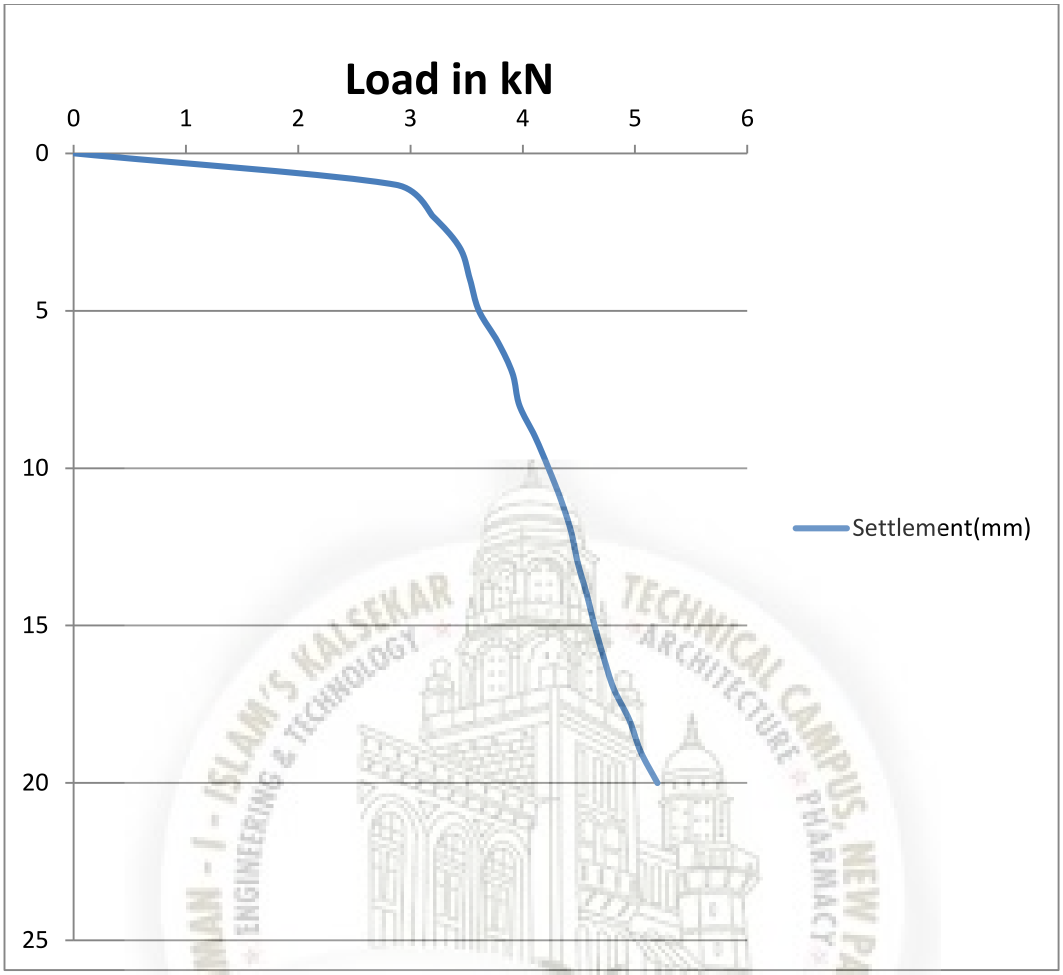


Fig 4.14 Load Vs Settlement of (2×2)-4D-400mm

Table 4.13Group of pile (3×3)-Spacing 2D-Length 300mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	1.75	1
3	2.25	2
4	2.73	3
5	2.94	4
6	3.22	5
7	3.52	6
8	3.8	7
9	3.97	8
10	4.15	9
11	4.27	10
12	4.6	11
13	4.8	12
14	5	13
15	5.12	14
16	5.28	15
17	5.66	16
18	5.98	17
19	6.27	18
20	6.66	19
21	6.86	20

