EFFECT OF MICROSILICA ON THE SWELLING CHARACTERISTICS OF EXPANSIVE SOILS WITH AND WITHOUT LIME

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Abstract

The chemical additives are one of the most common solutions to stabilize expansive clay. Microsilica is one of these additives used recently to improve the engineering properties of soft and plastic clay. This study investigates the suitability of such additive to improve the swelling characteristics. Moreover, two cases will be examined; the effect of adding (0 - 10) percentages of the microsilica alone and the microsilica in conjunction with lime. The results indicate that, the microsilica has a positive effect on the swelling characteristics especially in the presence of lime. The percent of free swell and swell pressure decreased 24.49% and 34.64% respectively due to adding up to 10% of microsilica. This reduction becomes 53.94% for free swell and 59.75% for swell pressure when added in the presence of 2% of lime. Moreover, approximately 85% of this reduction has been achieved at 4 % of microsilica and 2 % of lime.

تأثير السلكا الناعمة على خواص التربة الانتفاخية بوجود وعدم وجود النورة

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الخلاصة

المضافات الكيميائية واحدة من أهم الطرق المستخدمة لمعالجة التربة الأنتفاخية، السيلكات هي أحد هذه المضافات المستخدمة حديثا لتحسين خواص الترب الضعيفة واللدنة. تحرت هذه الدراسة عن مدى ملائمة هذا المضاف لتحسين خصائص الأنتفاخ، تم أخذ حالتين بنظر الأعتبار، الحالة الأولى تمثل تأثير أضافة ٠ – ١٠ % من السليكا على التربة الأنتفاخية بينما تمت دراسة تأثير السليكا بوجود ٢ % من النورة في الحالة الثانية. لقد بينت النتائج تأثيرا ايجابيا لهذا المضاف على خصائص الأنتفاخ وعلى وجه الخصوص بوجود النورة، حيث أضهرت النتائج نقصانا مقداره ٢٤.٤٩ % في الأنتفاخ الحر ونقصانا مقداره ٣٤.٦٤ % في ضغط الأنتفاخ نتيجة اضافة ١٠ % من السيليكا، بينما أصبح مقدار هذا النقصان ٥٣.٩٤ % للأنتفاخ الحر و ٥٩.٧٥ % لضغط الأنتفاخ عند أضافة ١٠ % من السيلكا و ٢% نورة. من الجدير بالذكر أن ٨٥ % من هذا النقصان قد تم عند اضافة ٤ % من السيلكا فقط عندما خلطت مع ٢ % من النورة.

1-Introduction

The term "Expansive Soils" usually refers to those clay minerals that possess contradictory behavior in consequence of variation in its moisture content in the course of time. The main reason of such behavior is attributed to the environmental conditions that escort its geological formation. There are many factors that control the behavior of expansive soils. This behavior may endanger the structures constructed on such soils and as a result, complex damages are expected.

Generally, the problem of expansive soil may be divided into two parts: First, heave problems, the soil swells as a result of increasing its moisture content causing a high uplifting pressure which may reach 2500 kN/m^2 if swell is not allowed and heave of 1000% if swell is allowed [Jones and Jones, 1987]. Second, shrinkage problems, the soil shrinks as a result of the reduction in its moisture content. Generally, the structures are less susceptible to damage from soil shrinkage than from heave. Therefore, it is more effective to limit heave than to limit shrinkage [Chen, 1975] and [Jones and Jones, 1987]

Chemicals additives for soil stabilization are one of the available successful solutions to improve the engineering properties of expansive soil. Microsilica is one of these additives that used in the chemical stabilization. This additive may used alone [Kalkan, E., 2009] and [Kalkan, E., 2008] or in conjunction with other additives [Bagherpour, I., Choobbasti, J. Asskar, 2007] and [McKennon et al. 1994] such as lime in the soil improvement. However, Lime is one of the most common and traditional chemical additive used for many years ago to; stabilize highly plastic clay soils, prevent the shrinking and swelling characteristics of such soil and to increase the load carrying ability of treated soil [McKennon et al. 1994].

