International Journal of GEOMATE, Oct., 2016, Vol. 11, Issue 26, pp. 2611-2619
Geotec., Const. Mat. & Env., ISSN: 2186-2982(Print), 2186-2990(Online), Japan

COMPREHENSIVE APPROACH FOR SWELLING SOILS REMEDIES

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ABSTRACT: The effect of drying and remolding on undisturbed expansive soil samples were investigated at different periods. The results showed that the swelling potentials for remolded samples were higher than those for undisturbed samples for different periods of testing. The results also showed that final swells and swell pressures increased as the initial moisture contents decrease for both remolded and undisturbed samples. The swelling potential increased as the initial dry density increases for both remolded and undisturbed expansive soil samples, and vice versa The cement dust used as a new additive material to decrease the swelling potential of the expansive soil. The results showed that the plasticity index, linear shrinkage, and clay minerals decreased with increasing cement dust percentage, where 50% of the montmorillonite disappeared after treatment the soil with 5% cement dust. The effect of cement dust columns on the swelling potential of the soil also studied extensively. The cement dust columns were embedded in the middle of the expansive soils using CBR mould .The results showed that the swelling potential decreased with increasing number of cement dust columns and when increasing the diameter of the cement dust columns ,a distinctive decrease in the swelling potentials were recorded. When decreasing the densities and increasing the diameters of cement dust columns resulted in decreasing the swelling potentials of the expansive soil. The swelling of the expansive soil been decreased when increasing the number of reinforced and non-reinforced cement dust columns. The swelling potentials showed distinctive decrease when the lengths of the reinforced cement dust columns increased.

Keywords: Swellings, Remedies, Cement dust, Reinforced cement dust

1. INTRODUCTION

Expansive soils are very common cause of foundation problems, depending upon the increase of moisture in the ground, expansive soils experienced changes in volume. [1] investigated the effect of wetting and drying of the expansive soil. The expansive soil experienced volumetric swelling upon wetting and shrinking to drying, they concluded that the water change has linear relation with swelling deformation, while drying reduces swelling deformation. [2] investigated into expansive clay buffers in radioactive waste disposal designs experience cyclic drying and wetting paths during different stages of their design life. Clayey soils subjected to these processes develop swelling and shrinkage deformations, which gave rise to the accumulation of compression or expansion strains during suction cycles. Extensive experimental studies conducted on an expansive soil from Nanning (China) area[3] , in order to establish a relationship between shear strength indices and cyclic drying and wetting parameters. They found that the shear strength of expansive soil decreases with increasing number of cycle and finally reached to a constant state. The value and cyclic number of the constant state reduced with increasing of amplitude of variation of water content. [4] reported that the expansive soils in semi-arid and arid regions of Texas are subjected to moisture fluctuations due to seasonal variation causing large volumetric changes. These ground movements were observed in the form of heave during wet season and shrinkage during dry season. They used geosynthetic reinforcements, both geogrids and geotextiles, to minimize the development of longitudinal cracks in the pavements. The effect of using lime and cement deep soil mixing to reduce the heave and shrinkage of expansive subsoil underlying pavements studied by [5] .They concluded that the potential of the deep soil mixing treatment to decrease the shrink-swell related movements from expansive subsoil of moderate depths.Lime slurry technique in desiccated state used to study the efficiency of in-situ stabilization of expansive soil [6] , they noticed a considerable decrease in swelling potential and increased in the unconfined compressive strength of the treated soil. The present research is devoted to investigate the effect of drying on both undisturbed and remolded samples on the swelling at different periods ,and the effect of remolding on the undisturbed expansive soil samples also investigated at different drying periods .The research also studied the effect on the mineralogical compositions , Atterberg limits and linear shrinkage when adding cement dust as a new additive to reduce swellings. The second stage of this research is devoted to study the effect of creating cement dust columns embedded into the expansive soils to reduce swelling potential. The effect of varying the diameter, density of cement dust columns on expansive soil also investigated. The study extended to show the effect of group cement dust columns, effect of reinforced cement dust columns on the swelling potential of the expansive soils. The effect of creating nanocomposite materials on the long-term durability of expansive soil been studied [7]. A series of tests were performed to examine the effect of induced nanocomposites on the durability behaviors of the expansive clay, the results showed that the improving factor in its unconfined strength was found to be 220%. A comprehensive assessment of multi storey building skeleton including geotechnical investigation resting on expansive soil was carried out [8] ,the building experienced structural cracks ranged from 15to 20 cm , the study recommended a number of solutions to prevent swellings .[9] used the bentonite to stabilize Loessic soils ,they concluded that the addition of bentonite increases the compressive strength by 400%.

