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Determination of Relative Density of Sand with Refrence to Compaction Energy and Effect of Nanoslica on Mechanical Properties of Sandy Soil

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ABASTRACT- Sands are typically compacted in the field using a variety of machinery, with the compaction energy varying greatly. The relative density is a better indicator for determining granular soil compaction. It can be more beneficial in the field if the relative density can be associated simply by any index property of the granular soil. The voids ratio is used to define relative density. The minimum and maximum voids ratios are known to be dependent on the mean grain size. However, when different energy levels are considered, there is no clear relationship for the void's ratio in terms of grain size. As a result, the effect of mean grain size on the relative density of sand has been investigated in this dissertation under various compaction energies.The voids ratio for standard, modified, reduced standard, and reduced modified energy levels. The simple nonlinear empirical relations have been derived by correlating Proctor tests with mean grain size. The proposed method estimates the relative density with a percentage variance of less than 5% of the measured value. The relative density correlations mentioned above will be useful for field design standards. Nano silica particles and artificial pozzolans, according to the study, can improve the structural qualities of cement-based materials. The influence of cement and Nano silica on the engineering parameters (compaction, unconfined compressive strength) of sand has been studied in the literature. According to the study's findings, the inclusion of nano silica. The results of the study presented that the addition of the nano silica improves the engineering properties of sands.

KEYWORDS- clean sand, compaction,compaction energy, relative density, effective size, void ratio, nano silica.

I. INTRODUCTION

Compaction is a mechanical soil improvement process that is by far the most widely utilised soil stabilization approach. Compaction is the process of changing a soil's engineering qualities for a specific purpose, such as sustaining a pavement section, a building foundation, or a bridge Abutment. In the field, density measurements are used to indirectly assess the efficacy of the compaction process in order to improve soil behavior for the intended application.

One of the tests that should be performed before any further work begins is a compaction test. The strength of soils is mostly determined by the kind of soil, density, and moisture content, all of which may be determined using compaction testing. The efficacy of a compaction is determined by a variety of elements, one of which is compactive effort (equipment kinds, weight, vibration, and number of passes). The study's main goal is to determine the effects of various compaction energies on soil compaction characteristics. Sands are typically compacted in the field using a variety of machinery, with the compaction energy varying greatly. The normal Proctor and modified Proctor tests were utilised to show the comparisons between the varied compaction energies. To fulfil the objectives, several tasks have been specified, including literature review, laboratory testing, and analysis of the results acquired from the laboratory tests. The Maximum Dry Density of soils increases as compaction energy increases, whereas the Optimum Moisture Content value falls as compaction energy/efforts increase. The water content has an impact on the compacted density of cohesionless soils with little or no particles. When compared to density produced by the same compactive effort for air dried or oven dried soil, density may decrease at low water concentrations and, especially, under low compactive effort. The density decreases due to capillary tension, which is somewhat offset by compactive effort and retains the particle in place. When a cohesionless soil is entirely saturated, density reaches its maximum. Again, this maximum density may not be significantly higher than that of air or oven dried materials. The achievement of maximal density at complete saturation should not be attributed to water's lubricating action, but rather to hydrostatic pressure reduction between soil particles. The relative density (Dr) of granular soils, rather than relative compaction, may be a better indicator of end-product compaction parameters. As a result, understanding the relative densities of sands at various compaction energies is critical from a practical standpoint. When presenting a full description of sand, limit density values should be recognized as significant attributes such as the coefficient of uniformity (Cu), coefficient of curvature (Cc), mean particle size (D50), and particle shape, among others. Density (or void ratio) restrictions are required for analyzing relative density of in-place soils and help to more fully describe the material under discussion. When characterizing a sand specimen, the maximum and minimum density values are among the most critical features to describe. Sand particle forms, sizes, and packing have a significant impact on relative densities, maximum and lowest void ratio values.

