Saudi Journal of Engineering and Technology (SJEAT)
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6272 (Print)
ISSN 2415-6264 (Online)

Effect of Additive Type and Percent on Soil Plasticity

Elaf Jassim Mahan[1*], Anas Kareem Hussein[2]
[1,2]Al-Mustaqbal University College, Civil Engineering Department, Babil, Hilla, Iraq

Original Research Article

***Corresponding author**
Elaf Jassim Mahan

Article History
Received: 02.12.2017
Accepted: 11.12.2017
Published: 30.12.2017

DOI:
10.21276/sjeat.2017.2.12.2

Abstract: In the current study, the effects of three types of additive (lime, cement and cement kiln dust) on the plasticity of a soil are studied. The results of the study indicate plasticity index are affected by the addition of (cement, lime and cement kiln dust) and the effectiveness of these additives depends on the soil treated and the amount and type of additive used. The main results show that with increase of Additive the plastic limit increases and liquid limit decreases, hence decreases plasticity index and it is revealed that a change of soil texture takes place. While Addicrete BV does not effect on the Atterberg limits or the soil texture of the soil. Then the plasticity properties of the soils including liquid, plasticity and shrinkage limits as well as plasticity index were investigated and compared among the specimens in different mixture proportions. Atterberg limits (Plastic limit "PL", Liquid limit "LL", and Plasticity index "PI" = LL-PL) play an important role in soil identification and classification.

Keywords: Soil, lime, cement, cement kiln dust, liquid limit, plastic limit.

INTRODUCTION

Plasticity

Atterberg limits (Plastic limit "PL", Liquid limit "LL", and Plasticity index "PI" = LL-PL) play an important role in soil identification and classification. These parameters indicate to some of the geotechnical problems such as swell potential and workability.

One of the important and principle aims of this study was to evaluate the changes of liquid, plastic limits, and plasticity index with addition of lime, cement, and cement kiln dust. To achieve this objective, Atterberg limits test (including PL, LL, and PI) was conducted on both natural soils and different lime, cement, and cement kiln dust-soil mixtures, for the three studied additives according to consistency test of DIN 18 122-1.

The improvement of engineering properties of soil by adding chemicals such as cement, lime and cement kiln dust , often alters the physical and chemical properties of the treated soil. There are the two primary mechanisms by which chemicals alter:

- Increase in particle size due to cementation, change in the plasticity properties, and reduced deformation potential.
- Absorption and chemical binding of moisture that will facilitate compaction.

It is more than several years that the focus of the researches has been on the stabilization of soils using various additives such as lime, cement, fly ash, industrial waste products, potassium nitrate, calcium chloride and phosphoric acid [1-3].The beneficial effects of cement treatment on the performance of a broad range of soils have been widely presented by previous researches [5-8].

LITERATURE REVIEW

Cement Kiln Dust (CKD)

Cement kiln dust (CKD) is a finely divided particulate material similar in appearance to Portland cement. During the manufacture of Portland cement, a large amount of dust is collected from kiln exhaust gases and disposed in landfills. The problem of disposing and managing solid waste materials in the industrial countries has become one of the major environmental, economic and social issues. The Cement Kiln Dust (CKD) has cementitious properties that make it an effective stabilizer for certain soil types. CKD represents a potentially useful and cost-effective. CKD is being used increasingly for soil stabilization. CKD has been used as a soil additive to improve the texture, increase strength and reduce swell characteristics. Treatment with cement kiln dust was found to be an effective option for improvement of soil properties, based on the literature review as a part of this research the plasticity was reduced [9]. Studied the effect of cement waste dust and lime on black cotton soil. Author observed that comparing three groups (Soil, Soil+CKD, Soil+CKD+Lime), Cement dust provides substantial and durable benefits when used as stabilizing agent for BC soil. Significant change in plasticity index of BC soil used with cement dust [10]. Studied the effect of cement kiln dust on silty-clay Authors observed an increase in OMC and decrease in MDD were observed with increasing amount of CKD..

