Effect of Ground Disruption on the Strength of Gatch Soil in Kuwait

Ziad Abdelsalam, PhD[1] and Nabil Ismael, PhD[2]
[1]*Center of Engineering Laboratories for testing and Calibration, College of Engineering and Petroleum, Kuwait University*
[2]*Department of Civil Engineering, College of Engineering and Petroleum, Kuwait University*
[1]*E-mail:* ziad06@outlook.com
[2]*E-mail*: nabil.ismael@ku.edu.kw

ABSTRACT: Kuwait soil is commonly known as 'Gatch' and classified as very dense cemented sand Kuwait sand has sulphates and calcium carbonated in form of gypsum components that caused cementation bonds with environment aids such as highly evaporation of rainfall in winter season. This soil is used as a backfill material and it is important to know the effect of excavation and recompaction on the strength characteristics. The present study provides experimental results on the effect of ground disruption on strength parameters of cemented sand in Kuwait, such as the are the cohesion c, and the angle of friction ϕ' and stress strain characteristics. The triaxial test was used to determine these parameters on undisturbed and remolded specimens at different depths. The results show a disturbance of cemented sands cause loss of the cohesion component of strength and a minor reduction in the angle of shearing resistance.

KEYWORDS: Cemented Sands, Kuwait Soil, Drained Triaxial Test, Compaction Test.

1. INTRODUCTION

Competent deposits of cemented sands exist in Kuwait and in many places of the world where arid or semi-arid condition prevail (Ismael et al. 1986, Ismael 1999). The degree of cementation varies from place to place. It also varies with depth at the same place from very weak or uncemented to very strongly cemented material. The highly evaporation of rainfall, even in the winter season, in Kuwait leads to the precipitation of cementing agents in the soil matrix and the formation of cemented soil layers. Among the principal cementing agents are carbonates, hydrous silicates, iron oxides, and gypsum. The decreasing of the water content of soil can be influenced of soil properties, such as increasing of soil strength (Salih and Kassim 2012).

The properties of these deposits in Kuwait were determined by a site investigation and a laboratory testing program on samples taken from two sites in Kuwait (Ismael 1999). From triaxial tests on undisturbed and remolded specimens having the same unit weight and void ratio, it was determined that cementation leads to a small increase in the angle of friction and the introduction of a cohesion intercept. This means increased strength due to cementation. Cemented sands locally known as 'Gatch' are often excavated leading to the crushing of the cementation bonds. The material is used quite often as a backfill in compacted form and it is important to know the effect of excavation and recompaction on the strength characteristics, and on the stress strain curves.

In some cases, the natural undisturbed cemented sand is disturbed upon excavation below the foundation level. The ground is then compacted and the foundation is poured. The question often asked is: what is the effect of ground disturbance below foundation level on the bearing capacity and the deformation under load.

This Study examines the influence of remolding cemented sand on the strength characteristics by means of a site investigation and a laboratory triaxial compression tests on undisturbed and remolded specimens at different depths. The soil parameters examined are the cohesion c, and the angle of friction ϕ'. The stress strain characteristics were also examined.

2. SAMPLING AND SITE INVESTIGATION

Undisturbed soil samples from a site in Kiefan were collected from a depth of 0.3m below the ground surface. All samples comprising calcareous gypsiferous cemented silty soil were taken in brass liners, 71 mm diameter and 150 mm length using the drive cylinder method. Pits of 1.5 m x 1.5 m were first excavated manually to the proper depth. The soils at the base were trimmed carefully to slightly oversize the brass liner sampler which was pushed in the soil and lightly tamped. After extraction, the tubes were sealed with special rubber caps and transported to the laboratory for testing.

In addition to the above sampling, one auger boring was drilled at the site to a depth of 6.5 m. sampling and standard penetration tests were carried out at 1m intervals. Liner samples were taken at each depth using Dames & Moore sampler.

