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Compression Strength of Treated Fine-Grained Soils with Epoxy or Cement

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Abstract**—**Geotechnical engineers face many problematic soils upon construction and they have the choice for replacing these soils with more appropriate soils or attempting to improve the engineering properties of the soil through a suitable soil stabilization technique. Mostly, improving soils is environmental, easier and more economical than other solutions. Stabilization soils technique is applied by introducing a cementing agent or by injecting a substance to fill the pore volume. Chemical stabilizers are divided into two groups: traditional agents such as cement or lime and non-traditional agents such as polymers. This paper studies the effect of epoxy additives on the compression strength of four types of soil and then compares with the effect of cement on the compression strength for the same soils. Overall, the epoxy additives are more effective in increasing the strength for different types of soils regardless its classification. On the other hand, there was no clear relation between studied parameters liquid limit, passing No.200, unit weight and between the strength of samples for different types of soils.

Keywords**—**Additives, clay, compression strength, epoxy, stabilization.

I. Introduction

SOIL may present inappropriate properties and undesirable behavior during engineering jobs, such as high swelling capacity, low bearing capacity and high factors of permeability. This causes many difficulties in construction on these soils. Therefore, geotechnical engineers do their best to solve this problem in situ of engineering projects. They have limited choices either by replacing the problematic soils with better quality one, which will cost more, or by attempting to improve the engineering properties of these soils by applying suitable improvement and stabilization techniques, which will be more economical than other solutions.

The practical purpose of stabilization of the soil is to minimize the void ratio by filling the pores that included in the soil structure by injecting different agents. This will affect positively the mechanical properties of soil such as strength and stiffness. Often, we use traditional chemical materials such as lime, fly ash, which develop a cementation bond between the particles of soil. However, modern researches have proven that polymers and petroleum-based emulsions are also effective material in stabilization process [1]. These are classed as non-traditional chemical stabilizers.

A significant number of researches have concentrated on the role of traditional agents, such as lime and cement in soil stabilization. The researchers have used lime to increase the strength of clay [2], studied the effect of combination of lime and cement on the swelling potential of expansive soils [3], investigated a stabilized soil by either mechanical means such as compaction and vibration and/or chemical stabilization by cement [4], concentrated on the effect of lime column on bearing capacity of soil [5], presented that the knowledge of soil composition can be used to predict successful cement stabilization [6], constructed a soil-cement tile and investigated the effect of flowing water on using the soil-cement tile in canal [7], evaluated the effectiveness of cement kiln dust as a soil stabilizer on increasing in the unconfined compressive strength of soil [8] and improved the soft clay with very high lime fly ash [9]. On the other hand, Bolander [10] studied the tensile strength and durability of dense-graded aggregate after adding polymers, Tingle and Santoni [11] evaluated the stabilization of low- and high-plasticity clay soils with nontraditional chemical or liquid stabilizers, Scholen [12] presented an improved understanding of the mechanism of nonstandard chemical stabilizers in the mineralogy and chemistry of clays and stabilizers, Ajayi-Mejebi [13] concentrated on the value of California bearing ratio (CBR) for mixture of clay and silt after adding epoxy, Katz et al. [14] used an ionic soil stabilizer and a sodium montmorillonite clay to study the mechanisms associated with the stabilization through physical-chemical study, Afreidi [15] presented the effectiveness of powdered emulsions (powdered cement modifiers) and aqueous polymer dispersions (aqueous cement modifiers) on improvements in strength and elastic properties of mortars where Gao [16] discussed the flexural and the compressive strengths of polyacrylic ester emulsion and silica fume -modified mortar. In addition, a number of studies have concentrated on the effects of resin on soil–cement mixtures. In addition, Anagnostopoulos [17] studied the physical and mechanical properties of grouts prepared by using cement, clay, water in different percentages along with an amount of acrylic resin or methyl methacrylate co-polymer emulsion and Estabragh et al. [18] investigated the mechanical behavior of soil-cement mixtures with different percentages of acrylic resin.

According to the literature study, we note that a large amount of researches have concentrated on the application of traditional stabilizing agents. However, little researches have directed towards the use of non-traditional agents in spite of the development of existing many types of non-traditional agents. Therefore, we aim in our research to study the effect of epoxy (nontraditional agent) on the compression strength of four types of soil and then to compare with the effect of cement (traditional agent) on the compression strength for

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these soils.

II. Materials and Methods

We have applied our tests on four types of soil A, B, C and D in order to specify it according to ASTM standards as shown in Table I. We use two types of additives. 1) Epoxy consists of two components A&B and Table II summarizes their properties. 2) The blast-furnace slag cement used in the experiments, CEM III/B 42.5 N LH/SR LA, consists of approximately 70% ground granulated blast furnace slag, 26% Portland clinker and 4% gypsum, the cement shows a minimal normalized mortar strength at 28 days, of 42.5 N/mm^2. Moreover, this cement's features improved the sulphate resistance, the low hydration heat and the low alkali content.

TABLE I
LABORATORIES TEST RESULTS

	Soil A	Soil B	Soil C	Soil D
Passing No.200 (%)	62	90	53.95	80
LL	32.5	74.18	65.81	83.12
PI	9	40.7	19.72	47.34
Specific Gravity	2.739	2.654	2.672	2.695
Unit Weight (kN/m^3)	**13.85**	**14.7**	**13.9**	**13.25**
Classification	**ML**	**CH**	**MH**	**CH**

TABLE II
PROPERTIES OF EPOXY

Property	Component A	Component B	Component A+B (A:B is 2:1)
Density	1.17 gr/cm^3	1.00 gr/cm^3	1.14 gr/cm^3
Viscosity at 25°C	ca. 600 mPa.s	ca. 400 mPa.s	ca. 550 mPa.s
Compression Strength			1000 kg/cm^2
Temperature Resistance			Max 50 °C
E- modulus			3000 kg/cm^2
Hardness shore A			95

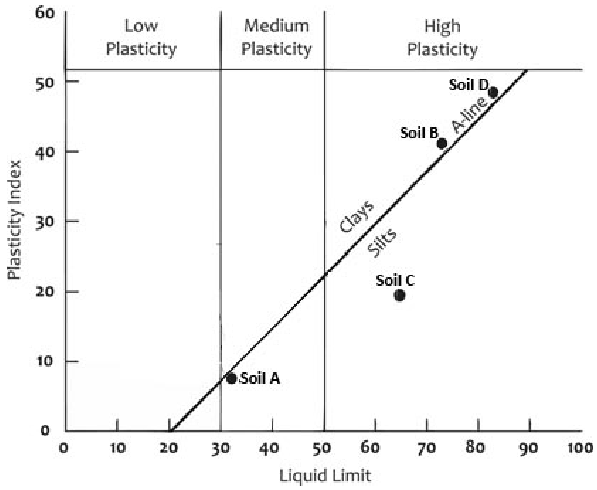

Fig. 1 Plasticity chart for four types of soils A, B, C, and D

A. Preparation

We have prepared 24 cylindrical specimens, divided into four groups. The first group contains six specimens from clay A divided: three are mixed with 8% epoxy and three are mixed with 30% cement. The second group contains six specimens from clay B: three are mixed with 8% epoxy and three are mixed with 30% cement. The third group contains six specimens from clay C: three are mixed with 8% epoxy; three are mixed with 30% cement. The fourth group contains six specimens from soil D: three are mixed with 8% epoxy and three are mixed with 30% cement. We have tried other additive percentages: 3% and 5% from epoxy, 10% and 20% from cement but the specimens had failed so we use 8% epoxy and 30% cement additives.

The process of preparing the specimens was as following:

We mix the dry soil and additives in a dough mixer for about 5 minutes until reach to a homogeneous paste. The consistency of the paste after mixing remained plastic. After we prepared a fresh mixture, we poured it into stainless steel cylindrical molds of different aspect ratios (0.6, 0.48, 0.4). We vibrated cylindrical molds lightly while filling them with the fresh mix to remove any trapped air bubbles. Then, we cured the epoxy treated soil specimens inside the molds for maximum one week in a conditioned room at about 20 °C, and we cured the cemented-soil specimens four weeks in a conditioned room at about 20°C. Following the period of curing, the specimens were strong enough to be extruded from the molds as shown in Fig. 2 for soil A. Next, we applied the compression test on all cylindrical specimens as shown in Fig. 3. Fig. 4 presents one of the specimens' groups after finalizing the compression test.

Fig. 2 Soil A with cement (a), with epoxy (b)

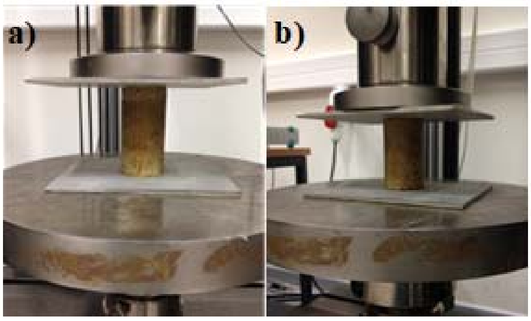

Fig. 3 Soil specimen with 30% cement (a), with 8% epoxy (b) on compression test

Fig. 4 Soil specimens after compression tests

III. Results

After analyzing the results for all types of soils A, B, C and D we find that epoxy- treated specimens presents higher strength than cemented treated specimens, at the same aspect ratio as shown in Fig. 5. However, the ratio of increasing differs according the type of soil. The strength of epoxy treated soil A has increased up to 180% of the strength of cemented treated soil. The strength of epoxy treated soil B has increased up to 250% of the strength of cemented treated soil. The strength of epoxy treated soil C has increased up to 220% of the strength of cemented treated soil, and the strength of epoxy treated soil D has increased up to 200% of the strength of cemented treated soil. When we compare the effect of epoxy and the effect of cement for the types of soils, we found different trends. As indicated in Fig. 6, we find that epoxy additives do not relate strongly to the type of soil as cement additives. We note that soil A and soil B reach to the same value of maximum load after adding the epoxy in spite A classified as (ML), and B classified as (CH). The lowest value was for soil type D which is also classified as (CH). However, we note that cement additives were more effective in silty soil A (ML) and C (MH) than high plasticity soils B and D. On the other hand, Fig. 7 shows us the relation between the liquid limit values for the types of soils and maximum load values. We note that there is a gap in this relation for both cemented and epoxy. At LL values that are higher than 60%, the strength decreases continually. Soil C shows the highest maximum load when treated with epoxy; however, soil A shows the maximum load value when treated with cement.

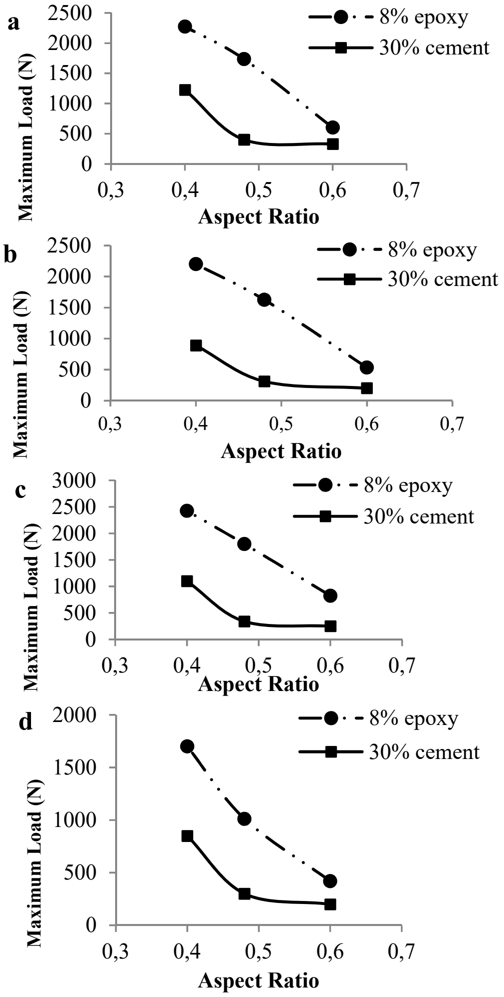

Fig. 5 Maximum loads vs aspect ratio for all treated soil specimens a) soil A, b) soil B, c) soil C, d) soil D

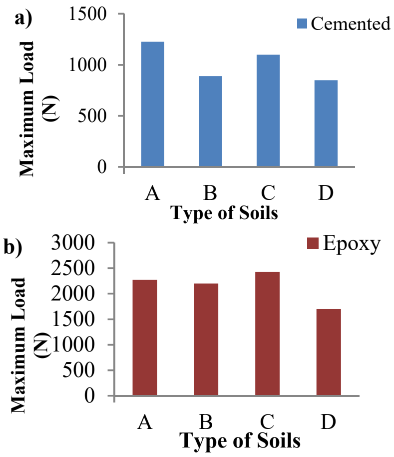

Fig. 6 Maximum loads vs types of soils a) cemented treated b) epoxy treated

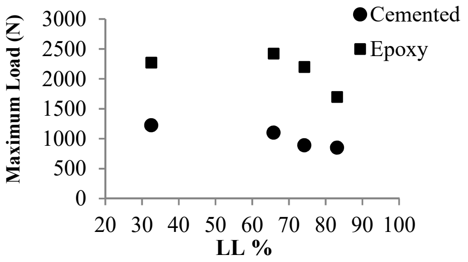

Fig. 7 Maximum load for treated soil vs liquid limit

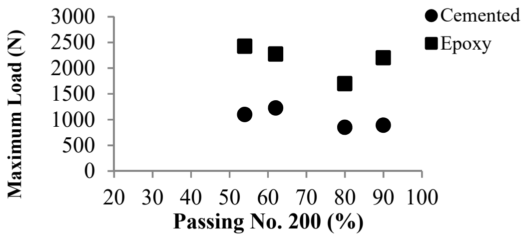

Fig. 8 Maximum load for treated soil vs Passing No.200

When we study the relation between maximum load and passing from No. 200 as shown in Fig. 8, we could not reach to a clear relation between the strength of soil specimens and its particles percent finer than No.200. Soil C presents the highest maximum load value when treated with epoxy; however, soil A presents the highest maximum load value when treated with cement. Moreover, if we study the relation between unit weight and maximum load as shown in Fig. 9, we do not find clear relation between both parameters. C soil presents the highest maximum load when treated with epoxy; however, soil A presents the highest maximum load when treated with cement.

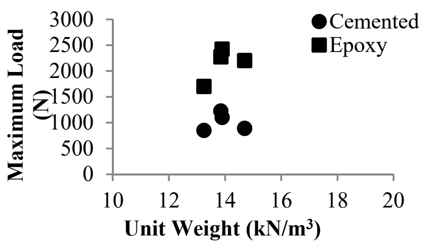

Fig. 9 Maximum load for treated soil vs unit weight

IV. Conclusion

According to our results, we find that epoxy additives are more effective in increasing the strength for different type of soils ML, MH, CH regardless the classification of the soil. However, the cement additives were more effective in silty soils A (ML) and C (MH) than clay soils B (CH) and D (CH).

With respect to liquid limit, the liquid limit may not be an exact measure of strength; it represents the required energy to close a furrow with 25 blows under standard conditions, and it is a sort of measure of strength. The liquid limit thus can be expected to vary with (1) clay type, (2) grain size [19]. Therefore, we could not reach to clear relation between LL and strength of samples for different types and grain size of soils.

The same unclear trends were between each of passing No.200 and unit weight with maximum loads. However, for all parameters we note that always soil A or soil C get the highest values of maximum load which mean that clay soils are more critical when we try to treat it and this return to its composition of many minerals where each mineral has special properties and unique behavior toward the chemical or polymer additives. So, we recommend to use pure minerals treating with cemented and polymer then comparing its effects on mechanical properties.

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