



LOAD STUDIES ON GRANULAR PILE WITH AND WITHOUT GEOGRID ENCASEMENT IN NON-SWELLING CLAY BEDS

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ABSTRACT

Sufficient infrastructure of buildings, roads, railways, tunnels, bridges and other civil engineering works is the prime requirement for the development of any country. Therefore, construction is now also being carried out on sites having poor ground conditions like soft clays, which cover a vast area in India.

Ground improvement has been one of the areas in geotechnical engineering that has been extensively researched in to various types of ground improvement have been derived depending upon the ground conditions for various types of structures.

Granular Pile (stone column technique) is one of the most commonly used soil improvement technique for soft soils and loose sand deposits. These are constructed in soft soils by making circular holes and filling them with granular material such as natural stone, sand or stone chips. The load carrying capacity of Granular Pile can be enhanced by reinforcing it with geosynthetics (geogrids or geotextiles) in the form of sheets or by jacketing.

In the proposed study, non-swelling clay beds prepared in moulds was reinforced with Granular Pile, with and without Geogrid encasement. The granular pile of diameter 60mm was constructed at the center of soil bed. The load test was conducted on the granular pile. The length to diameter ratio of the pile was varied from 1 to 6, and the effect of pile length on load carrying capacity was studied. Further, to observe the effect of pile material, it was wrapped by geogrid and the load test was conducted. The test results revealed that the load carrying capacity of the granular pile increases as L/d ratio increases in both the cases i.e. without and with geogrid encasement. The load settlement studies were carried out in a large cylindrical mould having 30cm diameter and 40cm length.



1. INTRODUCTION

1.1 GENERAL

Construction on natural soft soil deposits is still a challenge in geotechnical engineering. It gains even more importance as urban areas all over the world become more and more congested. For socio-economic development today's construction projects are frequently built on those areas, which were considered unsuitable for construction work a couple of decades ago.

Proper remedial measures are to be adopted to modify the soil or to reduce to its detrimental effects if non-swelling clay are identified in a project. The remedial measures can be different for planning and designing stages and post construction stages. Many stabilization techniques are in practice for improving non-swelling soils in which the characteristics of the soils are altered.

Additives such as lime, cement, calcium chloride, rice husk, fly ash etc., are also used to alter the characteristics of the weak soils. The characteristics that are of concern to the design engineers are permeability, compressibility of soils and durability of the structures. The effect of the additives and the optimum amount of additives to be used are dependent mainly on mineralogical composition of the soils.

Non-swelling soils tend to be problematic due to settlement undergo following moisture changes. Structures built in them are subjected to distress and as a result special techniques are to be adopted below foundations. Dynamic compactions, preloading of soil, injection of suitable grouts, electrical methods are some of the techniques are being used over all world to overcome the problems. However each one of the above practices limited to some depth. The Granular pile (GP) is an improvement technique, devised for mitigating settlement of clay beds and improving their engineering behavior.

In the proposed study, clay beds prepared in moulds will be reinforced with GP with and without geogrid encasement. The length to depth ratio of the GP will be variable from 1 to 6, and the load carrying capacity of GP with and without geogrid encasement for different L/d ratios was studied in large cylindrical moulds.

1.2 OBJECTIVES

The objectives of this study are,

- 1) In the proposed study of non-swelling clay beds, fabricated test moulds will be reinforced with **Granular Pile (GP)** with and without Geogrid encasement.
- 2) Load Settlement studies were carried out for different lengths of granular pile with and without geogrid encasement.

2. REVIEW OF LITERATURE

2.1 CLAY MINERAL

The basic igneous rocks, poor in silica and rich in feldspars, pyroxenes and amphiboles disintegrate to form clay minerals. Sedimentary rocks such as shale and clay stones, which contains varying amount of volcanic ash and limestone and marls rich in magnesium can also disintegrate to form clay minerals.

2.2 STRUCTURE OF CLAY MINERALS

The atomic structures of clay minerals are composed of two basic crystalline sheets, namely tetrahedral sheets and octahedral sheets. Based on the nature of the bonding forces present over there and metallic ions present in the crystal lattice, different clay minerals came into picture.

2.2.1 Kaolinite:

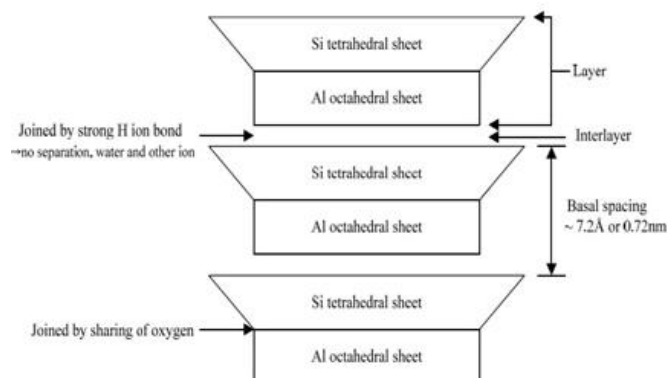


Fig 2.1 Structure of Clay Mineral Kaolinite

2.2.2 Illite:

Illites $[(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]]$ are clay minerals of 2:1 type of mica minerals. Structurally, illites consist of one octahedral sheet of either Fe^{3+} and/or Mg^{2+} ions and two tetrahedral sheets in which Al^{3+} occurs as a substituted ion in place of some of the Si^{4+} .

