

## Improvement of Selected Parts of Basrah Governorate Soil Using Resorcinol Resin

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### Abstract

Weak soils in some parts of Basrah Governorate were mixed with 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 2 percent by weight of resorcinol resin, and the same clayey silt soils also mixed with 3, 6, 9,12,15,and 18 percent by weight of Portland cement to achieve the primary objectives of this research, respectively. These involve: (a) the profitable amount of resorcinol resin, (b) improving some of the engineering properties of the studied soils that include: the plasticity, compacting these soils to increase the maximum dry density and lowering their optimum moisture content, and also reducing the ability of these soils to absorb water. A noticeable improvement in the plasticity of resorcinol -treated soils were noticed as reflected in the rise in their Plastic Limits, A reasonable increase in their dry densities, and lowering in their optimum water contents, finally an appreciable reduction in the ability of these soils to absorb water for cured soils. Cement –treated clayey silt soils failed to achieve any improvement in the soil engineering properties except the modest decrease in percent of the rapid water absorption values. The cost of using this polymer resin as soil binder was reduced by 50% as compared to the usual practices, which involve removing the clayey silt soils and replace them by sand or other materials a chemical plant is provided. It is also suitable for our climatic condition. Therefore, resorcinol resin acts as good soil binder.

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### Introduction:

Top surface layers of the soils in the Basrah Governorate have been subjected to a continuous changes resulting from the continuous erosion and deposition of recent sediments rising and sinking of the terrain or loading and unloading of them by alluvial processes and sedimentation during the recent geologic history of the Basrah region. Chemical analysis of these studied fine-grained soils were shown in table (1) indicates, the presence a mixture of clay

and non-clay minerals <sup>(1)</sup>. Mechanical grain size analysis of the top layer of soils in the Basrah region indicates a clayey silt type soil, where silt constitutes the higher percent (58%), followed by clay (32)%, and approximately 10% of sand. On these bases, Basrah soil is strictly determined by it's fine particles mainly silt, and clay, and also by the type and percent of clay minerals present in these soils table (2). Clay minerals distribution around Basrah city, indicate that, the clay minerals where

distributed in the following order: Illite – palyogorsikite (61%), Kaolonite (25%), Clorite (8%) and 6% Montmorillonite<sup>(2)</sup>.

The X-ray diffraction analyses conducted by (NIMCO, 1986)<sup>(1)</sup> showed the presence of the following clay minerals: Illite, Palygorskite, Kaolinite, Chlorite, and Montmorillonite, and other non-clay minerals such as Quartz, Calcite, Halite, Gypsum, and Feldspar. Therefore, this kind of soil usually becomes weak and soft, unless they experienced any solidification processes, resulting from physical, mechanical, or chemical means.

Chemical soil stabilization methods resulting from the addition of various combinations of materials such as cement, lime, fly ash, natural fibers, bitumen, sodium chloride, and magnesium chloride were used. Despite their success in many cases of soil improvement and reinforcement but these methods require lengthy curing periods and relatively large quantities of additives<sup>(2)</sup>. Recently developed, nontraditional soil improvement additives were also used such as: salts, acids, lignosulfonates, petroleum emulsions, fibers, and tree resins. Polymeric materials are considered to be the dominant foam materials such as polystyrene. Despite their low density could reach up to (1-2 %) of the density of soil, yet they are sufficiently strong to support many types of loads encountered in Geotechnical practices<sup>(3)</sup>. Some Laboratory experiments were carried out to stabilize silty sand soil including acids, enzymes, lignosulfonates, petroleum emulsions,

polymers and tree resins<sup>(4)</sup>. Tests results revealed an increase in the soil strength of some nontraditional stabilization alternatives. Polymers gave a good strength in both dry and wet conditions. Experiments also revealed that, there is an optimum additive quantity for the maximum dry density and unconfined compressive strength. This optimum polymer quantity ranged between 2.5 to 5 % by weight. Another experiment was designed to determine the effects of stabilizing clayey silt soils with combination of epoxy resin<sup>(5)</sup>. They concluded that admixing up to 4% stabilizer into caly – silt material produced large increase in the load bearing capacity of the material in terms of its CBR, They also observed that the increase in the temperature of the curing environment led to the increase of the strength and reduction in curing times to 3 hours only.

Comparatives studies using Urea-Formaldehyde (UF) and its copolymers to stabilize dune sand were performed in India<sup>(6)</sup>. Specimens were prepared at different combinations of UF ratios, pH levels and acid catalysts. The results showed that the additive mixture using phosphoric acid catalysts impved the strength of these specimens. Further studies were carried out for agricultral purposes using Polyacrylamide (PAM) as soil stabilizer for soil erosion control in Wisconsin, U.S.A.<sup>(7)</sup>. They concluded that it works well in preventing erosion, and when this polymer combined with Seed and Mulch gave good results in controlling the erosion and in turn

enhances the vegetation growth. The primary objectives of the present research is to stabilize the Basrah clay silt soils with the profitable amount of resorcinol resin, (b) improving some of the engineering properties of the studied soils that include:

the plasticity, compacting these soils to increase the maximum dry density and lowering their optimum moisture content, and also reducing the ability of these soils to absorb water

