EFFECT OF RELATIVE DENSITY ON TORSIONAL STRENGTH OF STEEL PILE

A DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

Submitted by

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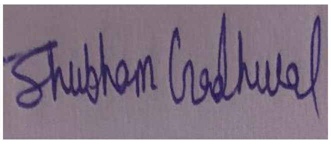
I, SHUBHAM GADHWAL, ROLL NO. 2K18/GTE/15, student of M.Tech (Geotechnical engineering), hereby declare that the project Dissertation titled "**EFFECT OF RELATIVE DENSITY ON TORSIONAL STRENGTH OF STEEL PILE** " which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.



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CERTIFICATE

I hereby certify that the Project Dissertation titled "**EFFECT OF RELATIVE DENSITY ON TORSIONAL STRENGTH OF PILE LOAD OF STEEL PILE**", which is submitted by Shubham Gadhwal, Roll no. 2K18/GTE/15 Civil Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best

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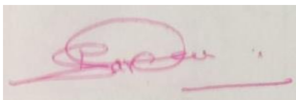

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SHUBHAM GADHWAL

ABSTRACT

The structure component behaviour before and after failing is needed for ensuring the safe design of structures. The structure failure is mostly governed by the subsequent causes of failure. If a structure collapse, it can be due to the failure of pile member. Sand plays a significant role in building a structure as one of its fundamental ingredients. Density parameter is also one of the significant term in case of sand also. The Relative density helps in determination of cohesion less soil both in compacted as well as in natural state and also predict the properties of the pile embedded in the soil. The relative density concept is important as it have direct relationship with the properties of soil such as California bearing ratio, friction angle, compressibility, permeability and also have great impact on the properties and strength of pile. The above characteristics represents its arbitrary character. Practically, density express how far the sand under investigation is dense. In coarse grained soil, determination of density helps in the compaction and for sandy soil, it determines the safe bearing capacity. Here a new in-situ field method for the measurement of density of sand by field calibration is developed. For the determination of void ratio and relative density, iteration is required with the variable heights of free fall. The Conclusion drawn from the experiment was that the density of sand follows direct relationship with the height of fall, sand density increases with the increase in number of fall. Thus the approach of varying height of fall of sand is used to determine the density of sand. River sand has been used for the test. With the increase in height of fall void ratio decreases and thus density increases, it was found that the given sand attains a maximum density and minimum void ratio when poured from a height of 1.5m and also it was observed that torsional strength of the pile increases with the increase in the relative density of the soil in which it is embedded. Hence effect of density on the torsional strength of pile is studied.

Table of Contents

LIST OF TABLES

TABLE OF FIGURE

CHAPTER-1 INTRODUCTION

1.1 General

The structure load is transferred through pile foundation which are usually slender and long and slender members of structure's components, they transfer the load of whole structure to the solid stratum through the unstable ground. In case when soil condition are poor, they resist the lateral forces by resisting the uplift forces. Depending on the requirement, they can be of different shapes and sizes. Concrete, steel or wood can also be utilised to make the piles. These piles are usually cast in situ in the ground, while the deep foundation follows the process of drilling and excavation.

The torsional shear test is utilized by geotechnical specialists to decide the shear modulus of soils at medium to elevated levels of strain. This is finished by fixing one finish of a strong or empty tube shaped soil example and applying a torsional weight on the opposite end of the tube.

This test can be performed related to the resounding segment test to decide the full shear modulus versus strain bend for a dirt. By understanding the whole shear modulus bend, specialists can decide the reaction of a dirt to different stacking conditions, for example, development of a structure (low strain), seismic tremor stacking (medium strain), or an atomic blast (high strain).

Torsion is defined as the twisting experienced on the application of torque. Torsion is expressed in either the Pascal, an SI unit for newton per square meter, or in pounds per square inch while torque is expressed in newton meters or foot-pound force.

The main things is that torsion calculation is needed, and also the shear force calculation, axial force or bending moment are also required alongside that can result dangerous for some elements. The moment's i.e bending moment and torsion act along altered axis. The twisting moment generates a twist in beam. Due to this, failure of beam can be observed leading to generation of shear stress. So proper consideration of structure design has to be taken into account.

The report utilized the same conventional method for carrying out pullout capacity. The eccentricity of load often leads to torque generation in loaded piles. The torsion effect on piles are limited but there are many analysis methods available.

These slender members resist compressive forces of the building Pile foundations resist (used to resist act non tension load) compressive force, superstructure by transferring these loads by the bearing ability to more profound rock or soil with high bearing limit, be that as it may, response from lateral structural load and the conduct of heaps under these forces are considerably lesser very much reported. The wind imposes overturning loads to jetty structures, tall chimneys, and transmission towers .These scenarios require the piles to counter attack the uplift forces, that weight seems to be larger than structure weight.

The failure load prediction by application of graphical and mathematical procedure allows us to determining the test results of load. In Geotechnical engineering, this prediction of load plays a vital role for the application of definite factor for safety for getting this pile safe load. Therefore it becomes significant for having exact ultimate load, which ultimately makes the investigation of behaviour of soil in predicting the accurate strain and deformations measurement easier.

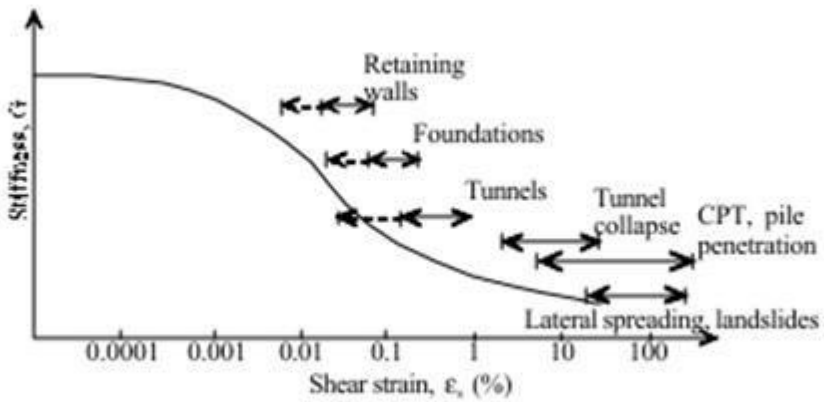

Figure 1 geo-technics strain ranges

Figure 1.2. It shows the strain ranges concerned with geotechnical processes

Explaining the ranges, when relevant behavior needs physical model and testing of elements, there should be equipment for the measurement of deformation to evaluate the strains before failure with the range of less than 0.02%.

If the failure zone is determined than through this, circular vertical pile uplift resistance can be found embedded in sand. The visualization of deformed shape is needed for obtaining the failure mechanism.

The soil weight in the zone of failure above base determines the pile's uplift capacity and also the foundation self-weight and frictional resistance. The parameters like embedded depth, pile diameter and density of sand are used to find pull out resistance by increasing their values.

The common things which are used in analytical modelling are axisymmetric packages along with

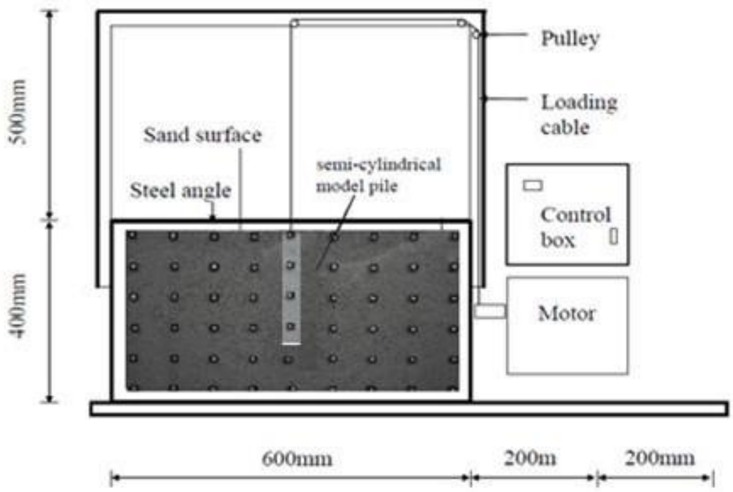

Figure 2 Procedure for failure mechanism

Plane strain. It requires a modified axisymmetric package such as in this below picture.

This failure of lab sample correlates the field failure of the specimen. If experimental path models of stress are good then it ensures representative field specimen. There will be no peak in the stress strain curve for the range in which the lab sample shows the plastic behavior along with no formation of failure plan

For such soils, failure zone is quite wide in the field. No definite plane of failure is observed along with large displacement values. These are not dangerous due to its impeding failure warning of displacement. Due to the failure character, as compared to the strength, design working stress is generally controlled by displacement field observations are useful for controlling construction, which implies the usage of low safety factors in the structure design. Moreover, safety factor results as failure function alongside test data reliability. There shows a peak in the stress strain graph when lab sample undergoes narrow zone failure.

