"A STUDY ON PULLOUT BEHAVIOUR OF INCLINED COMPOSITE PILES"

A
PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

MAY, 2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"A study on Pull-out Behaviour of Inclined composite Piles"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Saurabh Rawat**. This work has not been submitted elsewhere for the reward of any another degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"A study on Pull-out Behaviour of Inclined composite Piles"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Nikhilesh Thakur (151604), Dikshant Agarwal (151667) and Hetain Sahi (151608)** during a period from August, 2018 to May, 2019 under the supervision of **Dr. Saurabh Rawat,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: …………………

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ABSTRACT

Understanding the pile behaviour and predicting the capacity of piles under uplift loading are important topics in foundation design. The study revealed that the behaviour of single piles under uplift loading depends mainly on both the pile embedment depth-to-diameter ratio and the soil properties.

This research proposes an innovative solution for slope stabilization with less environmental footprint: AKARPILES. This study focused on stabilizing surficial slope failure. The idea of AKARPILES was generated from the tree roots system in slope stabilization. After the piles are installed in the slope and intercepting the slip plane, grout was pumped in and discharged through holes on the piles. The grout then filled the pores in the soil with random flow within the slip zone. A series of tests were conducted on the single-pile reinforced slope under vertical slope crest loading condition considering different slope gradients and nail designs.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
PMMA	Poly Methyl Methacrylate
PVC	Polyvinyl chloride
BCS	Black Cotton Soil
C	Cohesion
E	Modulus of Elasticity

CHAPTER 1
INTRODUCTION

1.1. General

Pile foundations is frequently used for transmitting the big structure loads to deeper layers of earth, if the subsurface soil is of less strength. Tension piles is a type of pile foundation which is used to resist uplift loads which might otherwise cause it to be extracted from ground. Uplift forces may develop as a result of, seismic activity, overturning moments or hydrostatic pressure. The Pile foundations are also used to support the heavy structures and act in dual role of carrying the applied loads to deeper, strong layers & also of reinforcing the soil. The lateral loads resistance of pile foundations is critically important in the designing of structures under loading from earthquakes, soil movement, waves etc.

1.2. Need of Study

Transmission towers, big chimneys, under-water platforms, jetting structures, masts & similar type of constructions on pile foundations are usually subjected to overturning moment due to winds, seismic activities, wave actions or ship impacts. In such structures, the generating overturning moments are transferred to the piles which supporting the structure in the form of the compression in the some piles and pull out on the others. The Foundations of some of the structures like the transmission line towers, mooring systems for ocean surfaces or underwater platforms, big and tall chimneys, jetty structures etc. are subjected to the uplift loadings. The Grillage footings, rock anchors, concrete steel caged piles & concrete cylindrical caged piles arc extensively used in such cases depending on the in-situ conditions. Caged or uncaged cylindrical piles are generally used where caving. High water table. Or other causes make it difficult to & costly for constructing the other types of foundation. The Large inclined uplift forces act on foundations of retaining walls, anchors, bridge abutments, piers & offshore structures. Which are generally supported on piles.

However, when a foundation is required to carry large inclined loads, inclined piles along with the vertical piles are used.

a) Degraded concrete pile *b) Corroded steel piles*

Fig. 1.1 Degradation of Conventional Piles

1.3. Design of Pile Foundation

Various hypotheses in regards to conduct of piles under the diverse loading situations have been grown as of late more than three decades. Design of pile foundation under compressive load is generally based on requirement which complete the collapse of pile group or of the supporting structures which should not occur under the most adverse and severe conditions & also that the displacement at working loads should not be excessive so as to impair the proper functioning of foundations or damage the superstructures. Thus for the structures in which displacement may or may not be critical, the design is of course governed by the ultimate resistance of pile or pile groups and allowable load is often the determined, by applying a suitable factor of safety (FOS) to the calculated load. Moreover uplift loads and forces may be exerted on piles due to swelling of surrounding soil. Hence, the studying of the behaviour of the piles under uplift forces as well as the parameters affecting the uplift capacity of the piles is one of the most critical and interesting areas of research in geotech engineering.

Uplift test results covered (Levacher and Sieffert 1984; McClelland 1974) on piles which were introduced by the various methods and indicated wide variety in the uplift capacity. It is demonstrated that the avg. proportion of extreme destroying obstruction of driven pile to extreme opposition of statically determined pile is around 0.5. The accessible explanatory strategies expect that the disappointment happens along the interface of pile and its encompassing soil. It has been altogether seen that the disappointment surface, its degree and the uplift obstruction of a pile are convoluted marvels' including factors like length, dia. of the pile, unpleasantness of pile surface, point of shearing opposition of the soil and the technique for establishment of the pile. Inc. utilization of the straight shafted piles to oppose and continue the uplift loads requires the precise evaluation of the uplift protection from accomplish more economy and more noteworthy security. Thus it's trusted that an increasingly summed up hypothetical way to deal with record for the various factors included would be progressively advantageous to this calling to comprehend the approaching pile-soil-uplift cooperation issues.

Most past investigations were implied toward the pole capacity of the piles exposed to the pivotal compressive burdens, while just a small amount of research was done on the pile reaction under the uplift loads. The net uplift capacity of piles Dec. with an Inc. in compressive loads.

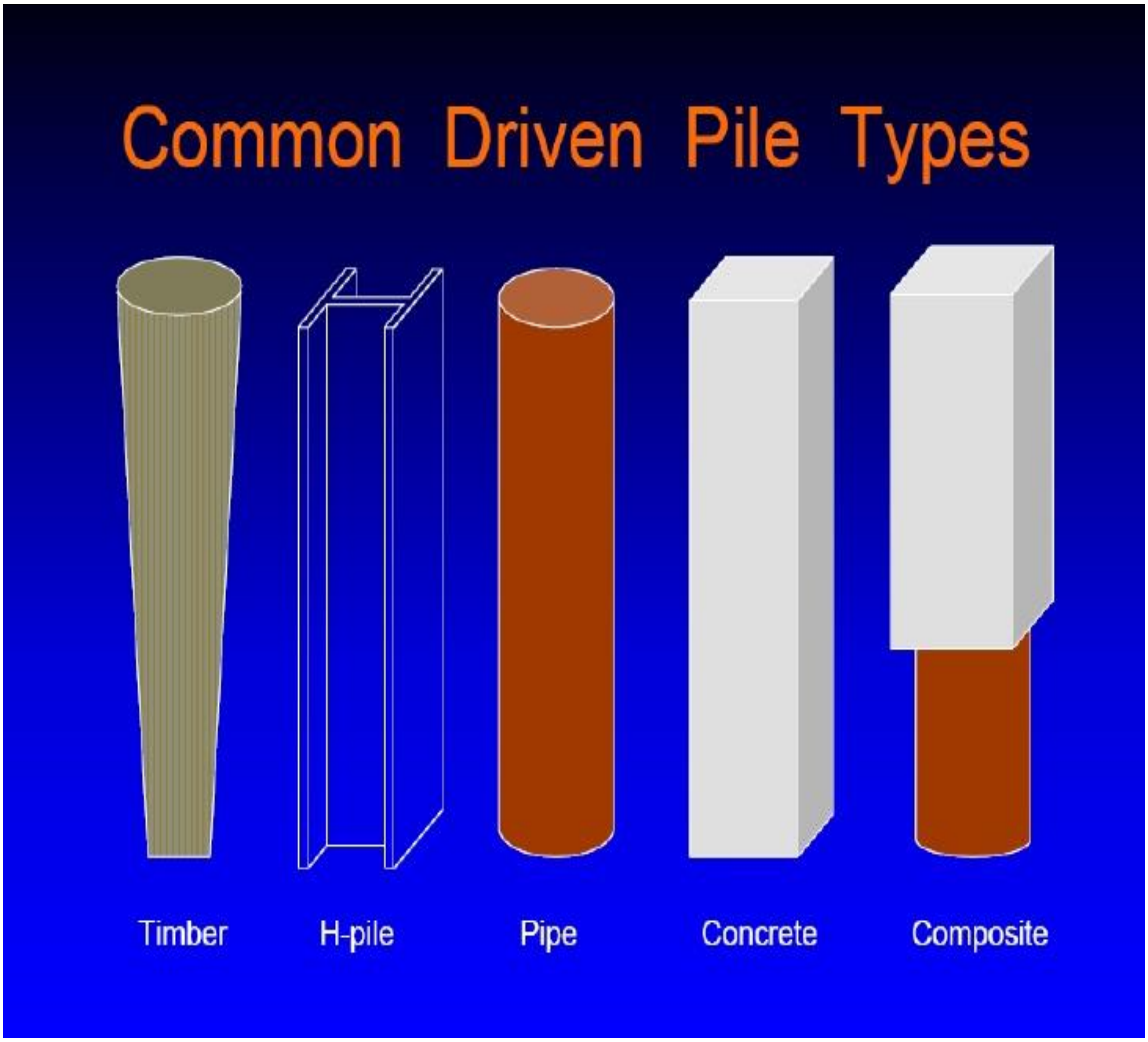


Fig. 1.2 Common Pile Driven Types

The unwavering quality of the hypotheses can be controlled by the examination of exploratory outcomes on model field piles with hypothetical forecasts. Full-scale field tests are very precise yet they are commonly costly and hard to perform on field. Without assets, little scale research facility model tests are led on the piles which are inserted in attachment less soil under controlled conditions that may fill the need somewhat. Legitimately led research facility tests with realizing parameters influences the soil to pile reaction under uplift loading. Would give data on subjective commitments of such parameter on extreme opposition of the piles. Likewise in the meantime, with expanding utilization of the piles to oppose and support the uplift loads requires precise appraisal of the uplift protection from accomplish economy and wellbeing. Consequently, it is sought after best that the present examination may prompt a superior comprehension of reaction of the single piles and pile bunches under unadulterated uplift loads.

1.4. Akarpile

The possibility of AKARPILES was thought by the tree establishes framework in slant adjustment. After the piles are introduced in the incline, blocking the slip plane and the grout was siphoned in and released through the openings of the piles. The grout was then filled by the pores in the soil with irregular stream inside the slip zone. With the ongoing populace development and additional fast improvement of society, late years have seen encounters from successive avalanches with a no. of real incline disappointments which cause harms and burdens to general society. Key component in the Akarpiles for incline adjustments, is the actuated root-designed pile to hold soil on the slants. Destinations of this paper are to: plan and examine the measurements and states of the Akapile and recognize the systems of the Akarpile for the slant adjustment technique.