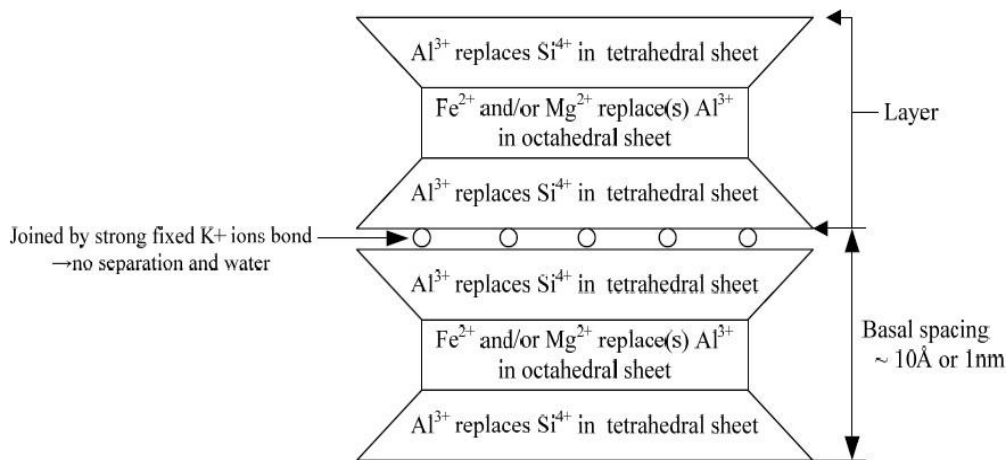


Fig 2.2 Structure of clay mineral Illite

2.2.3 Smectite:

The term smectite refers to a family of expandable 2:1 phyllosilicate clay minerals having a layer lattice structure in which two tetrahedral sheets are separated by a layer of octahedral sheet.

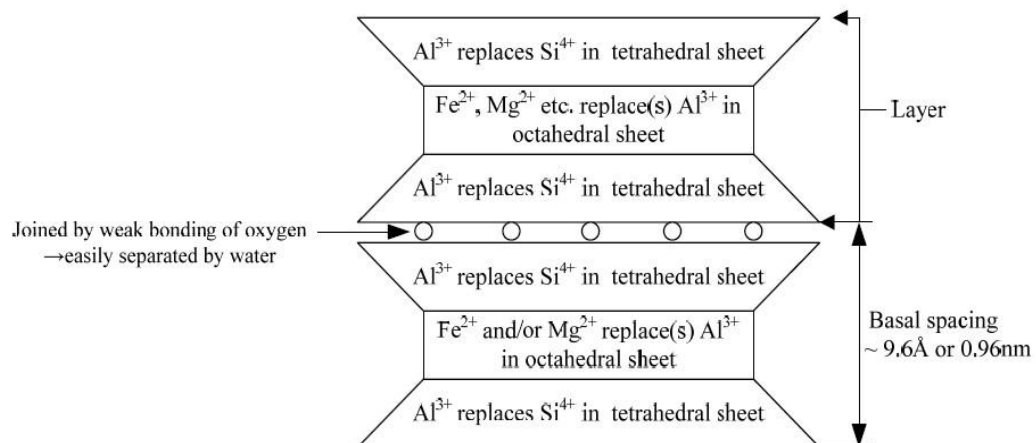




Fig 2.3 Structure of clay mineral Montmorillonite

Table 2.1 Clay Mineral Characteristics:

Mineral	Interlayer bond	Basal spacing	Specific surface area (m ² /gm)	Cation exchange capacity (meq/100 g)
Kaolinite	Hydrogen; Strong	7.2 Å	10-20	3-15
Montmorillonite	Oxygen-oxygen; Very weak	9.6 Å	700-840	80-150
Illite	K ions; Strong	10 Å	65-100	10-40
Vermiculite	Weak	10.5-14 Å	870	100-150
Chlorite	Strong	14 Å	80	10-40

2.3 CLAY PARTICLE ATTRACTION

Attraction and holding of water molecules is mainly due to

- 1) Hydrogen bonding
- 2) Cation attraction
- 3) Dipole attraction

2.4 REMEDIAL MEASURES TO OVERCOME PROBLEMS OF NON-SWELLING CLAYS

1) Chemical Stabilization

The most of clays are with sodium in exchange complex and probably the most effective chemical stabilization of clayey soils occur when sodium ions are replaced by divalent or trivalent cations. Many chemicals have been tried to alter the characteristics of clay minerals: for example ion exchange by the addition of divalent or trivalent salts, cation fixation in expanding lattice clays with potassium and water proofing with asphalt have all been attempted.

2) Mechanical Stabilization

Soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing.

