ABASYN University Peshawar

Department of Civil Engineering

Pakistan Engineering Council
Ataturk Avenue
Sector G-5/2
Islamabad

Subject: **Request for the Release of Remaining 60% Budget for Final Year Design Project**

Project Title: **Enhanced Capacity of Pile Foundation by Skin Resistance.**

Dear Sir/Madam,

I hope this letter finds you in good health and high spirits. We the students of Department of Civil Engineering, Abasyn University Peshawar are extremely proud to inform you that our final year design project has been successfully completed. This project represents the culmination of our academic journey, where we have applied the theoretical knowledge gained during our studies to real-world engineering challenges. By providing the necessary financial support, the Pakistan Engineering Council would not only be investing in our education but also contributing to the progress and innovation in the field of Civil Engineering. It would encourage us, as aspiring engineers, to pursue further excellence in our careers and become valuable contributors to the nation's development.

We kindly request the Pakistan Engineering Council to consider our plea and promptly release the 60% budget for our final year design project. Your support and encouragement will play a pivotal role in shaping our future and nurturing the next generation of engineers in Pakistan.

Our final report and poster is attached with it.

Thank you for your time and consideration. We look forward to a positive response from the esteemed Council.

Sincerely,

Group Members of PEC Award Project

Nasru Minallah (AUP-19FL-BECE-15572)
Zain Zia (AUP-19FL-BECE-15373)
Hamid Khan (AUP-19FL-BECE-16153)
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ABASYN
University Peshawar

Department of Civil Engineering

Title:

Enhanced Capacity of Pile Foundation by Skin Resistance

Group Members:

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Supervisor:

Engr. Wajid Ali

Abstract:

The capacity of the pile foundation can be limited by the strength of the soil surrounding the pile skin friction/resistance between pile foundation surface and soil can enhance the capacity of pile foundation. The main aim of the research was to increase the skin resistance of a pile foundation by adding admixtures i.e. sodium carbonate and aluminum powder in concrete. Adding these admixtures cause expansion in concrete. A strain will be observed in concrete specimen.

Introduction:

Pile foundation is a deep foundation that is used in situations like heavy loads and weak soil. It transfers the load of the superstructure to deep soil either by end bearing capacity or by skin resistance/friction. Skin resistance is defined as "the shear resistance between the pile surface and the surrounding soil along the length of the pile."
The skin resistance for soil is measured by Mohr Coulomb law of shear strength.

$$T = \sigma n * \tan\delta$$

Normal stress acting on a pile producing strain in sand surrounding the pile is given by equation.

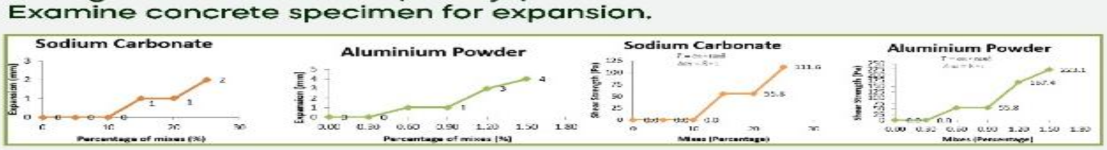
$$\Delta\sigma n = E * \varepsilon$$

Objectives:

To compute expansion in concrete by adding admixtures.
To enhanced the capacity of pile foundation by skin resistance.

Methodology:

Collection of materials
Casting of concrete cubes (6"x6"x6")
Curing of concrete cubes (28 days)
Examine concrete specimen for expansion.



Conclusion:

Adding sodium carbonate and aluminum powder causes expansion of concrete due to which the shear resistance between pile surface and surrounding soil is enhanced.

ENHANCED CAPACITY OF PILE FOUNDATION BY SKIN RESISTANCE

Final Year Design Project BECE 2022-23

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Session 2019-23

Enhanced Capacity of Pile Foundation by Skin Resistance

Thesis submitted in partial fulfillment of the requirements for the degree of B.Sc civil engineering

By

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FYDP Coordinator, CED, AUP

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Head of Department, CED, AUP

Department of Civil Engineering

DEDICATION

We are aware of the fact that this work has been a huge amount of responsibility and a milestone for our professional career endeavor, for which we have tirelessly worked day and night having tough time coping with the finding out the suitable admixtures but we didn’t stop. We will not be exaggerating if we say that this milestone was not possible without the emotional and moral support of our beloved parents, who nurtured us through every thick and thin and made us achieve this with passion, while getting inspiration from our seniors.

We are not forgetting to mention our respected teachers, Engr. Wajid Ali (Our Project Supervisor) & Engr. Muhammad Tufail Khan (FYDP Coordinator AU), whose stern yet affectionate motivation and push made us work harder every day and whose guidance personally guided to our destination.

Therefore, I am dedicating this work, with passion and warm heartedness to all of them.

Nasru Minallah ________________________

Zain Zia_______________________________

Hamid Khan___________________________

Anas Ahmad___________________________

ACKNOWLEDGMENT

We acknowledge that the work presented in this thesis is a contribution and collaborative work of a lot of people without whom we might not have reached this milestone in our life. First of all, I thank The Almighty and Most Merciful Allah for granting us the skills and abilities to reach the heights of success, then our parents, who were always there to support us through every thick and thin.

WeI thank our supervisor for being extremely cooperative, guiding us and helping out in all the problems and issues encountered during the development of the project.

In the last we thank all my friends who supported us morally. Thank you all and may Allah bless you.

ABSTRACT

The capacity of the pile foundation can be limited by the strength of the soil surrounding the pile skin friction/resistance between pile foundation surface and soil can enhance the capacity of pile foundation. The main aim of the research was to increase the skin resistance of a pile foundation by adding admixtures i.e. sodium carbonate and aluminum powder in concrete. Adding these admixtures cause expansion in concrete. A strain will be observed in concrete specimen.

The skin resistance for soil is measured by Mohr Coulomb law of shear strength.

$$T=\sigma n * tan\delta$$

Normal stress acting on a pile producing strain in sand surrounding the pile is given by

$$\Delta\sigma n=E*\varepsilon$$

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CHAPTER 1

Introduction

1.1 Background

The builders of ancient civilizations, such as the Greeks and Romans, exhibited a remarkable grasp of the importance of stable foundations for their structures. Through their ingenious construction techniques and knowledge, these ancient edifices have stood the test of time, proudly displaying their enduring strength. By employing stone blocks and arches, the Romans skillfully erected awe-inspiring structures of significant height, which have remained resolute for centuries, showing minimal signs of settlement. The Roman aqueducts, a marvel of engineering designed to carry water over vast distances using gravity, have left an indelible mark on history, with many sections still in existence today.

The illustrious Pantheon stands as a testament to ancient Roman architecture, boasting a colossal dome that soars to an astonishing height of 142 feet above the floor. The unwavering stability of such grand structures is a testament to the expertise and brilliance of the builders during the eras of Agrippa and Hadrian.

Likewise, the Coliseum in Rome, the imposing buildings at Baalbek, and the iconic Parthenon in Athens have endured the ages, exemplifying the enduring quality of their foundations and construction.

While these venerable structures have encountered challenges throughout history, including vandalism and seismic activity, restoration and preservation efforts have allowed them to persist. Their exceptional ability to endure through the ages is a resounding tribute to the knowledge and skill possessed by the builders of antiquity.

1.2 Foundation

Foundations play a crucial role in civil engineering, acting as essential structural elements to safely transfer loads from superstructures like buildings, bridges, dams, highways, walls, tunnels, and towers to the underlying ground. They serve as the vital connection between the structure and the supporting soil or rock, ensuring overall stability and safety.

The design of foundations centers around two fundamental criteria:

1.2.1 Bearing Capacity

Foundations must be meticulously designed to have ample bearing capacity, preventing any failure within the surrounding soil. A failure or instability in the soil beneath the foundation could pose a significant risk to the entire structure's integrity. Careful consideration is given to the foundation's dimensions, depth, and type to ensure that the soil can support the imposed loads safely, avoiding excessive settlement or failure.

1.2.2 Settlement

Settlement refers to the downward movement of both the foundation and the supported structure due to applied loads. While some degree of settlement is almost unavoidable, it must be limited to tolerable levels to prevent damage to the superstructure. Excessive settlement can lead to uneven settling of the structure, resulting in cracks in walls, floors, and other components, adversely affecting both functionality and aesthetics.

To meet these design criteria, engineers take various factors into account during the foundation design process, including:

- **Soil investigation and geotechnical analysis:** Understanding the soil properties and its load-bearing capacity is crucial for determining the appropriate foundation type.
- **Load analysis:** Engineers calculate the anticipated loads from the superstructure, considering diverse combinations of loads, including active loads (varying loads, such as occupants and furniture) and dead loads (permanent weights, such as the weight of the structure itself).
- **Foundation type selection:** Based on the soil conditions and load analysis, engineers select the most suitable foundation type, such as shallow foundations (e.g., spread footings, mat foundations) or deep foundations (e.g., piles, drilled shafts).

- **Foundation materials:** The choice of appropriate materials for constructing the foundation considers factors like soil corrosiveness, moisture content, and structural requirements.
- **Environmental considerations:** Factors such as water tables, frost lines, seismic activity, and other regional environmental aspects are taken into account as they may influence foundation performance.

By satisfying these design criteria and considerations, engineers ensure that foundations provide a secure and stable support system for the superstructures they underpin, enabling them to withstand the forces and loads they encounter throughout their operational lifetime.

