

DESIGN OF GEOSYNTHETIC REINFORCEMENT FOR SOIL STABILIZATION USING PLAXIS SOFTWARE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in
Civil Engineering

By

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**DEPARTMENT OF CIVIL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A++" by NAAC
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Agalya S (Register No:40200002), Vishnupriya S (Register No:40200016) who carried out the project entitled **"Design of Geosynthetic Reinforcement for soil Stabilization using Plaxis2D Software"** under our supervision from November 2023 to April 2024.


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DECLARATION

We Agalya S (Register No: 40200002), Vishnupriya S (Register No:40200016) here by declare that the Project Report entitled "Design of Geosynthetic Reinforcement for soil Stabilization using Plaxis2D software" done by us under the guidance of Dr. B. PRIYADHARSHINI is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Civil Engineering.

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ABSTRACT

This study investigates the application of geosynthetic reinforcement for soil stabilization and analysis using Plaxis2D software. The primary objectives encompass assessing the current stability conditions of the soil in the designated area, enhancing soil stability through the integration of geogrid materials, and analyzing the post-reinforcement behavior of the soil utilizing Plaxis2D software. The methodology involves conducting a comprehensive literature review to understand existing techniques and methodologies, followed by the selection of suitable geosynthetic material. Geogrids are used to support the contents of the soil matrix and help provide a strong material. Scientific tests such as gravity, particle size distribution, Atterberg limit and Proctor compression tests were carried out on soil samples to evaluate the performance of geosynthetic reinforcement. The soil capacity study was carried out using a measuring device consisting of a square steel tank of dimensions 610mmx490mmx490mm filled with sand and different layers of geogrid. The study exhibits the decrease in displacement of the soil with increase of geogrid layers. Subsequently, the soil's behavior is analyzed using Plaxis2d software, providing insights into the effectiveness of geosynthetic reinforcement. This study aims to contribute to the advancement of soil stabilization techniques and facilitate informed decision-making in geotechnical engineering practices.

TABLE OF CONTENTS

CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	x
1	INTRODUCTION	
	1.1 GENERAL	1
	1.2 SOIL STABILIZATION	2
	1.3 TYPES OF SOIL STABILIZATION	2
	1.4 GEOSYNTHETICS	6
	1.5 TYPES OF GEOSYNTHETIC MATERIAL	7
	1.6 GEOSYNTHETIC REINFORCEMENT FOR SOIL STABILIZATION	11
2	LITERATURE SURVEY	
	2.1 GENERAL	13
	2.2 REVIEW OF THE LITERATURE	19
	2.3 AIM OF THE STUDY	20
	2.4 OBJECTIVE OF THE STUDY	20
3	METHOD OF INVESTIGATION	
	3.1 METHODOLOGY	21
	3.2 SELECTION OF STUDY AREA	22
	3.3 COLLECTION OF SOIL SAMPLE	22
	3.4 SELECTION OF MATERIAL	23
	3.5 GEOGRID AS REINFORCING ELEMENT	24
	3.6 PROPERTIES OF GEOGRID	24

	3.7 SOIL STABILITY TESTS	24
	3.8 EXPERIMENTAL ANALYSIS	26
	3.9 SOFTWARE USED TO ANALYSE	27
4	RESULTS AND DISCUSSION	
	4.1 SOIL STABILITY TEST RESULTS	30
	4.2 PROCTOR COMPACTION TEST	31
	4.3 EXPERIMENTAL RESULTS AND DISCUSSIONS	32
	4.4 RESULTS FROM PLAXIS2D	36
5	CONCLUSION	
	5.1 SUMMARY	39
	5.2 CONCLUSION	40
	5.3 FUTURE SCOPE OF STUDY	40
	REFERENCES	42

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
1.1	VIBRO COMPACTION	3
1.2	GEOSYNTHETIC MATERIALS	6
1.3	NATURAL GEOSYNTHETIC MATERIAL	7
3.1	METHODOLOGY	21
3.2	STUDY AREA-SEMMANCHERI	22
3.3	COLLECTION OF SOIL SAMPLE	23
3.4	GEOGRID MATERIAL	23
3.5	SIEVE ANALYSIS	25
3.6	PROCTOR COMPACTION TEST	26
3.7	SCHEMATIC DIAGRAM OF STEEL TANK	27
3.8	FABRICATED STEEL TANK	27
3.9	MODEL WITHOUT GEOGRID	28
3.10	MODEL WITH ONE LAYER OF GEOGRID	28
3.11	MODEL WITH TWO LAYERS OF GEOGRID	29
3.12	MODEL WITH THREE LAYERS OF GEOGRID	29
4.1	PARTICLE SIZE DISTRIBUTION CURVE	30
4.2	DRY DENSITY WITHOUT GEOGRID	31
4.3	DRY DENSITY WITH GEOGRID	32
4.4	COMPARISON GRAPH	32
4.5	DISPLACEMENT WITHOUT GEOGRID	33

4.6	DISPLACEMENT WITH ONE LAYER OF GEOGRID	34
4.7	DISPLACEMENT WITH TWO LAYERS OF GEOGRID	34
4.8	DISPLACEMENT WITH THREE LAYERS OF GEOGRID	35
4.9	COMPARISON GRAPH	35
4.10	DISPLACEMENT AT DIFFERENT POINTS FOR VARIOUS LOAD WITHOUT REINFORCEMENT	36
4.11	DISPLACEMENT AT DIFFERENT POINTS FOR VARIOUS LOAD WITH REINFORCEMENT	37
4.12	STRESS IN GRID POINTS FOR VARIOUS LOAD	37
4.13	STRAIN IN GRID POINTS FOR VARIOUS LOAD	38

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
1.1	TYPES OF ARTIFICIAL GEOSYNTHETIC MATERIAL	8
3.1	PROPERTIES OF GEOGRID	24
4.1	LABORATORY TEST RESULTS	30

CHAPTER 1

INTRODUCTION

1.1 GENERAL

A developing country like India, with a large geographical area and a large population, needs a comprehensive infrastructure. Road and building network. Land is used everywhere, from ordinary houses to skyscrapers, from bridges to airports, from village roads to highways. Almost all engineering buildings are on different terrain levels. Soil can be defined as material consisting of rock, sand, silt and clay. It occurs as a result of gradual cracking or breaking of rock due to natural processes, including rock cracking under stress from expansion or contraction resulting from temperature change.

Weather and climate are caused by chemical changes that occur as water, oxygen and carbon dioxide gradually mix with minerals in rocks and break down into sand, silt and soil. Soil transported by wind, water, and ice forms many soil types, such as those found in river deltas, sand dunes, and glaciers. As in different climatic regions, temperature, precipitation and drainage are important factors in soil formation. Different irrigation methods produce different soils from the same original rock formation. Soils in India are divided into 6 main groups: alluvial soils, marine soils, sandy and later sandy soils, expansive soils, dunes and rocky sediments.

When construction encounters soft soil, it is necessary to pay for the improvement of the soil, such as solidification of the soil. Ground stabilization improves its strength, durability, etc. It is the process of improving the physical properties of the soil by mixing or blending it to increase it. It comes with attachments. Many methods are used in soil stabilization: cementitious soil stabilization, calcareous soil stabilization, asphalt soil stabilization, chemical stabilization and external stabilization technologies, namely geotextile and geosynthetic fiber soil stabilization. Geosynthetics are synthetic materials made from various polymers and can be woven or non-woven. They are used to improve the characteristics of the land and provide a good opportunity for financial use of civil engineering.

1.2 SOIL STABILIZATION

Soil stabilization is a geotechnical engineering technique. It involves improving the soil strength, durability, and its overall performance. The primary goal of soil stabilization is to transform unstable or problematic soils into a more reliable and structurally sound foundation for construction and infrastructure projects.

This process typically involves addition of various materials like cement, lime, fly ash, or geosynthetics, to the soil, resulting in increased load-bearing capacity, reduced settlement, improved resistance to erosion, and enhanced overall stability. Soil stabilization is essential for ensuring the long-term integrity and safety of civil engineering structures like roads, embankments, retaining walls, and foundations.

1.3 TYPES OF SOIL STABILIZATION

There are three broad types of soil stabilization:

- i. Biological soil stabilization
- ii. Physical soil stabilization
- iii. Chemical soil stabilization

Biological soil stabilization

Biological soil stabilization involves employing natural processes, particularly the growth of vegetation, to enhance soil stability and prevent erosion. This method harnesses the inherent properties of plant roots and their interactions with soil to create a stable environment.

Physical soil stabilization

Physical soil stabilization involves improving the soil stability and strength by modifying the physical properties of soil. This method focuses on altering characteristics such as particle size distribution, compaction, porosity, and interparticle bonding. Various techniques are employed to achieve physical soil stabilization.

1.1.1 TYPES OF PHYSICAL SOIL STABILIZATION

(i) *Compaction*: Compaction is a method used to increase the density of soil by mechanical means, usually using heavy machinery such as vibratory rollers or compactors. Compaction increases soil density and stability by reducing voids within the soil. This technique is particularly effective on granular soils such as sand and gravel.

(ii) *Vibro compaction*: Vibro compaction is a special compaction technique that uses vibrating probes to compact loose, granular soil. It is often used to improve the bearing capacity of foundations, especially in areas with loose or reclaimed soil.

(iii) *Dynamic compaction*: Repeatedly dropping a heavy weight from a height onto the ground is known as dynamic compaction. The impact energy generated during this process compresses and compacts the soil. Dynamic compaction is particularly useful for improving the stability of loose or saturated soils.

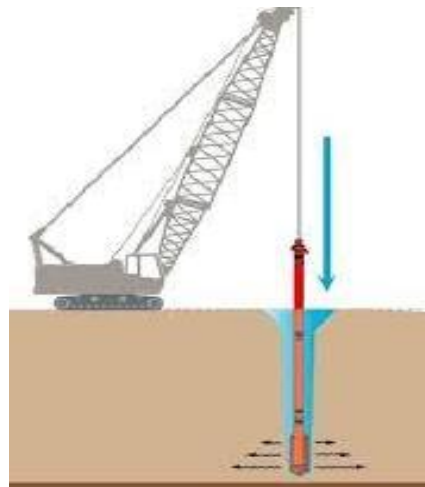


Fig 1.1 Vibro compaction

(iv) *Grading and Slope Modification*: Adjusting the shape and slope of the ground surface can improve stability and drainage. This technique aids in redistributing loads and mitigating erosion risks.

(v) *Tilling and Mixing*: Soil tilling or mixing enhances its uniformity and reduces property variations. Commonly utilized in agriculture, this method prepares soil for planting crops.

(vi) *Roller Compacted Concrete (RCC)*: RCC comprises a blend of concrete and soil compacted in layers using heavy rollers. It furnishes a robust and lasting surface, suitable for applications like dams, roads, and parking lots.

