International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:6, No:12, 2012

Evaluation of Shear Strength Parameters of Amended Loess through Using Common Admixtures in Gorgan, Iran

Seyed Erfan Hosseini, Mohammad K. Alizadeh, and Amir Mesbah

***Abstract*—**Non-saturated soils that while saturation greatly decrease their volume, have sudden settlement due to increasing humidity, fracture and structural crack are called loess soils. Whereas importance of civil projects including: dams, canals and constructions bearing this type of soil and thereof problems, it is required for carrying out more research and study in relation to loess soils. This research studies shear strength parameters by using grading test, Atterberg limit, compression, direct shear and consolidation and then effect of using cement and lime additives on stability of loess soils is studied. In related tests, lime and cement are separately added to mixed ratios under different percentages of soil and for different times the stabilized samples are processed and effect of aforesaid additives on shear strength parameters of soil is studied. Results show that upon passing time the effect of additives and collapsible potential is greatly decreased and upon increasing percentage of cement and lime the maximum dry density is decreased; however, optimum humidity is increased. In addition, liquid limit and plastic index is decreased; however, plastic index limit is increased. It is to be noted that results of direct shear test reveal increasing shear strength of soil due to increasing cohesion parameter and soil friction angle.

***Keywords*—**Loess Soils, Shear Strength, Cement, Lime.

I. Introduction

STUDYING and anticipating behavior of problematic soils (organic and vegetable based soils, saturated and soft clay soil, sand soil, loess silt, collapsible soils, earth fall soils, dispersive soil, embankments, rubbish and waste based soils) has recently received great attention by soil and foundation specialists. Basically problematic soils show unexpected behavior under specific conditions; in which, this unpredictable behavior cause many problems. Collapsible soils including: loess soils is among problematic soils and most provinces of Iran have collapsible soil and in case of not recognizing this type of soil and constructing a structure on it and if the soil beneath structure saturates due to explosion of pipe, infiltration of surface waters, rising aquifers or any other reason, poor and semi-stable joints is removed and shear strength of soil is decreased, joints between grains show slid and size of soil is decreased; therefore, it cause problem for foundation of structure. Thus, it seems necessary for recognizing and classifying this type of soil and find out appropriate methods for stability and construction of foundation on loess soil [1], [2]. Until now several studied were performed by scientists of different countries in relation to stability and improving construction of structure on problematic soils by using additives including: bitumen, lime, cement, ash, lime… so that after the year 1945 the issue of soil modification by using slaking lime is common in America and the issue of modifying stabilized clay soils with cement is common in Africa and according to climate condition and humidity, the issue of soil modification by using live lime instead of slaking lime is common Europe. This modification method was common in 1950's and 1970's in Europe. A comprehensive research plan was started in Sweden in relation to lime and cement columns since 1995. This research plan was performed by geotechnical institute and soil stability research association of Sweden by cooperation of great automobile manufacturing companies of this country. Some issues studied by this institute are including: properties of soil stabilized by lime and cement, executing columns, quality control methods, performance of stabilized soil in adjacency of fluctuations of underground waters. In this way, several researchers were performed in Japan in the field of injecting grouts and deep mixing soil which is still continuing [3], [4].

Seyed Erfan Hosseini is with the Islamic Azad University, Aghghala Branch, Aghghala, Iran (phone: 0098-9111718596; e-mail: Erfanhosseini@yahoo.com).

Mohammad Karim Alizadeh is with the Agricultural Sciences & Natural Resources University, Gorgan, Iran (e-mail: karim_1378@yahoo.com).

Amir Mesbah is with the Islamic Azad University, Gorgan, Iran (e-mail: amiremesbah@gorganiau.ir).

II. Methods

This is field and laboratory study with the goal of stabilizing loess soils through increasing shear strength of soil by adding different percentages of cement and limes either separately or together to desired soil in the year 2010. Research samples are consisting of 4 cases, so that one ton soil was collected from Naharkhoran valley in Gorgan city which bears great amount of loess soils in Iran, transferred to laboratory and by adding cement and lime as 2% and 4% respectively, weight of soil bearing different compounds was obtained according to the following table:

TABLE I
SOIL COMPOUNDS

Abbreviation	S	S+4L	S+2C	S+4L+2C
Type of compound	Natural soil	Natural soil +4% lime	Natural soil +2% cement	Natural soil + 4% lime +2%cement

In next stage, by grading test, Atterberg limit, determining percentage of humidity, density of soil's grains, compression, direct shear and consolidation, some strength parameters and to study effect of using additives (cement and lime) on stabilizing loess soils either solitarily or by compound ratio of different percentages are added to soil (according to aforesaid table) during different time [5] ,[6]. In addition, according to ASTM standard, each of the aforesaid tests in order to prevent from error and probable mistakes were repeated for 3 times; in which, obtained responses from each test was greatly close together. Then by using T-test and ANOVA test data were analyzed by SPSS software.

