ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering | e–ISSN: 2067 – 3809
Tome XVIII [2025] | Fascicule 2 [April – June]

[1.]Adekunle Olorunlowo DAVID, [2.]Julius Musyoka NDAMBUKI, [3.]Mpho MULOIWA,
[4.]Williams Kehinde KUPOLATI, [5.]Esther Adedoyin OGUNKANMI

IMPROVEMENT OF THE BEARING CAPACITY OF SANDY SOIL BY GROUTING

[1-4.]Department of Civil Engineering, Tshwane University of Technology, Pretoria, SOUTH AFRICA
[5.]Department of Civil Engineering, Olabisi Onabanjo University, Ibogun campus, Ogun State, NIGERIA

Abstract: Sandy soils, which have low strength and high permeability, present a challenge in construction because they are not sufficient to carry heavy structures. This study identifies the need for an effective way of improving the bearing capacity of such soils since the conventional methods of stabilization hardly work. To deal with this matter, a cement grout method has been used in the paper. The process involves pumping a cement slurry into the sandy ground that fills out voids and bonds soil particles together. The test investigates how different percentages (varying from 5% up to 20%) of cement slurry affect permeability, dry density and strength characteristics measured by California Bearing Ratio (CBR). The efficiency of this grouting technique is evaluated by comparing treated against untreated soil samples. The soil's properties have been observed to have improved significantly as evidenced by the results. The permeability of the soil was significantly reduced with a more pronounced decrease in case of the sample treated with 20% cement slurry that brought down permeability from 0.0171 cm/s to 0.00105 cm/s in untreated soil. For instance, dry density rose from 1.79 g/cm^3 for untreated soil to 1.99 g/cm^3 at 20% cement slurry implying better soil compaction had been obtained. Conversely, the CBR which serves as a measure of strength increased considerably from 11.7% in untreated soils to 36.5 % for the cement content tested on sandy soils. These findings confirm that cement-based grouting is highly effective in improving the bearing capacity and stability of sandy soils, making them more suitable for construction projects.
Keywords: Grouting, cement slurry, soil stabilization

INTRODUCTION

The stability of sandy soil is a crucial factor in the design and construction of various engineering structures such as buildings, highways, and dams.

In recent studies, grouting has emerged as a promising technique for improving the bearing capacity of sandy soil. Grouting techniques offer a viable solution for improving the stability of sandy soil, particularly in areas where traditional methods may not be as effective. One of the key advantages of grouting is its ability to address local variations in soil conditions, making it a versatile solution for a wide range of projects. In addition to its role in construction, grouting has also proved to be effective in soil stabilization for infrastructure rehabilitation and repair projects. The successful application of grouting in these scenarios underscores its potential for addressing both new construction and existing structures in need of reinforcement (Bui Van Duc et al,2023). As the demand for innovative and sustainable soil improvement methods continues to grow, grouting is poised to play a significant role in meeting these needs.

As new developments continue to emerge, grouting is expected to play an increasingly significant role in enhancing the stability and bearing capacity of sandy soil in various engineering applications. The improvement of the bearing capacity of sandy soil by grouting is a promising and versatile solution, it offers not only an environmentally friendly approach but also the potential for long-term stability and strength enhancement in construction projects (Castro et al., 2021).

This study seeks to utilize cement as a grout material to analyze how it affects soil properties. Specifically, it aims to measure the water flow rate through the soil, the rate of soil settlement, and the strength of both treated and untreated soil.

The distinguishing feature of our research lies in the application of cement as a grouting substance to enhance the load-bearing capacity of sandy soil, a departure from the typically limited bearing capacity inherent in sandy soil compositions.

MATERIALS AND METHODS

Materials

Sandy soil will be collected from Alasia, Ijanikin, Lagos State. Ordinary Portland cement will be gotten from Ibogun Market, Fashina, Ibogun, Ifo, Ogun State.

Methods

— The Pre-grouting Process

The pre-grouting process is crucial for ensuring the effectiveness of the grouting process by creating a stable and controlled environment for the injection of the grout material. It helps in maintain the position of pipes, preparing the sand bed and ensuring proper mixing of grout components to achieve a uniform suspension for effective permeation into the soil layers. Some of the pre-grouting tests which would be carried out on the sandy soil are:

- The permeability test is the measure of the flow of water or any liquid through a soil. The rate of flow of water will be determined using the constant head permeability test.
- Compaction test will be used to determine the density of the soil.
- The CBR test will determine the strength of the treated soil, this will help to determine the strength of the grouted soil

— Grouting Process

The sandy soil has been filled in the tank of desired volume, the already mixed grout materials are placed in the grout pump, which has been set up and connected to the injection nozzle. The injection nozzle is placed 5cm above the sand bed in the tank and the grout is pumped into the soil, the nozzle will be raised at intervals in order to get a uniform flow of grout over the entire thickness of the soil.