Problem Statement

The transmission towers, guyed lattice towers, tension cables, tall buildings structures, commercial buildings and all types of bridges require the normal concrete piles for construction of deep foundation.

All these structures are repeatedly prone to wind forces that leads to greater pullout forces as well as torsional forces came into existence than the structure weight. Additionally wind forces also influences the water structures. While doing the torsional test, there are scenarios where great extent of damage is caused to the pile foundations. Therefore it becomes important to have thorough soil behavior investigation.

Objective and Aims:

- Determination of the relative density with varying height of fall
- Determination of torsional load of the pile by ex-situ method
- Evaluation of torsional strength of pile with different parameters.

Scope of the study:

The thesis includes numerical as well as experimental work. The model testing is used for carrying out the analysis. The mechanism of failure would be observed by this analysis which includes the embedment of pile at the box center. There are two tests that would be carried out failure mechanism test based on circular modeled steel pile embedded in the center of the box test and failure mechanism test based on semicircle concrete pile embedded near glass side of box test. Failure mechanism tests for circle concrete piles are conducted to study the

Behavior of failure mechanism around the model pile subjected to uplift based on the different slenderness ratio. On the other hand, failure mechanism test for semi-circle concrete piles are conducted to compare influence of geometric factors on the failure mechanism of piles which obtain in PLAXIS by cross section. Normal concrete piles with circle and semi-circle shapes with diameter.

CHAPTER-2 LITERATURE REVIEW

2.1 General

This chapter deals with the various research works conducted in the field of bearing capacities of foundation. The literature review gives us a thorough scope of advantages and disadvantages of the methods used for the determination of various parameters related to the soil foundation.

Mahiyar and Patel examined the limited component investigation of an edge molded balance under whimsical stac

king. The horizontal displacement was prevented by projection of one vertical side of footing and the confinement of soil. The eccentric ratio of width will determine the footing depth projection. He performed the experiment with a mild steel specimen of the footing. At right angles this footing specimen was given shape of an angle. Footing projection term was given to this procedure. The angle between the two plates was at 90 degree. Numerous eccentricity was considered for the application of point load. He has taken100mm as the footing width. For a particular projection of footing depth, number of trials have been performed for the changed values of eccentric ratio.The cohesion value was taken as 1Kn/m2 and 27 degree was the value of internal friction angle. Different values of elasticity modulus was considered for steel and sand. There was two main characteristic taken into consideration eccentric width ratio and footing projection depth. The greater reduction in displacement can be achieved at load end by implying the use of vertical projection of footing. The above phenomena is independent of internal friction angle and footing material in case of non-cohesive soil. The internal friction angle showed direct relationship with bearing capacity. The results showed that the specimen experiences displacement or tilt much less than the footing model with same loading value.

(consoli, 2007), He conducted the Plate load tests on reinforced fibre sand and normal sand. Different values of relative density was taken and compacted. Polypropylene fibres was added to the reinforced fibre sand along with the some dry weight. Observance was that the addition of fibre in the sand greatly influenced the load displacement pattern of soil with changed failure kinematics. It was determined that highly densed fibre reinforced sand shows the best behaviour, and at almost zero deformation, load-settlement behaviour shows much change. The sand with comparative low densities, need much settlements to account for the change in pattern. The log graph of relative density versus settlement was plotted to get the required settlement of the observed divergence. The conclusion was that strength improvement was seen when sand was reinforced with polypropylene fibre with the technique of dilation suppression. This method also results in shear strength and confining pressure improvement.

K. Kimi Bose1, The vertical model piles and batter piles were used in the experiment which were embedded in the sand along with the subjection of pull out pressure in a (1m x 1m x 1m)specimen tank. Model piles steel piles and having different shapes, length and diameters. Sand from the river was taken with the values of the max and min void ratio of 0.81 and 0.54, it was the medium for foundation with 2.67 value of specific gravity and coefficient of uniformity as 3.53.The Investigation include the pile characteristics such as diameter, length, inclination of pile, shape and characteristics of surface. It was observed that increased length diameter proportion leads to increase in pull out capacity. As diameter size increases the increase in pullout capacity was also observed. It also follows the direct relationship with angle of batter, simulatenous increase and decrease can be seen. Smooth piles seems insignificant in resisting the the pull out pressure than the piles with sand coated. Piles with constant volume and different shape, more resistant is observed by circular pipe than the rectangular or square ones. Comparison was made with the different values observed for pullout capacity and also comparison was done for theories available related to them.

Francesco Basile, High rise structures are a key factors in regeneration and the present urban strategies. When the construction of these tall structure starts, there grows many problems related to design and geotechnical one, one of them is the pile assessment problem. The transfer of torsion to a pile because of the wind forces eccentricities has been a major concern. The research work focuses developing numerical analysis method on the non-linear single piles response and pile group response subjected to torsion load. The pgroupn computer program is used for the proposed analysis. The comparison was made between published case histories, analytical solutions, alternative numerical technique and centrifugal models test.

Jaswant Singh This research paper presented the granular anchor pile behaviour of the force deformation along with the investigation of force displacement behaviour of pile group subjected to pull out load in non-cohesive soil. This paper aimed at determination of pull out capacity, with varyinf effect of diameter, length of embedment, spacing and diameter of system of Granular anchor pile also with iterations in S/D ratio and L/D ratio with the different soil types. This system of pile resist the uplift pressure more effectively and is quite innovative and latest. The pull out capacity of the granular anchor pile varies linearly with the increment change in L/D ratio, as compared to 2 gap 4 granular anchor pile arrangement in the two soil type considered. It was also observed that single granular pile system with 100mm and 50 mm dia shows the pullout capacity increase rate wato a 40% L/D ratio increment. Therefore single granular anchor pile arrangement shows much greater advantages with length to diameter ratios of 7 and 10.50. The loose soil having relative density lower shows less increase in pull out capacity as compared to that of dense soil which have relative density quite high. The characteristics of soil and granular anchor pile diameter follows a linear relationship with pull out capacity. The observance in case of four and two gap systems was that there was an increment in the pull out capacity in both type of soil.

Meyerhof (1953) in his research work, a method to transform a footing with loading type eccentrical into a footing with central loading with width reduction. Due to the non-linearity of contact pressure at the ultimate load contact pressure follows a reduction mainly at heel and toe, in case of eccentric load subjected upon shallow foundation. The proposed width was given by an equation. Following this this idea, the limit of a constant establishment is dictated expecting that heap demonstrations midway alongside the viable contact width. In this manner, for a ceaseless establishment with vertical stacking, they rely on soil thickness and attachment unit. These shape factors for a consistent establishment equivalent unity. A definitive burden for every unit length of the establishment Qu can be determined He inferred normal bearing limit of balance diminishes, around illustratively, with an expansion in unusualness.

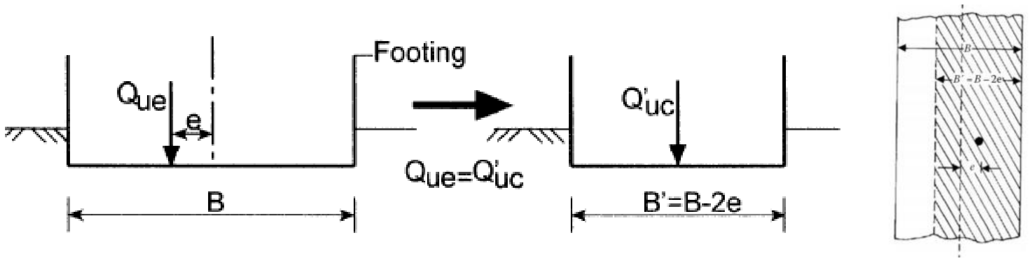

Figure 3 concept of effective width

Ingra and Baecher studied the methods of terzaghi and applied its principle of superimposition in determination of ultimate bearing capacity. The methods consist of both theory and numerical parts. The researchers have given a lot of theory examples along with their proof by laboratory experiments by prototype and model footing specimens. The predictions of bearing capacity had some ambiguity which were investigated through inferred analysing of existing experimental data statistically along with inclusion of uncertainty effects in properties of soil. The Load offset with proportionate to the dimension of footing is called the factor of eccentricity function. This eccentricity factor is independent by the influence of size of foundation and internal friction angle. The procedure to extend this superposition technique of terzaghi to determine the footings bearing capacity on sand was taken into account. Statistical technique includes the data of length of footing and ratio of width which are analysed.In this case ratio of width taken were one and six. The non-cohesive showed much changes according to the bearing capacity theories. Significant difference was seen by altering the values of factor of bearing capacity. Predicting of this ambiguity was more when angle of friction was identified.