Insufficient data is available to explain the relation between the swelling characteristics of expansive clay and microsilica additive. Thus, the suitability of such additive to improve the swelling property was investigated. Moreover, two cases will be examined; the effect of adding different percentage of the microsilica alone and the Microsilica in conjunction with lime. The performance of microsilica and microsilica-lime with expansive clay was evaluated to develop an alternative method to improve the swelling properties.

The results indicate that, the microsilica has positive effects to improve the properties of expansive soil especially in the presence of lime.

2-Chemical Interaction

MicroSilica, also known as Silica fume, is a byproduct of producing silicon metal or ferrosilicon alloys. It consists primarily of amorphous (non-crystalline) silicon dioxide (SiO2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO_2 content, Microsilica is a very reactive pozzolan when used in presence of the calcium compounds.

The active silica reacts with calcium hydroxide in the clay and forms calcium silicate hydrate gels ($CaSiO3.H_2O$). The basic reaction of microsilica – calcium in clay could be indicated as:

$Ca^{+2} + OH^{-}$ + soluble silica

$\longrightarrow$ calcium silicate hydrate [Kalkan, E., 2009]

They referred that, the material from this reaction became stronger and more brittle than previous form.

In 1994, McKennon, et al. found that the addition of microsilica is an important additive for the control of the formation of deleterious products such as ettringite in sulfate bearing soils stabilized with lime. They found that, by the addition of microsilica the soluble aluminum is significantly reduced and the calcium and silicon are increased. It is a strong indication that the pozzolanic reaction of calcium silicate hydrate in lieu of the development of ettringite is promoted. It has also been noted that the addition of silica significantly increases the level of mixture pH.

The microsilica promotes the formation of calcium silicate hydrates over the formation of calcium aluminate hydrates in the resulting pozzolanic reaction occurring in pozzolanic soils during lime stabilization treatments and by promoting speed of this reaction.

In the second stage of this study, to improve the stabilization process of the expansive clay, lime was added to the natural clay to increase the free calcium.

3- Experimental Work

3-1 Materials

A natural clay where used in this study. This clay is brought from a trial pit at depth 2m below the natural ground surface during the soil exploration for a dam project in Duhook governorate at the north of Iraq. The physical properties of the clay are given in table 1.

Chemical and physical properties of microsilica used as a stabilizer additive may vary significantly in accordance with power plant that produces it.

3-2 Samples Preparation

The soil samples were dried in the oven at approximately (105 - 110) °C before grinding process. Before mixing, the soil is sieved on sieve No. 10 for oedometer-tests and on sieve No. 40 for consistency limits tests. To prepare the mixtures of soil-microsilica and soil-microsilica-lime, first, the required amounts of soil and the microsilica or lime were measured by a total dry weight of soil sample and mixed together in the dry state. The soil-microsilica or soil-microsilica-lime was then mixed with the required amount of water. All mixing was done manually, and great care was taken to prepare homogeneous mixture.

The maximum dry density and the optimum moisture content for the natural clay are adopted for all swelling tests. The optimum moisture contents and the maximum dry density were determined by standard proctor tests. For all oedometer tests, the mixture mixed with 22.32 % of water and statically compacted in the consolidation ring to produce 1.63 g/cm^3 dry density.

It should be recalled here that all the tests mentioned in this research are conducted according to the procedures described by Head, K. H. (1984).

4- Effect of Microsilica on the consistency limits

Atterberg limits of the stabilized soils are determined after a curing time of 24 hours before testing. The effects of Microsilica on the consistency limits are presented in Figure 1, A. The liquid limit and plasticity index values slightly decrease whereas the plastic limit values slightly increase with an increase in microsilica content. The liquid limit decreased from 72.42 to 66.06% and the plasticity index decreased from 48.36 to 38.21% due to addition microsilica up to 10%. The plastic limit increased from 24.06 to 27.83% due the addition up to 10% of microsilica. The reduction in liquid limit may be attributed to cation exchange [Goswami et al. 2005] and the addition of low plastic material to the soil [Atom and Al-Sharif, 1998]. However, the effect of microsilica on the consistency limits becomes more recognized in the presence of lime, Figure 1, B. The liquid limit and plasticity index decreased from 72.42 to 60.23% and from 48.36 to 30.9% respectively. Whereas the plastic limit increased from 24.06 to 29.33% due the addition up to 10% of microsilica. This effect may be attributed to the pozzolanic reactions.