II. LITERATURE REVIEW

Masih (2000) was the first person to propose a mathematical model for determining soil density. For the determination of density, his model contained analytical parameters and a fine biasness coefficient. He then compared his predicted numbers to laboratory data and found that they were completely in accord, with a very small margin of error.Artificial neural networks, abbreviated as ANN, are introduced by Abdel-Rahman (2008) [2]. He created this model to figure out the best moisture content and dry density. The study was carried out in accordance with ASTM D 1557. Empirical linkages were constructed based on the results of the ANN model. In addition, the calculated and experimental findings were compared to one another.[1]

Patra et al(2010) developed a link between dr2, D50, and compaction energy (E), and conducted reduced standard and modified proctor tests on the same 55 soil samples published by Patra et al(2010)[3] (2010). According to him, for decreased proctor tests, the number of hammer blows each layer should be 15 and the E value should be 360 KN-M/M3. Number of blows/layer=12 and E=1300 KN-M/M3 for reduced modified proctor tests[3]

In his study "Functional relationships between compaction features, un-drained shear strength, and Atterberg limits," N. Vijayakumar Raju and et al. (2014) [4] Density was correlated with specific gravity and grain size distribution, with the conclusion that "density varied considerably due to grain size distribution and specific gravity variance."

In a study titled "Laboratory Liquefaction Test of Sand Based on Grain Size and Relative Density," Abdul Hakam (2016) determined that when we examine the mean grain size of the sand particles corresponding with the liquefaction resistance for a given acceleration, there is a density limit.[5]

In his research titled "Influence of gradation parameters on compaction of sand-silt mixtures: a laboratory assessment," Khayreddine DOUMI and et. Al (2017) [6] mentioned that compaction is a classic approach used for ground improvement in geotechnical structures. Many geotechnical engineering projects, such as motorways, airports, earth dams, and other structures, rely on it. Laboratory studies on several samples with low plastic fines content ranging from 0% to 30% were carried out for the aforementioned purpose, and the compaction of silty sands was evaluated for the aforementioned purpose. The results of the investigation show that the compaction response in terms of maximum dry density can be linked to the variable grading qualities of the investigated materials.

"Assessing the effect of density and water level on the degree of compaction of sand using Dynamic Cone Penetration Test," by Abdulrahman M Hamid et al (2019) [7-8], determined that "there is a substantial link between angle of internal friction, dry density, and void ratio." They analysed an analytical link between dry density, angle of friction, and void ratio by testing diverse soil samples [9].

III. AIMS AND OBJECTIVES

According to a survey of the literature, adequate research has been done on the void ratio, angularity, grain shape, grain size, and their packing patterns in various types of soil. Some researchers have given various testing methods for identifying the minimum and maximum voids ratio of sand, ANN models for predicting maximum dry density (MDD), and optimal moisture content (OMC) of soil [10]. However, determining correct compaction characteristics for sand, such as MDD and OMC, is difficult. The contractor is typically required to produce a compacted field dry unit weight of 95 to 98 percent of the maximum dry unit weight established in the laboratory using either the standard or modified Proctor test [11]. The following are the primary goals of the current study:

- Establishing a link between void ratios and mean grain size (D50) with respect to different compaction energies to characterise relative density of sand.
- Prediction of void ratios € based on D50 and the corresponding energy level of compaction.
- Determination of the soil's carrying capacity
- Finding out how cement and nano silica affect the mechanical qualities of sandy soil.
- Determination of sand's maximum dry density with different amounts of cement and nano silica.

A. Materials used

1) Sand

The sand utilised in this research was brought in from Kashmir. This study used coastal sand with a mean grain size of D50 = 0.221 mm, a coefficient of uniformity of Cu = D60/D10 = 2.128, a coefficient of gradation of Cc = 1.322, a maximum and minimum void ratio of emax = 0.8, emin = 0.526, and a specific gravity of Gs = 2.78.

2) Nano Silica

Amorphous Nano silica having a solid composition of greater than 99 percent was used in this study. Table 1 shows the physical properties of these particles.