**Table (1) Chemical Analysis Tests Results of Basrah < 2 $\mu$ m Soil Samples From Selected Locations <sup>(1)</sup>**

(% ) Oxides Contents	Sample Location			
	Abu-Alkhasseeb	Al-Ashar	Fao	Garmatt Ali
SiO <sub>2</sub>	36.01	35.03	34.20	35.00
Al <sub>2</sub> O <sub>3</sub>	10.10	10.20	10.22	10.22
Fe <sub>2</sub> O <sub>3</sub>	4.40	4.52	4.15	4.38
MgO	4.18	4.12	4.48	4.16
CaO	16.36	18.45	14.08	18.90
Na <sub>2</sub> O	0.73	0.80	0.84	0.82
K <sub>2</sub> O	0.78	0.75	0.75	0.73
SO <sub>3</sub>	4.80	4.50	4.85	4.60
TiO <sub>2</sub>	0.61	0.59	0.66	0.61
P <sub>2</sub> O <sub>5</sub>	0.11	0.16	0.17	0.16
Loss On Ignition	21.43	21.23	24.21	20.10
SUM.	99.51	99.35	99.01	99.18

### Materials And Methods:

Sufficient quantities of clayey silt soil samples at 0.8-meter depth from (Fao, Abu-Al-khasseeb, Al-Ashar, and Garmatt Ali areas) were collected. Two types of stabilization additives were used: for the first time in this type of research ; they include: 1-Resorcinol resin, 2-Portland cement. This polymer resin prepared in the Research Chemistry Laboratory, College of Science, University of Basrah.

To compare the improvement results obtained from resorcinol resin treated clayey silt soils with other additives; The Iraqi Portland cement is used to stabilize these clayey silt soils, and perform tests in the same manner used as in the case of resorcinol treated soils <sup>(8)\*</sup>. The preliminary tests results are summarized in table (2). These analyses were done according to the Specific Gravity Tests [ASTM (D854), 1975]<sup>(9)</sup>, Sieve Analyses and Hydrometer Tests [ASTM, 1975],

Atterberg's Limits For Untreated and resorcinol resin treated clayey silt soils (AASHTO T89 and T90, 1975, <sup>(10)</sup>. Three chemical tests are conducted. They include: organic matter test, sulphate test, carbonates test. The organic matter content was measured using (B.S. 1377, Walky, and, Black method <sup>(11)</sup>, while the sulphate content was measured by (ISS, 1998, Modified Sheen and Kahler Method) in <sup>(12)</sup>. The carbonates content was determined by calcimeter method <sup>(13)</sup>. Tests are conducted in the Marine Science Center, and in the chemistry Laboratory, College of Science at University of Basrah.

### Results And Discussion

Tests results for effects of untreated and resorcinol resin treated Basrah soil

samples of the specified locations are discussed in this section. The first investigation includes preliminary test such as: grain size analyses, hydrometer tests, specific gravity tests, Atterberg's limits tests, and related chemical tests are shown in tables (2). The soil variations in their Atterberg's limits essentially attributed to the differences in the quantities of their clay minerals, silts, and the presence of different soluble salts such as calcite or gypsum. Considerable improvements in the plasticity of the studied soils are noticed in the increase of their plasticity limits, and, consequently reduction in their plasticity index as a result of adding (0.75-1% w/W) of resorcinol resin.

Table (2) summarizes some preliminary characteristics of the studied untreated soils.

Location	Specific Gravity	Organic Matter %	Carbonate %	Sulphate %	L.L. %	P.L. %	P.I. %	Clay %	Silt %	Sand %
Fao	2.722	0.12	15.83	0.11	36	21	15	24	64	11
Abu-Al-Khasseeb	2.742	0.20	17.21	0.12	49	30	19	37	54	10
Ashar	2.699	0.11	17.79	0.12	44	23	21	34	55	11
Garmatt Ali	2.702	0.17	20.71	0.12	43	23	20	33	56	11

L.L.=Liquid limit, P.L.=Plastic limit, P.I.=Plasticity index

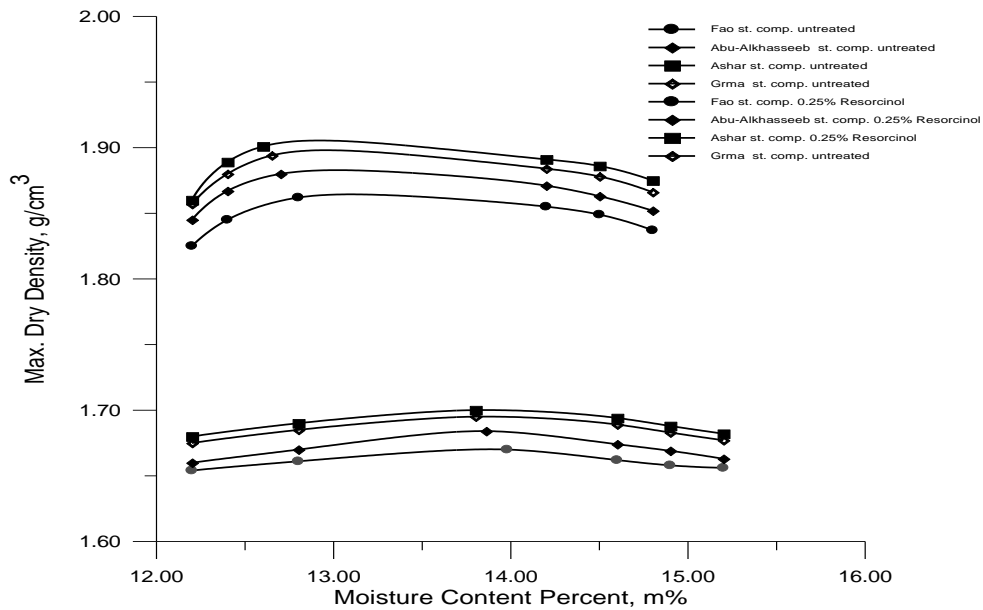
### Compaction Tests -Using Resorcinol Resin As Soil Stabilizer:

Standard compaction tests results after adding various amounts of resorcinol resin to those investigated soils indicate a