- Vibroflotation
- Dropping of heavy weight
- Sand compaction piles

2.4.1 Vibroflotation

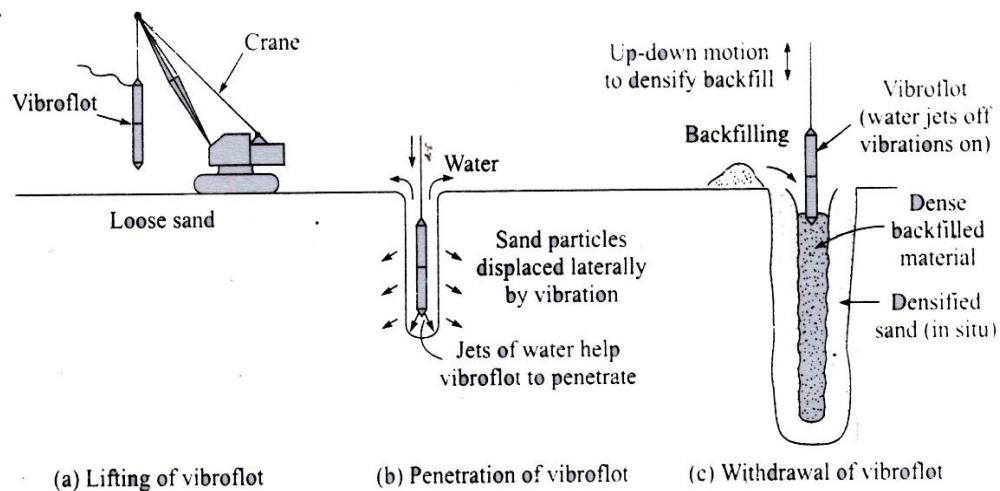


Fig.2.4: Vibroflotation technique of soil compaction

2.4.2 Dropping of Heavy Weight

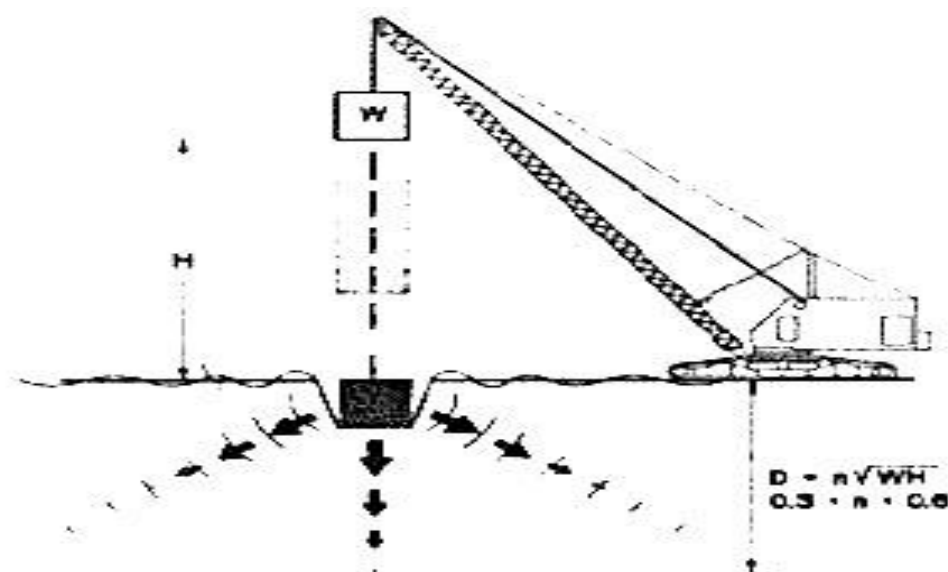


Fig. 2.5: Dynamic compaction of soil

2.4.3 Sand Compaction Piles

Compaction piles are constructed at several locations on grid pattern .Thus a uniform deposit of much denser than the original soil is formed.

2.5 METHODS OF DEWATERING

Dewatering means “The separation of water from the soil,” or perhaps “taking the water out of a particular construction problem completely.”

The most common methods for dewatering includes

- 1) Well point systems
- 2) Deep-well drainage
- 3) Vacuum dewatering
- 4) Electro osmosis