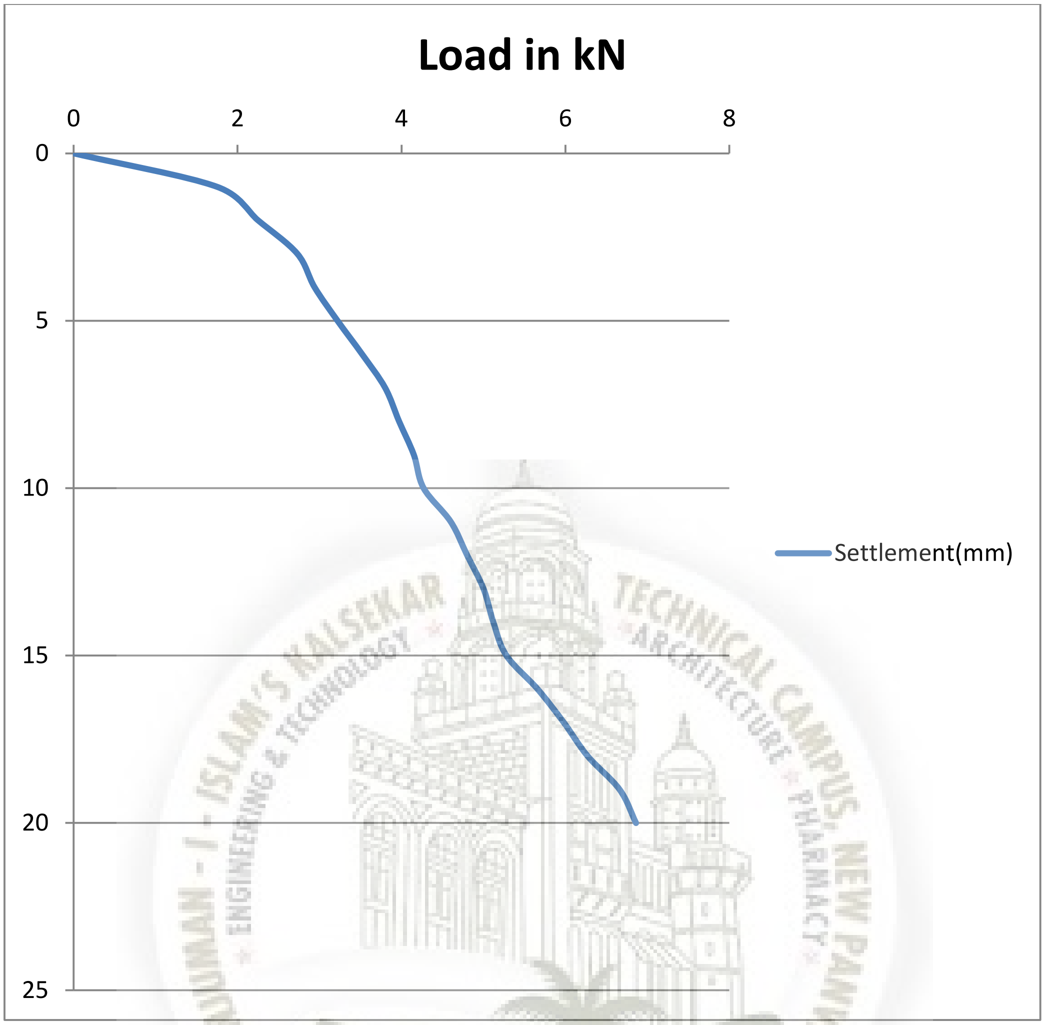


Fig 4.15 Load Vs Settlement of (3×3)-2D-300mm

Table 4.14Group of pile (3×3)-Spacing 3D-Length 300mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	4.5	1
3	4.95	2
4	5.44	3
5	5.9	4
6	6.66	5
7	7.12	6
8	7.39	7
9	7.8	8
10	8.13	9
11	8.4	10
12	9	11
13	9.4	12
14	9.84	13
15	10.2	14
16	10.57	15
17	10.84	16
18	11.05	17
19	11.3	18
20	11.51	19
21	11.89	20

