International Journal of GEOMATE, Nov., 2018 Vol.15, Issue 51, pp.233-239
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.51.19491
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

EFFECT OF ADDING POLYACRYLAMIDE POLYMER WITH LIME AND CEMENT KILN DUST ON THE PROPERTIES OF EXPANSIVE CLAYEY SOILS

* Qassun S. Mohammed Shafiqu

Civil Engineering Department, Al-Nahrain University, Baghdad, Iraq

*Corresponding Author, Received: 8 April 2018, Revised: 7 June 2018, Accepted: 20 June 2018

ABSTRACT: Using additives like chemical materials have been determined to be an important procedure for improving some properties of expansive soils. The present work had attempted to study the influence of adding various percentages of Polyacrylamide (PAM) polymer on the clayey expansive soil properties mixed with lime (L) and finely divided particulate Cement Kiln Dust (CKD), which is collected during the production of Portland cement. The properties are investigated under the influence of adding many percentages of Polyacrylamide polymer (i.e., 1%, 3% and 5%) with lime and cement kiln dust mixture of (3% lime and 8% cement kiln dust). The Atterberg limits, compaction, swelling potential, unconfined compression strength (UCS) and California Bearing Ratio (CBR) tests are carried out on the prepared samples. The results showed that addition of Polyacrylamide (PAM) polymer with (LCKD) has improved expansive clay soil properties more than adding (LCKD) alone. The optimum percentage for (LCKD-PAM) that achieves the lower free swell value and the maximum UCS and CBR values is at (3% L+8% CKD +5% PAM) which shows reducing in free swell by about 94.5%, increasing in UCS worth by about 262% and 400% for curing period of 7 and 28 days respectively and improving CBR value to 27 from 5.45.

Keywords: Expansive soil; Polyacrylamide polymer; Lime; Cement Kiln Dust; Swell; Strength

1. INTRODUCTION

A significant by-product material due to the process of cement manufacturing is cement dust, which causes an environmental threat. To solve such problem, researches are being carried out in various world countries to determine efficient ways for benefit from cement dust in many applications including soil stabilization [1]. Construction of geotechnical structures with light loads such as railways, roadways, pavements, and foundations or reservoir linings in expansive soil regions creates a number of problems for civil engineers because of its low value of California Bearing Ratio and alternate swell-shrink behavior when the soil contact with water. This will cause not only the large cost of construction but also demands the frequent repairing because cracks of different shapes and various depth are noticed on these soils [2].

McCoy and Kriner [3] studied the stabilization of soil using several CKDs and clay-type soils. The study predicted that for subbase applications using CKD was potentially promising in stabilizing soils. Also, it was indicated that the compressive strengths for mixtures of CKD with high free lime and moderate alkalies are comparable to those produced with cement and lime [4]. CKDs having low free lime and alkalies gave lower strengths. Generally, CKDs with moderate alkalies and free lime of high percentage shows enhanced stabilization with respect to improved compressive strengths and reduced plasticity.

Many researchers explain the enhancements in the hydraulic and mechanical properties of expansive clay by addition of lime, majorly from a macroscopic point of view. A lot of these studies focuses on investigating the changes associated with the consistency limits values and the soil properties, such as the volume change (i.e., swell pressure, free swell, expansion), shear strength and the coefficient of permeability of the stabilized expansive soils [5].

Recently Hasan [6] investigated the influence of adding Polyacrylamide (PAM) polymer on the expansive soil engineering properties recommending an optimum percentage of adding as 5%. More recently, Abass [7] examined the effect of adding Polymethacrylate (PMA) polymer with lime and cement kiln dust to an expansive clayey soil. Swelling potential lowered from 19% to 3% by adding (3%L + 8% CKD + 7% PMA). The highest values of UCS and CBR are obtained by adding (3% L + 8% CKD + 5% PMA).