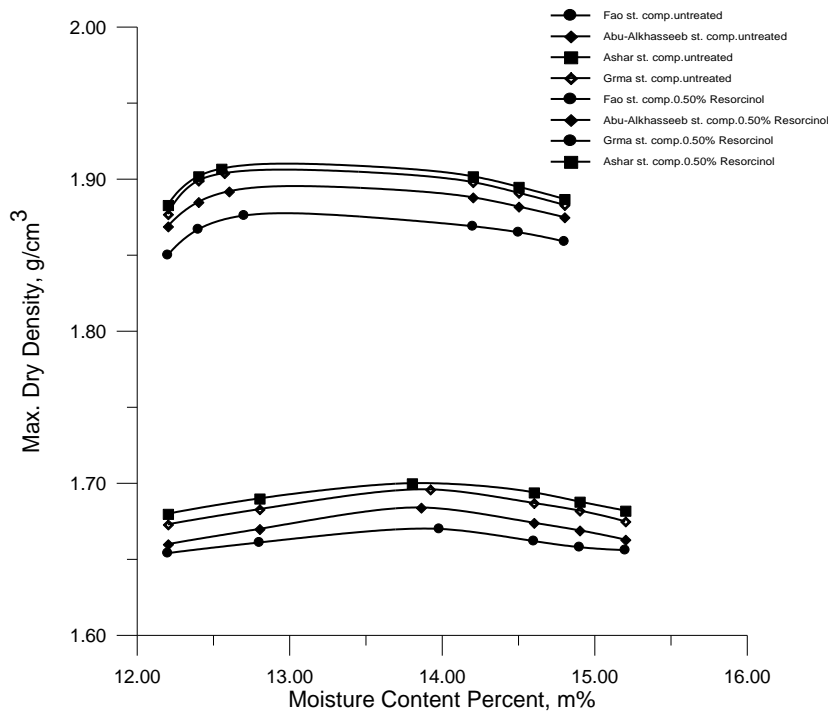
noticeable increase in their maximum dry densities, and appreciable decline in their corresponding optimum moisture contents as shown in Figs. (1to7). This increase in the dry density of the resorcinol resin

treated clayey silt soils may be attributed not only to the compactive effort and water lubrication effect, and also to the rise in the

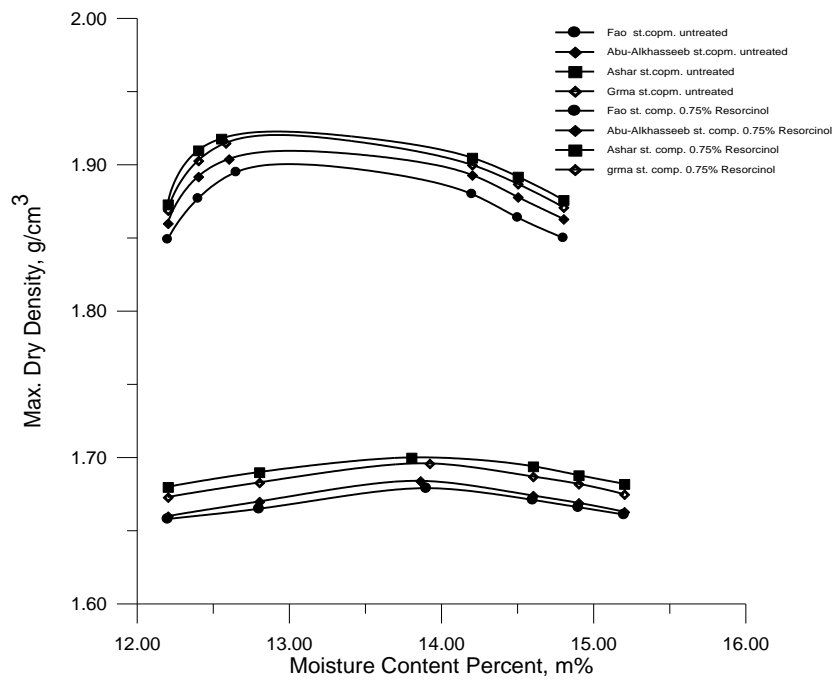
cohesion between the clay particles themselves, and the enveloping effect created by this added polymer resin.



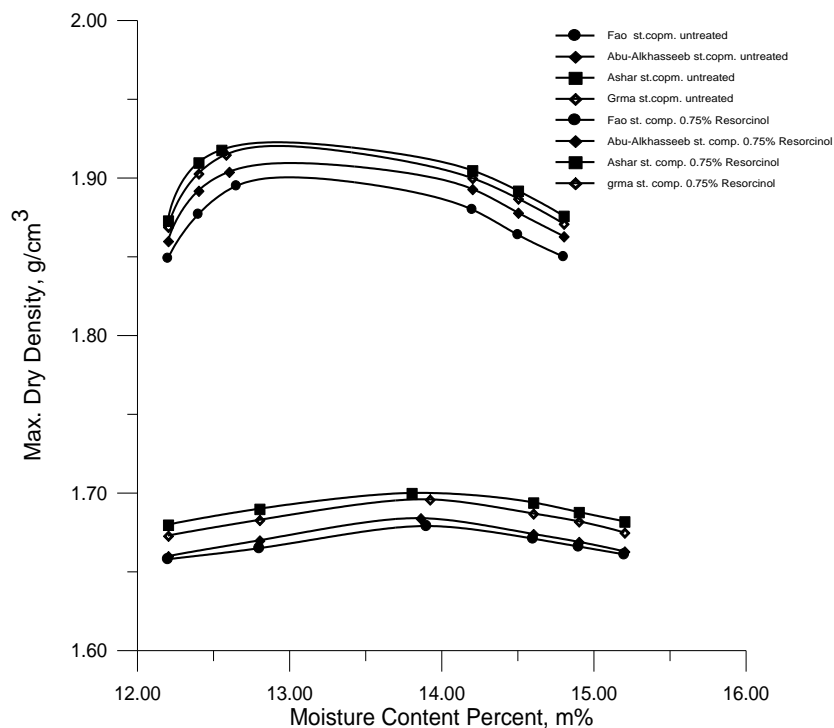
**Fig. (1) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (0.25% w/W) Resorcinol Resin as Soil Stabilizer Polymer**