5- Effect of Microsilica on the Swelling Characteristics

The free swell versus time for various microsilica percentage with and without lime content are plotted in Figures 2, A and B respectively. It can be seen that expansive soils need a long period of time to complete their expansion. It shows that the swelling may follow different paths with respect to time for different microsilica-lime percents.

In general, the increase in free swell for expansive soil-microsilica-lime with log time is initially slow, increased steeply, and then reaches an asymptotic value. It can be observed that the time required to reach an asymptotic value varies considerably depending upon the microsilica-lime content. However, presence of microsilica-lime mixture would decrease the permeability of expansive soil and hence increase time to reach the maximum value of free swell. Kalkan, E., (2009) notice that microsilica silica covered the surrounding of silt and clay particles and filled the voids in samples and hence decreases the permeability. Differentiations in swell time behavior are also pronounced by Seed et.al. (1962) and Al-Omari and Oraibi (2000). They attributed such behavior to the differences in permeability.

Figure 3, demonstrates the results of the oedometer tests carried out under identical conditions on compacted specimens. The values of swelling pressure decrease significantly with the increase in the percentage of addition.

In reality, the presence of microsilica-lime with its high pozzolanic reaction with soil is the reason of such reduction in the swell pressure.

The relations between microsilica percent versus free swell with and without lime are plotted in Figure 4. In general, the swell steadily decreased as the microsilica increased. The percent of free swell decreased 24.49% due to adding up to 10% microsilica. Addition of microsilica becomes too effective in the presence of lime. Moreover, a steep reduction in the free swell can be recognized at

4% of microsilica then return steady for the remainder percent. The reduction percent for free swell reached to 53.94% for stabilized soil with 10%microsilica and 2% lime. Moreover, 85.29% of this reduction achieved at 4% microsilica. However, the optimum percent of microsilica is greatly affected by the soil type and the added percent of lime.

The same behavior can be noticed for swell pressure Figure 5. This improvement in the swelling characteristics due to adding the microsilica to the clay-lime mixture may be attributed to the following reasons as referred by McKennon et al. 1994; significant increase of the soluble calcium, promoting formation the silicate calcium hydrate over silicate aluminum hydrate which in turn more strong and increase the pH of mixture to a point at which clay silica and clay alumina are liberated from the silica bearing tetrahedral sheets and the alumina bearing octahedral sheets respectively. As a result, high improvement in pozzolanic reaction emerges.

6- CONCLUSIONS

The effect of microsilica on the swelling characteristics of expansive soil has been investigated. The following conclusions may be drawn;

1- The microsilica slightly decreased the liquid limit and the plasticity index and increased the plastic limit. The reduction in the plasticity index slightly increased when the microsilica is added in the presence of 2% lime.
2- The free swell percent decreases as the microsilica percent increases. The total reduction in the swell percent reached to 24.49% due to adding 10% of microsilica.
3- The swell pressure is more sensitive to the addition of microsilica than the free swell percent. The swell pressure decreased 34.64% due to adding 10% of microsilica.
4- The addition of microsilica becomes more effective on the swelling characteristics in the presence of 2% of lime with the natural expansive soil. Furthermore, the reduction in the free swell percent and swell pressure reached to 53.94% and 59.75% respectively due to adding up to 10% of microsilica.
5- An optimum value of the microsilica additives to stabilize the swelling characteristics can be noticed in the presence of lime. Whereas, 85.29% and 87.15% of the total reduction in swell percent and swell pressure respectively is accomplished at 4% of microsilica with 2% of lime.