In this study, expansive clayey soil prepared [7] is improved using lime with cement kiln dust and Polyacrylamide (PAM) polymer. Experimental work is carried out for examining the influence of adding percentages of PAM polymer (i.e., 1%, 3% and 5%) with a mixture of lime and cement kiln dust (i.e., 3% L + 8% CKD) on the Atterberg limits, compaction characteristics, free swell, unconfined compressive strength with and without curing, and California Bearing Ratio values. Moreover, the comparison is carried out between the results of improvement using Polyacrylamide (PAM) polymer from this study with that using Polymethacrylate (PMA) polymer [7].

2. MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Natural and Prepared Expansive Soils

The soil samples were silty clay soil brought from Al-Karada city located east of Baghdad the capital of Iraq from (2.0-2.5m) depth under the ground surface. Preparation of the swelling clayey soil was made in the laboratory [7] by mixing (60%) of above natural soil with (40%) of bentonite. In this study and to achieve the requirements for improving the expansive clay properties, lime and cement kiln dust together with Polyacrylamide (PAM) polymer are added to the prepared expansive soil at different percentages in order to study their effects.

2.2 Polyacrylamide (PAM) Polymer

A large molecular weight polymer (i.e., Polyacrylamide, PAM) is a long chain, soluble with water polymer (Fig. 1). Characteristics like the chain length, degree of cross-linkage and both type and density of associated charges are changed to produce polymers with varying performance characteristics [8]. PAM is effective in improving the stability of clay aggregates and as it is a long-chain synthetic polymer which works as a strengthening agent, binding clay particle together and creates heavy aggregates that rapidly settle out of solution and holding soils in place [9 and 10].

It can be said that PAM may irreversibly adsorbed on clay minerals. And hydrogen bonding, water bridging, and ion-dipole interaction have been suggested for the adsorption of the nonionic polymer [10].

Fig. 1 Polyacrylamide polymer (PAM) used in the present research

2.3 Lime (L) and Cement Kiln Dust (CKD)

The used lime in the present study is made in Iran. And the cement kiln dust for this research was taken from Al-Kufa factory. As an effective option cement dust was used for treatment and improvement soil properties, considering its easy mix and use with soil because of its fine particle size.

2.4 Preparation of Test Samples

Before pulverized in the Los Angeles device, the soil is dried in an oven at 105 ◦C for 24 hours and used in the mixtures. The lime and cement kiln dust materials were then blended with prepared clay by the mixer until a homogenous color of the mixture is obtained, followed by putting the samples into nylon bags. In tap water at 20-65ºC, dissolving 5g\L of Polyacrylamide (PAM) polymer in emulsion state is first carried out as it is a water-soluble polymer. Knowing that the admixture of clay and liquids which are water-soluble and do not produce excessively viscous solutions are easier access to clay particle surfaces than granular admixture. Thus, PAM is melted in the appropriate amount of water until getting a homogeneous solution by a magnetic stirrer and then the blended soil left to air to dry out (Fig. 2).

Fig. 2 Dissolving the PAM polymer.

3. EXPERIMENTAL WORK

A program for performing an experimental study on enhancement of the properties of the expansive clay was carried out. Physical and chemical tests were conducted on expansive and improved soil samples at soil mechanics laboratory of the civil engineering department at Al-Nahrain University. The physical tests involve Atterberg limit, compaction, swell, unconfined compression and California Bearing Ratio (CBR) tests according to [11,12, 13, 14 and 15 respectively]. The chemical tests involved the chemical composition of PAM polymer, lime and cement kiln dust. Table 1 gives the properties results for prepared expansive clay, and chemical composition for PAM polymer, lime and cement kiln dust are shown in Tables 2 and 3.