Foundations can be divided into two primary types: **shallow foundations** and **deep foundations**. The classification is based on how deep they extend to transfer the load to the underlying and/or surrounding soil.

1.3 Type of Foundation

1.3.1 Shallow foundation

In the Figure 1, a typical **shallow foundation** is illustrated. Shallow foundations are referred to as such when the ratio of the depth of the foundation below ground level (Df) to the width of the foundation (B) is less than or equal to 1 ($Df/B \leq 1$). Various types of shallow foundations include continuous wall footing, spread footing, combined footing, strap footing, grillage foundation, raft or mat foundation, and more, as depicted in the figure.

In order to transmit the load or pressure coming from the column or superstructure, which frequently exceeds the safe bearing capability of the supporting soil, horizontally, shallow foundations are used. This allows the weight or pressure to be transmitted at a level that the soil can safely support. When the natural soil at the construction site has a reasonable safe bearing capacity, acceptable compressibility, and the column loads are not overly high, these foundations are used.

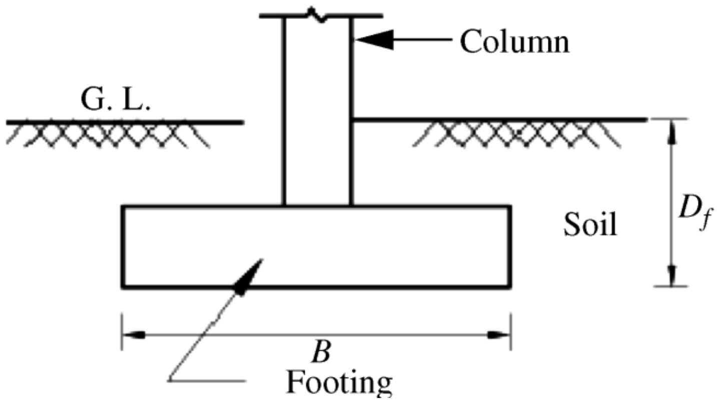


Figure 1: Shallow Foundation

Terzaghi's Bearing Capacity Theory

The pioneering work of **Terzaghi** in 1943 marked the introduction of a comprehensive theory for assessing the ultimate bearing capacity of rough shallow foundations.

Terzaghi suggested that the soil failure surface at ultimate load can be expected to match the picture shown in Figure 2 for a continuous, or strip, foundation (with a width-to-length ratio approaching zero). "General shear failure" is the name given to this kind of failure.

Foundations are typically placed on well-compacted ground, making the assumption of general shear failure valid. Moreover, the soil above the bottom of the foundation can be considered equivalent to an additional surcharge, q = g * Df (where g represents the unit weight of the soil above the foundation level).

The failure zone beneath the foundation can be divided into three parts, as seen in Figure 2:

i. The triangular zone ACD directly under the foundation.
ii. The radial shear zones ADF and CDE, where the curves DE and DF form arcs of a logarithmic spiral.
iii. Two triangular Rankine passive zones AFH and CEG.

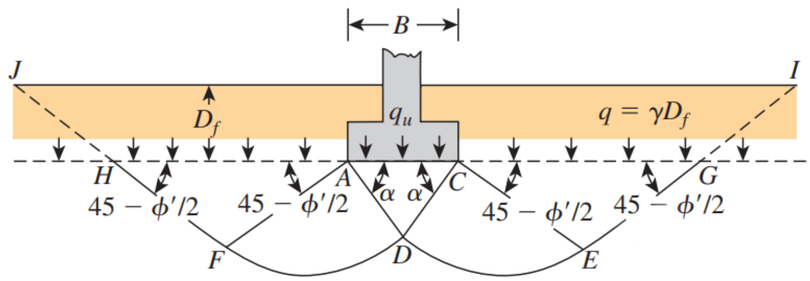


Figure 2: Bearing capacity failure of foundation

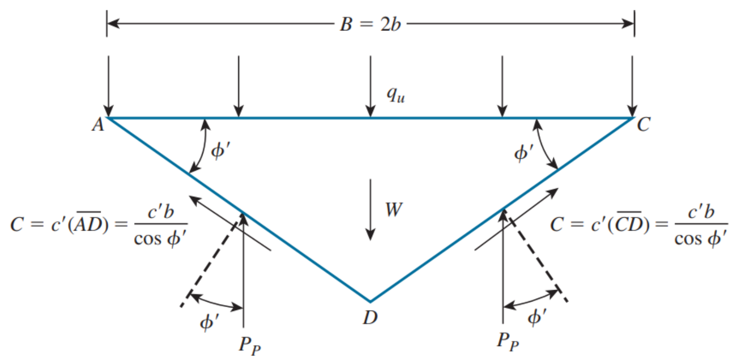


Figure 3: Derivation for equation

$$Q_u = c'N_c + qN_q + 1/2\ \gamma BN_\gamma$$

Equation of terzaghi's bearing capacity

For Square Foundation

$$q_u = 1.3c'N_c + qN_q + 0.4\gamma BN_\gamma$$

For Circular Foundation

$$q_u = 1.3c'N_c + qN_q + 0.3\ \gamma BN_\gamma$$

γ; is the unit weight of soil, ć; is the cohesion of soil, Φ ; is the internal angle of friction, N_c, N_q and N_γ are the Terzaghi factors depend on soil angle of internal friction.

1.3.2 Deep Foundation

In the diagram provided as Figure 4, a typical deep foundation is depicted. Deep foundations are referred to as such when the ratio of the depth of the foundation below ground level (Df) to the width of the foundation (B) is greater than 1 (Df/B > 1). Common examples of deep foundations include piles, drilled piers/caissons, well foundations, large diameter piers, and pile raft systems. Pile is a type of deep foundation.

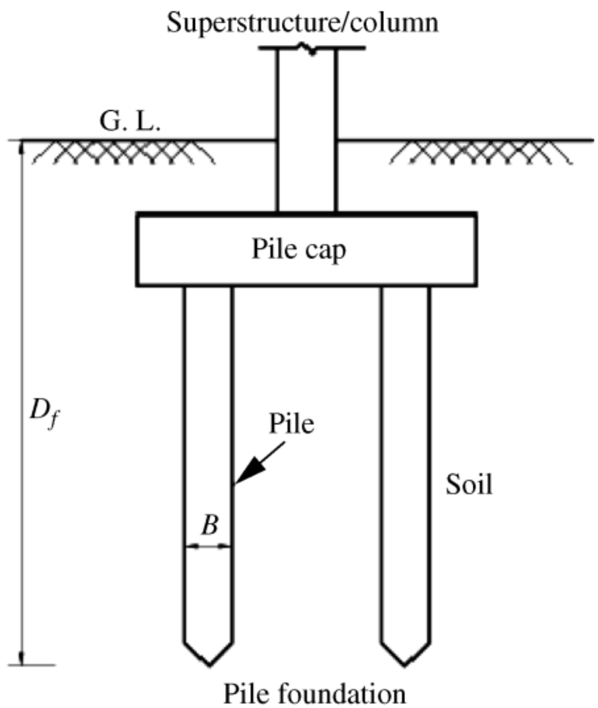


Figure 4: A type of deep foundation

Pile foundations become necessary when the soil near the surface lacks the capacity to support the loads transmitted by shallow foundations or when large-sized shallow foundations become economically and practically unfeasible due to weak soil conditions. In such cases, deep foundations are employed to transfer the loads to deeper soil layers capable of sustaining the superstructure's substantial loads.

The bearing capacity of these deep foundations can be evaluated by considering the shear strength of the soil along the boundary of the failure zone.

Piles are recommended in the following situations:

Week Soil condition: In situations where the soil conditions near the surface are unsuitable for supporting building loads, shallow foundations become inadequate, and the use of deep foundations becomes necessary. When bedrock exists at a reasonable depth, driving piles into the bedrock allows for the transfer of the entire load directly to the stable bedrock layer.

Carrying lateral loads: High rise buildings, earth-retaining structures, transmission towers, and bridges often face significant lateral loading from wind, earth pressures, or seismic forces. Unlike shallow foundations, piles are highly effective in resisting these lateral loads.

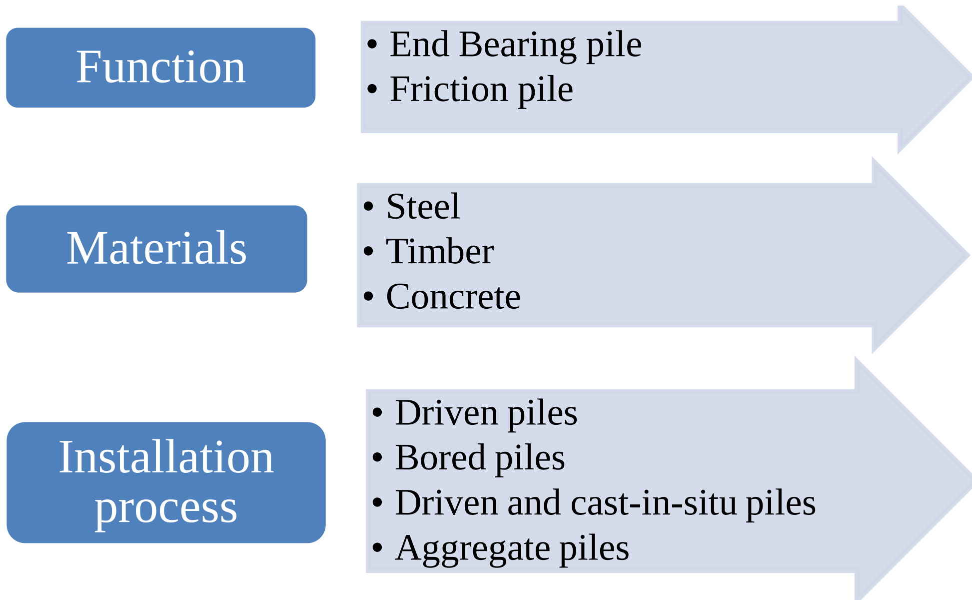
Bridge abutments: Pile foundations in bridge abutments provide robust support, high load-bearing capacity, lateral stability, adaptability to varying soil conditions, erosion protection, compact footprint, and efficient installation, ensuring durable and secure bridges.

