Lime Stabilization of Expansive Soil

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Abstract

Expansive soils occurring in arid and semi-arid climate region of the world cause serious problems on civil engineering structures. To avoid such damages prior to construction, expansive clays may be stabilized. Soil stabilization using chemical additives is the oldest and most widespread method of ground improvement.

In this study, hydrated lime was used for stabilization of a laboratory-prepared heavy clays (natural soil +bentonite). The following percentages (٠, ٣, ٦, ٩, ١٢ and ١٥ %) of lime have been added to the expansive soil. A series of laboratory experiments have been implemented (such as consistency limits, grain size distribution, specific gravity, compaction test, and swelling oedometer tests).

The result showed that the addition of lime was effective in improving the swelling behavior of the expansive soil. Lime was therefore found as an excellent choice for stabilization of swelling soils properties.

Key word: *expansive soil, soil stabilization , lime* .

تحسين التربة الانتفاخية بالنورة

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المستخلص

تحدث الترب الانتفاخية في منطقة المناخ الجاف وشبه الجاف من العالم ويمكن إن تسبب مشاكل خطيرة على هياكل الهندسة المدنية. لتجنب مثل هذه الأضرار يتم تحسين الترب الانتفاخية قبل الشروع بالبناء. إن استخدام المضافات الكيميائية هي الطريقة الأقدم والأكثر انتشارا لتحسين التربة .

في هذه الدراسة تم استخدام ألنوره المطفأة لتحسين خواص ترب انتفاخية معده مختبريا وذلك بخلط تربه طبيعيه غير انتفاخيه مع اخرى انتفاخيه (بنتونايت). تم اضافه النسب الاتيه (٠, ٣, ٦ , ٩ , ١٢ و ١٥ %) من النوره الى التربه الانتفاخيه. اجريت سلسله من التجارب ألمختبريه مثل (حدود قوام الطين ,التصنيف الحبيبي للتربه , الكثافه النوعيه , فحص الرص وفحوص الانتفاخ باستخدام جهاز الاودوميتر).

أظهرت النتائج أن إضافة ألنوره كان فعالا في تحسين السلوك الانتفاخي للتربة. وعليه وجد أن ألنوره اختيار ممتاز لتحقيق الاستقرار في خصائص الترب الانتفاخية.

١. Introduction

Expansive soils are those clay minerals which experience significant volume change upon wetting and drying.

Clay particles have a large specific area and electrical forces acting on the surface of the particles are more influential than gravitational forces **[١]**. Montmorillonite is the most expansive type of clay mineral **[٢].** The swell of Montmorillonite occurs due to the poor bond between the stacks of sheets forming the mineral. High osmotic pressure develops and water molecules are absorbed causing the mineral composition to break into ١٠ angstrom thick structural units resulting in the swell of the soil **[٣].**

Factors which affect the swelling of soils are as follows: the initial water content, the type and amount of clay mineral, the initial dry density and percentage of coarse-grained fraction **[٤].**

The parent materials that can be associated with expansive soil could be classified into two groups **[٥];** the first group comprises the basic igneous rock, such as the basalts of the Decca Plateau in India; the second group comprises the sedimentary rocks that contain Montmorillontite as a constituent which breaks down physically to form expansive soils.

In Iraq the expansive soils are dispersivly spread in the middle and north of Iraq causing damages to the structures. The swelling soils causes cracking and break up of pavement, roadways, railways embankment, building foundations, slab on grade members, channel and reservoir linings, water lines and sewer lines **[٦].**

٢.lime Stabilization

The high cost of repairing damaged structures has drawn attention to the need for more reliable investigation of such soils and necessitates method to eliminate, or at least reduce, the effect of soil volume change on the integrity of such structures.

Chemical stabilization with the aid of lime has been proven to be useful in decreasing the volume change of expansive soil **[٧, ٨ and ٩].**

Jones and Jones **[٧]** stated that among chemical stabilization options is: intimately inter mix or blend lime with expansive clays. Where lime is demonstrably reactive with the clay, this reduces the clay shrink / swells potential, enhances its workability under wet conditions, and increases its wet shear strength.

The chemical reaction occurring between lime and soil is quite complex. The stabilization apparently occurs as a result of two processes **[٨ and ٩]:**

In one process, a base exchange occurs with the strong calcium ions of lime replacing the weaker ions such as sodium on the surface of clay particle. Also, the additional non-exchanged calcium ions may be adsorbed so that the total ion density increases. The net result is low base-exchange capacity for the particle with a resulting lower volume change potential.

In other process, a change of soil texture through flocculation of the clay particles takes place when lime is mixed with clays. As the concentration of lime is increased, there is a reduction in clay content and a corresponding increase in the percentage of coarse particles. The reaction results in reduction of shrinkage and swell and improved workability.