Table 1 Summary of physical and classification properties for expansive clayey soil prepared

Material	Sand (%)	Silt (%)	Clay (%)	Liquid limit	Plastic limit	Plasticity index	Optimum moisture content (%)	Max. dry density (kN/m^3)	Specific gravity Gs
expansive clayey soil	0	20	80	95	27	68	28	1.47	2.65

Table 2 Chemical composition for PAM polymer

Rb	Sb	Ca	Si	Al	O	C	Mg	Fe
14.34	8.10	15.83	21.86	14.04	8.97	11.48	4.46	0.91

Table 3 Chemical composition of lime and cement kiln dust

Material	CaO	SiO_2	SO_3	Al_2O_3	MgO	K_2O	Na_2O	FeO
lime	71.36	2.56	1.67	3.00	4.15	-	-	-
cement kiln dust	44.61	17.48	8.12	5.22	4.29	4.23	1.73	1.02

4. RESULTS AND DISCUSSIONS

This section is devoted to presenting and discussing the experimental results obtained from physical tests, swelling potential, unconfined compression strength and California Bearing Ratio (CBR) tests conducted on expansive soil mixed with a mixture of lime, cement kiln dust and PAM polymer (LCKD-PAM).

4.1 Effect of Adding LCKD-PAM on Consistency Limits

The influence of adding several percentages of PAM polymer (i.e., 1%, 3% and 5%) with a mixture of lime and cement kiln dust (i.e., 3% L + 8% CKD) on the liquid and plastic limits and thus on the plasticity index value for the prepared expansive clay is investigated as shown in Table 4 and Fig. 3. The results indicate that the liquid limit (LL) and plasticity index (PI) values decreased with increasing PAM content, while plastic limit (PL) increases with the higher amount of PAM. The higher reducing in liquid limit and plasticity index and maximum increase in plastic limit is found with addition of (3% L + 8% CKD + 5% PAM), Addition of (3% L + 8% CKD) decreased (LL) and (PI) by about 13.7% and 22% respectively, and increased (PL) by about 7.5%. While the addition of (3% L + 8% CKD + 5% PAM) leads to decreasing in (LL) and (PI) by about 28.4% and 69% respectively and increasing (PL) by about 74%. Soil particles may bond together by the addition of LCKD and PAM polymer thus lowering the ability of the soil to adsorb excess pore water and thus decreasing the plasticity of clay.

Table 4 Influence of adding LCKD-PAM on L.L, P.L and P.I of expansive clayey soil

Properties	L.L. %	P.L. %	P.I. %
LCKD	82	29	53
LCKD+ 1% PAM	73	37	36
LCKD+ 3% PAM	70	43	27
LCKD+ 5% PAM	68	47	21

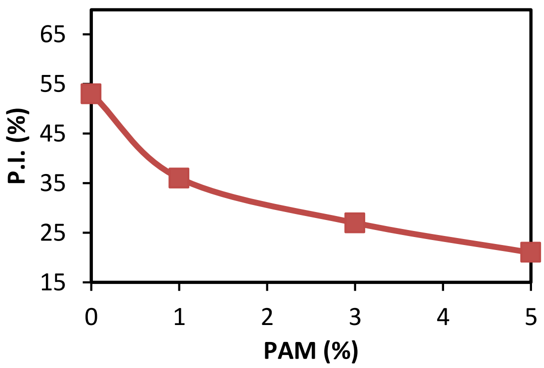

Fig. 3 Effect of adding LCKD and LCKD-PAM on Plasticity Index of expansive clayey soil

4.2 Effect of Adding LCKD-PAM on Compaction Parameters

The results showed that the addition of LCKD-PAM influenced the values of optimum moisture content and maximum dry unit weight. Optimum water content decrease and the values of maximum dry unit weight being higher with PAM addition as shown in Figs. 4 and 5 respectively.

