Kufa Journal of Engineering (K.J.E)
ISSN 2207-5528
Vol. 5, Issue 2, June, 2014
Printed in Iraq

IMPROVEMENT OF SELECTED PARTS OF BASRAH GOVERNORATE SOILS USING A MIXTURE OF CEMENT AND NOVOLAC POLYMER

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Received: 8 /3 / 2013 Accepted: 8 / 1 / 2014

Abstract

A weak clayey silt soils from Garmmat Ali and a sandy soil from AL-Nashoa region were used from different sites and depths and mixed with (0.2%,0.4%,0.6 w/W) of Novolac polymer with (2%,4%,6% w/W) of Cement to know the profitable amount of Novolac, and improving some of engineering properties of the soils that include: the plasticity and compacting. A noticeable improvement in the plasticity of these clayey soils as result of adding a mixture by the rise in their plastic limit, dry densities, lowering in their optimum moisture contents, and increase in tensile strengths as compared with crude soils. There are also an improve in treated sandy soil properties. The cost of using this polymer as a soil binder was reduced by about 50% as compared to the usual practice which involve removing the clayey silt soils and replace them by sand or other materials.

Keywords: Improvement Soil,Novolac Polymer, Cement, Engineering Properties, Plasticity

تحسين اجزاء مختارة من تربة محافظة البصرة باستخدام خليط الاسمنت وبوليمر النوفولاك

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الخلاصة

في هذه الدراسة استخدمت التربة الضعيفة الغرينية الطينية لمنطقة كرمة علي وتربة النشوة الرملية لغرض المقارنة والمأخوذة من مواقع و اعماق مختلفة. وتم مزجها مع خليط من بوليمر النوفولاك بنسبة (0.2%, 0.4%, 0.6%) w/W مع مادة الاسمنت بنسبة (2%, 4%, 6%) w/W لتحديد الكمية المناسبة من البوليمر وتحسين بعض الخواص الهندسية للتربة كاللدونة والانضغاط. ولوحظ ان معالجة التربة الطينية باستخدام الخليط ادى الى ارتفاع واضح في حد اللدونة و الكثافة الجافة وانخفاض في مقدار المحتوى الرطوبي وزيادة في مقاومة الشد مقارنة بالتربة الغير معالجة إضافة الى تحسن في خواص التربة الرملية المعالجة. إن الكلفة الاقتصادية الناتجة من المعالجة باستخدام الخليط كمادة رابطة للتربة ظهر بأنها تقلل حوالي 50% من الكلفة اللازمة للمعالجة من خلال إزالة التربة المكونة من الغرين الطيني واستبدالها بالرمل أو أي مادة أخرى

كلمات رئيسية: تحسين التربة, بوليمير النوفولاك , الاسمنت, الخواص الهندسية, اللدونة

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1. Introduction

Top surface layers of the soils in the Basrah Governorate have been subjected to a continuous change resulting from 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 fine-grained soils were shown in **Table 1** indicates, the presence a mixture of clay and non-clay minerals **Al- Marsoumi ,1997 and Hosain**, **2000 .**

Table 1 Chemical Analysis of Basrah < 2 mm Soil Samples from Selected Location (Hosain, 2000).

Oxides Content	Garmmat Ali
Sio_2	35.00
Al_2o_3	10.22
Fe_2o_3	4.38
Mgo	4.16
Cao	18.90
Na_2o	0.82
K_2o	0.73
SO_3	4.60
TIO_2	0.61
P_2O_5	0.16
Loss on Ignition	20.10
Sum	99.18

Mechanical grain size analysis of the top layer of soil in the Basrah region indicated a clayey silt type soil , where silt constitutes the higher percent (56%) followed by clay (34%) and approximately (6%) for 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. The X-ray diffraction analysis showed the presence of the following clay minerals, Illite, Palyogorskitc, kaolinite, chlorite, and Montmorrillonite, and other non- clay minerals such as Quartz, Calcite, Halite, Gypsum, and Feldspar. Therefore, these kind of soils usually become weak and soft, unless they experienced any solidification processes, resulting from physical, mechanical, or chemical means. Chemical soils stabilization methods were used in many cases of soil improvement or reinforcement by these methods require lengthy curing period and relatively large quantities of additives **Horvath *et al.*, 2000**. Polymeric materials are considered to be the dominant foam materials such as polystyrene. Despite their low density could reach up to or less than (1- 2 %) of the density of soil, yet there are sufficiently strong to support many types of loads encountered in Geotechnical practices **Horvath *et al.*, 2000 and Sanatoni *et al.*, 2003**. Stabilizing clayey silt with epoxy resin gave a good strength in both dry and wet conditions **Ajayi *et al* ., 1991**. Experiments also revealed that there is an optimum additive quantity for the maximum dry density and unconfined compressive strength. The optimum polymer quantity ranged between (2.5-6%) by weight. They also observed that the increase in temperature of the curing environment led to the increase of the strength and reduction in curing times to 3 hours only. Comparative studies using Urea-Formaldehyde (UF) and its copolymers to stabilize dune sand were performed **Singh and Das 1983**. Further studies were carried out using polyacrylamide (PAM) as a soil stabilizer for erosion control **Kenneth and Nwankwa, 2001**.