2.5.1 Well point systems

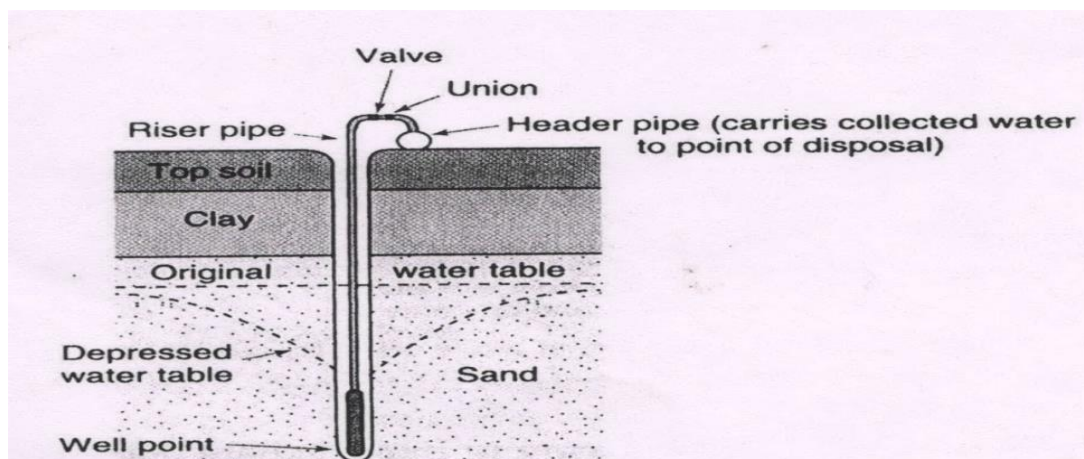


Fig 2.6 Cross Section of WellPoint System

2.5.2 Deep-well dewatering

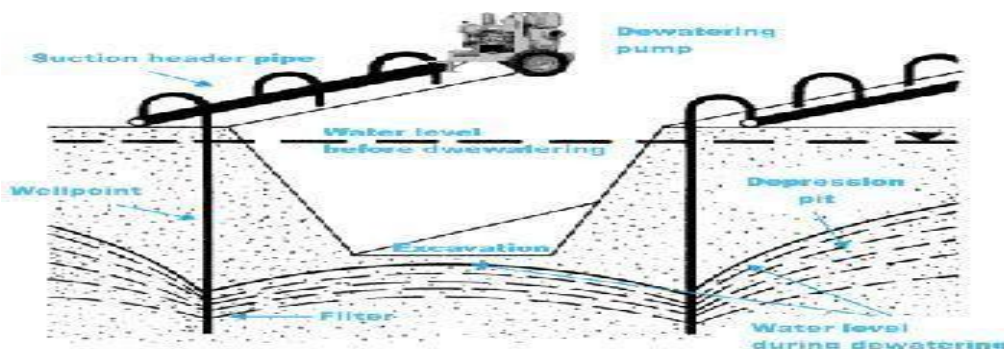


Fig 2.7 Cross Section of Deep-well dewatering

2.5.3 Vacuum Dewatering

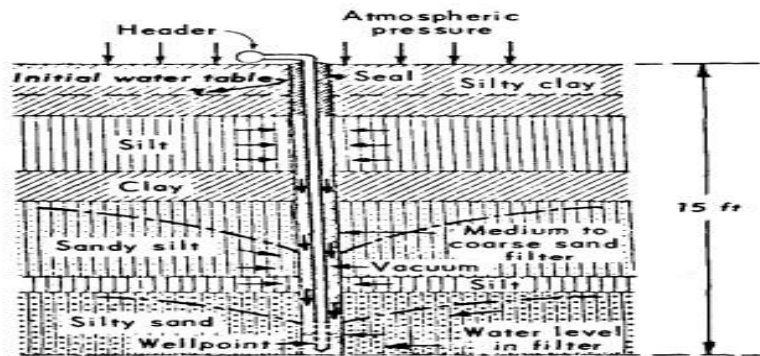


Fig 2.8 Cross Section Vacuum Dewatering

2.5.4 Electro-Osmosis

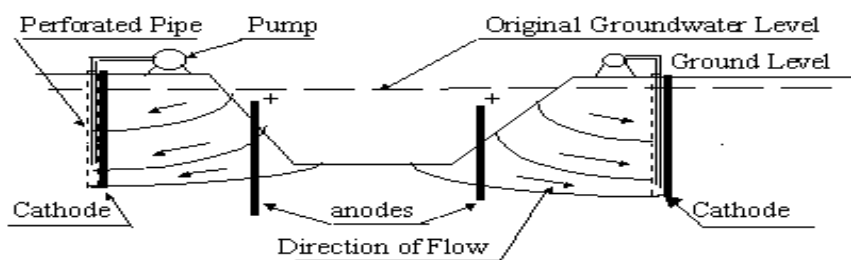


Fig 2.9 Cross Sectional Electro-osmosis dewatering

2.6 GRANULAR PILE REINFORCEMENT

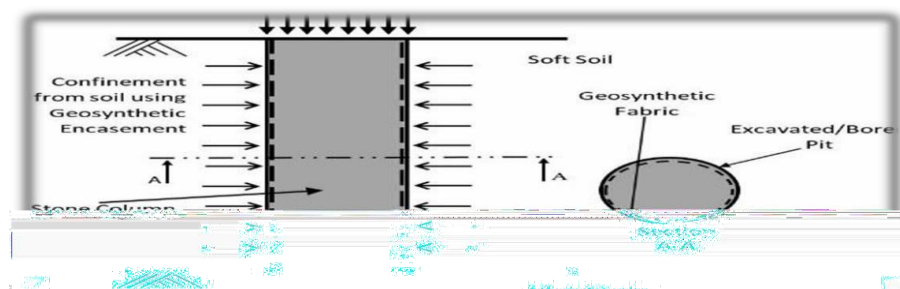


Fig 2.10 Schematic diagram of geogrid-encased granular pile

2.7 SUMMARY

In this chapter, the experiences of various reasearchers in the field of Granular Pile foundation have been presented briefly. In the next chapter, methodology for laboratory experimentation is presented.

3. LABORATORY EXPERIMENTATION

3.1 TEST MATERIALS

3.1.1 Soil

The non-swelling clay bed used in this study was collected from Chitrada of the state of Andhra Pradesh, India, from a depth of 1.5m – 2.0m below the ground surface. The soil had a maximum dry unit weight 16.1 kN/m^3 at optimum moisture content (OMC) of 21% as determined from the compaction test.

Properties of soil are shown in Table 3.1 IS Code procedures were adopted to determine the properties of soil samples.



Fig3.1 Collecting Soil sample.

Table 3.1 Properties of Non-Swelling Soil.

S. No	Property	Value
1	Differential Free Swell(%)	20
2	Specific Gravity	2.58
3	Grain Size Distribution:	
	Sand (%)	16
	Silt (%)	38
	Clay (%)	46
4	Atterberg Limits	
	Liquid Limit (%)	47
	Plastic Limit (%)	25
	Plastic Index (%)	22
5	IS Classification	CI
6	Compaction Properties	
	Optimum Moisture Content, O.M.C (%)	21
	Maximum Dry Density, M.D.D(kN/m^3)	16.1
7	UCS Test results	
	Cohesion, C (kPa)	45
	Angle of Internal Friction(ϕ)	0°



Fig 3.2 Pulverizing the air dried soil.

3.1.2 Granular Material

The granular material that was used for the installation of the granular piles was a mixture of 20% stone chips particle size ranged from 6mm to 4.75mm and 80% coarse sand with size of 4.75mm to 1.18mm. It was found from previous studies that, at this proportion of 20:80 gave the largest difference between maximum and minimum void ratios.

3.1.3 Geogrid

Plastic geogrid (polypropylene) with aperture size 8mmx8mm having elongation resistance is 2-4% and tensile strength of 10kN/m is overlapped to get aperture size of 3mmx3mm was used in the tests.

Table 3.2 Properties of Geogrid

S.No	Parameters	Value
1	Mesh Aperture Size	8mm×8mm(square)
2	Thickness	1mm
3	Ultimate Tensile Strength	10kN/m
4	Elongation resistance	2-4%

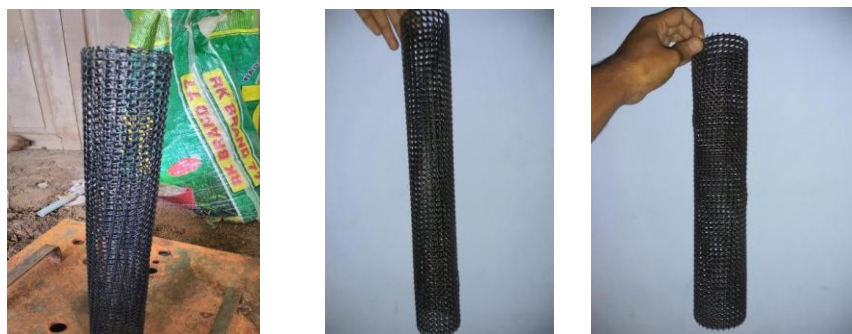


Fig 3.3 geogrids



3.2 TESTS CONDUCTED IN THIS INVESTIGATION

1. Specific Gravity
2. Grain Size Analysis
3. Atterberg Limits
4. Standard Proctor Compaction
5. UCS Test
6. Relative Density

3.3 METHODOLOGY

The experimentation program of the present work was conducted in steps.