The soil is grouted at different percentages of cement slurry, which are 5%, 10%, 15% and 20%. This is in order to compare the differences at various percentages of grouted soil with the untreated soil.

— Post-grouting Process

All the tests carried out during the pre-grouting process on the untreated soil (that is, the permeation, compaction test and CBR test) will be carried out after the grouting process has been done.

The pre-grouting and post-grouting tests will help to determine if the grouting process was effective or not.

RESULTS AND DISCUSSIONS

Sieve Analysis

Sieve analysis is a laboratory or field test method for determining the particle size distribution of granular materials such as soil, gravel, or crushed rock. This approach entails passing the material through a series of sieves with ever finer mesh sizes and weighing the amount of material that remains on each.

The process typically involves; drying and weighing a representative sample of material, placing the sample on the top sieve and shake the stack of sieves, either by hand or with a mechanical shaker. The sieves have varied mesh sizes, with the largest at the top and the lowest at the bottom. Each sieve's residual material is weighed independently after sieving. Then the proportion of the entire sample that made it through each sieve is usually displayed on a graph based on the results. This aids in the comprehension of the material's particle size distribution.

Table 1 shows the sieve analysis results for the untreated soil sample. It shows the particle size distribution of the untreated sandy soil and confirms that the soil is indeed sandy soil with the Coefficient of uniformity (Cu) and Coefficient of Concavity (Cc) being 2.255 and 2.033 respectively.

Table 1: Sieve Analysis Results for the Untreated Sandy Soil

Particle diameter (mm)	Weight retained	% Weight retained	% Cumulative	% Passing
9.5	0	0	0	100
6.3	0	0	0	100
4.75	50	5	5	95
2.36	140	14	19	81
1.18	450	45	64	36
600n	208	20.8	84.8	15.2
300n	100	10	94.8	5.2
150n	40	4	98.8	1.2
75n	10	1	99.8	0.2
pan	2	0.2	100	0
Total	1000	100		

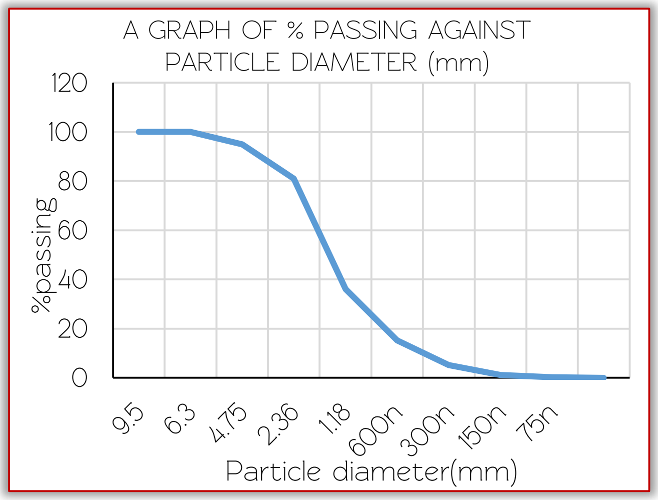

Figure 1: Frequency distribution of the soil sample

Permeability Test

Table 2 shows the permeability results for the untreated sandy soil with 0% cement slurry.

Table 2: Permeability Results for the Untreated Sandy soil with 0% Cement Slurry

Trial No.	Time (s)	Vol. Of Water Collected (cm^3)	Permeability (cm/s)
1	25	200	0.0160
2	26	220	0.0169
3	28	240	0.0171
4	27	230	0.017
5	26	210	0.0162