B. Lime Stabilization

Lime is widely used in civil engineering applications [11-23]. Found that when lime is added to clay soils in the presence of water, a number of reactions occur leading to the improvement of soil properties. These reactions include cation exchange; flocculation and carbonation .The cation exchange takes place between the cations associated with the surfaces of the clay particles and calcium cation of the lime. The effect of cation exchange and attraction causes clay particles to become close to each other, forming floc; this process is called

Flocculation is primarily responsible for the modification of engineering properties of clay soils when treated with lime. Adding of lime significantly reduces the swelling potential, liquid limit, plasticity index and maximum dry density of the soil, and increases its optimum water content.

Cement Stabilization

Cement stabilization is similar to that of lime and produces similar results. Cement stabilization develops from the cementitious links between the calcium silicate and aluminate hydration products and the soil particles. Add cement to clay soil reduces the liquid limit, plasticity index and swelling potential, also it causes increasing the shrinkage limit and shear strength "[24, 16-18].

Atterberg Limits

Investigated the change in Atterberg limits in different soil samples treated with CKD [25]. The results indicate that an increase in CKD increases the plastic limit, decreases the liquid limit thus, significant PI reduction occurs with CKD treatment, especially for soils with high PI. Cement increases plastic limit and reduces liquid limit, which mainly reduces plasticity index.

Lime changes the Atterberg limits of the soils. An increase in lime content decreases the liquid limit, increases plastic limit and that leads to a significant decrease in plasticity index (figure 1).

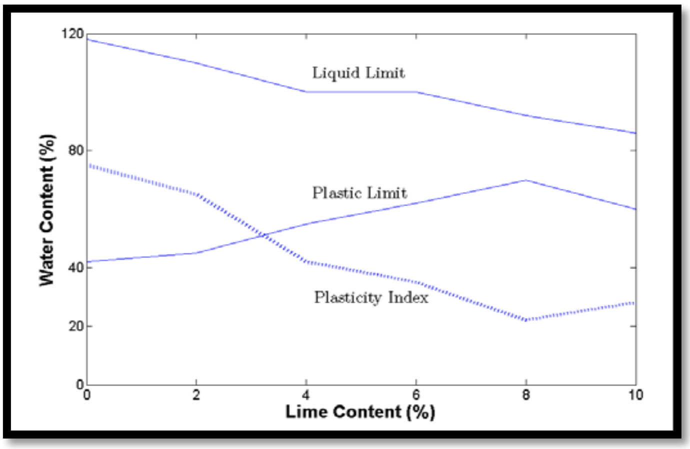

Fig-1: Relationship between Atterberg limits with lime content

MATERIALS

The following materials have been used in this study with definite properties as cited below:

Soil

The soil sample was obtained from Al-Hilla city center. Tables (1 and 2) show chemical and physical properties respectively for the original soil.

Table-1: Chemical Properties of the Original Soil

Chemical properties	Value
Sulphate Content %	1.1
Gypsum Content %	2.48
Total Soluble Salts Test%	2.9g/L
Chlorides CL	58.81 meq/L
Organic Matter Content%	0.95 g/kg
PH-Value	8
Ca++	7.8 meq/L
Mg++	5 meq/L.

Table-2: Physical Properties of the Original Soil

Soil Properties	Original Soil
LL %	50
PL %	25
PI %	25
Water Content (%)	23.0
Specific Gravity	2.7
O.M.C (%)	21
M.D.D (gm/cm^3)	1.7
% of Fines	94. 5
AASHTO Classification	A6
Unified Classification	Silty Clay

Water

Water shall be tested in accordance with and shall meet the suggested requirements of AASHTO T-26[26]. Water known to be of potable quality may be used without testing. Distilled Water is used in specific gravity and hydrometer tests. For other tests and curing, tap water has been used. Table (3) shows the chemical properties for tap water.