2. MATERIAL AND EXPERIENTAL METHOD

A device been developed to monitor the swelling, the device consists of compaction mold with 152 mm in diameter and 178 mm height with spacer disk with 151 mm in diameter and 61.4 mm height as can be seen in Fig.(1).A circular perforated plate been placed at the top and a mesh been placed at the base , the expansions of the measuring heave were monitoring by attaching a dial gauge to the top. This device is mainly used for testing soil treated with cement dust ,cement columns and reinforced cement dust columns embedded in the expansive soil as shown in Fig.(8) and Fig.(12) respectively . The reinforcement bars used with 6 mm in diameter. The specimens for free swell tests (untreated soil)were placed in the odometer device and the whole samples been subermerged with water and the readings of swelling been recorded with time .The swell pressure tests performed after completion the free swell tests in the odometer tests by applying vertical pressure with pressure increments ,each pressure increments maintain constant for 24 hours and the deformations were recorded at the end each increment, this procedure continue until zero reading in the swelling potential is recorded.

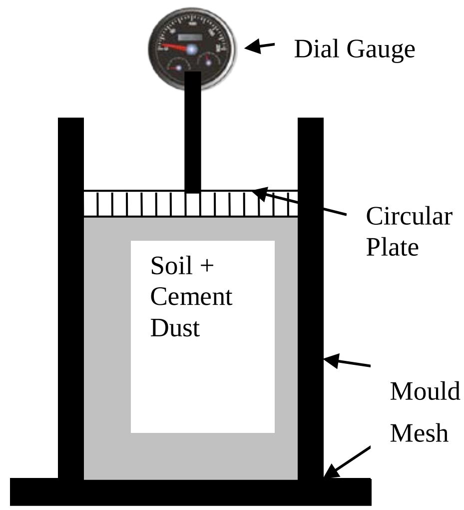

Fig.1 Details of Soil-Additive Mixture Treatment Technique

3. RESULTS AND DISCUSSION

The soil under study was silty clay and can be classified as (CH) ,the degree of expansion was found to be ranged from high to very high. The X-ray diffraction test was carried out to determine the proportion of the various minerals present in the soil as shown in Table 1 [10] . Chemical tests were also carried out as an additional method to identify the mineralogical composition of the soil as shown in Table 2. Cement dust that been used in present study is a side product, fine powdered material similar in appearance to Portland cement. The chemical analysis of the cement dust is shown in Table 3

Table1. X-ray diffraction results of tested expansive soil

	Mineral	%
Non-Clay Minerals	Quartz	24
	Calcite	34
	Feldspar	2
Clay Minerals	Montmorillonite	20
	Palygorskite	8
	Kaolinite	12

Table 2 Chemical compound of tested expansive soil

Compound	% by weight
Silica ,SiO_2	40.66
Alumina ,Al_2O_3	9.82
Iron, Fe_2O_3	1.09
Lime, CaO	28.98
Magnesia , MgO	0.99
Soda ,Na_2O	3.10
Potassium, K_2O	0.74
Loss on Ignition L.O.I.	13.93
PH	7.8

Table3. Chemical analysis of cement dust (Alzubaidi et al., 1991)

Chemical Composition	%
Silica SiO_2	15.46
Alumina Al_2O_3	3.91
Iron Fe_2O_3	3.05
Lim CaO	43.4
Magnesia MgO	2.98
Sulfuric anhydride SO_3	6.34
Potassium K_2O	2.44
Soda Na_2O	1.42
Chlorides Cl	0.92
Loss on Ignition, L.O.I.	28.86
Total	100
2. Free lime (%)	2.96
3. Specific gravity	2.31
4. Percentage passing 90 μm sieve	100

3.1 Effect of drying period on swelling of undisturbed samples

(12) free swell tests were conducted on undisturbed samples .Tests were performed on dried samples at different periods ranging from 1 to 7 days at air temperature (20) ° C. Fig.(2) and Fig.(3) shows the variation of swelling and swelling pressure respectively with time for undisturbed samples .The values of maximum swelling at the end of the tests were varied considerably depending on the initial condition ,but generally (48) hours were sufficient to complete the primary swelling ,while (4) days were sufficient for completion of the secondary swelling for curing period of (7) days .It can be noticed that the swelling increases with increasing the period of curing for the undisturbed samples while the volume expansion and the swell pressure increase with increasing the initial dry density and decreasing the initial water content.