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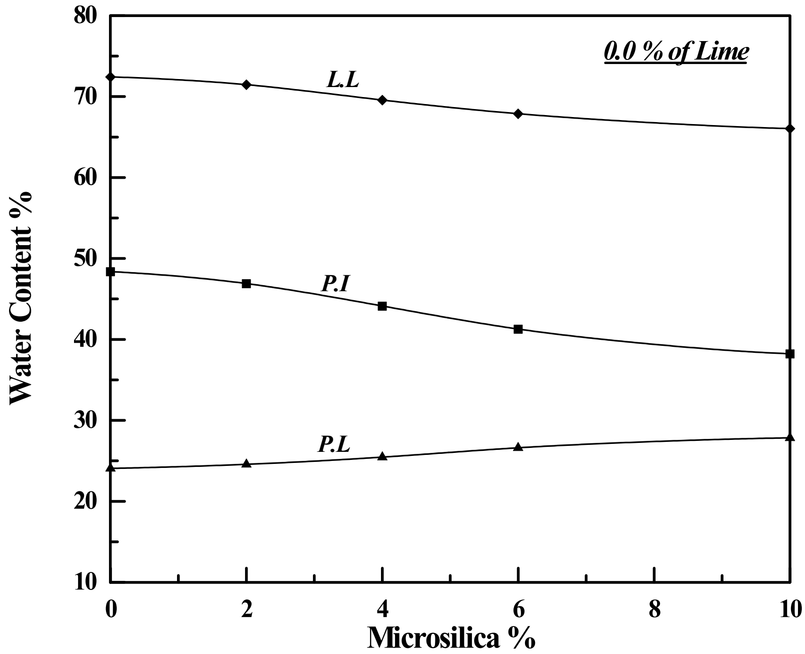
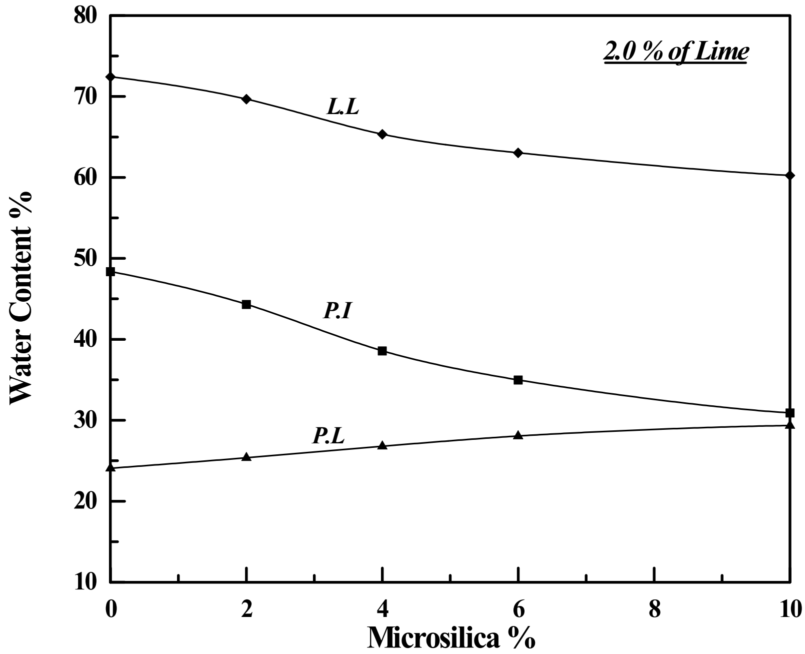
Table 1. The physical properties of the natural clay used in this study

Color	Reddish Brown
Liquid Limits, %	72.42
Plastic Limits, %	24.06
Plasticity index, %	48.36
Unified Soil Classification	CH
Clay, %	67.2
Silit, %	31.1
Sand, %	1.7
Specific Gravity	2.72
Maximum Dry density, g/cm^3	1.63
Optimum Moisture Content, %	22.32

