Improving the Properties of Swollen Clay Soil by Adding Lime

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ABSTRACT:

Clayey soils are widespread in world. Because of their disadvantages, the need to be stabilized becomes more and more urgent. Enhancement of clayey soils using mineral additives was well established in the literature.

This research aims to add lime in certain proportions to study the improvement of soil properties. We studied the effect of lime on swelling properties and soil texture.

The results of this study showed, with an increase in the percentage of lime, a decrease in both the plasticity index, shrinkage, and fluid limits. The plasticity limit increases at first with an increase in the percentage of lime and then decreases slightly.

Regarding the volumetric variation, the shrinkage and swelling capacity of the soil improved with lime decrease, and the swelling pressure and free swelling become almost negligible with 4% of lime..

Key Words: swelling- clay- lime- improve- treatment-stabilization

Introduction:

Swelling clay soils are spread over large areas, approximately approximately 30% of the general area, and are subject to significant changes in size due to changes in their humidity, which leads to major deformations in the soil that may be in the form of subsidence (shrinkage due to dryness) or in the form of swelling due to increased humidity.

Soils in dry seasons are characterized by having a network of large and small cracks in all directions. Thus, it causes structural cracks in the building structure and concavities and convexities of roads.

The urban development in the country and the difficulty of changing the locations of engineering projects, such as industrial or residential facilities, dams or roads, as the soil in those areas is clayey and swollen, requires the geotactical engineer to find appropriate and economic solutions, which are often replacing the soil or improving it physically by mixing it with coarse materials such as sand and perforated materials, or chemically by mixing it with other materials. It works to change the chemical composition of the dirt by mixing it with cement or lime, which is less expensive than replacement.

Choosing the optimal solution for improving soil depends on the type of soil, its grain gradation, its content of fine materials, its initial resistance, and the goal of the improvement process. Lime is considered one of the most available and used materials for improving turbid, turbid soils with a high fluidity limit, which have a greater clay content, and it has a lower cost than the methods mentioned. Previously (n Diego California-1997, B erger, Florida, 2005, Somerset 2001).

Whenever the soil contains an amount of aluminum and silicates, a treated soil with good specifications is subsequently produced. The ASTM system requires that the percentage of fine materials (passing through the 200 sieve) be greater than 25% and the plasticity index less than 30%. Table 1 shows some specifications of soils that can be treated with lime. .

Table 1 soil properties

	LL%	IP%	CBR%
Fills Soils	>45	>20	--
Sub-Base	>45	>15	40
Base	>30	>9	80

Ion exchange agents:

When lime is added to the soil, a relatively rapid reaction takes place, called the ion exchange reaction, and it results from the exchange of ions between the minerals of the soil and the lime, as the negatively charged surface of the clay attracts positive ions to modify its charge. Thus, the divalent calcium ions are strongly attracted to the clay and displace the weaker ones, N+ or H+, as well as It can displace molecules of the polarized substance (Bulletin, 2004).

Fusion and agglomeration reactions:

It takes several days for this reaction to occur, as the granules gather around each other, and it is possible for them to coalesce and increase the size of the granules. The reaction occurs to improve the plastic properties of the soil, and the soil becomes healthier and easier to handle. This is called soil amendment (Bulletin. 2004), as shown in Figure (1).

Lime flocculating clay

Figure (1) Fusion and agglomeration reactions

Bozolate reaction:

It can last for several years and forms chemical bonds between soil particles similar to cement bonds resulting from the hydration of cement.

They can be called cement bonds as in Figure (2). This reaction takes place in the presence of water and under high temperatures, as adding lime increases the acidity of the soil and leads to the dissolution of the soil components. The basic components (silicates and aluminates) and thus silicates and aluminates interact with calcium ions and form hydrated calcium silicates and hydrated calcium aluminates, which are hard crystalline materials that do not dissolve in water and lead to the binding of soil particles to each other (Bulletin. 2004).