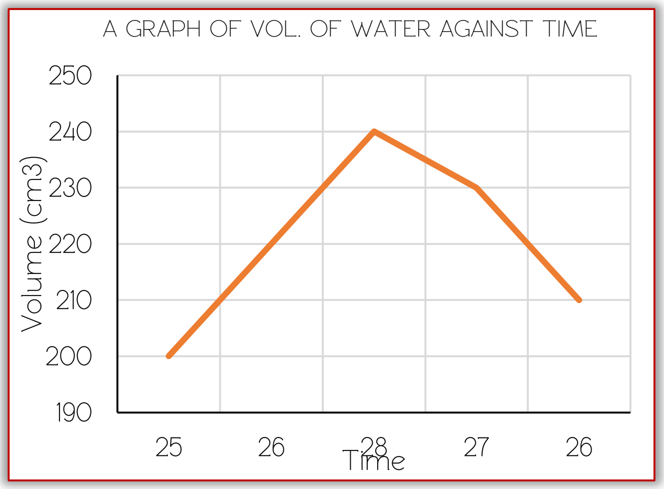

Figure 2: Permeability graph for untreated soil

Table 3 shows the permeability results for the treated sandy soil with 5% cement slurry.

Table 3: Permeability Results for the Treated Sandy soil with 5% Cement Slurry

Trial No.	Time (s)	Vol. Of Water Collected (cm^3)	Permeability (cm/s)
1	40	120	0.0060
2	42	130	0.0062
3	41	125	0.0061
4	39	115	0.0059
5	40	118	0.0060

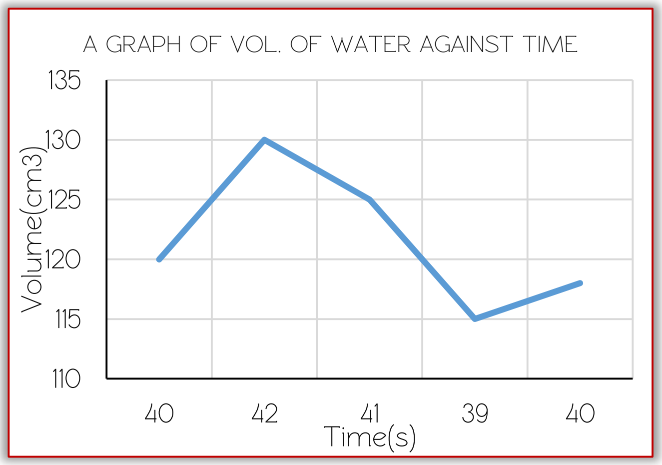

Figure 3: Permeability graph for Treated soil with 5% Cement Slurry

Table 4 shows the permeability results for the treated sandy soil with 10% cement slurry.

Table 4: Permeability Results for the Treated Sandy soil with 10% Cement Slurry

Trial No.	Time (s)	Vol. Of Water Collected (cm^3)	Permeability (cm/s)
1	45	80	0.0036
2	46	85	0.0037
3	44	78	0.0035
4	45	82	0.0036
5	44	79	0.0035

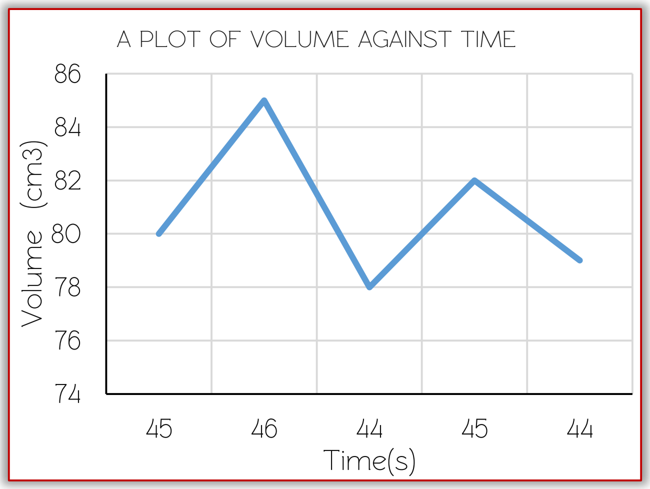

Figure 4: Permeability graph for Treated soil with 10% Cement Slurry

Table 5 shows the permeability results for the treated sandy soil with 15% cement slurry.