Table-3: Chemical Properties for Tap Water

Property	**Value**
PH	7.6
EC	960Mus
Turbidity	1.63 N.T.U Nephelometic Turbidity Unit
Total Hardness	276 mg/L
Chloride	112 mg/L
Mg	13.46 mg/L
Ca	218 mg/L
SO4	181mg/L
PO4	0.3 mg/L
Na	77 mg/L
K	3.8 mg/L
TDS	478 mg/L

Cement Kiln Dust

Cement Kiln Dust (CKD) is a powdery by-product of the Portland cement manufacturing process. As the raw materials for making cement are heated and tumbled in kiln, dust particles are shaped and passed with hot exit gases. Sample of CKD was attained from Al-Kufa cement factory. The beneficial properties of CKD and its cost effectiveness compared with other type of stabilizers have led to its use as a popular stabilization agent in recent times. The chemical composition of the dust is reported in Table 4. CKD was added at percentages (0, 3, 6, 9, and 12) % of soil weight.

Table-4: Chemical Composition of Cement Kiln Dust

No.	Chemical Composition (Oxide Compound)	Value
1	Al_2O_3	5.1
2	CaO	46.6
3	SiO_2	16.2 Unit
4	Fe_2O_3	3.01
5	MgO	2.7
6	SO_3	5.2
7	Na_2O	0.5
8	K_2O	0.15
9	Loss of Ignition	24.34

Cement

Sulphate resistance Portland cement (Jeser) has been used in this research. In order to obtained chemical and physical properties, chemical and physical tests have been done. The tests held according to I.O.S standard, No 5, 1984. Tables (5) and (6) show these chemical and physical properties, respectively

Table-5: Chemical Properties of Sulphate resistance Portland cement

Composition	Test Results	Limits According to I.O.S
CaO%	67.71	
SiO_2 %	18.8	
Al_2O_3 %	4.6	
Fe_2O_3 %	4.3	
MgO %	2.19	≤ 5%
SO_3 %	1.29	≤ 2.5% if C3A< 5% ≤ 2.8% if C3A >5%
Insoluble Residue%	0.12	≤ 4%
TOTAL	99.01	
Properties	Test Results	Limits According to I.O.S
Free Lime %	0.66	
Insoluble Residue%	0.69	≤1.5%
Lime Saturation Factor	0.79	0.66-1.02
Modulus Silica	2.48	
Modulus Alumina	0.89	
C3S %	51.89	
C2S %	22.6	
C3A %	2.86	≤ 3.5%
C4AF %	16.10	

Table-6: Physical Properties of Sulphate Resistance Portland Cement.

Properties	Test Result		Limits According to I.O.S	
Setting Time (min.)	Initial	119	≥ 45 min	
	Final	232	≤ 600 min	
Fineness(Blaine) in m^2 /Kg	310		≥ 230	
Compressive StrengthMN / m^2:	3 days		18.35	≥ 15
	7 days		28.62	≥ 23

Lime

The lime used in this work is hydrated lime $Ca(OH)_2$ from Kofa-lime factory in Iraq. The lime to be used may be either hydrated or quicklime, although most stabilization is done using hydrated lime. The reason is that quicklime is highly caustic and dangerous to use .Table (7) shows the chemical composition of hydrated lime that is tested according to the I.O.S standard, No. 807, 1989

Table-7: Chemical composition for lime used in the study

Properties	Value (%)	I.O.S standard
Activity	72.1	----
CO_2%	1.8	Not more than 5%
Mg% + CaO %	87.6	Not less than 64 %
MgO%	0.5	Not more than 5 %
Fe_2O_3%	0.15	Summation of oxide not more than 5%
Al_2O_3%	0.8	
SiO_2%	1.49	
SO_3%	0.32	
Loss Of Ignition	24.2	-----
)90µ(Retained On Sieve	4.1	Not more than 10 %
Ca (OH)2 %	86.8	-----

SAMPLE PREPARATION AND METHODOLOGY

Initially, oven-dry soil was thoroughly hand mixed with each stabilizer or combination of stabilizers in a large tray in a dry state. The testing program in this study can be summarized as follows:-

Classification tests include physical tests that comprised the water content, specific gravity, Atterberg limits, grain size analysis, hydrometer and maximum dry density

Atterberg Limit

The liquid limit and the plastic limit tests for original soil and soil with additives (lime, cement, cement kiln dust) were carried out according to the ASTM D-4318.The plasticity index (PI) is explain below:

Plasticity Index (PI)