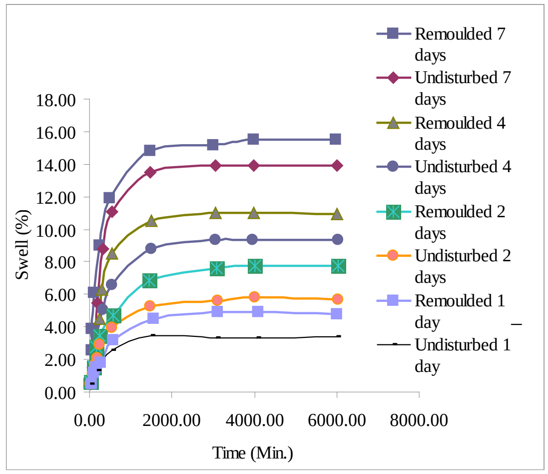

Fig. 2Swell pressure against time (min) for undisturbed and remolded samples for different curing periods

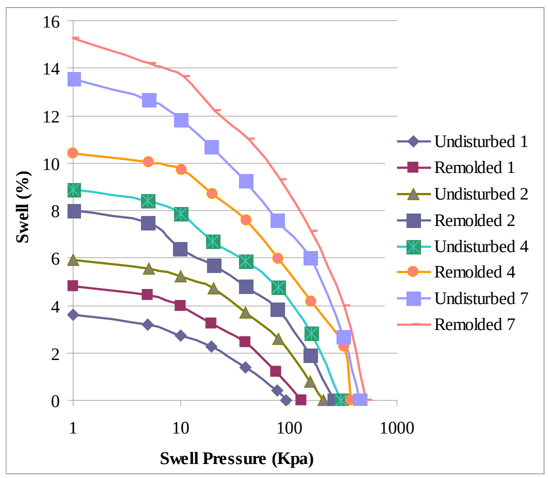

Fig.3 Swelling and swell Pressure for remolded and Undisturbed samples

3.2 Effect of intial water content and dry densties on swelling and swell pressure

The effect of initial water content and dry density on swelling potential of both undisturbed and remolded samples also been investigated .Fig.(4) and Fig.(5) showed the effect of initial moisture content on the swelling and swell pressure for remolded and undisturbed samples .It is clearly shown that the final swell and swell pressure increase as the initial moisture content decreases for both remolded and undisturbed samples .Also it can be noticed that the remolded samples gave higher swelling and swell pressure than those undisturbed samples. As shown in Fig.(6) and Fig(7) the initial dry density has a distinctive effect on swelling potential of both undisturbed and remolded samples . It is also can be concluded that the final swell and swell pressure increase as the initial dry density increase for both remolded and natural undisturbed samples.

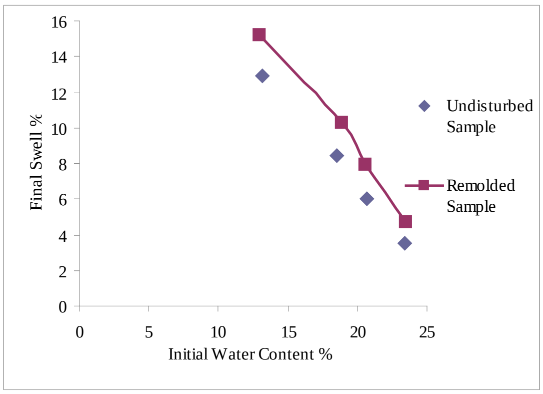

Fig.4 Variation of final swell percent with initial moisture content for air dried Samples