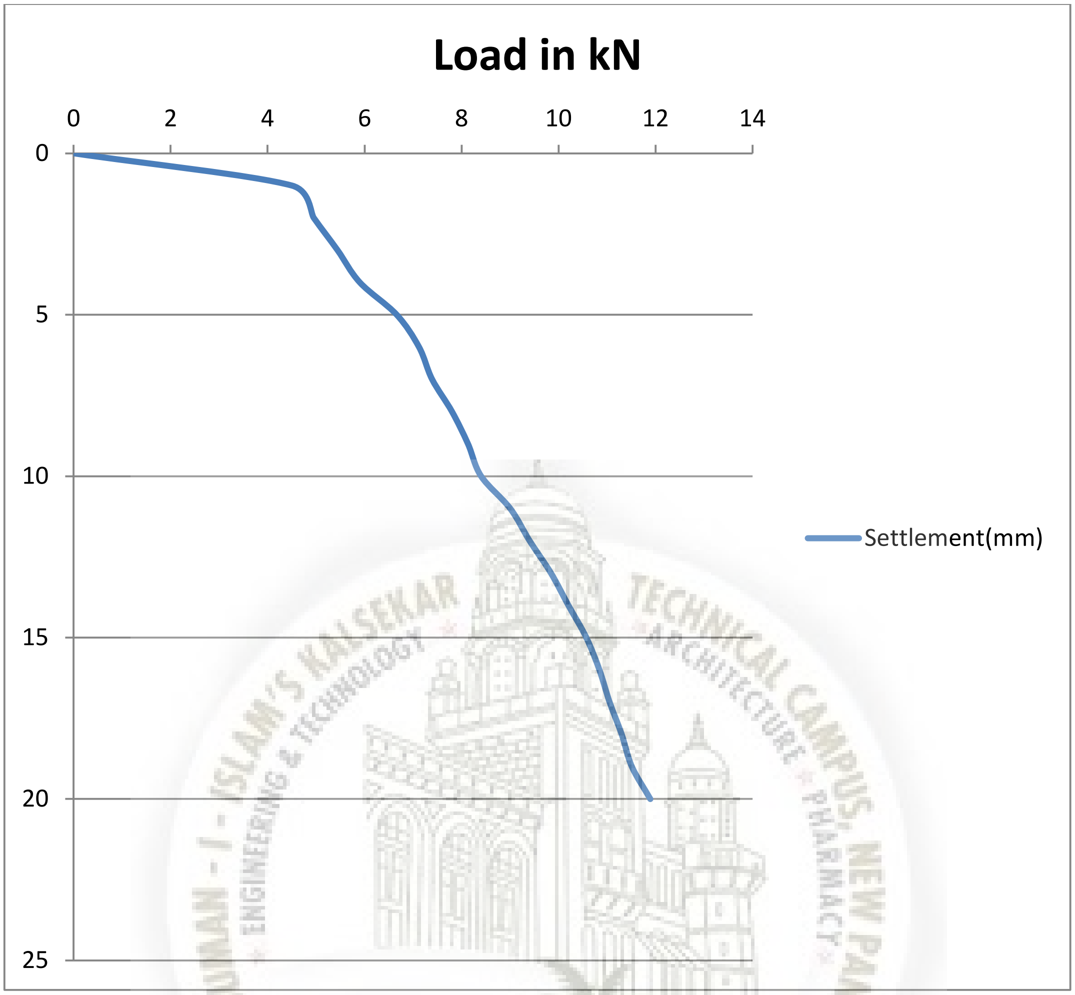


Fig 4.16 Load Vs Settlement of (3×3)-3D-300mm

Table 4.15Group of pile (3×3)-Spacing 4D-Length 300mm

Sr No.	Load (KN)	Settlement (mm)
1	0	0
2	4.27	1
3	4.77	2
4	5.14	3
5	5.28	4
6	5.43	5
7	5.64	6
8	5.82	7
9	5.94	8
10	6.18	9
11	6.3	10
12	6.8	11
13	7.1	12
14	7.25	13
15	7.45	14
16	7.6	15
17	7.75	16
18	7.95	17
19	8.15	18
20	8.33	19
21	8.43	20