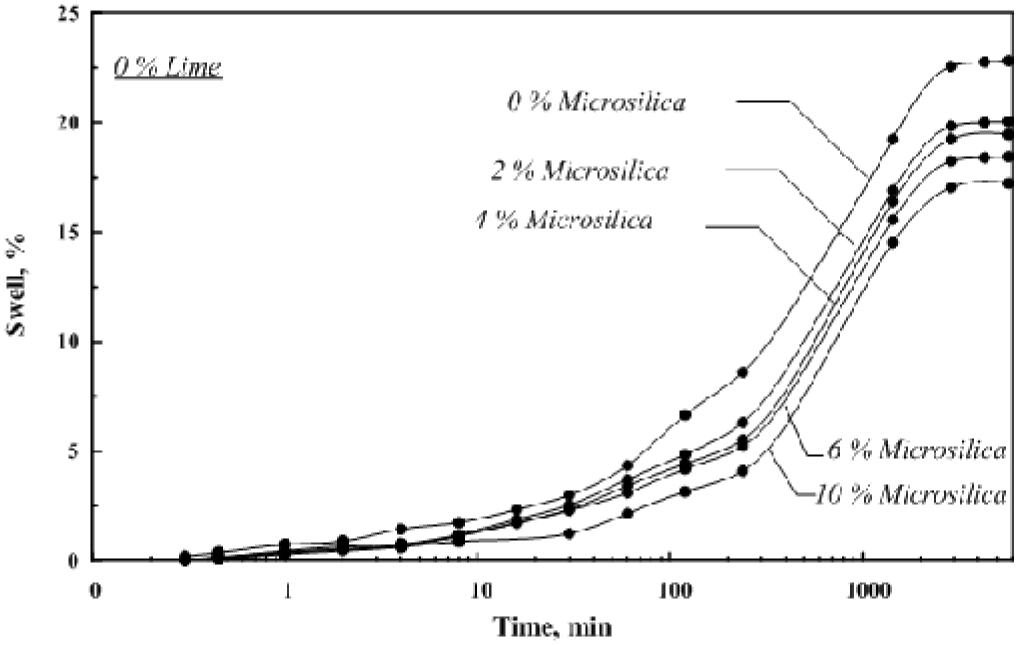


(A)

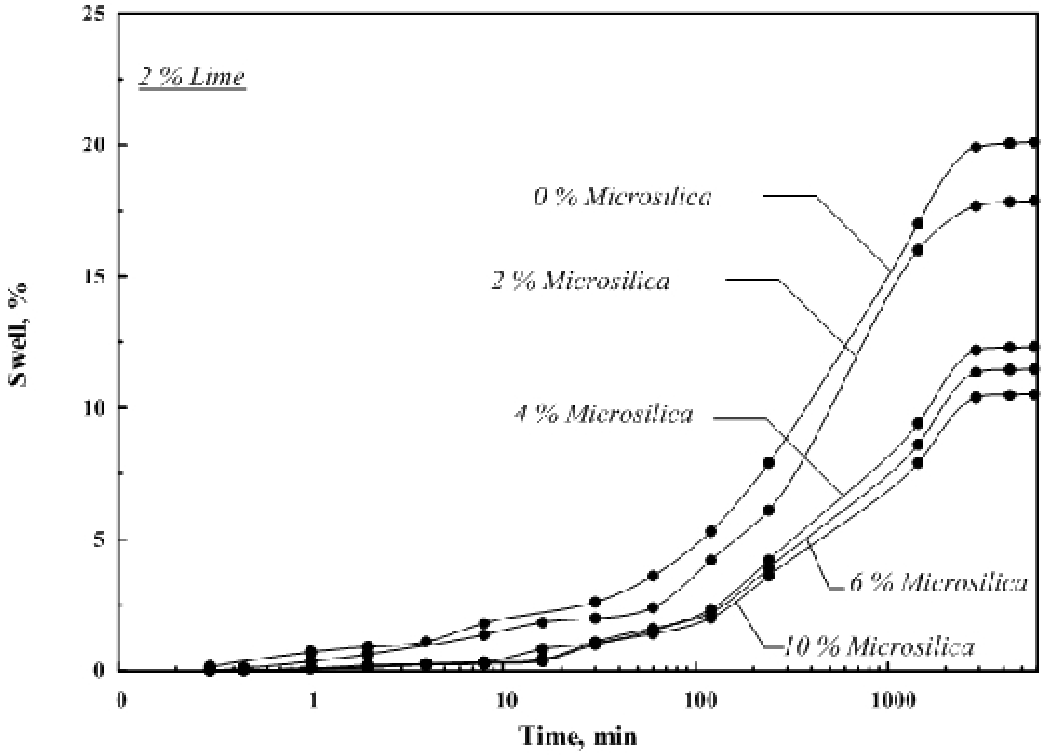


(B)

Fig. (1) Effect of microsilica percentage on Aterberge limits; (A) without lime and (B) with 2% of lime

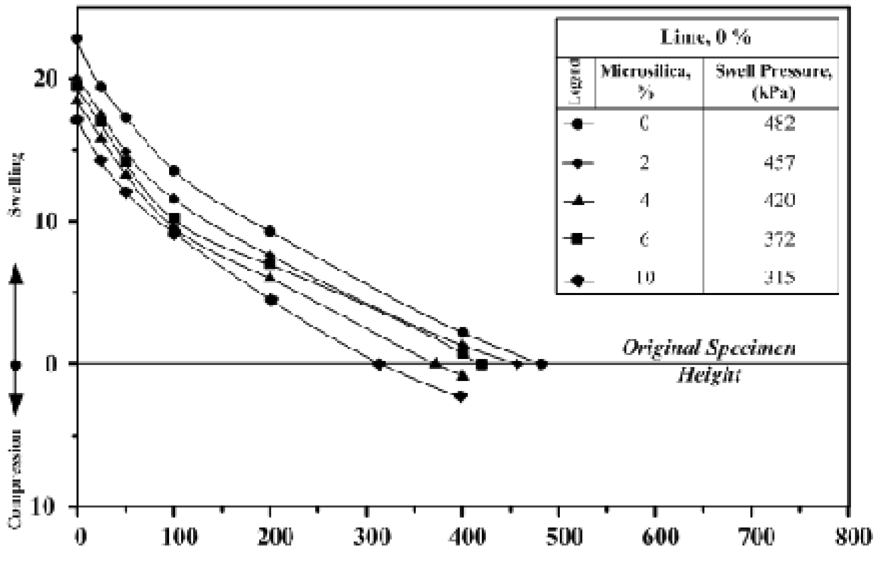


(A)

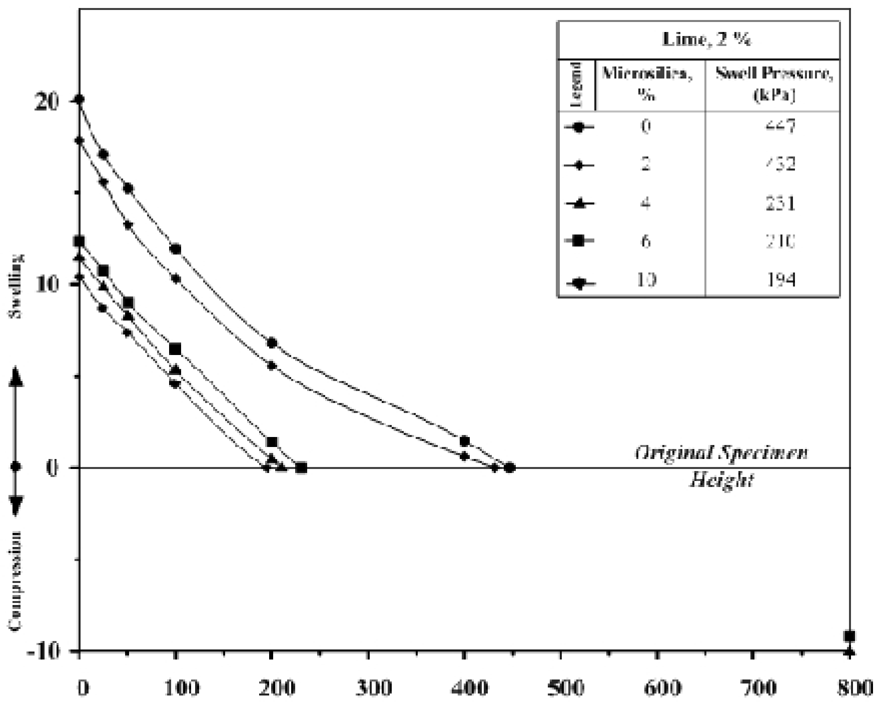


(B)

Fig. (2) Swell-time relationships with different percentages of microsilica; (A) without lime and (B) with 2% of lime



(A)



(B)

Fig. (3) Swell-pressure curves with different percentages of microsilica; (A) without lime and (B) with 2% of lime

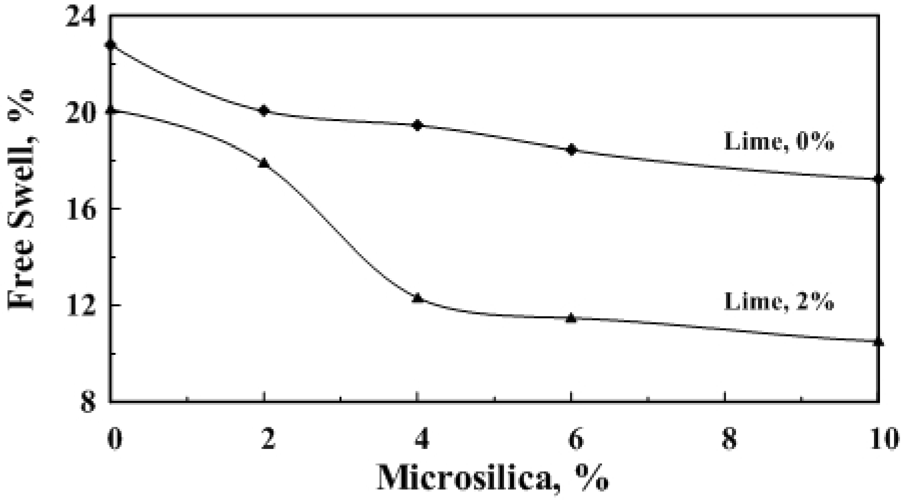


Fig. (4) Free swell-Microsilica relation with and without lime.

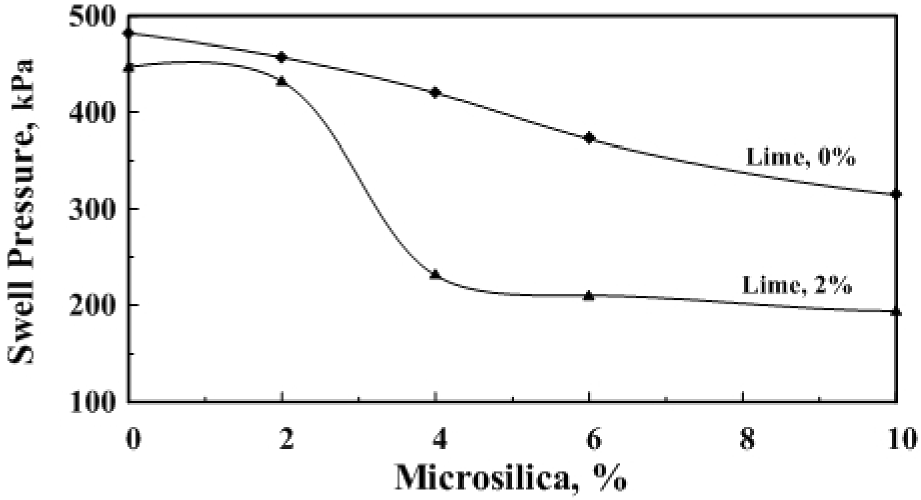


Fig. (5) Swell pressure-Microsilica relation with and without lime.