٣- Experimental Work

٣-١ Materials

Soil: The soil used in this investigation is prepared by mixing natural soil with commercial bentonite (١:١ natural soil to bentonite by weight). Table (١) shows the physical properties of the soil used. All the tests mentioned in this research were conducted according to the procedure described by **[١٠] and [١١].**

Lime: lime used in this investigation is a commercial lime available in the local market. Soil stabilization by lime involves the admixture of this material in the form of calcium oxide (quick lime) or calcium hydroxide (hydrated lime) to the soil. Calcium oxide may be more effective in some cases; however, the quick lime will corrosively attack equipment and may cause severe skin burns to personal **[٩].** Quicklime will slake in the presence of moisture to produce hydrated lime as a finer powder. The lime used in this study was selected according to ASTM specifications with regard to lime stabilization use (ASTM C٩٧٧-٨٩). This specification requires the use of high calcium hydrated lime Ca(OH)٢.

Table (١): Physical Properties of Soil-Bentonite Mixture

Test	Value	Specification
Consistency Limits:		
Liquid limit, L.L, %	٩٩	BS ١٣٧٧:١٩٧٥, Test ٢ (A)
Plastic limit, P.L, %	٣٠	BS ١٣٧٧:١٩٧٥ Test ٣.
Plasticity index, P.I, %	٦٩	
Specific gravity	٢.٧٢	BS ١٣٧٧:١٩٧٥, Test ٦ (B)
Grain Size Distribution:		ASTM D٤٢١-٧٢ & D٤٢٢-٧٢
Clay, %	٦٧,٥	
Silt, %	١٢,٦	
Sand, %	١٩,٩	
Soil Compaction:		BS ١٣٧٧:١٩٧٥, Test ١٢
OMC (Optimum Moisture Content), %	٢٢	
MDD (Maximum Dry Density), g/cm³	١,٦١	
Description According to Unified Classification System.	CH	

٣-٢ Swelling Test

The untreated and treated expansive soils were compacted statically in the oedometer to specific thickness (١٩mm) and maximum dry density of ١,٦١ g/cm³ with water content of ٢٢٪. The entire assembly is mounted in the consolidation cell and positioned in the loading frame with a nominal surcharge of ٧ kN/m².

Prior to mixing, the soil is first oven dried with (١٠٥-١١٠°C) and then pulverized by passing it on sieve No.٤٠ for consistency limits tests and No.١٠ for oedometer tests. Then distilled water is added to the dry soil, mixed thoroughly by hand and then compacted statically to the mentioned required initial dry density using a loading machine. The lime used, with respect to the stabilized soil, is mixed thoroughly with the prepared soil used (soil+bentonite).

٤-Results and Discussion

٤-١ Effect of Lime on Consistency of Clay

Fig.(١), Fig.(٢) and Fig.(٣) show the relations between lime percent versus liquid limit, plastic limit and plasticity index , respectively.

