© MAY 2022 | IRE Journals | Volume 5 Issue 11 | ISSN: 2456-8880

Improvement/Evaluation of Bearing Capacity of Sandy Soil in Kuje. Federal Capital Territory, Abuja, Nigeria by Grouting

ABIODUN ANDREW SUNDAY[1], BUSARI AFIS OLUMIDE[2]
[1, 2] Department of Civil Engineering, Faculty of Engineering, University of Abuja, Nigeria

Abstract-* This project work is on improvement/evaluation of bearing capacity of sandy soil by grouting. The sample was collected along Kuje road Abuja and subjected to various tests such as Compaction test, California Bearing Ratio (CBR), Atterberg Limit Test, Liquid Test, Plastic Limit Test, and Sieve Analysis Test. In relation to the subject matter, view of some scholars and authors were reviewed and the data collected which are presented and analyzed accordingly. According to the various test the experiment was subjected to it was concluded that the Improvement experiment shows that, Mc is static, while the cement grouting is increased, at 2% the strength increased to a value above 0%, when the grouting cement is further increased to 4% the strength increased to a higher value than 2%. However, when further increased to 6%, it is observed that, the strength of cement grouting dropped below the value of 4%. This result shows that at 4% grouting is the best hydration process of the strength valve. In the Evaluation process of the experiment as the cement grouting is increased by 2% Mc is increased, thus strength value is recorded, when further subjected to increase to 4%, the result value is higher than 2%, this process is repeated for 6% and the result is higher than 4% respectively, showing that, there is an adequate cement hydration process in the experiment.

***Indexed Terms-* Cement, Grouting, Sandy soil, Stabilization**

I. INTRODUCTION

The construction of structure on weak ground often requires the soil to be improved in order to ensure safety and stability of surrounding buildings. Ground improvement in granular soils can be achieved by different methods such as vibro-floatation, compaction piles, and compaction with explosives, excavation and replacement, grouting and so on. Selection of the most suitable approach depends on a variety of factors including soil conditions, required degree of compaction, types of structure to be supported, as well as site specific considerations like available time for completion of the project as well as availability of equipment and materials. Soil compaction can offer effective solutions for many foundation problems and is specifically useful for reducing total settlement in sand.

Sandy soil implies most of the soil particles are larger than 2mm in diameter. It gives good water drainage and has a low capacity to hold nutrients. Sandy soil does not hold moisture very well. It is granular and consists of rock and mineral particle which are very small. Therefore, the texture is gritty and is formed by the disintegration and weathering of rocks such as limestone, granite, quartz and shale. It is also easier to cultivate if it is rich in organic materials but then it allows more drainage than required. This results in over drainage and dehydration of the plant in summer. It warms very fast in the spring season. Sandy soil is the largest particle in the soil when you rub it, if feels rough. This is because it has sharp edges and it does not hold many nutrients.

Soil stabilization with cement grout injected under pressure has come into wide spread use in construction. At present, the method of grouting is highly prevalent in a number of branches of structural engineering, hydraulic engineering for the building of anti-seepage curtains for imparting mono-lithicity and impenetrability to the concrete masonry of structures; in mining for the opening of shafts, side drifts, and other workings; and in foundation engineering for the reinforcement of existing foundations beneath buildings and structures as well strengthening the soils in their beds. The primary merits of the method of grouting, lie in its technical simplicity, convenience of use, and high reliability of the results achieved. Moreover, the method is sufficiently economical and does not require complex equipment and is also ecologically safe for the environment [1].

Permeation grouting is commonly used in geotechnical engineering either to reduce the permeability or improve the mechanical properties of soil and rock. Success in any given grouting operation requires that the desired improvements in the properties of the formation are attained. Grouts are generally categorized as suspension or particulate grouts, which are prepared with ordinary Portland or other cements, clays, cement-clay mixtures, in some cases fine sand, solution, or chemical grouts, which could include sodium silicate acrylamide, acrylates, lignosulfonates, phenoplast and aminoplast as well as other material that have no particles in suspension [2].