Taiebat and Carter (2002) The footings with shape circular and strip under moment and the vertical load conditions were analysed by finite element method. Homogenous soil was made the foundation of this footing and with conditions of un-drained one. The values of elasticity modulus and shear strength at the condition of un-drained were determined. 0.5 was the value of poisson's ratio. The values of elasticity modulus shows that the soil was less stiff as compared to the foundation. Therefore the foundation are considered to be significantly rigid or non flexive. Spacing between soil and footing cannot resist adequate tension forces.

The modelling of interfaces of foundation was done by no tension layer which was comparatively thin. The tensile forces at these interfaces are governed by soil foundation separation. Any shear stress is sustain after the process of separation of these interfaces. Following the partition no shear pressure can be supported in the interface components. Be that as it may, correlation of the disappointment envelopes got in this investigation shows that the compelling width technique, ordinarily utilized in the examination of establishments exposed to flighty stacking, gives great approximations to the breakdown loads for these issues.

Review of Summary

After studying the research paper, it is concluded with reference to the bearing limit of shallow foundation less work is done to for the estimation of of the ultimate bearing capacity of square foundation with the eccentric load .The majority of these investigations depend on hypothetical examinations and numerical investigations upheld by not many number of model tests. The thesis aimed at

CHAPTER-3 BRIEF THEORY AND CONCEPT

3.1 General

When sand is poured from the varying height, its density increases with increase in height of fall. Also its void ratio keeps on decreasing with increase in height of fall, this is because of the fact that as the height of fall increases, the soil align itself into more compacted state. This variation with height of fall is used for the determination of γ_{dmax} i.e. maximum density (density in most compacted state), γ_{dmin} i.e. minimum density (density in loosest state). Corresponding values of e_{max} i.e. void ratio in loosest state, e_{min} i.e. void ratio in densest state.

It is significantly important to get the soil behaviour characteristics before building the structure foundation. The important aspect of building a strong foundation is the soil or sand and also its relative density. It is defined as sand weight which is needed to occupy the specified unit volume container. By this relative density concept, we can check the compactness of a soil in artificial or in natural state. Different properties of soil such as friction angle, compressibility, California bearing ratio and permeability are function of the relative density. It implies this sandy deposit's character which is arbitrary. Practically it is used for the investigation of denseness. It is helpful in safe bearing capacity determination for cohesion-less soil and coarse grained soil compaction. Relative density determination plays a major role in investigation of site for the purpose of landfilling. There is no direct method for determining the profile of density then indirect methods comes into play as in situ tests.

The bearing capacity determination requires need of relying on these in-situ test method of soil in its natural state meant for slope stability analysis purpose, pressure determination required for the settlement calculation for underground structures design. This implies this test is quality controlled and the pavement construction and embankment requires compaction.

3.2. SIGNIFICANCE OF DENSITY:-

1. The unit weight of a soil offer its strength, compressibility, and permeability. Higher unit weights propose higher strengths and lower compressibility and permeability. These properties are commonly worn in geotechnical engineering design. However, different soils by the same unit weights have different strengths, compressibility, and permeability. Hence, the unit weight, while useful and often used to approximation these properties, is not directly transferrable across soil types.
2. It is strictly used for cohesion less soil and not for cohesive soils as maximum void ratio is not defined for the same.
3. Relative density determination cannot be achieved by direct method so it requires only indirect method utilising the methods such penetration of cone test. The correlation of validation influences these indirect result.
4. Different properties of soil such as compressibility, resistance of penetration, California bearing ratio, friction angle, and permeability shows the linear relationship with relative density of soil. So it gives a compactness measure of artificial as well as natural soil.

3.3 TORSION:

The torsional shear test is utilized by geotechnical specialists to decide the shear modulus of soils at medium to elevated levels of strain. This is finished by fixing one finish of a strong or empty tube shaped soil example and applying a torsional weight on the opposite end of the tube.

This test can be performed related to the resounding segment test to decide the full shear modulus versus strain bend for a dirt. By understanding the whole shear modulus bend, specialists can decide the reaction of a dirt to different stacking conditions, for example, development of a structure (low strain), seismic tremor stacking (medium strain), or an atomic blast (high strain).

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The main things is that torsion calculation is needed, and also the shear force calculation, axial force or bending moment are also required alongside that can result dangerous for some elements. The moment's i.e bending moment and torsion act along altered axis. The twisting moment generates a twist in beam. Due to this, failure of beam can be observed leading to generation of shear stress. So proper consideration of structure design has to be taken into account.

The report utilized the same conventional method for carrying out pullout capacity. The eccentricity of load often leads to torque generation in loaded piles. The torsion effect on piles are limited but there are many analysis methods available.

3.4 Materials used in the experiment:

Sand

River sand is used in the experimental program. The cleaning and washing of sand was done after taken out from the site. 300 micron and 710 micron sieves were used for sieving and drying purpose for analysis of data. For excluding the dampness effect, sand in dry condition is considered.

Table 1 Sand properties

Parameter	Data
Specific gravity (*G*)	2.63
Effective particle size (D_{10})	0.32mm
particle size (D_{30})	0.42mm
particle size (D_{60})	0.46 mm
Uniformity Coefficient Cu	1.43
Coefficient of Curvature (C_c)	1.18
Maximum unit weight	15.08 kN/m^3
Minimum unit weight	13.01 kN/m^3

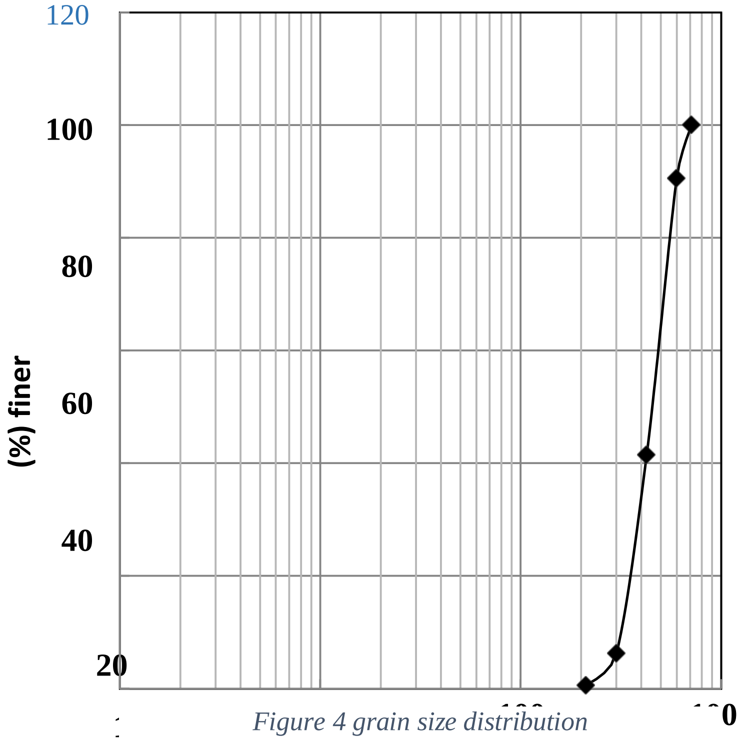

Figure 4 grain size distribution

3.5 Determination of Torsional capacity of piles in sand

The structures are subjected to uplift forces when the construction is done under water. For submerged platforms, mooring systems, tall chimneys, and transmission line towers are influenced greatly by the pressure of wave, or wind, and impact of ship and experiences overturning moments. The foundation of structure take these load as overturning moments in the compression form or as pull-out load. An arrangement of double pulley were made and pull-out loads are applied in axial direction. Chamber length movement by application of inverted pulley for aligning the wire rope and batter pile. Bolting is done for attaching the wire rope. This rope of steel was taken first through a rearranged pulley and afterward throughout the subsequent pulley. Figure shows the wire end comprises the dead loads put in the pan. Pile and Wire rope alignment is used to fix the first pulley position along with pile inclination. The dial gauges were mounted by the steel plate adjacent to the chamber width. The position of these dial gauges are done at equal distant from the axis of pile. The application of dead load is done in gradual increments stages. When dial gauges show stability, readings are taken and noted down. The applied pull out load was taken from the dial gauges in form of average displacement values as the pile axial displacement.

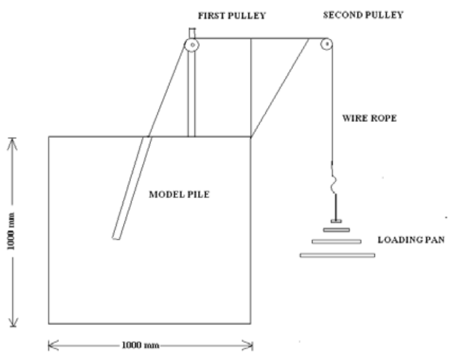

Figure 5 setup and model piles

CHAPTER-4 RESULTS AND DISCUSSION

4.1 General

The method for in-situ determination of density and Preliminary requirements for the same are elaborated below-

4.2 Sand tank

The sand tank was made from brick masonry with dimensions 0.71m X 0.1m X 2.1m, the inner walls of the tank were plastered properly.