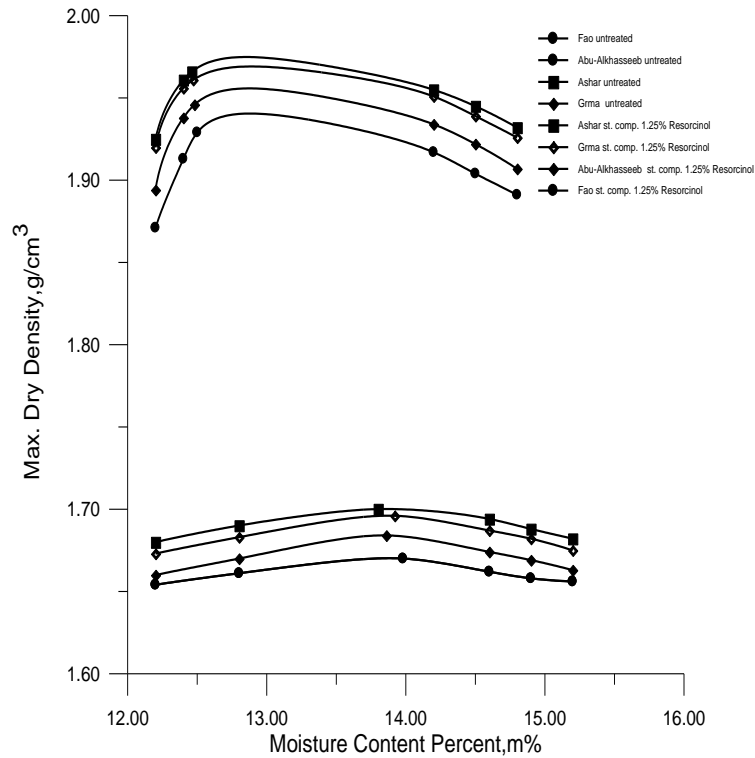
**Fig. (2) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (0.50 %w/W) Resorcinol Resin as Soil Stabilizer Polymer**



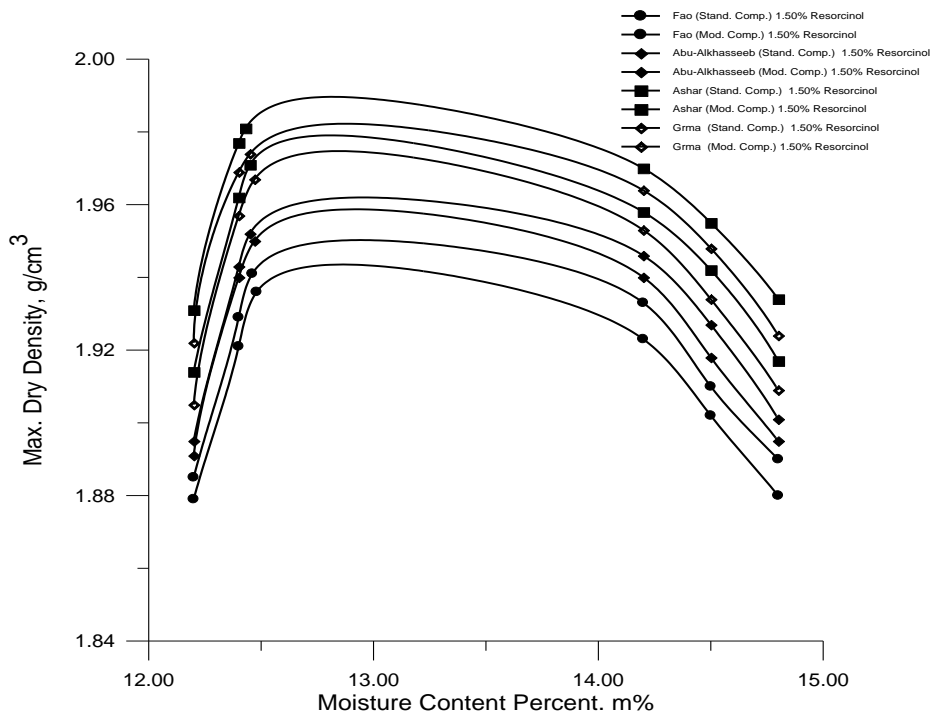
**Fig. (3) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (0.75 %w/W) Resorcinol Resin as Soil Stabilizer Polymer**