III. FINDINGS

Grading and Hydrometry Test (ASTM D422-63): According the tests on soils of this zone, it is concluded that this soil has nearly 19.9% sand, 70.4% silt and 9.7% clay and is made of ML-CL.

Test of Determining Humidity Percentage (ASTM D2216-90): Goal of this test is to determine weight percentage of humidity of soil in comparison to dry grains and we already knew by using this test it is not possible to obtain real percentage of humidity of building materials bearing considerable amount of Mont, Marionette and plaster ore and results show that natural humidity of soil is 14.5%.

Test of Determining Density of Soil's Grain (ASTM:D 854-58): Goal of this test is determining ratio of unit weight at solid section of soil to unit weight of water; in which, this ratio for grains passed from sift number 200 was obtained as 2.67 (Gs=2.67)

Density Test (ASTM: D2167): This test was performed to determine unit weight for volume of dry soil under natural mode or one layer of soil mixed with calibrated sand or plastic balloon. Test for determining unit weight for volume of dry soil was performed at desired zone for evaluating compression of embankment. According to this test, density of natural soil was obtained as 13.84kilo Newton/m3.

Test of Determining Atterberg Limit (ASTM: D 4318-87): Reason of studying Atterberg limit is importance of this parameter for determining behavior and property of soil. Factors including: shear strength between surface of grains, thickness of double reaction layer, type of soil ore and cation ability, size of cation valance and PH of system influences on Atterberg limit. By adding lime and cement or mixing lime and cement to soil, properties of plastic index and liquid limit is decreased, so that, sometimes mixture of soil and cement is completely turned into plastic index. Soils having higher level of lime and cement have more non-plastic index mode. In case of adding this mixture to soil within several stages, generally the mixed amount that is added to soil in the first stage has highest effect on decreasing plastic index properties of soil; therefore, effect of this issue is more decreased in next stages.

Standard Compression Test (ASTM: D698): Goal of this test is studying effect of adding lime and cement to soil on maximum dry unit weight and optimum humidity of soil, producing sample for direct shear test, consolidation, pressure strength on optimum compression and humidity; in which, results of this test showed that stabilized soil with lime and cement has less specific dry weight and higher percentage of optimum humidity than non-stabilized soil. The higher level of consumed ingredients for stability of soil, the lower amount of difference will be. By adding lime and cement to soil, level of unit weight is decreased due to reaction of free water on sample for chemical reaction and its turning into molecular water; since, samples with some percentage of lime and cement due to having higher contact (because of having more smaller grains) require higher amount of water and whereas this water is located between building materials, it decreases level of maximum dry unit weight and increases optimum level of humidity.

Consolidation Test (ASTM: D5333-92): Sample soil with natural humidity is prepared by using (ASTM: D2435) consolidation test. Loading steps were according to standard 12 KP, 50 KP, 100 KP and 200 KP and before saturating samples, time interval between loading steps was observed as 1h. After reaching to 200 KP stress and 1h later sample is overflow in water and within time interval of 0.1 min, 0.25 min, 1 min, 2 min, 4 min, 8 min, 15, 30min and 1h, 2h, 4h, 8h and 24h the amount of sample was read that according to table 2 (Jing, Nite in the year 1975) the following results were obtained based on different percentages of lime and cement.

TABLE II
COLLAPSE POTENTIAL FOR INTENSITY

Intensity of problem	Collapse potential (%)
No problem	0-1
Moderate trouble	1-5
Trouble	5-10
Severe trouble	10-20
Very severe trouble	20

Results of test show that soil stabilized with lime and cement due to change in collapsible property under most cases the collapsible problem of such soil is solved and as consumption or more building materials, it has positive effect; however, rate of effecting these results in relation to collapsible property is different with increasing building materials. Remember that in order to perform this test, level of humidity is observed as 14.5% fixed and for some samples the maximum dry unit weight is observed.

Unlimited Pressure Strength Test (ASTM: D2166): Sample cylinder produced by different percentage of lime and cement in this test has 3.8cm diameter and 8.5cm altitude and speed of 1mm/min. After reaching sample to the desired age, it is exited from nylons and its dimensions are exactly measured

and are transferred to clamp of machine. The most important issue is that test should be performed within initial humidity of sample and there should not be any change at its humidity or saturated sample and the samples should be dried in warm house after each test for controlling their humidity. Due to adding chemical materials to soil, some different reactions may occur; in which, the most influencing reaction on strength and durability of soil is hydration. The most considerable property due to effect of stabilizing small grain soil stabilized with cement is increasing strength with time. Generally, these strengths are mentioned with parameters including: single axis strength. Upon increasing percentage of lime, the time of processing single axis strength of samples is also increased, so that changes of single axis strength at first 14 days of modification is higher than rate of changes after 14 days.