The movements are resisted by mobilizing the shear strength of the soil along the failure surfaces and the weight of soil & pile. In the limiting equilibrium condition, the ultimate uplift capacity of the pile is attained. The net uplift capacity of piles Dec. with an Inc. in compressive loads. The Pile Driving Methods (Displacement Piles) are:-

1. Dropping weights
2. Explosion
3. Vibrations
4. Jackings
5. Jettings

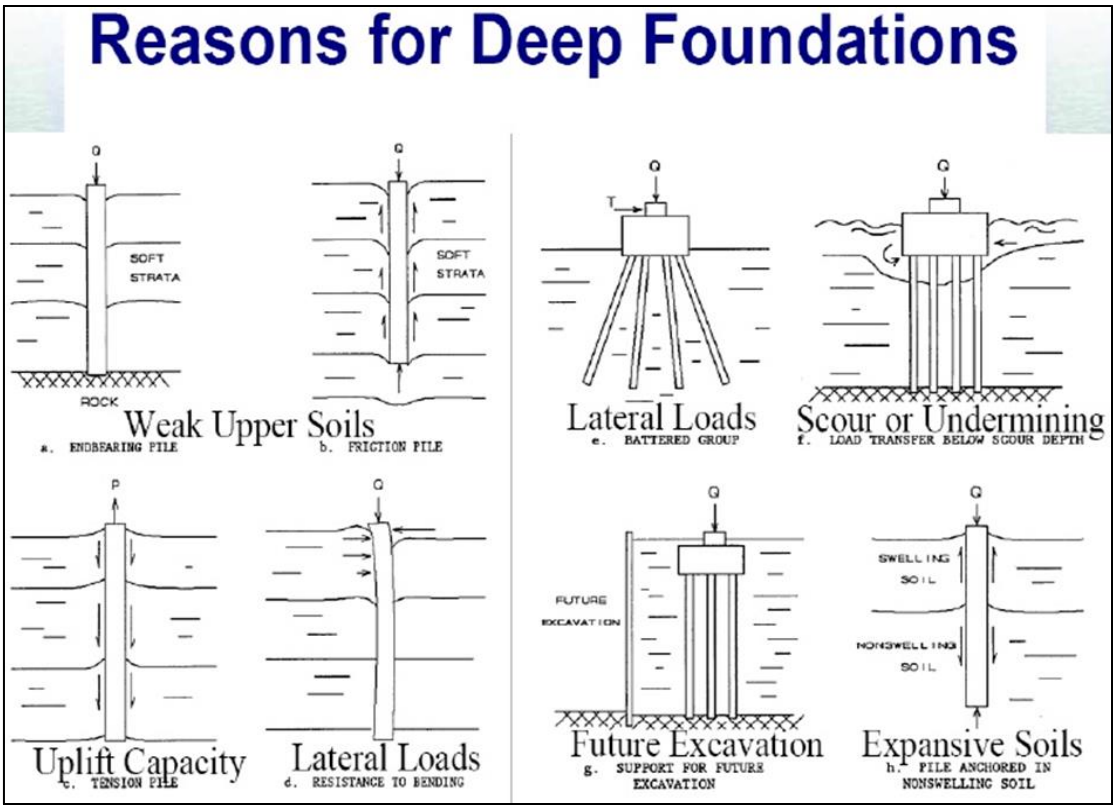


Fig. 1.3 Reasons for Deep Foundations

This ongoing examination depends on the uses of Akarpile in the surficial slant adjustment technique. Which alludes to the shallow incline disappointment with a depth of under 4 meters. The aftereffects of this paper gives another thought of the establishment with creative plans and systems to ease procedure of the slant adjustment. In addition the Akarpile is planned in remote size so transportation expenses can be cut off in examination with the soil nailing and driven piles. The Construction businesses can balance out incline for the advancement with less labor and apparatuses. Since, the instruments to introduce Akarpile are so basic. The time required for incline adjustment forms are decreased. This approach is accepted to limit the danger of slant disappointment, and improve the security of inclines in both characteristic and synthetic slants.

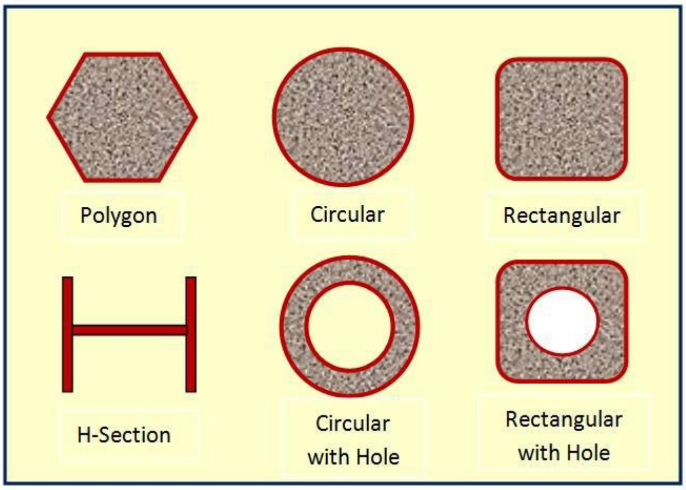


Fig. 1.4 Common Pile shapes

1.5. Pile-Soil Interaction

The pile shapes also affects the pile response behavior. The square piles are more resistant to lateral loads than the circular shape due to high contact surface area (S.A.) b/w the pile and the surrounded soil.

Fig. 1.5 Akarpiles of different lengths

The Pile-load capacity calculation will determine the ultimate load so that the pile foundation can take under-service load condition. This capacity is also called as the bearing capacity of the piles. Piles installed can be in a single pile or in a group. Therefore, load calculation for single pile and group of piles will be different. This is done for the given load conditions or for the size of foundations.

Efficiency factor E_g is defined as ratio of the ultimate group capacity to sum of the ultimate capacities of each of the pile in the group. This factor is mostly used to express the ultimate load considerations.

In order to support heavy loads, the piles are arranged in groups. The piles are arranged in groups so that size & cost of the construction of the pile cap can be reduced to make it safe and economical. The undisturbed Bearing capacity and required driving conditions are obtained by providing min. Clear Distance b/w the piles. This distance is equal to twice the pile diameter (D). It empowers a sensibly coherent investigation and quantitative assessments to be made of the impacts of parameters like length-to-breadth proportion, heap grating edge 8, edge of shearing opposition 4>, on a definitive elevate limit just as by and large skin erosion esteems.. It has been discovered that the basic profundity of installation past which the normal skin erosion accomplishes a consistent esteem depends not just on the point of shearing opposition of sand however altogether on heap rubbing edge. Among the accessible speculations the proposed investigation predicts sensible estimations of extreme elevate obstruction and normal skin grating demonstrated by correlation with detailed test outcomes.

1.6. Soil Nailing System

Soil nailing is a development medicinal measure to treat unsteady regular soil slants or as a development strategy that permits the safe over-steepening of new or existing soil inclines. The procedure includes the addition of moderately slim fortifying components into the incline – frequently broadly useful strengthening bars (rebar) albeit restrictive strong or empty framework bars are additionally accessible. One incredible preferred standpoint of soil nail dividers is their cost-viability over different choices. At the point when ordinary soil nailing development strategies are utilized, soil nail dividers are significantly more practical than solid gravity dividers and comparably or more financially savvy than ground grapple dividers.

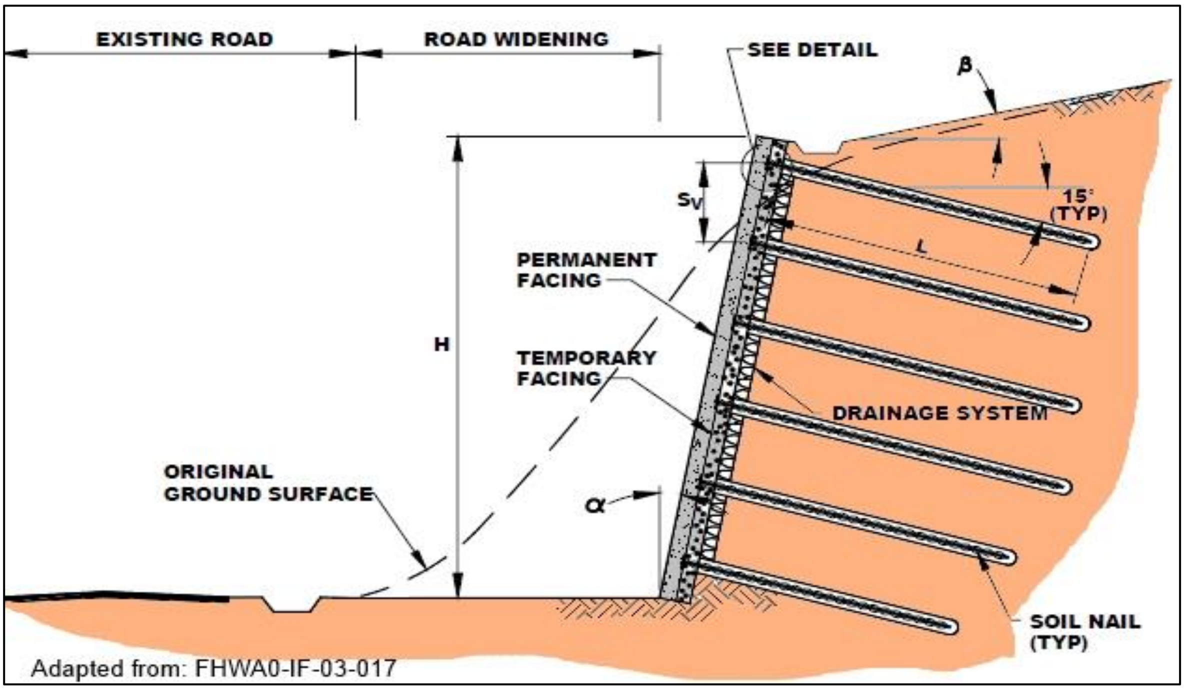


Fig. 1.6 Soil Nailing System

1.7. Organization of Thesis

The principal section quickly depict the extent of Pull-out Behavior of slanted composite heaps. In this model we have directed slanted conduct on three distinct lengths of heaps and furthermore on two unique courses of action that is triangular game plan just as on square game plan.

The second part is an outline of different parametric investigations and examination led on the examination depends on the conduct of the heap and furthermore foreseeing the limit of heaps under elevate loads are significant themes in the establishment structure.

The third section predicts about the technique in which the extraordinary course of action is made out in which various heaps are made of various length for the assurance of inspire conduct of single just as gathering heaps.

The Fourth section manages the outcomes we acquired from the research facility test and exploratory examination, and classified and correspondingly the diagrams have been plotted. This specific section includes the correlation and the approval of the outcomes which we got.

The Fifth section bargains about the finish of the whole investigation and the examination in this postulation. This Chapter additionally centers and knowledge into extent of future work.

CHAPTER 2
LITERATURE REVIEW

2.1. General

Pile behaviour and furthermore anticipating the capacity of piles under uplift loads are significant subjects in the establishment structure. The Experimental model tests have been effectively led on the single piles and diverse pile bunches installed in union less soil like sand and furthermore exposed to unadulterated uplift loading. The exploratory tests were additionally directed on straight-shafted vertical steel pile with diameter of 26 mm in a steel container. The tried piles have inserted length-to-diameter proportion (L/d) of 15, 22, and 25. The sand bed is set up at 3 distinct estimations of relative density of 77%, 87%, and 97%. These Single piles and distinctive pile bunches containing three, four, and six piles installed in sandy soil were tried, and the outcomes are displayed and talked about in this theory.

2.2. Literature Review

- **Zarrabi, M.Eslami ; 2016 [1]**

  This method can reduce the detrimental construction effects on cast in- place and increase their bearing capacity. Further studies on these piles are required to take into account & quantify all of the factors that can influence their behaviour like grout injection pressures and volumes & also shaft and tip post grouting methods. Precise determination of the influence of these factors would indicate whether the post grouted piles may be economical & effective alternative to conventional drilled shafts & driven piles.