(vii) *Earth Reinforcement*: Employing natural or synthetic materials to fortify the mechanical properties of soil. This may involve utilizing plant roots for biological reinforcement or integrating geosynthetic materials such as geotextiles or geogrids for enhanced soil strength.

(viii) *Deep Soil Mixing*: This involves injecting a binder material, often cement or lime, into the soil while continuously mixing it to form columns of stabilized soil. These columns bolster soil strength and reduce settlement, commonly utilized in foundation construction.

CHEMICAL SOIL STABILIZATION

Chemical soil stabilization can be achieved through the use of conventional chemicals and non-chemicals. The difference between two groups of additives lies in the presence of existing additives compared to newly developed ones. Traditional stabilizers, such as lime, cement, and fly ash, are mostly calcium. When exposed to water, they undergo short-term and long-term chemical changes that lead to complete healing of the soil matrix. This improvement includes reduced swelling, increased shear strength, and stronger resistance to the effects of wetting and drying.

1.2.2 TYPES OF CHEMICAL SOIL STABILIZATION

- i. *Lime Stabilization*: Lime is usually mixed with the soil in the form of quicklime (calcium oxide) or slaked lime (calcium hydroxide), which reduces plasticity, increases cohesion and increases workability. It also reduces swelling and

increases the bearing capacity of the soil, which is especially important for clay soils.

- ii. *Cement Stabilization:* Cement is amalgamated with soil to produce a soil-cement amalgam, heightening the soil's resilience, diminishing permeability, and bolstering its resistance to erosion. Soil-cement finds widespread application in road construction and serves as a foundational material for pavements.
- iii. *Bitumen Stabilization:* Bituminous materials, such as asphalt or bitumen emulsions, are integrated into soil to enhance its robustness and water repellency. Widely utilized in road construction, this method is especially advantageous in regions with elevated moisture levels.
- iv. *Fly Ash Stabilization:* Fly ash, a byproduct of coal combustion, serves as a soil stabilizer by augmenting its pozzolanic reactivity, curbing plasticity, and enhancing long-term strength. It is often combined with lime or cement for optimal results.
- v. *Polymer Stabilization:* Soil-stabilizing polymers are introduced to enhance soil strength and mitigate erosion by binding soil particles and refining mechanical properties. Commonly employed in landscaping and erosion control endeavors.
- vi. *Sodium Silicate Stabilization:* Sodium silicate, or water glass, is mixed with specific soils to bolster stability and diminish swell potential, particularly effective with expansive clay soils.
- vii. *Salt Stabilization:* Salts like calcium chloride or sodium chloride can be infused into soils to ameliorate compaction properties, frequently utilized for temporary stabilization during construction activities.
- viii. *Electro-Osmosis:* Electro-osmosis entails applying an electrical current to soil, prompting water and ions to migrate through soil particles, thereby enhancing strength and diminishing settlement. Valuable particularly in soft, saturated soils.

- ix. *Enzyme Stabilization:* Enzymes are introduced to degrade organic matter in soil, refining its properties and stability, often employed in agricultural contexts.

1.4 GEOSYNTHETICS

Geosynthetics serve as crucial components within engineering systems and structures, designed to fulfill diverse objectives. Typically crafted from polymeric materials, these products combine "geo," representing the Earth or soil, with "synthetics," indicative of the synthetic or polymer-based composition. Geosynthetics play a pivotal role in enhancing soil stability. They encompass a variety of materials tailored for specific functions such as reinforcement, filtration, separation, drainage, and water barrier applications. Widely utilized in soil-centric construction projects across civil engineering domains, geosynthetics find extensive use in roads, railways, dams, hydraulic works, retaining walls, canals, marine structures, foundations, embankments, and more.

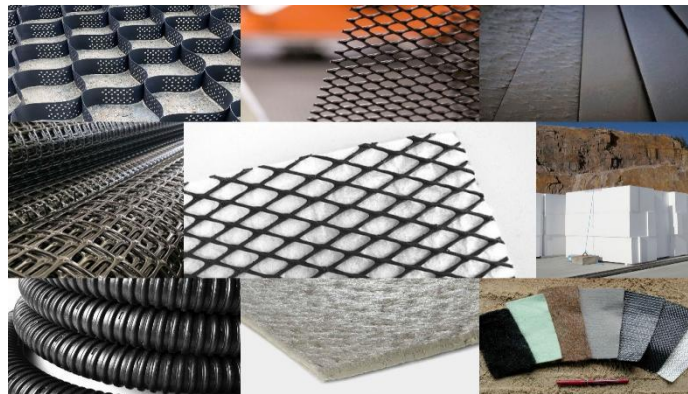


Fig 1. 2 Geosynthetic Materials

1.5 TYPES OF GEOSYNTHETIC MATERIALS

Geosynthetic material is classified into two types they are,

1. Natural Geosynthetic material
2. Artificial Geosynthetic material

1.5.1 NATURAL GEOSYNTHETIC MATERIAL

Natural geosynthetic materials are relatively uncommon compared to synthetic geosynthetics, but they can serve similar functions in geotechnical and environmental engineering applications. They are,

- 1.Coconut Coir
- 2.Jute
- 3.Bamboo



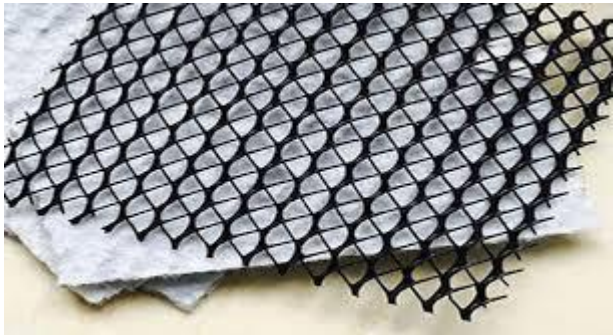
Fig 1.3 Natural Geosynthetic Material

1.5.2 ARTIFICIAL GEOSYNTHETIC MATERIAL

Artificial geosynthetic materials, also known as synthetic geosynthetics. It is man-made materials specifically designed for various geotechnical and civil engineering applications. These materials are engineered to provide specific functions and properties to improve the performance and stability of soils and structures. Here are some common types of artificial geosynthetic materials,

TABLE 1.1 TYPES OF ARTIFICIAL GEOSYNTHETIC MATERIAL

TYPES	DESCRIPTION
 <i>Geotextiles</i>	Geotextiles are synthetic materials made from polymers such as polypropylene, polyester or polyethylene. They come in woven, non-woven, or knitted forms.
 <i>Geogrids</i>	Geogrids are synthetic grids or mesh-like materials made from polymers like polyethylene, polypropylene, or polyester. They are employed primarily for soil reinforcement and stabilization.
	Geomembrane is a waterproof sheet or liner containing synthetic materials such as high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinyl chloride (PVC)) and EPDM Rubber (EPDM).

Geomembranes	
 Geonets	Geonets are open mesh-like materials made of synthetic polymers often used in liquid and visible applications.
 Geosynthetic clay liners	Geosynthetic clay liner consists of two layers of non-woven geotextile with a layer of sodium bentonite powder sandwiched between. Two layers of geotextile are stitched together using a stitching technique to create a perfect balance with internal shear resistance.
 Geofoams	Geofoam is a block or plate created by expanding polystyrene foam to create a dense, dense structure., inflatable battery. Known for their lightweight nature, they exhibit durability even under harsh environmental conditions.



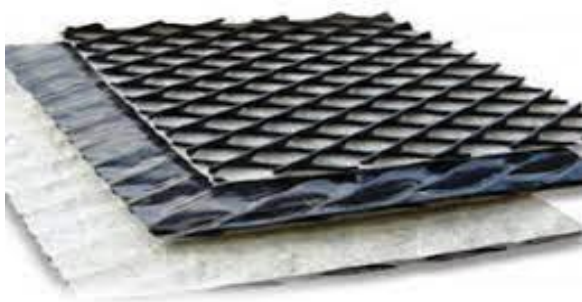
Geocells

Geocells or cellular insulation systems are pulled from ultrasonically welded HDPE strips and can be expanded on site to form a honeycomb pattern. The cells are filled with dense optional soil materials bounded by the cell walls, and the compound develops a rigid or semi-rigid structure..



Geopipes

Geopipes are polymer pipes designed with either perforated or solid walls, serving the purpose of draining gases and liquids. In certain applications, these pipes are enveloped with a geotextile filter for enhanced filtration capabilities.



Geocomposites

Geocomposites are specialized geosynthetics formed by combining two or more distinct types of geosynthetics. Examples include combinations like geonet-geotextile, geogrid-geotextile, and geomembrane-geonet.

1.6 GEOSYNTHETIC REINFORCEMENT FOR SOIL STABILIZATION

Geosynthetic reinforcement for soil stabilization refers to the use of synthetic materials, known as geosynthetics, within soil structures to improve their mechanical properties and overall stability. These geosynthetics, which can include materials like geogrids, geotextiles, and geocells, are strategically placed within or on the soil to enhance its load-bearing capacity, reduce settlement, and control erosion. This technique is employed in civil engineering and construction projects to mitigate soil-related challenges and ensure the longevity and performance of structures such as retaining walls, embankments, roadways, and slopes. Geosynthetic reinforcement is a versatile and effective method that helps optimize soil behavior and promotes sustainable and cost-effective solutions in geotechnical engineering.

1.6.1 EFFECTS OF GEOSYNTHETIC REINFORCEMENT IN SOIL STABILIZATION

Geosynthetic reinforcement plays an important role in improving the soil stability and various structures in geotechnical and civil engineering applications. Here are the key effects and improvements in stability that result from geosynthetic reinforcement

i. Slope Stability:

Geosynthetic reinforcement is often used to increase the stability of slopes and embankments. They reduce the risk of slope collapse and landslides by distributing the load more evenly. This increased stability is particularly important in road construction, where slope failure can lead to road closure and safety.

ii. Stabilization of Soft Soils:

Geosynthetics can stabilize soils that are not suitable for construction. These materials provide reinforcement, increasing the load-carrying capacity and stability of the soil, allowing the formation of complex soils.

iii. Prevention of Soil Erosion:

Geosynthetic reinforcements are used to prevent soil erosion caused by wind, rain and water. This increases site stability and prevents soil erosion over time.

iv. *Reduced Settlement:*

Geosynthetic reinforcement can reduce soil settlement under loads, helping to maintain the stability and long-term performance of structures and foundations.

v. *Enhanced Safety:*

By improving the stability of soil and structures, geosynthetic reinforcements enhance safety for both construction workers and the public. This is particularly important in projects involving critical infrastructure like roads, bridges, and dams.

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

The following major research project has been taken from international journals as reference to analyze the concepts for the project.