Step 1:

- The first step finding the properties of the Virgin Soil.
- These properties include Differential Free Swell Index (DFSI), Atterberg Limits, Specific Gravity, Compaction and UCC characteristics are find out.

Step 2:

- In second step tests are conducted on Granular Material like Relative Density and Direct Shear tests at interface of granular material and soil with and without geogrid.

Step 3:

- Load Settlement tests were conducted on **Granular Pile** with and without geogrid encasement by varying lengths with constant diameter in large moulds of non- swelling clay.

3.4 EXPERIMENTAL SETUP

Throughout the test program the non-swelling clay beds were compacted at dry unit weight of 12 kN/m³ and placement water content of 29%. These conditions were chosen for convenience of compaction. Tests were performed in the following cases.

- Large cylindrical moulds of size 30cm×40cm. The thickness of the non-swelling clay bed was kept constant at 400mm. The diameter of Granular Pile is kept constant 60mm. Three series of laboratory test models were performed.
- First series of tests were performed on the Non swelling clay bed without any granular pile by placing a mild steel plate of 60mm diameter on the soil top.
- Second series of test were performed on granular piles without geogrid

encasement of length L equal to 60mm,120mm,180mm,240mm,300mm and 360mm. Thus Length to depth (L/d) ratio was varied as 1,2,3,4,5 and 6.

➤ The Third series of tests were performed on encased granular piles in which the geogrid was wrapped around the granular pile for the different cases of Length to depth (L/d) ratios as mentioned in granular pile without geogrid encasement.

3.5 COMPACTION OF NON-SWELLING CLAY BED

The soil was compacted in convenient number of layers. The weight of soil required to be compacted in each layer to give the dry unit weight of 12kN/m^3 was predetermined. Compaction of the soil was done with rammer. The process of compaction was continued until clay bed reached the desired thickness of 400mm in large cylindrical moulds.



Fig 3.1 Experimental set-up showing compaction of soil and installation of GP

3.6 PILE LOAD TEST



Fig 3.2 Pile Load test setup



3.7 SUMMARY

In this chapter the work done in the laboratory was presented which includes the following.

- Soil sample collected and basic laboratory experiments conducted on the non-swelling soil. Basic experiments like Differential Free Swell Index (DFSI), Atterberg Limits, Sieve analysis, Specific Gravity, Compaction characteristics were conducted.
- For granular material tests like Specific Gravity and Relative density were conducted.
- Direct shear test was conducted for two cases. One with non-swelling soil on one half and granular material on the other half. Secondly with non-swelling soil on one half and granular material on another half in between geogrid was inserted.
- Load tests were conducted in large moulds on non-swelling clay bed and granular pile of different lengths with and without geogrid encasement in non-swelling clay bed.

4. DISCUSSION OF TEST RESULTS

4.1 LOAD STUDIES

The load - settlement response was taken for the following cases in the laboratory.

- Unreinforced clay bed in large mould.
- Reinforced non swelling clay beds with Granular Pile with and without geogrid encasement in large mould.

The Load vs Settlement graphs for different cases as said earlier were presented in this chapter.

4.2 COMPARISON OF RESULTS

The load tests were conducted on the following case

- Unreinforced non-swelling clay bed.
- Granular piles without geogrid encasement of diameter 60mm and length L equal to 60mm, 120mm, 180mm, 240mm, 300mm and 360mm. Thus Length to depth (L/d) ratio was varied as 1, 2, 3, 4, 5 and 6.
- Granular piles with geogrid encasement of diameter 60mm and length L equal to

60mm, 120mm, 180mm, 240mm, 300mm and 360mm. Thus Length to depth (L/d) ratio was varied as 1, 2, 3, 4, 5 and 6 and the results were presented in the form of graphs and the tables.

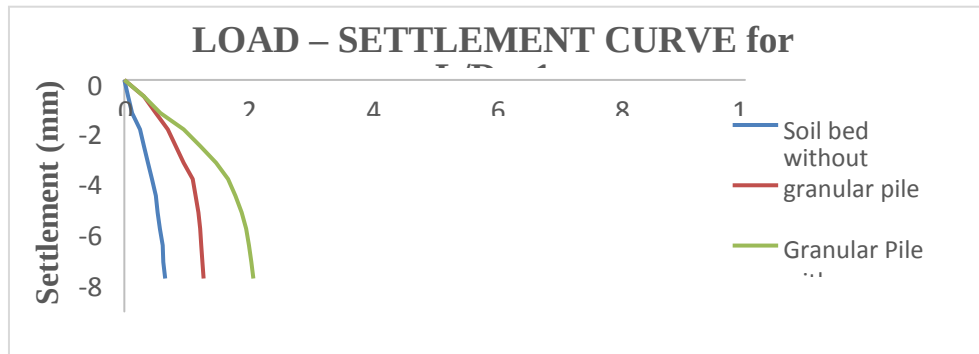


Fig 4.1 Load vs Settlement curve for length to depth ratio 1. (L/d = 1) Table 4.1:

load carried by granular pile for different settlements for L/d = 1

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile without Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.32	0.32
2	0.13	0.51	0.58
3	0.25	0.7	0.96
4	0.32	0.83	1.22
5	0.38	0.96	1.48
6	0.45	1.1	1.67
7	0.51	1.15	1.79
8	0.54	1.2	1.89
9	0.57	1.22	1.96
10	0.62	1.24	2.01
11	0.63	1.26	2.05