Table 5: Permeability Results for the Treated Sandy soil with 15% Cement Slurry

Trial No.	Time (s)	Vol. Of Water Collected (cm^3)	Permeability (cm/s)
1	50	50	0.002
2	52	52	0.002
3	49	48	0.00196
4	50	51	0.002
5	50	49	0.00196

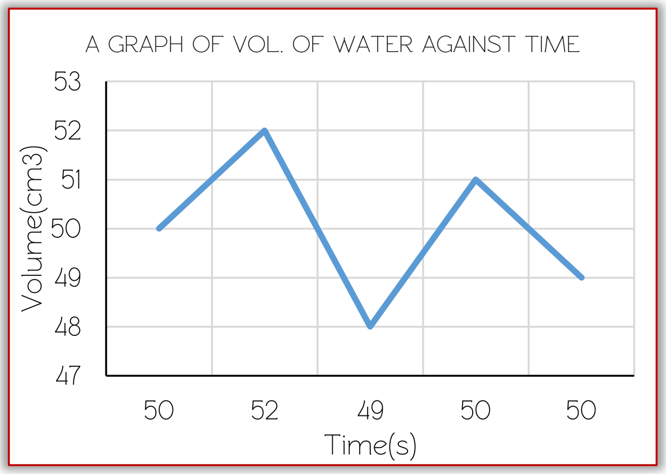

Figure 5: Permeability graph for Treated soil with 15% Cement Slurry

Table 6 shows the permeability results for the treated sandy soil with 20% cement slurry.

Table 6: Permeability Results for the Treated Sandy soil with 20% Cement Slurry

Trial No.	Time (s)	Vol. Of Water Collected (cm^3)	Permeability (cm/s)
1	55	30	0.0011
2	57	32	0.00112
3	54	29	0.00107
4	56	31	0.0011
5	53	28	0.00105

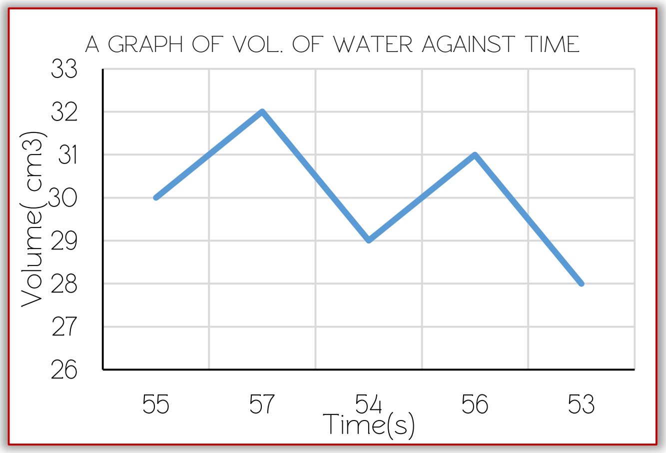

Figure 6: Permeability graph for Treated soil with 20% Cement Slurry

Compaction Test

Table 7 shows the density values of the untreated sandy soil with 0% cement slurry.

Table 7: Compaction Results for Untreated Soil with 0% Cement Slurry

Sample No.	Moisture Content	Dry density g/cm^3
1	6	1.6
2	6.5	1.64
3	7	1.68
4	7.5	1.72
5	8	1.75
6	8.5	1.78
7	9	1.79
8	9.5	1.78
9	10	1.75
10	10.5	1.72

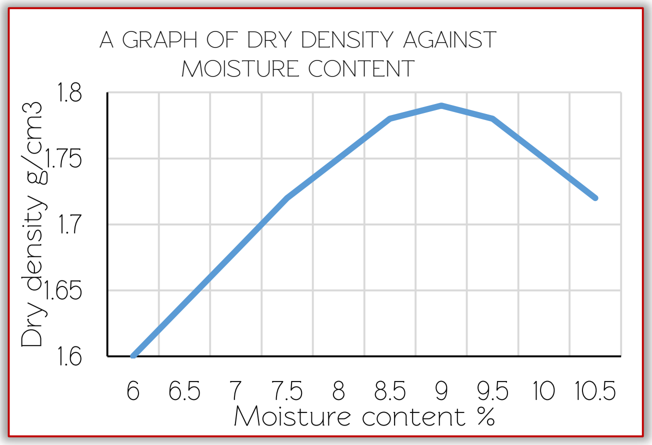

Figure 7: Compaction Graph for untreated soil with 0% Cement Slurry

Table 8 shows the density values for the treated sandy soil with 5% cement slurry.