2.2 REVIEW OF THE LITERATURES

Meenakshi Singh et al (2022) investigated the use of three different geosynthetics for supporting different subgrade soils to improve the California Transport Rate (CBR). The main purpose of this study is to investigate the location of the geosynthetic reinforcement layer in the subgrade thickness, a subject that has not received sufficient attention in previous studies. The benefits of integrating geosynthetic layers into non-uniform structures are not limited to efficiency and durability, but also include construction performance and budget [23]. The use of geosynthetics as support materials in the construction and construction of uneven roads emerged in the 1970s and led to a number of experimental and numerical studies shown in the paper. With the successful application of geosynthetic materials in road engineering, many types of geosynthetic materials have been produced worldwide and the market is constantly expanding.

Shuwan et al., 2022 studied the deformation characteristics of geosynthetic soil (GRS) and settlement walls, highlighting their importance in engineering design when encountering different conditions. This study presents an experimental model to examine the deformation and damage behavior of GRS walls with and without internal constraint under different conditions. Through analysis and measurement of parameters such as strength, vertical movement of geosynthetic materials and lateral deformation of the cover plate, this study demonstrates the effective control of settlement of the GRS wall during construction and in different situations. The results show the importance of the stress state of the coating in controlling the GRS wall; This demonstrates the potential solution of the coating and material geosynthetic effect. To aid understanding and design, this study presents two analysis methods based on

elastic cable theory to predict strains and stresses in GRS walls with and without side restraints on the outside. This description provides a simple method to evaluate the GRS behavior of the wall and may be useful in developing a design process for this structure.

Cuelho et al., 2017 examined the current use of geogrids and geotextiles to stabilize weak subgrade seepage in construction. Applications for subgrade safety include temporary transportation, low-volume roads, and low-impact sidewalks. This study included the design, handling and monitoring of all test sections to compare the performance of various geosynthetics used for subgrade stabilization and determine which materials were most relevant to performance. The test sections were constructed using twelve different geosynthetics, including various geogrids and geotextiles. Additionally, various test methods have been developed to evaluate the effects of subgrade performance, base layer thickness, and the presence of geosynthetics on performance. Although geotextile materials show good performance in terms of material stability, it is difficult to determine the characteristics of their performance due to the small number of sections, and tests and evaluations are not sufficient for improvement. Using longitudinal rutting as the key performance factor and performing horizontal analysis, it was determined that the stiffness of the geogrid connection had the best correlation with operating conditions. Using this understanding, the design equation associated with the Giroud-Han method was modified to include the importance of geogrid joint stiffness as the initial geosynthetic property, replacing the geogrid span stability modulus.

Unnam Rajesh et al. 2016 discussed the advantages of geosynthetic reinforcement at the interface between the foundation and subgrade soil and the advantages of preventing truck-induced stress at the affected interface. Geogrids exhibit elastoplastic behavior, increasing their elastic structure and allowing them to respond quickly to data requests. This feature prevents slippage from occurring during short-term impact loads, thus fully mobilizing the tensile capacity of the geogrid. Additionally, geogrids help improve the dynamic damping properties of hardened soil compared to unhardened soil. This improvement is achieved by the energy absorbed

by the geogrid itself and the friction generated during dynamic loading. CBR tests were carried out in the laboratory on soil samples with and without geogrid reinforcement. For all tests performed on geogrid-hardened samples, a layer of geogrid was placed at mid-height of the soil in the mould. The samples were placed in the CBR mold, keeping the moisture content and density (determined in the compression test) at optimum levels. To improve the interaction between soil and geogrid, the supporting material is placed on a thin layer of sand.

Paravita Sri Wulandaria et al., 2015 conducted a study on the design of geotextile reinforced embankments regarding the need to meet the required safety and displacement properties. Previous studies have investigated the use of geotextile reinforcement in soft soils. Qasim et al. Determining the safe backfill height on soft soil foundations using different geotextile sizes to support the ground was examined.

Paravita Sri Wulandaria et al., 2015 studied that the design of geotextile reinforced embankment should have the necessary safety and flexibility. There are few studies on the use of geotextile reinforcement in soft soils. Qasim et al. For backfill construction on soft soil foundations, geotextiles of different sizes are used to support the soil and provide safe height. Siavoshnia et al. The effect of the number of geotextile layers, geotextile hardness and geotextile length was investigated. Vahi et al. Horizontal and vertical stresses as well as horizontal and shear displacements of the filled geotextile reinforced backfill surface were examined. The aim of this study is to determine the best tensile strength of geotextiles as filling reinforcement, taking into account safety and location permission. Stability analysis of the filler was carried out using the finite element method using PLAXIS version 8.2. To determine the effective tensile strength of geotextiles as filler reinforcement, the tensile strength of geotextile reinforcement varies between 100 and 1000 kN/m. Use PLAXIS 2D to analyze the stability of the infill using the finite element method. The Mohr-Coulomb model is used as a simple preliminary analysis of the problem under consideration. The water test and sand test were modeled as flowing water, while all clay soils were modeled as unirrigated. Three types of sequential modeling were performed in this study. First, the stability of the set without applying force is analyzed. The second model is to consider

the stability of the backfill model to determine the length of geotextile reinforcement. The final step is to examine the stability of the backfill support structure at different geotextile reinforced tensile strength.

Vashi et al. The analysis focuses on horizontal and vertical stress and horizontal and shear displacements for the façade fill reinforced with geotextiles in the backfill soil. The aim of this study is to determine the optimum tensile strength of infill geotextile reinforcement, taking into account safety and allowable release. The finite element method and PLAXIS version 8.2 software were used to analyze the stability of the infill. The tensile strength of geotextile reinforcement varies from 100 to 1000 kN/m to determine the strength. Preliminary analysis was performed using the Mohr-Coulomb model; The embankment and sand pad were modeled under undrained conditions, and the clay foundation was modeled under undrained conditions. Three types of modeling were carried out: verifying the stability of unstable fillers, determining the geotextile hardening length, and examining the stability of fillers with different geotextile hardening tensile strength.

Jian-Feng Chen et al., 2014 evaluated the 2D connection and hydraulic finite element (FE) model of a very high built-up reinforced earth retaining wall (RSW) with a height of 7.6 m. Thick clay. The effects of elongation, reinforcement, and stiffness on the stability support of RSW were further investigated using the test model. The results show that extending the bottom stiffening layer can increase the stability of RSW on soft soil. In addition, less base layer is needed to continue the strengthening and hardening reinforcement, thus maintaining the stability of the structure. There is an upper limit in strength and stiffness for a length of steel extension; Beyond the above limit, the increase in strength and hardness becomes less stable.

Haggard et al. (2014) examined the limitations of modeling geocells as boxes, highlighting the importance of capturing their curvature. They added that representing the geocell as a box would increase the stress at the corners and lead to erroneous results. The curvature of the honeycomb structure in the geocell provides uneven stress across its boundary, a feature found in commercial geocells. The proposed models solve the curvature problem, increase the accuracy of the results and contribute to the

advancement of numerical simulations of geocells. Information obtained from this study can aid in the numerical simulation of various geotechnical problems, including geocells. In their study, the real shape of the geocell was modeled by determining its real curvature, and two different models were used to actually simulate the soil and geocell material. To validate their numerical model, plate load tests were performed on a geocell-reinforced sand bed and the results were compared with the 1-g test model using FLAC3D software. Sample sizes match bench testing and geocell material is consistent with experimental studies. The model was validated and used to analyze the effects of various geocell properties, including geocell modulus, height, pocket size, and friction angle, on bed performance.

Siavoshania et al. (2010) investigated the use of geosynthetics (using synthetic materials) in land use. They identified a unique family of geosynthetics that includes geotextiles, geogrids, geomembranes, and geocomposites. Geotextiles are created by knitting synthetic fibers into easily porous materials or intertwining them into woven and non-woven structures. Geogrids are plastics that form an open network structure. Geotextiles and geogrids are often used as additional materials for soil improvement and have the advantages of corrosion resistance, low strength and easy prevention of large deformations. These features make it ideal for additional off-road use. Due to the increasing use of geotextiles in fills, this article aims to investigate the suitability of finite element methods for the analysis of soft soils as well as fills. The first step is to create the geometry of the model, which includes the contours of the foundation soil, such as fill height, slope, crest width and thickness of the soft soil layer. Filling materials and underlying soil are then provided. For examination purposes, a model with a length of 5 m, a crest width of 10 m and a slope of 1:1.5 (V:H) was placed on 4 m thick soft clay. Because the model is symmetrical about the centerline, only half of the infill is included in the analysis. The analysis was performed using PLAXIS 2D software version 7.2.

Ling Zhang et al. (2010) studied ground improvement using geocells, a technique widely used in many areas of geotechnical engineering. Their research proposed a model for the foundation of geocell-supported embankments and a simple self-assessment capability based on the analysis of the strength of the geocell system

in the embankment. The proposed model and calculation method include the "vertical stress effect" and "membrane effect" of geocell reinforcement. It has been validated by testing and comparing with the Koerner method. The results show that the results obtained from this model are in good agreement with the experimental results, especially better than the Koerner method for the large root contract. Studies have also shown that placing geocells in a stone pad can increase the capacity of the soft material. Loads from the fill deflect the geocell reinforcements, creating additional tensile forces. The vertical component of the tensile forces reduces the height of the subbase soil, thus reducing vertical deformation and increasing the bearing capacity of the subbase soil. Additionally, as the rut depth increases, the deformed shape of the geocell reinforcement strengthens the effect by creating additional tensile forces due to the membrane effect.

2.3 INFERENCE FROM THE LITERATURES

[1] The application of geosynthetic materials in soil solidification has changed the previous soil solidification model, reduced the solidification cost, reduced the pollution caused by the old soil solidification method, and offered people a good life.

[2] Geosynthetics increase the bearing capacity of the subgrade soil and serve as a stability alternative.

[3] Geogrids and geotextiles are geosynthetic materials commonly used in road structures to stabilize foundations and subsoil layers.

[4] The utilization of geogrids as reinforcement provides enhanced interface resistance compared to geotextiles, owing to their interlocking mechanism.

[5] Geotextiles are widely used to improve the performance and durability of highways while reducing construction costs.

[6] Geotextiles have many uses, including soil stabilization, erosion control, drainage, and supporting asphalt and concrete.

[7] Geotextile reinforced CBR of ground soil the improvement in strength can reduce the thickness of the coating, thus the construction cost can be achieved.

[8] PLAXIS 2D software was used to analyze the stability of the embankment using the finite element method.

[9] Geotextiles also help increase the bending stiffness of the base layer, thus reducing the maximum vertical load on the ground. subbase.

[10] Geotextiles can also be used as additional material in asphalt pavements to reduce cracks.