Expansive or collapsible soil: Around the world, low-rise buildings, roadways, and infrastructure are seriously at risk from expansive soil. Shallow foundations in such soil suffer from swelling and shrinking, causing severe damage. Piles driven deep beyond the expansive soil depth can prevent this issue.

As compaction piles: In specific situations, compaction piles are driven into granular soil to achieve adequate soil compaction near the ground surface. The length of these piles is influenced by the soil's relative density before and after compaction and the desired depth of compaction. Typically, compaction piles are relatively short, but field tests are essential to determine the appropriate length.

1.4 Types of Pile Foundations

Pile foundations are categorized based on their function, materials, and installation process.



1.4.1 Types by Function

Piles primarily transfer column loads through skin friction along the pile shaft and bearing capacity at the pile tip. When the pile carries the ultimate load Qu, the ultimate shaft resistance (Qs) and ultimate point resistance (Qp) are considered.

$$Q_u = Q_p + Q_s$$

1.4.1.1 End bearing pile

When weak soil near the ground surface cannot support shallow foundations, pile foundations are a suitable solution. Piles can be driven through the weak soil to reach bedrock or a stiff stratum at relatively shallow depths. The pile's load is then transferred to the underlying stiff stratum, through the end of pile creating a secure foundation. Point bearing piles achieve this by extending a few meters and socketing into the stiff stratum.

$$Q_u = Q_p$$

$$Q_p = A_p \times q_p = A_p\,(c'\,N^*_c + q'\,N'q)$$

Where

A_p = area of the pile tip

c' = cohesion of the soil supporting the pile tip

q_p = unit point resistance or ultimate bearing capacity of the pile point

q' = effective vertical stress at the level of the pile tip

N_c^*, N_q^* = the bearing capacity factors for piles

1.4.1.2 Friction Pile

In the absence of a stiff stratum within a reasonable depth, relying solely on point bearing piles can be costly. In such cases, the load transfer depends on shaft resistance, which comes from skin friction or adhesion. Point resistance becomes negligible, leading to Qp ≈ 0 .Therefore, friction piles are the preferred option.

$$Q_u = Q_s$$

$$Qs = \Sigma p \, \Delta L f$$

Where

p = perimeter of the pile section

ΔL = incremental pile length over which p and f are taken to be constant

f = unit friction resistance at any depth z

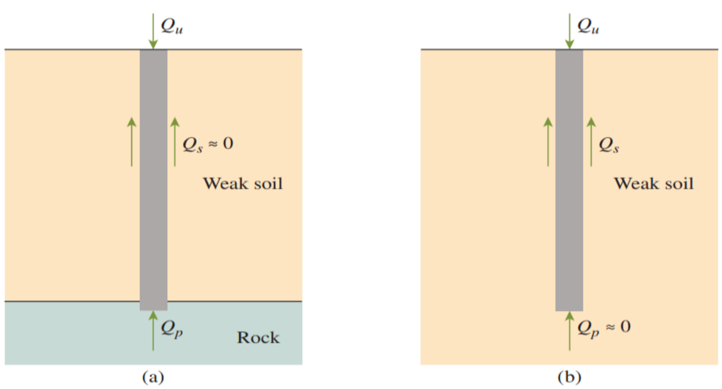


Figure 5: (a) End bearing point; (b) Friction pile

1.4.2 Types by Material

1.4.2.1 Steel Pile

Steel piles can be available in hollow pipes or H-sections. They are concrete-filled. Steel piles are of different diameter depending on load the carry, but the typical thickness is 34 inches. The piles are simple to drive because of their tiny sectional area. They mostly transfer the load by end-bearing.

The allowable capacity of steel piles is given by

$$Q_{all} = A_s \text{ X } f_s$$

Where A_s; is the cross sectional area of steel: f_s; is the allowable stress of steel whose value varies from 0.33 to 0.5

Advantages of Steel Piles

- Easy installation.
- Ability to carry heavy loads.
- Penetration through hard soil layers due to smaller cross-sectional area.
- Simple splicing of steel piles.
- Greater depth reach compared to other pile foundations.

Disadvantages

- Susceptible to corrosion, especially in marine or aggressive soil environments.
- Higher cost compared to some other types of pile foundations.
- Possibility of difficulty in driving piles in hard or rocky soils.
- Limited load-carrying capacity in certain soil conditions.
- Relatively more challenging to adapt to variable soil conditions and site-specific requirements.

1.4.2.2 Concrete Piles

Concrete piles can be categorized into two main types: (a) precast piles, and (b) cast-in-situ piles.

Pre-cast Concrete Pile

Prepared using standard reinforcement, precast piles come in square or octagonal cross sections. The reinforcement is incorporated to ensure the pile can withstand the bending moments during handling, transportation, vertical loads, and lateral forces. After casting to the desired lengths, the piles are carefully cured before being transported to the construction sites.

Advantages

- Capable of enduring rigorous driving conditions
- Highly resistant to corrosion
- Easily integrated with a concrete superstructure

Disadvantages

- Challenging to achieve precise cutoff.
- Transportation poses difficulties.
- Length of the pile cannot be easily adjusted once determined.
- Requires heavy and costly equipment for driving.
- Possibility of breakage or damage during handling and driving of piles.

Cast-in-Place Concrete Piles

Cast-in-situ, or cast-in-place, piles are constructed by creating a hole in the ground and subsequently filling it with concrete. These piles come in various types, patented by their manufacturers, and are widely used in construction. They can be categorized into two main groups: (a) cased and (b) uncased piles, with the possibility of both types having a pedestal at the bottom.

Cased piles include inserting a mandrel within a steel casing and using that to help drive the casing into the earth. The mandrel is removed and the casing is filled with concrete once the pile has reached the desired depth.

$$Q_{all} = A_s f_s + A_c f_c$$

Where A_s; is the cross sectional area of steel, A_c; cross sectional area of concrete, f_s; allowable stress of concrete, A_c; allowable stress of steel.

Advantages

- Comparatively inexpensive
- Permits inspection prior to concrete pouring
- Simple to extend

Disadvantages

- Challenging to splice after concrete placement
- Thin casings may suffer damage during the driving process.

Uncased piles are created by initially driving the casing to the desired depth and subsequently filling it with fresh concrete.

$$Q_{all} = A_c f_c$$

Advantages

- Initially cost-effective
- Can be completed at any elevation

Disadvantages

- Voids may form if concrete is poured too quickly.
- Challenging to splice after concreting.
- In soft soil, the hole's sides may collapse, exerting pressure on the concrete.

1.4.2.3 Timber Piles

Timber piles are tree trunks that have been carefully trimmed of branches and bark. Typically, their maximum length ranges from 10 to 20 meters. To be considered suitable for use as a pile, the timber must be straight, sound, and free of any defects. However, timber piles have limited capacity to withstand intense driving stress.

To protect the pile tip (bottom) from damage, steel shoes may be employed. Additionally, the driving process can potentially harm the tops of timber piles, leading to the crushing of wooden fibers, known as "brooming." To safeguard the top of the pile, a metal band or cap can be utilized.

$$Q_{all} = A_p f_w$$

$A_{p;}$ average area of cross section of timber, f_w; allowable stress of timber

Advantages

- Regular-sized timber piles are readily available
- An economical option for foundation needs.
- They are easy to install, with a low likelihood of damage during the process.
- After installation, timber pile footings can be cut off at any desired length.
- Moreover, if needed, timber piles can be easily removed or pulled out without much difficulty.

Disadvantages

- Longer lengths of piles may not always be readily available.
- Obtaining straight piles can be challenging when the required length is short.
- Driving piles becomes difficult when the soil strata are exceptionally hard.
- Splicing timber piles poses difficulties.
- Timber or wooden piles are not suitable for use as end-bearing piles.
- Ensuring the durability of timber piles requires special measures to be taken.

1.4.3 Types by Installation Process

1.4.3.1 Driven Piles

Prefabricated driven piles, also known as precast piles, are engineered elements made from materials such as timber, steel, or concrete. They are forcefully inserted into the ground using machinery through percussion, pressing, or vibration. This construction technique allows for swift implementation regardless of local ground conditions and offers excellent stability in soft soils. Nevertheless, it's important to note that this type of pile is not suitable for soils that contain hard obstructions, such as rocks.

Figure 6: Driven of Piles

1.4.3.2 Bored piles

Bored pile foundations, also known as drilled shafts or drilled pier foundations, are deep foundations supporting large structures like buildings and bridges. A cylindrical hole is drilled into the ground, filled with steel bars and concrete, offering robust support. Ideal for weak soil and heavy loads, they boast easy construction, high load capacity, and minimal noise. Though costlier and requiring specialized equipment, bored piles are favored for their adaptability, accommodating various soil types and installation angles. Overall, they provide a reliable and cost-effective solution for supporting substantial loads in challenging construction projects.