Jet grouting is conducted to stabilize underlying marine clay using double fluid system. A thick layer of jet grouting pile provided from 5 m thick using ultra high-pressure cement grout under controlled insertion, rotation and withdrawal. The formed jet grouting pile, increase in shear strength acts as a barrier forming impermeable strata, structs the sheet pile as structural support excavation [3]. Compaction grouting could be effectively used to mitigate liquefaction of the susceptible soils. The greatest improvement from grouting was achieved in sands. Silts were also improved but the grouting was less effective [3].

Microfine cement suspensions with a water: cement ratio of 4 or higher can be successfully injected into fine sand (D10 as low as 0.15 mm with a hydraulic radius as small as 0.002 mm) under a pressure of about 10 psi which will have a depth of penetration of at least one-half meter. Cement particles are captured around the contact points between grains and are deposited on the grain surface to form a thick cake, which upon hardening, provides the grouted mass with improved mechanical properties. Microfine cement grouts are being proposed increasingly as an alternative to chemical grouts (which often contain one or more toxic components) for grouting fine sands. However, their successful use is influenced strongly by the relationship between the suspended solids (individual's particles particle aggregations) in the grout the pores in the porous medium. Although advocated by some practitioners, the use of concentrated (low water: cement ratio) suspensions and high injection pressures can lead to non-homogeneity in the grouting of a soil formation due to the development of preferential paths during injection or hydraulic fracturing of the soil mass [4].

The concept of a limiting effect or a boundary effect of grouting is of great value in both theoretical research and practical application of grouted sand. The selection of grouting for a specific job is mainly affected by the amount of improvement, in strength and/or stiffness, that can be achieved, and the limitations for this improvement, in strength with increased depth or confinement [5]. Particle size distributions are used in characterizing the soil and to determine the grouting ability of soil [6]. The procedure adoption for preparation of a grouted bed in the laboratory was given by [5]. The sand placed with zero fall height in a transparent and rigid cylindrical column made of PVC of diameter of 80 mm and height 900 mm. A few simultaneous hammer strokes on the PVC tube compacted the soil. A fixed volume of grout equal to 1.2 times the initial volume of the granular skeleton was injected from the base to the top of the column at a flow rate of 3 cm^3/s column was kept in a humid condition for a period of 28 days. [7, 8] made significant contribution on the study of grout materials, properties, equipment and procedure for grouting. The safe construction and operation of many structures frequently require improvement of the mechanical properties and behavior of soils by permeation grouting using either suspensions or chemical solutions. The former has lower lost and are harmless to the environment but cannot be infected into soils with gradations finer than coarse sands. The latter can be injected into fine sand or coarse silts but are more expensive and some of them pose a health and environmental hazard [9]. Grouting has a minimal effect on the angle of internal friction of sands or yields an increase of up to 4.5 ^{o}. There are strong indications that pulverized cementitious, fly ash with appropriate additives can be effectively utilized for permeation grouting of coarse sands [10]. In the work of [11], reported that in many situations, the bottom up method can be used as effectively as the top down method if appropriate modification are adopted at shallow depths. Even this the extra cost of much modifications, it is likely that the bottom-up method will be the most economical choice.

Paoli et al, [12] studied the settlement, structural failure and in-place repair of above ground storage tanks with many sizes placed on foundation of varying nature. The causes of tank stress on foundation of varying nature. The causes of tank stress and failure are reviewed including some environmental control concern and causes and related to tank foundation problems the uneven movement and settlement of foundation soil can be stopped by grouting. Permeability and strength of grouted sand is strongly influenced by the method of grouting because different mechanism govern the deposition and packing of cement particles within the pure structure. During the injection process, preferential flow paths allow the migration of cement particles into the soil, and micro structural packing undoubtedly varies within the pores of the grouted sand, this is in contrast to the more uniform distribution of cement particles in hand mixed specimens [13].

Grout ability ratio is not a universally applicable criterion, and values large or smaller than the limiting value of 25 do not necessarily indicated success of failures respectively, as a specific grouting operation using a particulate grout, experimental evidence suggests that the grain size distribution and relative density of the fine sands may control the grouting operation [13]. The grouting technique is the MRRB project at Kaohsing city in the southern part of Taiwan, shows a significant increase of horizontal stress within the improved soil mass. Preloading effect was more significant in reducing wall displacement than anticipated. Jet grouting also increase the overall strength of improved soil mass. Other improvement method, such as compaction grout column and displacement pile driving may be even more effective than jet grouting [14].