A reduction in the plasticity index is often used to determine the effectiveness of (lime, cement and cement kiln dust) treatment on a particular soil. Atterberg limit tests were conducted according to AASHTO T-89 and AASHTO T-90[27]. In this research the soil was dry mixed with the additives (lime, cement and cement kiln dust) and allowed to mellow prior to initiating the test. The percentages of additive were (0, 3, 6, 9, 12) % from the weight of soil. The reduction in the PI is caused by flocculation and agglomeration of clay particles in the presence of Cao [28]. Figure(1) to Figures (3) shows soil-additives mix, liquid limit test and plastic limit test respectively at different percentages of additives .Enhanced workability of materials has been shown to be associated with reduction in plasticity index [29, 30]. A series of tests with different cement content were conducted to determine the effect of cement content on the Atterberg limits of Palouse and Aberdeen soils. Note that, since the Everett soil is sandy, plasticity limits were not considered. Tests were conducted 30 minutes after addition of cement according to ASTM D4318 [31]. Atterberg limits tests were conducted 30 minutes after addition of cement according to ASTM D, 4318[31].Whereas the Atterberg limits were done on the soil samples two-days after addition of lime.

RESULTS AND DISCUSSIONS

In order to examines the effect of additive type and additive percent on atterberg limits (LL, PL, PI), specimens of the original soil were fabricated at five different percentages of additive (0,3,6,9,12)% and three types of additive(lime ,cement and cement kiln dust) and then made comparison between them. The obtained results for these comparisons are presented in Figures (2) to (4). In these Figures, indicate that initially liquid limit of the soil-additive mixture specimens decreased slightly at the addition of 3% additive (lime, cement and cement kiln dust). In other word. While plastic limit increased slightly relatively constant. Consequently the plasticity index of soil-cement mixture decreased initially (in cement content equal to 3%) with increasing of additive content. But best results for liquid limit, plastic limit and plasticity index are obtained when we use cement. Cement shows more reduction in the plasticity index (PI) and 12%represent best percentages for all additives.

It must be noted plasticity index PI for CKD treated soil are noticeably lower than that attained by addition of cement [32]. However, it is noted that due to lack of standards and guidelines, The Environmental Protection Agency (EPA) has reviewed and studied the impact of CKD on human’s health and environment. It is concluded that the health and environmental risks associated with CKD are low. However, there is a potential danger to human’s health and environment under particular circumstances and may damage or burn the skin (third degree burn) It can be seen that liquid limit increased initially and decreased gradually as cement content increased. Plastic limit increased initially and remained relatively constant with increasing in cement content. Therefore plasticity index increased initially and decreased as cement content increased. The addition of lime resulted in a reduction of the liquid limit in comparison with the natural soil. This fact complies to the results obtained by other investigators [33-35] who have observed a significant reduction in the LL of fine-grained soils following their treatment with additives. The admixture of lime rapidly initiates flocculation and cation exchange reactions, leading to a reduction of the specific area of the soil. The reduction of the thickness of the diffused double layer causes the reduction of the liquid limit. In this stage Atterberg limits tests with different cement or lime contents were done to determine the effect of stabilizer contents on the Atterberg limits of the soil. From our study we found the best additive is cement and (12%) best percentage of additive (cement) which gives less plasticity index for the tested soil.

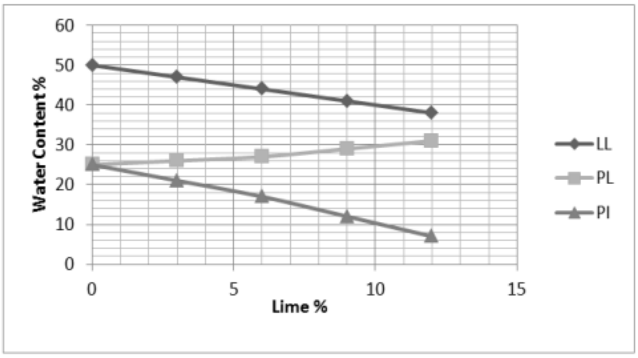

Fig-2: Liquid limit, plastic limit and plasticity index of lime-soil mixture at different percentages