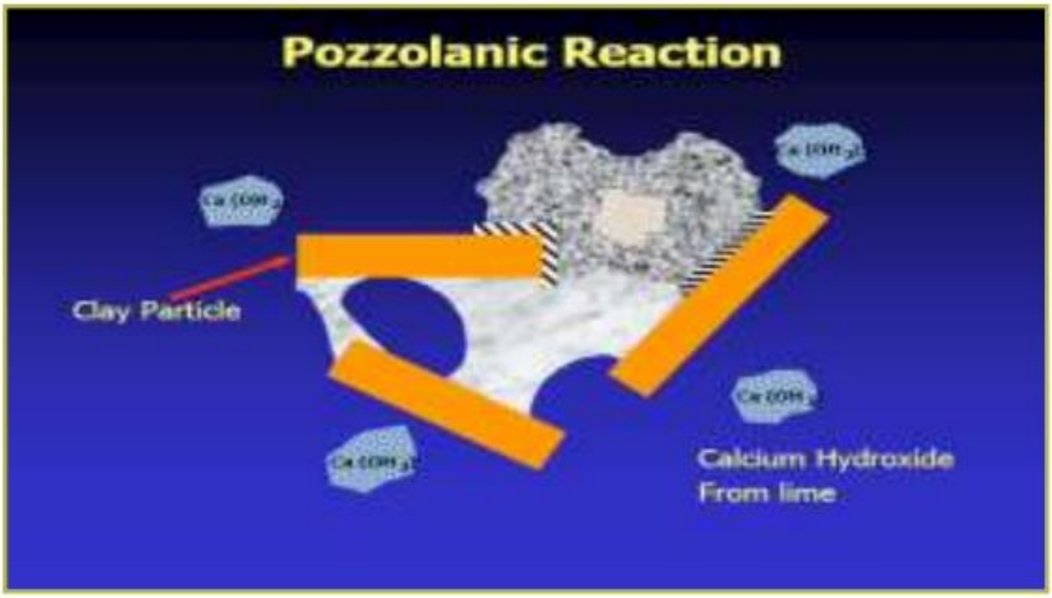

Figure (2) Pozolatte reaction

In general, improving swollen clay soil with lime is an improvement of the chemical specifications of the soil, which leads to improving the physical and mechanical specifications, and thus includes improving the properties of the soil, reducing its subsidence, swelling, and shrinkage, and reducing the soil’s susceptibility to external factors such as frost and ice. Research related to improving clayey and turbid soils with lime has proven that the optimal lime ratio for treatment and the treatment time differ from one soil to another depending on its properties, nature, and the location of the study (Osun 2002, Benue 1997, Isaac O 2004, Ankur 2014, Agbede 2010).

Lime has been known as one of the good soil stabilization materials, especially for clay stabilization properties that have a large swelling and generally contain high levels of clay, but its swelling properties will be much reduced, even eliminated, if the soil mixed with lime. The presence of Ca2 + cations on the elements of lime can provide bonding between the larger particles that expands on soil properties (Ruckman A. 2018) and (Ingles O.G dan, Metcalf J.B. 2017) .

From the results conducted by (Warsiti. 2019), there is an increase in CBR and decrease swelling of the subgrade soil using a method of stability with soil and lime, soil samples from Spring Mulyo and lime from Purwodadi original soil + lime by the percentage of 0%, 5%, 8% ,10% %12 , lime. CBR did not submerged: the percentage of 10% lime, obtained an increase in CBR of 11.8% to 22.1% ,but the percentage of 12% lime CBR decreased slightly to 22%. CBR submerged: the percentage of 10% lime, obtained an increase in the CBR from 2.45% to 7.6% ,but for 12% the percentage of lime CBR decreased slightly to 7.58%. Swelling decreased with increasing percentage of lime in other words, the more the percentage of lime small swelling that occurs .

Liquid limit and plastic limit do not directly provide the value that can be used in the calculation .Limits used in this experiment are the Atterberg limits the description will represent the properties of the land concerned. High liquid limit soil usually has a poor technical nature, which is a low carrying capacity ,towering and difficult compressibility in compaction. For various of soil, Atterberg limits can be linked empirically with other properties, such as shear strength or index compression and so on (Bowles J.E. 2014) and (Anonim. 2013).

Compaction is a process by which the air in the pores of the soil removed by mechanical means to achieve the density requirements. Soil density is usually measured in dry unit weight, not by the number of pores. The dry unit weight great its mean that the number of smaller pores and higher compaction .Swelling is the process of entry of water into the pores which causes swelling of the soil volume. The amount of swelling is the ratio between height changes after immersion of the original height of the sample is usually presented in the form of percent (Bowles J.E. 2014) and (Anonim. 2013) .