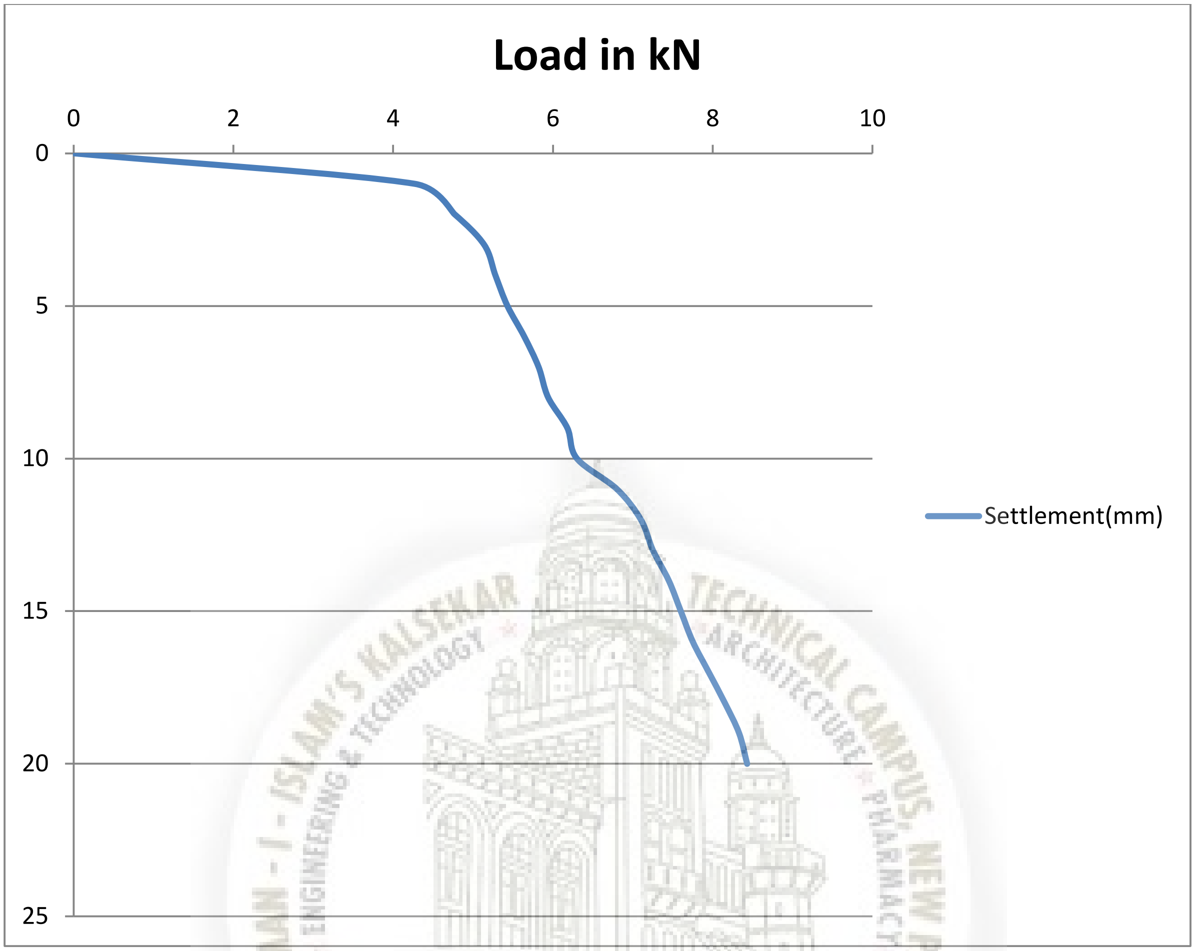


Fig 4.17 Load Vs Settlement of (3×3)-4D-300mm

4.7 Tension Test

This series of tests were meant for the assessment of the average unit shaft resistance of pile without any compressive load acting on the piles. The placement of piles and the pouring of sand were carried out in identical manner as in compression test. The pulling load was applied by screw jack arrangement in suitable increments. The corresponding values of load and deflection were noted from the proving ring and displacement dial gauges. After that with the help of given formulae we can easily find out the average unit shaft resistance of different piles.