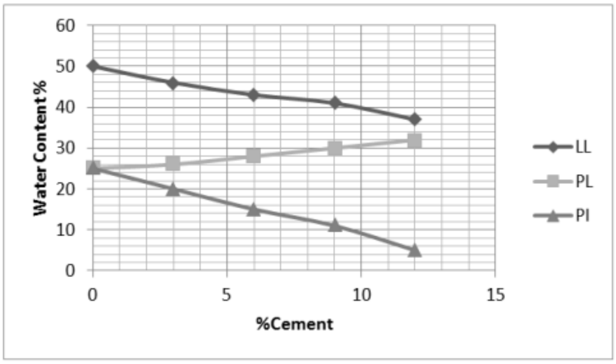

Fig-3: Liquid limit, plastic limit and plasticity index of cement-soil mixture at different percentages

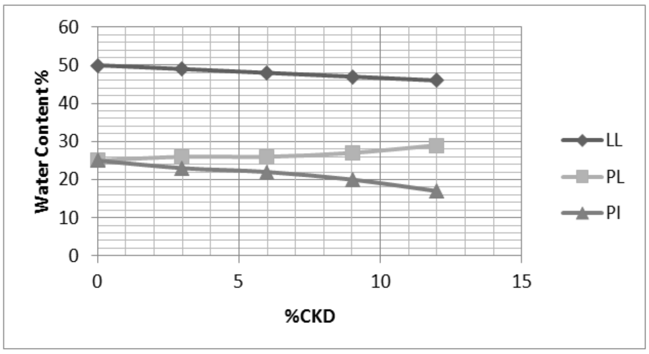

Fig-4: Liquid limit, plastic limit and plasticity index of CKD-soil mixture at different percentages

REFERENCES

1. Rahman, M. A. (1986). The potentials of some stabilizers for the use of lateritic soil in construction. *Building and Environment*, *21*(1), 57-61.
2. Rahman, M. A. (1987). A comparative study of the potentials of rice husk ash on cohesive and cohesionless soils. *Building and Environment*, *22*(4), 331-337.
3. Bryan, A. J. (1988). Soil/cement as a walling material—I. Stress/strain properties. *Building and Environment*, *23*(4), 321-330.
4. Das, B. M. (1990). *Principles of Foundation Engineering, 2nd Edition, PWS-KENT Publishing Company, BOSTON*.
5. Balmer, G. G. (1958). *Shear strength and elastic properties of soil-cement mixtures under triaxial loading* (No. D-32).
6. Rocha, M., Folque, J., & Esteves, V. P. (1962). *The application of cement stabilized-soil in the construction of earth dams*. Laboratório Nacional de Engenharia Civil.
7. Nash, J. K., Jardine, F. M., & Humphreys, J. D. (1900, January). The economic and physical feasibility of soil-cement dams. In *Soil Mech & Fdn Eng Conf Proc/Canada/*.
8. Jumikis, A. R. (1966). Proceedings of the Sixth International Conference on Soil Mechanics and Foundation Engineering. *Soil Science*, *102*(4), 288.
9. Oza, J. B., & Gundaliya, P. J. (2013). Study of black cotton soil characteristics with cement waste dust and lime. *Procedia Engineering*, *51*, 110-118.
10. Solanki, P., Khoury, N., & Zaman, M. (2007). Engineering behavior and microstructure of soil stabilized with cement kiln dust. In *Soil Improvement* (pp. 1-10).