Table 1: Physical properties

Physical properties	Value
Diameter (nm	20 – 30
Surface volume ratio (m2 /g)	193
Density (g/cm3)	1.7
1.7 Purity (%)	>99

Below is the Figure 1 shows the different ratio of UCS used

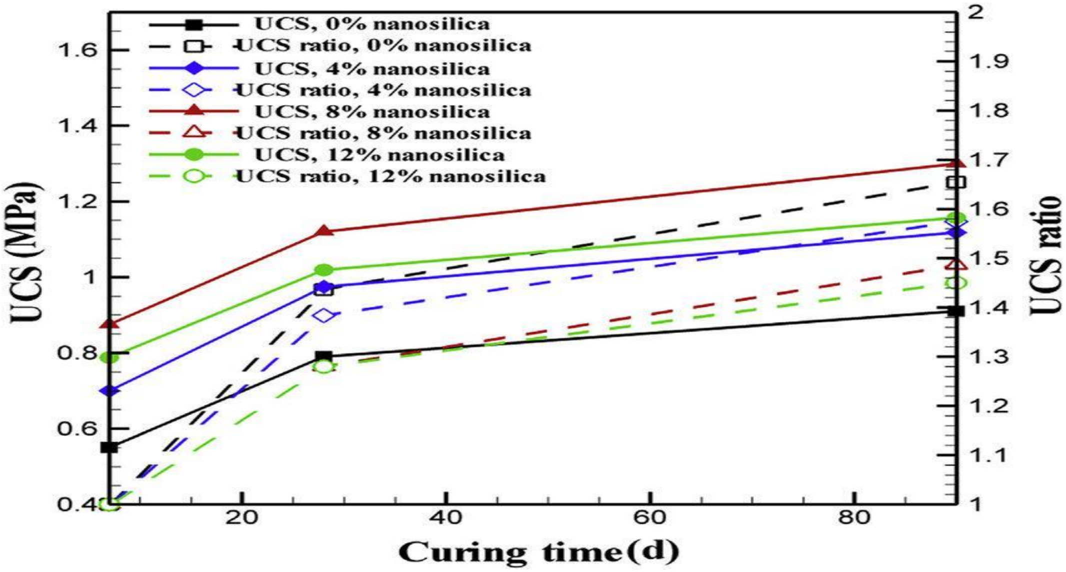

Figure 1: Shows the different ratio of UCS used

IV. TEST METHODOLOGY

The following methodologies have been used in order to achieve objectives of this research work

- Grain size analysis
- Determination of specific gravity
- Determination of emin
- Determination of emax
- Determination enatural
- compaction test
- Unconfined compressive strength

V. EXPERIMENTAL PROCEDURE

Sand samples were taken from various rivers in Jammu and Kashmir. For the determination of mean size, effective size, coefficient of homogeneity and strength of sandy soil, and relative density, a total of 20 samples were collected from three separate locations.

Standard Proctor Compaction Test: (as per IS: 2720 – Part VII, 1980)

Sand was compressed into a mould in three equal levels, with each layer getting 25 blows from a 2.6 kg hammer. The hammer dropped from a height of 0.31m. In this test, 593 kN-m/m3 of energy (compactive effort) was delivered.

Modified Proctor Compaction Test: (as per IS: 2720 – Part VIII, 1983)

Sand was compressed in 5 equal layers into a mould, with each layer getting 25 blows. A larger hammer 4.89 kg and a greater drop 0.45m height for the hammer were employed to produce the increased compactive effort (energy supplied = 2698 kN-m/m3).

Reduced Standard Proctor Compaction Test:

The process and equipment used for the Standard Proctor exam are substantially the same. Each layer, on the other hand, received 15 hammer blows per layer. In this test, 356 kN-m/m3 of energy (compactive effort) is delivered.

Reduced Modified Proctor Compaction Test:

The process and equipment used for the Modified Proctor test are substantially the same. Each layer of sand got a total of 12 hammer strokes per layer. In this test, 1295 kN-m/m3 of energy (compactive effort) is delivered.