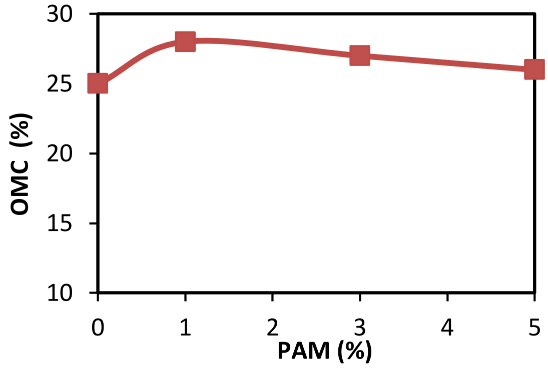

Fig. 4 Effect of adding LCKD-PAM on optimum water contents of expansive clayey soil

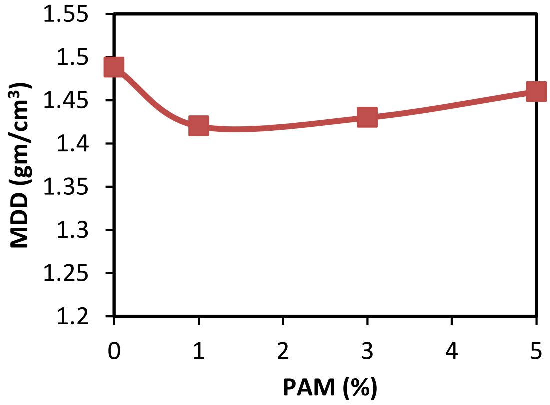

Fig. 5 Effect of adding LCKD-PAM on the maximum dry unit weight of expansive clayey soil

4.3 Effect of Adding LCKD-PAM on Free Swell Percentage

Adding the different percentage of PAM polymer with LCKD ratio cause reduction in the free swell% value as shown in Fig. 6. It has been pointed out that the higher decreasing in free swell is obtained with the percentages (3% L + 8% CKD + 5% PAM). The free swell decreased by about 52.6% by addition of (3% L + 8% CKD) while it reduced by about 94.5% for (3% L + 8% CKD + 5% PAM) soil mixtures. Thus, the addition of PAM polymer has a higher effect on reduction the free swell of expansive clay with all percentages of adding. The decrease may be attributed to the reduced tendency for water adsorption of the samples due to the addition of PAM thus decreases compressibility during the period consumed for the completed of the swelling and that can resist expansion.

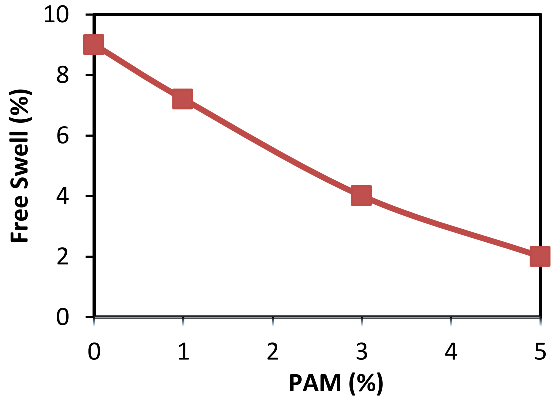

Fig. 6 Effect of adding LCKD-PAM on the free swell of expansive clayey soil

4.4 Effect of Adding LCKD-PAM on Unconfined Compressive Strength (UCS)

Fig. 7 shows the effects of blending different percentages of PAM polymer with (3% L + 8% CKD) on the unconfined compressive strength (UCS) values for expansive clay taking into consideration the influence of the period of curing on the values as well. The maximum UCS is obtained when 5% PAM polymer is added to the soil mixture with LCKD that its value increased up to 488.36kPa from 160.98kPa without curing and to 582.53kPa and 804.284kPa for both curing duration of 7 and 28 days respectively. While the figure show raising in the value of UCS up to 279.89 kPa, 302.6 kPa, and 628.76 kPa by only adding LCKD for the cases of without, 7 days and 28days curing period respectively. Thus the induced PAM polymer led to a significant enhancement in the unconfined compressive strength value.