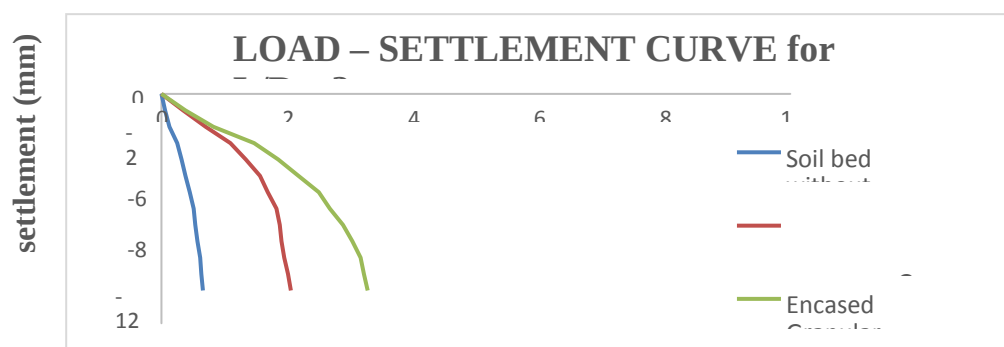


Fig 4.2 Load vs Settlement curve for length to depth ratio 2. (L/d = 2)

Table 4.2: load carried by granular pile for different settlements for $L/d = 2$

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile without Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.35	0.38
2	0.13	0.7	0.83
3	0.25	1.1	1.47
4	0.32	1.34	1.86
5	0.38	1.57	2.18
6	0.45	1.69	2.5
7	0.51	1.83	2.68
8	0.54	1.88	2.89
9	0.57	1.91	3.04
10	0.62	1.95	3.17
11	0.63	2.01	3.22
12	0.66	2.06	3.28

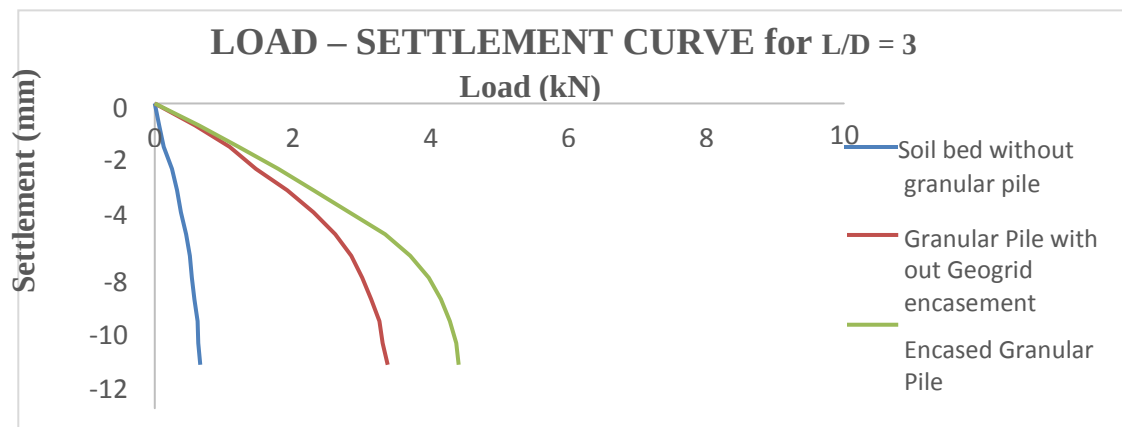


Fig 4.3 Load vs Settlement curve for length to depth ratio 3. ($L/d = 3$)

Table 4.3: load carried by granular pile for different settlements for $L/d = 3$

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile without Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.58	0.64
2	0.13	1.09	1.22
3	0.25	1.47	1.79
4	0.32	1.92	2.3
5	0.38	2.3	2.82
6	0.45	2.62	3.34
7	0.51	2.85	3.71
8	0.54	3.01	3.98
9	0.57	3.14	4.15
10	0.62	3.26	4.28
11	0.63	3.31	4.38
12	0.66	3.38	4.41

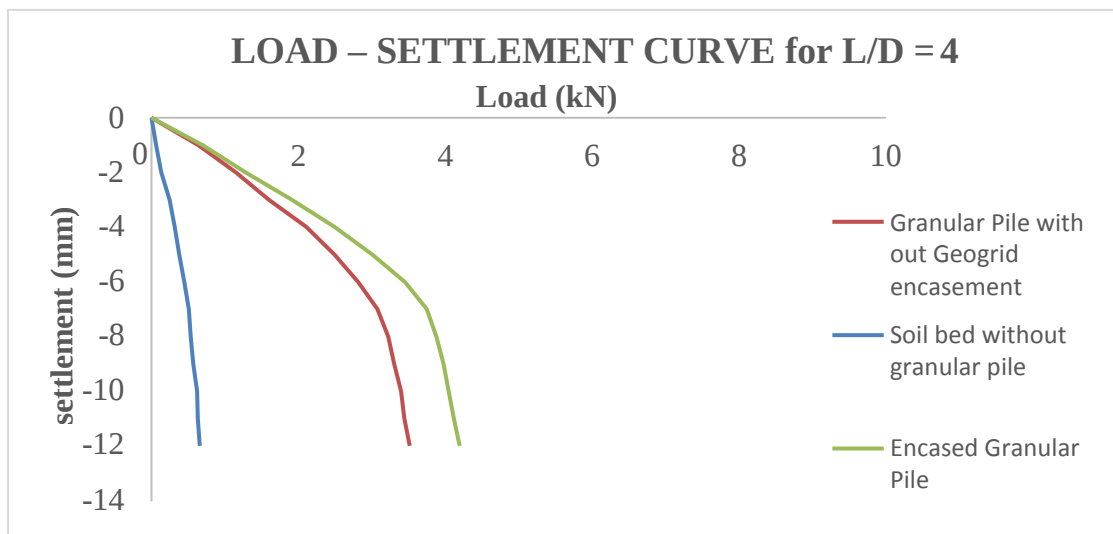

Fig 4.4 Load vs Settlement curve for length to depth ratio 4. ($L/d = 4$)