Table 8: Compaction Results for treated Soil with 5% Cement Slurry

Sample No.	Moisture Content %	Dry density g/cm^3
1	5.5	1.66
2	6.0	1.72
3	6.5	1.75
4	7.0	1.78
5	7.5	1.82
6	8.0	1.85
7	8.5	1.87
8	9.0	1.86
9	9.5	1.84
10	10.0	1.80

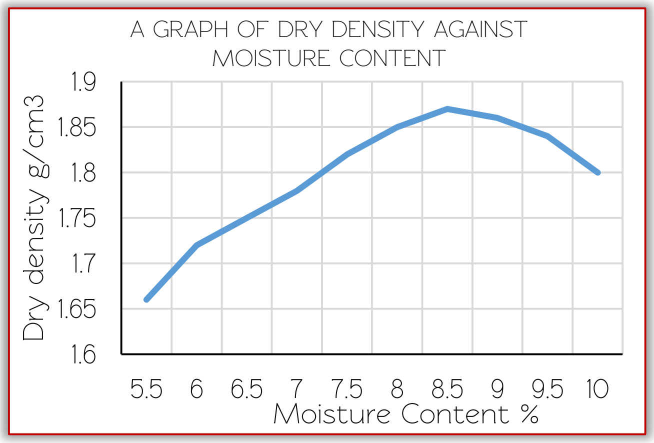

Figure 8: Compaction Graph for treated soil with 5% Cement Slurry

Table 9 shows the density values for the treated sandy soil with 10% cement slurry.

Table 9: Compaction Results for treated Soil with 10% Cement Slurry

Sample No.	Moisture Content %	Dry density g/cm^3
1	5.0	1.70
2	5.5	1.74
3	6.0	1.78
4	6.5	1.82
5	7.0	1.86
6	7.5	1.89
7	8.0	1.91
8	8.5	1.90
9	9.0	1.88
10	9.5	1.84

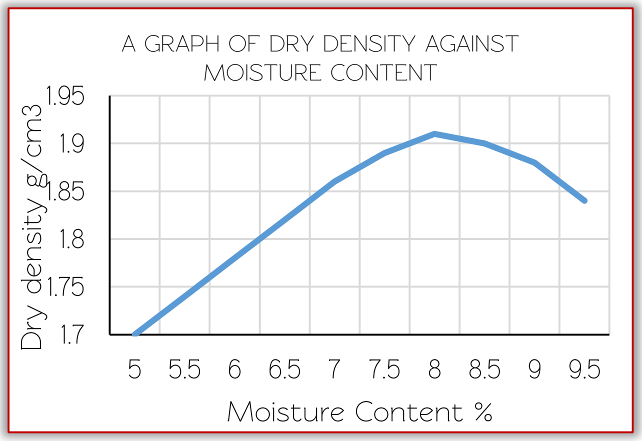

Figure 9: Compaction Graph for treated soil with 10% Cement Slurry

Table 10 shows the density values for the treated sandy soil with 15% cement slurry.

Table 10: Compaction Results for treated Soil with 15% Cement Slurry

Sample No.	Moisture Content %	Dry density g/cm^3
1	4.5	1.72
2	5.0	1.76
3	5.5	1.80
4	6.0	1.85
5	6.5	1.89
6	7.0	1.93
7	7.5	1.95
8	8.0	1.94
9	8.5	1.92
10	9.0	1.88

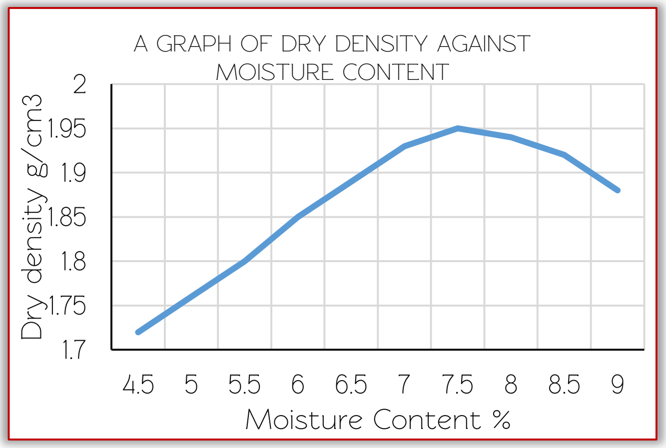

Figure 10: Compaction Graph for treated soil with 15% Cement Slurry

Table 11 shows the density values for the treated sandy soil with 20% cement slurry.