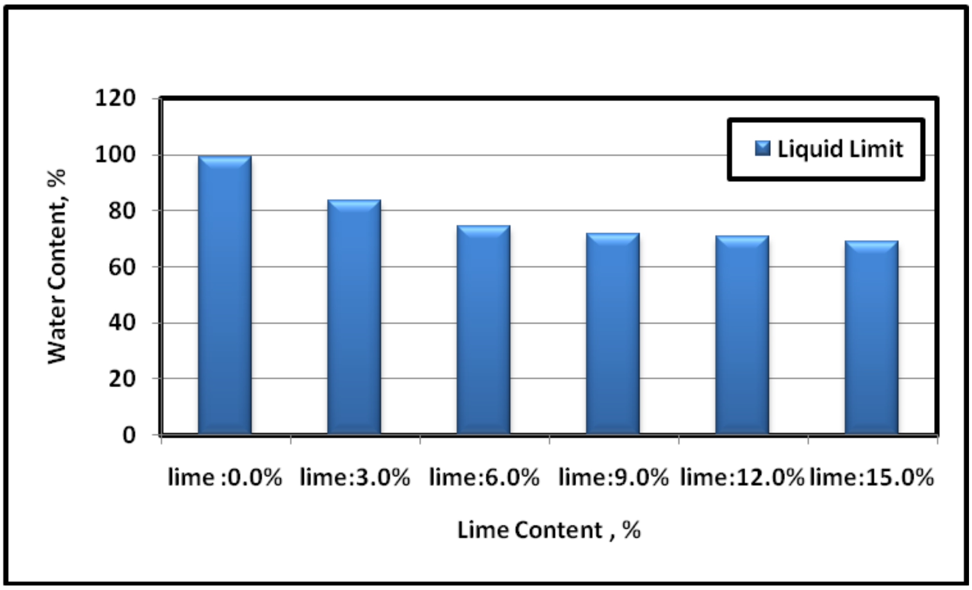

Fig.(١): Effect of lime Content on Liquid limit

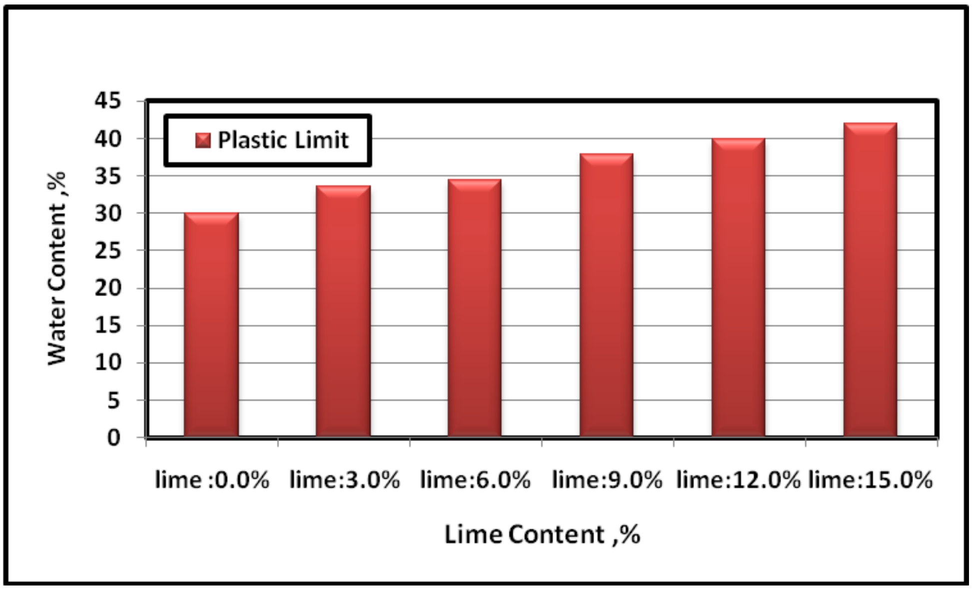

Fig.(٢): Effect of lime Content on Plastic limit

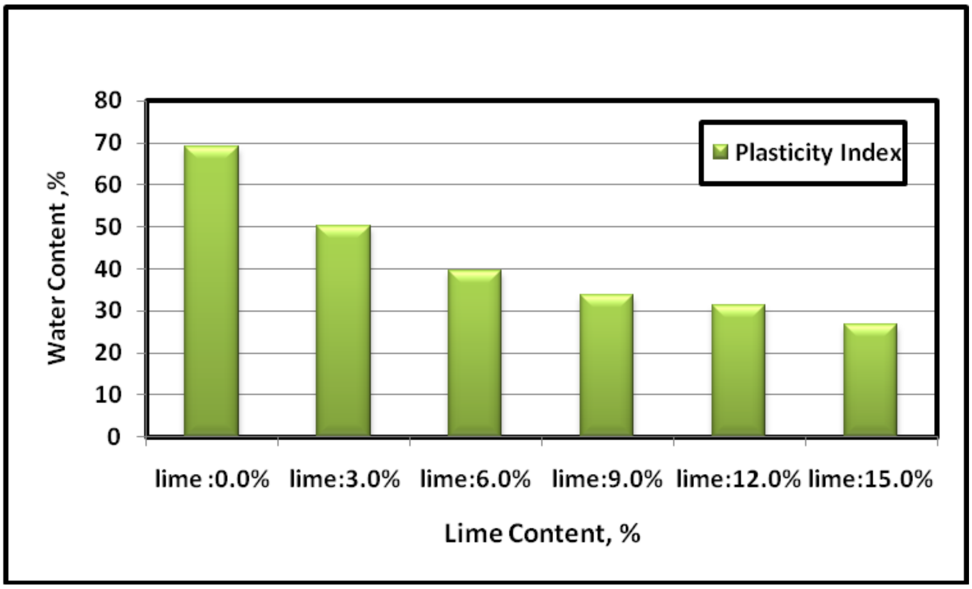

Fig.(٣): Effect of lime Content on Plasticity Index

Fig.(٤) shows the relations between lime percent versus Reduction Factor (R.F, %) for (L.L and P.I).

Al_Omari and Oraibi **[١٢],** defined the Improvement Factor (I.F, %) and / or the Reduction Factor (R.F, %) as: the ratio of {the difference between the value of the untreated sample and that of the treated one} to the value of the untreated sample.