VI. DIRECT SHEAR TEST

The goal of this test is to determine a soil's shear strength. This is accomplished by pushing the soil to shear at a consistent rate along an induced horizontal line of weakness [12]. It determines the soil's tensile strength.

Unconfined compressive strength test

The diameter of the cylindrical specimens utilised in the unconfined compressive strength test is 38.1 mm, and the height is 76.2 mm. The specimens were extruded from the mould after compaction and maintained in the humidity room at a constant temperature of 252°C. After curing, specimens were placed in a load frame machine with a 0.10 percent min strain control and crushed until failure occurred [13]. The diameter of the cylindrical specimens utilised in the unconfined compressive strength test is 38.1 mm, and the height is 76.2 mm. The specimens were extruded from the mould after compaction and maintained in the humidity room at a constant temperature of 252°C. After curing, specimens were placed in a load frame machine with a 0.10 percent min strain control and crushed until failure occurred [14]. Table 2 shows the different indes properties of sand samples.Table 3 shows the Percentage deviation shown by predicted & experimental relative density values in case of standard proctor test.Table-4 shows the Percentage deviation shown by predicted & experimental relative density values in case of modified proctor test.

VII. RESULTS

Table 2: Sand sample index properties

Sample No.	G	D50	D60	D30	D10	Cu	Cc	emax	emin
1	2.580	1.00	1.250	0.500	0.300	4.240	0.710	0.596	0.303
2	2.574	1.100	1.300	0.420	0.260	5.000	0.520	0.521	0.288
3	2.557	1.250	1.500	0.430	0.270	5.560	0.450	0.618	0.341
4	2.537	1.300	1.500	0.970	0.410	3.660	1.530	0.621	0.331
5	2.554	1.400	1.450	0.760	0.310	4.680	1.280	0.548	0.292
6	2.617	1.150	2.000	0.370	0.260	7.690	0.260	0.498	0.297
7	2.593	1.600	2.000	0.600	0.270	7.410	0.670	0.492	0.223
8	2.770	0.379	0.401	0.313	0.256	1.560	0.954	0.715	0.399
9	2.700	0.523	0.530	0.419	0.300	1.767	1.104	0.671	0.364
10	2.690	0.385	0.455	0.329	0.246	1.850	0.967	0.665	0.358
11	2.730	0.401	0.497	0.350	0.296	1.680	0.830	0.690	0.379
12	2.650	0.454	0.501	0.423	0.301	1.664	1.186	0.640	0.338
13	2.645	0.399	0.450	0.303	0.289	1.557	0.706	0.637	0.336
14	2.700	0.350	0.395	0.301	0.297	1.330	0.772	0.671	0.364
15	2.696	0.349	0.400	0.320	0.240	1.670	1.070	0.802	0.543
16	2.687	0.590	0.400	0.280	0.230	1.740	0.850	0.808	0.543
17	2.683	0.381	0.700	0.400	0.310	2.260	0.740	0.731	0.482
18	2.667	0.352	0.410	0.320	0.200	2.050	1.250	0.760	0.515
19	2.678	0.341	O.370	0.310	O.230	1.610	1.130	0.831	0.568
20	2.689	0.359	0.360	0.300	0.200	1.800	1.250	0.852	0.565

Table 3: Percentage deviation shown by predicted & experimental relative density values in case of standard proctor test

Sample No.	Standard proctor test.		
	Experimental Dr values	Predicted Dr values	% age deviation
1.	57.67918	48.97922	15%
2.	83.2618	51.08779	38.6%
3.	64.25993	50.56063	21.3%
4.	66.55172	43.18161	35.1%
5.	72.65625	48.45211	33.31%
6.	76.61692	51.08779	33.32%
7.	70.26022	50.56063	28%
8.	45.88608	51.29865	11.8%
9.	65.47231	48.97922	25.19094%
10.	62.86645	51.82583	17.56202%
11.	58.84244	49.19007	16.40376%
12.	54.63576	48.92651	10.44966%
13.	58.47176	49.55906	15.24274%
14.	55.70033	49.13736	11.78264%
15.	67.56757	52.14214	22.82964%
16.	76.22642	52.66933	30.9041%
17.	61.04418	48.45211	20.6278%
18.	73.06122	54.25098	25.74586%
19.	77.94677	52.66933	32.42911%
20.	64.1115	54.25098	15.38027%