C.B.R. was developed as a way to assess the strength of the foundation soil, so that we can know the materials that will be used for the manufacture of pavement. CBR values calculated at the rate of penetration of 0.1 "and 0.2" by dividing each penetration load standards 3000 and 4500 pound load obtained from experiments on a wide crushed stone considered to have a CBR 100%. Experiments C.B.R. can be performed on samples of native soil or compacted soil or carried on the spot. Several previous studies (Ruckman A. 2018), (Harnaeni Senja. Rum. 2017) and (Wardana I., Gusti. Ngurah. 2019) only discuss the stability of the soil with lime without waiting time due to chemical reactions. In this research, the waiting times are concerned.

Search goal:

The study aims to determine the optimal proportions and time for treating swollen clay soil through a set of soil properties improved with lime, which included:

Texture properties (liquidity limit, plasticity limit, plasticity limit, shrinkage limit)

Swelling properties (relative free swelling, inflation pressure)

research importance:

The importance of the research comes from contributing to alleviating the damage resulting from foundations on swollen clay soils spread over large areas after improving them with lime, and reducing the amounts spent on repairing deformities in industrial and residential facilities, roads, and dams that are located on those soils.

Practical:

Treating swollen clay soils with lime transforms them from soils unsuitable for construction from an economic and geotactical standpoint to soils suitable for constructing residential and industrial facilities. Improvement with lime can be carried out according to the steps:

1- Grind the soil until the amount passing through the No. 40 sieve is greater than 60%.

2- Spread the lime and mix it with the soil so that we get a homogeneous mixture. Mixing is done dryly before adding water to the soil or by placing the lime and distributing it homogeneously so that it produces the required ratio. It is suitable for small projects as it requires labor, manual treatment and a large amount of time and is applied well for wet soils. 3- Mix lime with the soil to obtain a homogeneous mixture.

4- Add water to the lime soil mixture equally to achieve the ideal moisture content of the mixture and mix to reach a homogeneous mixture.

5- Level the site with a leveling mechanism, then compact the stabilized soil. Compaction must be done quickly to reduce the risk of carbonation.

6- Protect the final surface of the stacking upon completion of stacking to reduce the risk of carbonation, maintain moisture, and continue the reactions and their completion. It is necessary to avoid applying loads to the surface before a period of curing has passed.

Research methods and materials:

The research is based on completing three stages:

1- Study of the physical, chemical and mechanical properties of clay soil.

2-Study of the physical and mechanical properties of the soil after treatment with lime.

3- Comparison between turbid clay soil without lime and with lime and discussing the results.

Specifications of the soil used for sand and lime:

An amount of soil of about 100 kilograms of the highly swellable type was brought, dried in the sun, and then crushed with a rubber pestle, which would not break or destroy the soil particles.

The lime material was analyzed to determine the percentage of calcium oxide. Table (2) shows the chemical composition of the lime.

Table (2) Chemical composition of lime in percentages

72.23	Cao
0.34	Mgo
0.11	Fe_2o_3
0.93	Al_2o_3
1.51	Sio_2
0.25	So_3
2.77	Co_2
24.69	Tio_2

It is noted that calcium oxide 72.23% is greater than 64&, and therefore lime is suitable for use in soil improvement.

Soil experiments included the following:

Experiments to determine the chemical specifications of natural soil by determining the mineral composition using X-ray diffraction, experiments with the percentage of organic matter, the percentage of carbonate and gypsum, and electrical conductivity. Also, determining the mineral composition without lime using XRD rays was carried out according to the ideal soil moisture and maximum dry density. 1-Experiments to determine physical specifications (grain analysis, Atterberg limits, and specific gravity).

2- Experiments to determine the mechanical specifications (relative free swelling, odometer inflation pressure by gradual loading while maintaining a constant sample size).

Figure (3) shows the granular analysis curve for fine natural soil (87.7% of the dry weight of the sample passes through the 200 sieve)