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The primary objectives of this research is to stabilize the Basrah clayey silt soil with (a) profitable amount of a mixture of Novolac and Cement, (b) improving some engineering properties of the studied soils that include: the Plasticity, Compacting dry density, and lowering optimum moisture content, and also reducing the ability of these soils to absorb water. The expected structure of Novolac as an average of 5 – 6 benzene rings per molecule as shown in Figure 1, given by **Al Ali and Abm , 1997**.

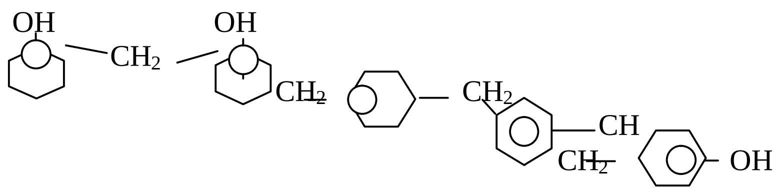

Fig. 1 Expected Structure of Novolac.

2.Materials and Methods

Sufficient quantities of clayey silt soil samples from (0.6-0.8) meters depth at three different sites from Garmmat Ali area were collected. Two types of stabilization additives were used. They include 1-Novolac 2-Portland Cement. This polymer powder prepared in the research chemistry laboratory, College of science, University of Basrah.

These analyses were done according to specific gravity test **ASTM D856, D850**, Atterberg's limits for treated and untreated soils according to **ASTM D422-63,** for grain size. Three chemical tests were conducted , they include organic matter test according to **B.S. 1377,** Walky and Black method. Walky and black method **Akroyd, 1964** using ISS, 1998 modified Sheen and Kahler method. The carbonates content was determined by calcimeter methods **Vantan, 1967**. All tests are done in soil mechanics laboratory civil engineering department, in the marine science center laboratory, and in the chemistry laboratory, college of science at the university of Basrah. Compaction proctor test was done according to **ASTM D1557.** and split tensile strength test according to **ASTM D3967.**

3.Results and Discussion

Tests results for effects of untreated and Novolac , Cement and their mixtures treated Garmmat Ali soil samples of the specified locations are discussed in this section , The first investigation includes preliminary tests such as grain size, hydrometer, specific gravity , and atterberg's limits are shown in **Tables 2, 3, 4, 5 and Figures 2, 3 and 4**. The soil variations in their Atterberg's limits especially attributed to the differences in quantities of their clay minerals, silt and the presence of different soluble salts such as calcite or gypsum. Considerable improvement in the plasticity of the studied soils are reflected in the increase of their plasticity limits , and consequently reduction in P.I. as a result of adding a mixture of (6.6 %w/W) of Novolac and Cement.

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Table 2 Grain Size Analysis Results for Untreated Soils for Garmmat Ali.

Site	Clay Particles %< 0.002mm	Silt Particles % (0.063-0.002mm)	Sand Particles % (0.063– 2mm)	Description
S1	38	60	2	Clayey silt soil
S2	45.0	51.0	4	Clayey silt soil
S3	52	42	6	Silty clay soil

Table 3 Atterberg's Limits for the Untreated Soils for Garmmat Ali.

Location (S1)		Location (S2)		Location (S3)	
N (%)	M.C (%)	N (%)	M.C (%)	N (%)	M.C (%)
21	39.6	16	44.6	17	41.3
16	41.24	28	41.1	28	39.38
44	38.1	36	39.00	39	36.5
P.L= 28%		P.L= 20.3%		P.L= 22.1%	

Table 4 Atterberg's Limits for the Treated Soil with a Mixture for Garmmat Ali.

