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Influence of compaction on the properties of remoulded cemented sands

POLAMURI RAMA MOHAN REDDY 1, BANTU SAILESH 2,
ASSOCIATE PROFESSOR 1, ASSISTANT PROFESSOR 2,
Mail ID: sailesh.bantu04@gmail.com, Mail ID:polamurirammohanreddy@gmail.com
Dept.: Mechanical
Pallavi Engineering College,
Kuntloor(V),Hayathnagar(M),Hyderabad,R.R.Dist.-501505.

ABSTRACT

Both in-depth laboratory analysis and scale models were used to investigate the characteristics and behaviour of compacted cemented sands in Kuwait. While being dug up, the cementation bonds are broken and the catch, as it is called in the area, is changed into clayey sands with a high percentage of particles (anywhere from 20% to 40%). All the fundamentals were checked: basic characteristics, compaction, permeability, direct shear, and consolidation. A circular plate was also loaded to failure in model testing on compacted soils. The relative compaction of the test soil was 85%, 90%, 95%, and 100%. Results show that when relative compaction is reduced from 100% to 85%, the ultimate bearing capacity and the shear strength parameters c, decline significantly, while the compressibility parameters Cc, Cs, and the permeability rise. Rates of change in a number of soil characteristics are analysed as a function of relative compaction.

Keywords:

tests for relative compaction, remoulded cemented sands, direct shear, consolidation, permeability, and models.

INTRODUCTION

In the state of Kuwait, you may find large amounts of cemented sands both on the surface and buried behind layers of blown sand (Ismael et al. 1986). Cementing chemicals precipitate at the sites of contact between particles due to an excess of evaporation over rainfall even in the winter (Keyline and Judd 1957), leading to bonding and cementation and the production of cemented layers. Calcium carbonates, magnesium carbonates, and calcium sulphates are all used as cementing agents (gypsum). Cementation varies in intensity from location to location and even within a single location at various depths. Extreme anisotropy and possible moisture sensitivity characterize these materials (Barton 1993). Cementation's involvement in elevating the strength parameters c, has been the exclusive focus of recent studies, which have been limited to laboratory determinations of a small number of cemented sand samples (Clough et al. 1981, Saxena and Latrice 1978). These competent deposits in Kuwait City are often buried behind a thin layer of desert sand and range in depth from 0 to 7 meters. We took a close look at their characteristics and behaviour (Ismael 1999, Ismael 1993, Ismael et al. 1986). When the material, known as catch in the region, is excavated, the cementation connections are broken and the material is transformed into silty sands or clayey sands with a fine content (0.075 mm) of 20 to 50%. It's a staple of the engineering and earthwork construction industries as a kind of backfill. Specifications must have arelative compaction, the ratio of the field compacted dry density to the highest laboratory value established by the Standard or the Modified Proctor Test, defines this level of compaction. Between ninety and one hundred percent is a common range for this level of compactness. Understanding how relative compaction affects soil characteristics and behaviour under applied loads is of major importance. This was accomplished by doing extensive laboratory soil testing on a clayey sand "catch" soil sampled from a single location in Kuwait. Basic properties, direct shear, consolidation, and permeability tests were performed on remoulded samples compacted to relative densities of 100%, 95%, 90%, and 85%. These relative compaction values were also used in model testing using a circular steel plate loaded to failure in a sand box. Specifically, the effects of relative compaction on the strength parameters, compressibility, and permeability are discussed in this study. Model experiments are also analysed to see how the effects of the applied loads change the final bearing capacity and settling. These findings highlight the significance of field compaction to the success and safety of earthwork projects.

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SOIL TESTING METHODS AND PLANS

Sophy was responsible for identifying the fundamental soil qualities and compaction characteristics used in this application (2021). Soil samples were taken at a depth of 1 to 1.5 meters in the Al-Ariyaneighbourhood of Kuwait City. The cementing ties are broken when this material is excavated. Quartz, the primary component, accounts for 65% of the overall composition, while carbonates and sulphates, which make up the rest of the composition and decrease with depth, occupy the vast majority. According to the Unified Soil Classification System, it is a clayey sand, or "SC." It has a plasticity index of PI=12.9%, a fines content (0.075 mm) of 21.3%, no gravel, a liquid limit of 36.3%, a plastic limit of 23.4%, and a plasticity limit of 36.3%. The following analyses were conducted on materials compacted to relative compaction ("RC") =95%, 90%, and 85% and optimal moisture content, as well as on samples processed at maximum density and optimal moisture content, that is, RC =100%: 1, Specimens 63 mm in diameter and 20 mm in thickness were subjected to direct shear testing. All of the tests were performed in accordance with ASTM D3080. 2 Conduct consolidation tests on a 75 mm diameter by 20 mm thick sample, as specified by ASTM D2435. Permeability tests using a falling head on samples with a diameter of 100 mm and a height of 130 mm, as specified by ASTM D5084. Model testing using a steel plate with a 70 mm diameter loaded into a 0.3 m 0.3 m 0.28 m deep sand box Until the ultimate bearing capacity failure was attained, a load of 1.4 mm/min was applied with values obtained at 1 mm penetration intervals. Maximum load was determined via steady penetration at a constant pressure.

A MODEL SETUP

The samples were stacked in four layers and tamped to the appropriate density for the direct shear, consolidation, and permeability tests. The soil for the model testing was spread out in 50 mm thick layers, with the intention that, after tamping to the appropriate relative compaction, the layers would be perfectly even and stable. This ideal moisture level was achieved in all of our testing.

SEARCH OUTCOMES

In Figure 1, we can see the outcomes of the Modified Proctor Compaction Test. A dry density of 1895 kg/m3 and a moisture content of 12.8% are both ideal. Figures 2 and 3 depict the direct shear test-determined change in the shear strength parameters and c as a function of relative compaction. As relative compaction rose from 85% to 90%, the friction angle dramatically increased from 30° to 37.5°. Next, it went up 2 degrees as RC went from 90% to 95%, and another 2 degrees as RC went from 95% to 100%. Cohesion c rose by just 15 kPa when RC was raised from 90% to 100%. Samples compacted to RC = 100% and RC = 90% are compared in Figure 4 in terms of shear stress vs relative lateral displacement. When compared to the maximum value of 5 mm that may be recorded by the direct shear equipment, the shear displacement is the relative lateral displacement. It has been shown that when RC = 90%, the response is softer, with a lower modulus and no obvious peak stress. Table 1 provides a synopsis of all test findings. Figure 5 shows e-log graphs of the consolidation test results. Table 1 shows how the compressibility parameters Cc and Cs change with the degree of relative compaction. Table 1 lists the values for the aforementioned variables as well as the zero-swell pressure, free swell, and consolidation coefficient Cv.

The traditional consolidation test was used to calculate the free swell and zero swell pressures (Das 2016). In an oedometer, the specimen is subjected to a modest surcharge of 6.9 kN/m2 before water is injected to cause swelling and eventual equilibrium. The free swell is defined as the percentage of height loss relative to the starting height. The specimen is then subjected to a progressive load and solidified. The zero swell pressure,'sw, may be inferred from the plot of the deformation against log' when ‘is the effective stress. The compressibility went down as the relative compaction went up. While increasing RC from 85% to 90%, the compression index dropped from 0.0356 to 0.0242, a 32% drop; and when increasing RC from 90% to 100%, the index dropped from 0.0356 to 0.0242, a 36% drop. Between RC = 85% and 90%, there was no change in the swell index, and between RC = 90% and 100%, there was a little decrease. Despite the low Cc and Cs values, the compressibility visibly decreased with increasing relative compaction. Consolidation test results are shown in Table 1, illustrating the change in free swell and zero swell pressure with relative compaction.

There was a same level of moisture when we compressed all of the samples. Both the free swell and the zero swell pressure rose with increasing relative compaction, as predicted. As relative compaction went from 90% to 100%, the free swell rose from 0.75% to 1.021% and the zero swell

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pressure went from 39.45 kPa to 62.3 kPa. That's a rise of 36% for the free swell and 58% for the zero swell. Larger free swell and no swell pressure were seen with denser soil, as predicted. In any case, with RC = 100%, the maximum free swell for this soil is just around 1%, therefore it's safe to say that it doesn't expand. Table 1 provides the average values of the coefficient of consolidation Cv for each RC value. It is interesting to note that with the exception of the value recorded at RC = 90%, all values at different relative compaction are very similar. Given that all values are relatively small, however, the difference is negligible.

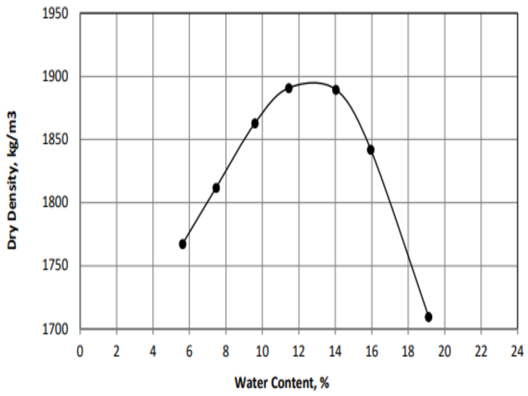

Figure 1. Compaction test results (after Sophy 2021).

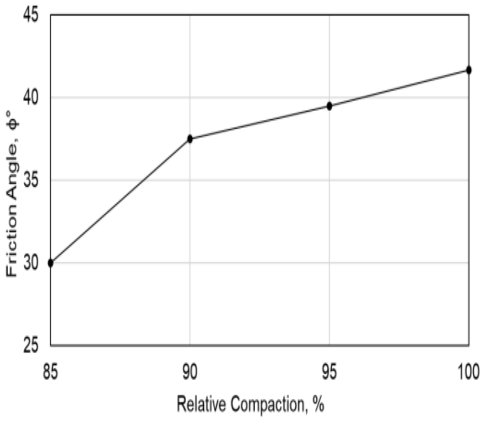

Figure 2. Variation of the friction angle ϕ with relative compaction.

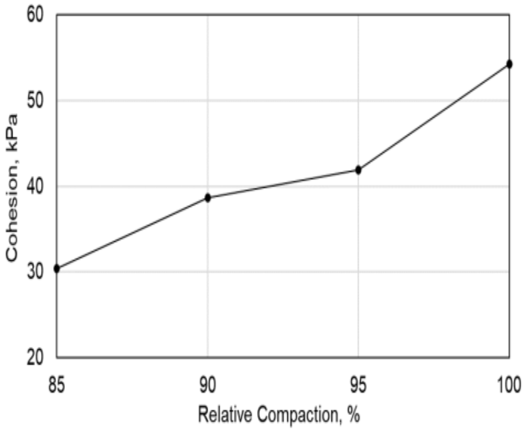

Figure 3. Variation of the cohesion with relative compaction

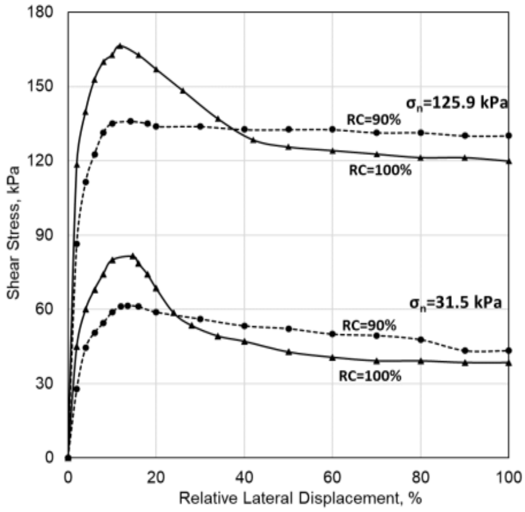

Figure 4. Shear stress vs. relative lateral displacement for samples compacted to relative compaction of 100% and 90%.

Table 1. Summary of Test Results.

Parameters	Relative Compaction (%)			
	100	95	90	85
ρ_d (kg/m^3)	1895	1800.25	1705.5	1610.75
w (%)	12.8	12.8	12.8	12.8
ϕ°	41.7	39.5	37.5	30
C (kPa)	54.3	41.9	38.7	30.4
C_c	0.0242	0.0289	0.0356	0.136
C_s	0.0099	0.012	0.013	0.013
Avg. C_v (mm^2/min)	649	648	542.7	626
Free Swell (%)	1.021	0.884	0.75	0.63
Swell Pressure (kPa)	62.3	49.84	39.45	32.2
k (cm/sec)	$0.83*10^{-8}$	$5.7*10^{-8}$	$11.5*10^{-8}$	$51.8*10^{-8}$
Ultimate Bearing Capacity (kPa)	7491.5	4513.9	2766.4	1388.5

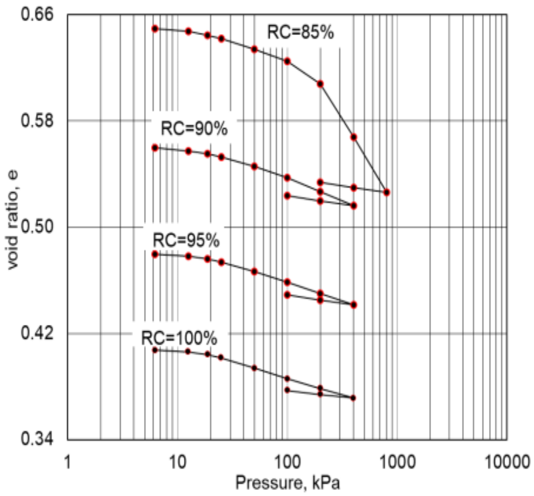

Figure 5. e-logo plots from consolidation tests.