II. MATERIALS AND METHODS

2.1 MATERIALS

The soil sample was sandy soil obtained from Kuje road located at Kuje Area Council of the Federal Capital Territory, Abuja, Nigeria. Trail pits of 1.0 m in depth were dug and the samples located at that depth were obtained and put in a sag which were properly z to the geotechnical laboratory of Soil-Men Engineering Ltd, Kubuwa Abuja. The cement used in this research in the Dangote cement obtained in an open market in Abuja.

2.2 METHODS

2.2.1 COMPACTION TEST

The aim of compaction test is to determine the relationship between moisture (water) and soil as it is being compacted at a particular comparative standard. Compaction is a process by which the soil particles are artificially rearranged and packed together into a closer state of contact by mechanical means in order to decrease the porosity (or voids ratio) of the soil and this increase its dry density [15]. The compaction process may be accomplished by rolling, tamping or vibration. It occurs when the weight of heavy machinery compresses the soil causing it to lose pore space. Soil compartment may also occur due to a lack of water in the soil.

2.2.2 CALIFORNIA BEARING RATIO TEST PROCEDURE

The California Bearing Ratio (CBR) test is aimed at determining the suitability of a soil, this method covers the determination of the California. Bearing Ratio (CBR) of a soil that is obtained by measuring the relationship between force and penetration when a cylindrical plunger of cross- sectional is area 1935 mm2 is made to penetrate the soil at a given rate [16]. At any value of penetration, the ratio of the force to a standard force is defined the California Bearing Ratio (CBR). Because of the plunger size, the test is appropriate only to materials having a maximum particle size of 20mm. The test is more applicable in those tropical and subtropical areas where drier conditions prevail under roads and air fields [17].

2.2.3 ATTERBERG LIMIT TEST

The Atterberg limit test involves the determination of the liquid limits, plastic limits and the plasticity index.

2.2.3.1 LIQUID LIMIT TEST

The aim of this test is to determine the minimum water content at which the soil will flow under a specified force.

2.2.3.2 PLASTIC LIMIT TEST

This test aim to determine the water contents below which the soils no longer behave as a plastic material (non-plastic).

2.2.4 SIEVE ANALYSIS TEST

The grading of an aggregate is the quantitative distribution of its various article sizes in terms of the proportion passing through sieves with square openings of different standard a apparatus. Grading is determined by a sieve analysis on a sample to aggregate, in which a series of standard sieves are tested on stacked one on top of another with increasing apertures size from bottom to top and through which a sample of aggregate is passed from the usually aided by shaking or vibrating the sieves.

2.2.5 GROUTING PROCEDURE

Grouting, which has several applications in the field of civil engineering, was once considered as a mysterious operation. The effectiveness of grouting requires a lot of understanding, skill, meticulous attention and an intuitive perception. Even though grouting was started 200 years ago, it was treated for a long time, as an art which eluded scientific investigation and improvement. Grout is injected under pressure into the material to be grouted until it fills the desired volume of material around the hole or until the maximum specified pressure is attained and a specific minimum grout flow is reached. This paper discusses the strength improvement of loose sandy soils through cement grouting. Various cement percentages (2, 4, 6 and 8% respectively) were used for grouting medium sand beds in the loosest state. The effectiveness of grouting was evaluated based on the actual cross-sectional area of the intact grouted mass at different depths and by determination of cement content at various depths and laterals distances of the grouted medium. The improvement in strength due to grouting was assessed with the help of load tests. 4 % cement grout was found to be more effective in medium sand compared to 2 and 6 %. The results undoubtedly prove the effectiveness of using grouting as an efficient technique in improving the foundation beds of loose sandy soils