Table 4.4: load carried by granular pile for different settlements for $L/d = 4$

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile without Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.64	0.7
2	0.13	1.15	1.28
3	0.25	1.6	1.92
4	0.32	2.11	2.49
5	0.38	2.49	3.01
6	0.45	2.82	3.46
7	0.51	3.08	3.75
8	0.54	3.23	3.88
9	0.57	3.31	3.98
10	0.62	3.4	4.05
11	0.63	3.45	4.12
12	0.66	3.52	4.2

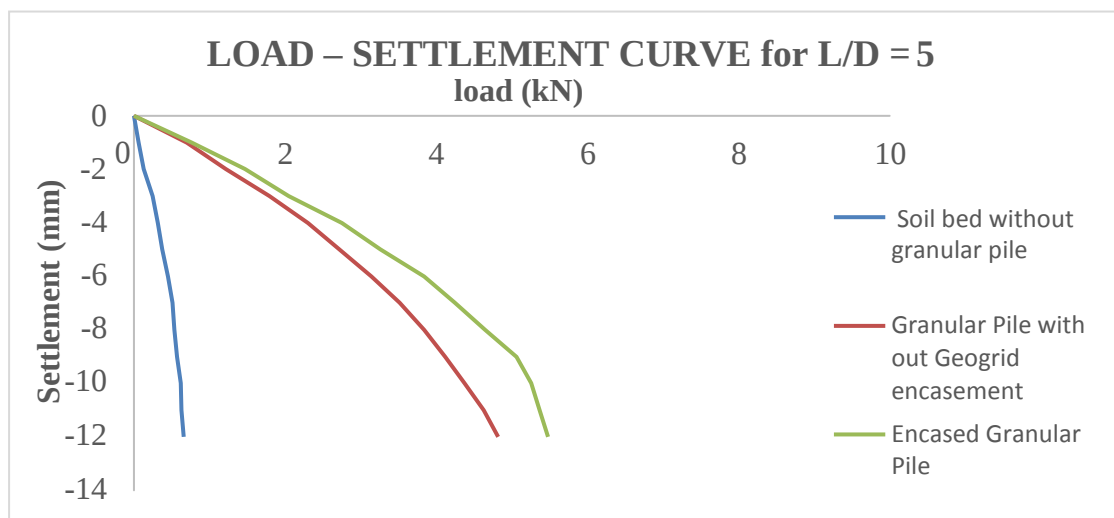


Fig 4.5 Load vs Settlement curve for length to depth ratio 5. ($L/d = 5$)

Table 4.5: load carried by granular pile for different settlements for $L/d = 5$

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile wit out Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.7	0.77
2	0.13	1.22	1.47
3	0.25	1.79	2.05
4	0.32	2.3	2.75
5	0.38	2.72	3.26
6	0.45	3.14	3.84
7	0.51	3.52	4.25
8	0.54	3.84	4.65
9	0.57	4.12	5.06
10	0.62	4.37	5.26
11	0.63	4.63	5.37
12	0.66	4.82	5.48

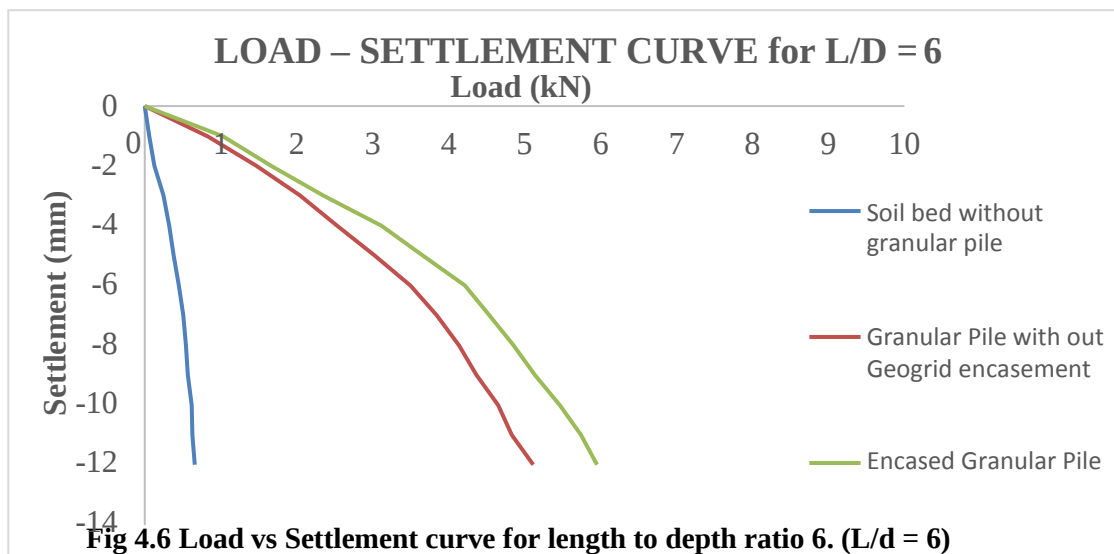


Table 4.6: load carried by granular pile for different settlements for $L/d = 6$

Settlement (mm)	Load carried by (kN)		
	Soil bed without granular pile	Granular Pile wit out Geogrid encasement	Encased Granular Pile
0	0	0	0
1	0.06	0.83	1.03
2	0.13	1.47	1.67
3	0.25	2.05	2.35
4	0.32	2.54	3.12
5	0.38	3.03	3.66
6	0.45	3.5	4.22
7	0.51	3.85	4.54
8	0.54	4.14	4.86
9	0.57	4.37	5.14
10	0.62	4.66	5.47
11	0.63	4.84	5.75
12	0.66	5.12	5.96