Direct Shear Test (ASTM:D 3080-90): In this test changes of maximum shear angle in different ingredients of soil with lime and cement in comparison to time of processing is studied, so that after producing samples with desired percentage of lime and cement and putting them in shear machine, movement speed of machine is selected as 1mm/min and vertical stress applied to 1kg, 1.5kg and 2.5kg is measured; consequently, findings according to the following figure is offered: (see Fig. 1 & Fig. 2)

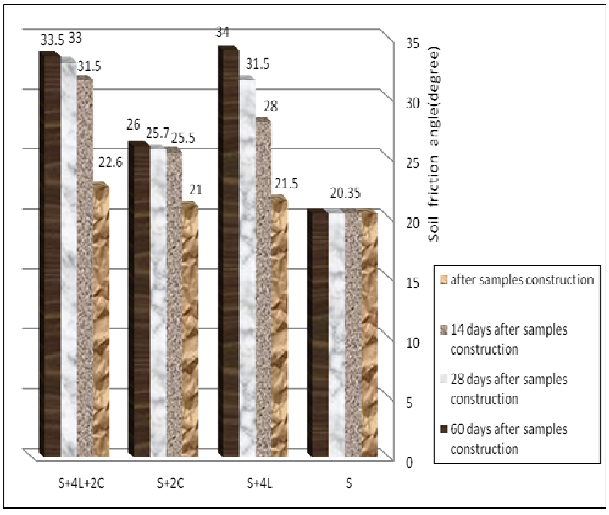

Fig. 1 Comparison of changes in Soil friction angle on the different percentage of Lime and cement, at different times of processing

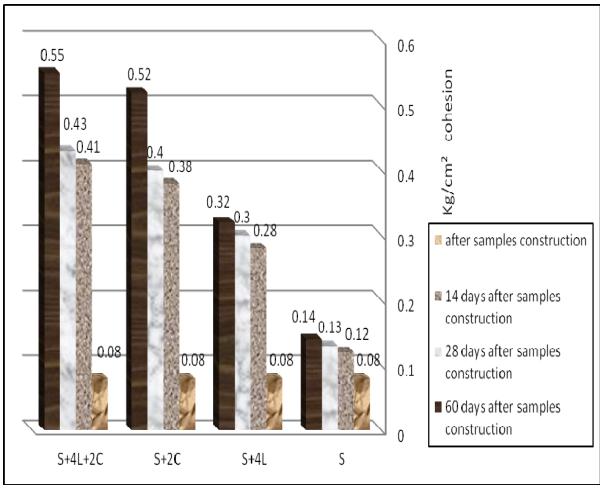

Fig. 2 Comparison of changes in cohesion on the different percentage of Lime and cement, at different times of processing

Studies show that increasing level of lime does not greatly influence on soil friction angle in comparison to cohesion; however, both amounts are increased so that after 28 days since production of samples, level of cohesion is increased up to 4 times and level of inner friction is increased up to 10 degree; thus, shear strength of these soils are also increased. Increasing level of cement, does not greatly influence on soil friction angle in comparison to cohesion; however, both amounts are increased. In addition it is possible to say that influence of increasing cement has more effect on shear parameters within same percentage of lime; in which, these results are observed through comparing ingredients of lime and cement separately. Friction angle of soil mixed with lime and cement is generally more than maximum friction angle and cohesion of natural soil; therefore, certainly it is recommended to use lime and cement and be sure that shear strength of soil is increased; nevertheless, according to previous studies higher increase in cement does not create considerable level of increase at parameters of shear strength of soil; thus, increasing cement more than 2% seems to be non-economic issue.