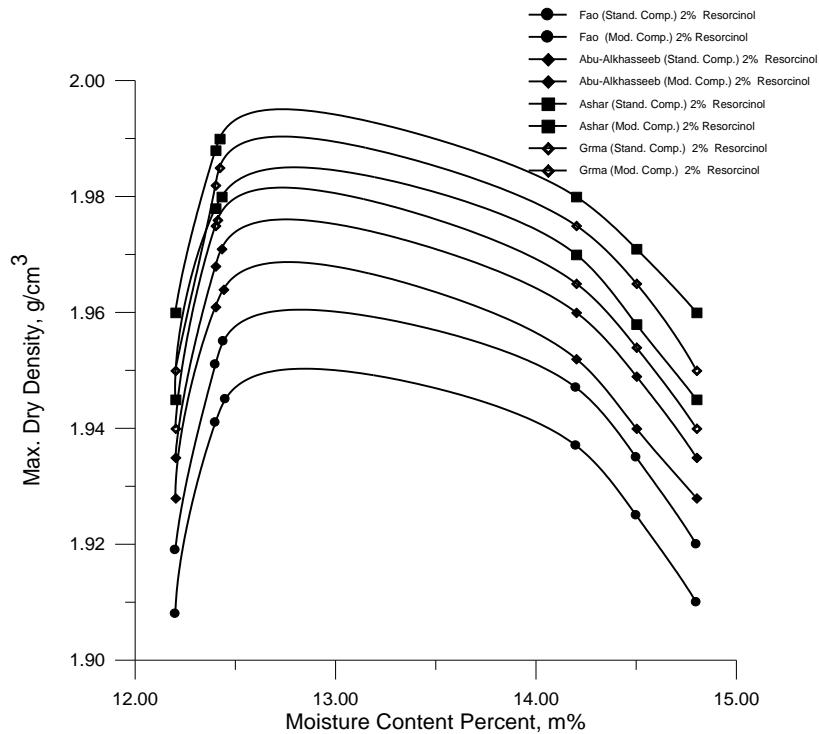
**Fig. (4) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (1%w/W) Resorcinol Resin as Soil Stabilizer Polymer**



**Fig (5) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (1.25%w/W) Resorcinol Resin as Soil Stabilizer Polymer**



**Fig. (6) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (1.50%w/W) Resorcinol Resin as Soil Stabilizer Polymer**



**Fig. (7) Compaction Tests Results of Stabilized Basrah Clayey Silt Soils Using (2%w/W) Resorcinol Resin as Soil Stabilizer Polymer**

Statistical analysis using the least significant differences method (LSD), also revealed significant differences ( $p \leq 0.01$ ), the best and more useful increase in the mean value of the maximum dry density was (1.897 g/cm<sup>3</sup>) for (Fao, Abu-Al-Khasseeb, Al-Ashar, Garmatt Ali soils), respectively. While the corresponding optimum moisture contents mean value was (12.52%) that corresponds to 1.25 w/W% of resorcinol resin. Therefore, the addition of (1.25% w/W) of resorcinol resin is sufficient to produce noticeable increases in the maximum dry densities of these studied soils, and reasonable declines in their corresponding optimum moisture contents.

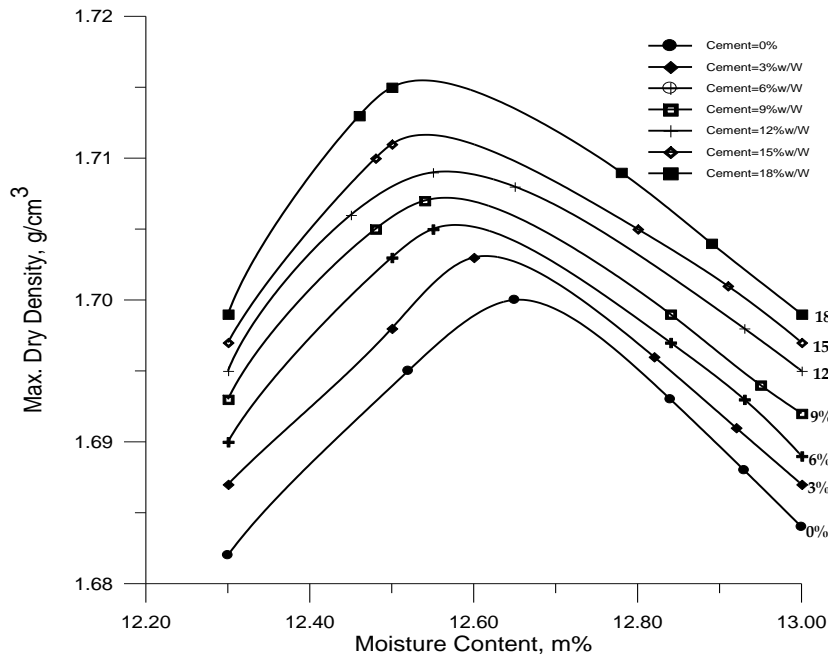
#### **Compaction test results of cement-treated clayey silt soils:**

Standard compaction tests results of untreated and cement -treated soils using various percents (w/W%) of cement are shown in table (3) and fig. (8). It is clear that compaction of cement treated clayey silt soil has very little effect on its dry density. This little increase in the dry density of cement treated soil may be due to the density of cement itself, and also to the degree of its fineness. Therefore, the addition of large quantities of cement becomes economically unprofitable and impractical to handle in the field



**Table (3) Standard Compaction Tests Results of Untreated And Cement –Treated Clayey Silt Soils**

Property/ Test No.	1	2	3	4	5	6	7
% w/W Cement	0	3	6	9	12	15	18
Dry density, $\gamma_d$ g/cm <sup>3</sup>	1.700	1.703	1.705	1.707	1.709	1.712	1.715
O.M.C.%	12.65	12.55	12.50	12.48	12.44	12.46	12.42