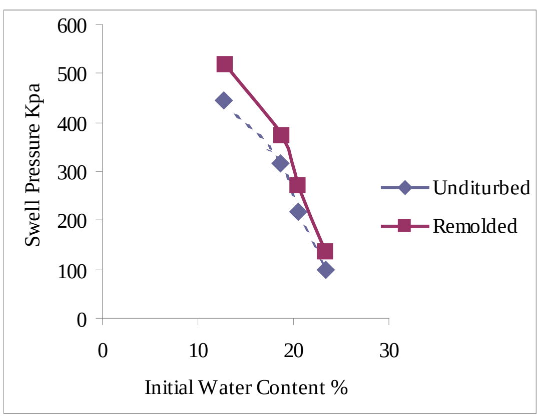

Fig.5 Variation of final swell pressure with initial moisture content for air dried Samples

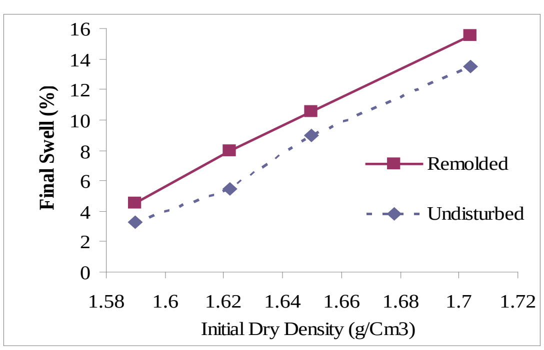

Fig.6.Variation of final swell percent with initial dry density for air dry samples

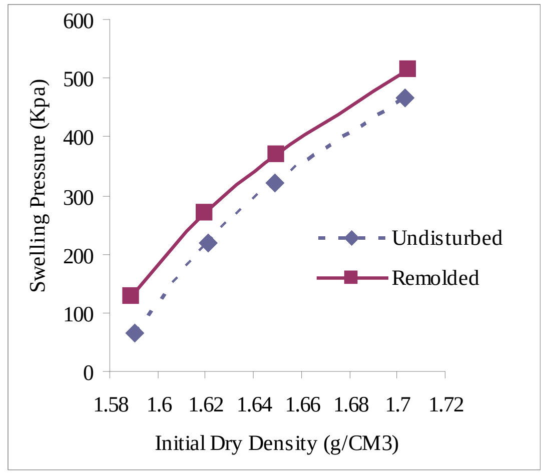

Fig.7 Variation of swell pressure with initial dry density for air dry samples

3.3 Effect of cement dust on mineralogical compostion

Air dried remolded soil samples were mixed with 5% cement dust by weight, X-ray diffraction method carried out to analyze the mineralogical composition of the mixture. Tests were conducted to determine the proportion of various minerals in the soil after treatment with 5% cement dust and carry out a comparison with the minerals of the original soil as shown in Table 4. The results indicated that the non-clay minerals increased while the clay minerals decreased after treatment the soil with 5% cement dust as compared with untreated soil (Table 1). The content of the most important minerals (montmorillonite) decreased from 20% to 9% after treatment. This reflected the decrease in the swelling potential of the expansive soils.

Table 4. X-ray analysis after treatment with 5% cement dust

Non-Clay Minerals	Mineral	%
	Quartz	25
	Calcite	29
	Feldspar	2
Clay Minerals	Montmorillonite	9
	Palygorskite	17.8
	Kaolinite	8

3.4 Effect of cement dust on atterberg limits

Different percentages of cement dust (0%, 2%, 4%, and 5%) were mixed thoroughly with a predetermined amount of air dried remolded soil, water was added to the mixture, and kept in a sealed container for 48 hours, the liquid limit, plastic limit, and shrinkage tests were carried out. Table 5 shows the effect of cement dust percentage on Atterberg limits and linear shrinkage. The properties of the soil were improved by the addition of cement dust to the soil. Since the liquid limit and plasticity index decreased while the plastic limit increased, the reduction in plasticity index was observed when adding the first amount of cement dust; then the plasticity index decreased with further increases in the amount of cement dust. The plasticity index decreased from 32.4% for untreated soil to 6.7% for soil treated with 5% cement dust. The linear shrinkage was decreased by adding cement dust to the soil, since the linear shrinkage decreased from 31.8% for untreated soil to 5.4% for soil treated with 5% cement dust. The variation in the plasticity index and the linear shrinkage was a positive sign to reduce the swelling characteristics of the soil; this reduction may be attributed to the effect of the chemical reaction and cementation on the structural composition of the soil. The modification of clay particles led to an increase in the effective particle size