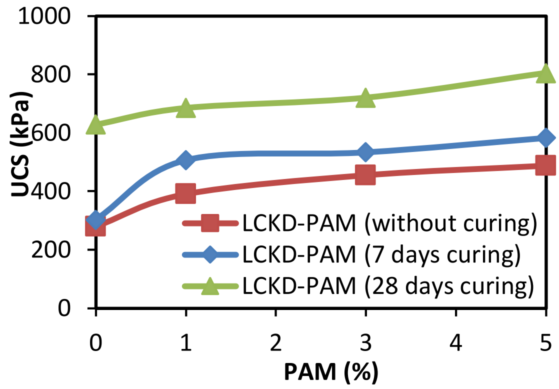

Fig. 7 Effect of adding LCKD-PAM on the unconfined compressive strength of expansive clayey soil

4.5 Effect of Adding LCKD-PAM on California Bearing Ratio (CBR)

The influence of adding LCKD and PAM polymer to the value of California Bearing Ratio (CBR) for expansive clay soil is presented in Fig. 8. It can be concluded that the CBR value improved with increasing PAM addition and the higher value of CBR is obtained when adding (3% L + 8% CKD + 5% PAM). Adding LCKD alone led to increases in CBR value from 5.45% to 18% while adding (LCKD) with 5% PAM enhanced the value of CBR from 5.45% to 27% with a percentage improvement of about 395%.

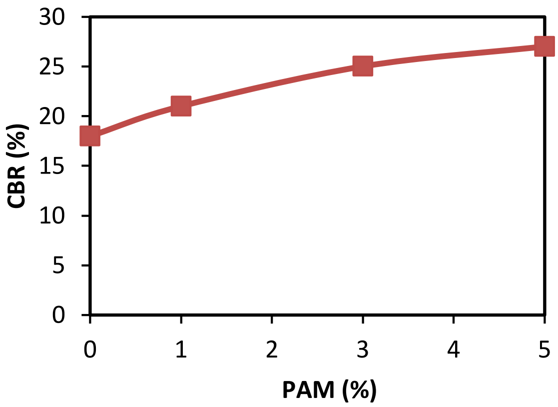

Fig. 8 Effect of adding LCKD-PAM on CBR of expansive clayey soil

5. COMPARISON BETWEEN THE RESULTS OF ADDING LCKD-PAM POLYMER AND LCKD-PMA POLYMER

The comparison between the PI, free swell, UCS and CBR values obtained from this study by adding LCKD-PAM polymer with that from adding LCKD-PMA polymer [7] is presented in this section and as shown in Figs. 9,10, 11 and 12 respectively. Comparison proved that the reduction in PI and swelling with the increase in CBR value of the expansive clay soil is more pronounced using PAM polymer. Adding 5% of PAM and PMA polymers decreased the PI value by about 69% and 37% respectively and the free swell value by about 94.5% and 79% respectively and increased CBR value from 5.45% to 27% and 25% respectively. While it has been specified that adding 5% PMA gives significant increasing in UCS value with curing duration of 7 and 28 days up to 716.30 kPa and 1453.93 kPa respectively comparing with adding 5% PAM that gives increasing in the value of UCS up to 582.53kPa and 804.284kPa for curing period of 7 and 28 days respectively.