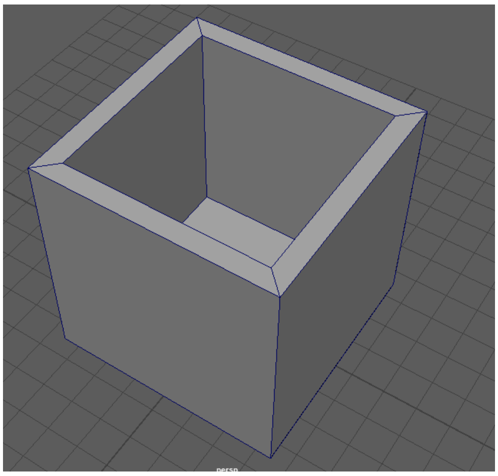

Figure 6 Diagrammatic sand tank

Figure 7 Actual sand tank

These dimensions were chosen so that a sufficient amount of sand can be poured into the tank, moreover we have to test the pull out capacity of pile, effect of lateral pressure on piles, torsion, compression on piles etc. Hence piles of varying length, diameter can be tested for a wide range of compression, tension, torsion etc. If a tank of smaller dimensions is to be used in determination of relative density, it will put a constraints on the range of testing for the later. That’s why a sand tank was made from brick masonry with dimensions 0.71m X .71m X 2.1m.

Figure 8 Sand tank with box

4.3 SAND POURING BOX:-

A box of dimensions 0.7m X 0.7m X 0.2m is constructed with wood in order to pour the sand into the sand tank from the desired height as shown below.

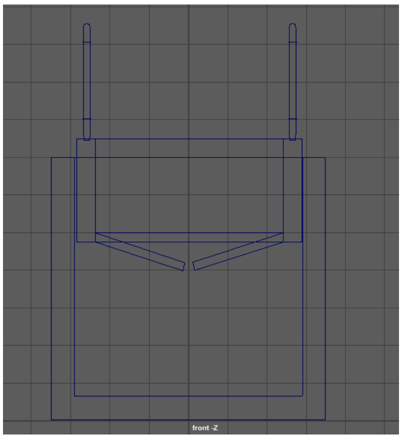

Figure 9 Lowering of box

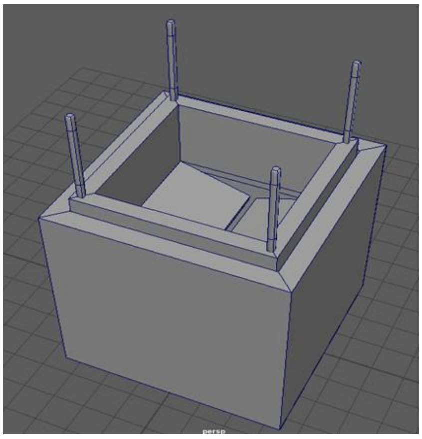

Figure 10 Lowering of box into tank

Figure 11 Actual box

Figure 12 Actual box 1

4.4. ARRANGEMENT FOR LOWERING OF BOX:-

A pulley is attached on the top the tank in order to lower the box fill with the sand into the tank, so as to pour the sand from desired height.

Pulley arrangement is attached to top of tank as shown in the figure below. Two pulleys were attached so that pullout test can also be performed.

Figure 13 Pulley arrangement

Procedure steps:

1. Take certain amount of soil in the bucket.

2. Note down the height of the sand in the bucket and also weigh it.

3. Transfer the sand from bucket to the box.

4. Gradually lower down the box in the masonry pit with help of ropes.
5. Lower the box in such a way that the box is at 15cm from the base of the pit.
6. Detach the base gradually to transfer the sand in the box to the masonry pit.
7. Repeat the above steps to fill the pit completely.
8. After complete filling of tank, remove the sand completely from the tank and repeat the procedure for pouring from 30cm, 45cm…………..165cm. Note down the weight of sand in tank in each trial.
9. Height of fall will be varied till the weight of sand into the tank become constant.
10. Calculate corresponding unit weight in each trail.
11. Calculate the void ratio corresponding to unit weight in each trial.
12. Calculate density as shown in calculation
13. After complete filling of sand tank a pile of diameter 3.18cm is inserted in to the sand and lateral load has been applied by the apparatus and the load is increased till failure occurred
14. Hence angle and maximum load for the failure is noted

4.5 CALCULATIONS:-

- Volume of tank = length X width X height

  = 0.7m X 0.7m X 2.1m

  = $1.02m^3$
- Calculation of unit weight i.e. **γ** in each trial

Unit weight i.e. γ (kN/m^3) = $\frac{\textbf{weight of sand in box(in kg) X 9.8 m/sec2}}{\textbf{volume of tank(m3) X 1000}}$

Therefore for first trial, γ **(kN/m^3)** = $\frac{\mathbf{1578.21}\ \boldsymbol{X}\ \mathbf{9.8}}{\mathbf{1.02}\ \boldsymbol{X}\ \mathbf{1000}}$

= 15.17 KN/m^3

- Similarly calculate unit weight for each trial.
- Calculation of void ratio i.e. **e** in each trial

Void ratio i.e. e = $\frac{\textbf{specific gravity of sand (G) X unit weight of water } (\gamma w)}{\textbf{unit weight of sand } (\gamma)} - 1$

Therefore for first trial, e = $\frac{2.67 \text{ X } 10}{15.17} - 1$

= 0.760

- Calculate the values of unit weight and void ratio for each trial in the same way as calculated for first trial.
- Plot the graphs showing variation of unit weight, weight of sand in tank, void ratio, and relative density etc. with respect to change in height of pouring.

Figure 14 Crack occurred due to torsion

3.5. RESULTS:

Table 2 Observation and calculation of each trial

S.No	HEIGHT OF POURING (CM)	WEIGHT OF SAND IN TANK (KG)	WEIGHT OF SAND IN TANK / VOLUME OF TANK (Kg/M^3)	UNIT WEIGHT (KN/M^3)	TORSION ANGLE	VOID RATIO(e)	TORSION LOAD (KN)	RELATIVE DENSITY(%)
1	15	1578.21	1547.26	15.17	0.03501	.760	7.176	0
2	30	1650.00	1617.64	15.86	0.0990	.680	7.576	30
3	45	1682.14	1649.15	16.17	.101	.651	8.116	41
4	60	1713.21	1631.63	16.47	.1108	.621	8.61	53
5	75	1738.93	1704.83	16.72	.2010	.596	9.216	62
6	90	1768.50	1733.82	17.08	.507	.563	9.71	70
7	105	1787.14	1752.09	17.18	.98	.554	10.31	78
8	120	1808.57	1773.10	17.39	1.01	.535	10.81	85
9	135	1827.86	1792.01	17.57	1.91	.519	10.99	91
10	150	1848.21	1811.97	17.77	2.07	.502	11	98
11	165	1855.71	1819.32	17.84	2.16	.496	11.16	100

Figure no.