Permeability coefficient k varies with relative compaction, as seen in Table 1. When the relative compaction was raised from 85% to 90%, the values of k dropped dramatically. From 90% RC to 95% RC, the coefficient of permeability reduced by 50%, from 11.5*10-8 cm/sec to 5.7*10-8 cm/sec. Between 95% and 100% relative compaction, the coefficient of permeability (K) reduced by 87%, from 5.7108 cm/sec to 0.83108 cm/sec. In order to avoid excessive water flow and concrete damage, these results highlight the need of correct compaction of soils around foundations and earth structures to achieve low permeability.

Analysing the Differences Between Original and Recreated Examples

For this study, remoulded samples were used for every testing. Several investigations were conducted to determine how much soil disturbance and crushing of the cementation bonds reduced the strength of cemented sands (Ismael 1999, Abdulsalam and Ismael 2018). Remoulding caused a loss of the cohesion component of the strength c and a modest drop of 1 degree in the angle of friction, as determined by consolidated undrained triaxial tests with pore pressure measurement on natural cemented samples and on remoulded samples brought to the same unit weight. The secant modulus values for remoulded specimens were lower than those for natural, undisturbed specimens sheared at the same confining pressure, indicating that the stiffness was reduced as a result of the melding process. Because of its greater strength and lower compressibility than disturbed compacted earth, natural undisturbed catch soil is usually preferable for placing foundations.

EXPERIMENTS ON MODELS

In order to learn how relative compaction impacts the final bearing capacity and settling of shallow foundations, experiments were conducted on model systems. Steel plates with 70 mm diameters were loaded to failure in a sand box measuring 0.3m*0.3m*0.28m deep. Soil was spread out in layers and compacted to achieve the desired relative compaction and optimal moisture content. With each vertical deformation of 1 mm being measured, a constant strain rate was applied. The setup for the load test is shown in Figure 6a. Without any heave of the soil surface surrounding the plate, punching shear failure occurred in all experiments. Example 6b illustrates this point. Figure 7 shows the pressure vs settlement curves from each test. Table 1 summarizes the values for final bearing capacity, and Figure 8 shows how they change with relative compaction. The maximum load was determined by measuring the pressure at which the load was no longer causing any further deformation. While the manner of failure is consistent across experiments, the above indicates that ultimate bearing capacity significantly increases with increase in relative compaction. As RC was raised from 90% to 95%, the ultimate bearing capacity went up from 2766.4 kPa to 4513.9 kPa, or by 63%. Also, the ultimate bearing capacity at RC = 100% was measured to be 7491.5 kPa, which is an increase of 66% over the equivalent value at RC = 95% and an increase of 2.71 times over the value at RC = 90%. Soil samples compacted to 100% and 95% relative compaction showed linear and elastic pressure vs. compaction showed linear and elastic pressure vs. settlement curves up to 1500 kPa (Figure 7). While tests on soil compacted to RC = 85% failed before this pressure was achieved, soil with RC = 90% had

14 mm of settlement that exceeded the elastic range at this pressure.

Figure 6a. Load test set up on clayey sand (catch) soil.

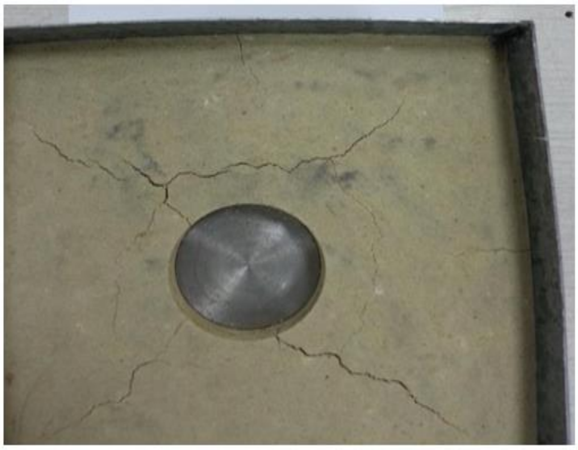

Figure 6b. After failure view showing punching failure and radial cracks (RC = 90%).