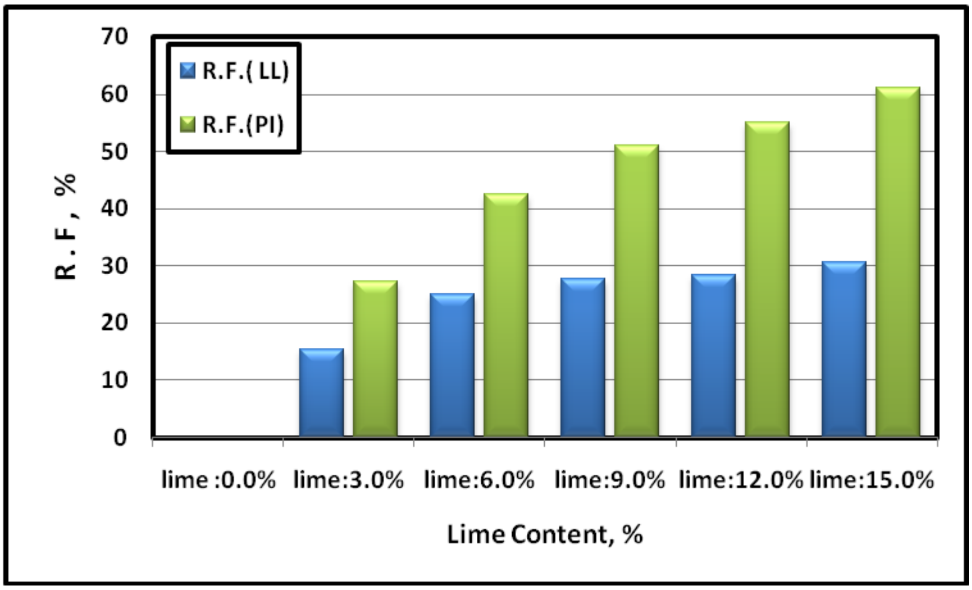

Fig.(٤): Relations between lime Content and (R.F) for (L.L and P.I)

It is shown that as the lime percentage increase both the(L.L) and (P.I) decrease by a reduction factor of (١٥,٤-٣٠,٥٤) for (L.L) and (٢٧,٢-٦١,٠) for (P.I) {Fig.(٤)}. This behavior may be attributed to the reason that the lime can cause a reaction called "cation exchange" where "ions" are positively charged atoms in solution are substituted for other species of ions which are attached to the clay mineral crystals and that lead to decrease the L.L and P.I i.e., the soil suddenly switches from being plastic (yielding and sticky) to being crumbly (stiff and grainy). In the latter condition it is easier to excavate, load, discharge, compact and level. These results confirm the results obtained by **[٩].**

٤-٢ Effect of Lime on Clay and Silt

Fig.(٥) and Fig.(٧) show the effect of lime content on clay and silt respectively, while Fig.(٦) and Fig.(٨) show the relations between lime content versus (R.F) for clay and (I.F) for silt respectively.