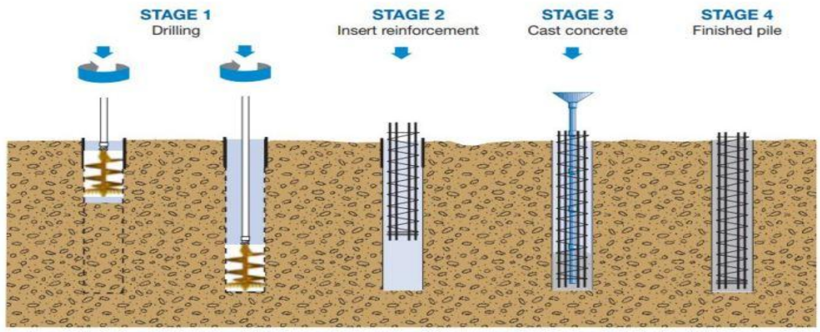


Figure 7: Bored Pile

1.4.3.3 Driven and cast-in-situ piles

Driven cast in-situ concrete piles are created by driving a closed-ended hollow steel or concrete casing into the ground, later filling it with concrete. The casing can remain as part of the pile or be extracted for future use as concrete is poured in. During withdrawal, a hammer compacts the concrete, ensuring solid contact with the soil. Caution must be exercised to avoid over-ramming or rapid casing removal, which could cause voids or necking in the upper part of the pile. To prevent this, high-quality concrete and gradual casing withdrawal are essential. These piles are cost-effective for sand, loose gravels, soft silts, and clays, especially in projects requiring numerous piles.

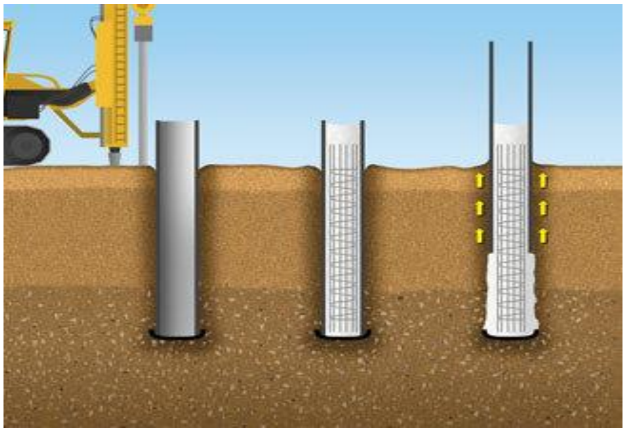


Figure 8: Driven cast-in-situ piles

1.4.3.4 Aggregate piles

Aggregate piles, or stone columns, utilize compacted aggregate to form the pile instead of concrete. A casing is inserted during boring, and aggregate is added in layers. As the casing is withdrawn, the layers are vibrated or compacted, dispersing the aggregate sideways into the surrounding soil, enhancing its bearing capacity.

Vibro-type aggregate piles are made using a vibrating casing, creating densely compacted columns from gravel or similar materials. The vibration densifies the granular soils around it, improving stability.

Geopier-type aggregate piles involve ramming aggregate into a casing, creating a dense bulb. This is done in stages as the casing is withdrawn, gradually densifying and strengthening the surrounding soil. These methods are valuable for enhancing ground support in construction projects.

1.5 Problem Statement

Given the increasing population and the need for high-rise structures, it becomes imperative to develop foundations that can effectively bear and transfer heavy loads to the soil, especially in confined spaces. Pile foundations play a pivotal role in future construction for several reasons. Firstly, as urbanization and population grow rapidly, taller and heavier structures demand robust foundation systems. Secondly, pile foundations offer effective solutions for challenging soil conditions like weak or expansive soils.

To meet evolving construction demands, it is crucial to enhance the load-bearing capacity of pile foundations by optimizing skin resistance. By improving the interface between the pile and surrounding soil, we aim to bolster the foundation system's overall capacity, ensuring greater structural stability and support for heavy loads. This research aims to devise innovative solutions to meet these demanding requirements effectively.

1.6 Objectives

The main purposes of this research are as under:

a. To compute expansion in concrete by adding admixtures.

b. To enhanced the capacity of pile foundation by skin resistance.

CHAPTER 2

Literature Review

2.1 Pile Foundation

Typically, the pile foundation is built to extend from the weak soil to the strong stratum. The pile capacity and the surrounding soil conditions are closely related. When installed in cohesion-free soil, the bored pile affects the surrounding soil by releasing deposits by replacing pile volume and using an existing pile casing. (Makki K & Al-Recaby (2017).

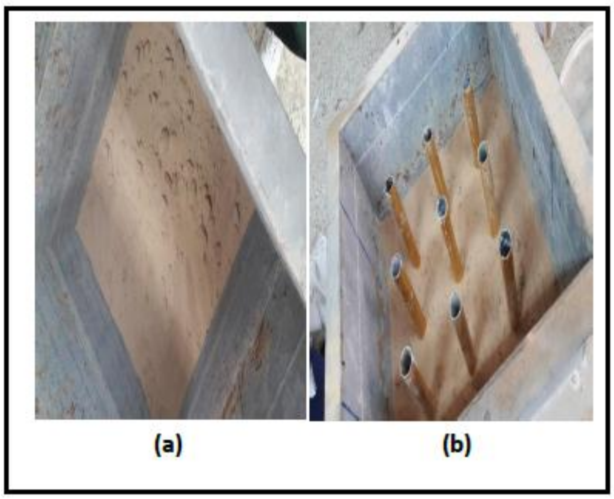


Plate 2. Steel box and pile layout

Plate 3. Pile layout and sand bed.

Figure 9: Pile foundation preparation sample

The fundamental issues in foundation procedures are settling and the soil's carrying capability. The greatest load that can be supported by the soil stratum is known as bearing capacity. We utilize shallow foundations when the soil is sturdy enough to support the entire weight that is being placed upon it. When hard soil strata are accessible at a depth where foundation construction is not prohibitively expensive, shallow foundations are typically used.

2.2 Admixtures

Admixtures are liquids or powders that are added to concrete based on calculations for the mix design in order to increase the qualities of the concrete in both the fresh and hardened states. There are also admixtures that prevent corrosion and encourage expansion. (Abhijeet, S. Gandage March-2023)

During binding, most common composites of cement shrink, primarily as an effect of water evaporation. The unwelcome occurrence of shrinkage can cause cracks to develop in buildings made of concrete. Among other factors, the type of cement and the conditions of concrete hardening affect how much shrinkage happens. It is possible to obtain expansive concretes, or those whose volume grows during setting and the first few days of hardening, as well as non-shrinkage concretes. Expansive cements or additives that increase the quantity of concrete are utilized for this purpose.

2.2.1 Aluminum Powder as additive

Aluminum powder is a fine, odorless, a silver-white to gray powder. This element is "Reactive Flammable". In the presence of air, moist aluminum powder could catch fire and generate combustible hydrogen gas. It is a "Combustible Dust" as well. Aluminum powder produces flammable hydrogen gas when it comes into presence of water, powerful acids, solid bases, or alcohols. With many inorganic and organic compounds, it can have serious or explosive effects. After brief exposure, aluminum powder appears to be non-toxic.

Use of Aluminum Powder in the concrete can cause expansion. Aluminum powder is the most widely used gas-liberating substance in concrete. Concrete pores between 0.1 and 1.0 mm in size develop when aluminum reacts with calcium hydroxide, which releases hydrogen (Justyna Kuziak et al. 2021).

2.2.2 Sodium Carbonate (Na2CO3) as additive

Sodium carbonate is an example of an inorganic chemical. Sodium carbonate is the more popular name for soda ash.

The sodium carbonate, often known as washing soda or soda ash, is the most important of all the heavy basic substances. One of its key benefits is that it is less dangerous to handle than sodium hydroxide due to its non-corrosive nature.

The analysis came to the conclusion that Na2CO3 causes piles to expand because the pile's volume grows, compressing the earth around it and raising shaft resistance, which in turn raises pile capacity. This implies that the design length or diameter of bored piles can be reduced, which would lower the cost and speed up the construction process (Makki K & Al-Recaby (2017).

2.3 Use of other expansive materials in the admixture

When bored piles were being built, an engineering characteristic test on cement milk was done utilizing expansive additives. Extensive additive combinations in a range of mixing ratios were created. Analysis was done on the porosity, compressive strength, frictional resistance stress, scanning electron microscopy pictures, segregation resistance, and economic viability. All specimens met or exceeded the compressive strength criterion (Hyeonggil Choi et al.).

The process of injecting cement slurry into pores at a high pressure and speed is known as "jet grouting," and it is frequently used to strengthen soil and increase watertightness.

2.4 Design of Pile Foundation

Determining whether or not piles must be used on the site is the first challenge the designer of a foundation must overcome. The use of piles is necessary in situations where scour is anticipated to happen, where potential excavation will take place near to the structure, where expansive or collapsible soils extend to a great depth, or when footings are unable to transmit inclined, horizontal, or uplift forces.

Due to the multiple uncertainties inherant in the analysis of pile foundations, it has become standard, and in many cases obligatory, to conduct a certain number of full-scale pile load tests at the site of increasingly substantial projects. The main objective of these tests is to experimentally verify that the pile's actual response to load, as demonstrated by its load-displacement relationships, corresponds to the response anticipated by the designer and that the actual ultimate load of the pile is equal to or greater than the computed ultimate load used as design principle for foundations. (S. Vesi Duk,2008).