Location	Liquid Limit	Plastic Limit	P.I
S1	39	28	11
S2	41.5	20.3	21.2
S3	39.2	22.2	17.1

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Table 5 Summarizes Some Characteristics of the Studied Untreated Clayey Silt Soils for Garmmat Ali.

Location	Specific	Organic	Carbonate	Sulpate
S1	2.702	0.170	20.71	0.12
S2	2.700	0.175	20.51	0.12
S3	2.71	0.177	20.42	0.12

4.Compaction Test Using Cement as Soil Stabilizer

Standard compaction tests results for clayey soil for Garmmat Ali after adding various amount of Cement only (6% w/W) to those investigated soils indicate some increase in their maximum dry densities and decline in their corresponding optimum moisture contents as shown in **Figures 5,6, and 7.**

5.Compaction Test Using Novolac as Soil Stabilizer

Standard compaction tests results for clayey soil for Garmmat Ali after adding various amount of Novolac polymer only (0.6% w/W) to those investigated soils indicate a noticeable increase in their maximum dry densities and appreciable decline in their corresponding optimum moisture contents (higher than when using Cement) as shown in **Figures 8, 9 and 10**.

6.Compaction Test Using Mixture of Novolac and Cement as Soil Stabilizer

Standard compaction tests results for clayey soil for Garmmat Ali after adding various amount of mixture of Novolac and Cement (6.6% w/W) to those investigated soils indicate noticeable increase in their maximum dry densities and appreciable decline in their corresponding optimum moisture contents (higher than when using Cement or Novolac only) as shown in **Figures 11,12 and 13.**

7.Split Tensile Strength Test for Clayey Soil for Garmmat Ali

Split tensile strength cylinder tests of an atmospheric dried cylinders of treated and untreated clay silt soils show a considerable increase in their split tensile strengths as a result of adding (6% w/W) Cement , (0.6% w/W) Novolac, and (6.6% w/W) mixture of Novolac and Cement. The amount of increase in split tensile strength is increasing gradually when using Cement , Novolac, and mixture of them as shown in **Figures 14,15 and 16**.

8.Compaction Test Using Cement,Novolac,and Mixture of Them as A Sandy Soil Stabilizer

For a comparison to study the effect of the adding on sandy soil samples from a different sites and depths of Al- Nashoa region were studied after adding the same percentages Cement, Novolac, Mixture of Novolac and Cement to the soils. These soils also investigated for their Grain size distributions as shown in **Figure 17**. After compaction, results indicate increase in their maximum dry densities and decline in their O.M.C. when using Cement only as shown in **Figures 18,19 and 20** for three site, and indicate appreciable increase in their maximum dry densities and decline in their O.M.C. when using. Novolac only (higher than when using Cement) as shown in **Figures 21,22 and 23** for three site, and finally compaction results indicate a good increase in their maximum dry densities and decline in their O.M.C. when using a mixture (higher than when using cement or Novolac only) as shown in **Figures 24 and 25** for two sites. Shear tests indicated a rise in their angle of friction from 35° to 37.5° to 37.8° when using (6% w/W) Cement only, then when using (0.6% w/W) , finally when using (6.6%w/W) of their mixture to 39.5°. This rise could be attributed to the enveloping effect of Cement and Novolac to the sand grains of these soil.

9.Novolac Clayey Silt Soils Interaction

Clayey minerals are described as hydrous aluminum silicates minerals with isomorphic substitution in their mineral structures. These isomorphic substitutions usually involve: (1) AL^{+3} replacing Si^{+4} in the silicaterahedral layer, and usually replacement of aluminum with Mg^{+2} or Fe^{+3} in the octahedral layer, (2) the disassociation of OH ion, and finally the broken bonds of the edegs of clay particles. In general, this causes the overall mineral structure unstable and having a negative charge. The clay mineral family with the most isomorphic substitution is the semectite_group, while the one with least is Kaolinite group, Both illite and chlorite have a moderate substitution . This negative charge imbalance needs to be balanced by the addition of water and cations or other most active groups of Novolac. Therefore, this improvement in the soil plasticity as a result of adding this polymer may due to the reaction occurring between Novolac and the above – mentioned functional group of the clay particles present in these soils, in turn causes a rise in the internal friction between silt and or sand grains as a filling material resulting from enveloping effect this added polymer. The mechanism involves using Novolac as soil stabilizer may be explained in the following manner. The binding Novolac form matrix with soil through the functional groups present in the clay minerals. Two main types of bonding may take place either secondary bonding as in the case of hydrogen bonding between the hydroxyl group of the polymer, while the second type of chemical bonding are concerned with bonds formed due to elimination of water.