3.6. VARIATIONS GRAPHS:-

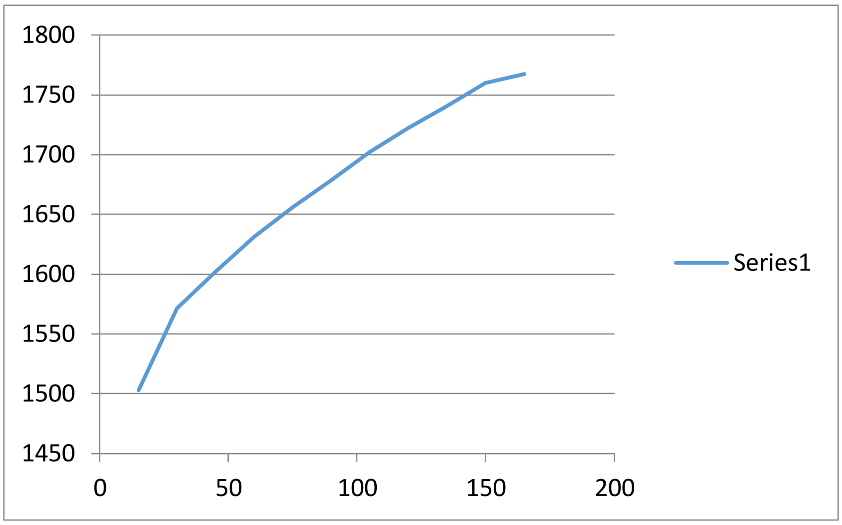

Figure 15 Weight of sand in tank versus height of fall

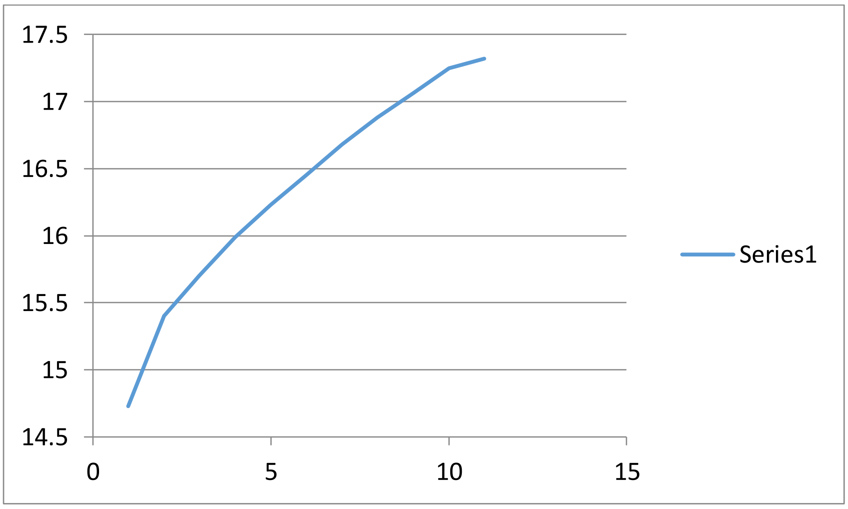

Figure 16 Density in tank versus height of fall

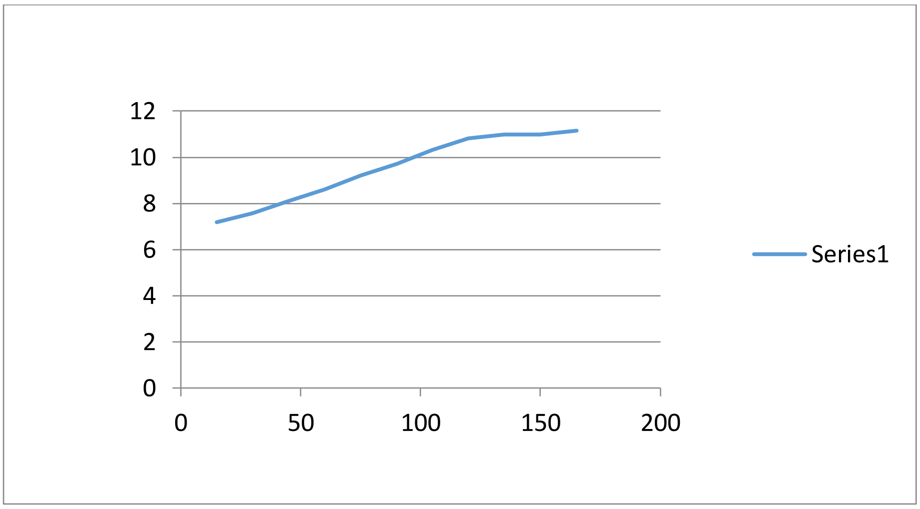

Figure 17 Torsion angle on sand in tank versus height of fall

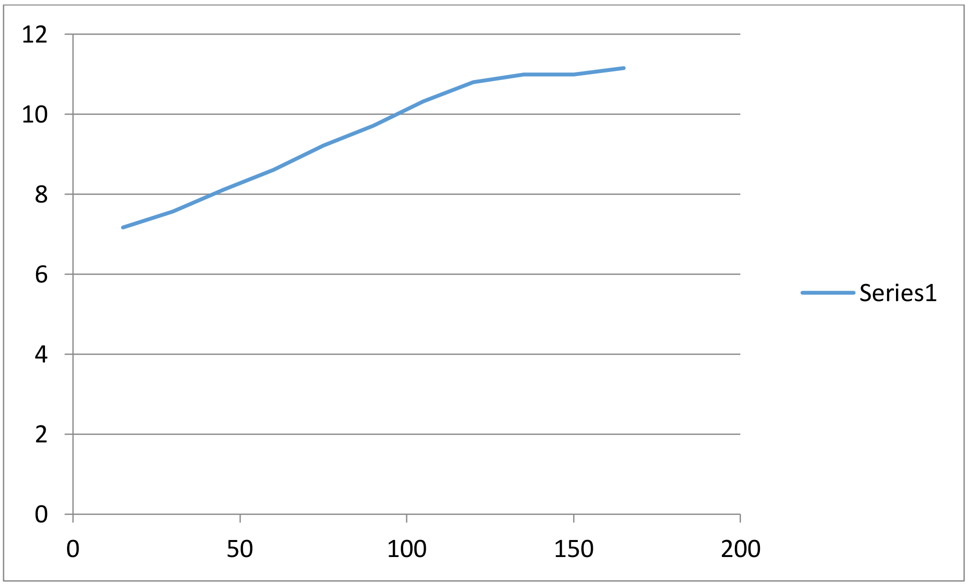

Figure 18 Torsion load on sand in tank vs height of fall

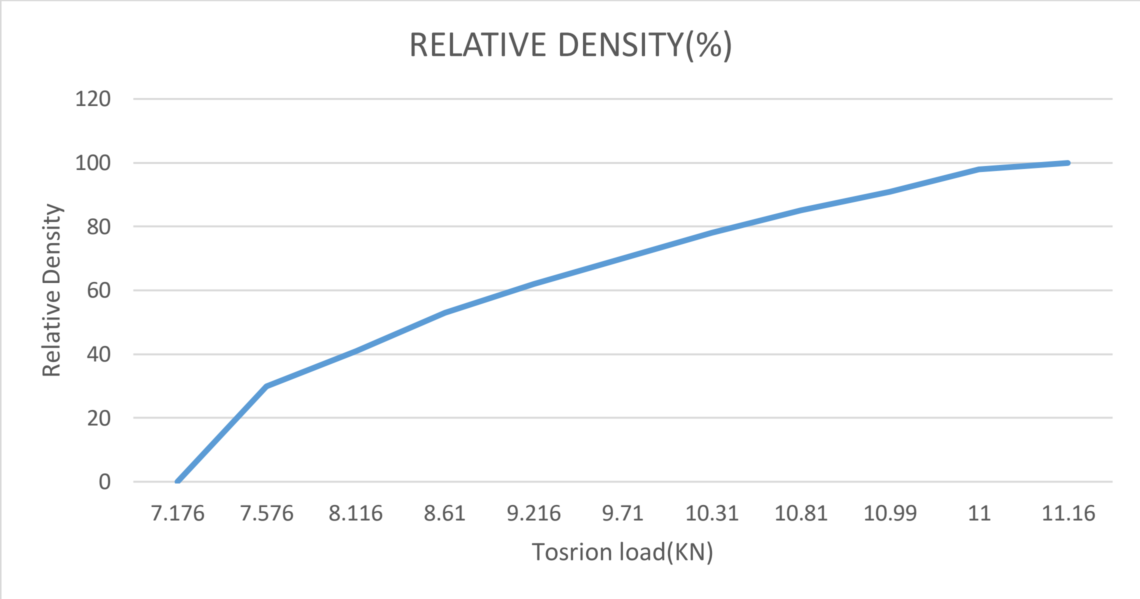

Figure 20 Relative density versus Torsion load

MATERIAL TEST

Pile

The tensile test is used to determining the yield strength, tensile strength, reduction of area and ductility for samples of steel piles. The different sections piles used in this experiment have the

same stress-strain curve shown in figure (4).

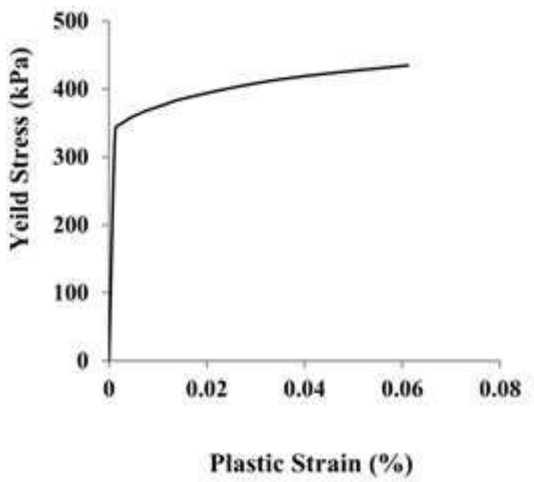

Figure 19 Stress-strain curve of steel pile

Abacus software is used to achieve a nonlinear analysis of the problem and check the results. Element (B32), 3-node quadratic beam in space was used to represent the pile element. Also, the soil was assumed an isotropic elastic-plastic continuum with surface failure limited by the Mohr-Coulomb principle and represented by a 20-node brick element (C3D20R). Penalty interface between the pile and soil was assumed. The fixed boundary condition is used for all side and bottom of soil to reduce the model size [12]. Table (1) show the prosperities of material obtained by tests, and table (2) shows the different sections used in the study.