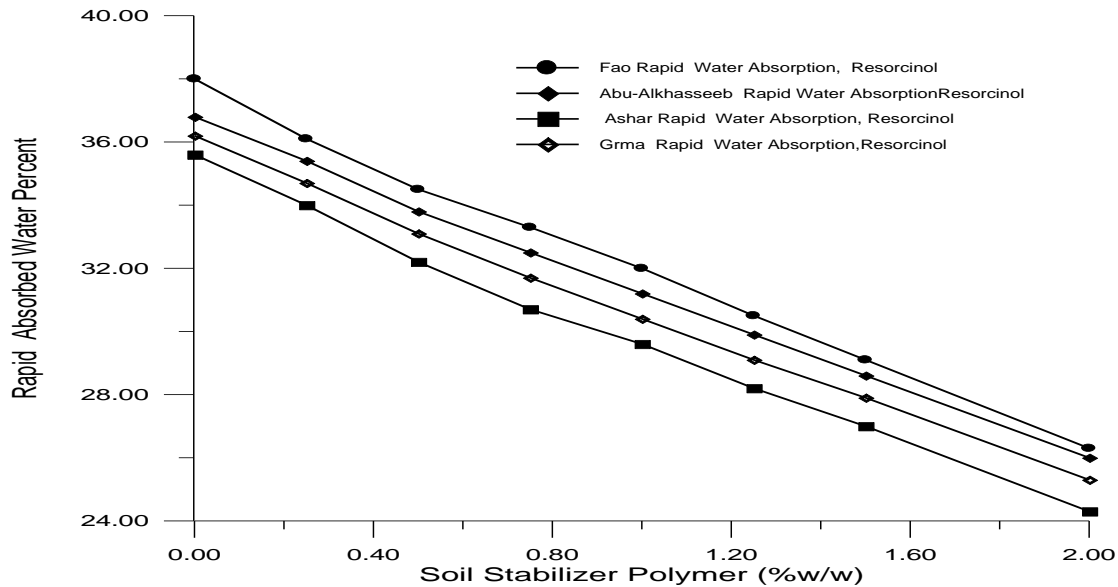


**Fig. (8) Standard Compaction Tests Results of Untreated And Cement –Treated Clayey Silt Soils**

**Rapid water absorption results for cured untreated and Resorcinol Resins-treated clayey silt soil cylinders:**

Rapid water absorption tests results on cured untreated clayey silt soil cylinders for (Fao, Abu-Al- Khasseeb, Al- Ashar, and Garmatt Ali Soils) were:(38.2, 36.8, 35.6, 36.2 %), respectively. Cured resorcinol

resin-treated clayey silt soil cylinders have witnessed reasonable reductions in their rapid water absorption abilities for all these investigated silty clay soils. Tests results for both polymer -treated and untreated soils are shown in fig. (9).



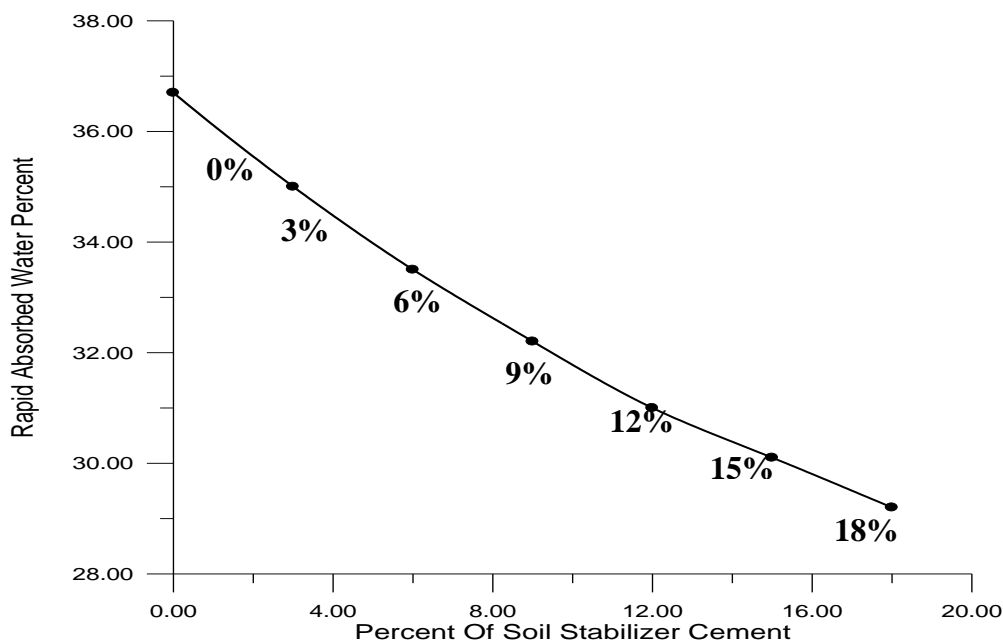
**Fig. (9) Rapid Water Absorption Tests Results of Cured Untreated And Resorcinol Treated Clayey Silt Soil Cylinders**

This reduction in the rapid water absorption abilities for these investigated soils are also attributed to the interaction between the clay minerals and the reactive parts of this added polymer, reinforced by the exerted compactive effort during preparation of specimens and curing periods. Statistical analysis using the least significant differences method (LSD) also revealed significant differences ( $p \leq 0.01$ ). As a result of adding 1% of resorcinol resin the mean value reduction of rapid water absorption was (31.0%), which represents the mean values for (Fao, Abu-Al-Khasseeb, Al-Ashar, Garmatt Ali soils), respectively. Therefore, This added

resorcinol resins would act as a good binder and waterproofing agent.

#### **Rapid water absorption results For cured untreated and cement treated Clayey Silt Soil cylinders:**

Rapid water absorption tests results on cured untreated clayey silt soil cylinders chosen from Garmatt Ali area showed that, its rapid water absorption was (36.2 %). But after treating this soil with (3, 6, 9, 12, 15, 18 %w/W) of cement, its rapid water absorption was reduced by ((5, 5.5, 6.2, 6.6, 6.9, and 7.4 %), respectively. These results are shown in fig. (10). This small reduction in the rapid water absorption ability of the cement treated clayey silt soil may be related to the curing time only.