Figure 1 shows a summary of the soil conditions at the test site. Indicated from left to right are the soil description, Standard Penetration Test results, moisture contents, and bulk unit weights. The soil profile consists of medium dense to dense, whitish gray moderately cemented, fine to medium calcareous silty sand, with a few pockets and bands of gypsum crystal concretions to a depth of 4.0 m. This is underlain by very dense gray, calcareous, non-plastic, fine silty sand with occasional cemented modules to the bottom of the boreholes. The lower layer being uncemented is typical of the soil profile in Kuwait where very dense cemented and uncemented layers appear in succession in the boreholes. Ground water was encountered at a depth of 2.35 m below the existing grade.

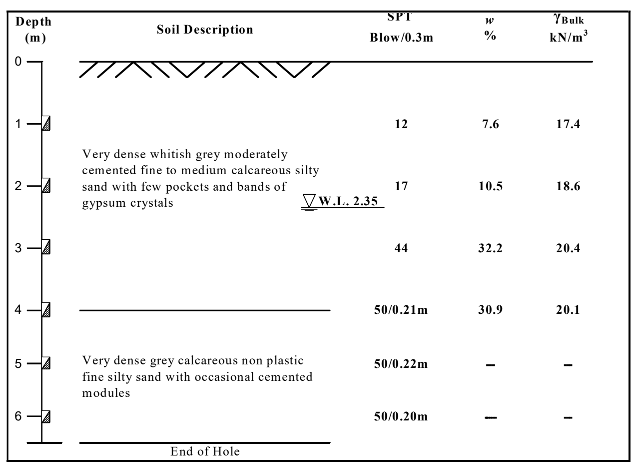

Figure 1 Soil Condition

3. SAMPLE PREPARATION

Samples taken from the cemented sand layer at a depth of 0.3m, 2m and 4m were selected for testing. Drained triaxial compression tests with pore pressure measurements and tests for basic properties were carried out on undisturbed samples and remolded samples. The undisturbed specimens were extracted from the liner cell. The sharp cutting edge of the specimen cutter (50 mm diameter and 100mm length) was pushed into the center of liner cell gently. The extractor tool was used to pull out the specimen. The specimen was then pushed gently in the Triaxial rubber membrane tube and handled carefully to apparatus. The remolded samples were compacted by static compaction to reach the same unit weight as the undisturbed samples. A total of 18 triaxial tests were carried out to obtain the shear strength parameters of undisturbed and remolded samples. The scope of the testing program is given in Table 1.

Table 1 Summary of the Triaxial Testing Program

Depth (m)	Number of Test	
	Type of Sample	
	Natural	Remolded
0.3	3	3
2	3	3
4	3	3

4. TRIAXIAL TEST

Consolidated triaxial compression tests with pore pressure measurement were carried out on the samples in accordance with BS Standard 1377-8:1990 section 8 (Methods of test for Soils for civil engineering purposes – Shear strength tests, effective stress, consolidated drained triaxial compression test with measurement of volume change). The triaxial test is used test to the evaluation of the shear strength parameters of the soil with a range of possibilities in its conduction, as the option to control the load applied to the sample or the deformation suffered by it (Alias et al. 2014). The Triaxial can be used to mimic field condition to understand the behavior of soil by controlling of drainage conditions and measuring the pore pressure (Ratananikom et al. 2015). The specimens were first saturated under back pressure of 200 kPa until full saturation was achieved. Three tests were carried out on the undisturbed samples and three tests on the remolded samples at each depth to determine the effective strength parameters c', ϕ'. The samples were first consolidated under confining pressures of 250, 350, 450 kPa, followed by shearing in the axial direction.

Figure 2 shows stress-strain and pore water pressure versus axial strain curves for the naturally and remolded samples at a depth of 0.3 m. The failure envelopes are shown in Figure 3 for the undisturbed and remolded samples respectively at a depth of 0.3m.