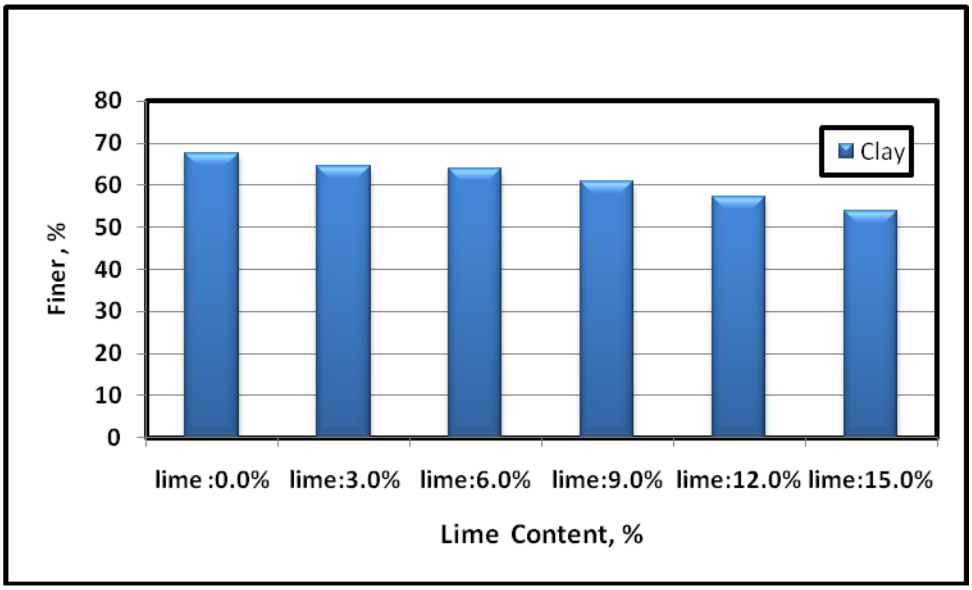

Fig.(٥): Effect of lime Content (%) on Clay Content

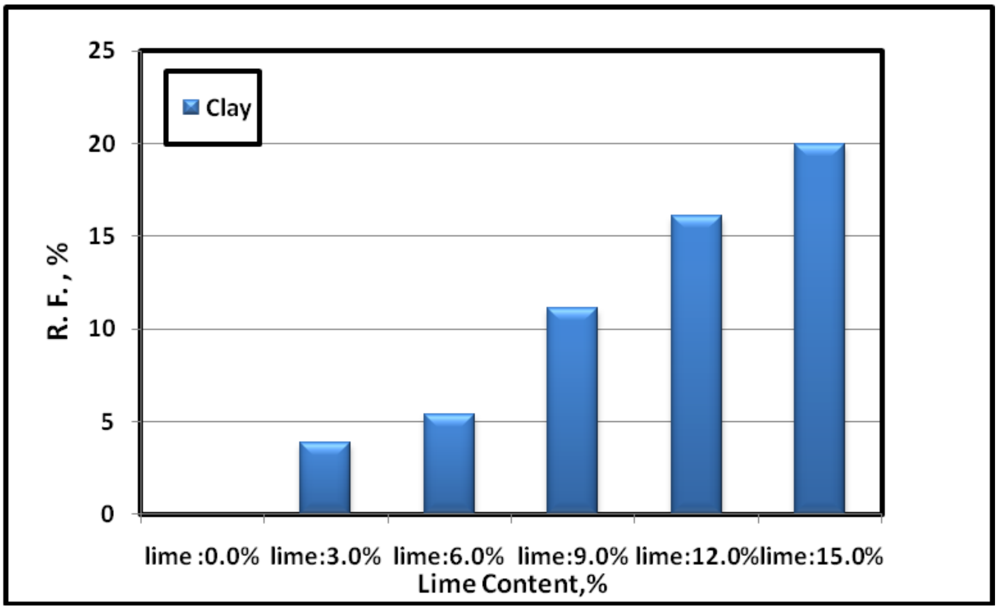

Fig.(٦): Relation between lime Content (%) and R.F of clay, %

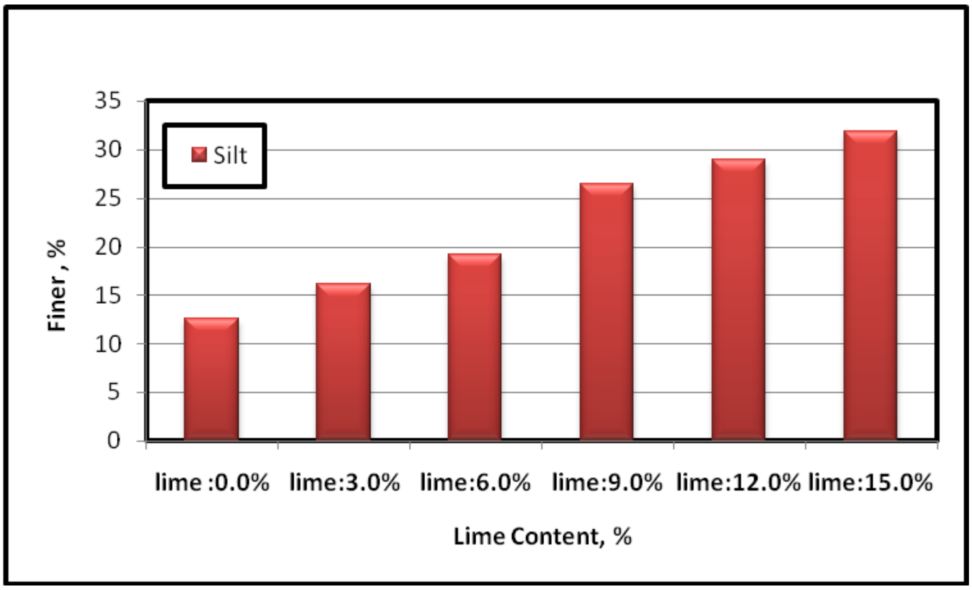

Fig.(٧): Effect of lime Content (%) on Silt Content

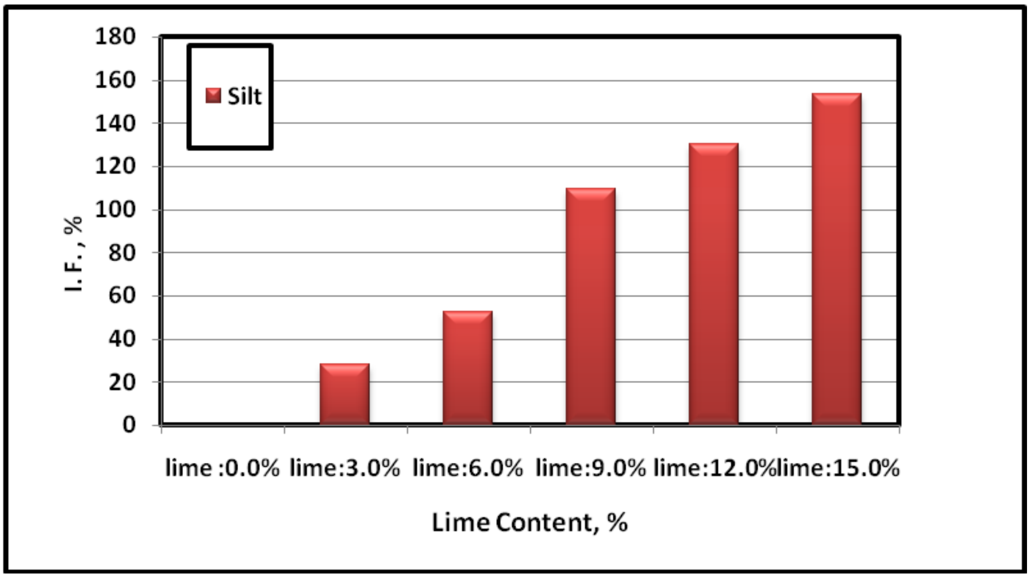

Fig.(٨): Relation between lime Content (%) and I.F of silt, %

It is clear that the clay content reduced and the silt content increased as the lime percent increase. Also, as the lime content increase, both the R.F and I.F for that of clay and silt increase. The reason of such behavior is that the lime treatment of expansive soil causes "flocculation- agglomeration" in which the positive charged ions react with negative charged particles and create other conditions which allow the small clay particles to clump together into large particles (i.e., as lime causes flocculation, a lumping together of clay particles leads to increase their effective grain size causing these particles to inter to the range of the silt).