III. RESULTS AND DISCUSSIONS

3.1 PROPERTIES OF NATURAL SOIL USED FOR THIS STUDY

The soil sample was obtained at Pasali located along Kuje road in Kuje Area Council in the Federal Capital Territory, Abuja, Nigeria. The soil sample is described as lateritic silty sand. The sand particles contain some amount of lateritic clay. The soil has a low natural moisture content of 2.5 %. This is due to the fact that sandy soils have very low water retention ability and the large pore spaces located between the particles. The natural soil before the addition of cement has index properties shown in the summary of the test result sheet shown in Figure 3.1. The liquid limit and plastic limit are both non plastic. This implies a plasticity index of non-plastic since it is a function of the liquid and plastic limit. The non-plastic nature if the sample is a typical feature of sand. Sieve analysis conducted on the sample showed that only 2 % and 5 % of the fine sample pass through BS sieve No 200 and No 100 respectively as shown on the particle size distribution curve in Figure 3.2 and 4.2. On classifying the soil using the AASHTO system of soil classification shows the soil sample belongs to the A-3(0) soil group [18]. Conducting compaction test using the British standard proctor at 25 No of blows in three layers with a 2.5 kg weight of hammer falling at a height of 30 cm, shows the soil sample has an optimum moisture content of 5.9 % and a dry density of 1700 kg/m^3. The unsoaked CBR value of the sample was 31 %.

PASALI KUJE ROAD							SIEVE ANALYSIS											CLASSIFICATION	
CEMENT CONTENT	LAB OMC %	DRY DENSITY KG /M3	CBR % UNSOAKED		LL %	PI %	3/4	1/2	3/8	3/16	7	14	25	36	52	100	200	TRH4	AASHTO
0 %	5.9	1700	31		NP	NP	100	100	100	98	97	96	66	61	30	5	2		A-3 (0)
2%			31																
4%			31																
6%			25																

Figure 3.1 Summary of test results

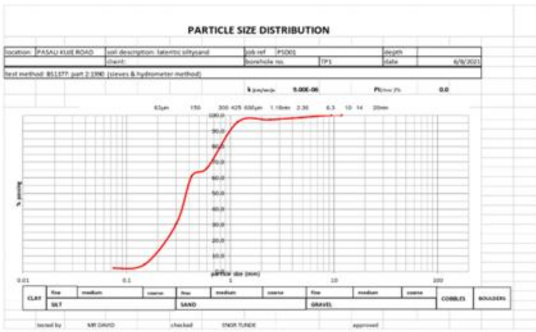

Figure 3.2 Particle size distribution for the natural sand sample

3.2 COMPACTION CHARACTERISTICS

A compaction test was conducted on the natural soil using the British Standard Light to determine the relationship between the moisture content and dry density. Figure 3.3 shows the compaction test results conducted on the sample. As can be seen from the figure, the dry density increased with increasing moisture content until it reached a peak value of 1.700 g/cc equivalent to a moisture content of 5.9 %, then it starts to reduce as the moisture content is increased. Therefore, for the natural soil sample, the optimum moisture content was obtained as 5.9 and a maximum dry density of 1.700 g/cc.

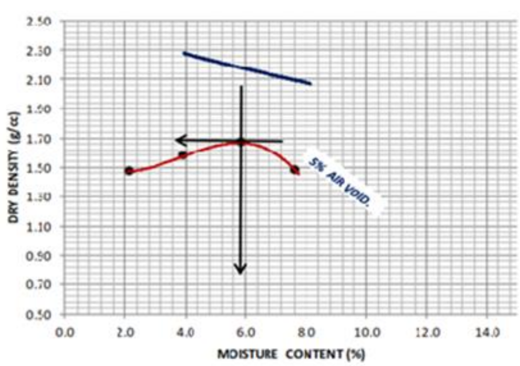

Figure 3.3 Compaction test for natural sample

3.3 CALIFORNIA BEARING RATIO (CBR)

California Bearing Ratio (CBR) test is carried out to determine the strength of a soil. It is a penetration test which appraises the strength of a soil for use as a layer material for road pavement and other engineering purpose. The thickness of the pavement of usually obtained using the help of empirical curves from the results gotten. Figure 3.4 shows the plots of unsoaked CBR against dry density and degree of compaction. It can be seen that a linear relationship exists between the unsoaked CBR and dry density and likewise the same relationship between the unsoaked CBR and the degree of compaction giving an unsoaked CBR value of 30.7 %. This shows the significance of the dry density and the degree of compaction on the strength characteristics of a soil sample. Figure 4.5 shows the test form and procedure taken in determining CBR. It involves measuring the penetration from applying the load plunger which is a replica of an applied force. The level of penetration is used to determine the CBR value.