10.Conclusions

Test results using a Novolac and Cement mixtures as a soil binder was significantly enhanced some physical and engineering properties of these investigated soils. These changes in soil properties are reflected in:

1-Considerable improvements in the plasticity of studied soils are noticed in the increase in their plasticity limits, and consequently reduction in their Plasticity Index as a result of adding (2.2-6.6% w/W) of a mixture of Novolac and Cement.

2-Increased the value of the dry density of the studied soils and a appreciable decline in their optimum moisture content as a result of adding (2.2 - 6.6% w/W) of a mixture of the polymer and cement.

3- This mixture of Novolac and Cement show a good binding and water proofing ability which are reflected in reducing their rapid absorption ability.

4- A reasonable rise in their split tensile strength after adding (2.2-6.6%w/W) of a mixture from Novolac and Cement.

5- The cost of improving one cubic meter of clayey silt soil is reduced by about 50% at the present price as compared to the ordinary reinforcement by sand.
6- A noticeable rise in the maximum dry density of the studied sandy soils as well as appreciable decline in their O.M.C. was noticed.

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Kufa Journal of Engineering (K.J.E)
ISSN 2207-5528
Vol. 5, Issue 2, June, 2014
Printed in Iraq

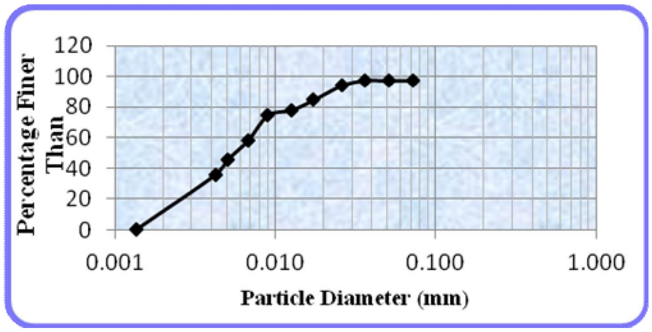

Fig. 2 Grain Size Analysis Results for Clayey Silt Soil for Garmmat Ali (S_1)

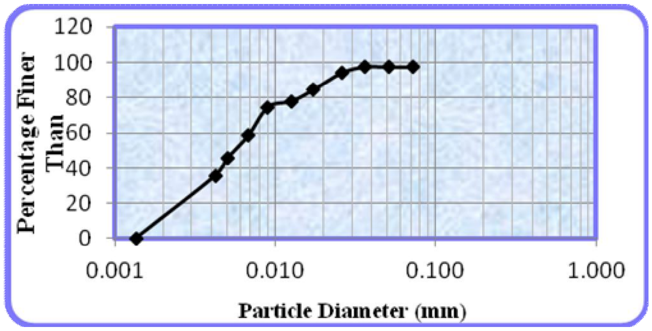

Fig. 3 Grain Size Analysis Results for Clayey Silt Soil for Garmmat Ali (S_2)

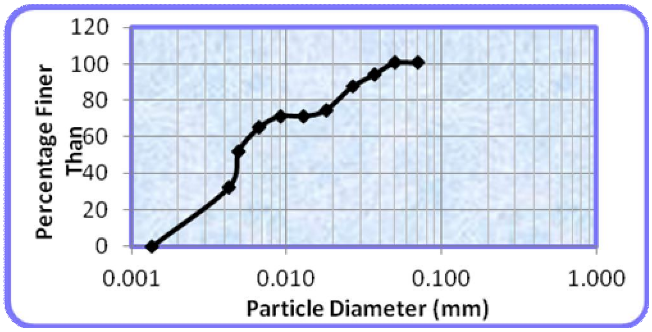

Fig. 4 Grain Size Analysis Results for Clayey Silt Soil for Garmmat Ali (S_3)

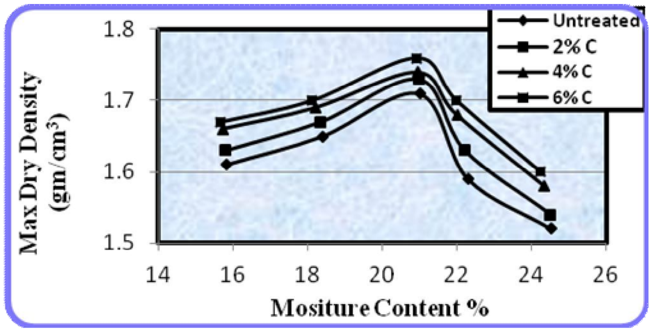

Fig. 5 Compaction Results before and after Added Cement for Clayey Soil for Garmmat Ali(S_1)