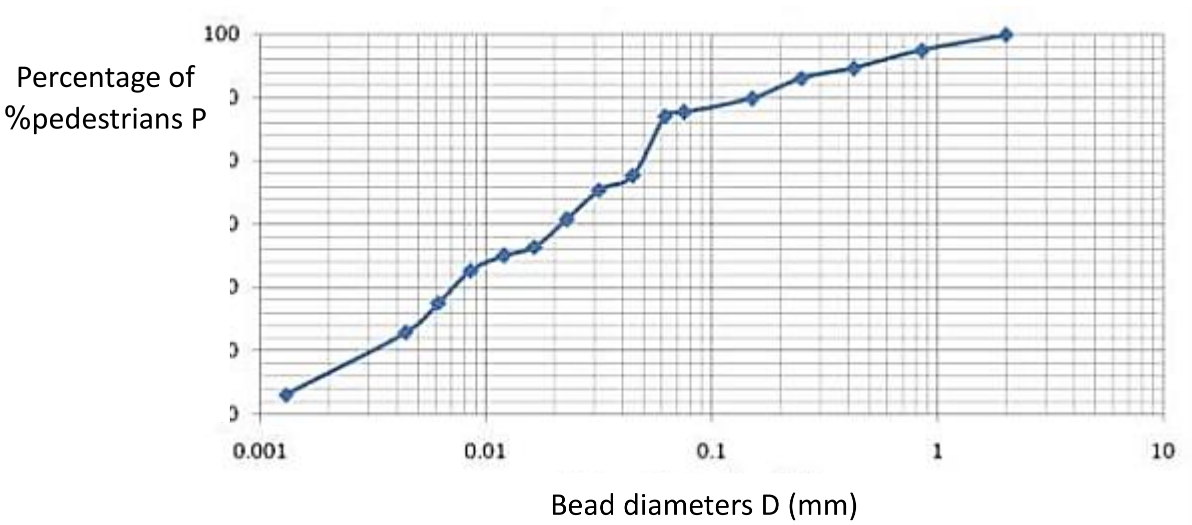

Figure (3) Grain analysis curve for natural soil without lime

Table (3) shows the chemical composition of natural soil and Table (4) the physical and mechanical properties of natural soil.

Table (3) Chemical composition of natural soil %

Calcite	3.40
quartz	4.12
Zeolite	2.61
Hemelite	2.15
Millarite	3.46
Elite	74.14
Kaolinite	10.13
Calcium	0.1
Calcium sulfate	0.16
Dissolved salts	0.24
Organic materials	0.33
pH	8.52

Table (4) Physical and mechanical properties of natural soil

Specific gravity Gs	2.9
Liquidity Limit LL%	72.22
Plastic limit PL%	30.8
Plasticity presumption PI%	42.5
Shrinkage limit SL%	17
Passing through the sieve 200%	87.9
USCS	CH
Natural humidity %	33.6
Dry density Kg/m3	14.8

Cohesion C(KN/m2)	96
Angle of internal friction in degrees	8.6
Relative free swelling in odometer %	5.16
Inflating pressure KN/m2	210

From the swelling pressure we classify the soil as highly plastic turbidity, CH and the primary mineral in the soil are illite.

Method for forming samples for testing lime-amended soil:

The soil was mixed with lime and samples were formed according to (Bulletin 2004):

1- Mix air-dried soil well with increasing percentages of lime 0-1-2-4-6-8-10-12%, determined as a weight value of the dry weight of the soil, then add water to the mixture in appropriate quantities to give moisture to the mixture equal to the natural moisture of the soil. 2- Wrap the mixture in nylon bags to obtain a homogeneous distribution of moisture and place it in covered plastic containers in a humid and safe place so that it is not exposed to high heat or laboratory movements and vibrations for different periods from two days to a month depending on the treatment.

3- Take the mixture out of the storage place and form samples using the dynamic method of density and natural humidity for a period of days under the same experimental conditions for the soil without improvement.

4- Conduct the same soil experiments without improvement on soil with improvement.

Results and discussion:

Study of the effect of lime ratio and time on the Atterberg limits:

This was done for a two-day reaction period for lime, where the liquidity limit experiment was conducted using the Casagrande method and the plasticity experiment with wicks. Different percentages of lime were used from 1 to 12%. Figure (4) shows the curves of the change of Atterberg limits with lime percentages.