Table The real prosperities of material obtained by tests

Material	**Sand**	**Clay**	**Steel**
Density kg/m^3	1700	1800	7850
Young Modulus MPa	15	20	200000
Poisson's Ratio	0.3	0.3	0.2
Friction angle degree	32	0	-
Cohesion MPa	0	20	-

Table The sections used in the study

Sample	**Section Name**	**Dimension mm**	**Thickness mm**
CS	Circular Solid section	D=12.5	------
CH	Hollow circular section	D=12.5	1
RS	Rectangular Solid section	12.5*12.5	------
RH	Rectangular hollow section	12.5*12.5	1

RESULT AND DISCUSSION

Torsion-Twist Angle

Torsion twist angle is measured from the experimental and checks with numerical by using ABAQUS software. The results are shown in figures (5) and (6). The convergence variation

Between experimental and analytical is very good. Figure (5) shows the relationship between applied torsions and twist angle when pile embedded in clay soil and figure (6) shows the relationship between applied torsions and twist angle when pile embedded in sand soil. From these figures, it is shown that the torsion is very sensitive to the section's mass distribution (polar moment of inertia) and type of soil.

For solid and hollow sections the torsion increases from 32% to 38% from a circular section to rectangular section when the pile is embedded in clay soil and from 20 % to 26% from a circular section to rectangular section when the pile is embedded in sand soil. Clay soil has a cohesive property which makes it more resistive for torsion loads when compared with sandy soil. When soil changes from clay to sand the torsion resistive is decreased from 210 kN.m to 27 kN.m for solid rectangular section, for solid circular section decreased from 134 kN.m to 21 kN.m, for hollow rectangular section decreased from 86 kN.m to 19 kN.m and for hollow circular section decreased from 54 kN.m to 15 kN.m. This decrease shows that the hollow sections are more sensitive than solid sections for soil type.

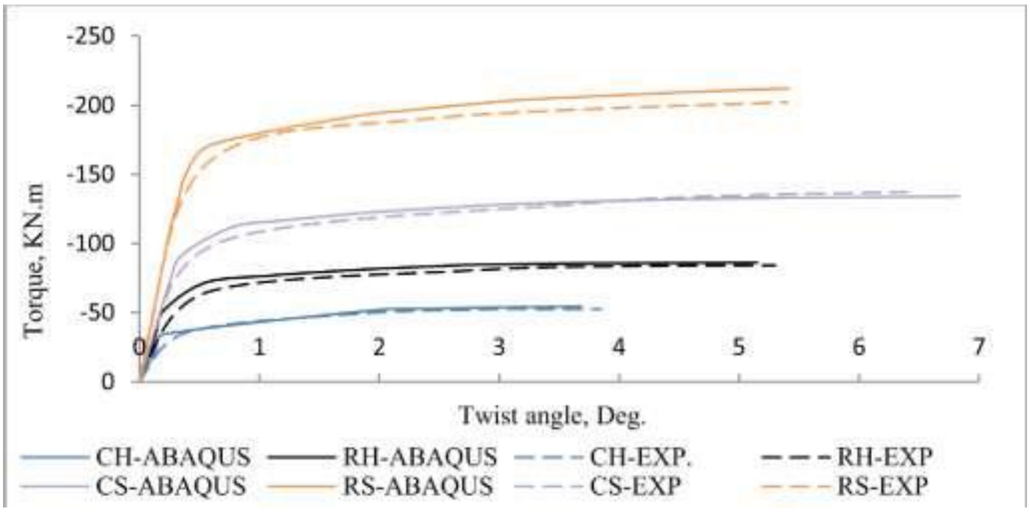

Figure 5 Torque –Twist angle for pile embedded in clay soil

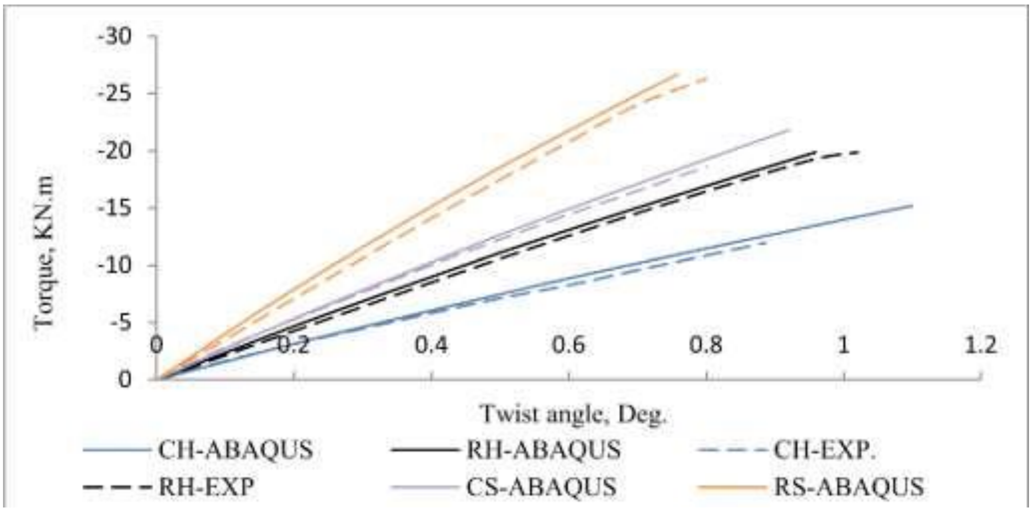

Figure 6 Torque –Twist angle for pile embedded in sand soil

6.1. Twist angle and Displacement along pile length

The value of twist angle and displacement along the pile length is shown in from figures (7) to (10). These values are obtained by a numerical solution with ABAQUS software. It is observed from these figures that the twist angle and displacement are affected by the type of soil and section properties. When soil changes from clay to sand the twist angle are decreased from 1.1 deg. to 0.73 deg. for solid rectangular section, for solid circular section decreased from 1.36

deg. to 0.62 deg, for hollow rectangular section increased from 0.72 deg. to 0.76 deg and for hollow circular section increased from 0.57 deg. to 0.84 deg. The Displacement for sand soil beginning with the same value (0.32 mm) at pile head but for clay soil the displacement effected by section type, 2.2 mm for solid rectangular section, 1.7 mm for the solid circular section, 1.13 mm for the hollow rectangular section and 0.83 mm for the hollow circular section. The twist angle becomes zero at depth 10 cm to 12 cm for clay whereas in the sandy soil it becomes 12m to 18 cm. This depth depends on section type, while the displacement becomes zero at depth 4cm to 6 cm for clay and 6 to 10 cm for sand (this called critical pile depth).

It can be seen that clay soils have the ability to resist high torsion load, this lead to an increase in the twist angle and displacement reverse sand soils where failure under very low torsion loads.