٤-٣ Effect of Lime on Specific Gravity (Gs)

Fig.(٩) shows the effect of increasing lime content on Gs. Fig.(١٠) shows the relation between lime percentage and R.F of Gs.

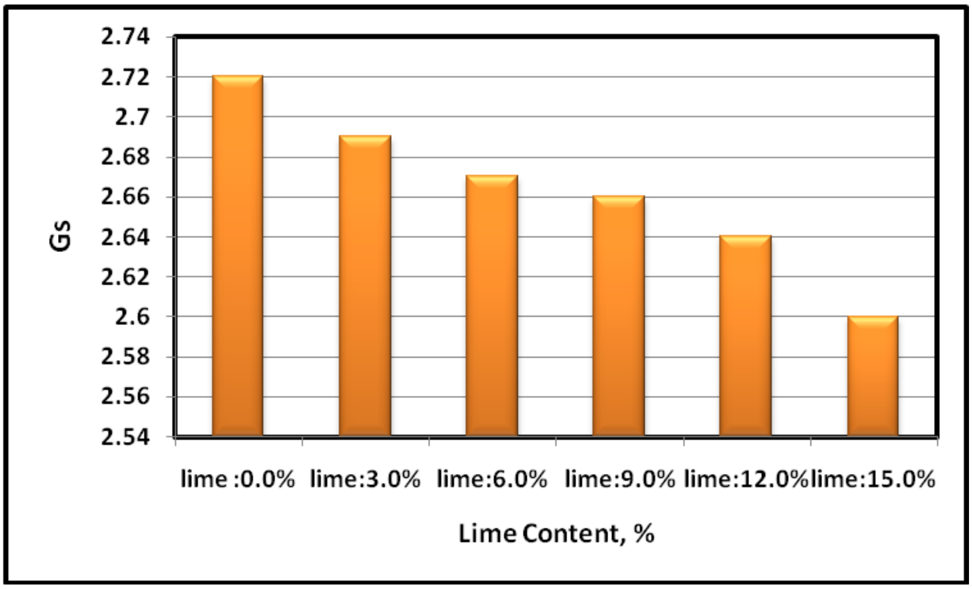

Fig.(٩): Effect of lime Content (%) percentage on Gs

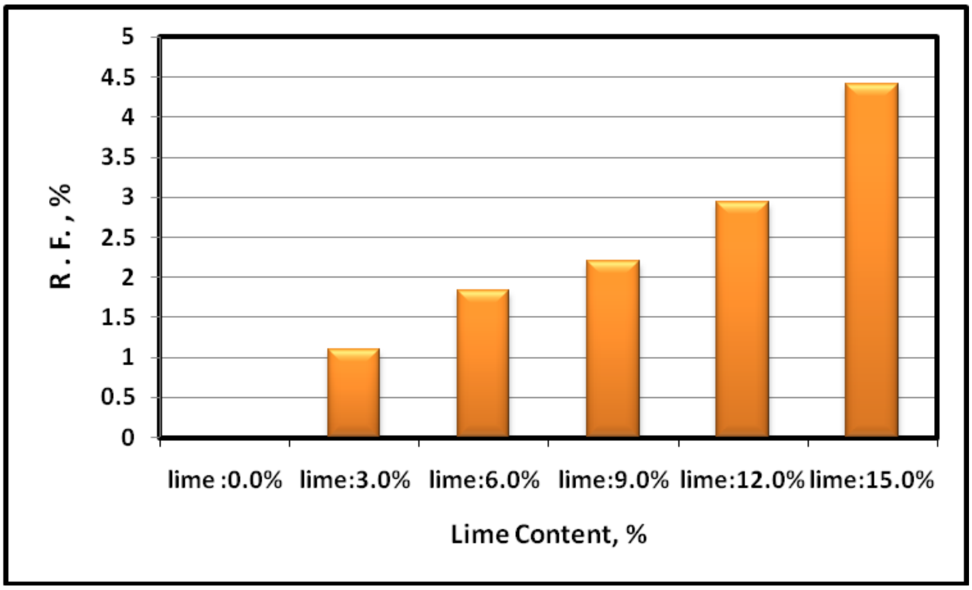

Fig.(١٠): Relation between lime Content (%) and R.F of Gs, %

It is seen that as the lime content increase the specific gravity decrease. The R.F of the specific gravity increase also as the lime content increase. This indicates that the soil is lighter than that of its natural condition.

٤-٤ Effect of Lime on Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

Fig.(١١) and Fig.(١٢) show the effect of lime on maximum dry density (MDD) and optimum moisture content (OMC) respectively.