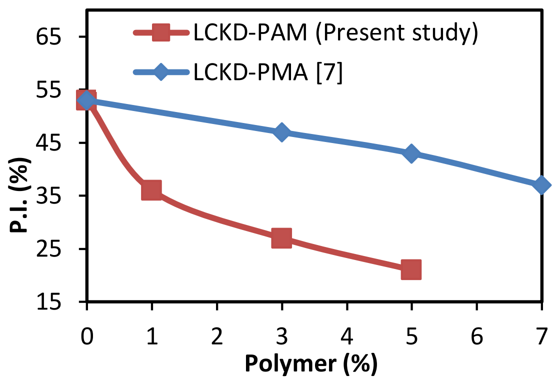

Fig. 9 Effect of adding LCKD-PAM and LCKD-PMA on PI of expansive clayey soil

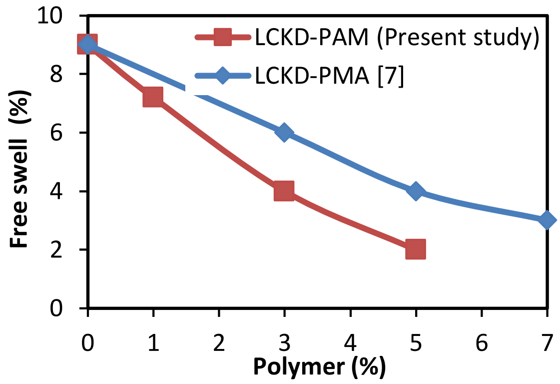

Fig. 10 Effect of adding LCKD-PAM and LCKD-PMA on the free swell of expansive clayey soil

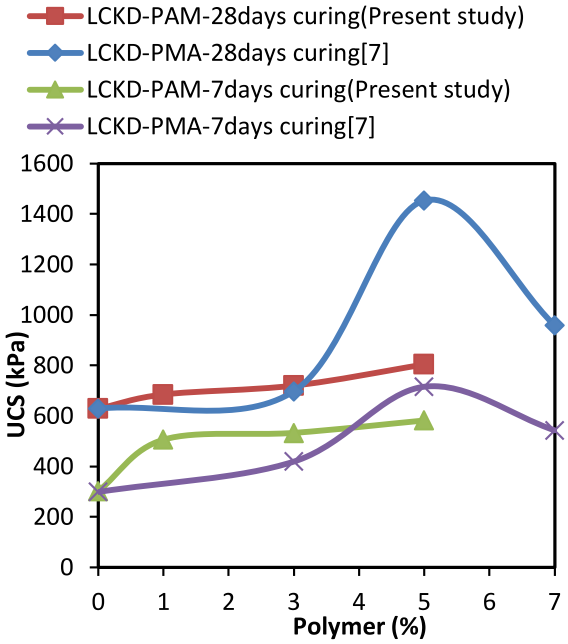

Fig. 11 Effect of adding LCKD-PAM and LCKD-PMA on UCS of expansive clayey soil

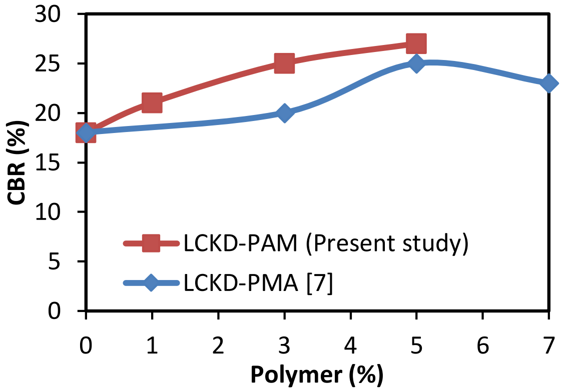

Fig. 12 Effect of adding LCKD-PAM and LCKD-PMA on CBR of expansive clayey soil

6. CONCLUSIONS

The conclusions that may draw from the present study can be summarized as follows:

i. The addition of Polyacrylamide (PAM) polymer with (LCKD) to expansive clay soil has enhanced the swell and strength characteristics better than adding just the (LCKD).

ii. Addition of LCKD-PAM reduces liquid limit (LL) and plasticity index (PI) increase (PL). The higher reducing in liquid limit and plasticity index and maximum increase in plastic limit is found with addition of (3% L + 8% CKD + 5% PAM), Addition of (3% L + 8% CKD) decreased (LL) and (PI) by about 13.7% and 22% respectively, and increased (PL) by about 7.5%. While the addition of (3% L + 8% CKD +5% PAM) leads to decreasing in (LL) and (PI) by about 28.4% and 69% respectively and increasing (PL) by about 74%.

iii. Addition of LCKD-PAM influenced the values of optimum moisture content and maximum dry unit weight.