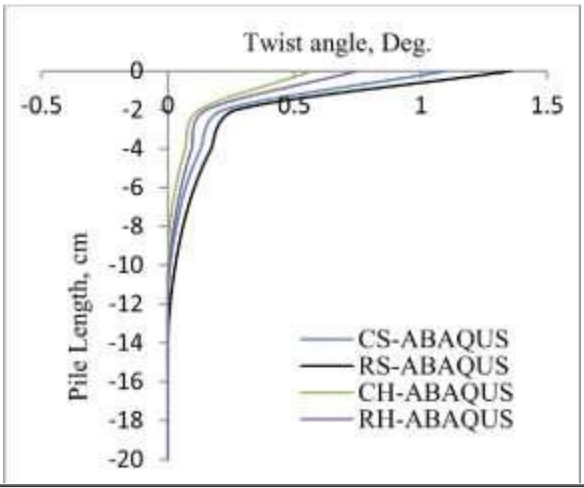

Figure 7 Twist angle along the pile length for pile embedded in clay soil

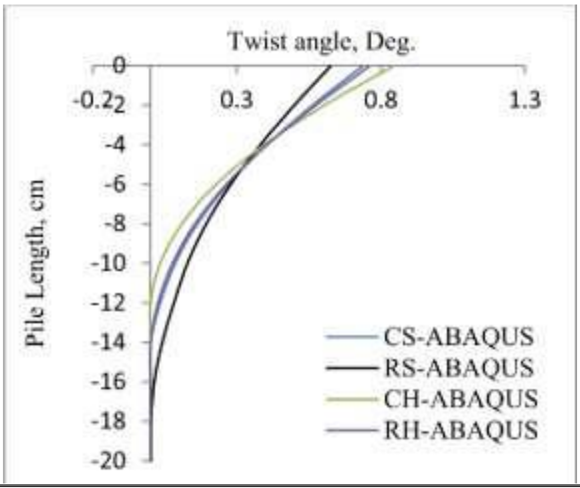

Figure 8 Twist angle along the pile length for pile embedded in Sand soil

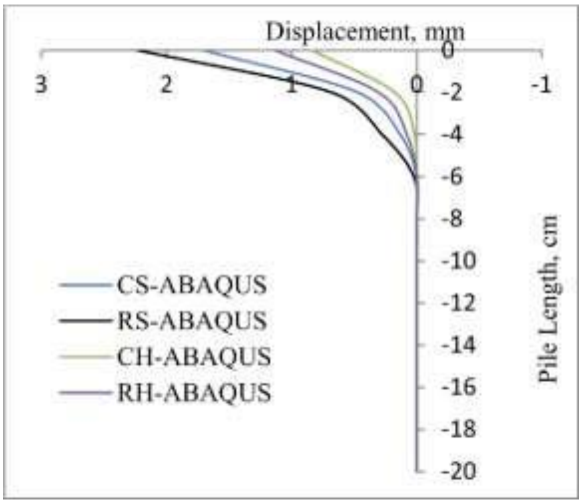

Figure 9 Displacement along the pile length for pile embedded in clay soil

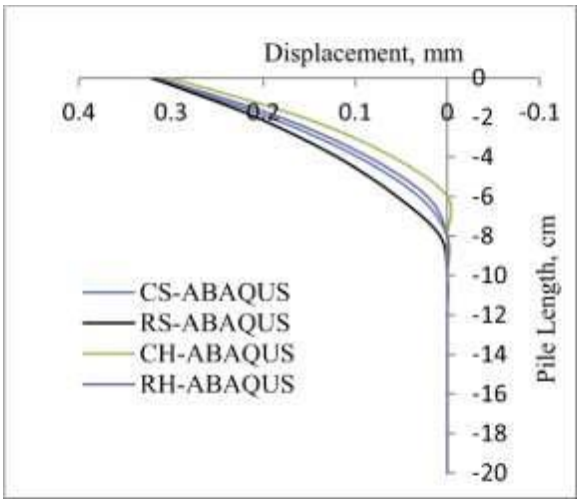

Figure 10 Displacement along the pile length for pile embedded in sand soil

6.2. Shear force and bending moment along pile length

The effect of torsion on the shear force and bending moment along the pile length is presented through the numerical solution. Figures (11) and (12) show the shear force curve for pile embedded in clay and sand soil respectively. For sand soil the shear force start with same value

(24 kN) at pile head and begins to change according to pile stiffness and soil properties but when pile embedded in clay soil the shear force beginning with different values depending on pile stiffness and soil properties from pile head, the shear force is, 50 Kn for solid rectangular section, 38 kN for solid circular section, 25 kN for hollow rectangular section and 19 kN for hollow circular section.. Shear force becomes zero from 10 cm to 14 cm for clay soil and 12 to 16 cm for sandy soil. Figure (13) and (14) show the variation of bending moment along pile length, the change in soil from clay to sand decrease bending moment from 210 kN.m to 27 kN.m for solid rectangular section, for solid circular section decreased from 134 kN.m to 21 kN.m, for hollow rectangular section increased from 86 kN.m to 19 kN.m and for hollow circular section increased from 54 kN.m to 15 kN.m. The fixity length (constant moment along pile length) is about 6cm to 10 cm for clay and sandy soil.

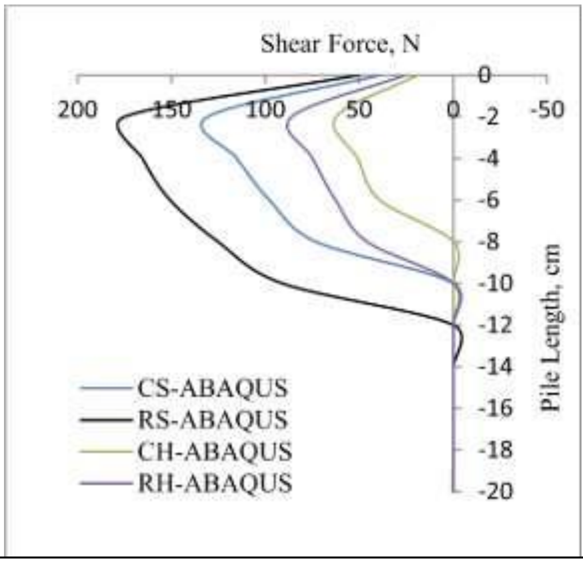

Figure 11 The shear force along pile length for pile embedded in clay soil

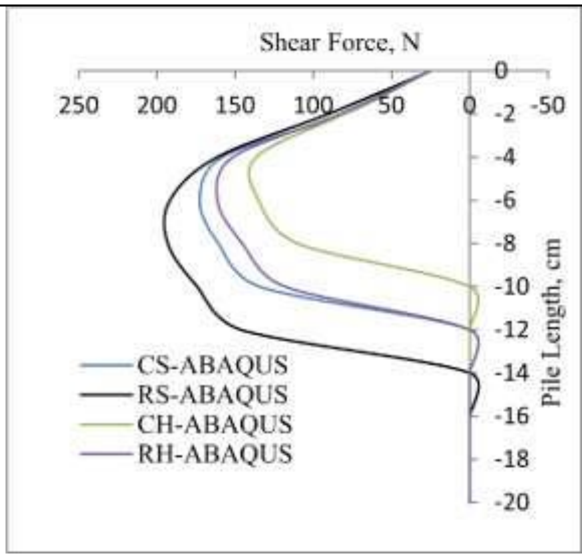

Figure 12 The shear force along pile length for pile embedded in sand soil

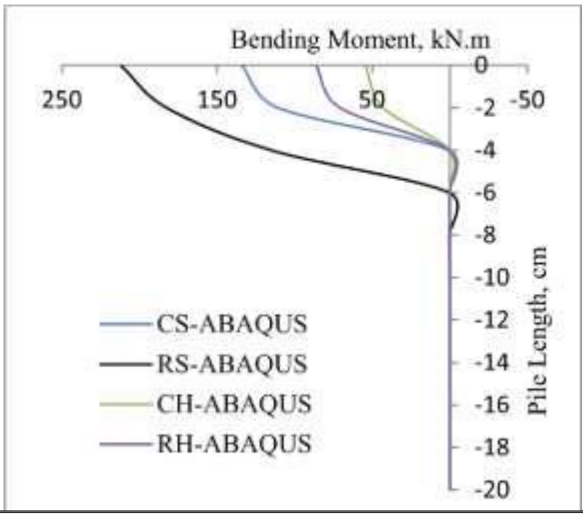

Figure 13 Bending moment along pile length for pile embedded in clay soil

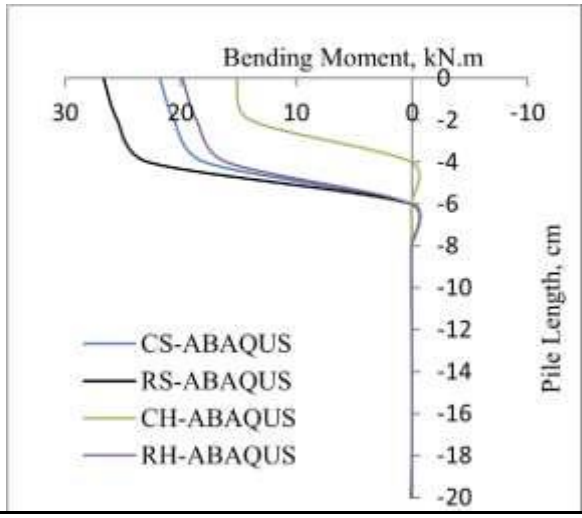

Figure 14 Bending moment along pile length for pile embedded in sand soil

PARAMETRIC STUDY

Effect of pile thickness and soil type on rotation along the pile:

The effect of pile thickness and soil type on rotation along pile is shown in figures (15) and (16), from these figures as the thickness of pile increases this leads to increase in applied torsion and this will reflect with increased rotation but when the pile embedded in the clay soil the increased is more visible than rotation when pile embedded in sand soil.