Fig. 3: Samples of The Pile Model

Figure 10: Samples of the Pile Models

2.5 Effects of Expansive Additive on the bored piles

Because of its low noise, low vibration, and ability to come in a variety of sizes to accommodate various loading requirements and subsoil conditions, bored piles are frequently used to support heavily laden structures like high rise buildings and bridges. Numerous methods have been suggested to increase pile capacity. A novel method for boosting pile capacity that makes use of swelling concrete (Mohamed E. Elsaid et al. ,2020). Comparing ribbed bored piles to traditional straight-shafted bored piles, higher shaft capacity is known to be possible. The goal of the study is to determine whether adding ribs to a pile increases its overall capacity and to determine how this increased capacity is created.(Jay Gorasia and Andrew McNamara MSc, PhD (2016).

Figure 2. Types of additives. (a) High-polymer. (b) Red mud. (c) Metakaolin.

Figure 11: Types of additives

2.6 New Trends in the soil Stabilization

Three categories of problems—geoenvironmental, standardization, and optimization problems—were addressed about the efficient use of new trends in expanding soil stabilization. In order to make sure that expanding soil stabilisation is effective, techniques including predictive modelling and exploring methodologies such as reliability-based design optimisation, response surface methodology, dimensional analysis, and artificial intelligence technology were also presented (Chijioke Christopher Ikeagwuani, Donald Chimobi Nwonu (2018)

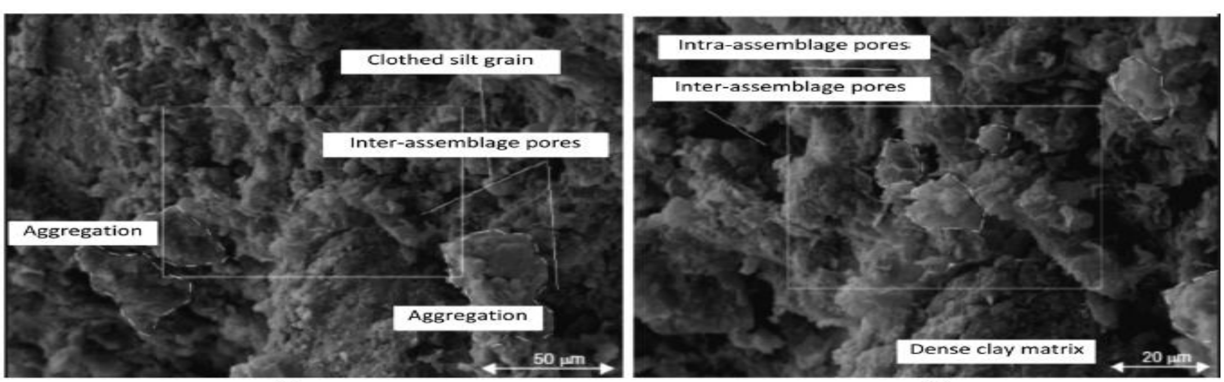


Figure 12: Soil Stabilization trends

2.7 Pile Skin Resistance

The primary factor in the total pile capacity is the pile skin resistance. Numerous studies have been done in this area, and it has been found that the soil's density, over-consolidation ratio, and compressibility are all important influences on the loss of frictional capacity. (S.M. Marandi & M.A. Karimzadeh, 2009).

2.8 Negative skin friction and settlement of piles

Shear tension develops at the interface where a pile and a soil move relative to one another. A push-load on the pile can force it downward into the earth or a pull-load might force it upward, causing the movement. ` The soil may also move relative to the pile when it settles or, in the case of swelling soils, when it moves upward relative to the pile. By definition, the direction of the shear is positive if the pile is moving downward, meaning that the shear tension created in the pile is upward. The produced shear stress is referred to be positive or negative depending on whether the pile is moving uphill or downward (Dr. Bengt H et al., 2005).

Several articles have described the size of the movement required for negative skin friction to arise. Negative skin friction might occur down to a depth of 18 meters with just a 35 mm settlement of the ground surface caused by a 3-meter-high surcharge placed around single piles. (Walker and Darvall,1973). According to measurements made at a close proximity to the pile (about 0.12 meters), negative skin friction was fully mobilized to a depth of about 25 meters after a relative displacement of around 5 mm. The relative displacement at a distance of 5 meters was roughly 8 mm (Bjerin, 1977)

2.9. Ways to Reduce Negative Skin Friction

Solutions like lengthening the pile or making it smaller in diameter may help when the design calculations suggest that the pile settling may be excessive. Solutions like increasing the pile section or the pile material's strength could help when calculations show that the structural capacity of the pile is insufficient. When these approaches are impractical or unaffordable, the negative skin friction can be decreased by coating the pile surfaces with bituminous coating or another viscous material prior to installation (Fellenius, 1975; 1979; and Clemente, 1981).

2.10 Effect of additive Percentage on Capacity of Piles

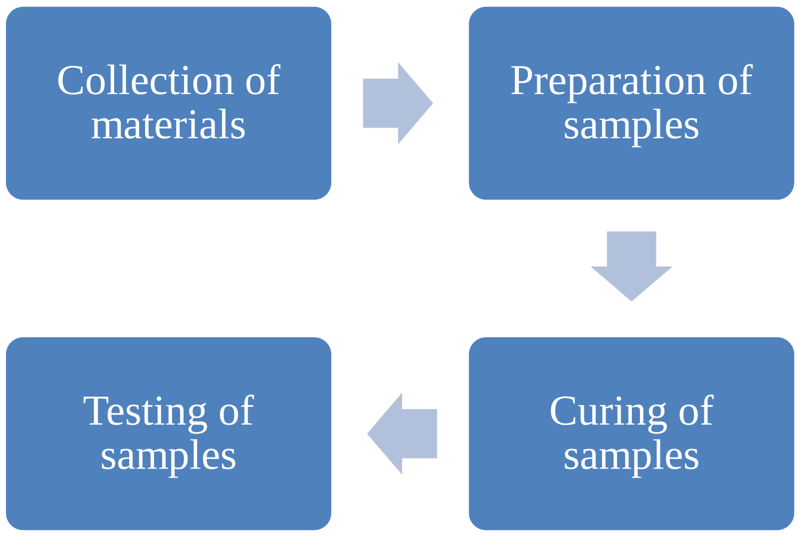
Length of pile, and diameter are design variables, that are used to achieve the required skin friction to support a bulding. By this the constructiom cost increases, So for the affordable construction, unit skin friction friction shoud be increased, by reducing pile length and diameter by using expansive additive in it, by which the friction angle at the interface between the soil and the concrete pile could be increased. (Makki K & Al Recaby)

CHAPTER 3

Methodology

3.1 Introduction

This chapter provides a concise explanation of the proposed methodology employed in this research project. A systematic step-by-step approach was taken to achieve the research objectives. The process involved selecting specific admixtures known to cause concrete expansion. Subsequently, various material samples were collected for laboratory testing, with a focus on observing expansion and conducting compression tests on these sample cubes.



3.2 Collection of materials

Concrete is a composite material that comprises several essential constituents, each serving a vital role in determining its properties and performance. The key constituents used in concrete include:

3.2.1 **Cement**: This serves as the binder that holds the concrete together, with Portland cement being the most widely used type in construction.

3.2.2 Aggregates:
Consisting of coarse and fine particles, aggregates constitute the major portion of the concrete. Coarse aggregates are typically made of gravel or crushed stone, while fine aggregates are commonly sourced from sand.

3.2.3 Water:
An essential component, water is mixed with cement to initiate the chemical reaction responsible for binding the concrete.

3.2.4 Admixtures:
These are optional additives that can be incorporated into the concrete mix to modify its properties, such as enhancing workability, reducing water content, or improving durability. Admixtures may be either chemical or mineral-based. In our research the admixtures we use are to cause expansion in concrete.

By carefully combining these constituents, along with an appropriate mix design and curing process, concrete can be tailored to exhibit a range of strengths, durability, and other specific characteristics, making it suitable for diverse construction applications

3.3 Preparation of Samples

3.3.1 Gradation of fine aggregate by sieve analysis

To select the most suitable type of sand, we need to consider its gradation, which refers to the distribution of particle sizes. Well-graded sand contains particles of various dimensions, enabling it to form a strong and compact structure compared to fine sand. Although fine sand can also create a compact structure, it requires more water when used in concrete, leading to a decrease in concrete strength. The degree of gradation is also known as the fineness modulus of sand, which helps in evaluating its particle size distribution. By assessing the gradation and fineness modulus, we can determine the optimal sand type to use in construction projects to ensure the desired concrete strength and performance.

3.3.1.1 Procedures

- Ensure that the sand sample is brought to an air-dried condition before proceeding with weighing and sieving.
- Measure precisely 500 grams of the sand sample.

- Arrange the sieves in descending order of size, placing the sieve with a 4.75mm opening at the top.

- Carefully pour the sand into the 4.75mm sieve and shake it for 10 minutes without applying any manual pressure to force the material through the sieve.

- After 10 minutes, stop the shaker and remove the sieve with a 4.75mm opening from the apparatus. Using a balance, weigh the particles retained on this sieve, and record this weight in the table.

- Measure the weight of particles retained in each sieve and also records these values in the table.

- Calculate the percentage of weight retained on each sieve.