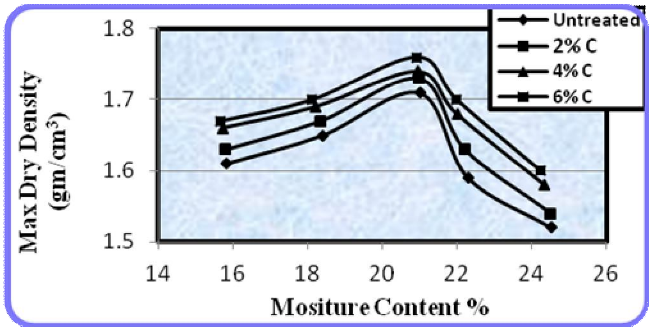

Fig. 6 Compaction Results before and after Added Cement for Cayey Soil for Garmmat Ali(S_2)

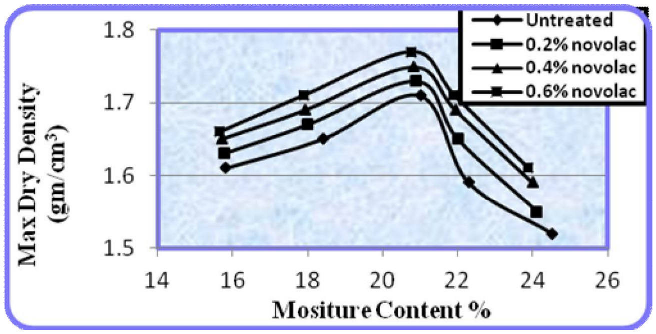

Fig. 7 Compaction Results before and after Added Cement for clayey Soil for Garmmat Ali (S_3)

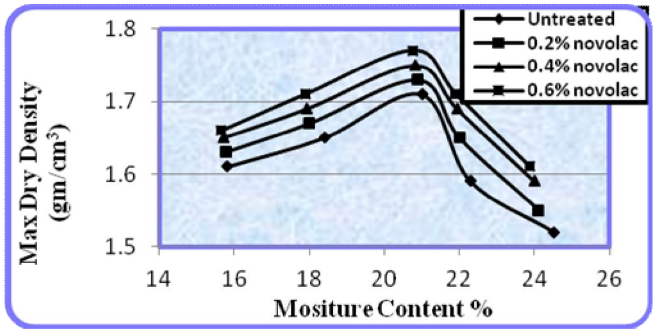

Fig. 8 Compaction Results before and after Added Novolac for Clayey Soil for Garmmat Ali (S_1)

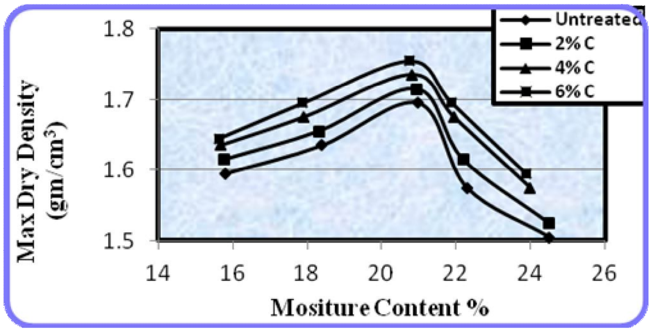

Fig. 9 Compaction Results before and after Added Novolac for Clayey Soil for Garmmat Ali (S2)

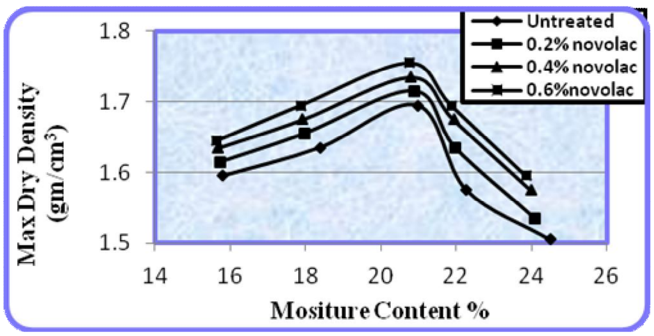

Fig. 10 Compaction Results before and after Added Novolac for clayey soil for Garmmat Ali (S_3)