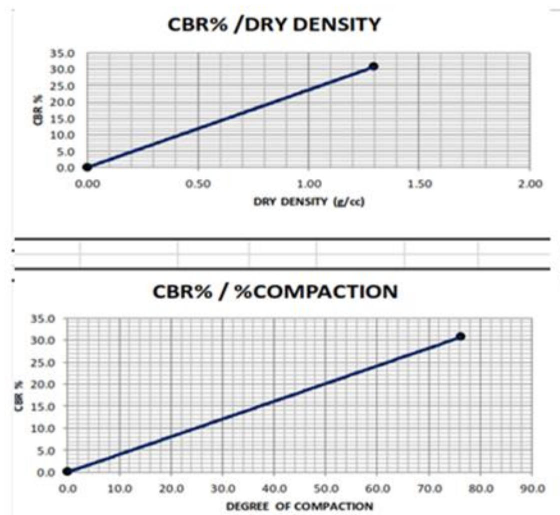

Figure 3.4 Relationship between CBR and dry density/degree of compaction

3.4 PROPERTIES OF SOIL IMPROVED WITH GROUTED CEMENT

Results obtained from test conducted on the natural sample showed that the sandy soil is unsuitable for engineering purposes. Therefore, in an attempt to improve its properties and render it favorable for engineering purpose, the sample was grouted with cement. Cement is a suitable material which due to its composition and content. The sandy material contains very low content of fine particles. Therefore, the cement which is made of mostly fine particles fill in the large void spaces thereby compensate and create a more compact particle. The cement content was added in percentage to the sand particles to improve the bearing capacity. The percentage were from 0 % which is the control to 2 %, 4% and finally 6%. All the required test were conducted on the mixed simple. The results of test conducted on each percentage blending were analyzed to see which if this this percentage will provide the most desired output suitable for the engineering purpose.

3.5 IMPROVING THE BEARING CAPACITY OF THE SANDY SOIL BY GROUTING WITH CEMENT

To improve the bearing capacity and other engineering properties of sand, various percentage by weight of cement was added to the sand particles for each of the test conducted. Various test including sieve analysis, compaction, California Dearing Ratio (CBR), Atterberg limit, similar to what was done on the natural sample was also conducted on this blended sample.

3.6 CALIFORNIA BEARING RATIO (CBR)

California Bearing Ratio (CBR) test is carried out to determine the strength of a soil. It is a penetration test which appraises the strength of a soil for use as a layer material for road and other engineering purpose. Normally, the thickness of the pavement of usually obtained using the help of empirical curves from the results obtained. Figure 3.5 shows the results of the CBR test conducted on the sample with 2 % cement content. Using an optimum moisture content of 5.9 % and a maximum dry density of 1.7 g/cc, an unsoaked CBR of 36.9 % was obtained. The CBR value varies linearly with dry density. Likewise, a linear relationship exists between the same CBR and the degree of compaction. It was at 100 % compaction the unsoaked CBR value of 36.9 was obtained.

Similar to the 2 % cement content, a 4 % cement content was also conducted and the various test carried out. Figure 3.6 shows the California Bearing Ratio (CBR) for the 4 % cement content. From the figure, it can be seen that at a moisture content of 5.9 which is the optimum and a maximum dry density of 1.7 g/cc, the value of an unsoaked CBR was obtained as 43.2 %. This value is higher than the 36.9 obtained for 2 % cement content.

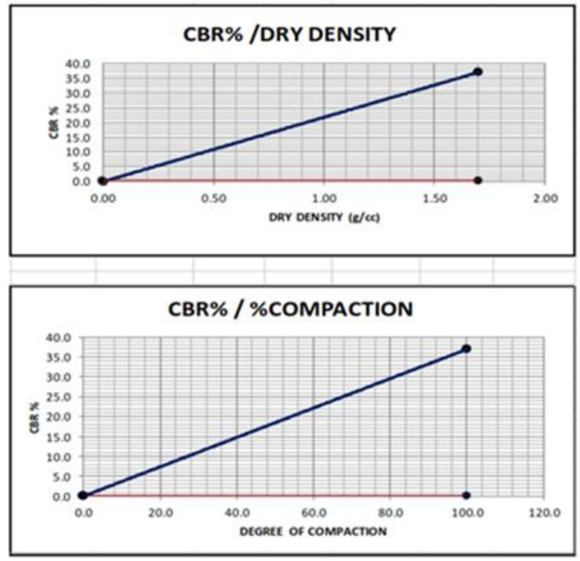

Figure 3.5 CBR at 2 % cement content

This shows that as the percentage of cement content increases, the CBR, which is a measure of strength of the soil sample increases, and likewise with the degree of compaction