11. El Sharif, M. A., Taha, Y. K., Kenawi, M. A., & Kamel, A. O. (1765). Treatment of Expansive Soil with Chemical Additives.
12. Basma, A. A., & Tuncer, E. R. (1991). Effect of lime on volume change and compressibility of expansive clays. *Transportation research record*, (1295).
13. Bell, F. G. (1996). Lime stabilization of clay minerals and soils. *Engineering geology*, *42*(4), 223-237.
14. Ji-ru, Z., & Xing, C. (2002). Stabilization of expansive soil by lime and fly ash. *Journal of Wuhan University of Technology--Materials Science Edition*, *17*(4), 73-77.
15. Al-Rawas, A. A., Hago, A. W., & Al-Sarmi, H. (2005). Effect of lime, cement and Sarooj (artificial pozzolan) on the swelling potential of an expansive soil from Oman. *Building and Environment*, *40*(5), 681-687.
16. Croft, J. B. (1967). The influence of soil mineralogical composition on cement stabilization. *Geotechnique*, *17*(2), 119-135.
17. Al-Rawas, A. A. (2002). Microfabric and mineralogical studies on the stabilization of an expansive soil using cement by-pass dust and some types of slags. *Canadian geotechnical journal*, *39*(5), 1150-1167.
18. Bozbey, I., & Garaisayev, S. (2010). Effects of soil pulverization quality on lime stabilization of an expansive clay. *Environmental Earth Sciences*, *60*(6), 1137-1151.
19. Al-Mukhtar, M., Lasledj, A., & Alcover, J. F. (2010). Behaviour and mineralogy changes in lime-treated expansive soil at 20 C. *Applied clay sciences*, *50*(2), 191-198.
20. Ramesh, H. N., Manoj, K., & Mamatha, H. V. (2010). Compaction and strength behavior of lime-coir fiber treated Black Cotton soil. *Geomechanics and Engineering*, *2*(1), 19-28.
21. Kumar, A., Walia, B. S., & Bajaj, A. (2007). Influence of fly ash, lime, and polyester fibers on compaction and strength properties of expansive soil. *Journal of materials in Civil Engineering*, *19*(3), 242-248.
22. Sahoo, J. P., & Pradhan, P. K. (2010). Effect of lime stabilized soil cushion on strength behaviour of expansive soil. *Geotechnical and Geological Engineering*, *28*(6), 889-897.
23. Al-Mukhtar, M., Khattab, S., & Alcover, J. F. (2012). Microstructure and geotechnical properties of lime-treated expansive clayey soil. *Engineering geology*, *139*, 17-27.
24. Mavroulidou, M., Zhang, X., Gunn, M. J., & Cabarkapa, Z. (2013). Water retention and compressibility of a lime-treated, high plasticity clay. *Geotechnical and Geological Engineering*, *31*(4), 1171-1185.
25. Sherwood, P. (1993). *Soil stabilization with cement and lime*.
26. Miller, G. A., & Azad, S. (2000). Influence of soil type on stabilization with cement kiln dust. *Construction and building materials*, *14*(2), 89-97.
27. Sagoe-Crentsil, K. K., Brown, T., & Taylor, A. H. (2001). Performance of concrete made with commercially produced coarse recycled concrete aggregate. *Cement and concrete research*, *31*(5), 707-712.
28. Wood, D. M., & Wroth, C. P. (1978). The use of the cone penetrometer to determine the plastic limit of soils. *Ground Engineering*, *11*(3).
29. Herrin, M., & Mitchell, H. (1961). Lime-soil mixtures. *Highway Research Board Bulletin*, (304).
30. Baran, B., Ertürk, T., Sarıkaya, Y., & Alemdaroğlu, T. (2001). Workability test method for metals applied to examine a workability measure (plastic limit) for clays. *Applied Clay Science*, *20*(1), 53-63.
31. Barnes, G. E. and Reylonds, W. S. (1989)″Lime Stabilization of Glacial Clay. *Journal of the Institution of Highways and Transportation, 36*, 26-32.
32. Mallela, J., Quintus, H. V., & Smith, K. L. (2004). Consideration of lime-stabilized layers in mechanistic-empirical pavement design. *The National Lime Association*, 200-208.
33. Standard, A. S. T. M. (2000). Standard test methods for liquid limit, plastic limit, and plasticity index of soils. *ASTM International, West Conshohocken, PA*.
34. Sariosseiri, F., & Muhunthan, B. (2008). Geotechnical properties of Palouse loess modified with cement kiln dust and Portland cement. In *GeoCongress 2008: Characterization, Monitoring, and Modeling of GeoSystems* (pp. 92-99).
35. Sridharan, A., Rao, S. M., & Murthy, N. S. (1986). Liquid limit of montmorillonite soils.