- **Chun-Lan Lim and Chee-Ming Chan ; 2017 [2]**

  In this paper they discussed the method to reduce the expandability of bentonite grout and increase its shear strength. A series of tests were conducted on the single reinforced pile under vertical slope crest loading condition considering the different slope gradients and nailing designs. Parameters such as ultimate load, failure time & failure strain were recorded and compared for different lengths of pile.

- **Sunil Bhardwaj and S.K Singh ; 2017 [3]**

  In this paper they told us about the Horizontal displacement of vertical pile head increases with Inc. in pull-out load inclination. Also, the Effective depth of pile decreases as inclination of pull-out load increases with pile axis. Significant decrease occurs at small inclinations of pull-out load that is about 30% upto 15° of load inclination.

- **Qin Yue, Meng Qingshan, Wang Ren ; 2017 [4]**

  Distribution of pile displacement, skin friction & force transmission were examined in this paper. The uplift bearing capacity in sand reflects the differences in particle breakage, plastic deformation & the shear dilatancy characteristics of the sand.

- **Doohyun Kyung, Junhwan Lee ; 2017 [5]**

  The Uplift load carrying behaviour of piles were investigated in this paper, focusing on the effects of installation angle and pile spacing. The uplift load-carrying mechanism of piles in an inclined condition was proposed based on the axial, lateral load and resistance components. Both the vertical and inclined piles were installed and tested. The uplift load capacities estimated using the proposed method were in close agreement with the measured capacities.

- **Hussein A. Shaia ; 2013 [6]**

  This paper told us that it is used to predict axial strength enhancement of Fibre Reinforced piles. Some Small scale laboratory pile loading tests were carried out to assess the FRP pile behaviour under the axial and lateral loads. The effect of Fibre Reinforced piles hardness, roughness of a surface on its interface shear behaviour against granular material was also investigated in this paper.

- **Khaled E. Gaaver ; 2013 [7]**

  The behaviour of single pile under the uplift loads depends mainly on both pile embedment length to diameter ratios (L/d) and also the soil properties. The net uplift capacities of a pile improves significantly with an Inc. in both the (L/d) ratios & relative density of soil. An upward displacement of about 1.5–2.4% of the pile dia. is required to attain the net uplift capacity for the single pile. A very small upward displacement which is 0.5–0.6% times the pile dia. is required to develop the allowable uplift load.

- **Azzam, W. R., & Elwakil, A. Z. ; 2016 [8]**

  This paper explains that experimentally the effect of groundwater level rising on the soil-pile interaction under uplift loads. The series of model tests for piles embedded inside the partially submerged sand along with pile depth under the pull-out loads was carried out and also embedded pile length (h/L), pile stiffness (L/D), installation method & sand density.

- **Budania, R., & Arora, R. P. ; 2016 [9]**

  This paper explains that Self-Drilling Soil Nail, Hollow bars were driven and the grout was injected through the hollow piles simultaneously during the drilling. This method is faster than grouted nailing & also exhibits more corrosion protection than driven soil-nail.

2.3. Summary of Literature Review

1. Limited work has been done on the pullout of inclined composite pile.

2. Cement was introduced into bentonite grout so as to reduce the expandability of bentonite grout and increase the shear strength.

3. Investigation of all factors affecting its behaviors like spacing ratios, and post grouting at the tip, shaft may be beneficial for better understanding of these piles.

4. Use of FRP piles as an alternative to the conventional piles under compressive loading or axial loading is also investigated.

2.4. Objectives

1. To find the pull-out behaviour of Akarpile under inclined uplift at 30°.
2. To evaluate pile pull-out force, pile displacement, strains along pile length and earth pressure variation during pull-out.
3. To study the effect of varying number of perforation along Akarpile length on inclined pull-out behaviour.
4. To determine inclined pull-out behaviour of Akarpile group.
5. To focus on stabilizing surficial slope failure.

CHAPTER - 3
METHODOLOGY

3.1 General

In this project a list of certain equipment's are used. A model tank of dimension 85 cm x 75 cm x 87 cm is constructed using Perspex sheet of 2.5 mm thickness. Ten layers of 10 cm thickness each are laid in the model tank up to height of 80 cm. Before the final testing on the fictitious model, certain tests are performed on the soil to determine its physical properties. The tests involved grain size distribution, unconfined-undrain test, Attbergs limits.

3.2 Materials Used

3.2.1 Black cotton soil

Black cotton soil is one of the soils which are present in India in abundance. It is generally present in central India. This type soil is considered as very good for agricultural purposes as it is very fertile. Crops such as jowar, maze, wheat etc. and cotton are grown in this type of soil. It is formed by the weathering of basaltic rocks and is black in colour. This soil is inorganic in nature.

Black cotton soil is one of real soil stores of India. They display high rate of swelling and shrinkage when presented to changes in dampness content and subsequently have been observed to be most troublesome from building thought.

The rate of montmorillonite is more in black cotton soil which causes extensiveness and break happens in soil Black cotton soils additionally called Regur soils are commonly clayey, profound and impermeable. These soils grow and become sticky amid blustery season and contract amid the dry season causing profound breaks into the dirt. Synthetically black soils comprise of lime, iron, magnesium, alumina and potash yet they need in nitrogen, phosphorus and natural issue. In view of their ability to hold water, they are appropriate for the development of cotton subsequently called as black cotton soil. They are dull in shading. They create splits amid dry period and swell whenever got dampness, henceforth they are self-working in nature, that is the reason they are rich and can hold water for long time. This limit is utilized for Cotton development.

Fig. 3.1 Natural Black Cotton Soil

Because of its far reaching character, it increments in volume to the degree of 20% to 30% of unique volume and applies weight. The upward weight applied turns out to be high to the point that it will in general lift the establishment upwards. This switch weight in the establishment causes breaks in the divider above. The splits are tight at the base and are more extensive as they go up.

The irregular qualities of the dirt make it hard to build establishment in such soil. Exceptional technique for development of establishment is required in such soil. In Black Cotton and other far reaching sort of soils, structures split because of differential ground developments. This is brought about by interchange swelling and shrinkage of the dirt because of changes in its dampness content.

So as to safe-make preparations for this development successfully, the best cure is to stay the structure at a profundity where volumetric difference in soil because of regular and other variety is immaterial. This has been accomplished monetarily in shallow just as in profound layers of broad soil by utilizing under-reamed heaps.

Procurement - The Black cotton soil used in this project was acquired from Guna, Madhya Pradesh, India.

Fig. 3.2 Oven dried sample of Black cotton soil

3.2.2 Sand

The model piles were implanted in dry siliceous sand of medium to fine particles. All tests are led on sand as per applicable ASTM standard test strategies. In the wake of putting piles with pile top in the soil canister, sand with an all-out stature of 700 mm was saved in the soil container in seven layers, every 100 mm profound. Sand put in the soil receptacle was chosen with relative densities of 77%, 87%, and 97%. Controlled pouring of sand and packing methods are utilized to set up a homogeneous layer. The amount of sand for each layer was evaluated and weighed to an exactness of 0.10 N, set in the soil container, and packed until achieving the required stature. The sand layers put in the soil canister to accomplish the objective thickness inside a precision of ±2 mm to achieve the required relative density.

Procurement - The sand was acquired from Amb Tehsil in district Una, Himachal Pradesh.

Fig. 3.3 Sand sample

3.2.3 Model Piles and Pile Caps

Model heap tops were organized and produced using smooth delicate steel tubes with a 26 mm outside distance across (d) and 3 mm sheet thickness. A steel shoe was machined and used to close the completion of each heap. The heap lengths (L) considered were 364, 520, and 676 mm, which identify with (L/d) extents of 14, 20, and 26 independently. The top pieces of the heaps were hung to append them with the heap top. The heap tops were machined from smooth steel plates of 30 mm thick. The heap top was machined to the arranged estimations inside a precision of ±2 mm. A string at the point of convergence of the top surface of the heap top was given for partner it exhibiting ring for inspire stacking. The heaps were totally embedded in the sand in the midst of most of the drove tests. Exactly when heap bundles were attempted, the isolating between the heaps to-distance across extent (s/d) was kept enduring.

Likewise there were Different Pile Groups courses of action used to check the soundness of soil under various conditions. We utilized Triangular just as Square course of action for introducing heaps at a slant. For that we needed to make Triangular and square heap top for our venture. In this we utilized two diverse heap lengths to work upon. For first we utilized the best length of heap (out of 36.4 cm, 52 cm, and 64.6 cm) to use in gathering heap try, and in the second case we utilized the second best heap length.

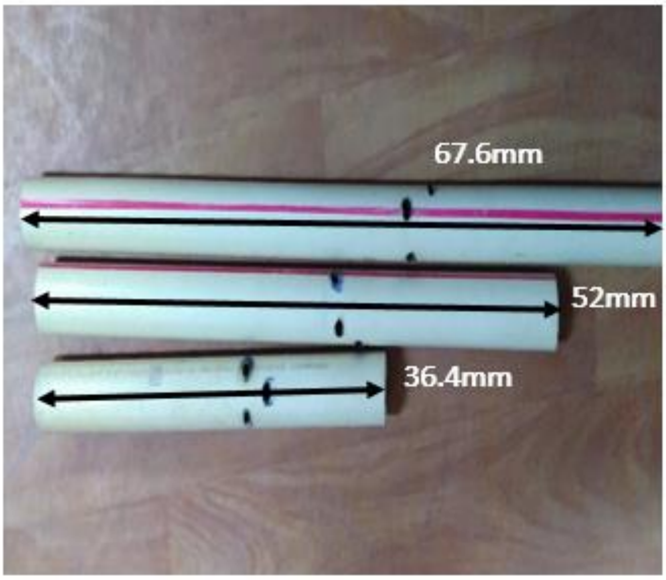


Fig. 3.4 (a) Akarpile (Longitudinal View)

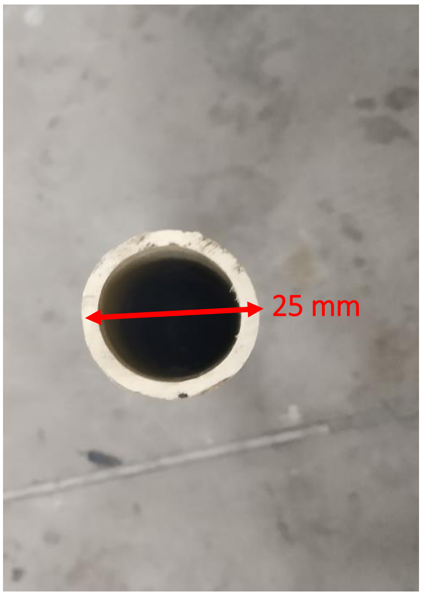


Fig. 3.4 (b) Akarpile (Plan View)