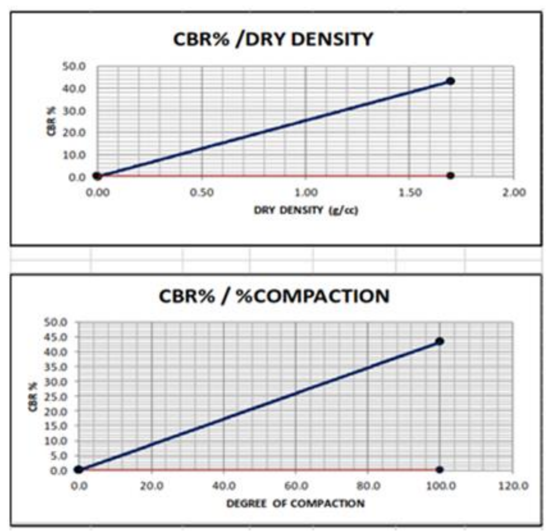

Figure 3.6 CBR at 4 % cement content

In addition, the same procedure was repeated for 6 % cement content with the various test conducted on the sample. Figure 3.7 shows the CBR plot for the 6 % cement content. From Figure 4.10, at s moisture content of 5.9 which is the optimum and a maximum der density of 1.68 c/cc, an unsoaked CBR of 50.0 was obtained. This unsoaked CBR value was gotten at 100 % compaction since the degree of compaction has as well as the dry density has significant effect on the CBR which is a measure of the strength of a soil. In addition, it the unsoaked CBR value at 6 % cement content was observed to be higher than that of 4 %. This buttress the fact that as the cement content in the sample in increased, the value of the unsoaked CBR also increases.

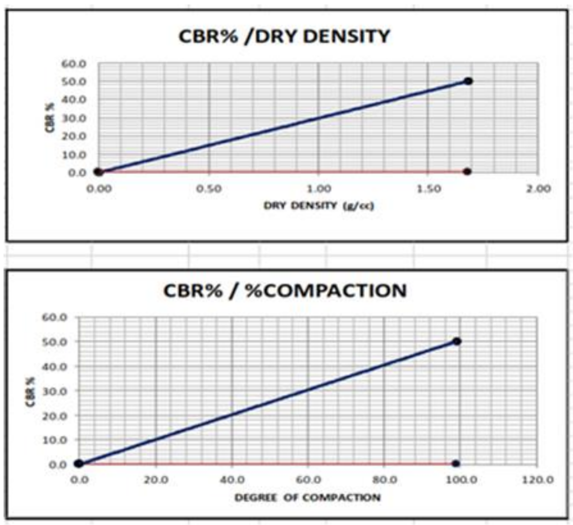

Figure 3.7 CBR at 6 % cement content

IV. CONCLUSION

The sample obtained at Pasali, located along Kuje road in Kuje Area Council in Federal Capital Territory, Abuja, Nigeria. The sample description was lateritic silty sand classified according to AASHTHO as A-3(0) which is unsuitable for several engineering purpose. To improve its engineering properties making it suitable to engineering works, the sample was treated with cement at 2 %, 4 % and 6 % by weight of the sample and subjected to compaction and California Bearing Ration (CBR) which are measure of strength of a soil.

Compaction test conducted on the natural soil before treatment showed the lateritic silty clay has an optimum moisture content of 5.9 % and a maximum dry density of 1700 kg/m^3, likewise an unsoaked CBR of 31 %.