- Determine the percentage of the weight that has passed through each sieve.

- Calculate the cumulative percent retained on each sieve.

- Finally, calculate the Fineness Modulus based on the values obtained from the cumulative percent retained.

Following these steps will allow us to assess the fineness modulus of the sand sample, which provides essential information about the particle size distribution and suitability of the sand for various construction purposes.

Fineness modulus of Fine aggregate

S.No	Sieve No	Retained weight (gm)	% Retained on sieve	% Passed weight	% cumulative
1	4	0	0	100	0
2	8	4	0.8	99.2	0.8
3	16	23	4.6	94.6	5.4
4	30	109	21.8	72.8	27.2
5	50	198	39.6	33.2	66.8
6	100	137	27.4	5.8	94.2
	Pan	29	5.8		

Fineness modulus = $$\frac{0 + 0.8 + 5.4 + 27.2 + 66.8 + 94.2}{100}$$

Fineness modulus = 1.944

3.3.2 Gradation of coarse aggregate by sieve analysis

Sieve analysis is employed to assess the particle size distribution of aggregates. When grading coarse aggregates, the process involves segregating them into distinct size fractions using the results of the sieve analysis. This method includes passing the aggregate through a sequence of sieves with progressively reducing openings, while measuring the quantity of material that remains on each sieve.

Procedure:

- Weigh 3000 grams of crush using a triple beam balance to ensure accuracy.
- Place the crush on the top sieve with a 1 ½ inch opening and vigorously shake it until no more grains can easily pass through.
- Record the weight of the retained crush in each sieve.
- Calculate the percentage of the weight retained on each sieve.
- Determine the percentage of weight that has passed through each sieve.
- In the next column, calculate the cumulative percentage retained. This represents the percentage of weight that would be retained if the crush were directly placed on that sieve. For the 1 ½ inch sieve, the value remains the same. However, for the 1-inch sieve, it would be the sum of the percentage retained by the 1 ½ inch sieve and the percentage retained by the 1-inch sieve. Similar calculations are done for other sieves, denoted as a1, a2, a3, and so on.

Fineness modulus of coarse aggregate

S.No	Sieve No	Retained weight (gm)	% Retained on sieve	% Passed weight	% cumulative
1	1 in	0	0	100	0
2	3/4 in	346	11.53333333	88.46666667	11.5333333
3	1/2 in	1834	61.13333333	27.33333333	72.6666667
4	3/8 in	641	21.36666667	5.966666667	94.0333333
5	#4	171	5.7	0.266666667	99.7333333
6	Pan	8	0.266666667		

Fineness modulus =
0+11.533+72.667+94.03
3+99.733/100

2.779666667

3.3.3 Casting of concrete cubes

Procedure:

- Ensure the mold surfaces are clean and apply grease to all molds for effective lubrication.
- Fill each mold with concrete in three layers.
- After each layer, compact the concrete thoroughly by applying 35 strokes using a tamping rod.
- Upon completing the compaction of the third layer, smoothen the top surface using a flat trowel.
- Allow the specimens to rest undisturbed for 24 hours.
- After 24 hours, carefully remove the specimens from the moulds.
- The next crucial step is to mark each specimen with the date of casting and assign a unique specimen number.

3.4 Curing of Samples

The curing of concrete cubes in a laboratory setting is a critical step to replicate real-world conditions and ensure precise testing of concrete strength and properties. This crucial process is conducted after casting the concrete cubes, preparing them for subsequent compressive strength tests.

3.5 Calculations for Preparation of Samples

<u>According to standard ASTM C-617</u>

Calculation for Cube:

1:2:4

1 + 2 + 4=7

Volume:

V= 6"x 6"x 6"

V= 216 inch cube

Wet Volume

V= 0.5' x 0.5' x 0.5'

V= 0.125 ft cube

Dry Volume = 1.54 x 0.125

= 0.1925 ft cube

Quantity of Cement

=1/7xWt of Cement

Weight = r x v

= 94 lb/ft^3 x 0.1925 ft^3

W = 18.095 lb

Quantity of Cement = 1/7x18.0951 lb

= 2.585 lb

= 1.173 kg

= 1173 gm

Quantity of Sand

=2/7xWeight of Sand

Weight = 110 lb/ft^3 x 0.1925 ft^3

=21.175 lb

=2/7 x 21.175 lb

=6.05 lb

=2.745 kg

W=2745 gm

Quantity of Coarse Aggregates

= 4/7xWeight

W= r x v

= 93642 lb/ft^3 x 0.1925 ft^3

=18.03 lb

Quantity of C.A = 4/7 x 18.03

= 10.3 lb

= 4.67 kg

= 4670 gm

Water Cement Ratio

= 0.5

= 0.5 x 1173

= 586.5 gm

Hence the required quantity for preparation of one Sample

Weight of Cement = 1173 gm

Weight of Sand = 2745 gm

Weight of C.A= 4670 gm

Weights Of Admixtures Required For A Sample On Different Ratio

We know that

Weight of Cement W=1173 gm

Sodium Carbonate:

5%

0.05x1173

= 58.65 gm

10%

0.10x1173

= 117.3 gm

15%

0.15x1173

=175.95 gm

20%

0.20 X 1173

= 234.6 gm

25%

0.25x1173

=293.3 gm

Aluminum Powder:

0.3%

0.003x1173

=3.52 gm

0.6%

0.006 x 1173

=7.04 gm

0.9%

0.009x1173

=10.6 gm

1.2%

0.012 x 1173

=14.07 gm

1.5%

0.015x1173

= 17.59 gm

3.6 Lab Work/ Experimental Work

3.6.1 Materials Collection

Cement, fine aggregate, coarse aggregate, water, are the main components of the concrete mix. by review we find out that aluminum powder and sodium can expand concrete so the admixtures we select aluminum powder and sodium carbonate.

Figure 13: Sand, Crush and Cement collected for preparation of sample

Figure 14: Sodium Carbonate and Aluminum Powder Samples

3.6.2 Preparation of Samples

The 1:2:4 was selected for the concrete mix and different proportion of admixtures were used to prepare the mix and that mix was casted in 6"X6"X6" cubes. The percentage of aluminum powder for mix are 0.3%, 0.6%, 0.9%, 1.2%, 1.5% and for of sodium carbonate was 5%, 10%, 15%, 20%, 25%.

Figure 15: Pouring of mixture in cube mould

Figure 16: Prepared Samples

Figure 17: Samples removed from cube moulds after 24-hours

3.6.3 Curing of Samples

After unmolding of samples from the cube we kept the samples in water tank for curing for twenty-eight (28) days.

Figure 18: Samples put in water tank for curing

3.6.4 Test on Samples

After curing of twenty-eight (28) days, we took the height reading to measure the change in height. The initial reading was 6” because cube has 6” height and compressive tests were performed on samples to check its compressive strength. Initially the samples without admixtures were measured but no change in the hight was observed. Then those samples were measured who have different percentage of admixtures and change in their heights were observed as shown in the below mentioned figure

Figure 19: Measuring height of sample

Figure 20: Measurement of height of different samples have admixtures (Change in the height observed)

Figure 21: Compressive strength test (Aluminum Powder)-Before applying load

Figure 22: Compressive strength test (Aluminum Powder)-after applying load

Figure 23: Compressive strength test (Sodium Carbonate)-Before applying load

Figure 24: Compressive strength test (Sodium Carbonate)-After applying load

CHAPTER-4

Results

4.1 Introduction

This research study aim is to increase the capacity of pile foundation by skin resistance in order to achieve our goal we add admixtures that is sodium carbonate and aluminum powder which cause expansion in concrete. The expansion in concrete will generate stress between the pile surface and surrounding soil which will increase shear strength between pile and soil.

Below are the results of our works which we have conducted for our research study.

4.2 Expansion Results

The admixture which we add in concrete mix caused the following expansion.

4.2.1 Aluminum Powder

Number of percentage (%)	Initial reading (mm)	Final Reading (mm)	Change in Height (mm)
0.3	150	151	1
0.3	150	151	1
0.3	150	152	2
0.6	150	152	2
0.6	150	153	3
0.6	150	152	2
0.9	150	153	3
0.9	150	153	3
0.9	150	153	3
1.2	150	152	2
1.2	150	153	3
1.2	150	153	3