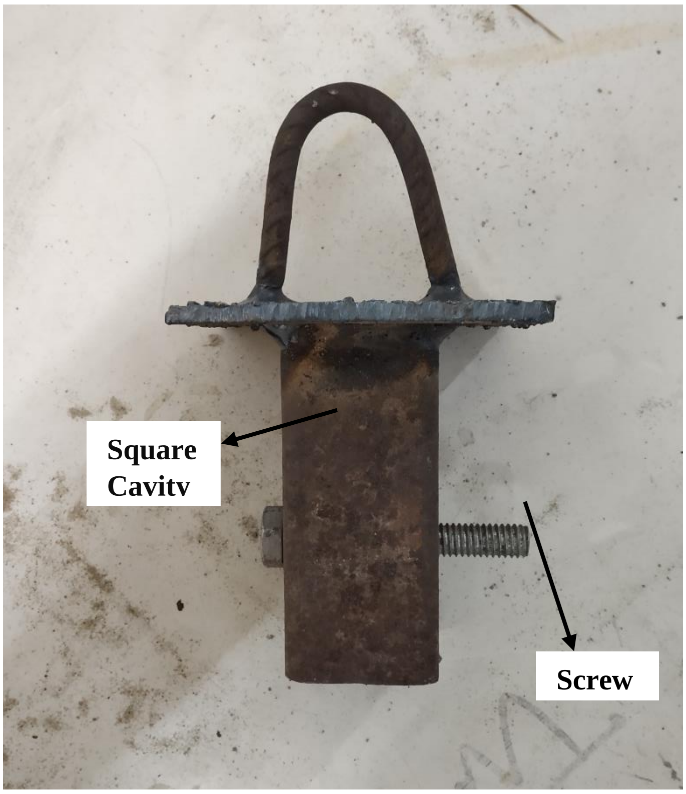


Fig. 3.5 Pile Cap

(For Single pile arrangement)

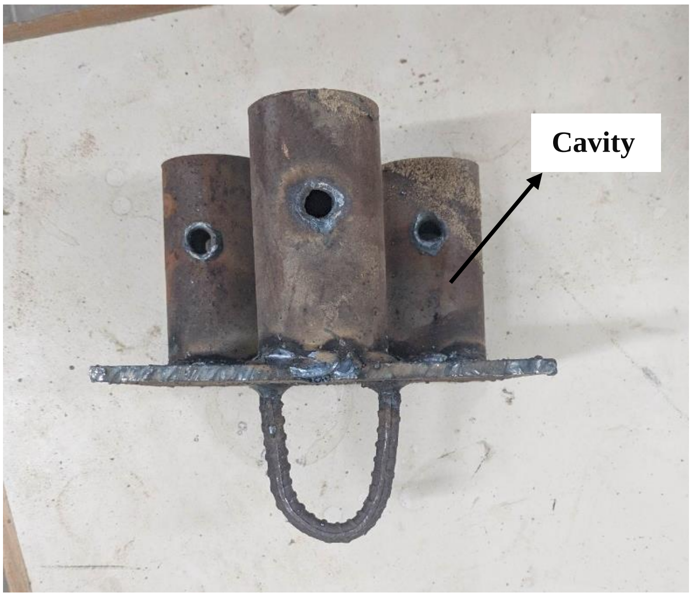


Fig. 3.6 Pile Cap

(For Triangular Group pile arrangement)

Fig. 3.7 (a) Pile Cap

(For Square Group pile arrangement)

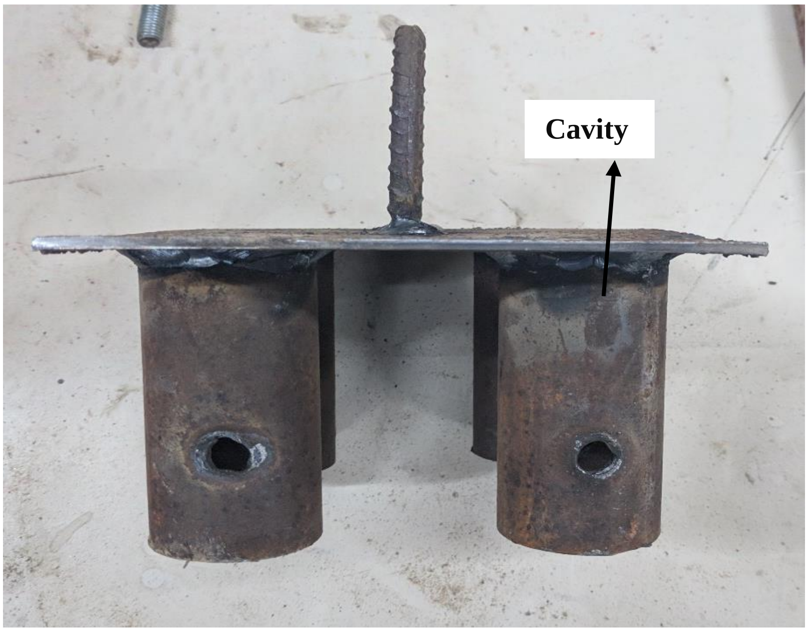
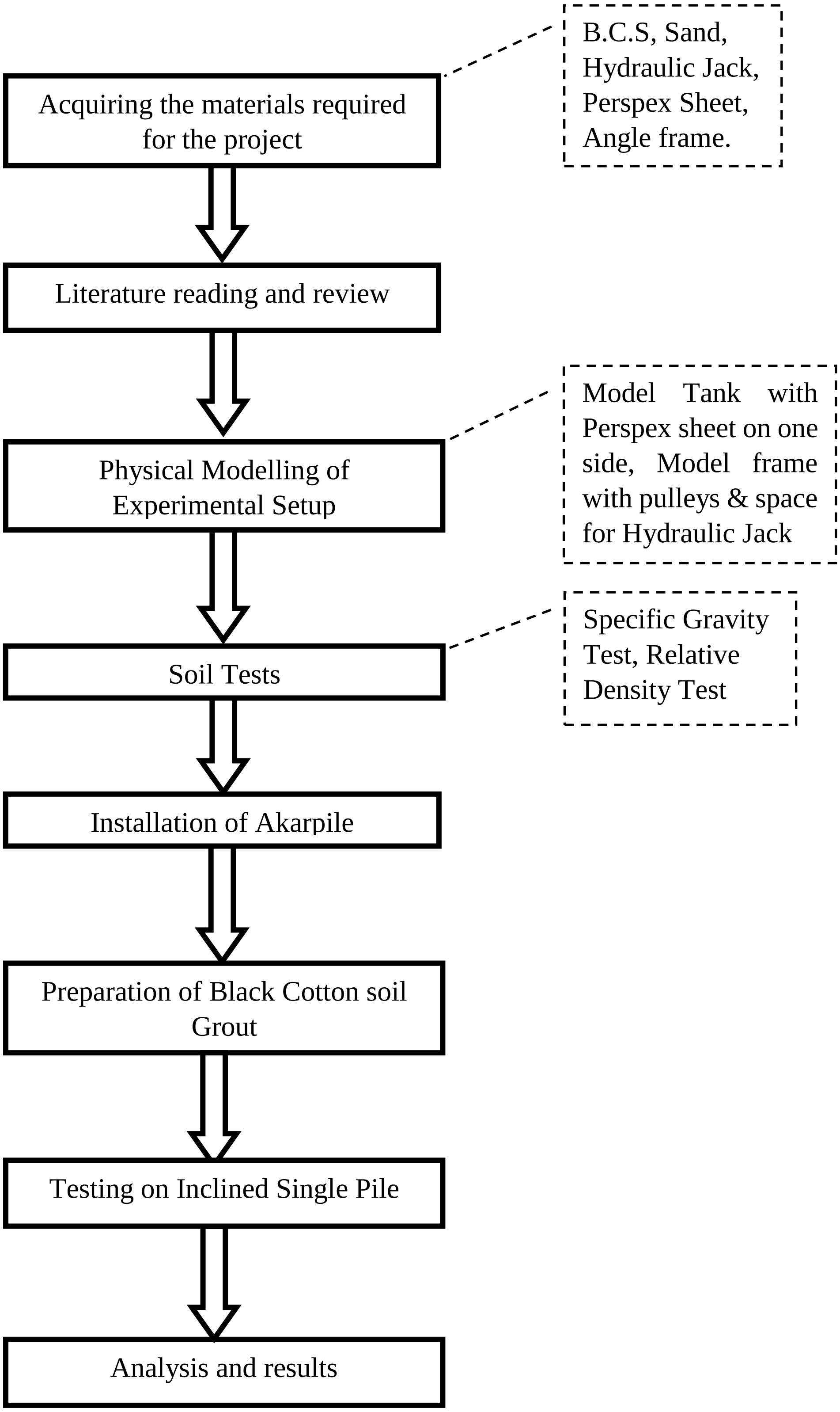


Fig. 3.7 (b) Pile Cap

(For Square Group pile arrangement)

3.4 Work Plan Methodology



3.4 Model Tank

The experimental tests are performed on model piles in an Iron tank. Model tank has measurements of 850 mm x 750 mm x 870 mm. It should be recollected that the points of confinement of the dirt container may impact the weight and relocation fields in the connection less soil. Additionally, the vertical stresses in soil may Dec. due to scouring b/w the dirt and the compartment dividers. To constrain such impedance we expected to make inside dividers of the dirt repository cleaned smooth to confine the disintegration with soil anyway much as could be normal. The zone in which the dirt will be impacted by tank limits changes with the dirts relative thickness and strategy for heap foundation.

The fabricated model tank has been shown in fig. below. Materials utilized in the fabrication were as follows:

a) **Perspex Sheet** – Poly-methyl Methacrylate (PMMA) likewise called as acrylic glass or by its market name - Plexiglas, Lucite, Acrylate and Perspex, is a straightforward thermoplastic. Usually utilized as a lightweight or a break safe sheet. It essentially works as an other to glass. A similar material can be used as a throwing pitch in inks and different employments. Despite the fact that it isn't the kind of a natural silicate based glass yet dissimilar to numerous thermoplastics, usually actually delegated a sort of glass. Artificially, this material is an engineered polymer of methyl methacrylate. The thickness of the Perspex Sheet we used is 2.5 mm.

   Acrylic is a synthetic fibre which can be changed over to nearly anything. It toughens and increments in quality when cool. Likewise, it is safe against the outside condition. Individuals choose an acrylic sheet for bunches of reasons. In the first place, something delivered from an acrylic is considerably more adaptable than glass, and it's such a great deal less prone to break. For security reasons and common sense reasons, it appears to be reasonable to purchase an acrylic sheet by and large. Those that have youngsters around may require something increasingly safe against physical contact, which is actually what acrylic will offer as contrasted and glass. Show cases are built from a straightforward acrylic sheet. Acrylic show cases are certainly more prominent than glass cases essentially in light of the fact that they have a few favourable circumstances over glass shows. Acrylic cases are lighter and sturdier.