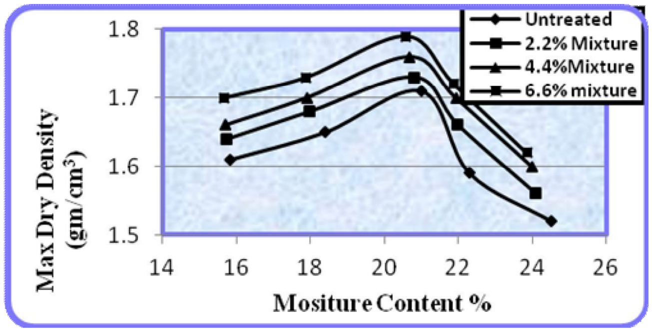

Fig. 11 Compaction results before and after added Mixture for clayey soil for Garmmat Ali (S_1)

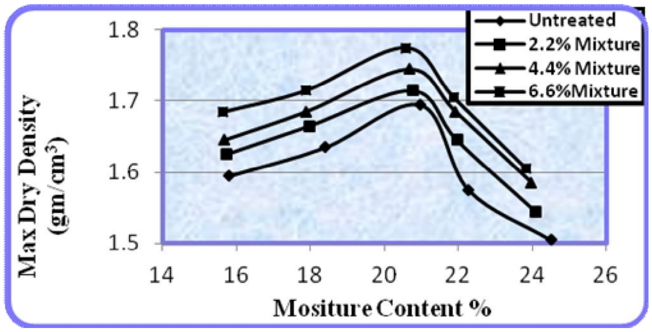

Fig.12 Compaction Results before and after Added Mixture for Clayey Soil for Garmmat Ali (S_2)

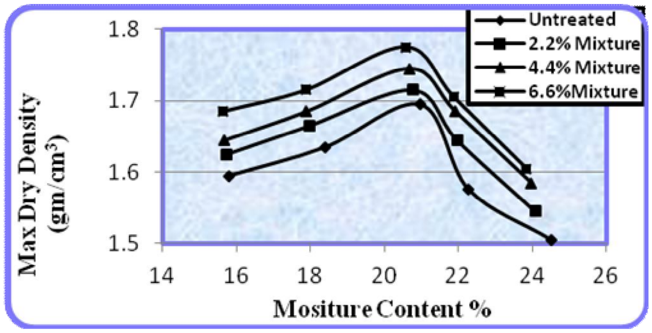

Fig.13 Compaction Results before and after Added Mixture for Clayey Soil for Garmmat Ali (S_3)

Kufa Journal of Engineering (K.J.E)
ISSN 2207-5528
Vol. 5, Issue 2, June, 2014
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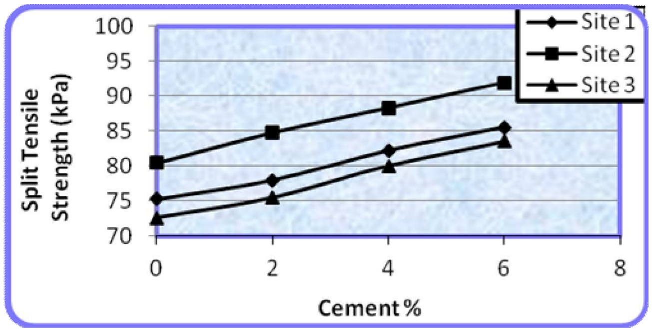

Fig.14 Split Tensile Strength Results after Added Cement for Clayey Soil for Garmmat Ali for (S_1,S_2,S_3)

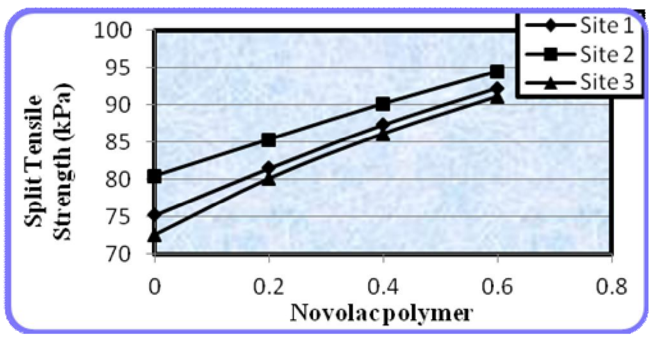

Fig. 15 Split Tensile Strength Results after Added Novolac for Clayey Soil for Garmmat Ali for (S_1,S_2,S_3)