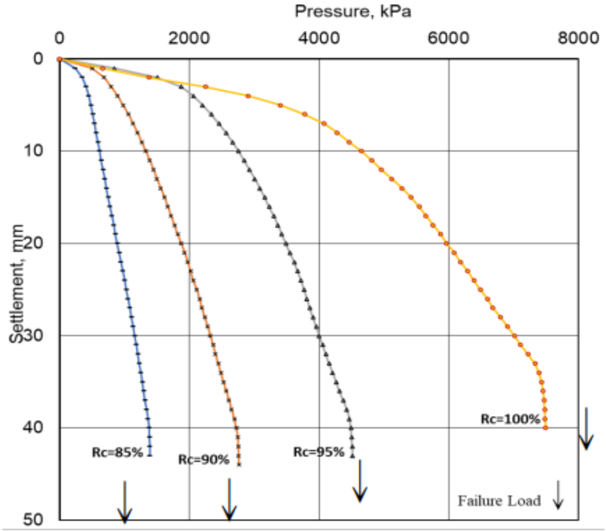

Figure 7. Pressure vs. settlement at relative compaction of 85%, 90%, 95%, 100%.

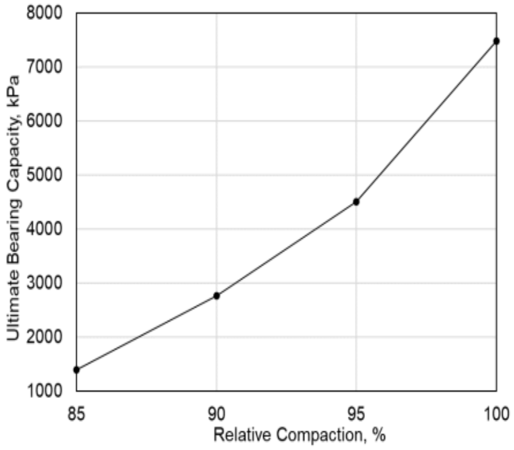

Figure 8. Ultimate Bearing capacity vs. relative compaction from model tests.

CRITICAL CONSIDERATIONS AND APPLICATIONS

This study's laboratory studies on clayey sand (gatch) reveal that relative compaction affects soil behaviour and characteristics. The angle of internal friction rose by 2° when RC went from 90% to 95% and from 95% to 100%, whereas the ultimate bearing capacity went up by 63% and 66%, respectively. Tabulated 1 provides all values. While the strength and stiffness did rise with relative compaction, the compressibility did decrease. The free swell increases from 0.75 percent to 1.02 percent between RC = 90 and 100 percent, respectively, which is regarded to be low and indicative of a nonswelling soil. These two values equate to a zero-swell pressure of 39.45 and 62.3

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kPa. Importantly, all samples were made at the ideal moisture content. In Table 1, we see that as RC increases, the coefficient of permeability drops dramatically. At 90% RC, the value was 11.5 x 108 cm/sec, whereas at 100% RC, the value was 0.83 x 108 cm/sec, a decrease of 92.8%. From what we can gather from the data shown above, it is clear that more compaction effort and relative compaction in the field are required. Increases in strength and bearing capacity, together with decreases in compressibility and permeability, are substantial changes that need close field monitoring and supervision.

CONCLUSIONS

Using both laboratory soil testing and model studies, researchers in Kuwait investigated how relative compaction affected the soil characteristics and bearing capacity of a remoulded clayey sand. The following conclusions were drawn based on the results of the tests: The metrics of strength, c, and, both increased with increasing relative compaction. As RC went from 90% to 95%, the angle of friction grew by two degrees, and as RC grew from 95% to 100%, the angle of friction grew by another two degrees. Additionally, cohesiveness c has increased somewhat. It was found that the compressibility decreased with increasing levels of relative compaction. For RC = 90%, the compression index Cc was 0.0356, for RC = 95% it was 0.0289, and for RC = 100% it was 0.0242. Even the largest numbers are on the little side. As relative compaction rose, so did free swell and swell pressure. 4. Relative compaction led to a significant reduction in the coefficient of permeability k. As RC was raised from 90% to 95% and 100%, the velocity dropped from 11.5108 cm/sec to 5.7108 cm/sec and 0.83108 cm/sec, respectively. 5.

The ultimate bearing capacity of a circular plate rose from 2766.4 kPa to 4513.9 kPa and 7491.5 kPa, according to the model tests, as the relative compaction increased from 90% to 95% and 100%. This is the same as an increase in ultimate carrying capacity of 63%, followed by an increase of 66%. The test findings indicate the significance of high relative compaction values "RC." The strength characteristics and ultimate bearing capacity of a material improve dramatically when the relative compaction is increased, as does the reduction of its compressibility and permeability. Because of the importance of this for building with solid foundations, this is well suited.

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