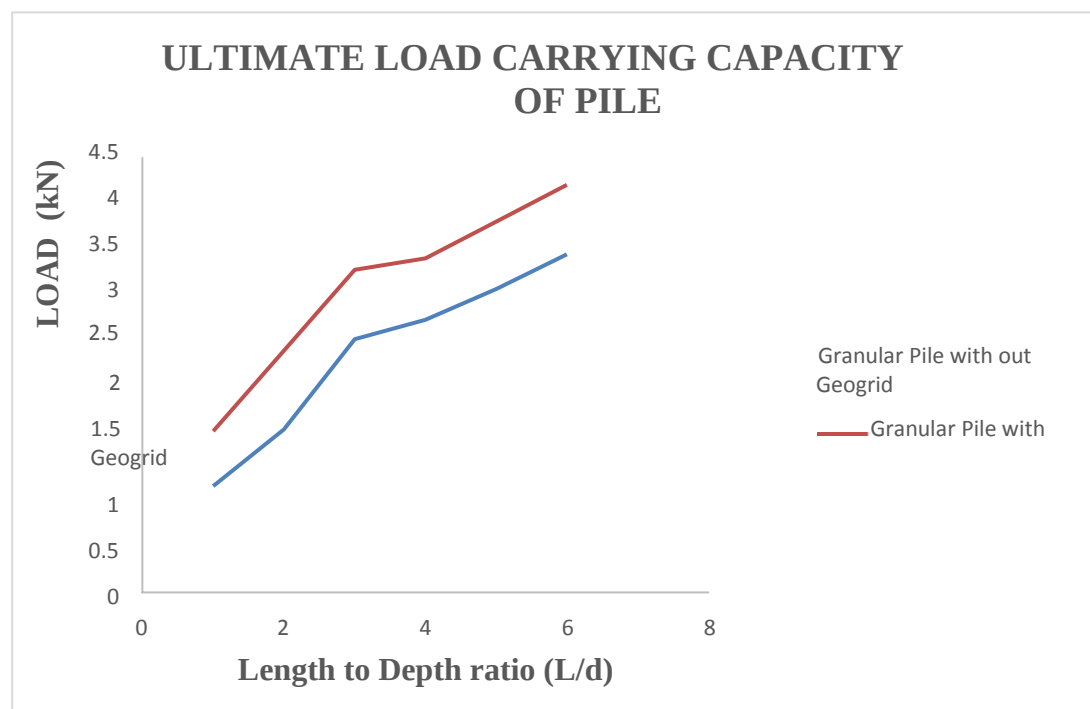


Fig 4.7 Ultimate load carrying capacity of pile with and without geogrid encasement for different length to depth ratios.



Length to depth ratios L/d	Load carried by (kN)	
	Granular Pile without Geogrid	Granular Pile with Geogrid
1	1.1	1.67
2	1.69	2.5
3	2.62	3.34
4	2.82	3.46
5	3.14	3.84
6	3.5	4.22

5. CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSIONS

- The ultimate load, Q of Granular Pile without geogrid encasement is found as **1.10 kN** and with geogrid encasement is found as **1.67 kN** for length to depth ratio 1. The diameter of the Granular Pile is 60 mm and **length 60 mm**.
- The ultimate load, Q for Granular Pile without geogrid encasement is found as **1.69 kN** and with geogrid encasement is found as **2.50 kN** for length to depth ratio 2. The diameter of the Granular Pile is 60 mm and **length 120 mm**.
- The ultimate load, Q for Granular Pile without geogrid encasement is found as **2.62 kN** and with geogrid encasement is found as **3.34 kN** for length to depth ratio 2. The diameter of the Granular Pile is 60 mm and **length 180 mm**.
- The ultimate load, Q for Granular Pile without geogrid encasement is found as **2.82 kN** and with geogrid encasement is found as **3.46 kN** for length to depth ratio 2. The diameter of the Granular Pile is 60 mm and **length 240 mm**.
- The ultimate load, Q for Granular Pile without geogrid encasement is found as **3.14 kN** and with geogrid encasement is found as **3.84 kN** for length to depth ratio 2. The diameter of the Granular Pile is 60 mm and **length 300 mm**.
- The ultimate load, Q for Granular Pile without geogrid encasement is found as **3.50 kN** and with geogrid encasement is found as **4.52 kN** for length to depth ratio 2. The diameter of the Granular Pile is 60 mm and **length 360 mm**.
- The load carrying capacity of a footing on granular pile is found more in

comparison to that resting on soil alone for all L/d ratio of the pile.

5.2 FUTURE SCOPE

The following avenues may be investigated:

- In the proposed study the experiments were conducted in the laboratory fabricated moulds. It can be applied on field to provide in-situ conditions.
- Further work can be done by using various diameter of Granular Pile.
- In the present investigation, plastic geogrid (polypropylene) was used. This work can be studied further by using different geogrids like glass fiber geogrid, polyvinyl geogrid, etc.,
- Single granular pile was used in the present study. The behaviour of group of granular piles in non-swelling clay soil may also be studied

REFERENCES

- **Alexiew, D., Brokemper, D., & Lothspeich, S. (2005)**, “Geotextile encased columns (GEC): load capacity, geotextile selection and pre-design graphs”, Geo-Frontiers, pp. 497-510.
- **Alexiew, D., Moormann, C., & Jud, H. (2005)**, “Foundation of a coal/coke stockyard on soft soil with geotextile encased columns and horizontal reinforcement”, Geo-Frontiers Conf.
- **Ali, K., Shahu, J.T., Sharma, K.G. (2014)**, “Model Tests on Stone Columns Reinforced with Lateral Circular Discs”, Int. Jnl. of Civil Engineering Research, 5(2), pp. 97-104.
- **Ali, K., Shahu, J.T., & Sharma, K.G. (2014)**, “Model tests on single and groups of stone columns with different geosynthetic reinforcement arrangement”.