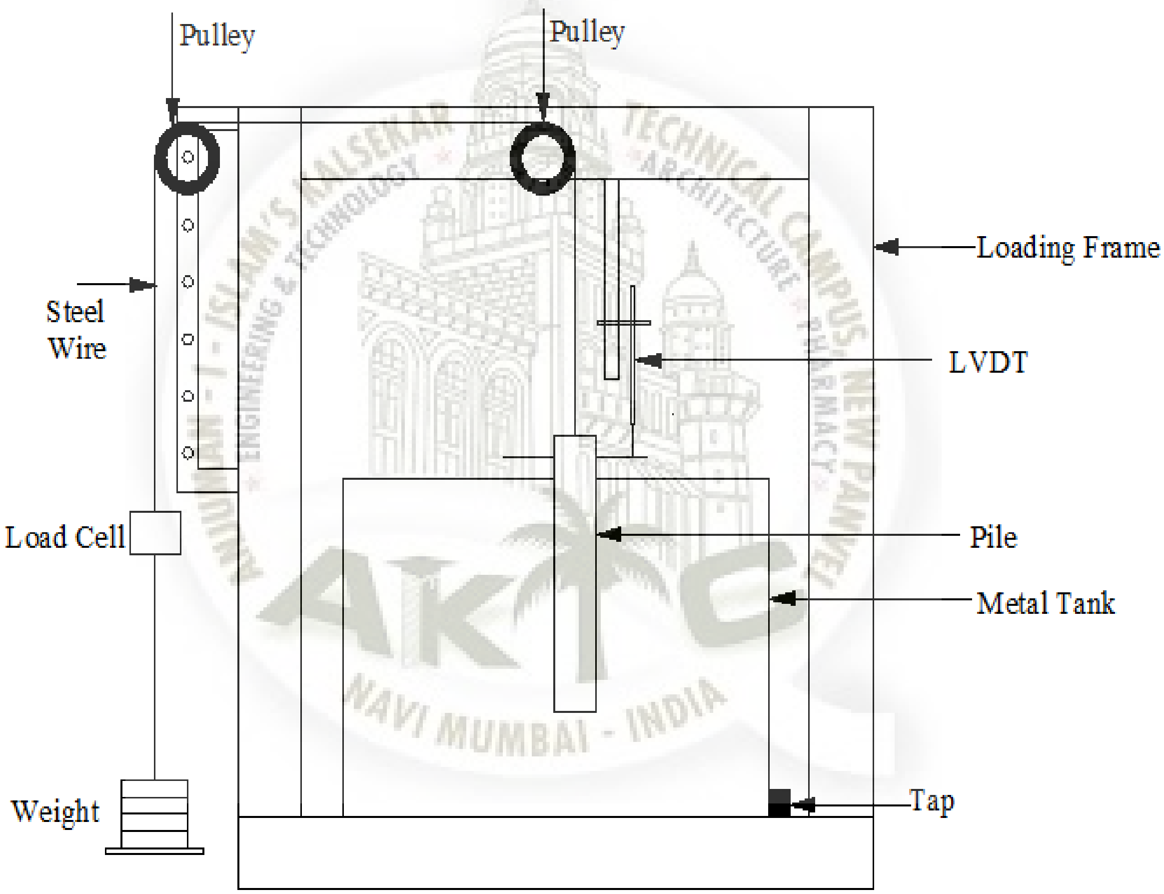


Fig 4.18 Tension test setup

Fig 4.19 Experimental setup of tension test

Table 4.16 Average unit shaft resistance at ultimate uplift

Diameter (m)	Length (m)	Load capacity in (kN)		Avg. unit shaft resistance (kPa)	
		Smooth	Rough	Smooth	Rough
0.04	0.6	0.15	0.18	2.38	2.86
0.05	0.6	0.17	0.2	2.16	2.54
0.06	0.6	0.2	0.23	2.12	2.44

FORMULA:

$f_a = \frac{Q}{A}$ Where Q= Net ultimate uplift load in kN

fa= Average unit shaft resistance kPa

A= Embedded pile surface area m2

For Example:-

f_a= 0.15/(3.14x0.04x0.6)

=2.38kPa

Chapter 5

Numerical analysis for pile

4.1 General

In the following sections, the Field Load Displacement curves 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

Table 5.1 Numerical analysis

Soil Model	Value used	Remark
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	Default value in software
Interface		
R inte	0.65	Default value in software
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	Default value in software
Cohesion (C ref)	100 kN/m^2	
Interface		
Strength reduction factor (R inte)	0.5	Default value in software
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)	0.05m	
Poisson's ratio (μ)	0.15	

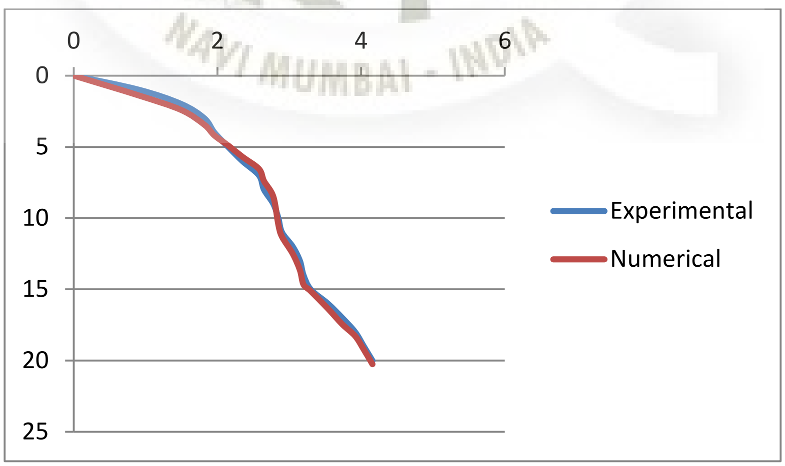


Fig 5.1 Experimental and Numerical load displacement curve for pile group (2×2)3D-200mm