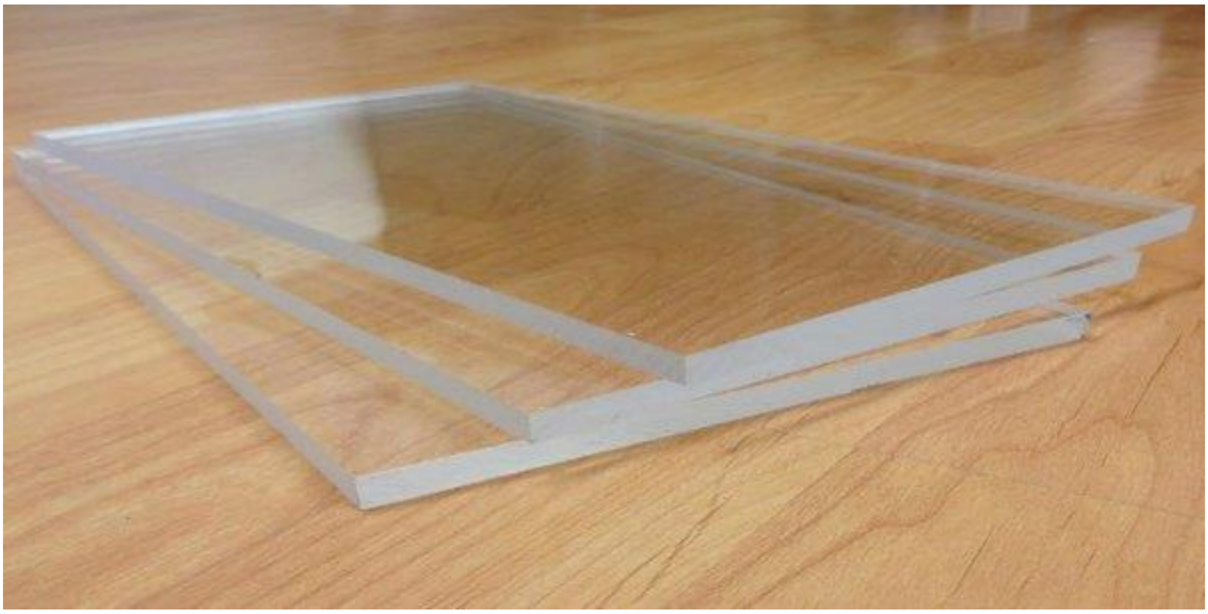


Fig. 3.10 Perspex Sheet (2.5mm)

An acrylic sheet is significantly more adaptable than glass, so there's unquestionably to a lesser extent a possibility that an acrylic show case will break. While glass breaks into sharp sections, acrylic shapes bigger, innocuous pieces on the off chance that it breaks. The edges of acrylic sheet show cases are adjusted to make them ok for youngsters. Acrylic can be formed and cut like wood, in this manner it is effectively tweaked to construct show instances of various shapes and sizes.

b) Iron Angles

An iron or steel bar, brace or cleat is used in the form of an angle. A piece of structural iron or steel having cross section in the form of an L.

Fig. 3.11 Iron Angles

c) Nut and Bolts

Fig. 3.12 Nut-Bolt used

d) Inextensible wire

They consist of two parts: an inner cable of braided stainless steel wire and an outer cable housing, and work by transmitting force using a combination of tension on the inner cable and compression to the housing.

Fig. 3.13 Inextensible Wire

e) Hydraulic jack

Hydraulic jack is a device used for lifting heavy loads which can’t be lifted by a human, by the application of much smaller force. It is based on Pascal's law, which states that intensity of pressure is transmitted equally in all directions through a mass of fluid at rest.

Fig. 3.14 Hydraulic Jack

Fig. 3.15 Casing for Hydraulic Jack

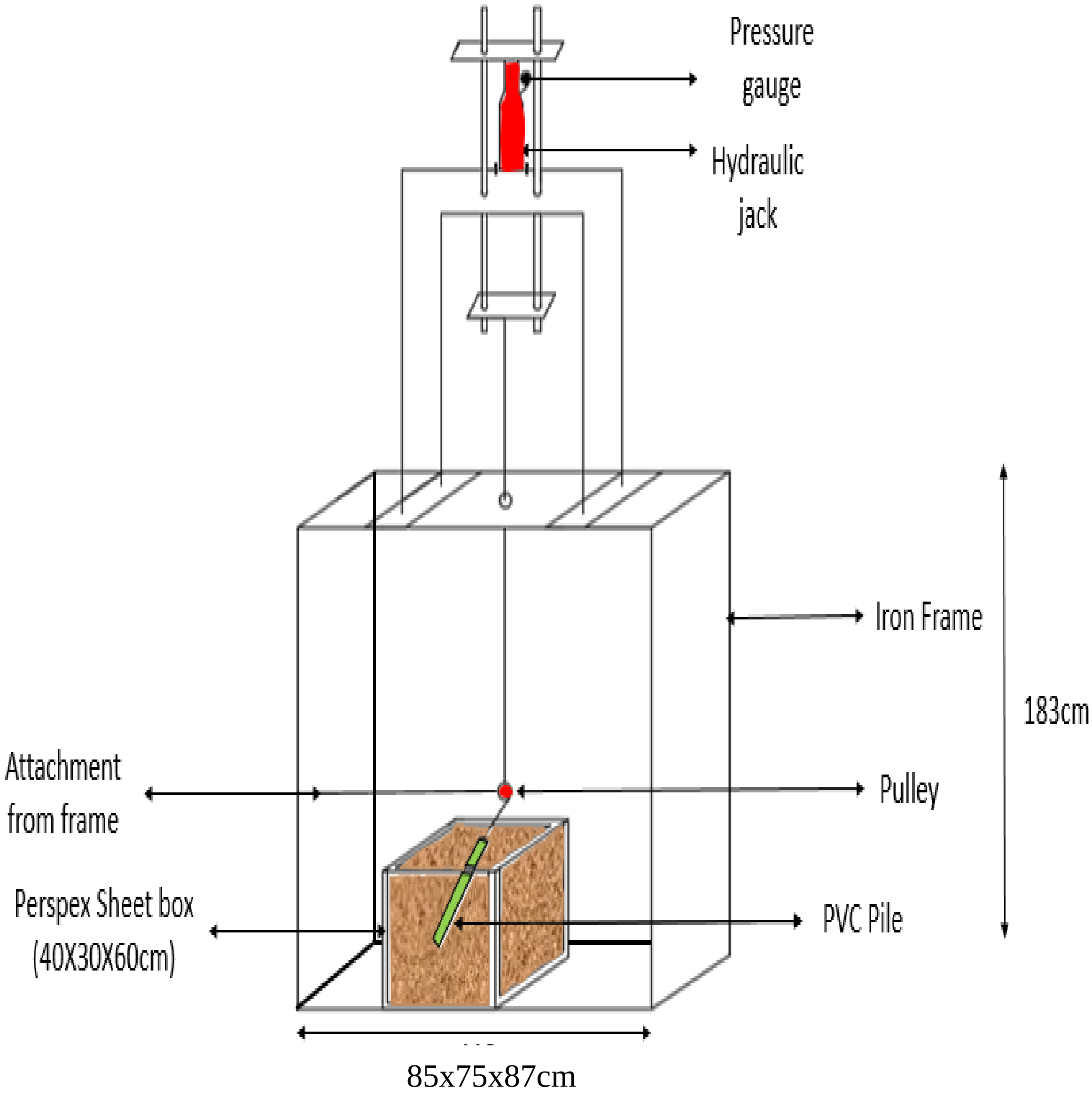


Fig. 3.8 AutoCAD Model

Fig. 3.16 (a) Model Tank

Fig. 3.16 (b) Model Tank

3.5 Soil Layer Preparation

A model tank of dimension 85 cm x 75 cm x 87 cm is constructed using Perspex sheet of 2.5 mm thickness. Eight layers each of 10 cm thickness are laid in the model tank up to height of 80 cm. Controlled pouring of sand and tamping techniques were used to prepare a homogeneous sand layer. The sand layers placed in the soil bin to achieve the target thickness within an accuracy of ±2 mm to attain the required the relative density & with a total height of 700 mm sand was deposited in the soil bin in seven layers, each 100 mm deep. Sand used formed in the soil bin was at selected relative densities of 77%, 87%, and 97%.

3.6 Preparation of BCS Grout

The Grout to be used in the model test was a mixture of BCS, Sand and water with ratio of 1: 3:4. The sand needs to be dried and sieved before mixing the process. The grout then filled the pores in the soil with random flow within the slip zone.

Grout is a thick liquid which is utilized to fill holes or utilized as reinforcement in existing structures. Grout is commonly a blend of water, cement, and sand and is utilized in pressure grouting, installing rebar in stone work dividers, interfacing areas of pre-cast concrete, filling voids, and fixing joints, for example, those between tiles Structural grout is frequently utilized in fortified brick work to fill voids in workmanship lodging strengthening steel, verifying the steel set up and holding it to the stone work. Non-contract grout is utilized underneath metal bearing plates to guarantee a steady bearing surface between the plate and its substrate.

Fig. 3.17 Weighing Black Cotton Soil

Fig. 3.18 Pouring Grout in Installed Pile

Fig. 3.19 Preparing BCS Grout

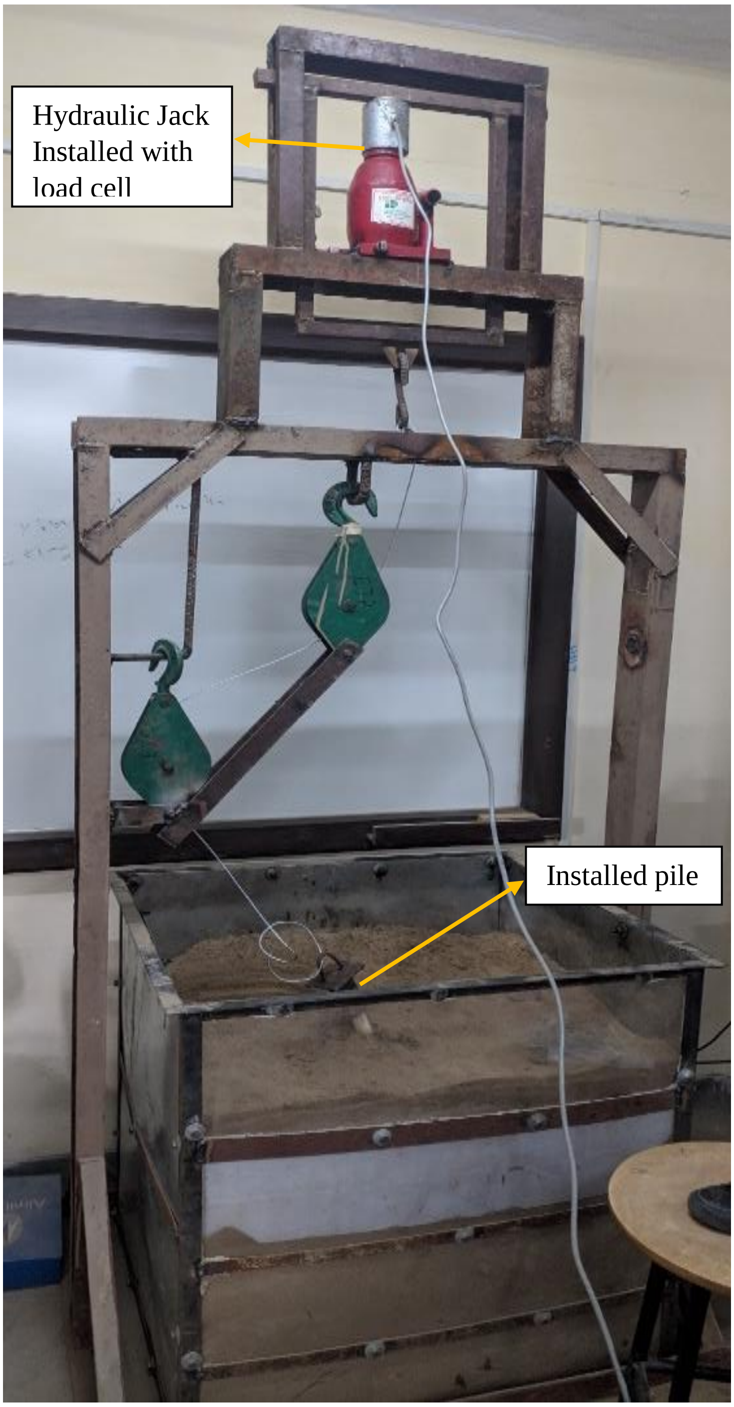


Fig. 3.20 Hydraulic Jack with load cell Fitted on Model test frame

3.7 Experimental Steps

- Filling of Perspex sheet with soil using suitable method.
- Insertion of hydraulic jack over the angle frame.
- Preparation of BCS Grout.
- Insertion of pile inclined to the surface.
- Arrangement of Dial gauges.
- Upliftment of pile through hydraulic jack.
- Uplifting would be done on single as well as group of piles at different angle.
- Noting the reading of Dial gauges and hydraulic jack.
- Analysis of result.
- Comparison and validification of results.

CHAPTER - 4

RESULTS

4.1. General

Test outcomes are gathered in two game plans of headings addressing the direct of single heaps and two heap packs under inspire stacking. Aftereffects of the heap social affairs will be diverged from the looking at consequences of a singular heap. The going with regions look at the obtained outcomes in detail.

4.2. Relationship b/w Height of Fall & Relative Density

- According to relation, $I_D = \frac{emax - e}{emax - emin}$ x 100
- Using this relation, $e = \frac{G_s.\gamma_w}{\gamma_d} - 1$
- $I_D = \frac{\gamma_{dmin} (\gamma_d - \gamma_{dmin})}{\gamma_d (\gamma_{dmax} - \gamma_{dmin})}$ x 100

$\gamma_{dmin} = \frac{W}{V} = \frac{1289}{1000} = 1.289$ g/cc

$\gamma_{dmax} = \frac{1703}{1000} = 1.703$ g/cc

$\gamma_d = \frac{1421}{1000} = 1.421$ g/cc

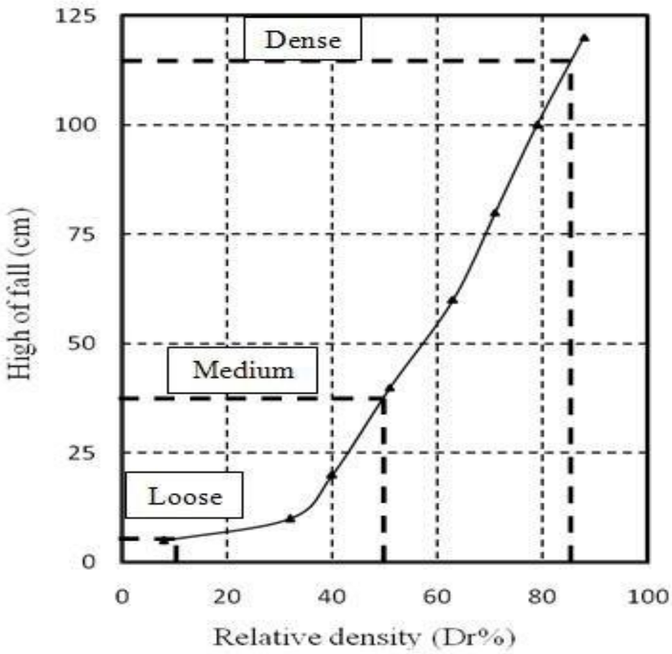


Fig. 4.1 Relationship b/w Height of Fall & Relative Density of Sand (Source: A.I.Fadhil, 2014)

Substituting above values, in eq.1,

$I_D = \frac{1.289(1.421 - 1.289)}{1.421(1.703 - 1.289)}$ x 100 = 68.11 g/cc

Height of fall = 71cm (through interpolation)

4.3. Single pile under Uplift Loading

In this experiment, we have done with single pile of different lengths (36.4 cm, 52 cm, and 64.6 cm). The pile is placed inside the sand tank .Inside the pile we poured Black cotton soil grout and made it stay there for 48 Hours.

4.3.1 For 52 cm pile length

Fig. 4.2 Inclined Pull-out on Pile

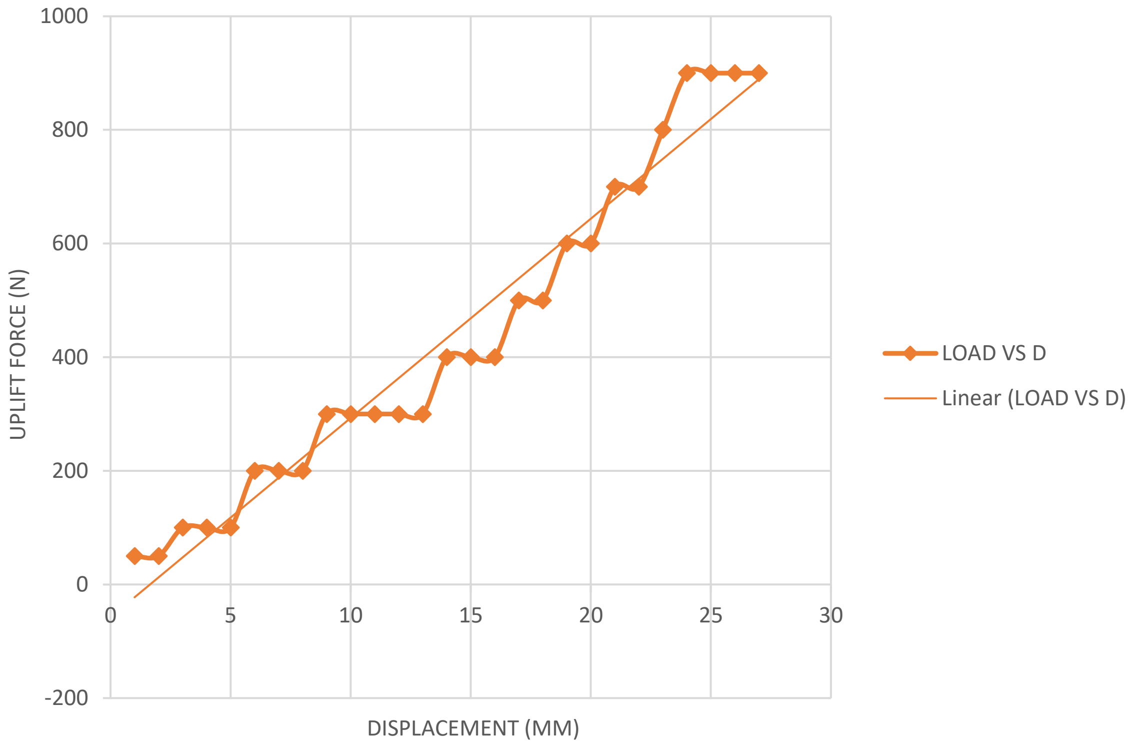


Fig. 4.3 Load VS Displacement curve for 52 cm Pile

4.3.2 For 36.4 cm pile length

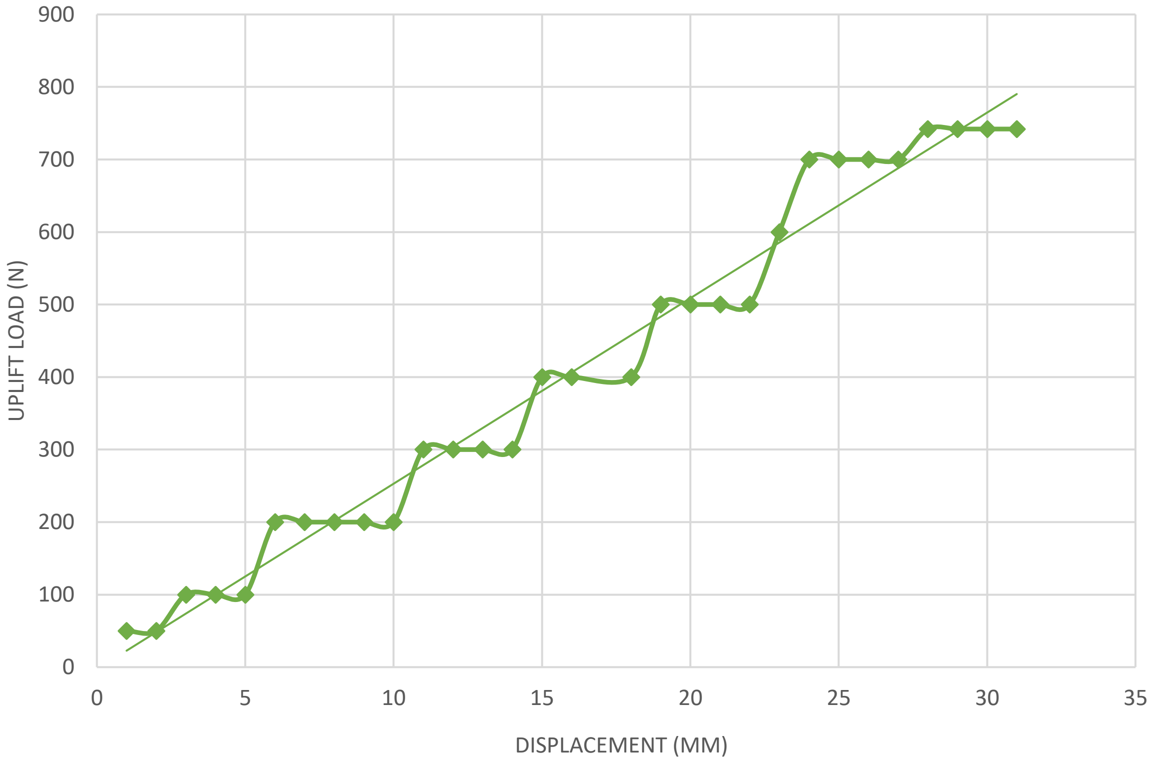


Fig. 4.4 Load VS Displacement curve for 36.4 cm Pile

4.3.3 For 64.6 cm pile length

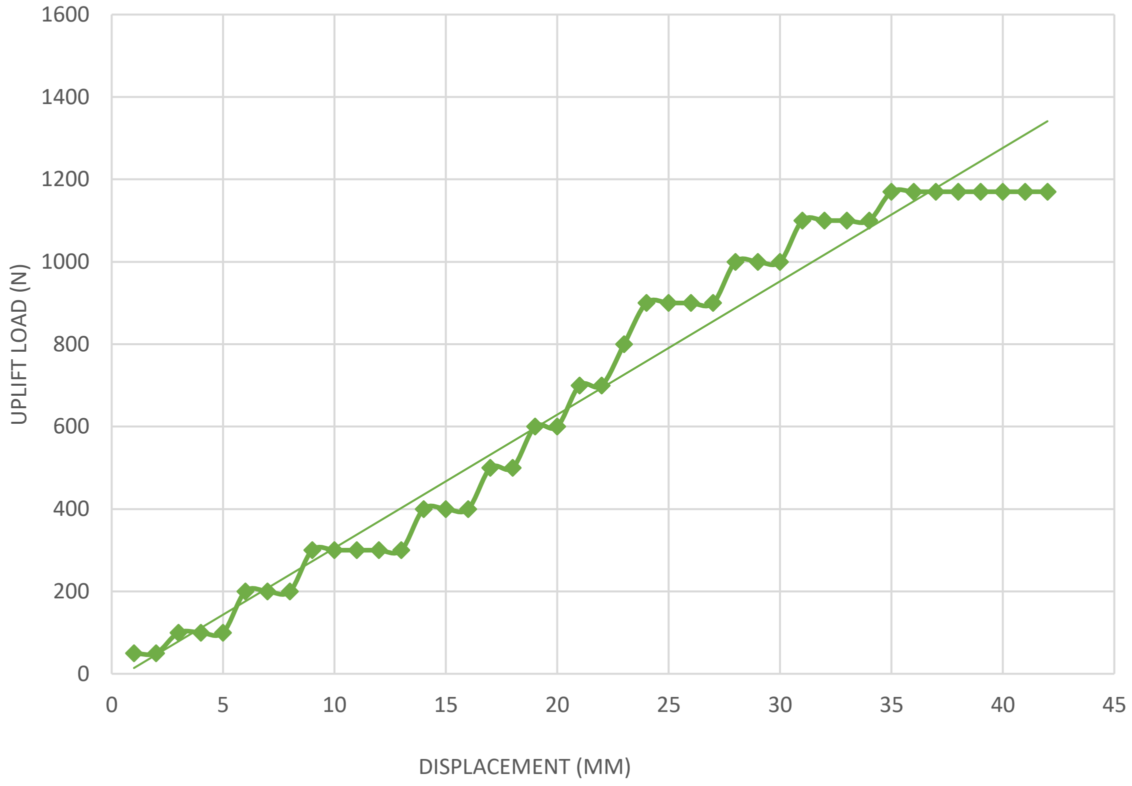


Fig. 4.5 Load VS Displacement curve for 64.6 cm Pile

Fig. 4.6 Load value measured using Load Cell

4.4. Pile groups under Uplift loading

In this experiment we uplifted piles in a group. The Pile Group is arranged in the form of Triangle and a square. This is performed by uplifting group piles with the help of special arrangement which consists of Hydraulic jack, Load cell, Strain Gauge. In this test we will find out the uplift load, Uplift Capacity, Pile Displacement. For Triangular and Square arrangement we made pile cap in which the pile is fit inside the cap from where the pile is pull out. Inside the pile, Grout is poured which is made with Black cotton soil, Sand, water in the ratio of 1:3:4 and is kept for 48 Hours. Then with the help of special arrangement the pile group is pulled out.

4.4.1 Triangular Arrangement

In this, the piles are arranged in the Triangular form with 5mm spacing between the piles. Pile cap is made for triangular arrangement to pull-out the piles. Grout is poured inside the piles which is kept for 48 hours. From this, Pile uplift capacity as well as Pile-displacement is found out. First we performed test using three 64.6 cm length piles and after that using three 52 cm length piles.

Fig. 4.7 Inclined Pull-out on Triangular Arrangement of Piles

- **For 52 cm pile length**

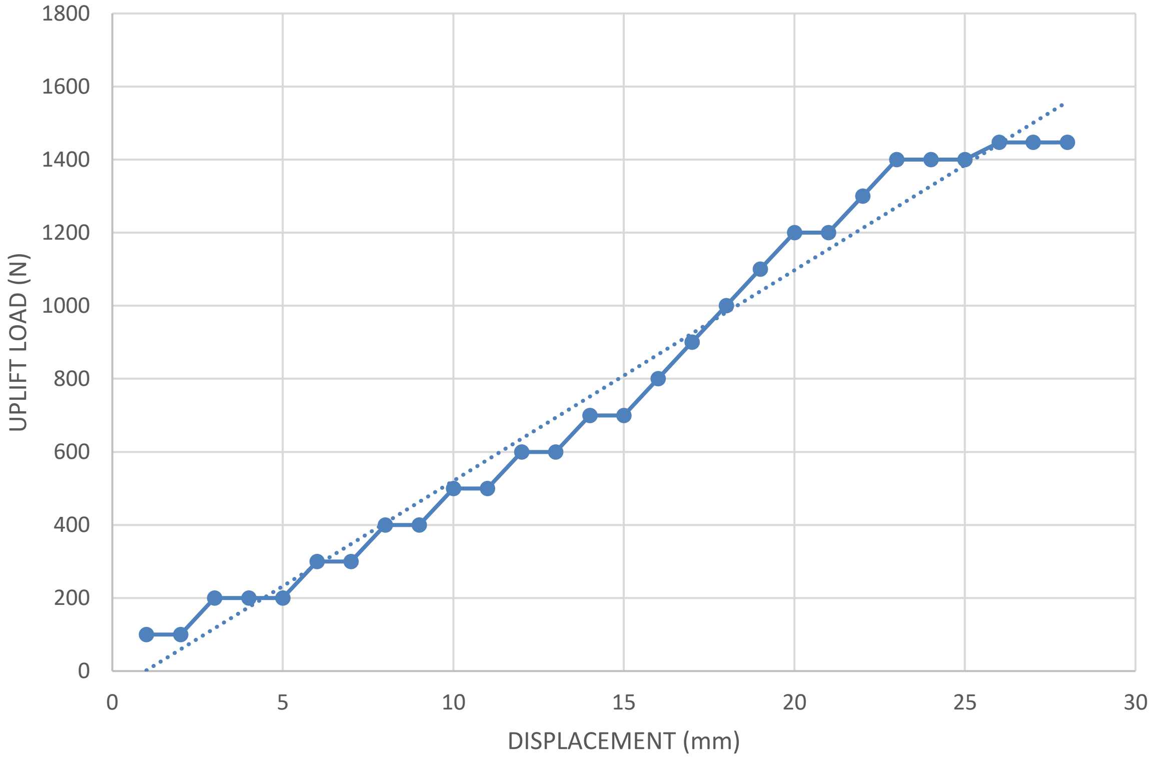


Fig. 4.8 Load VS Displacement curve for three 52 cm Piles

Fig. 4.9 Inclined Pull-out on Triangular Arrangement of Piles

- **For 64.6 cm pile length**

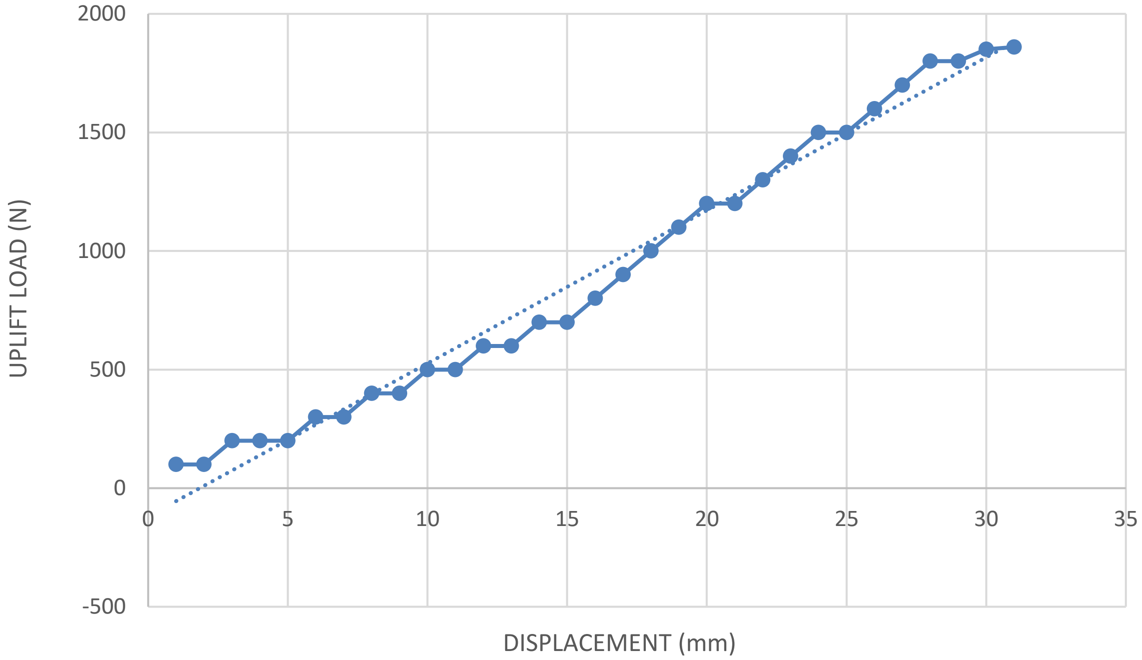


Fig. 4.10 Load VS Displacement curve for three 64.6 cm Piles

4.4.2 Square Arrangement

In this, the piles are arranged in the Square form with 5mm spacing between the piles. Pile cap is made for Square arrangement to pull-out the piles. Grout is poured inside the piles which is kept for 48 hours. From this, Pile uplift capacity as well as Pile-displacement is found out. First we performed test using four 64.6 cm length piles and after that using four 52 cm length piles.