iv. Addition of LCKD-PAM has a greater effect on reducing the free swell with all percentages of adding. The free swell decreased from 19 to 2 with percentage decreasing of about 94.5% for (3% L + 8% CKD + 5% PAM) soil mixtures.

v. The period of curing has a greater influence on the improving the UCS value. Addition of LCKD-PAM increase UCS and for all addition percentages. The UCS increased with the addition of (3% L + 8% CKD +5% PAM) up to 488.36kPa from 160.98kPa without curing and to 582.53kPa and 804.28kPa for both curing periods (i.e., 7 days and 28 days respectively).

vi. Addition of LCKD-PAM has also the greater effect on the CBR value with all percentages of PAM adding. The CBR increased from the value of 5.45% to 27% with a percentage improving of about 395% for (3% L + 8% CKD + 5% PAM) soil mixtures.

vii. The decrease in PI and swelling with the improving in CBR value of the expansive clay is more pronounced by adding PAM polymer more than adding PMA polymer with LCKD. That adding 5% of PAM and PMA polymers reduced the PI value by about 69% and 37% respectively and the free swell value by about 94.5% and 79% respectively and increased CBR value to 27% and 25% respectively. Also adding 5% of PAM and PMA polymers increased UCS value up to 582.53 kPa and 716.30 kPa respectively for curing time of 7 days and up to 804.28 kPa and 1453.93 kPa respectively for curing period of 28 days.

7. REFERENCES

[1] Al-Hassani A. M. J., Kadhim S. M., and Fattah, A. A., Characteristics of Cohesive Soils Stabilized by Cement Kiln Dust, International Journal of Scientific & Engineering Research, 6(4), April. 2015.

[2] Sabat, A. K., and Bose, B., Improvement in Geotechnical Properties of an Expansive Soil using Fly Ash - Quarry Dust Mixes, EJGE, 18, Bund. Q, 2013, pp. 3487-3500. http://www.ejge.com/2013/Abs2013.321.htm

[3] McCoy, W. J., and Kriner. R.W., Use of Waste Kiln Dust for Soil Consolidation, Lehigh Portland Cement Co., Allentown, Pennsylvania, U.S.A, 1971.

[4] Bhatty, J.I., Bhattacharja, S. and Todres, H.A., Use of Cement Kiln Dust in Stabilizing Clay Soils, Portland Cement Association, PCA Serial No. 2035, Skokie, Illinois, USA, 1996, p. 28.

[5] Al-Mukhtar, M., Khattab, S. and Alcover, J. F., Microstructure and Geotechnical Properties of Lime-Treated Expansive Clayey Soil, Engineering Geology, 2012, pp. 43-49.

[6] Hasan, S., Improvement an Expansive Soil using Polymer Materials, MS.c. Thesis, Al-Nahrain University: Civil Engineering Department, 2017.

[7] Abass, R., Engineering Properties of An Expansive Soil Stabilized With Cement Kiln Dust And Lime, MS.c. Thesis, Al-Nahrain University: Civil Engineering Department, 2018.

[8] Shainberg, I., Warrington, D.N. and Rengasamy, P., Water quality and PAM interactions in reducing surface sealing, Soil Sci., 149, 1990, pp.301–307.

[9] Letey, J., Adsorption and desorption of polymers on soil, Soil Sci., 158, 1994, pp. 244-248.

[10] Deng, Y., Dixon, J.B. and White, G.N., Adsorption of polyacrylamide on smectite, illite,

and kaolinite. Soil Science Society of America Journal, 70, 2006, pp. 297-304.
[11] ASTM D4318. 00., Standard Test Method for the liquid limit, plastic limit, and plasticity index of soil, Annual Book of ASTM Standards Vol, 04.08.
[12] ASTM D698-00., Standard Test Methods for Laboratory Compaction Characteristics Using Standard Effort (600 kN-m/m3).
[13] ASTM D 4546-90., Standard test method for one dimensional swell or settlement potential of cohesive soils.
[14] ASTM D2166-00., Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.
[15] ASTM D1883-87., Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils.