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Improvement of Gypseous Soil by Clinker Additive

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Abstract

In this paper, mechanical properties were studied for gypseous soil brought up from Al-Axandria region, Babylon Governorate. Gypsum content is equal to (40%). Many tests were employed on disturbed and undisturbed samples collected at depth (1-1.5) m.

Clinker material used in cement was chosen as additive to study its effect on improvement of gypseous soil by using three crushed percentages (2, 4, & 6) %.

The results marked that (4) % clinker decreases the collapsibility sharply; more than 73 % of improvement in collapse potential has been achieved at this percent of clinker. Also, compressibility decreases with increase of clinker percentage. The compression index decreased from 0.17 to 0.1 (29 – 41% reduction with increases of clinker).

The shear strength parameters of the treated soil determined by direct shear test are more those than for natural soils due to increase in the cohesion and decrease in angle of internal friction.

Keywords: Gypseous soil, soil treatment, collapsibility, problematic soils, clinker.

تحسين التربة الجبسية باستخدام مضاف الكلنكر

الخلاصة

في هذا البحث تمت دراسة الخصائص الميكانيكية لتربة جبسية جلبت من الإسكندرية في محافظة بابل ذات محتوى جبسي يبلغ (40)%. اجريت عدة فحوص مختبرية على نماذج مشوشة وغير مشوشة جمعت على عمق (1-1.5) م.

اختيرت مادة الكلنكر المستخدمة في صناعة الأسمنت كمضاف لدراسة تأثيره علي التربة الجبسية وأضيف إلى التربة بثلاثة نسب (2 ، 4 و 6)% بعد طحنه ليلائم تدرج التربة. ومن خلال تحليل نتائج الفحوصات تم الاستنتاج بان نسبة (4%) من الكلنكر تؤدي إلى تقليل الانهيارية بشكل ملحوظ وتقليل قابلية التربة على الانضغاط, حيث قلت حدة الانهيار بنسبة اكثر من 73%. بينما تراوح النقصان في مؤشر الانضغاط بين (29 – 41)% من قيمته الاصلية .

كذلك بينت نتائج فحص القص المباشر بان مقاومة القص للتربة المعالجة بالكلنكر هي اكبر من مقاومة القص للتربة المعالجة نتيجة زيادة التماسك ونقصان زاوية الاحتكاك الداخلي.

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1. Introduction:

Large areas of the earth's surface are covered by soils that are susceptible to large decreases in bulk volume when they became saturated. Such materials are termed collapsing soils. Collapse may be triggered by water alone or by saturation and loading acting together.

In most cases, the deposits are characterized by loose structures of bulky grains, often in the silt to fine sand size range. In residual soils, collapsible grain structures form as a result of leaching of soluble and colloidal material. Water and wind deposited collapsing soils are usually found in arid and semi arid regions.

Gypseous soils are usually considered to be problematic and exhibit unpredictable behaviour, which could cause significant troubles concerning civil engineering, (Seleam, 1988). Therefore, many researchers studied the behaviour of such soils and suggested different materials as additives for improvement, such materials are barium chloride, carbonates components, lime and kaolin. (Al-Busada, 1999, Al-Neami, 2000, Al-Badran, 2001, Al-Beiruty, 2003).

2. Experimental Program

Several laboratory tests are employed on disturbed and undisturbed samples to describe the soil properties of soil study. The tests were embodied the following:

2.1 Physical tests: involve soil classification (specific gravity, relative density, Atterberg limits, and grain size distribution), All tests were carried out according to the ASTM specification except the specific gravity which was carried out according to the British Standard (BS:1377:1975) (white spirit was used instead of distilled water).

2.2 Chemical tests: comprise the total soluble salt (TSS), sulphate content (SO_3), and gypsum content ($CaSO_4.2H_2O$). These tests were performed according to the US agriculture Handbook No. 60.

2.3 Mechanical tests: Three types of tests are used. Collapse test (procedure of Jennings & Knight, 1975), and double oedometer test to identify the collapsibility and direct shear test to obtain the shear strength parameters of soil study. The last tests were determined according to the ASTM 2435 specifications.

3. Results and Discussions

The results of soil classification showed that the soil is poorly graded sand (SP) with gypsum content equals (40%) with low specific gravity (2.35). Figure (1) and Table (1) summarized the grain size distribution and physical and chemical analyses respectively which were employed on soils study.