Fig. 4.11 Inclined Pull-out on Square Arrangement of Piles

- **For 64.6 cm pile length**

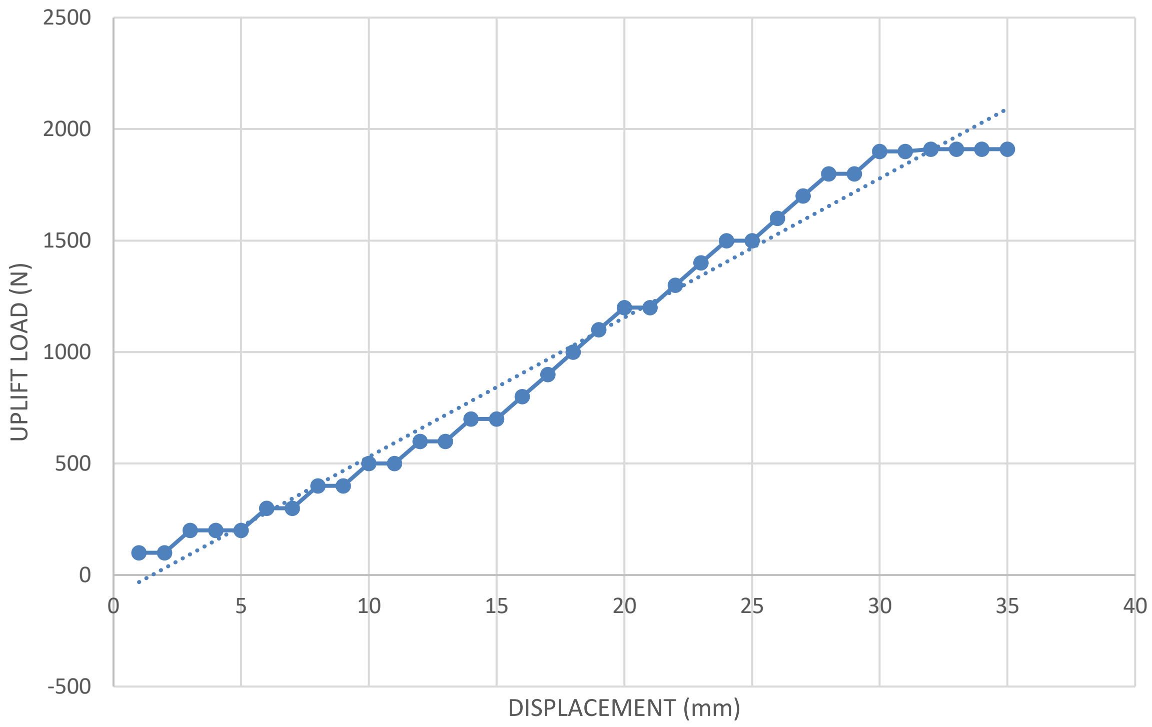


Fig. 4.11 Load VS Displacement curve for four 64.6 cm Piles

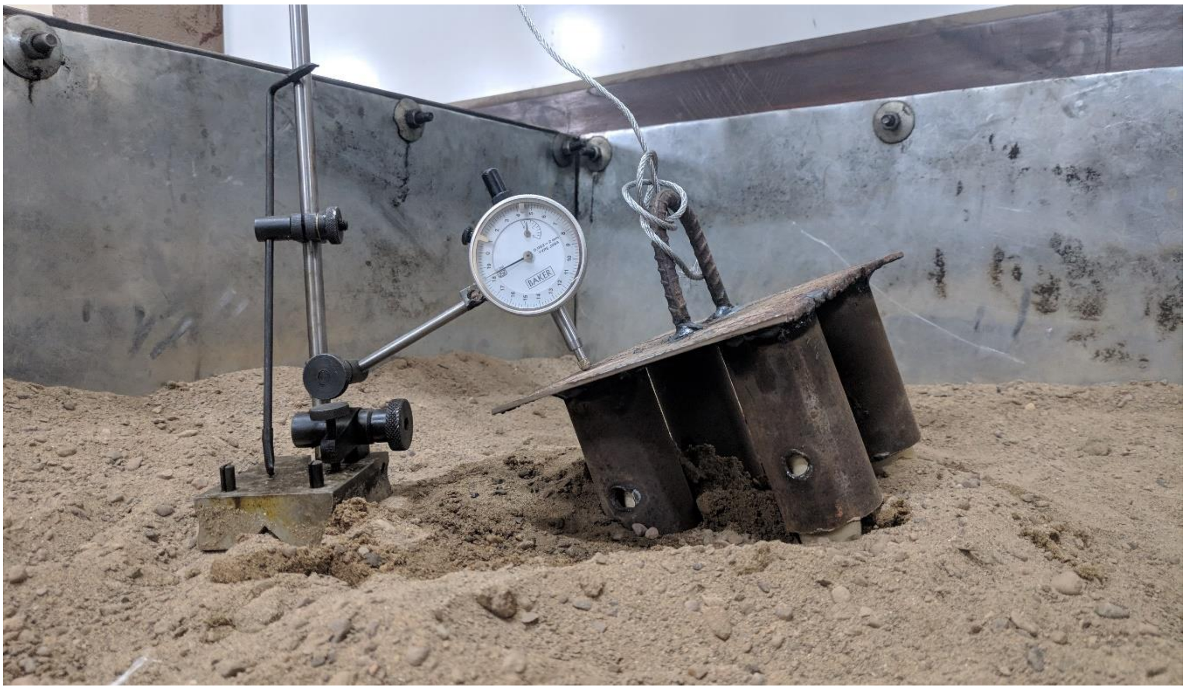


Fig. 4.12 Inclined Pull-out on Square Arrangement of Piles

- **For 52 cm pile length**

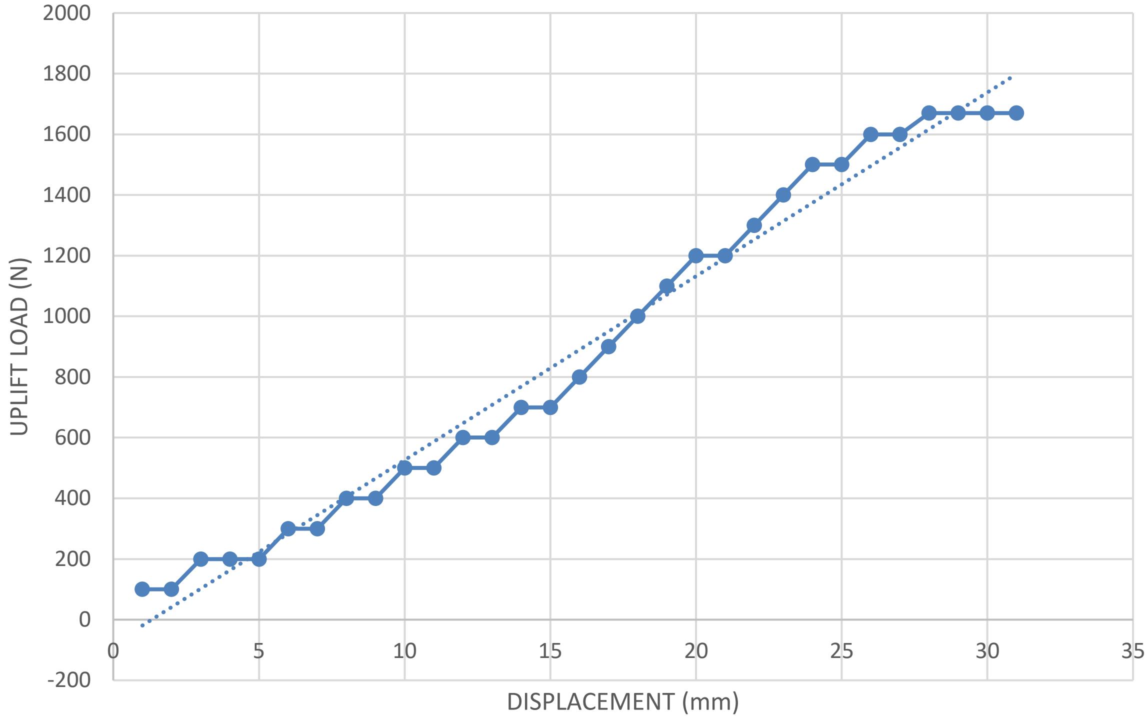


Fig. 4.13 Load VS Displacement curve for four 52 cm Piles

CHAPTER – 5

CONCLUSION

5.1. General

Preliminary tests were driven on three one of a kind lengths of single heaps and two heap clusters containing three and four heaps under inspire stacking. The test outcomes are shown and inspected in this hypothesis.

5.2. Conclusions

In view of study and investigation of results, the accompanying ends are drawn:

- The conduct of single piles under uplift load depends generally on both the pile depth-to-diameter extent (L/d) and the soil properties. The net uplift capacity of a pile improves in a general sense with an extension in both the (L/d) extent and the relative density of soil.
- An upward displacement of about 1.4– 2.5% of the pile diameter is required to accomplish the net uplift capacity for both single piles and pile gatherings. An uncommonly minimal upward displacement, 0.4–0.6% events the pile diameter, is required to develop the sensible uplift load.
- The load– displacement lead of a lone pile embedded in sand under uplift loading can be addressed palatably by a power condition that joins fundamental parameters. This condition ought to be affirmed by driving full-scale uplift-loading tests on single piles.
- For a net elevate load for each heap in a social event proportionate to a solitary heap load, the upward removal of a steadily dispersed heap pack increments in light of correspondence impacts between heaps.
- The ampleness of the endeavored heap bundles under inspire stacking ranges from 0.32 to 0.83 as appeared by the measure of heaps in the

social event, the heap implant profundity to-width degree, and the general thickness of sand.

- The ability of a heap group under elevate stacking decreases with an advancement in the measure of heaps in the social occasion and with an expansion of the heap install profundity to-distance across degree.
- The ability of a heap cluster under elevate stacking diminishes with an improvement in the measure of heaps in the social affair and with an augmentation of the heap implant profundity to-breadth degree.

5.3. Scope of Future Work

The accompanying wide territories of research have been recognized to examine the conduct of pile foundations exposed to uplift loads:

- System of failures including failure surfaces and methods of failure.
- Parametric examination on the coefficient of earth pressure K and adhesion factor.
- Impact of grain size distribution of soils and size impacts of piles and pile groups.
- Impacts of techniques for establishment.
- End states of piles.

We have worked on a small scale model, therefore for a detailed analysis for future work a large scale model should be made. Also, we have worked on a static model, so in future, work needs be done on a dynamic model.

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APPENDIX

Table. 4.1 Net Uplift Capacity for 52 cm Pile

Displacement	Uplift Force
(mm)	(N)
1	100
2	100
3	100
4	200
5	200
6	200
7	200
8	300
9	300
10	300
11	300
12	400
13	400
14	500
15	600
16	700
17	800
18	800
19	900
20	900
21	900
22	900
23	910
24	910
25	910
26	910
27	910

Table. 4.2 Net Uplift Capacity for 36.4 cm Pile

Displacement	Uplift Load
mm	N
1	50
2	50
3	100
4	100
5	100
6	200
7	200
8	200
9	200
10	200
11	300
12	300
13	300
14	300
15	400
16	400
18	400
19	500
20	500
21	500
22	500
23	600
24	700
25	700
26	700
27	700
28	742
29	742
30	742
31	742

Table. 4.3 Net Uplift Capacity for 64.6 cm Pile

Displacement	Uplift load
mm	N
1	50
2	50
3	100
4	100
5	100
6	200
7	200
8	200
9	300
10	300
11	300
12	300
13	300
14	400
15	400
16	400
17	500
18	500
19	600
20	600
21	700
22	700
23	800
24	900
25	900
26	900
27	900
28	1000
29	1000
30	1000
31	1100
32	1100
33	1100
34	1100
35	1170
36	1170
37	1170
38	1170
39	1170
40	1170
41	1170
42	1170

Table. 4.4 Net Uplift Capacity for three 52 cm Piles

Displacement	Uplift Load
mm	N
1	100
2	100
3	200
4	200
5	200
6	300
7	300
8	400
9	400
10	500
11	500
12	600
13	600
14	700
15	700
16	800
17	900
18	1000
19	1100
20	1200
21	1200
22	1300
23	1400
24	1400
25	1400
26	1447
27	1447
28	1447

Table. 4.5 Net Uplift Capacity for three 64.6 cm Piles

Displacement	Uplift Load
mm	N
1	100
2	100
3	200
4	200
5	200
6	300
7	300
8	400
9	400
10	500
11	500
12	600
13	600
14	700
15	700
16	800
17	900
18	1000
19	1100
20	1200
21	1200
22	1300
23	1400
24	1500
25	1500
26	1600
27	1700
28	1800
29	1800
30	1850
31	1860
32	1860
33	1860

Table. 4.6 Net Uplift Capacity for four 64.6 cm Piles

Displacement	Uplift Load
mm	N
1	100
2	100
3	200
4	200
5	200
6	300
7	300
8	400
9	400
10	500
11	500
12	600
13	600
14	700
15	700
16	800
17	900
18	1000
19	1100
20	1200
21	1200
22	1300
23	1400
24	1500
25	1500
26	1600
27	1700
28	1800
29	1800
30	1900
31	1900
32	1910
33	1910
34	1910
35	1910

Table. 4.7 Net Uplift Capacity for four 52 cm Piles

Displacement	Uplift Load
mm	N
1	100
2	100
3	200
4	200
5	200
6	300
7	300
8	400
9	400
10	500
11	500
12	600
13	600
14	700
15	700
16	800
17	900
18	1000
19	1100
20	1200
21	1200
22	1300
23	1400
24	1500
25	1500
26	1600
27	1600
28	1670
29	1670
30	1670
31	1670