2.4 AIM OF THE STUDY

Comparative study was done for the stabilization of clay soil using geogrid fibre and reinforcement by PLAXIS software.

2.5 OBJECTIVE OF THE STUDY

- 1.To examine the existing stability condition of soil in our study area.
- 2.To do experimental investigation on the effect of geosynthetic reinforcement.
- 3.To compare the amount of displacement with respect to varying geogrid layers.
- 4.To analyse the stability of the soil using Plaxis2D software.

CHAPTER 3

METHOD OF INVESTIGATION

3.1 METHODOLOGY

The methodology of the experimental study is shown in the below fig 3.1.

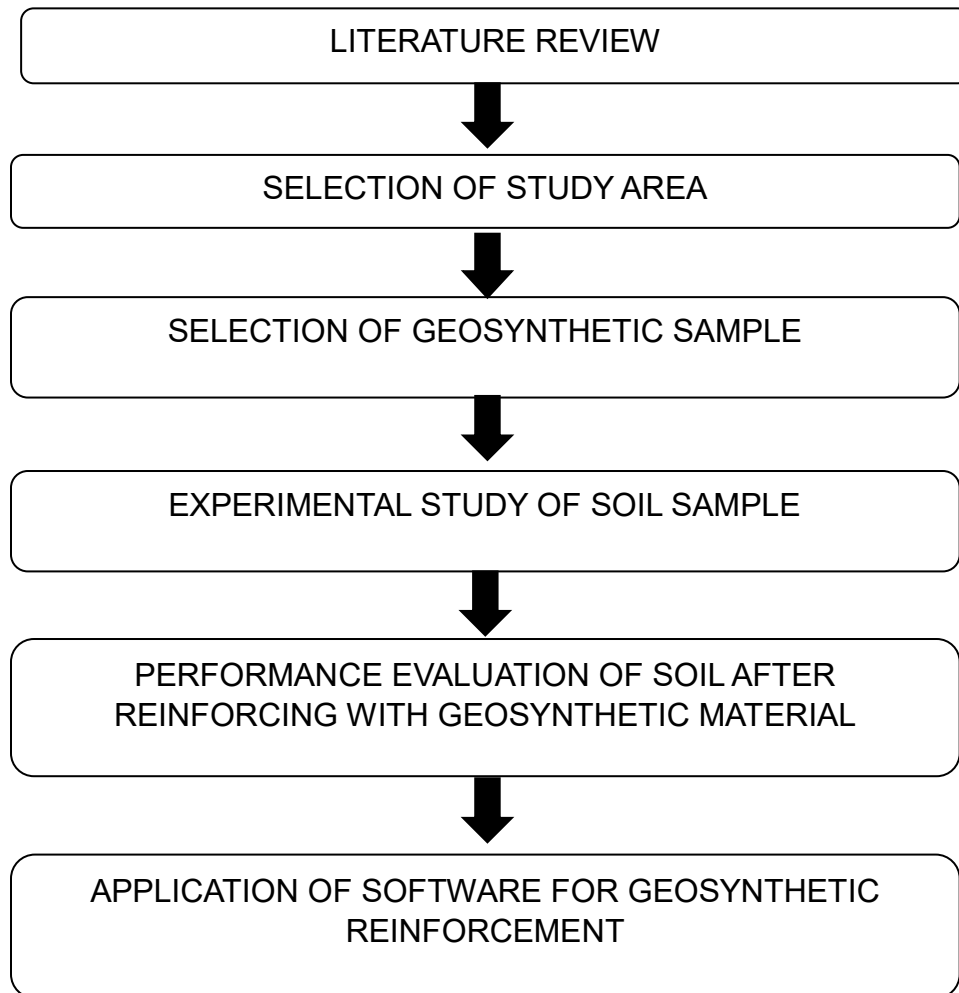


Fig 3.1 Methodology flow chart

3.2 SELECTION OF STUDY AREA

The study area of this present study is Semmancheri, which is situated in Kanchipuram District, Tamil Nadu with 12.860143 Latitude and 80.227225 Longitude. Semmancheri is a locality in the southern part of Chennai, India. The soil type in this area is predominantly clayey soil. Clay soils have fine particles and can be highly cohesive when wet, but they shrink and crack when dry. It leads to issues like soil erosion, landslides, and foundation problems in construction. Stabilization is often required to prevent excessive swelling and shrinking, making them suitable for foundations, roads, and other structures. Proper stabilization measures, such as compaction or the addition of stabilizing agents, may be required to improve its stability.

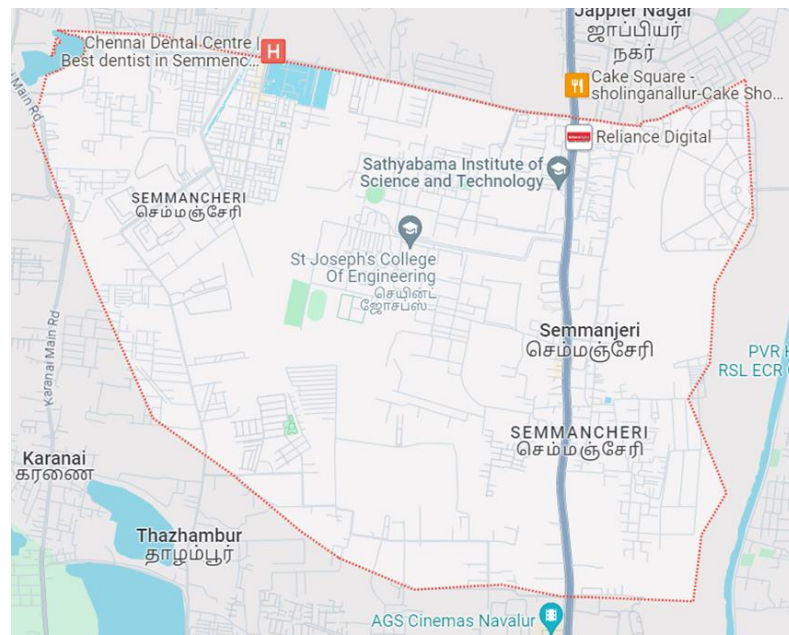


Fig 3.2 Study area - Semmancheri

3.3 COLLECTION OF SOIL SAMPLE

Clay sample were collected from Sathyabama Institute of science and Technology, Jeppiar nagar, Semmancheri. Soil sample collected was in the form of very large pieces of clay. It was broken down manually and was sieved in 425 micron and 4.75 mm sieve to perform the tests given in the fig 3.3.

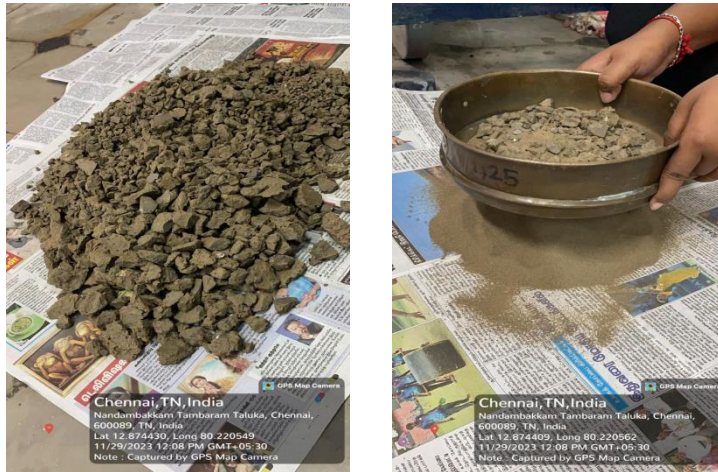


Fig 3.3 Collection of Soil Sample

3.4 SELECTION OF MATERIAL

Geogrid is a geosynthetic material used to support and stabilize soil in civil engineering and construction projects. It is usually made of polymer materials such as polyethylene, polypropylene or polyester, which form a mesh-like structure. Geogrids are used in many applications such as construction, retaining walls, backfill and slope stabilization. They work by distributing the load over a larger area, thus reducing the stress of the soil and increasing its load-bearing capacity.



Fig 3.4 Geogrid Material

3.5 GEOGRID AS REINFORCING ELEMENT

Geogrids serve as a reinforcement component within the soil matrix, enhancing structural integrity. They must effectively transfer their strength to the soil they reinforce, maintaining this strength to maximize effectiveness, and facilitating water passage while filtering out fine materials that could compromise soil stability. Therefore, the main performance criteria of geogrid reinforcement include retention strength, elongation, tearing and quality. Geogrids perform many functions such as insulation, screening, reinforcement, protection and drainage. They are usually made of polypropylene or polyester material.

3.6 PROPERTIES OF GEOGRID

The properties of geogrid material are given in the table 3.1

Table 3.1 Properties of Geogrid

PROPERTY	SPECIFICATION
Aperture Size(mm)	40x40
Material Composition	High-density Polyethylene
Thickness(mm)	2
Maximum Tensile Strength(kN/m)	40
Tensile Strength at 5% elongation	32
Load capacity(tons/m ²)	350

3.7 SOIL STABILITY TESTS

Soil stability testing is performed to evaluate the engineering properties and stability properties of soil. These tests are important for many geotechnical engineering applications, including foundation design, slope stability assessment, and construction management. Some soil stability tests are given below.

3.7.1 SPECIFIC GRAVITY TEST

The specific gravity of soil is an important feature that provides valuable information about the composition and characteristics of the soil. Soil which is passing through 4.75mm sieve is used for this test.

3.7.2 PARTICLE SIZE DETERMINATION (SIEVE ANALYSIS)

Sieve analysis is a method for determining the size of soil samples by measuring the number of soil samples. The material is collected in sieves with different pore sizes. The process involves placing the sample on a series of sieves arranged in size order as shown in Figure 3.5. When the sieves vibrate, the sample is separated into corresponding sieves according to size. Then, the grain size distribution is determined by measuring the weight of the material collected on each sieve.



Fig 3.5 Sieve analysis

3.7.3 PROCTOR COMPACTION TEST

Proctor Compression Test is a standard technique used to determine particle size. The maximum weight for a soil type can be achieved by controlling compaction and moisture content. This test is widely used in laboratories and is used as a basis for placing rammed earth in a variety of engineering applications such as embankments, pavements, and structural fills. Engineers compare field compacted fill density measurements with results from the Proctor test to measure the density of finished soil.