The results of collapse test are plotted in Figure (2) which shows the relationship between the void ratio and applied pressure. The collapse potential is calculated according to the definition of Jennings and Knight (1975) in which:

$$Cp = \frac{\Delta e}{1+e_o}\times 100 \quad ....(1)$$

Where:

Δe = difference between void ratio before and after soaking of sample.

e_o = initial void ratio.

It can be concluded that the collapse potential (Cp) equals (10.6). According to the classification of

Clemence and Finber (1981) for gypseous soil depending on (Cp), the soil is considered as a trouble.

The evaluation of compressibility parameters of gypseous sandy soil has always been a problem of major interest to the geotechnical engineers and researchers.

It can be seen that the sudden settlement took place upon flooding in water. The settlement can be observed as vertical lines in figure, and this indicates that the soil is collapsible.

Figure (2) illustrates (void ratio – log P) relationship. It can be seen that at first stage (dry state) a little strain is take place but after adding water a rapid increase in strain occurs due to the destruction of intergranular bonds (cementing bonds), and this leads to instantaneous and large compression (vertical line).

Also, the collapse potential was identified by double oedometer test. So, two identical specimens for soil were tested independently, one in dry state and the other was soaked by water. Collapse potential represents the difference between the two tests at each stress level. Typical results of double oedometer tests of the soil are shown in Figure (3).

The shear strength of soils is an important aspect in many foundation engineering problems such as the bearing capacity of shallow foundations and piles, the stability of slopes of dams and embankment, and lateral earth pressure on retaining walls. Therefore, the shear strength parameters of soil are studied and they were defined by utilizing direct shear tests.

In this test, the angle of internal and cohesion were measured and to be (35.5^o) and (7.5 kPa) respectively. It is worthy noting that the samples were remoluded in the metal shear box at the same field dry unit weight (15.25 kN/m^3).

Ø Effect of Treatment on Soil Properties

For treatment of the soil, clinker material used in cement manufacturing was chosen. Clinker is consisting mainly of lime, silica alumina and iron oxide. The compounds of clinker are listed in Table (2).

Three percentages of clinker additive had been chosen (2, 4 and 6) % to investigate the effect of this material on the behaviour of gypseous soil (especially, for reducing the compressibility, collapsibility and increasing shear strength). Clinker additive was crushed at first, and then passed from sieve # 200 to be compatible with the soil gradation.

Figure (4) illustrates the effect of clinker material on collapsibility of the soil under 200 kPa applied stress. It was found that the collapse potential decreases sharply at (2) % clinker and continues in decrease with (4%) clinker, but at (6%) clinker, the collapsibility represented by collapse potential returns to increase with a little value. This may be due to filling the voids in the soil skeleton by clinker material, which increases the cementing bonds between particles and decreases the solubility of gypsum. The same behaviour can be observed in the results of double oedometer test shown in Table (3).

To give a clear picture about the variation of compressibility characteristics with the treatment, the compression index is plotted against the clinker content as shown in Figure (5). It can be seen that the values of the compression index of the samples decrease with the increase of the clinker content.

Also, the stress – void ratio relationships of the treated soil are plotted in the Figures (6) and (7) for soaking and unsoaking samples. It can be seen the most advantage was achieved at 4% clinker in both cases.

The results of shear strength achieved by direct shear strength test of soil treated with (2, 4 and 6%) under different normal stresses (100, 200 and 400 kPa) marked increases with an increase of the clinker additive due to increase of cohesion and decrease of friction as shown in Figures (8) and (9).

A comparison between the results of compression index of the treated and untreated soils considered in this study and previous studies is plotted in Figure (10). Two studies were selected for comparison; the first study had been done by Al-Busoda, (1999) which treated the gypseous soil with 2.5 % and 5 % dehydrate calcium chloride ($CaCl_2.2H_2O$) as a chemical additive. The second study had been carried out by Al-Neami, (2000) who treated the soil with kaolin material as a natural additive.

The comparison shows that the treatment of gypseous soil with clinker improve the compressibility in a good manner as compared to other methods of treatment.

4. Conclusions

The following conclusions can be drawn from the study:

1. The treatment of sandy gypseous soil with 4 % of clinker material represents the optimum percentage which gives more advantage comparing with other percentages which used in this research.
2. The collapsibility of gypseous soil in this study decreases more than 73% when adding (4%) clinker after crushing and passing sieve #200 and mixing with soil.
3. The compression index shows a decrease (in between 29 – 41%) with increase of clinker additive in gypsouse soil.
4. Increase in clinker percentage in the soil leads to increase in the shear strength due to increase in the cohesion and reduction of the friction.
5. Double oedometer test gives uniform results of collapse test in spite of the difficulty in preparing specimen for the test.