**Fig. (10) Rapid Water Absorption Tests Results of Cured Cement- Treated Clayey Silt Soil Cylinders**

#### **Capillary water absorption results of cured untreated and Resorcinol Resin - treated clayey silt soils:**

Capillary water absorption tests on cured untreated for (Fao, Abu –Al Khasseeb, Al-Ashar, and Garmatt Ali clayey silt soils cylinders) was (2.46, 2.18, 2.06, 2.11 %), respectively. Polymer resin-treated soils have witnessed reasonable reductions in their capillary water absorption for these investigated clayey silt soils. Tests results for cured untreated and resorcinol resin-treated soil cylinders are shown in figure (11). This reduction in the capillary water absorption for these cured polymer resin-treated soil cylinders are also related to the reaction between the active parts of clay minerals and the active parts of these added polymer, reinforced by compacting efforts

and curing time. Statistical analysis using the least significant differences method (LSD) also revealed significant differences ( $p \leq 0.01$ ). As a result of adding 1.25 % of resorcinol resin the mean value reduction of water capillary absorption was (1.574%), which represents the mean values for (Fao, Abu-Al-Khasseeb, Al-Ashar, Garmatt Ali soils), respectively. Therefore, This added resorcinol resins would act as a good binder and waterproof due to the interaction between the fine particles of the clayey silt soil and this ability was decreased by (1.13, 1.14, 1.14, 1.142, 1.43, 1.45%),

#### **Capillary water absorption results for cured untreated and cement –treated clayey silt soil cylinders:**

Capillary water absorption tests for untreated Garmatt Ali clayey silt soil was (2.11%). Using (3, 6, 9, 12, 15, 18 %w/W) of cement, respectively. Tests results show that the soil capillary water absorption respectively. These results are shown in fig. (12). Therefore, using cement as soil binder for reducing the capillary water absorption in the case of clayey silt soils was ineffective due to the continuous reaction between water and cement

### **Resorcinol Resin–Clayey Silt Soils Interaction**

Clay minerals are described as hydrous aluminum silicates minerals with isomorphic substitution in their mineral crystal lattice structures. These isomorphic substitutions usually involve: (1)-  $Al^{+3}$  replacing  $Si^{+4}$  in the silica tetrahedral layer, and usually replacement of aluminum with either  $Mg^{+2}$  or  $Fe^{+2}$  or  $Fe^{+3}$  in the octahedral layer, (2)-the disassociation of OH ion, and finally the broken bonds of the edge of the clay particles. In general, this causes the overall mineral structure unstable and having negative charge. The clay mineral family with the most isomorphic substitution is the Smectite group, while the one with least is the Kaolinite group. Both Illite and Chlorite have moderate substitutions <sup>(14)</sup>. This negative charge imbalance needs to be balanced by the addition of water and cations or other most active groups of resorcinol resin. Therefore, this improvement in the soil plasticity as a result of adding this polymer resin may be due to the reaction occurring between

resorcinol resin and the above-mentioned functional group of the clay particles. These interactions, consequently, enhance the cohesion between the clay particles present in these soils, in turn causes a rise in the internal friction between the silt and/or sand grain, resulting from the enveloping effect of this added polymer resin. The mechanism involves using resorcinol resin as soil stabilizer may be explained in the following manner: The binding resin form matrix with soil through the functional groups present in the clay minerals. Two main types of bonding may take place either as secondary bonding as in the case of hydrogen bonding between the hydroxyl groups of phenol and the no reacted methylol. While, the second type of expected chemical bodings are concerned with bonds formed due to elimination of water or dehydration <sup>(15)</sup>

### **Conclusions**

Tests results Using resorcinol resin as soil stabilizer was significantly enhanced some physical and engineering properties of these studied soils. These changes in soil properties are reflected in:

1. Considerable improvements in the plasticity of the studied soils are noticed in the increase of their plasticity limits, and, consequently reduction in their plasticity index as a result of adding (0.75-1% w/W) of resorcinol resin.
2. Raised the dry density of the investigated soils and an appreciable decline in their corresponding optimum

moisture contents as a result of adding 1.25%w/W of resorcinol resin.

3-Resorcinol resin has shown good binding and waterproofing abilities, which are reflected in the percents reduction of their rapid and capillary water absorption ability as a result of adding 1.25%w/W of this polymer.

rapid and capillary water absorption ability. In the case of cement- treated soils as related to the water absorption ability were ineffective.

4- The mean value reduction in the capillary water absorption ability was (1.574%) as compared to the mean value (2.202%) of the untreated soils as a result of adding (1.25%) by weight of this proposed polymer resin. Test for detemining the capillray water absorption ability for cement treated soils was failed.

Polymer resin treated Fao soils exhibited significant improvements in its most engineering characteristics. These are reflected in the rise of its plasticity, dry density, rapid and capillary water absorption ability. In the case of cement-treated soils as related to the water absorption ability were ineffective.

6- Despite that , Al-Ashar polymewr resin treated soil shows the best values in these improvement changes. Yet, Abu-Alkhasseeb and Grmat Ali Polymer resin treated soils behave in the same manneras withAl-Ashar soil.

7-Cement -treated clayey silt soils failed to achieve any significant improvements in the studied engineerig properties except in the case of the strength tests.