Fig 3.6 Proctor compaction test

3.8 EXPERIMENTAL STUDY

Laboratory studies were carried out to verify the previously mentioned model and calculation method. This study also aims to investigate the effect of geogrid hardening on increasing the load-bearing capacity of clay. Four tests were performed for comparison: (1) without soil reinforced with geogrid, (2) with soil reinforced with one layer of geogrid, (3) with soil reinforced with two layers of geogrid, (4) soil reinforced with three layers of geogrid. Soil reinforced with geogrid. . For the load test of the sand bed, a steel plate with a diameter of 400 mm and a thickness of 10 mm was placed on the embankment. The experimental setup uses a square steel tank placed under the container and filled with soft clay. The internal dimensions of the tank are 610 mm x 490 mm x 490 mm. In addition, a 6 mm thick acrylic glass sheet was fixed to the front of the tank so that the sand reinforcement system could be seen. The loading plate was centered inside the tank to minimize the effect of size on the test. Hydraulic jacks welded to the reaction system are used to provide additional load. The load was gradually increased at a constant rate, starting with a gradual load of 1 kN and then increments of 1 kN. Surface solubility is measured using a micrometer placed on a steel

plate. Figure 3.7 depicts the schematic diagram of the steel tank, while Figure 3.8 illustrates the fabricated steel tank.

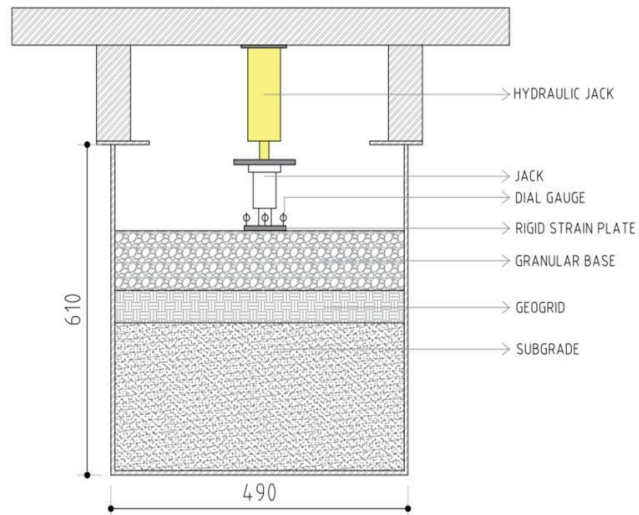


Fig 3.7 Schematic diagram of Steel Tank



Fig 3.8 Fabricated steel tank

3.9 SOFTWARE USED TO ANALYSE: PLAXIS SOFTWARE

PLAXIS is a well-known and widely used finite element analysis (FEA) software package designed for geotechnical engineering applications. Developed by Bentley Software, this software is used by geotechnical engineers, civil engineers and geologists to analyze and design various geotechnical structures and soil-structure interactions. PLAXIS includes advanced functionality for modeling and analysis of additional geosynthetic materials such as retaining walls, embankments, reinforced concrete and foundations. Below is the modeling of the tank using PLAXIS software. Figure 3.9 shows a tank model without a geogrid layer. One-, two- and three-layer geogrid models are shown in Figures 3.10, 3.11 and 3.12, respectively.

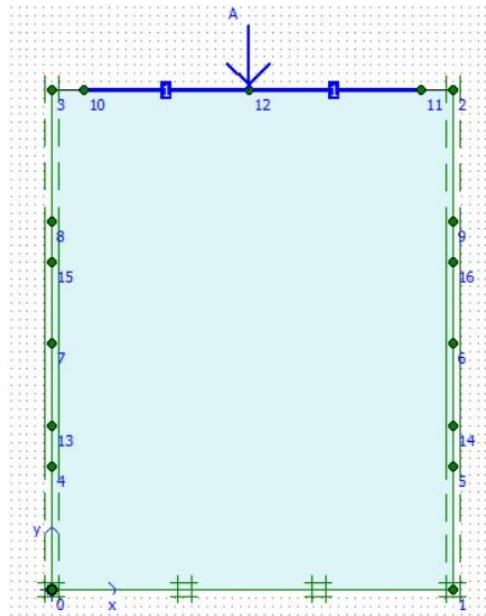


Fig 3.9 Model without Geogrid

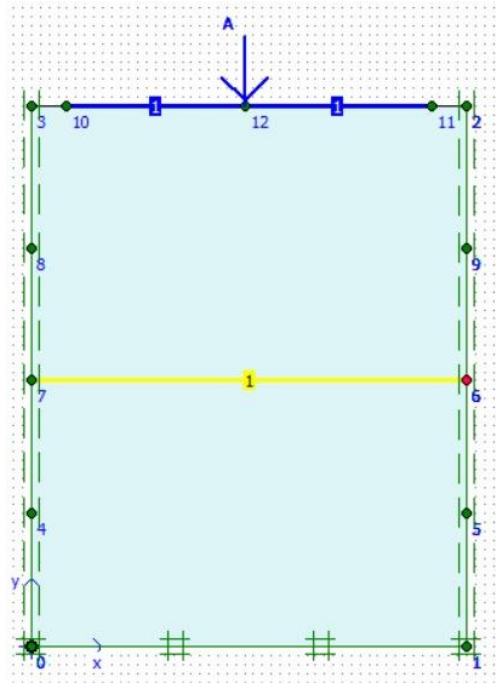


Fig 3.10 Model with one layer of geogrid

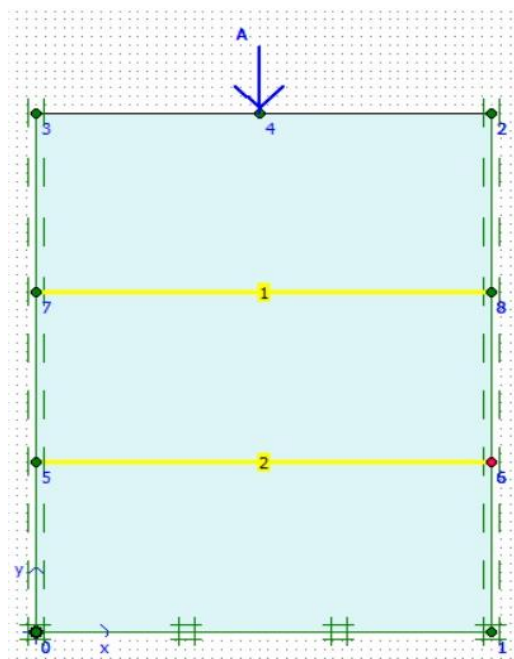


Fig 3.11 Model with two layers of geogrid

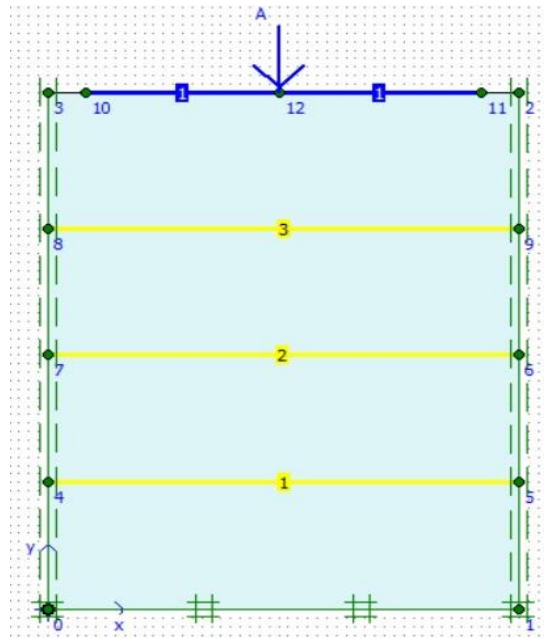


Fig 3.12 Model with three layers of geogrid

CHAPTER 4

RESULTS AND DISCUSSION

4.1 SOIL STABILITY TEST RESULTS

Soil stability tests such as gravity, particle size, Atterberg limit and pressure tests have been carried out and the results are shown below,

Table 4.1 Laboratory test results

S.NO	LABORATORY TEST	RESULTS
1	Specific Gravity	2.64
2	Particle Size Distribution	$C_u = 3.39$ $C_c = 1.12$
3	Liquid Limit	63%
4	Plastic Limit	17.42%
5	Compaction Test	Max. dry unit weight $= 1.85 \text{g/cm}^3$ Optimum water content $= 14\%$

From table 4.1, Since the specific gravity of the soil sample is 2.64, the soil is classified as organoclay. When fine clay changes between different phases, its moisture content is determined by the liquid limit and plastic limit.

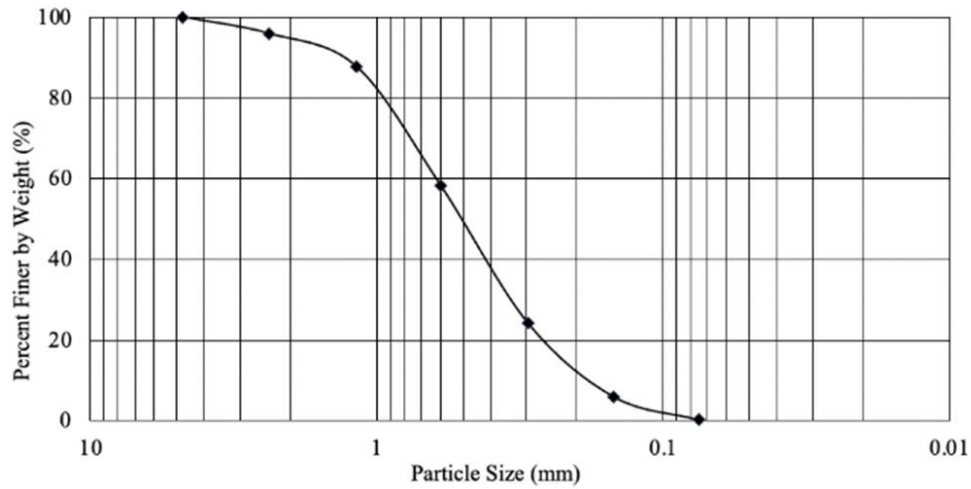


Fig 4.1 Particle size distribution curve

From the graph Fig 4.4 we find that $D_{10} = 0.18$, $D_{30} = 0.35$, $D_{60} = 0.61$, hence the uniformity coefficient $C_u = D_{60}/D_{10} = 3.39$, the coefficient of gradation $C_c = (D_{30}^2) / (D_{60}/D_{10}) = 1.12$, So, according to the classification, when C_u is below 4, it is classified as poor soil.

4.2 PROCTOR COMPACTION TEST

The Proctor compression test is used to determine the maximum dry density of soil with and without geogrid reinforcement. Figure 4.4 shows the density comparison with and without geogrid. The maximum dry density with geogrid is 1.9 g/cm³. The maximum dry weight without geogrid is 1.85 g/cm³. Therefore, soil with geogrid has higher density than soil without geogrid.

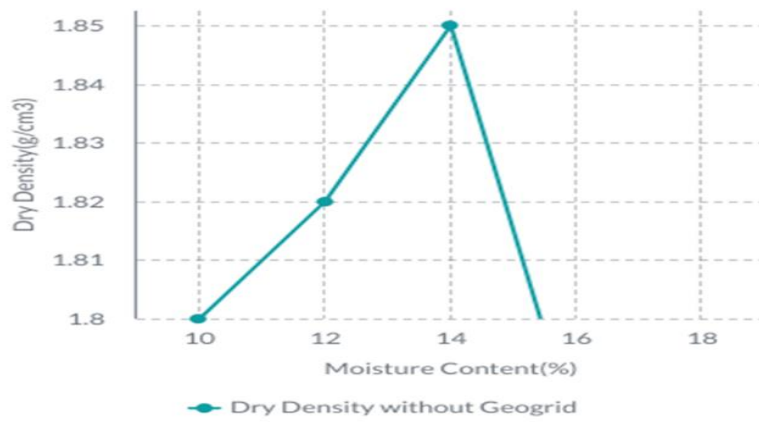


Fig 4.2 Dry density without geogrid

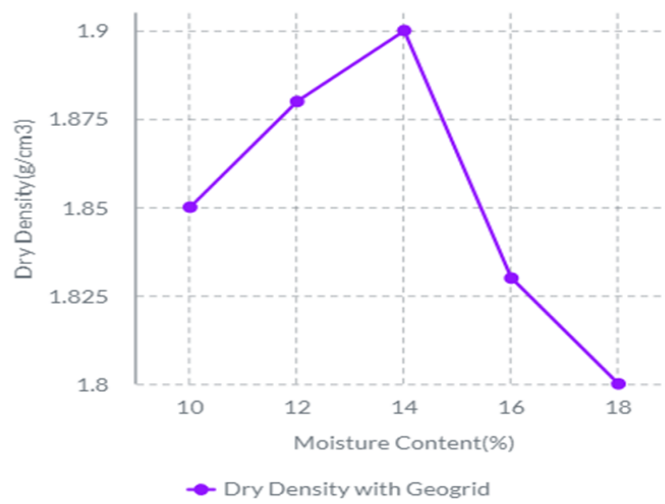


Fig 4.3 Dry density with geogrid

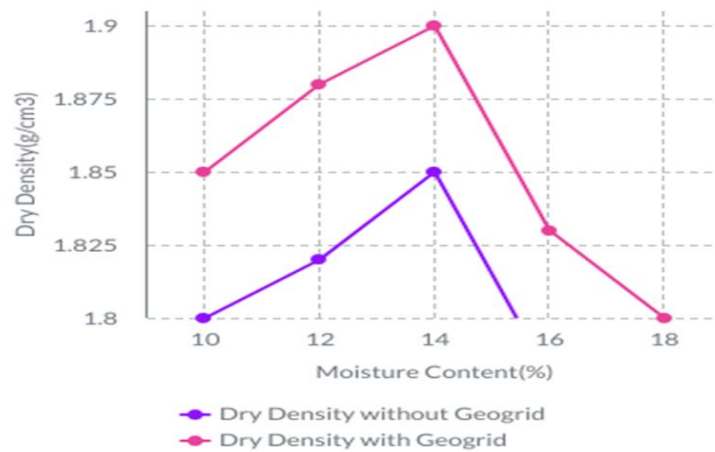


Fig 4.4 Comparison graph

4.3 EXPERIMENTAL RESULTS AND DISCUSSIONS

In the first test, the test system was placed inside a tank within a container and filled with clay to a depth of 610 mm. The load was gradually increased at a constant rate, starting with steps of 1.5 kN and then increasing to 0.5 kN. After the initial testing was completed, all soil and measuring equipment was removed from the tank. In the second test, the properties of the base soil and backfill material were kept the same as in the first test for ease of comparison. But some changes were made: (1) geogrid reinforcement was placed 300 mm from the bottom of the tank, (2) two layers of geogrid reinforcement was placed 200 mm behind the tank, and (3) our geogrid reinforcement was placed 150 mm. away from the bottom of the tank. After the soft clay is leveled, a 20 mm thick layer of gravel is laid on top of the clay layer and three displacements are placed. The results of different geogrid layers were recorded and compared. Figure 4.5 shows the development of different geogrid systems at different load levels in a single graph. Figure 4.7 shows the change when two geogrid layers are reinforced. 4.8 describes the transition of three layers of geogrid reinforcement.