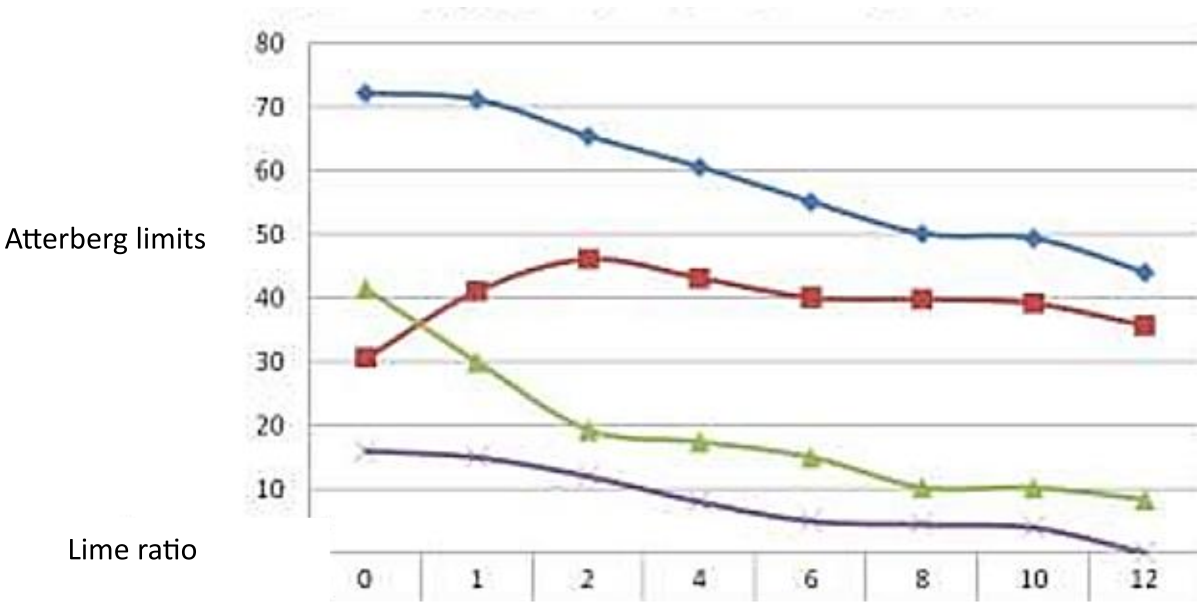

Figure (4) Atterberg boundary change curves (blue is the fluid limit, red is the plasticity limit, green is the plasticity limit, violet is the contraction limit)

It is observed from the curves:

1- A decrease in the liquidity limit with an increase in the percentage of lime up to 8%, then the decrease becomes slight. The decrease in the liquidity limit can be explained by the positive lime ions compensating for some of the cations attached to the surface of the dust atoms, including the polarized water molecules. This leads to a decrease in the thickness of the double layer of water surrounding the vegetable grains and the equalization of the charges. The negative impact on the surfaces causes the structure of the clay to become closer to the flocculent structure, the fluidity of the soil decreases due to the decrease in the thickness of the double layer of water, and the voraciousness of the grains to water decreases due to their charge being equalized by the calcium ions. 2- The limit of plasticity increases with increasing the percentage of lime up to 2%, then it decreases with increasing the lime to 6%, and the decrease becomes slight with increasing lime in higher proportions. It can be explained that the role of lime up to 2% is limited to drying the soil and flocculating the dirt grains, which improves the plasticity of the soil and with the increase of lime. The pozzolanic reaction begins, where the lime forms crystalline bonds with the clay grains and connects them to each other, which leads to an increase in the roughness of the soil and a decrease in the plasticity limit.

3- The shrinkage limit decreases with increasing lime up to 6%, then the decrease becomes slight above this percentage. As a result, the plasticity index decreases with the increase of lime, which reflects the improvement in the plastic properties of the soil treated with lime.

The lime reaction time was also studied from two days to a month in order to determine the lime ratio from 1 to 12% at the Atterberg limits.

Figure (5) shows the effect of the lime reaction time on the Atterberg limits for lime ratios of 8%. Figure (6) also shows the effect for ratios 0-1-2-4-6-8-10-12%.