Furthermore, on treating with cement, it was observed that as the cement content is increased, the CBR value also increases. At 2 %, 4 % and 6 %cement content, the unsoaked CBR was observed to be 36.9 %, 43.2 % and 50.0 % respectively. This can be connected to cement which consist of fine particles filling the large void spaces in the sandy soil making it more compact hence increasing its strength properties. Another important factor which affects the strength of the soil is the degree of compaction. As the degree of compaction is increased, likewise the CBR.

On evaluation, it was observed that at a constant moisture content and at 2 % cement content, the value of strength increased to a value above 0 %. Further increase of cement content to 4 % showed that the strength increased to a value higher than 2 %. However, on further increasing the cement content to 6 %, the strength of reduced to a value below 4 %. This showed that 4 % cement content produces the best hydration for an optimum strength value.

In addition, it was observed that at when the cement content is increased from 2 % to 4 %, the strength was higher as the moisture content is increased, and on increasing to 6 %, the strength results were higher than in 4 %. This shows an adequate hydration of cement in the experiment process.

REFERENCES

[1] M. Ibragimov, Soil stabilization with cement grouts, Soil mechanics and foundation engineering, 42 (2005) 67-72.

[2] P.V. Lade, D.D. Overton, Cementation effects in frictional materials, Journal of Geotechnical Engineering, 115 (1989) 1373-1387.

[3] J.K. Mitchell, J.C. Santamarina, Biological considerations in geotechnical engineering, Journal of geotechnical and geoenvironmental engineering, 131 (2005) 1222-1233.

[4] L. Arenzana, R. Krizek, S. Pepper, Injection of dilute microfine cement suspensions into fine sands, Proceedings of the 12th International Conference on Soil Mechanics and Foundation Engineering, Publ by AA Balkema, 1989, pp. 1331-1334.

[5] A. Ata, C. Vipulanandan, Cohesive and adhesive properties of silicate grout on grouted-sand behavior, Journal of geotechnical and geoenvironmental engineering, 124 (1998) 38-44.

[6] B. Standard, 1377. 1967, Methods of testing soils for civil engineering purposes.

[7] H. Shahnazari, Y. Jafarian, M.A. Tutunchian, R. Rezvani, Undrained cyclic and monotonic behavior of Hormuz calcareous sand using hollow cylinder simple shear tests, International Journal of Civil Engineering, 14 (2016) 209-219.

[8] W.J. Clarke, M.D. Boyd, M. Helal, Ultrafine cement tests and dam test grouting, Grouting, Soil Improvement and Geosynthetics, ASCE, 1992, pp. 626-638.

[9] D.U. Deere, Cement-bentonite grouting for dams, Mine Induced Subsidence: Effects on Engineered Structures, ASCE, 1982, pp. 279-300.

[10] I. Pantazopoulos, D. Atmatzidis, Dynamic properties of microfine cement grouted sands, Soil Dynamics and Earthquake Engineering, 42 (2012) 17-31.

[11] T.S. Kumar, B.M. Abraham, B.T. Jose, A. Sridharan, INFLUENCE OF ADMIXTURES ON STRENGTH OF CEMENT GROUTED SOILS.

[12] B. De Paoli, B. Bosco, R. Granata, D. Bruce, Fundamental observations on cement based grouts (2): Microfine cements and the Cemill® process, Grouting, Soil Improvement and Geosynthetics, ASCE, 1992, pp. 486-499.

[13] A. Bolognesi, O. Moretto, Stage grouting preloading of large piles on sand, Proceedings of 8th ICSME, Moscow, 20 (1973).

[14] M.N. Al-Awad, Simple correlation to evaluate mohr-coulomb failure criterion using uniaxial compressive strength, Journal of King Saud University-Engineering Sciences, 14 (2002) 137-144.

[15] K. Nusit, P. Jitsangiam, Damage behavior of cement-treated base material, Procedia engineering, 143 (2016) 161-169.

[16] M.S. Pakbaz, M. Farzi, Comparison of the effect of mixing methods (dry vs. wet) on mechanical and hydraulic properties of treated soil with cement or lime, Applied Clay Science, 105 (2015) 156-169.

[17] N.C. Consoli, A method proposed for the assessment of failure envelopes of cemented sandy soils, Engineering geology, 169 (2014) 61-68.

[18] T. Officials, Standard specifications for transportation materials and methods of sampling and testing, AASHTO, 2011.