Table 11: Compaction Results for treated Soil with 20% Cement Slurry

Sample No.	Moisture Content %	Dry density g/cm^3
1	4.0	1.74
2	4.5	1.78
3	5.0	1.82
4	5.5	1.87
5	6.0	1.91
6	6.5	1.94
7	7.0	1.97
8	7.5	1.99
9	8.0	1.98
10	8.5	1.96

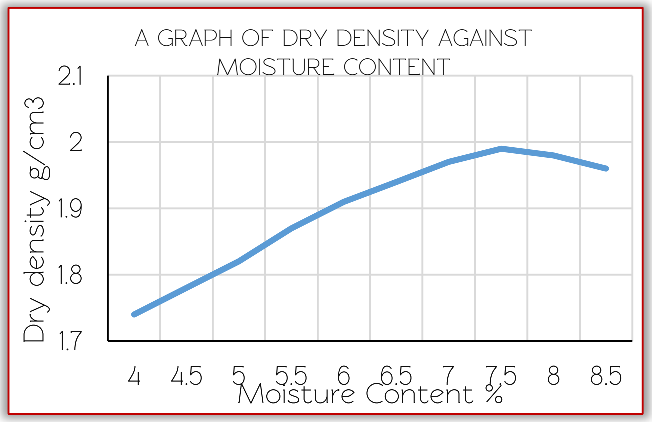

Figure 11: Compaction Graph for treated soil with 20 % Cement Slurry

CBR Test

Table 12 shows the California Bearing Ratios of the untreated sandy soil with 0% cement slurry.

Table 12: CBR Results for Untreated Soil with 0% Cement Slurry

Penetration Reading (mm)	Load Readings (Kg)	Stress (kg/cm^2)	CBR (%)
0.5	30	0.015	3.5
1.0	70	0.035	4.2
1.5	105	0.053	4.5
2.0	130	0.065	5.0
2.5	160	0.080	5.7
3.0	180	0.090	6.0
4.0	210	0.105	6.8
5.0	240	0.120	7.5

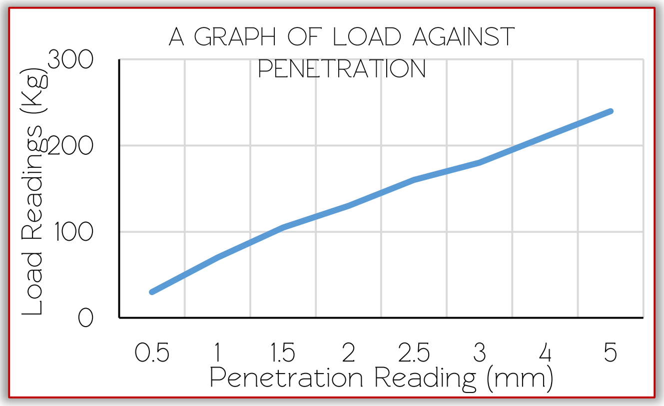

Figure 12: California Bearing Ration for Untreated soil with 0 % Cement Slurry

Table 13 shows the California Bearing Ratios of the treated sandy soil with 5% cement slurry

Table 13: CBR Results for Treated Soil with 5% Cement Slurry

Penetration Reading (mm)	Load Readings (Kg)	Stress (kg/cm^2)	CBR (%)
0.5	50	0.025	5.2
1.0	100	0.050	6.5
1.5	150	0.075	7.0
2.0	190	0.095	7.8
2.5	240	0.120	10.5
3.0	280	0.140	11.7
4.0	320	0.160	13.5
5.0	360	0.180	15.1

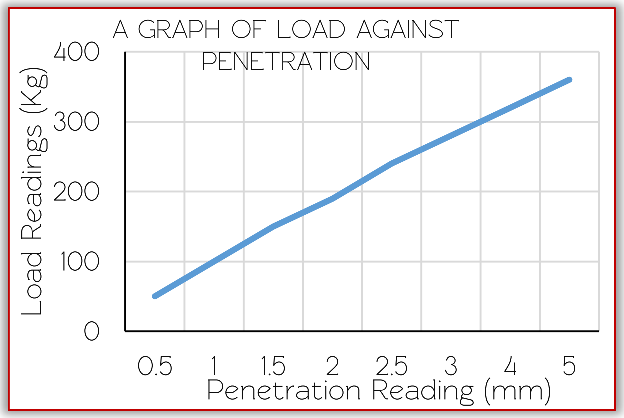

Figure 13: California Bearing Ration for treated soil with 5% Cement Slurry

Table 14 shows the California Bearing Ratios of the treated sandy soil with 10% cement slurry.