IV. Discussion & Conclusion

In order to increase strength parameters of soil it is used from several methods including: stabilizing soil by biologic methods, stabilizing soil by bitumen and its derivates, stabilizing soil by ash, stabilizing soil by lime, stabilizing soil by lime and bitumen, stabilizing soil by cement and bitumen, stabilizing soil by polymer materials; in which, each method according to its application has some advantages and disadvantages [7]. For example, biologic stabilization method which consists of growing plants is generally used for increasing strength and stability of slopes exposed to sliding or increasing strength of soil against erosion and washing by rain and surface waters or stabilizing soil by bitumen and its derivates is only used for soils with 25% small grains and 10% plastic index grains. In addition, according to some standards level of sand, multiplication of plastic index grain

and percentage of soil passed from 200 sift for stabilizing soil by bitumen is 30 and 72. Using other compound ingredients of bitumen-cement and bitumen-lime for stabilization of soil has application for accelerating rate of obtaining required strength; otherwise, using bitumen and its derivates in comparison to other stabilizers does not have economic justification in Iran. It is concluded that soil stabilization method by using lime-cement is most appropriate and applied method with respect to technical, economic issues and availability of building materials and following results were obtained [8], [9], [10] :

* Upon increasing percentage of cement and lime, compounding these 2 materials decreases liquid limit of soil; reason of this issue is compounding cement-lime in soil in comparison to effect of cement-lime separately. In addition, by increasing percentage of cement-lime the compound of cement-lime decreases liquid limit of plastic index, so that some compounds turn soil into completely non-plastic soil.

* By increasing initial humidity percentage of soil, the collapse potential is decreased; since, due to humidity the bonds between grains is more loess; consequently, due to increasing humidity, these soils show less amount of collapsible property in comparison to soils with less initial humidity .

* Results of single axis test show higher influence of cement on increasing single axis strength in comparison to lime; so that, this increase show high influence of additives on strength of soil. Increasing single axis strength of stabilized soils is due to hydration reaction.

* By studying different overloads on collapsible soils it is concluded that in case of increasing vertical overload, the collapsible potential is increased; however, level of this potential for 28 days sample is smaller than 1 day sample which shows effect of time of processing on samples.

* Studying samples compounded with cement shows that effect of adding cement to soil samples, decreases collapsible property potential of soil, which is due to higher effect of cement for reaction with soil, ion exchange and changing soil to grain structure.

* Studying direct shear test showed that increasing lime to soil do not create considerable change on cohesion and soil friction angle (it partially increases both properties); however, after 28 days since constructing and processing samples, level of cohesion has considerable increase and friction angle shows low partial increase. In addition, in case of adding cement to collapsible soil and under sudden loading, there is no considerable change at friction angle and cohesion friction (there is low partial increase in cohesion); however, after 28 days since constructing and processing samples, we observe 4 times increase in level of cohesion and increasing soil friction angle u to maximum 10 degree.

* By using consolidation test on compound samples under fixed overload or lime it is observed that collapsible property potential does not have considerable change after constructing sample. In case of 28 days since constructing and processing sample, there is considerable decrease in collapsible property potential and rate of decreasing collapsible property in lime is 4%.

REFERENCES

[1] Pashaei,A.(1997). *Studying physical and chemical properties of loess soils at Gorgan and Dasht region.* issue.23-24, p.67-68.
[2] Khajeh,F.(2002). *Studying sedimentation, sediment environment and de-sedimentation of quarter deposits at Gorganroud basin*, PhD thesis in geology. Islamic Azad University. Science & Research branch, p.250
[3] Stahculescu, I.(1967). *Active zone settlement of shallow foundations on loessial soils.* proceedings of the 5th Australia- New Zealand conference on soil mechanics and foundation engineering, Auckland New Zealand.
[4] Houston, SL. Ehwany, El. (1991). *Sample disturbance of cemented collapsible soils.* journal of geotechnical engineering, ASCE vol.117, No.5, pp 731-752.
[5] Clevenger, WA.(1959). *Experiences with bess as foundation material.* journal of the soil mechanics and foundation division, proceeding of the American Society of Civil Engineers, paper.1025.
[6] Clemencc, Sp. and Finharr, AO.(1981). *Design consideration for collapsible soils. journal of the geotechnical engineers division.* proceedings of the American Society of Civil Engineers, Vol.107, No.Gt3.
[7] ISBN: O-408-01457-1(1993). *Annual book of ASTM standard, standard test method for measurement of collapsible potential of soils.*
[8] Barden, L. Gown, Mc. and Collins K.(1973).*The collapse mechanism in party saturated soil.* Eng geology. No.7, pp.49-60.
[9] Grabowska, B.(1988). *Geological problems of losses in Poland Eng.* Geology journal, vol 125, No.S, 2-4 , pp.177-199.
[10] Bell, FG. (1983).*Properties of soils and rocks butter worth & co Ltd.*

Seyed Erfan Hosseini was born in Gorgan, Iran in 1983. He graduated in civil engineering at Islamic Azad University, Gorgan branch (2007) and earned his M.s degree in soil mechanics at Islamic Azad University, Arak Branch(2010). He is now faculty member in Islamic Azad University of Aghghala.