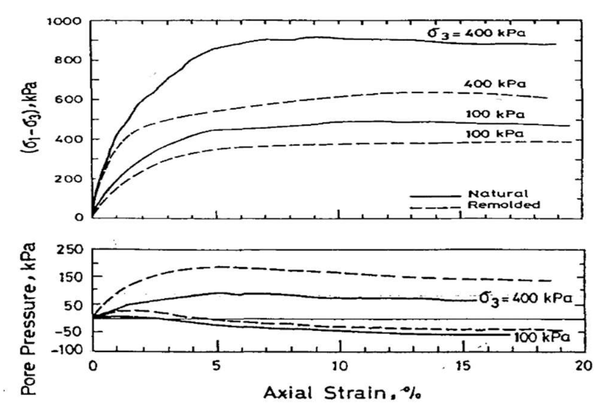

Figure 2 Stress and pore-water pressure versus axial strain for naturally cemented and remolded specimens, Depth = 0.3 m (Ismael 1999)

Figure 4 showd stress-strain and pore water pressure versus axial strain curves for the naturally and remolded samples at a depth of 2 m. The failure envelopes are shown in Figure 5 for the undisturbed and remolded samples at a depth of 2m.

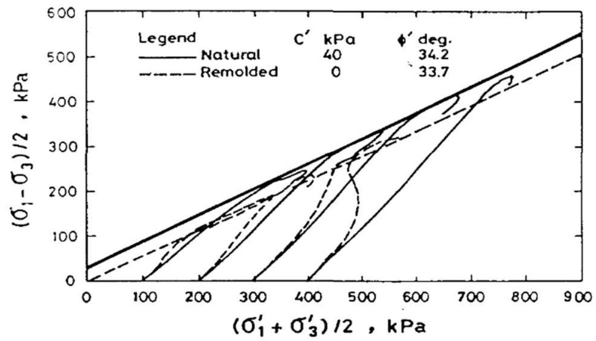

Figure 3 Effective stress path and failure envelope for naturally cemented and remolded specimens, Depth = 0.3 m (Ismael, 1999)

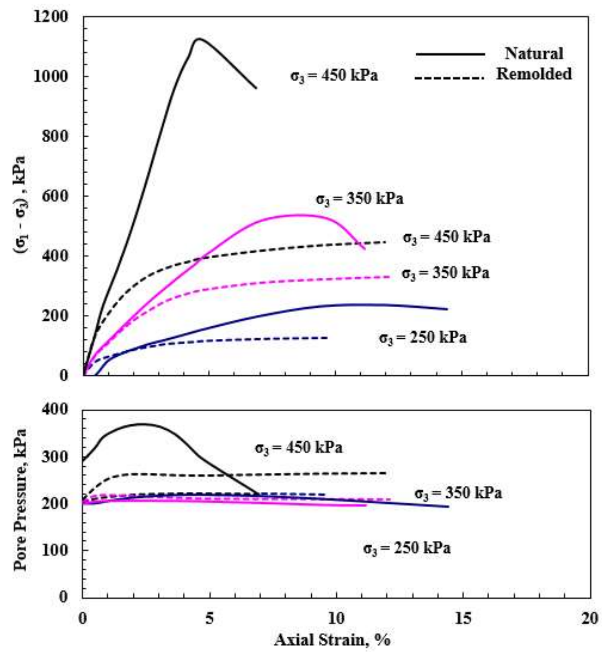

Figure 4 Stress and pore-water pressure versus axial strain for naturally cemented and remolded specimens, Depth = 2 m

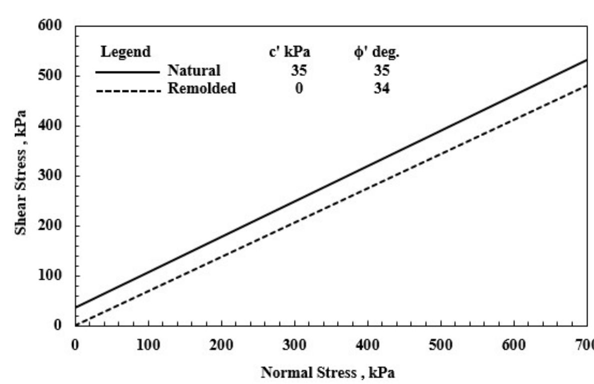

Figure 5 Failure envelopes for naturally cemented and remolded specimens, Depth = 2 m

Figure 6 shows the stress and pore water pressure versus axial strain curves for the three naturally and remolded specimens at a depth of 4 m. The failure envelopes are shown in Figure 7.