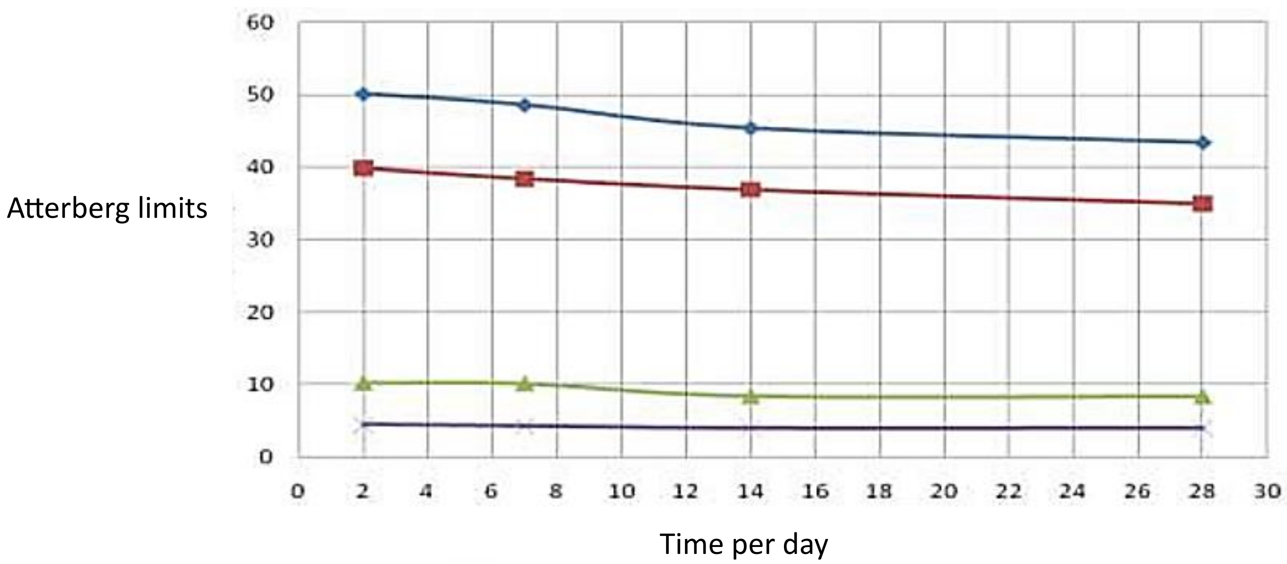

Figure (5) Effect of lime reaction time on the Atterberg limits for 8% lime ratios ((blue is the fluidity limit, red is the plasticity limit, green is the plasticity limit, violet is the shrinkage limit)