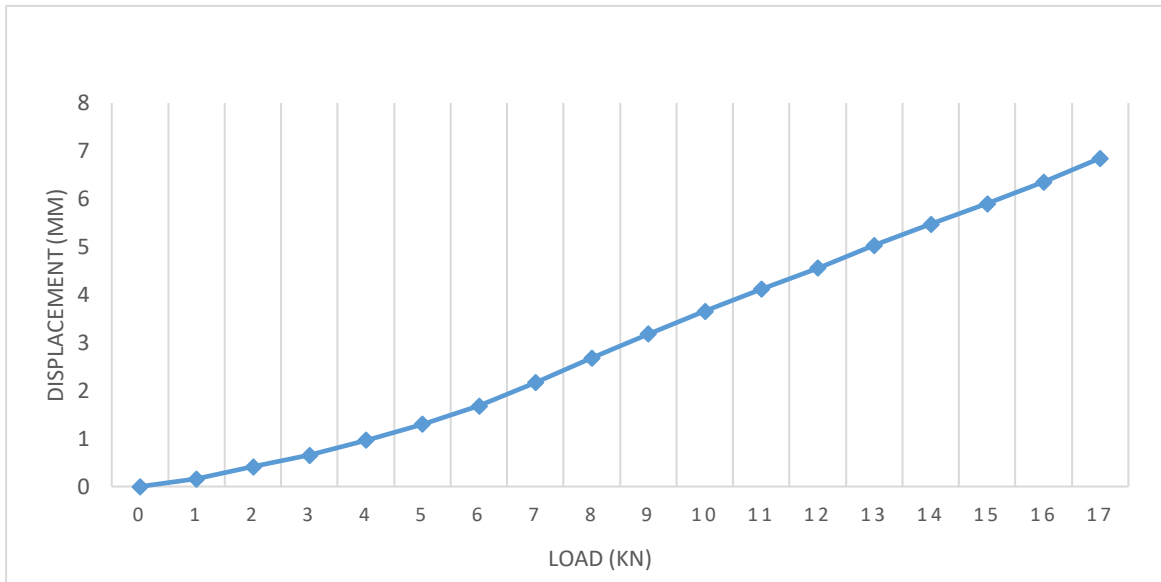


Fig 4.5 Displacement without geogrid

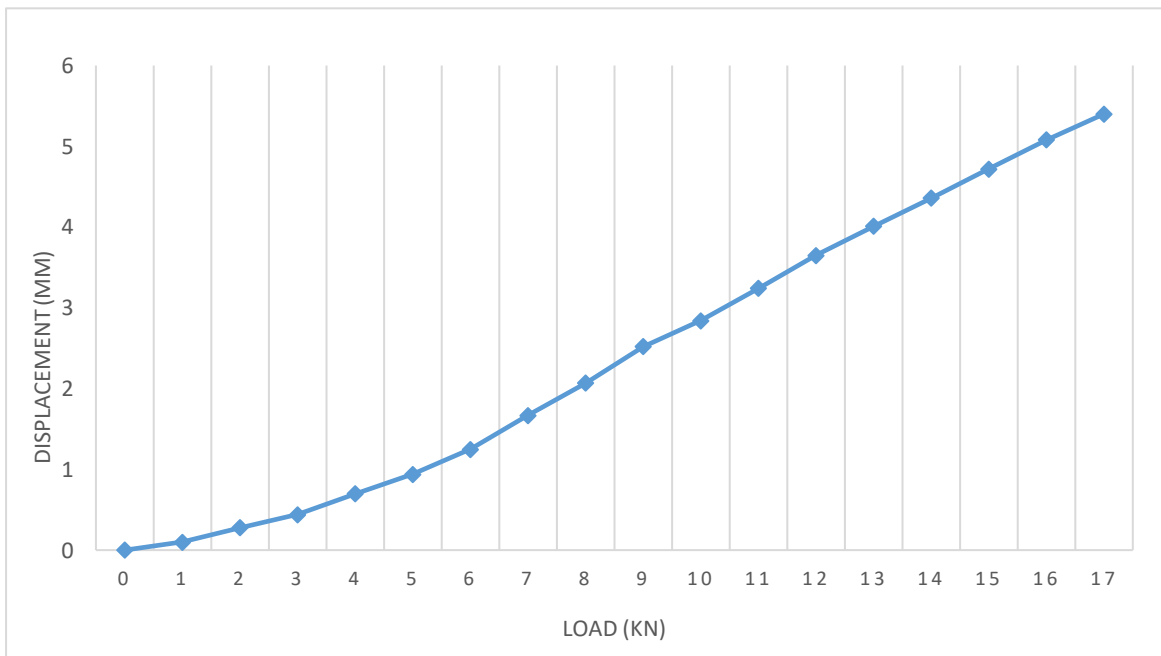


Fig 4.6 Displacement with one layer of geogrid

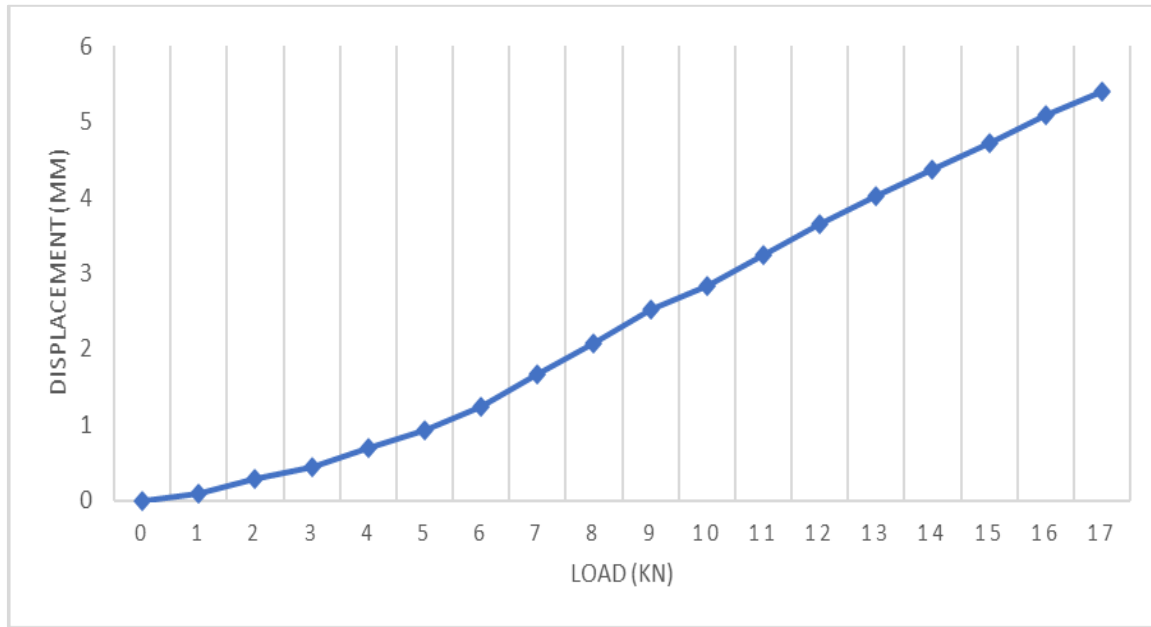


Fig 4.7 Displacement with two layers of geogrid

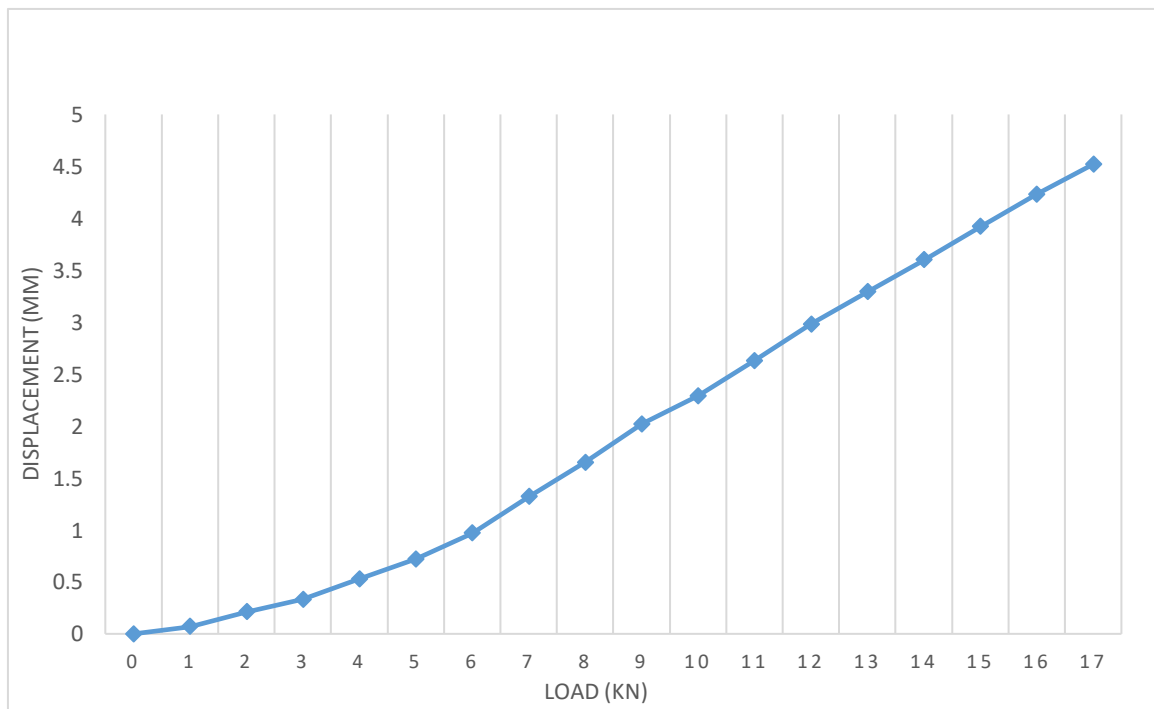


Fig 4.8 Displacement with three layers of geogrid

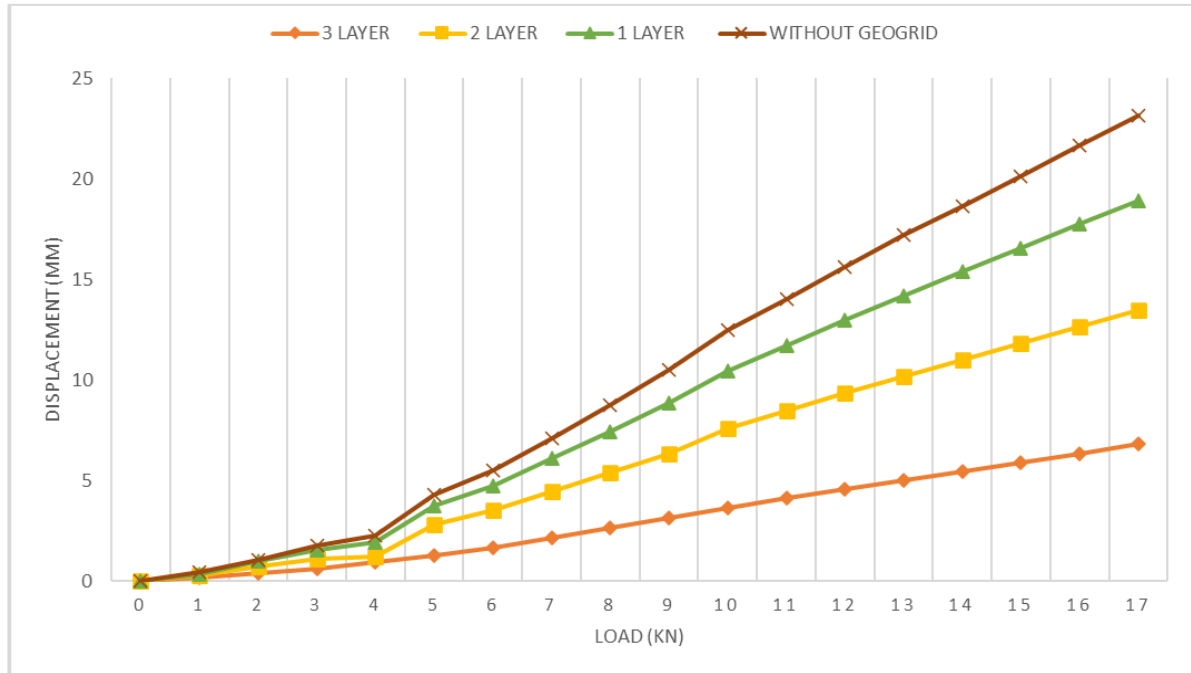


Fig 4.9 Comparison graph

From fig 4.9, The maximum settlement was observed when there is no geosynthetic reinforcement as 23 mm and the settlement was 6mm when the soil is reinforced with three layers of geogrid, Therefore the settlement is reduced by 27% when the layers of geogrid is increased, thus it is recommended to apply geogrids in reinforcing clay soil.

4.4 RESULTS FROM PLAXIS2D

The analysis conducted in Plaxis2D comparing soil behavior with and without geogrid reinforcement provides valuable insights into the effectiveness of geogrids in the mechanical response of soil under loading conditions. By subjecting the numerical model to representative loading scenarios and analyzing the resulting load-displacement graphs, this study evaluates the influence of geogrid inclusion on parameters such as settlement, lateral displacement, and bearing capacity. The results from plaxis2d are given below the Fig 4.10 represents the settlement at each point for different loads at the grid without geogrid reinforcement. Fig 4.11 represents the

settlement at each point for different loads at the grid with geogrid reinforcement. Fig 4.12 represents the stress at each point of grid. Fig 4.13 represents the strain at each point of grid for various load.