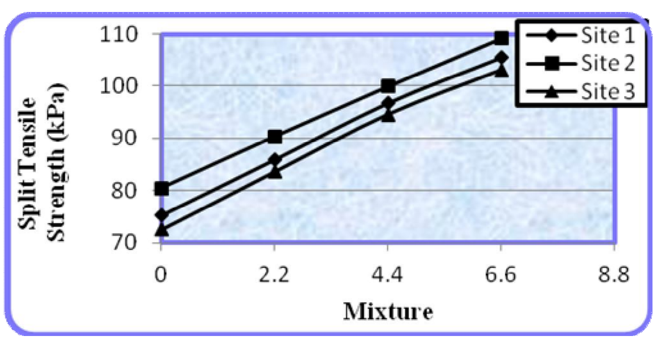

Fig. 16 Split Tensile Strength Results after Added Mixture for Clayey Soil for Garmmat Ali (S_1,S_2,S_3)

Kufa Journal of Engineering (K.J.E)
ISSN 2207-5528
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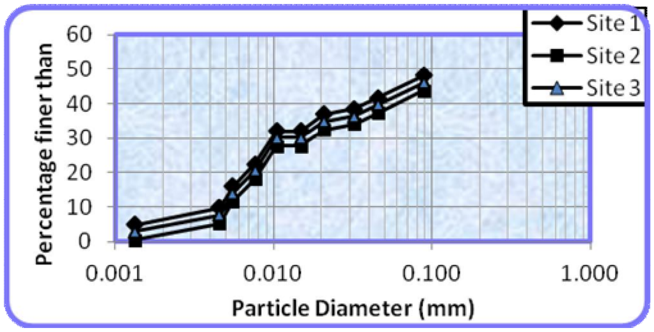

Fig. 17 Grain Size Analysis for Sandy Soil for AL- Nashoa area (S_1,S_2,S_3)

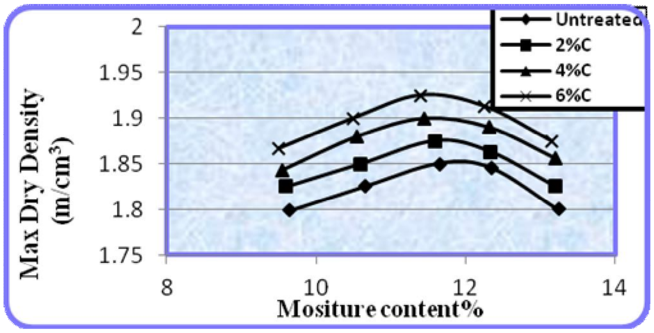

Fig. 18 Compaction Results before and after Added cement for Sandy Soil for AL- Nashoa (S_1)

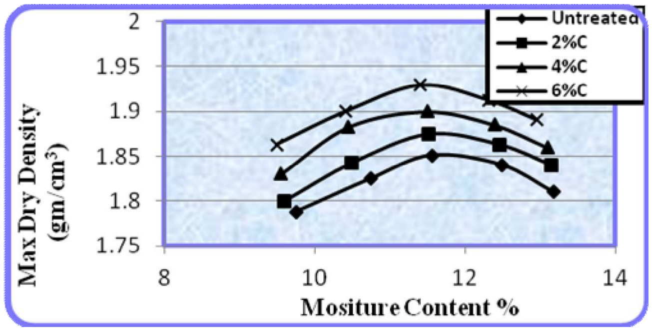

Fig.19 Compaction results before and after Added Cement for Sandy Soil for AL- Nashoa (S_2)

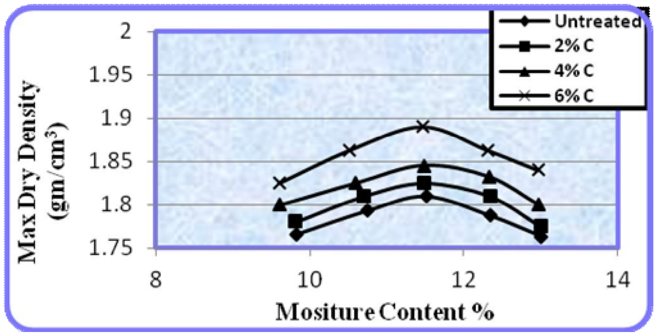

Fig. 20 Compaction results before and after added cement for Sandy soil for AL-Nashoa (S_3)