Table 14: CBR Results for Treated Soil with 10% Cement Slurry

Penetration Reading (mm)	Load Readings (Kg)	Stress (kg/cm^2)	CBR (%)
0.5	80	0.040	7.0
1.0	150	0.075	9.0
1.5	200	0.100	10.2
2.0	260	0.130	11.3
2.5	320	0.160	18.3
3.0	360	0.180	21.5
4.0	420	0.210	25.6
5.0	480	0.240	30.1

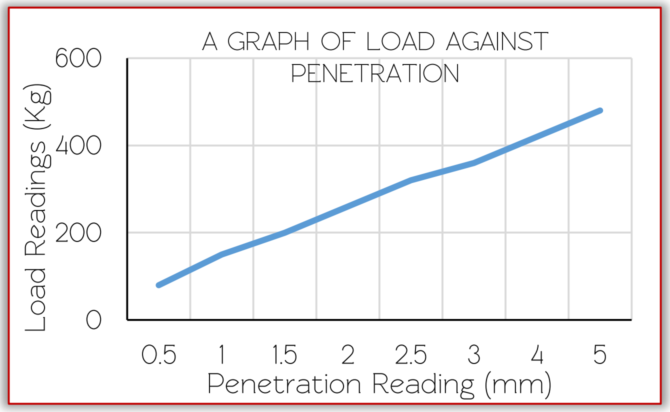

Figure 14: California Bearing Ration for treated soil with 10% Cement Slurry

Table 15 shows the California Bearing Ratios of the treated sandy soil with 15% cement slurry.

Table 15: CBR Results for Treated Soil with 15% Cement Slurry

Penetration Reading (mm)	Load Readings (Kg)	Stress (kg/cm^2)	CBR (%)
0.5	100	0.050	10.5
1.0	200	0.100	13.5
1.5	270	0.135	16.0
2.0	350	0.175	18.5
2.5	420	0.210	25.7
3.0	480	0.240	28.8
4.0	540	0.270	32.5
5.0	600	0.300	37.5

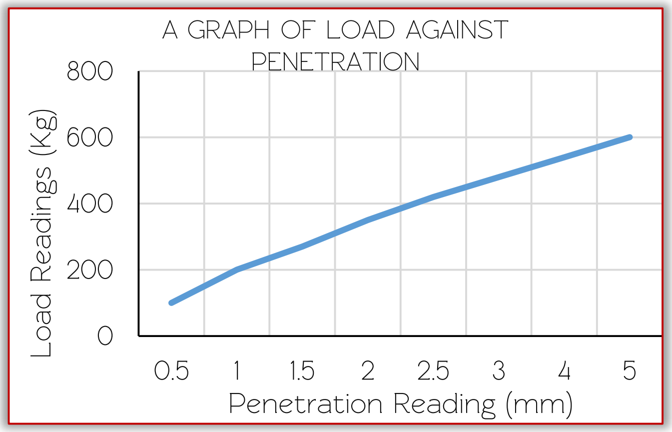

Figure 15: California Bearing Ration for treated soil with 15% Cement Slurry

Table 16 shows the California Bearing Ratios of the treated sandy soil with 20% cement slurry

Table 16: CBR Results for Treated Soil with 20% Cement Slurry

Penetration Reading (mm)	Load Readings (Kg)	Stress (kg/cm^2)	CBR (%)
0.5	120	0.060	14.0
1.0	250	0.125	17.0
1.5	320	0.160	22.0
2.0	400	0.200	25.5
2.5	500	0.250	35.0
3.0	550	0.275	38.5
4.0	600	0.300	42.5
5.0	650	0.325	47.5

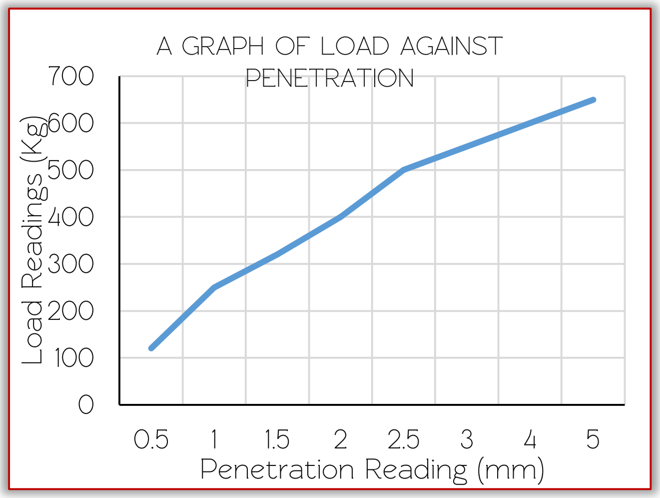

Figure 16: California Bearing Ration for treated soil with 20% Cement Slurry

DISCUSSIONS

The calculated permeability values for the sandy soil in Table 2 are in the range of 0.016 to 0.0171cm/s, which indicates that the soil has high permeability due to the large pore spaces between sand grains. In tables 3, 4, 5 and 6, we see that there is a substantial decrease in the permeability values compared to the permeability values for the untreated soil in table 4.2.