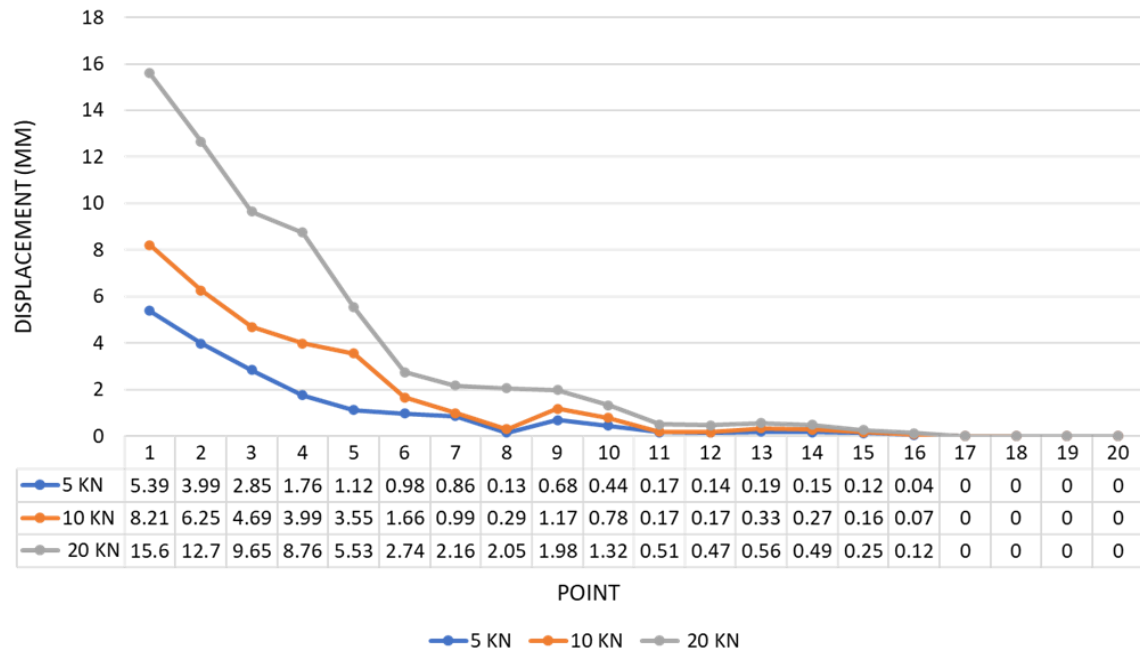


Fig 4.10 Displacement at different points for various load without reinforcement

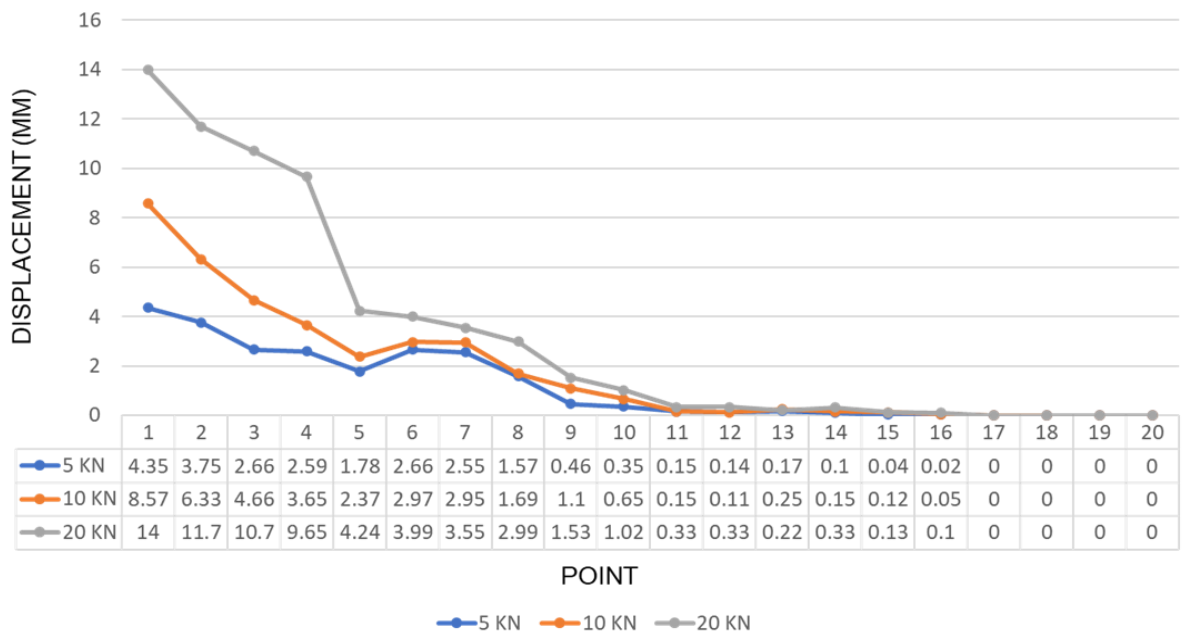


Fig 4.11 Displacement at different points for various load with reinforcement

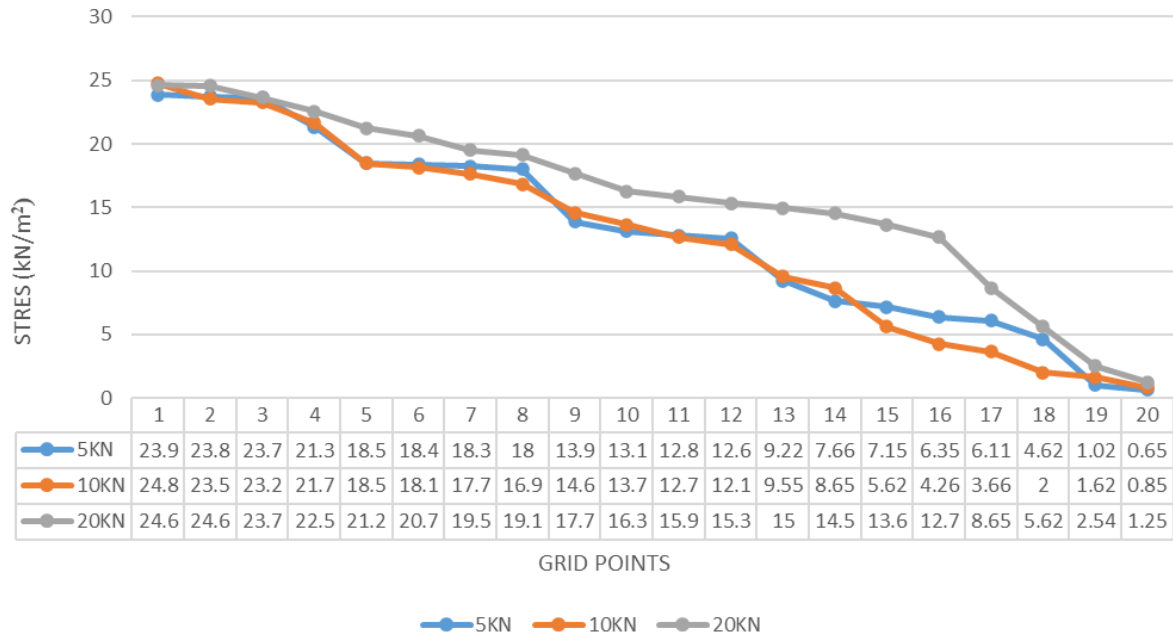


Fig 4.12 Stress in grid points for various load

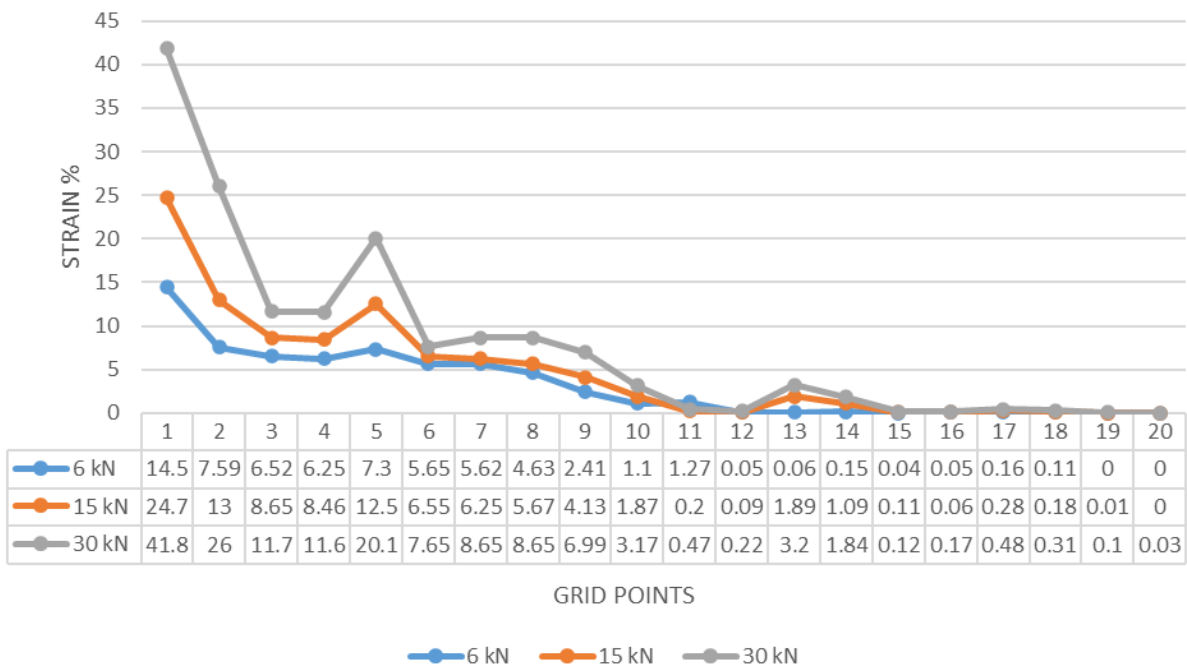


Fig 4.13 Strain in grid points for various load

From figures 4.10 and 4.11, it is evident that the maximum displacement occurs when the soil is not reinforced with geosynthetics. Conversely, when soil is reinforced with geogrids, it becomes stronger and stiffer compared to unreinforced soil. This observation was analyzed using Plaxis2D software. The incorporation of geogrid material into soil enhances its bearing capacity and load-carrying capacity. Experimental studies have demonstrated an increase in subgrade strength, supporting theoretical findings. Therefore, geogrids should be used as a modern method to improve the construction of weak materials.

CHAPTER 5

CONCLUSION

5.1 SUMMARY

- I. Literature Review: Conducted extensive review of existing literature on soil mechanics, geotechnical engineering, and geosynthetic materials.
- II. Selection of Geogrids: Chose geogrids for their versatility and proven performance as the primary geosynthetic material.
- III. Material Sourcing: Procured geogrids directly from manufacturers to meet stringent specifications.
- IV. Soil Preparation: Collected and sieved clay soil samples to achieve homogeneity and eliminate extraneous variables.
- V. Standard Soil Tests: Conducted particle size distribution analysis, Atterberg limits tests, and compaction tests to understand soil properties.
- VI. Experimental Setup: Fabricated a steel tank to exact specifications for soil-geogrid interaction studies.
- VII. Loading Protocols: Utilized a loading frame for controlled loading, enabling precise measurement of settlement under varying reinforcement configurations.
- VIII. Data Collection and Analysis: Gathered data from experiments to understand the interplay between geogrid reinforcement and soil behavior.
- IX. Statistical Analysis and Numerical Simulations: Employed rigorous statistical analyses and PLAXIS 2D software for a comprehensive understanding of soil stabilization mechanisms.
- X. Findings: Affirmed the efficacy of geogrid reinforcement in reducing settlement and enhancing soil stability, with a clear correlation between the number of geogrid layers and settlement reduction.

5.2 CONCLUSION

Geosynthetics have become a well-established technology in geotechnical engineering projects, yet innovation remains crucial in their utilization. This is due to the capability to customize mechanical and hydraulic properties to meet various geotechnical engineering needs. Analysis conducted using Plaxis2D comparing soil behavior with and without geogrid reinforcement has provided valuable insights into the effectiveness of geosynthetic materials in soil stabilization. The observed decrease in displacement values with an increase in geogrid layers signifies an enhancement in soil stability and load-bearing capacity post-reinforcement. This aligns with the project objectives, which aimed to assess soil stability conditions, enhance stability with geogrid materials, and analyze post-reinforcement soil behavior. The results underscore the potential of geosynthetic reinforcement for soil stabilization, demonstrating its ability to reduce deformation and improve structural integrity. Maximum settlement was noted as 23 mm without geosynthetic reinforcement, whereas with three layers of geogrid, settlement reduced to 6 mm, indicating a 27% reduction in settlement with increased geogrid layers. Hence, the application of geogrids in reinforcing clay soil is recommended as it enhances soil bearing capacity. Further validation through experimental studies and field applications would be beneficial to confirm the efficacy of geogrid reinforcement and optimize its design for specific soil conditions and engineering requirements.

5.3 FUTURE SCOPE OF STUDY

This study lays the groundwork for several avenues of exploration and development in the field of soil stabilization and geotechnical engineering. One significant direction for future research involves the application of our findings to real-world infrastructure projects. By delving into the integration of geosynthetic reinforcement techniques, particularly geogrids, into large-scale construction projects such as roads, railways, and retaining structures, we can potentially revolutionize the way we approach soil stability challenges. This entails further investigating optimal reinforcement configurations, including the spacing and depth of geogrid layers, to

maximize their effectiveness in enhancing soil bearing capacity and mitigating settlement. Moreover, exploring innovative reinforcement methods, such as the use of composite materials or novel construction techniques, could offer new solutions for addressing specific soil stabilization needs in different geological and environmental contexts. This study extends to long-term performance evaluation and durability assessment of geosynthetic-reinforced soil structures. While our experimental studies provide valuable insights into short-term behavior and immediate effects of reinforcement, long-term monitoring and field studies are essential to understand how these structures perform over extended periods under varying environmental conditions and loading scenarios. By conducting longitudinal studies and monitoring the performance of geosynthetic-reinforced structures in real-world settings, we can gather crucial data on factors like material degradation, creep behavior, and long-term settlement, which are vital for informing engineering design and maintenance practices.

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