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Table (1) The properties of the soil under study.

G_S	LL	PL	Passing #200	USCS	Field Unit Weight (kN/m^3)	Max. Unit Weight (kN/m^3)	Min. Unit Weight (kN/m^3)	Relative Density (%)
2.41	NP	NP	5	SP	15.25	17.55	12.1	75%
SO3 (%)			Gypsum content (%)			T.S.S (%)		
18.2			40			42.35		

Table (2) The compounds of clinker.

Name of compounding	Composition
Tricalcium silicate	$3CaO.SiO_3$
Dicalcium silicate	$2CaO.SiO_3$
Tricalcium Aluminates	$3CaO.Al_2SO_3$
Tetra Calcium alumina iron	$4CaO.Al_2O_3.Fe_2O_3$

Table (3) Results of double oedometer test for treated soil at 200 kPa applied stress

Clinker %	Cp %
0	10.3
2	7.8
4	2.4
6	5.9

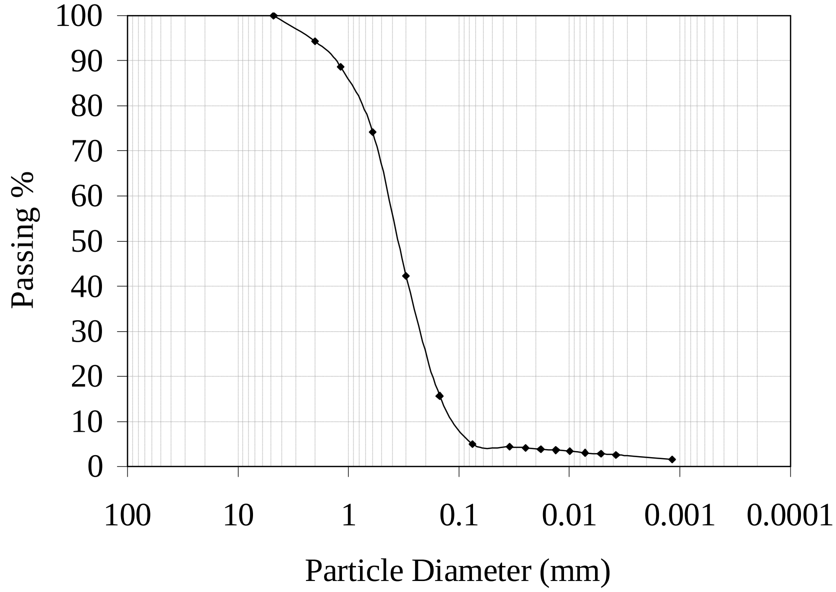

Figure (1) – Grain size distribution for the natural soil.

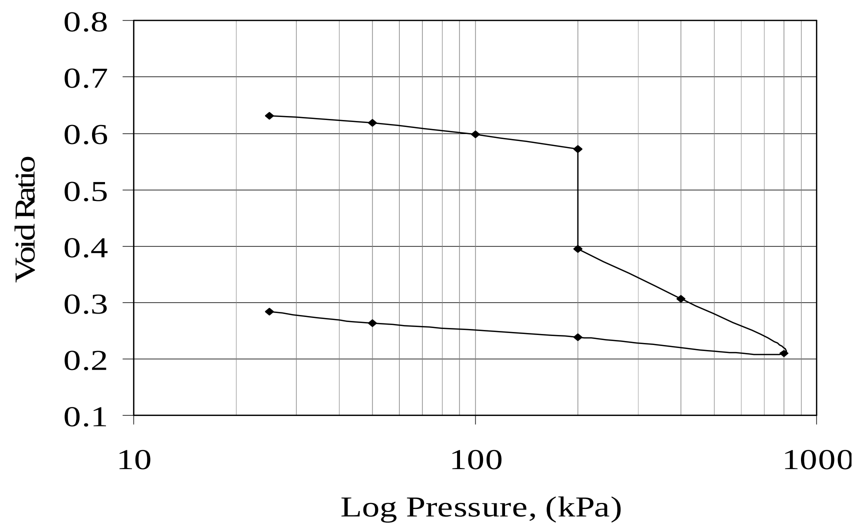

Figure (2) Results of collapse test for the natural soil.