The untreated sandy soil without any cement slurry has lower dry density, higher optimal moisture content and less stability compared to cement-stabilized soil as shown in table 7. It is more susceptible to erosion and water infiltration, making it less suitable for demanding construction applications. The results obtained in tables 8, 9. 10 and 11 shows an increase in the dry density values compared to untreated sandy soil due to the binding effect of the cement, which improves the density of the soil.

Table 12 shows that the strength of the untreated sandy soil is at 11.7% which is of moderate strength. The results of the CBR tests of the treated soil in figure 13, 14, 15 and 16 shows the values of the sandy soil grouted with various percentages of the cement slurry. It could be observed from the results that with an increase in percentage of the cement slurry, there is a corresponding increase in the CBR value. This shows that with an increase with the percentage of cement slurry grouted with soil, there is an increased strength in the soil.

CONCLUSIONS

It is concluded that cement grouting can be used to increase the bearing capacity of sandy soils. The results showed that with the aid of cement grouting, the mechanical characteristics of sandy soils could be improved to make them suitable for carrying loads.

This study provides practical knowledge about how cement grouting is applied in geotechnical engineering and gives recommendations on getting optimal results from it. Moreover, this study reveals the need to consider environmental factors and suggests that alternative forms of traditional cement grouting should be sought.

More detailed studies should look into long-term behaviour and environmental performance of cement-grouted soils as well as possible alternatives for soil stabilization among other areas.

In conclusion, we can say that this research offered new insights into the understanding of soil stabilization techniques pertinent to engineers and researchers specializing in geotechnical fields.

References

[1] Ali H. Shareef, Mohammed A. Al-Neami, Falah H. Rahil (2023). Some of the field and laboratory studies on grouting properties for weak soils: A Review

[2] Bui Van Duc, Pham Duc Tho, Nguyen Duc Chieu, Somjai Yobonchit (2023). A case study of the improvement of an old building's shallow foundation resting on sandy clay soil using cement slurry grouting technique.

[3] Faten Alsakr1,* Toufik Fayad 1 and Rami Alabdeh (2023). Effect of permeation grouting using cement kiln dust (CKD) on some mechanical properties of sandy soil.

[4] Hukma Ram, Deepanshu Solanki, and Mayank Dave (2023). Grout improvement methods to increase weak soil's bearing capacity.

[5] J. Sree Naga Chaitanya, Dr. K. Chandramouli, K. Divya, K. Babu Rao (2023). A review on grouting technique.

[6] Mohammed S. Mohammed*, Samir H. Hussein, and Mahmood D. Ahmed (2022). Comparison between cement and chemically improved sandy soil by column models using low-pressure injection laboratory setup

[7] Md. Hamjala Alam*, Tanmoy Mondal, Tarun Dev, Arijit Kumar Banerji, Chanchal Das (2024). Use of construction and demolition waste material for soil stabilization.

[8] N. Valarmathy, G. Preethi Sindhu and M. Vinodhini (2023). Experimental research on loose soil stabilization using compacting and grouting.

[9] Samir H. Hussein and Mahmood D. Ahmed (2024). Effect of jet grouting columns to mitigate seismic effects in sandy soil under raft foundation.

[10] Sakina Tamassoki1,2, Nik Norsyahariati Nik Daud1*, Mohammad Nazir Nejabi2 and Mohammad Jawed Roshan2,3 (2022). Fibre-Reinforced Soil Mixed Lime/Cement Additives: A Review

[11] Shengnian Wang, Xingjin Zhang, Peng Zhang, amd Zewei Chen (2023). Strength performance and Stabilization mechanism of fine sandy soils stabilized with cement and metakaolin.

[12] Zhi Qin, Quanjun Shi, Dong Qin, Haihua Wang, Yuejing Luo and Wensheng Wang (2023). Performance comparison of grouting pastes and goaf effect evaluation of grouting backfilling method.

ISSN: 2067-3809