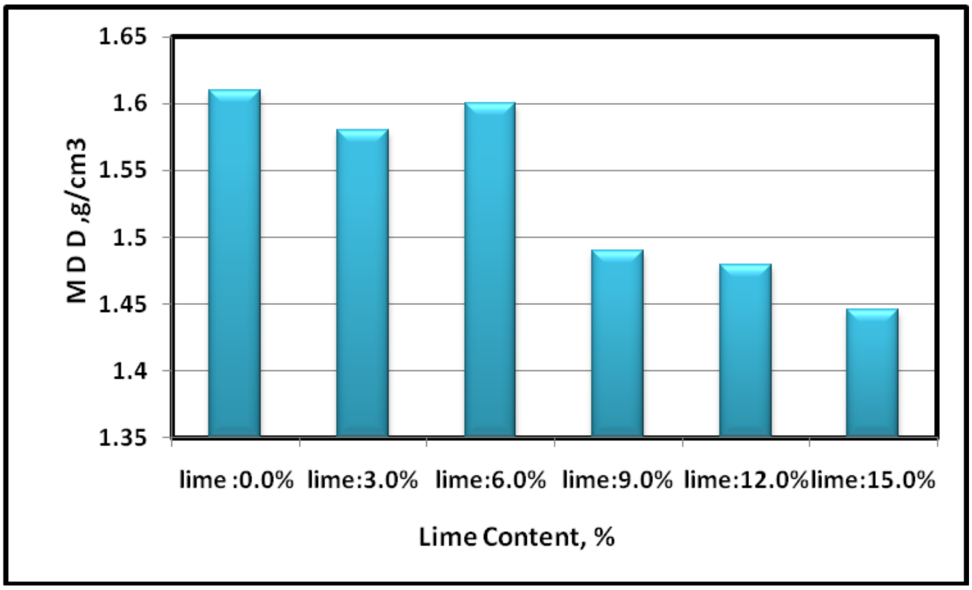

Fig.(١١): Effect of lime Content (%) on Maximum Dry Density (MDD)

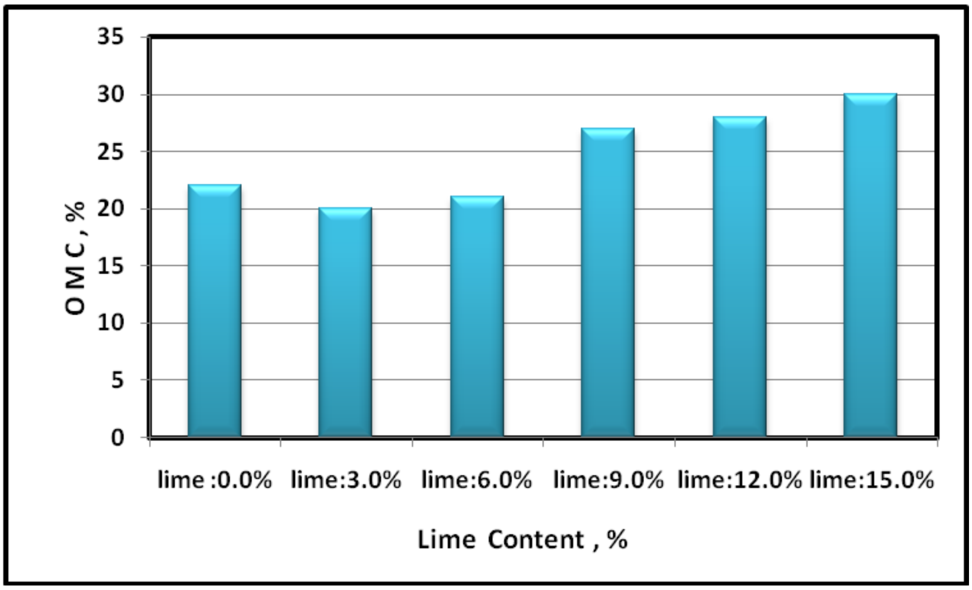

Fig.(١٢): Effect of Lime Content (%) on Optimum Moisture Content (OMC)

The figures show that the MDD drops, while the OMC rises, so that the soil moves into a humidity range that can be easily compacted. This effect is important when used with soil of a high water content, which is common in our areas.

٤-٥ Effect of Lime on Free Swell (%) and Swelling Pressure (Ps)

Fig.(١٣) and Fig.(١٤) show the effect of lime on free swell and swelling pressure (Ps) respectively. Free swell is defined as the increase in volume of the soil from a loose dry powder form when it is poured into water, expressed as a percentage of the original volume **[١٠].**

Swelling pressure (Ps) of clay minerals may be defined as the swelling pressure required to consolidated back a swollen soil to its original volume and / or the pressure required to keep the initial volume of swollen soil constant **[١٣].**

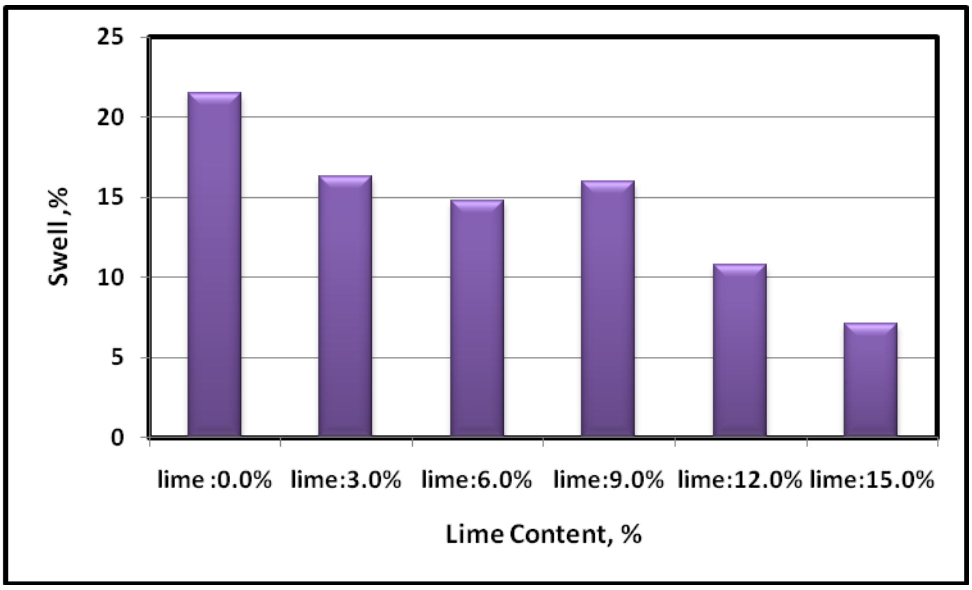

Fig.(١٣): Effect of Lime Content (%) on Free Swell

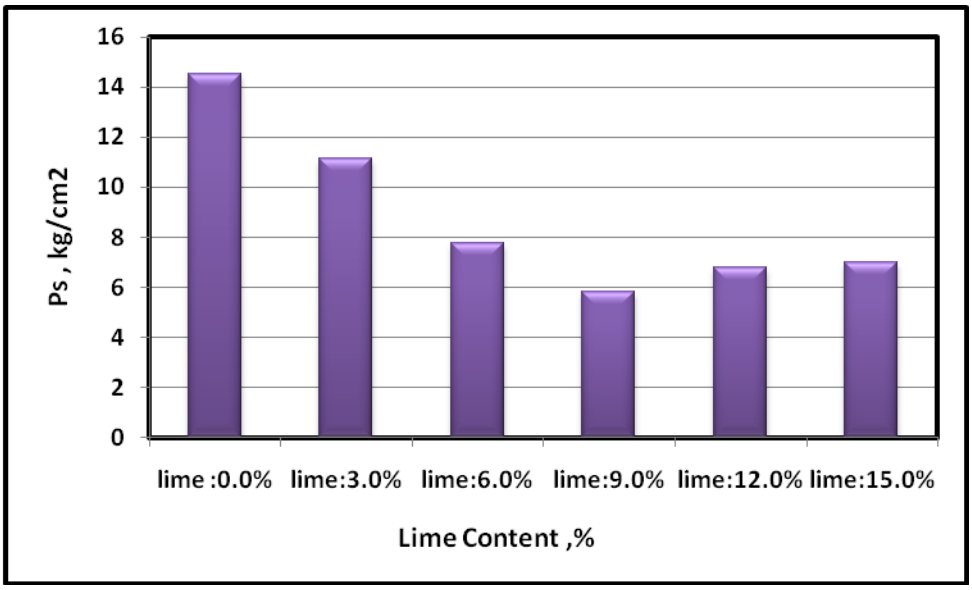

Fig.(١٤): Effect of Lime Content (%) on Swelling Pressure (Ps), Kg/cm²

It`s clear that as the lime content increase both the free swelling (%) and swelling pressure decreased. As mentioned before, the lime treatment of expansive soil cause "flocculation agglomeration" and that cause a reduction in the thickness of the Double layer and consequently in the repulsive force which led to a reduction in swelling and swelling pressure. These results in a good agreement with the results obtained by **[٧]** and **[٨].**

٥ - Conclusions

Generally, lime is found to be most effective in stabilizing heave of expansive soils. The following conclusions may obtain:

١- Lime decreases the liquid limit and plasticity index. The optimum advantage occurs at ١٥٪ lime, where the plasticity index reduced by a factor of about ٦١% and about ٣٠,٥% of that for liquid limit. Plastic limit increases with the increase of lime.

٢- Lime decreases the clay content and increases the silt content .The decreases of clay content ranges from (٣,٨٥-٢٠٪) the increase of silt content ranges from (٢٧,٧٨-١٥٣,١٧٪).

٣- Lime decreases the specific gravity by a reduction factor of about (٤,٤١٪).

٤- Lime decreases the maximum dry density and increases the optimum moisture content. The addition of ٦% causes a slight increase in MDD and then drops. For the optimum moisture content it decreases with ٣٪ and then increases with (٦-١٥%).

٥-Lime reduces the free swell and swelling pressure. Again best enhancement occurs at ١٥٪ lime for free swell where it reduced by about ٦٦٪ for the swelling pressure the lowest value was attained at ٩٪ lime, decreasing it by a factor of about ٥٩٪.

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