Table 5. Effect of cement dust on Atterberg limits and linear shrinkage

Cement dust (%)	L.L (%)	PL (%)	PI (%)	LS %
0	60.5	28.1	32.4	13.8
2	56.8	34.5	22.3	11.2
4	48.5	38	10.5	7.8
5	46.7	40	6.7	5.4

3.5 Effect of cement columns

Small scale model was manufactured in the laboratory to investigate the effect of cement dust columns on the swelling potential of expansive soil as can be seen in Fig.8. Different type of tests were conducted to show the changes in the swelling potential of the expansive soil

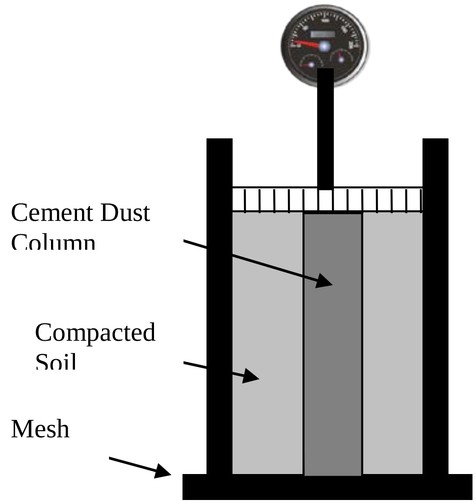

Fig.8 Details of Cement Dust Column Technique

3.6 Effect of cement dust columns diemeters on swelling potential

The diameters of cement dust columns used in present study were 31, 40 and 50 mm .The cement dust been compacted in the bored hole in the middle of the sample with 5 to 6 layers to achieve the required density equivalent to density produced from pouring 5% of cement dust by weight of the soil to a single column of diameter 31 mm as shown in Fig.8. The mold been sealed with a thick plastic sheet and cured at air temperature for 7 days . The mold clamped with perforated plate at the top, then the molds were immersed in water and the swelling readings to be recorded with time. Fig.(9) shows the variation of swelling with time for different cement dust column diameters with the same maximum density for the expansive soil(2.21 gm/cm^3). The results indicate two stages of swellings, the higher rate of swelling was decreased slowly with increasing the diameter of cement dust column . The primary swelling extends from the start of the test up to (7) days, the tests continued to (15) days to ensure to reach the equilibrium state, the final swell percent were 5.73 , 5.2 and 4.61% for cement dust columns of diameter of 31 ,40 and 50 mm respectively.

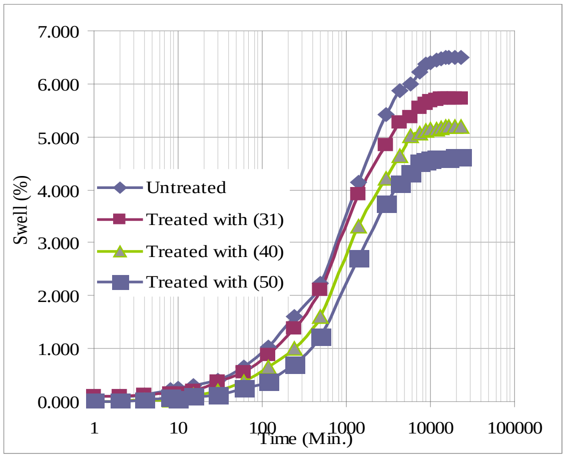

Fig. 9 Swelling Potential for Soil treated with cement columns and untreated soils

3.7 Effect of cement dust columns group on swelling

After completion of soil compaction in C.B.R molds a number of boreholes were made in the samples as follows:

(1)-Two boreholes with diameters of (15) mm

(2)-Three boreholes with diameters of (13) mm

(3)-Four boreholes with diameters (12.7)mm

The cement dust then poured in the holes and compacted to give the required density that equivalent to density produced from pouring (5)% of cement dust by weight of the soil to the single column of diameter (31)mm ,the molds been sealed with plastic sheets and cured at air temperature for 7 days ,the samples then tested to measure the swelling potential .The results of three model tests were performed to investigate the behavior of group of cement dust column. Fig.(10) shows the variation between the swell potential with time for all groups, the behavior of each group was approximately the same as the behavior of a single cement dust column. The higher swell potential decreased as increasing the number cement dust columns in each group . The change in final swell ,increases with increasing the number of columns in each group compared with a single cement dust column, thus the final values were 5.73 ,5.17 and 4.4 % for two columns with 15 mm diameter ,three columns with 13 mm and four columns with 12.7 mm diameter respectively .