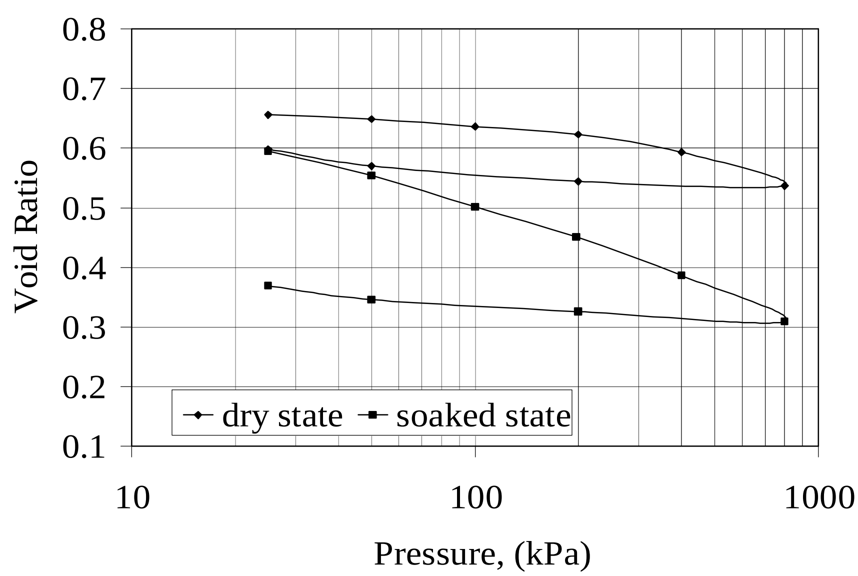

Figure (3) Results of double oedometer test for the natural soil.

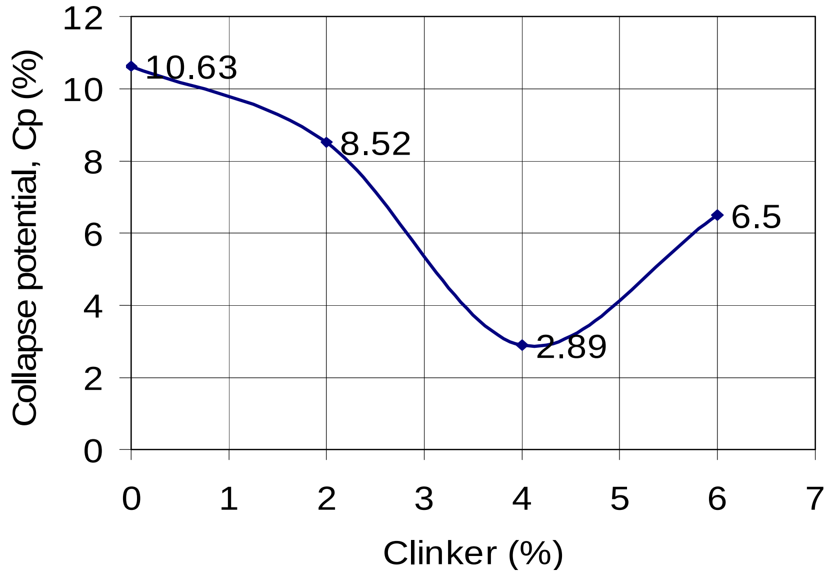

Figure (4) Effect of clinker materials on collapsibility under 200 kPa.

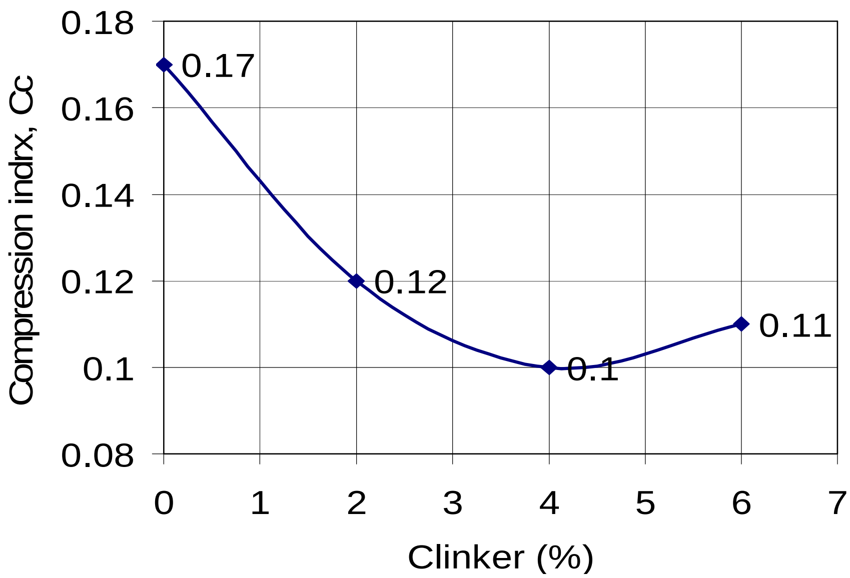

Figure (5) relationship between clinker percent and compression index.

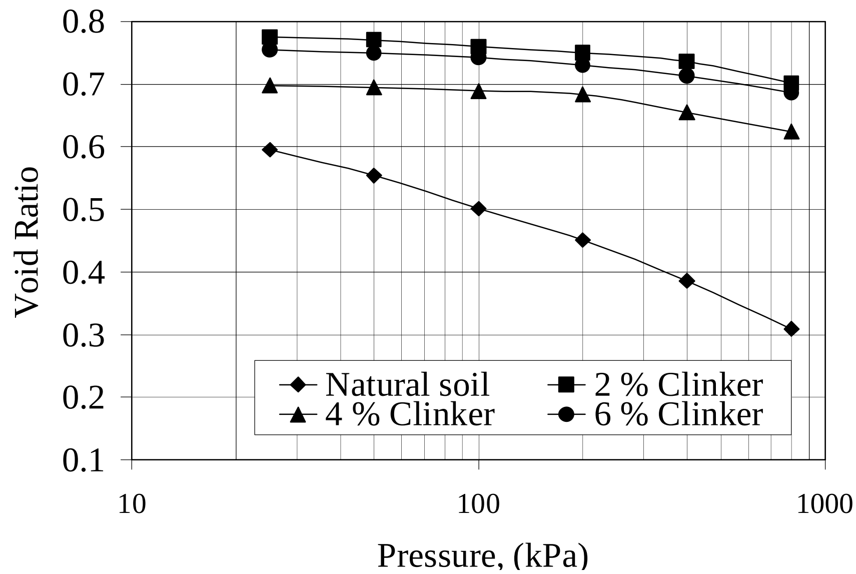

Figure (6) Applied stress vs. void ratio at soaking state.

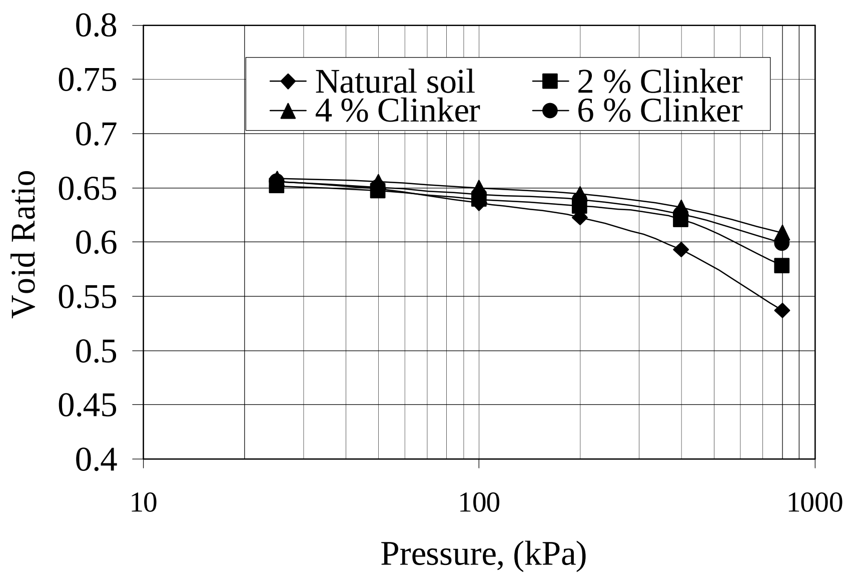

Figure (7) Applied stress vs. void ratio at unsoaking state.