1.5	150	153	3
1.5	150	153	3
1.5	150	154	4

Table 4.1: Expansion readings of Aluminum powder

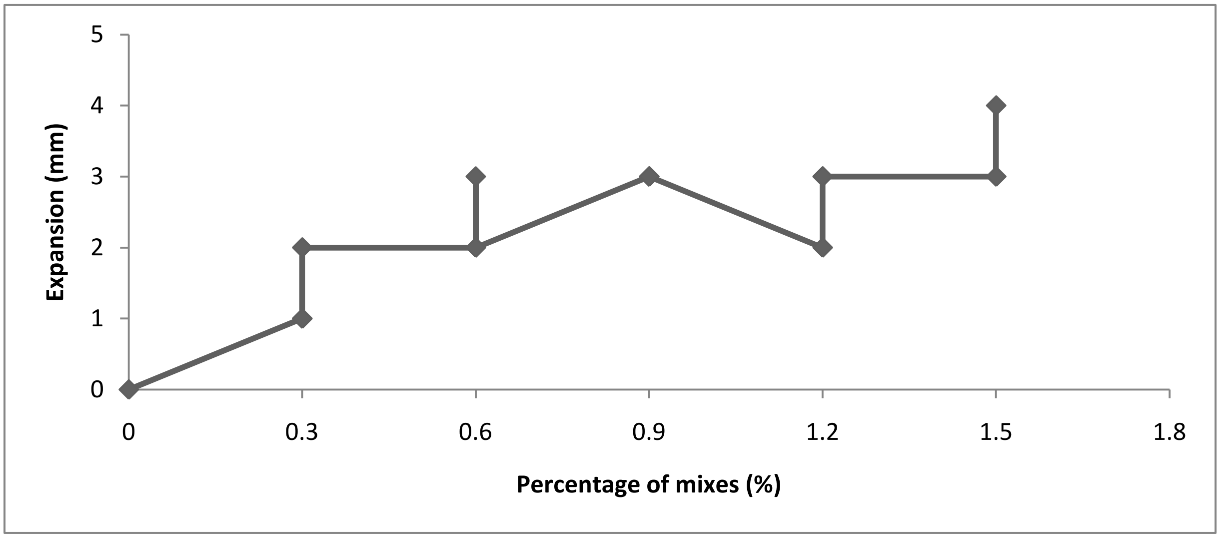


Figure 25: Aluminum Powder Expansion Graph

4.2.2 Sodium carbonate

Number of percentage(%)	Initial reading (mm)	Final Reading (mm)	Change in Height
5	150	150	0
5	150	150	0
5	150	150	0
10	150	151	1
10	150	151	1
10	150	151	1
15	150	152	2
15	150	151	1
15	150	152	2
20	150	152	2
20	150	152	2

20	150	153	3
25	150	152	2
25	150	153	3
25	150	153	3

Table 4.2: Expansion readings of Sodium Carbonate

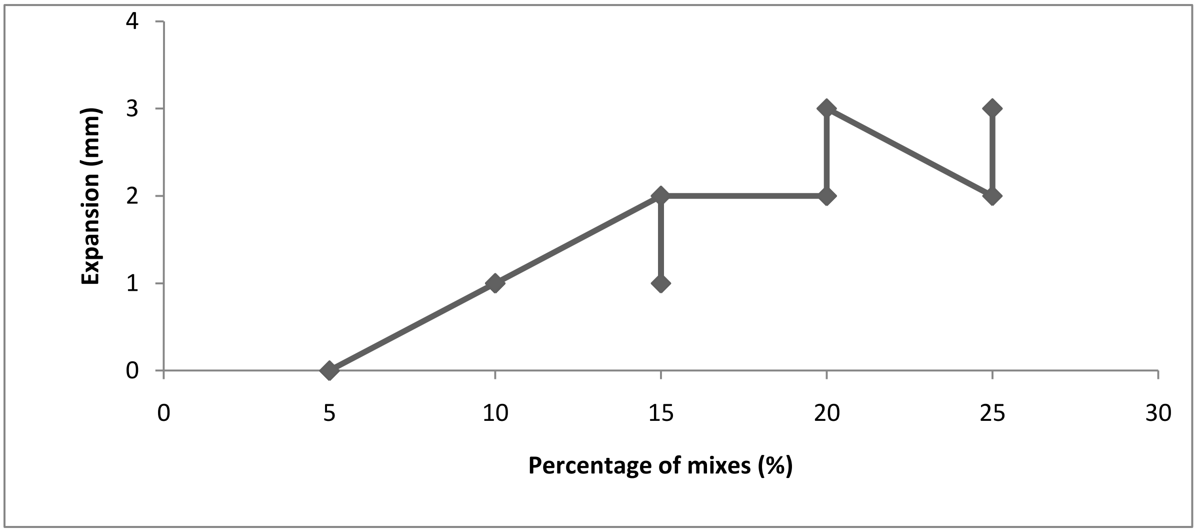


Figure 26: Sodium Carbonate Expansion Graph

4.2.3 Samples with no admixture

Number of percentage	Initial readings (mm)	Final Reading (mm)	Change in Height (mm)
0	150	150	0
0	150	150	0
0	150	150	0

4.3 Compressive Test results

Following are the results of compressive test of our cube samples

4.3.1 Compressive test of Aluminum powder

Percentage %	Area $(In)^2$	Load (lbs.)	Compressive Strength (psi)	Compressive Strength (Mpa)
0.3	36	110900	3080.55	21.23
0.3	36	119700	3325	22.92
0.3	36	123700	3436.11	23.69
0.6	36	135500	3763.88	25.95
0.6	36	90600	2516.66	17.35
0.6	36	101300	2813.88	19.45
0.9	36	132400	3677.77	25.35
0.9	36	114700	3186.11	21.96
0.9	36	125800	3494.44	24.09
1.2	36	144200	4005.55	27.61
1.2	36	149000	4138.88	28.53
1.2	36	147700	4102.77	28.28
1.5	36	160200	4450	30.68
1.5	36	108700	3019.44	20.81
1.5	36	112800	3133.33	21.60

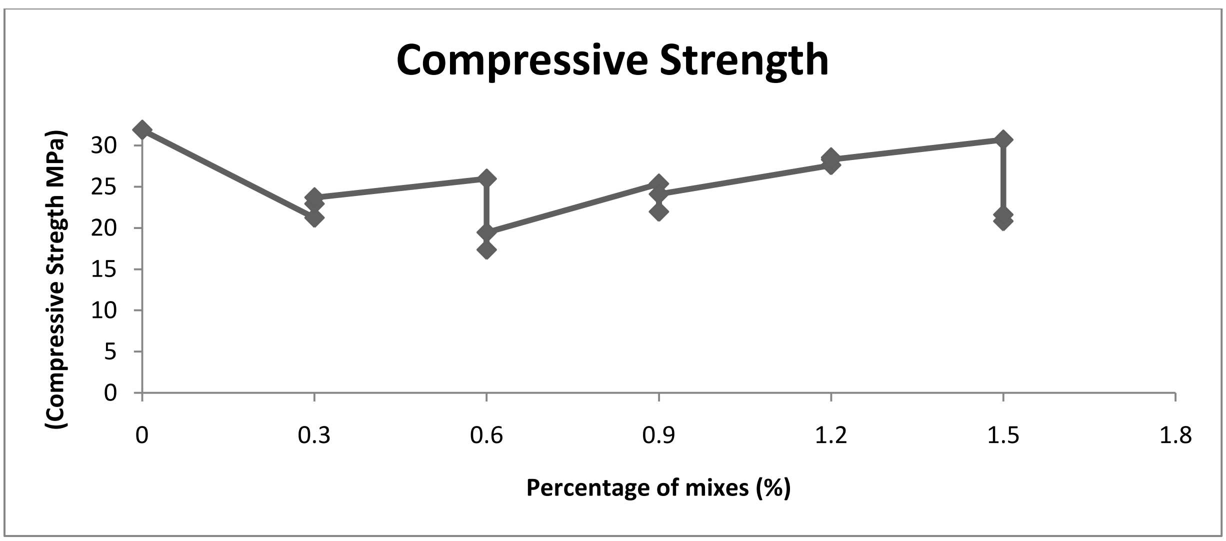


Figure 27: Aluminum Powder- Compressive Strength

4.3.2 Compressive test of Sodium Carbonate

Percentage %	Area $(In)^2$	Load (lbs.)	Compressive Strength (psi)	Compressive Strength (Mpa)
5	36	71200	1977.7	13.63
5	36	67000	1861.11	12.83
5	36	63900	1775	12.23
10	36	68400	1900	13.10
10	36	2600	722.22	4.97
10	36	75900	2108	14.53
15	36	65200	1811	12.48
15	36	51600	1433.33	9.88
15	36	65500	1819.44	12.54
20	36	53200	1477.77	10.18
20	36	54100	1502.77	10.36
20	36	65100	1808.33	12.46
25	36	45100	1252.77	8.63
25	36	39200	1088.88	7.50
25	36	55700	1547.22	10.66

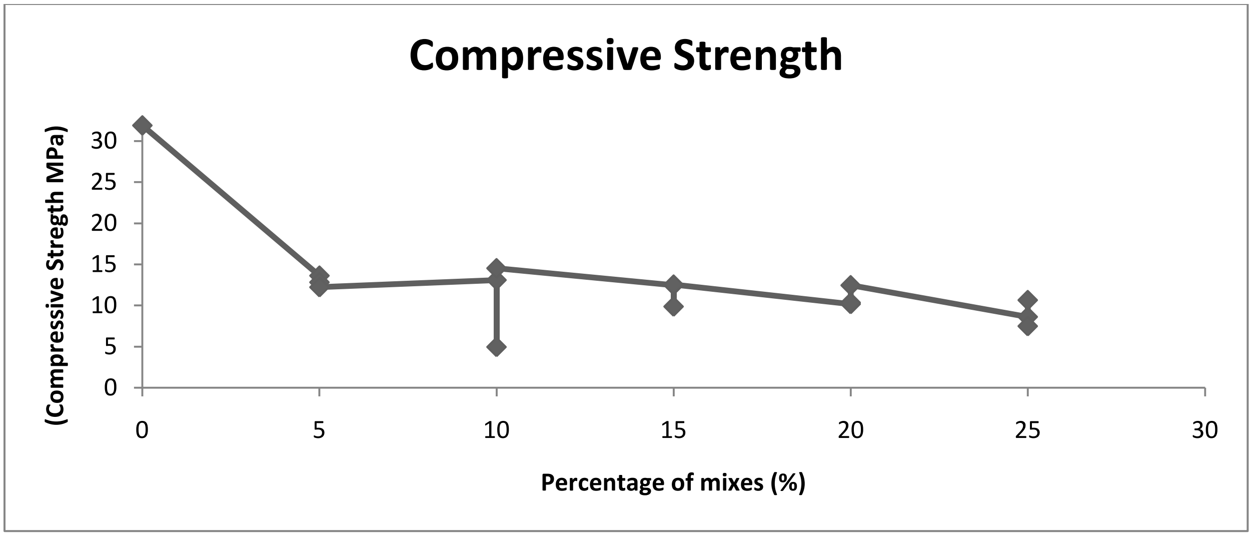


Figure 28: Sodium Carbonate- Compressive Strength

4.3.3 No Admixture Compressive strength

Percentage %	Area $(In)^2$	Load (lbs.)	Compressive Strength (psi)	Compressive Strength (Mpa)
0	36	126100	3502.77	24.15
0	36	166500	4625	31.88
0	36	137600	3822.22	26.35