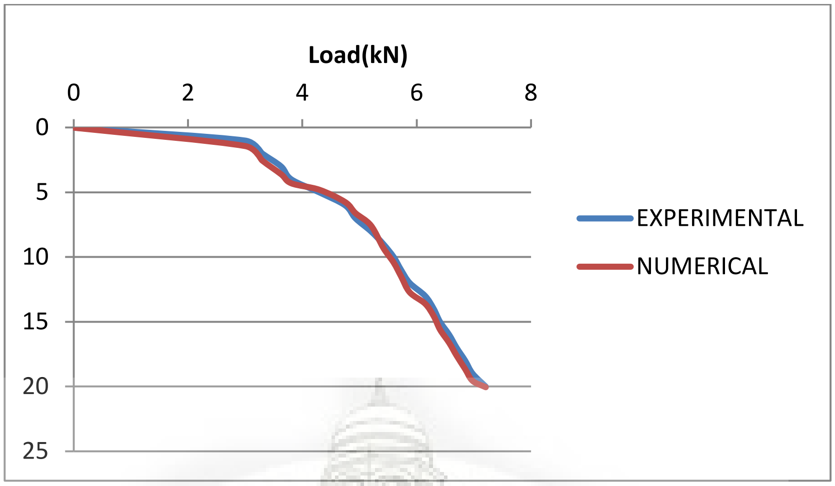


Fig 5.2 Experimental and Numerical load displacement curve for pile group (2×2)3D-300mm

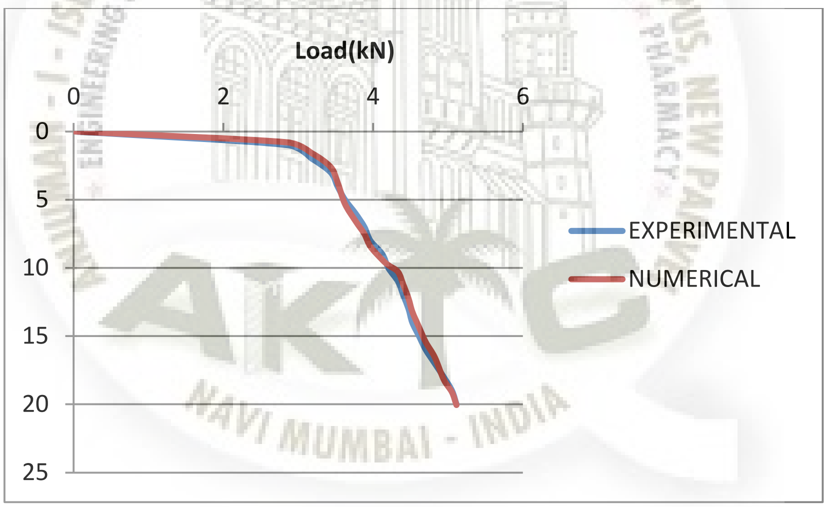


Fig 5.3 Experimental and Numerical load displacement curve for pile group (2×2)3D-400mm

Chapter 6

Results & Conclusion

6.1 General

Total eighteen numbers of tests were conducted and following results has been observed:-

Compression test on single pile in sand has been conducted and calculated load vs settlement curve for 25% settlement 0.32kN, for 50% 0.47kN, for 75% 0.62kN, for 100% 0.73kN

In group of pile test we have conducted an experiment with spacing 2D, 3D, 4D. in this we observed that as spacing increases bearing capacity increases upto 3D & beyond 3D load carrying capacity of pile group decreases.

We have conducted compression test on group of piles having length 200mm, 300mm and 400mm and we found that upto L=30D load carrying capacity of pile group increases and beyond 30D its constant or more or less same.

We have conducted tension test on single pile of smooth and rough surface and we found that average unit friction for smooth pile are 2.38, 2.16 & 2.12kPa & rough pile are 2.86, 2.54 & 2.44 kPa.

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