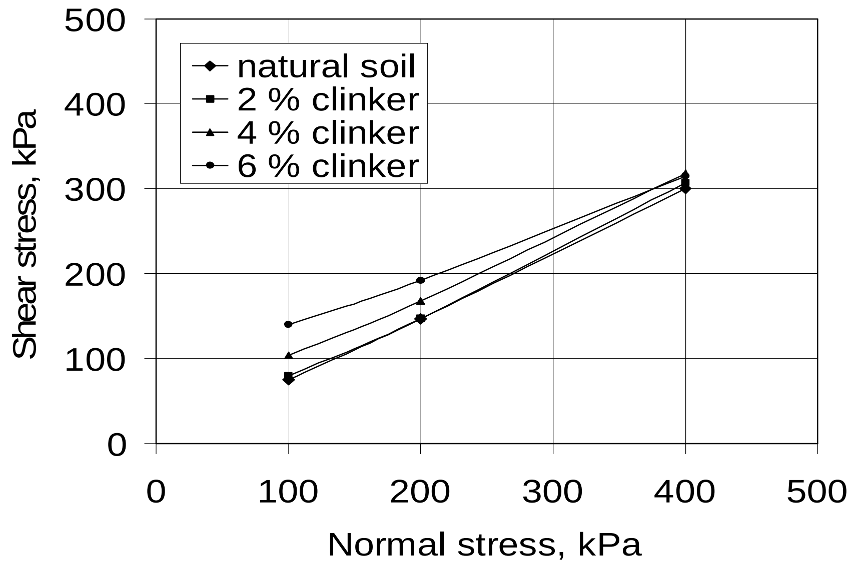

Figure (8) Results of direct shear tests.

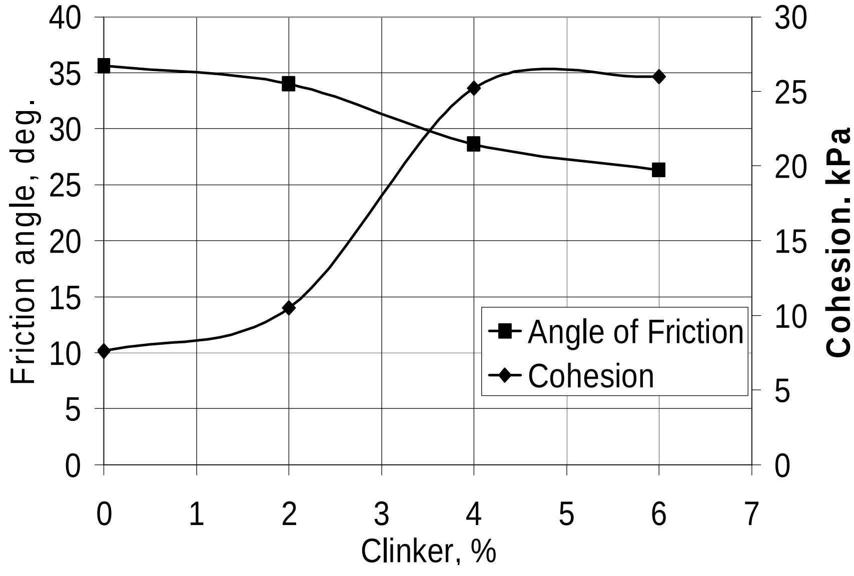

Figure (9) Variation of **shear strength parameters with clinker material.**

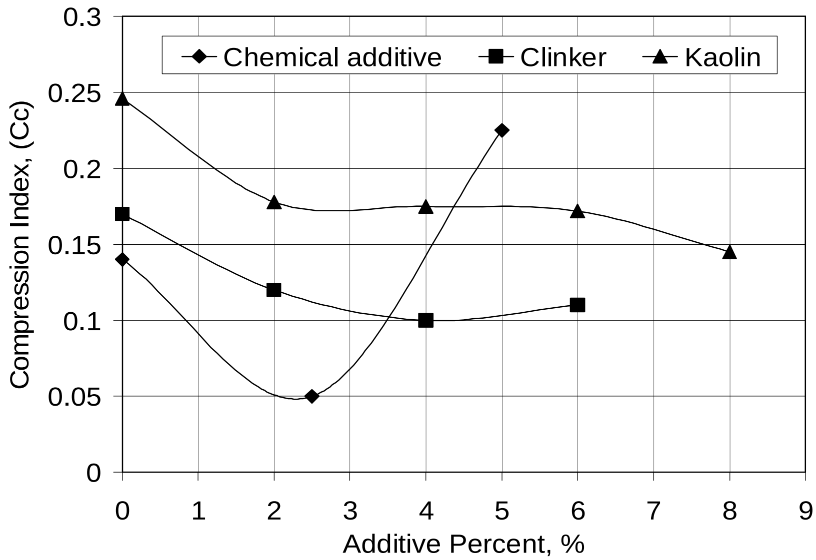

Figure (10) Comparison of compression index from different studies.