4.4 Shear strength

The skin resistance for soil is measured by Mohr Coulomb law of shear strength.

$$T = \Delta\sigma n * tan\delta$$

Normal stress acting on a pile producing strain in sand surrounding the pile is given by equation.

$$\Delta\sigma n = E * \varepsilon$$

4.4.1 Aluminum Powder

Percent of admixture (%)	Initial Height (mm)	Final Height (mm)	Delta ΔH (mm)	Strain ε	Normal Stress $\Delta\sigma n$	Shear stress T
0.3	150	151	1	6.67E-06	100	55.78517
0.3	150	151	1	6.67E-06	100	55.78517
0.3	150	152	2	1.33E-05	200	111.5703
0.6	150	152	2	1.33E-05	200	111.5703
0.6	150	153	3	0.00002	300	167.3555
0.6	150	152	2	1.33E-05	200	111.5703
0.9	150	153	3	0.00002	300	167.3555
0.9	150	153	3	0.00002	300	167.3555
0.9	150	153	3	0.00002	300	167.3555
1.2	150	152	2	1.33E-05	200	111.5703
1.2	150	153	3	0.00002	300	167.3555
1.2	150	153	3	0.00002	300	167.3555
1.5	150	153	3	0.00002	300	167.3555
1.5	150	153	3	0.00002	300	167.3555
1.5	150	154	4	2.67E-05	400	223.1407

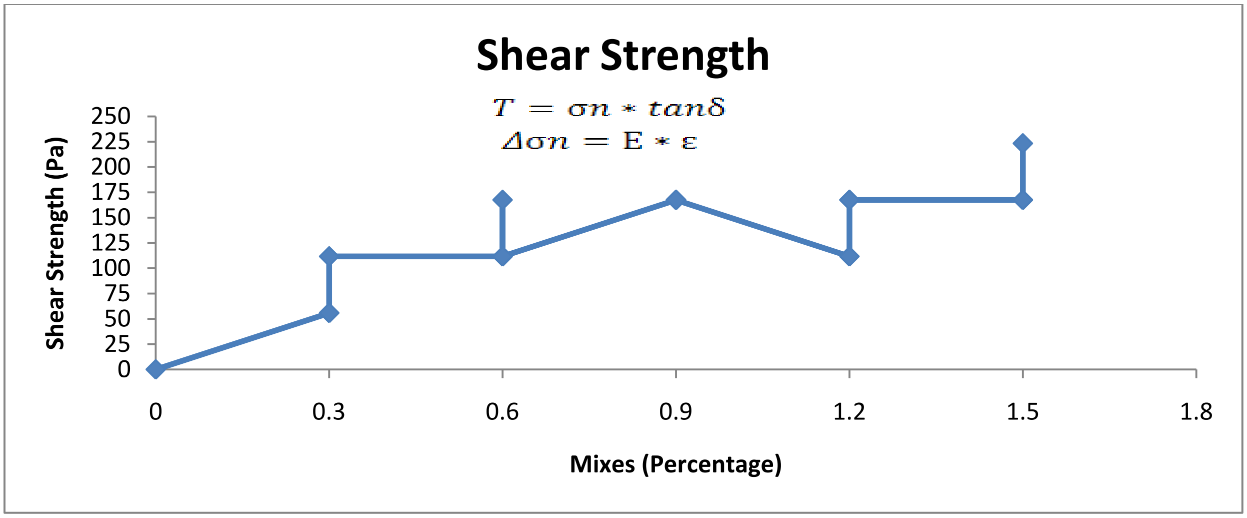


Figure 29: Aluminum Powder- Shear Strength

4.4.2 Sodium Carbonate

Percent of admixture (%)	Initial Height (mm)	Final Height (mm)	Delta ΔH (mm)	Strain ε	Normal Stress $\Delta\sigma n$	Shear stress T
5	150	150	0	0	0	0
5	150	150	0	0	0	0
5	150	150	0	0	0	0
10	150	151	1	6.67E-06	100	55.78517
10	150	151	1	6.67E-06	100	55.78517
10	150	151	1	6.67E-06	100	55.78517
15	150	152	2	1.33E-05	200	111.5703
15	150	151	1	6.67E-06	100	55.78517
15	150	152	2	1.33E-05	200	111.5703
20	150	152	2	1.33E-05	200	111.5703
20	150	152	2	1.33E-05	200	111.5703
20	150	153	3	0.00002	300	167.3555
25	150	152	2	1.33E-05	200	111.5703
25	150	153	3	0.00002	300	167.3555
25	150	153	3	0.00002	300	167.3555

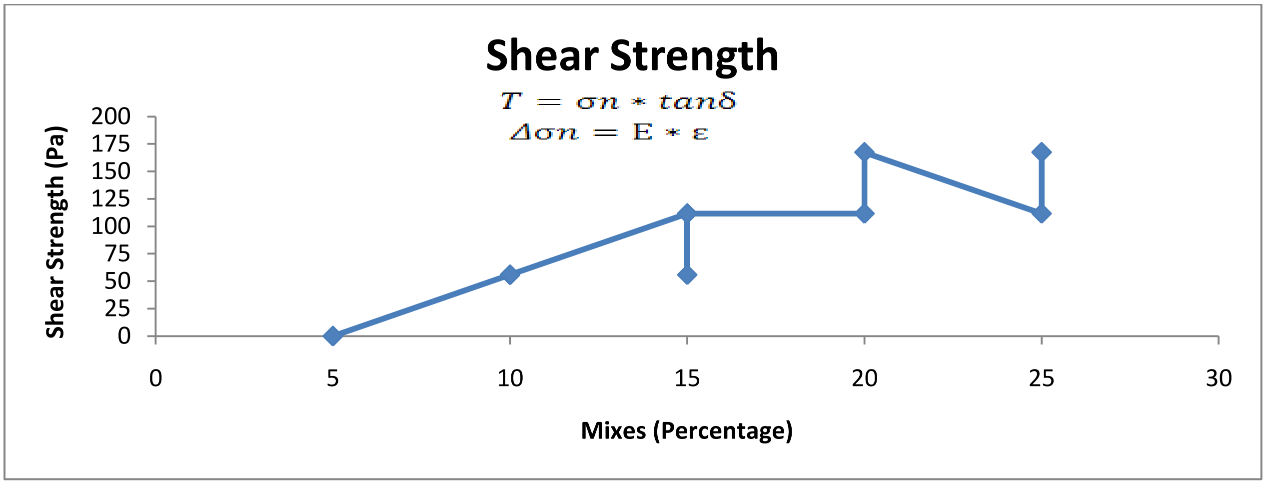


Figure 30: Sodium Carbonate- Shear Strength

4.4.3 with No Admixture

Percent of admixture (%)	Initial Height (mm)	Final Height (mm)	Delta ΔH (mm)	Strain ε	Normal Stress $\Delta\sigma n$	Shear stress T
0.3	150	150	0	0	0	0
0.3	150	150	0	0	0	0
0.3	150	150	0	0	0	0

CHAPTER- 5

Conclusion and Recommendation

5.1 Conclusion

The following is the conclusion which is drawn from the work that has been done.

No expansion was observed without adding admixture in the sample. Separate samples of Sodium carbonate and aluminum powder were prepared with different percentage of these admixtures. Resultantly, expansions of concrete in both the samples were observed.

Similarly, the samples were tested for compressive strength and it was observed that the compressive strength of aluminum powder samples was far better than the sodium carbonate samples. The aluminum powder also caused good expansion as compared to sodium carbonate.

5.2 Recommendations

Upon conclusion, it is recommended to use the aluminum powder as admixture in concrete for pile foundation for increasing the shear resistance between the pile surface and the soil. The aluminum powder has the capability to react with the cement to enhances the durability, workability, and reduces cracking and shrinkage.

Sustainable Development Goals

Goal 11 Sustainable Cities and Communities

Target 11.1 Access to adequate, safe, and affordable housing and upgrading slums

Safe and secure housing is the basic requirement for all human beings. In order to fulfill these requirements there is a need to construct the buildings having good foundations. Especially in those areas where the soil condition is not good and required to add the expansive additives in the concrete of foundation for safety against any unavoidable situation.

Goal 4 Quality Education

Target 4.4 Increasing the proportion of young individuals with suitable skills, such as technical and vocational skills for improved employment and businesses

Encourage geotechnical engineering innovation and research to look into novel ways to improve pile foundation skin resilience during building construction. An educational institution might work with business partners to conduct research and distribute findings through conferences and scholarly publications.

References

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