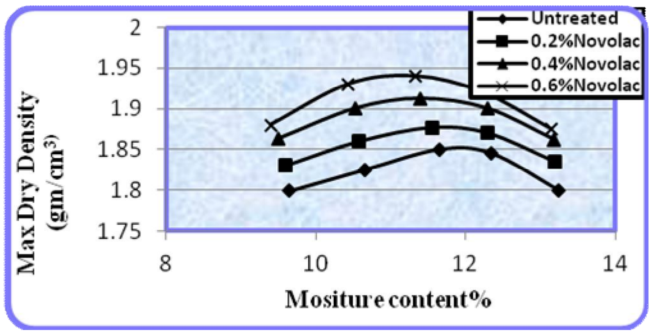

Fig. 21 Compaction Results before and after Added Novolac for Sandy Soil for AL-Nashoa (S_1)

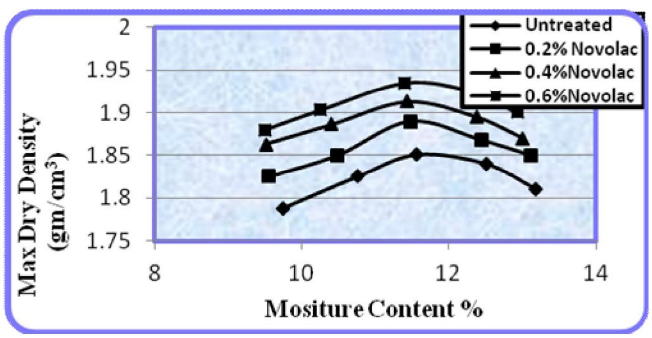

Fig. 22 Compaction results before and after added Novolac for Sandy soil for AL-Nashoa (S_2)

Kufa Journal of Engineering (K.J.E)
ISSN 2207-5528
Vol. 5, Issue 2, June, 2014
Printed in Iraq

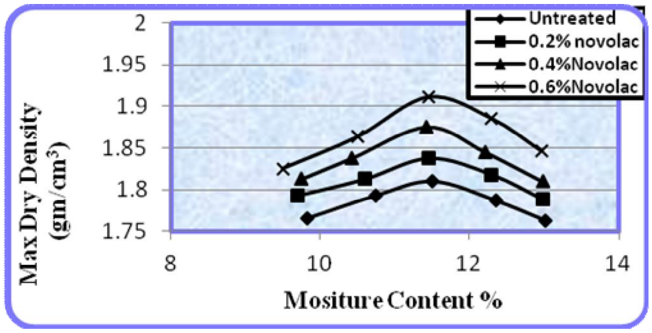

Fig. 23 Compaction Results before and after Added Novolac for Sandy Soil for AL-Nashoa (S_3)

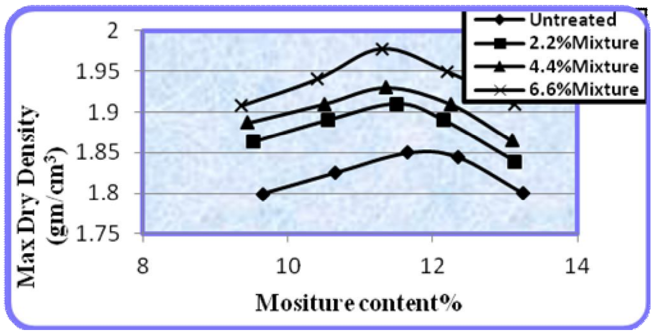

Fig. 24 Compaction Results before and after Added Mixture for Sandy Soil for AL-Nashoa (S_1)

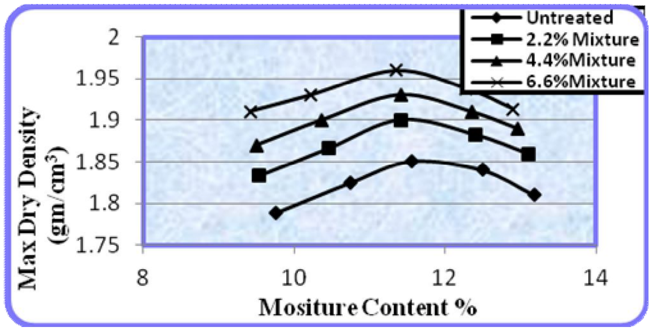

Fig. 25 Compaction Results before and after Added Mixture for Sandy Soil for AL-Nashoa (S2).