3.8 Effect of different densties with different columns diameters on swelling

After completion of soil compaction in C.B.R molds, a single borehole to be made with different diameters of 31 mm,40 and 50 mm, then 5% of cement dust was poured in each mold to fill the full depth of the boreholes ,since different densities of cement dust column in each mold were achieved .The molds were sealed with plastic sheet and cured at air temperature 20 °C for 7 days ,where swelling tests been conducted. The results of at least 5 tests were performed to investigate the behavior of a single cement dust column diameters at different densities ranging from 2.12 , 1.27 to 0.81 gm/cm^3 represented maximum ,medium and minimum densities respectively .The columns with diameter 31 mm were tested at medium and minimum densities ,the columns with diameter 40 mm were tested at medium densities and the columns with 50 mm were tested at minimum densities. Fig.(11) shows the variation of swell potential with time for different densities. There is a reduction in the final swell percent with decreasing the density of cement dust column at different diameters as listed in Table 6 ,the final swell percent decreased as decreasing the density with increasing the diameter of the cement dust column as listed in Table 7. For columns with diameter 31 mm ,the final swell was 5.73% for maximum density but with medium and minimum densities the final swell became 5.53% and 5.34% respectively. Columns with diameters 40 mm ,the final swell decreased from 5.2% to 4.945 for maximum and medium densities respectively . Columns with diameters 50 mm, the final swell were 4.61% and 4.11% for maximum and minimum densities respectively.

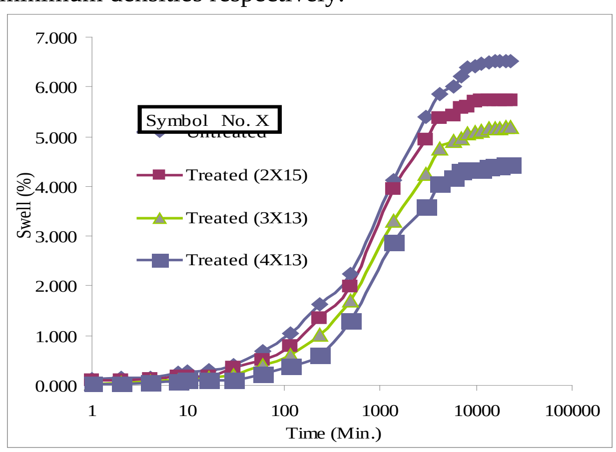

Fig. 10 Swelling Potential for group of cement dust columns at same density

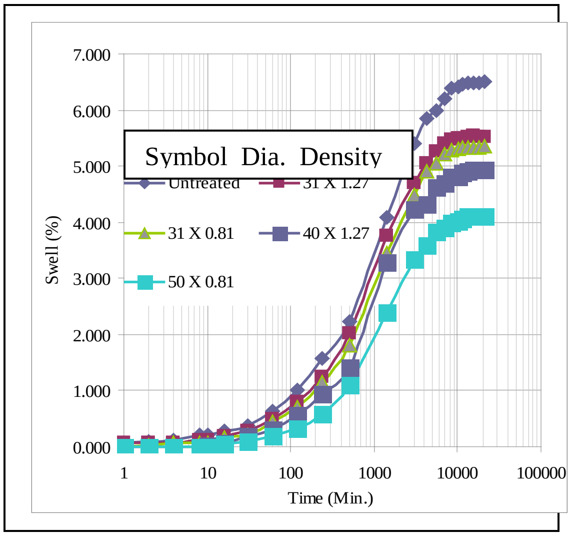

Fig.11 Swelling potential for soils with different cement dust columns diameters at different densities

Table 6. Effect of Different Densities at Different Diameters on Final swelling Reduction

Density (gm/cm^3)	Dia (mm)	31	40	50
2.28	Final Swelling Reduction (%)	11.8	20	29
1.28		14.9	24	-
0.82		17.8	-	36.7