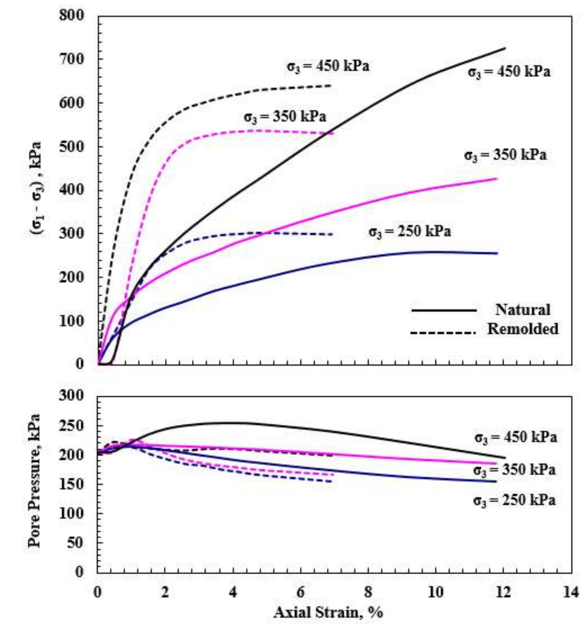

Figure 6 Stress and pore-water pressure versus axial strain for naturally cemented and remolded specimens, Depth = 4 m

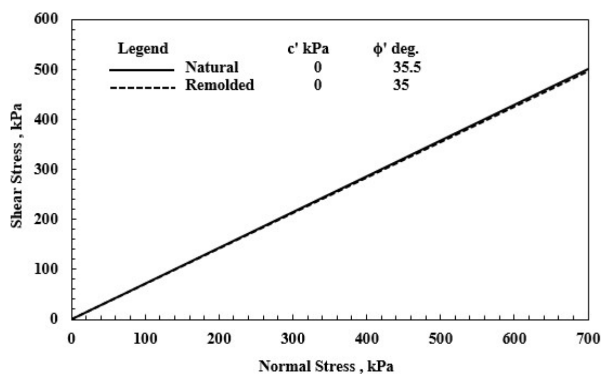

Figure 7 Failure envelopes for naturally cemented and remolded specimens, Depth = 4 m

The shear strength parameters were determined from the proceeding test results. Table 2 summarizes these parameters for the 18 samples tested at a depth of 0.3m, 2m, and 4m. Shown from left to right are the depth, sample type, the moisture content w, the bulk density γ_B, the cohesion c', and the angle of friction ϕ'.

Table 2 Summary of the Soil Parameters in the Cemented Layer

Depth (m)	Sample Type	*w* %	γ_B kN/m^2	Strength c' (kPa)	Parameters ϕ ' (Degree)
0.3	Natural	13.8	18.2	40	34.2
0.3	Remolded	13.8	18.2	0	33.7
2	Natural	10.5	18.6	35	35
2	Remolded	10.5	18.0	0	34
4	Natural	30.9	20.1	0	35.5
4	Cemented	30.9	20.3	0	35

Figures 2, 4 and 6 indicate that the initial or secant modulus value is generally lower for remolded specimens compared to natural specimens shared under a confining pressure of 100 kPa and 350 kPa.