Table 4: Percentage deviation shown by predicted & experimental relative density values in case of modified proctor test

Sample No.	Modified proctor test.		
	Experimental Dr values	Predicted Dr values	% age deviation
1.	86.68942	75.99622	12.33507%
2.	86.69528	75.99808	12.33885%
3.	71.84116	75.99761	-5.78561%
4.	71.37931	75.99109	-6.46095%
5.	91.01563	75.99575	16.50253%
6.	82.08955	75.99808	7.420518%
7.	72.86245	75.99761	-4.30285%
8.	56.01266	75.99826	-35.6805%
9.	81.75896	75.99622	7.048451%
10.	62.54072	75.99873	-21.5188%
11.	67.20257	75.9964	-13.0856%
12.	66.55629	75.99617	-14.1833%
13.	83.72093	75.99673	9.226128%
14.	61.23779	75.99636	-24.1004%
15.	67.95367	75.99901	-11.8394%
16.	87.92453	75.99948	13.56282%
17.	83.13253	75.99575	8.584822%
18.	76.32653	76.00087	0.426667%
19.	84.41065	75.99948	9.964584%
20.	86.06272	76.00087	11.6913%

VIII. EFFECT OF NANO SILICA

The effect of nanosilica content on the unconfined compressive strength of sand is investigated. The unconfined compressive strength of the sample was observed to improve significantly when the nanosilica content was increased to an optimal value of 10% in the sample. It can be seen that raising the nanosilica content from 0% to 5% has no meaningful effect on unconfined compressive strength [15-16]. It appears that a significant amount of nanosilica (20%) reduces the unconfined compressive strength. .All results are presented in terms of the ratio between the unconfined compressive strength of the cemented sand mixed with nanosilica and that of cemented sand without nanosilica for a more comprehensive presentation of the effectiveness of adding nanosilica on the unconfined compressive strength of the cemented sand [17-18]. As can be observed in this graph, the sample containing 5% cement has a better improvement ratio than the other cement content samples for all percentages of nanosilica. This finding indicates that nanosilica enhances unconfined compressive strength less for samples containing a lot of cement [19-20].

IX. CONCLUSION

The relative density at a certain compaction energy corresponding to the standard, modified, reduced standard, and reduced modified Proctor compaction tests was determined in a laboratory test on 20 samples taken from various places in Kashmir. The void ratios at various energy levels were determined using dry density measurements taken in the lab. The equations for void ratios at such specific energy levels have been anticipated from laboratory measurements by correlating with mean grain size. The equations of void ratios, which are a function of mean grain size, have been used to predict relative densities at such energy levels. The following are some broad conclusions drawn from this research:

- The mean grain size is the most important factor influencing the void ratio.
- 2.The difference between predicted and experimental relative densities at a given energy level is less than 5%.
- Relative densities at different energy levels can be correlated using empirical formulae in terms of mean grain size.
- 4.Empirical equations in terms of mean grain size can be used to correlate relative densities at different energy levels.
- 5.Because the relative density at a given energy level is connected with a single parameter, such as mean grain size, this will be useful for field design specifications.
- The maximum dry density of sand increased with the increase in the cement content. There was an increase in the maximum dry density with increasing nanosilica content for low percentages of cement.
- Increasing the nanosilica concentration of the cement to 10% raised the unconfined compressive strength of the samples significantly. The unconfined compressive strength of the samples is reduced by increasing the nanosilica content of the samples by more than 10%. The optimal percentage of nanosilica for cement sand stabilisation was 10% cement content.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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