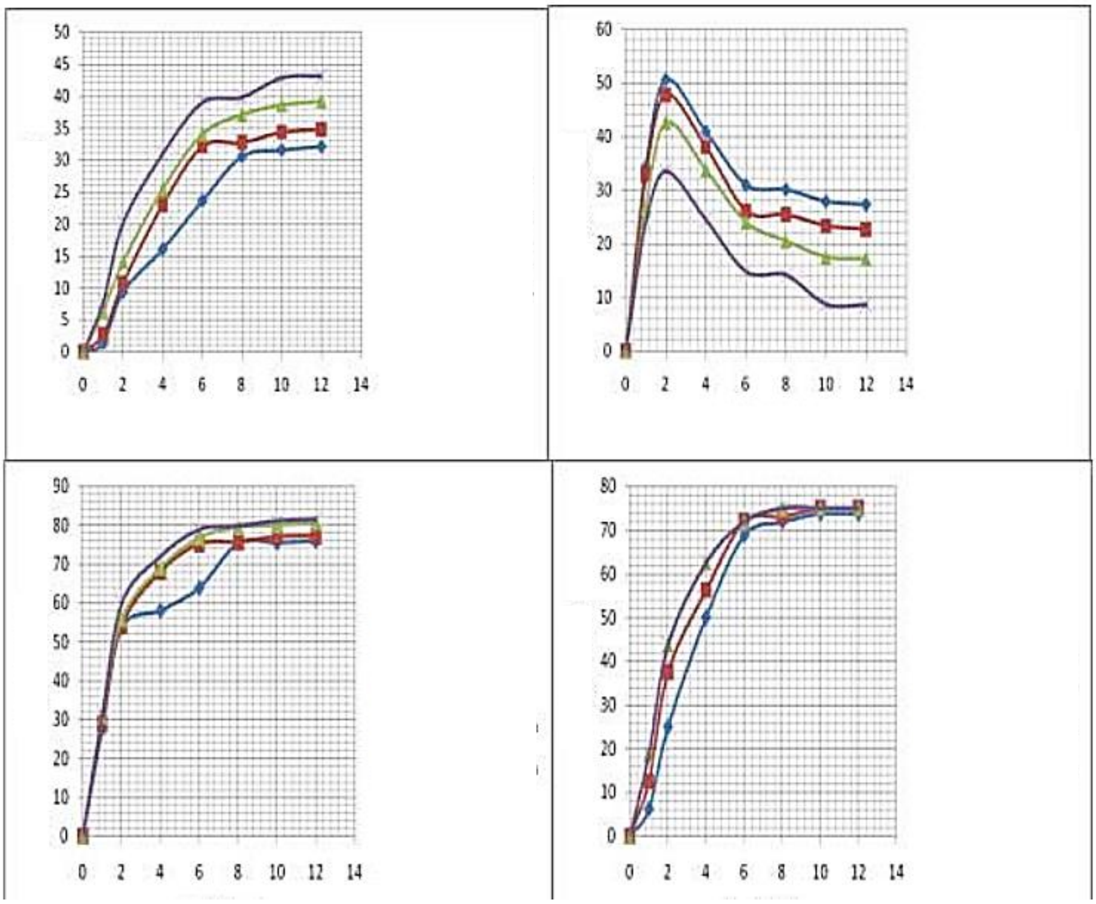

Figure (6) Effect of the reaction time of lime on the Atterberg border, where the horizontal axis is the percentage of lime and the vertical axis is % the rate of change

It is noted that most of the changes in the contraction limit occurred within two weeks, but as for the liquidity limit, it continued for longer periods, and the change in the Atterberg limit becomes slight after the .lime ratio of 6-8%

Effect of lime ratio and time on relative free swelling and swelling :pressure

The study was carried out over a reaction period of two days using 1-4% .lime

Figure (7) shows the curves of change of relative free swelling and swelling pressure with increasing lime proportions

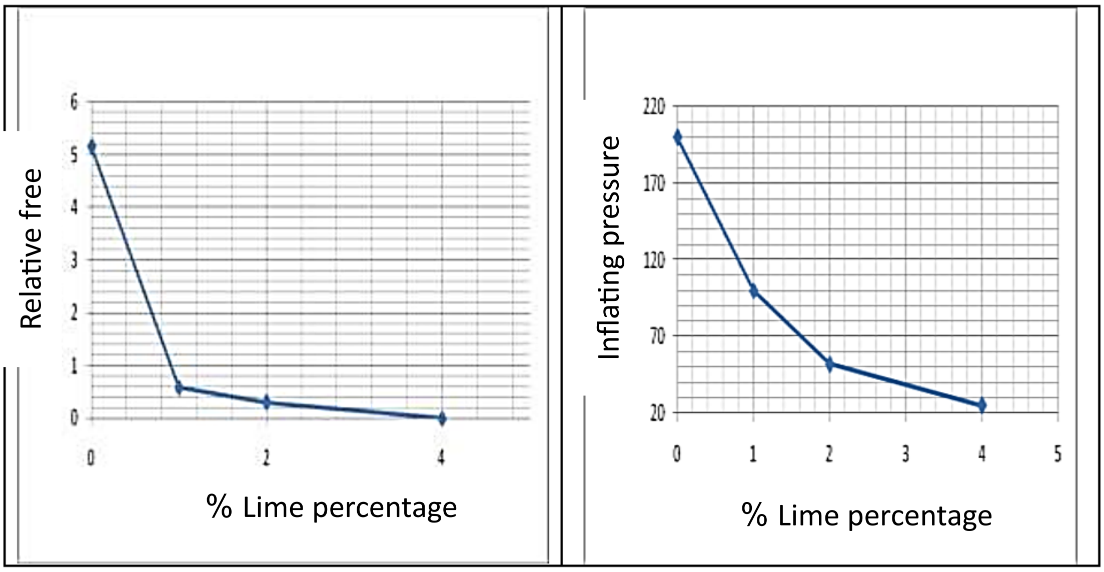

Figure (7) Curves of change in relative free swelling and swelling pressure with increasing lime proportions

It is noted that the ability of soil stabilized with lime to swell and shrink with increasing lime decreases, so that the ability to swell becomes almost non-existent at 4% lime. This can be explained by the fact that lime binds the soil grains together with semi-cement bonds, which increases the strength of the bond between the soil grains and reduces swelling.

Figures (8) and (9) show the effect of lime reaction time on the relative free swelling and swelling pressure for different lime ratios.