Table 7. Effect of Different Densities at Different Diameters on Final Swell %

Density (gm/cm^3)	Dia (mm)	31	40	50
2.28	Final Swellin g(%)	5.73	5.2	4.61
1.28		5.53	4.94	-
0.82		5.34	-	4.11

3.9 Effect of reienforced cement dust columns on sewllings

Two boreholes were drilled in the compacted soil in C.B.R mold with 25 mm diameter and also another three boreholes with 16 mm diameter in the same mold. A single reinforced steel bar was inserted in each boreholes and 5% of cement dust was poured equally in each borehole as shown in Fig. 12. The mold sealed with a plastic sheet and cured for 7 days in air temperature. Swelling tests were performed to record the swelling potential. The tests showed that using cement dust column of diameter (50) mm with minimum density, decreased the swelling potential to (36.7) %. Because of development several tension cracks in the column especially in the portion of wetted zone of upper soil for such problems a reinforced cement dust column of diameter (50) mm, was suggested. Fig.(13) shows the behavior of swell potential of reinforced and non-reinforced cement dust column with time. The variation of swell percent in the early stage was close to each other; then with further times the different of swell potential for reinforced and non-reinforced cement dust column was increased. The higher rate of swelling was observed at approximately (6) days for non-reinforced cement dust column while for reinforced columns the period was (4) days, and the final swell was (4.11) % for non-reinforced column but for reinforced columns the final swell was (2.11) %.

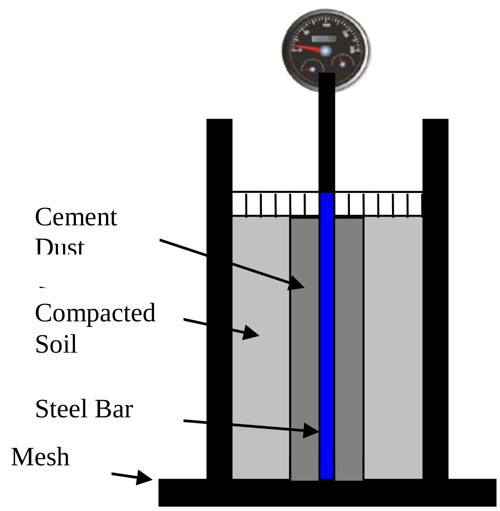

Fig.12 Details of Reinforced Cement Dust

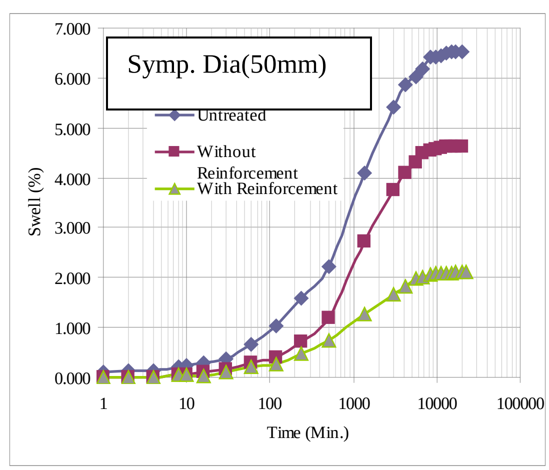

Fig.13 Swell Potential for reinforced cement dust columns

3.10 Effect of depth reinforced cement dust columns on swellings

Three types of tests were performed to investigate the effect of different lengths of reinfUrced column on swell potential. Fig.(14) shows the variation of swell potential with time for untreated, full, half and quarter reinforced cement dust column respectively. The reduction of swell potential was increased with increasing the reinforced cement dust length and vice versa. The effect of the depth was more pronounced on primary swell, since the primary swell increased with decreasing the depth of cement dust column. The required time to complete the primary swell was (4), (5) and (7) days for full, half and quarter depths for reinforced cement dust columns respectively. The final swell percent was (5.8), (2.95) and (2.1) % for full, half and quarter for reinforced cement dust columns respectively.