Table 3 compares the Secant Modulus E50 for natural and remolded specimens at 2m where E50 is the modulus corresponding to stresses as shown in equation below:

$$\sigma_1 - \sigma_3 = \tfrac{1}{2} (\sigma_1 - \sigma_3) \text{ maximum} \quad (1)$$

Table 3 Comparison of the Modulus Value E_{50} for Natural and Remolded Specimens

σ_3 (kPa)	Secant Modulus, E_{50} (MPa) Natural (2m)	Remolded (2m)
450	27.40	21.74
350	10.0	9.80
250	3.75	5.40

In order to have a clear view of the influence of remolding cemented sand on the strength characteristics, all shear strength parameters at the three sampling depths are show in Table 2. For the natural samples the strength parameters c', ϕ' at a depth of 0.3m, 2m, and 4m were (40 kPa, 34.2º), (35 kPa, 35º), and (0, 35.5º) respectively. The corresponding values for the remolded specimens were (0, 33.7º), (0, 34º), and (0, 35º). Thus, remolding and the destruction of cementation bonds resulted in the complete loss of the cohesion intercept and a minor decrease of 0.5º to 1º in the angle of shearing resistance at each sampling depths. The stiffness also decreased due to remolding, particularly at low confining pressure as shown from the slope of the stress-strain curves.

To explain the results, it is beneficial to refer to Figure 8 showing the types of interparticle contact, and the main sources of cohesion in cohesive sands. Interlocking and bonding of particles are the two main sources of cohesion produced by the digenetic alteration of sands (Barton, 1993). However, mild interlocking is not likely to produce true cohesion, since it can be overcome during dilation when it will make a notable addition to the shear resistance with an increase in the angle of friction ϕ'.

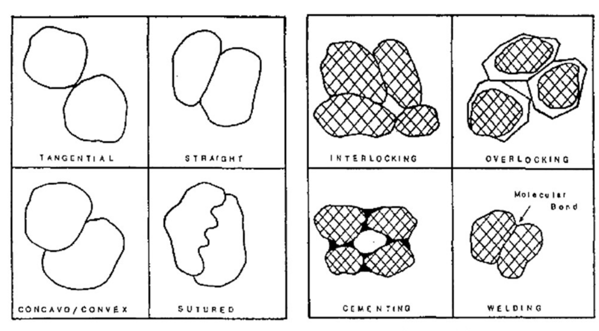

Figure 8 Types of interparticle contact and main sources of cohesion in cohesive sands (Barton 1993)

The bonding produced by cementation, however, forms a true cohesion since shearing must involve disruption of the cement or the particles, or both. Therefore, upon remolding of cemented sands, cementation bonds are destroyed leading to the expected loss of the cohesion intercept. Since the samples were remolded to the same density and void ratio, the small reduction in the angle of internal friction would not logically be expected. However, due to particle movement and rotation during compaction, crushing of some grains during the tamping process, particle interlocking will not be the same as the original condition.

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Cohesion may also result from surface tension in partially saturated soils. These water-soluble cementations were not considered herein since all samples were saturated before testing.

The preceding results point to the importance of careful excavation for foundation placement in cemented sand. Otherwise, disturbance of the ground below foundation level results in the crushing of cementation bonds which reduces the soil strength and increases its compressibility regardless of the compaction effort carried out prior to foundation placement.

5. CONCLUSION

A site investigation was carried out at Keifan, Kuwait and a laboratory testing program was conducted at the soils laboratory, civil engineering department, Kuwait University to determine the strength characteristics of cemented sand samples (Gatch), and the effect of remolding after crushing the cementation bonds on the strength characteristics. The following conclusions were reached:

1) Naturally cemented sand appears from ground level to a depth of 4 m at the test site in Kiefan. The deposit increases in strength and unit weight with depth as demonstrated by the SPT-N values and the density measurements.
2) Cemented sands are competent nonhomogeneous deposits with the presence of cemented and uncemented layers in succession and the presence of cemented layers having different cementation levels.
3) Regardless of the nature of the nonhomogenity and the variability of the cementation level of cemented sand deposits, the stiffness, as determined by the modulus values, increases sharply with depth.
4) Within a cemented sand layer, near ground surface, the strength generally increases and the compressibility decreases with depth.
5) Disturbance of cemented sands and crushing of the cementation bonds results in the complete loss of the cohesion component of strength and a minor reduction in the angle of shearing resistance. It may also lead to possible swelling upon saturation if remolded and compacted to large density at very low moisture content.

6. ACKNOWLEDGEMENT

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