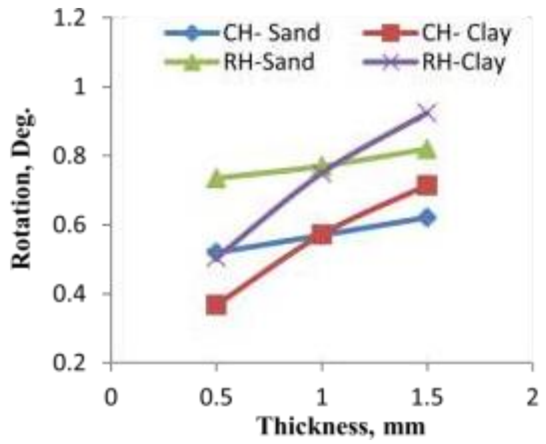

Figure 15 Effect of pile thickness on rotation along the pile

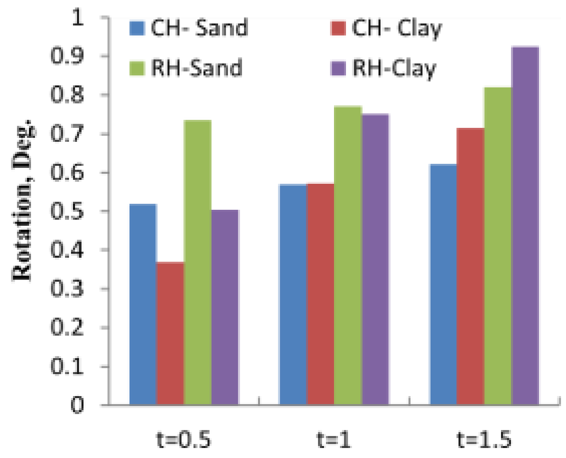

Figure 16 Effect of soil type on rotation along the pile

Effect of pile thickness and soil type on displacement along the pile

The displacement along pile length is affected by pile thickness and type of soil, this influence is shown in figures (17) and (18). The clay and sandy soils are more sensitive for the change in pile thickness. From figure (17) the increase in pile thickness leads to an increase in the displacement due to the increase in the applied torsion.

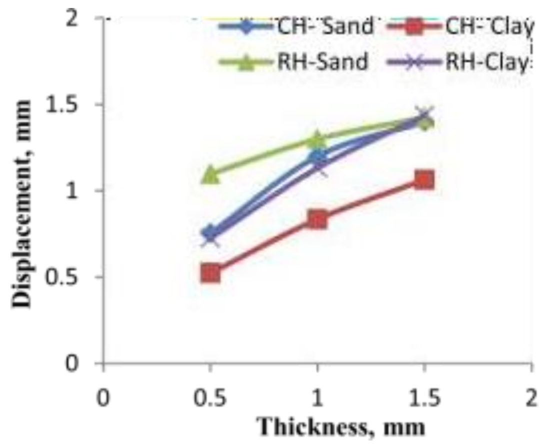

Figure 17 Effect of pile thickness on displacement along the pile

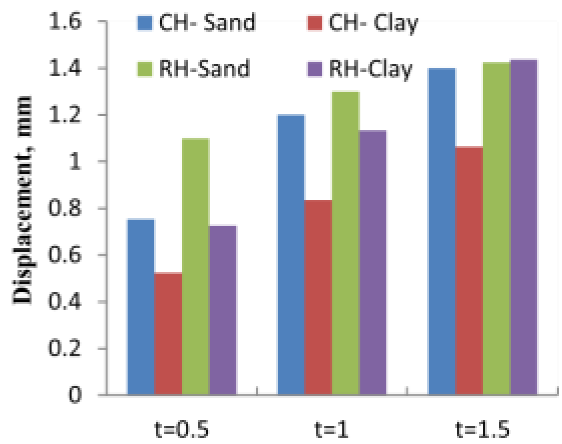

Figure 18 Effect of soil type on displacement along the pile

7.1. Effect of pile thickness and soil type on shear force along the pile

Figures (19) and (20) show the effect of pile thickness and soil type on shear force along the pile. The increase in pile thickness leads to increase in shear force along the pile; also the increase in displacement of that pile embedded into clay is greater than in displacement as compare with pile embedded in sand soil

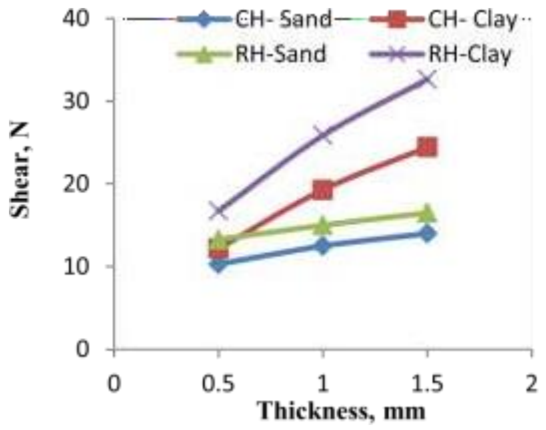

Figure 19 Effect of pile thickness on shear force along the pile

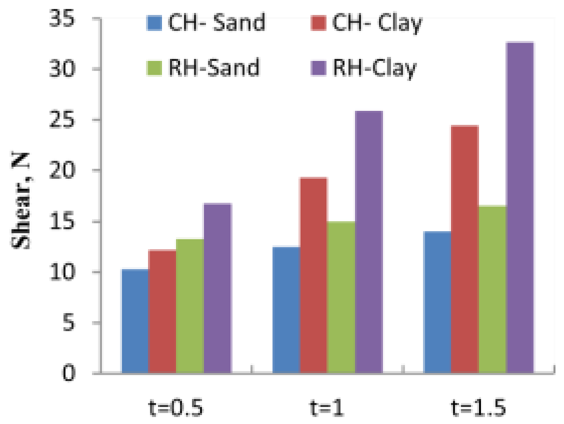

Figure 20 Effect of soil type on shear force along the pile

7.2. Effect of pile thickness and soil type on bending moment along the pile

The pile capacity is increased with increase in pile thickness, for clay soil the increase is very high as compared with the sandy soil, this increase can be seen in figures (21) and (22).

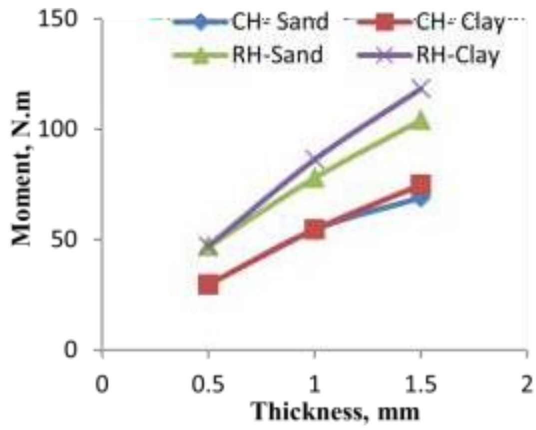

Figure 21 Effect of pile thickness on bending moment along the pile

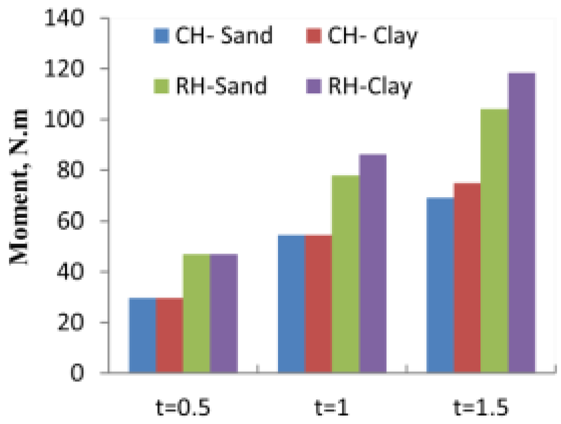

Figure 22 Effect of soil type on bending moment along the pile

CHAPTER-5 CONCLUSION

It can be concluded as stated in the above search on the following:

- Torsion load depends on two factors these are section's mass distribution and type of soil.
- The clay soil is more sensitive to torsion load than other sand soil.
- When soil change from sand to clay the torsion strength is increased 23% for solid rectangular section, 28% for the solid circular section, 12% for the hollow rectangular section and 18% for the hollow circular section.
- The solid sections are capable of bearing torsion load than other hollow sections for a circular and rectangular section.
- Rectangular sections have the capability to bearing torsion load more than circular sections.
- The twist angle becomes zero about 0.5 to 0.6 pile length for pile embedded in clay soil and from 0.6 to 0.8 pile length for pile embedded in sand.
- The critical length for pile under pure torsion is 0.2 to 0.3 pile length for pile embedded in clay soil and from 0.3 to 0.5 pile length for pile embedded in sand.
- Shear force is starting with the same value for pile embedded in soil and begins to change according to pile stiffness and soil properties.
- Shear force becomes zero from 0.5 to 0.8 pile length for pile embedded in clay and sandy soil.
- The fixity length for pile under pure torsion is about 0.3 to 0.5 pile length for pile embedded in clay and sandy soil.
- The change in the pile thickness from 0.5 mm to 1 mm, leads to an increase in the bending moment about 70% for clay and sandy soil. Shear force increases about 20% for sandy soil

and 55% for clay soil. Displacement increases by 45% for clay and sandy soil. The rotation increases 10% for sandy soil and 50% for clay soil.

- When changing the pile thickness from 1 mm to 1.5 mm, the bending moment increases about (25 to 30) % for clay and sandy soil. Shear force increased by about 10% for sandy soil and 25% for clay soil. Displacement increases by about 10% for sandy soil and 25% for clay soil. The rotation increases 10% for sandy soil and 20% for clay soil.

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