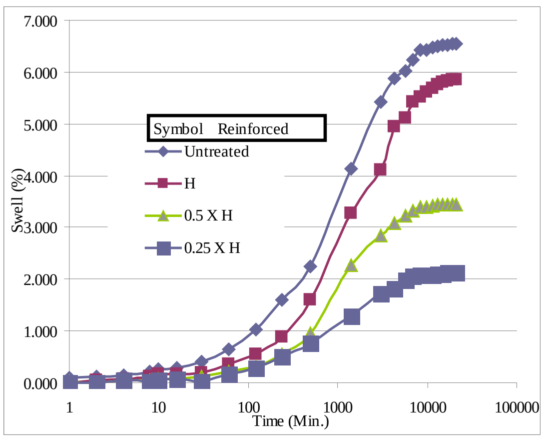

Fig. 14 Swell Potential for reinforced cement dust columns with different lengths

3.11 Effect of group reinforced cement dust columns on swelling

Two types of tests were performed to investigate the effect of group of small reinforced cement dust columns with untreated soil. Fig.(15) shows the variation of swell potential with time for two groups of reinforced cement dust columns. The behaviors of groups of reinforced cement dust columns were similar to that of a single reinforced cement dust columns except a distinctive decreases in the final swell been recorded . The final swell percentages were (1.61) % and (1.52) % for two cement dust columns with (25) mm, diameter and three cement dust columns with (16) mm. diameter respectively. The final swell reduction percentages were (75) % and (76.6) % for (2) cement dust columns with (25) mm. diameter and three cement dust columns with (16) mm. diameter respectively.

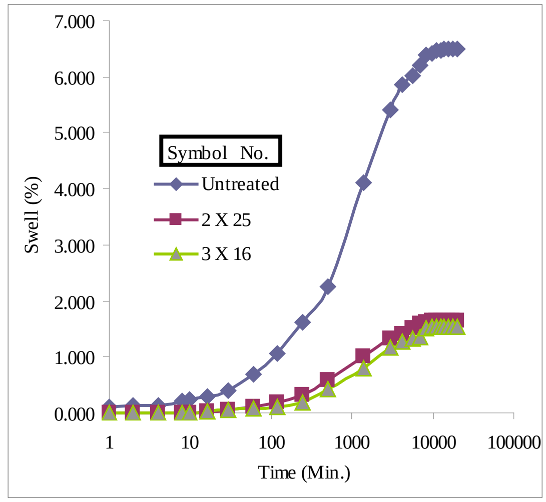

Fig.15 Swell Potential for group reinforced cement dust columns

4. CONCLUSSIONS

The present research has led to the following conclusions for expansive soil.

1-The swelling potentials for drying samples are more than wetting samples ,so care should be taken during sealing the expansive soil samples for testing.

2-The effect of cement dust on the mineralogical composition of the expansive soil is more pronounced for clay minerals, where 50% of the montmorillonite disappeared after treatment the soil with 5% cement dust.

3- The variation in the Atterberg limits and linear shrinkage are positive indication of reduction in the swelling characteristic, since the plasticity index and linear shrinkage decreased from 32.4% and 13.8 % to 6.7% and 15.4%, respectively, after the soil been treated with 5% cement dust.

4-The swelling potentials for remolded are more than undisturbed expansive soil samples, care should be taken and prevent any disturbance during sampling.

5-The final swell and the swell pressure increased as the initial moisture content decreased for both remolded and undisturbed expansive soil samples.

6-The swelling potential increased as the initial dry density increases for both remolded and undisturbed expansive soil samples, and vice versa.

7-The swelling potentials decrease with increasing the diameter of cement dust columns, thus 29% of swell potentials were eliminated with increasing the diameter of cement dust columns to (50) mm at maximum density.

8-The swelling potential decreased with increasing number of cement dust columns, thus swelling potential decreased to more than 32% with increasing number of column to (4) columns.

9-The swelling potentials decreased with decreasing the density of cement dust columns, thus swelling potentials for columns of diameter (50) mm decreased from 29% to more than 36% with the minimum density.

10-The swelling potentials decreased from 36.7% for soil treated with cement dust columns without reinforcement to 67% for soil treated with steel reinforced cement dust columns

11-The swelling potentials decreased from 67.5% to 10.8% with decreasing the length of steel reinforcement columns to (0.25H).

12-The swelling potentials decreased from 75% to 76.6% with increasing the number of reinforced columns to three columns.

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International Journal of GEOMATE, Oct., 2016, Vol. 11, Issue 26, pp. 2611-2619.

MS No. 151121 received on Nov. 21, 2015 and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in Oct. 2017 if the discussion is received by April 2017.

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