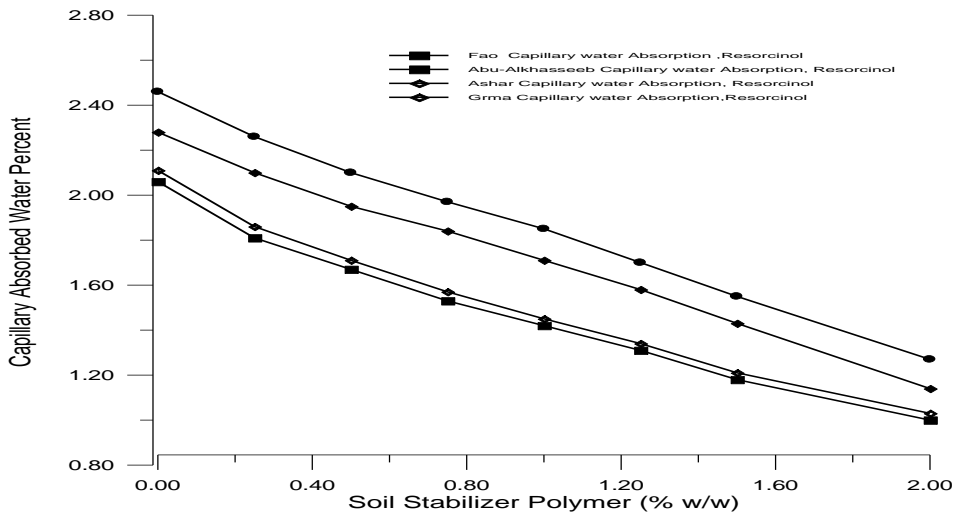
8- The cost of improving one cubic meter of clayey silt soil is reduced by 50% at the present prices(2004)provided that a polymer producing plant was established as compared to the ordinary reinforcement by cement or ordinary replacement by sand.

9- Futhere more, the advantages of using resorcinol resion as soil filler and binder over other traditional means stem from the fact that : It is quick, efficient, easily to handle, and also economically feasible where the costis reduced by certain percentages as compared to the traditional practices used in soil stabilization.They can be applied in all earthwork projects such as runways, parking yards, channel linings, erosion control ,road embankments, and other small engineering practices under the same enviromental conditions.

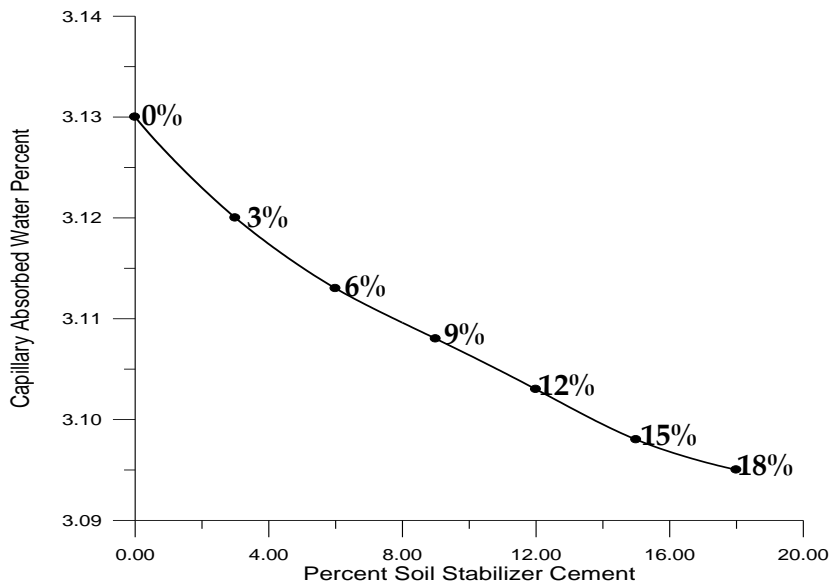
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**Fig. (11) Capillary Water Absorption Tests Results of Cured Untreated And Resorcinol Treated Clayey Silt Soil Cylinders**



**Fig. (12) Capillary Water Absorption Test of Cured Untreated and Cement –Treated Clayey Silt Soil Cylinders**

## الخلاصة

تم مزج عدة نماذج من ترب ضعيفة مختارة من مناطق مختلفة من محافظة البصرة وبنسبة 0.25، 0.50، 0.75، 1.25، 1.50، 2.00 % بالوزن من راتنج الريسورسينول المتميز بالتصلب الذاتي، ونفس هذه الترب المكونة من الـغرين الطيني مزجت أيضا بالنسبة 3، 6، 9، 12، 15، 18 % بالوزن من مادة الأسمنت الاعتيادية بهدف تحسين الخواص الهندسية لهذه الترب. والأهداف الرئيسية المتوخاة من هذه الدراسة تتمثل بالآتي::

أ) تحديد أفضل كمية مناسبة من هذه الراتنج البوليميري المقترح.

ب) تحسين بعض الخواص الهندسية لهذه الترب قيد الدراسة والمتضمنة تحسين لدونية التربة، زيادة كثافتها الجافة والوصول الى أفضل محتوى مائي، تقليل قابلية هذه الترب الغرينية الطينية لامتصاص الماء السريع والشعيري.

أظهرت النتائج المختبرية تحسن ملحوظ في كافة الخواص الهندسية التي تمت دراستها سواء في ما يخص اللدونة أو الكثافة الجافة أو انخفاض نسبة إمتصاص الماء السريع والشعيري لهذه الترب . حيث أعطى هذا الراتنج البوليميري نتائج جيدة بالنسبة للترب الغرينية الطينية. في حين فشلت تجارب تثبيت التربة الغرينية الطينية بمادة الإسمنت في تحقيق أي تحسن يذكر ما عدا في قيم إمتصاص الماء السريع . لذلك يمكن إعتداد راتنج الريسورسينول كعامل جيد لربط و تثبيت هذه الترب ، فضلا عن انخفاض كلفة استخدامه بمقدار 50 % مقارنة بمثبتات التربة التقليدية الأخرى التي تشمل إزالة الطين واستبداله بالرمال أو مواد أخرى إذا توفر معملا كيميائيا لهذا الغرض . وهي أيضا ملائمة لظروفنا المناخية الحارة. ولذلك يمكن اعتبار راتجات الريسورسينول كمواد مناسبة لربط الترب الضعيفة.