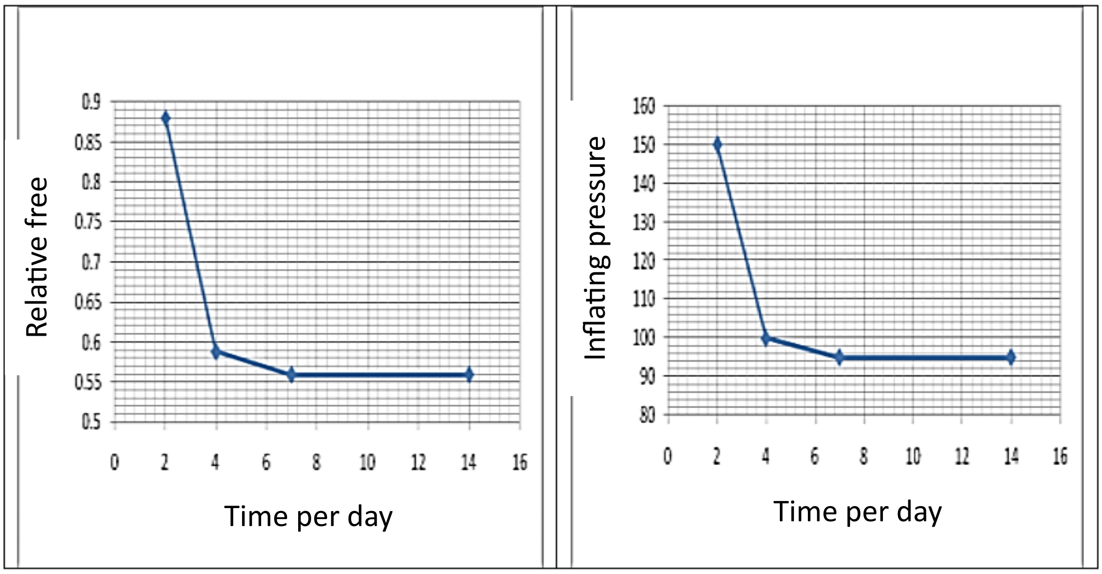

Figure (8) Effect of lime reaction time on relative free swelling and swelling pressure for 1% lime ratios

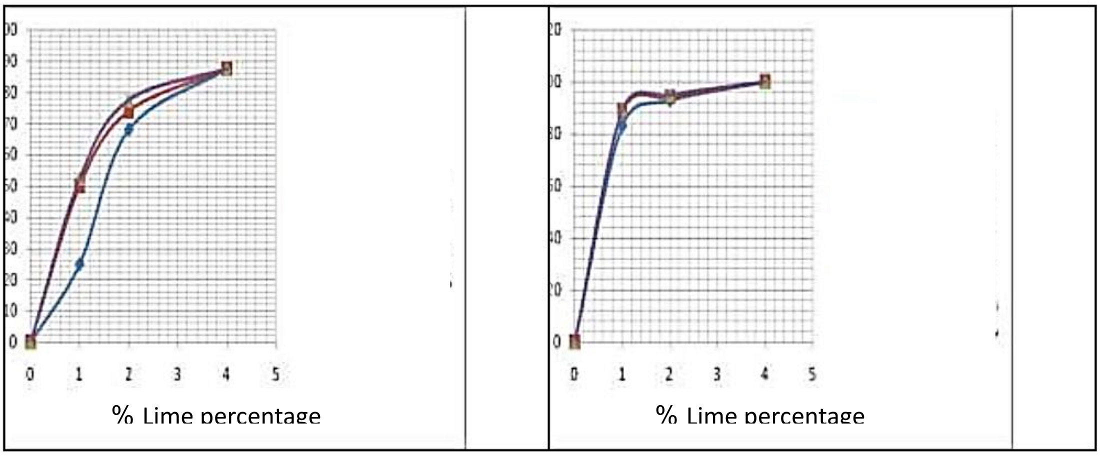

Figure (9) Effect of lime reaction time on swelling coefficients

It is noted that the reaction of lime is rapid and affects the swelling properties within a relatively short time, approximately one week. A week can be sufficient as an ideal period of time to complete the treatment with regard to swelling.

Conclusions:

1- Most of the changes to the contraction limit occurred within two weeks. As for the liquidity and plasticity limit, we needed 28 days to limit the changes taking place.

2-The liquidity limit decreases with the increase of lime up to 8%, then the decrease becomes slight after this percentage.

3- The plasticity limit increases with increasing lime up to 2%, then decreases with increasing lime to 6%, after which the decrease becomes slight.

4-The shrinkage limit decreases with an increase of 6% lime, then the decrease becomes slight above that.

Consequently, the study showed a decrease in the ability of soil stabilized with lime to swell with increasing lime, and its ability to swell becomes non-existent at 4%.

Recommendations:

1-Study of the shear resistance properties of the soil before and after adding lime.

2- Study the angle of internal friction of the soil before and after adding lime.

3-Study of soil cohesion before and after adding lime.

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