EFFECTS OF CEMENTITIOUS MATERIALS ON THE PERFORMANCE OF CLAYEY SOILS

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Abstract

In this study, lime and cement were used to improve the performance of bentonite soils representing sandy clay to clay soil. The bentonite soils were treated with cement and lime before testing them for compaction characteristics and stress-strain relationships. Characteristics of the treated mixtures were determined by adding 3% lime or cement to the soils. The results showed that there was changes in the compaction properties , strength, and failure strain of the stabilized soils. Based on the compressive strength, addition of lime and cement enhanced the bentonite clay (10% sand) while lime was more suitable for the sandy clay (90% sand). Addition of 3% cement also reduced the failure strain of the sandy clay. The cement stabilization had better strength with bentonite clayey sand (50% sand and 50% bentonite) compared to the lime treatment. Addition of 3% cement and lime affected dry density , optimum moisture content,and failure strain of the clay soil (10% sand) and sandy clay.

Keywords- concrete: lime, cement, bentonite, sand, Harvard miniature test*.**

1. INTRODUCTION

Soil compaction is one of the most important process in road construction, earthen dams, embankments, foundations and rammed earth walls. Compaction is the process of mechanically densifying a soil. The principal soil properties affected by compaction involve consolidation and settlement, shearing resistance, movement of water and volume change (shrinkage and swelling) very decisive when soils are used as subgrades for roads and airfield pavements. Using dry density to characterize the stabilized soils is inadequate.

The compaction process is not enough to improve the soil properties particularly in arid and semi arid regions where the compacted soils are unsaturated, and as a consequence the engineering properties are influenced by the matric suction during winter time affecting then the strength and density.

Over the last few decades lime and cement have been used for soil stabilization. Mitchell and Basma (1981), Nagih et al (1991), Arabani and Karami (2005), Boardman et al (2001), clough et al (1981), Dallas (1995), Diamond and Kinter (1965), Dallas (1996), Consoli et al (2007), Healthcote (1991), Shrinivas (1993), Venkartarama (1995), Walker and Stace (1997) indicated the effectiveness of lime and cement for soil stabilization. These studies were mainly limited to one type of soil and there is no clear trend in the effectiveness of the stabilizing materials on the wide spectrum of soils.

This study therefore quantifies the influence of lime and cement on the strength of a variety of mixtures involving sand and CH clay (Bentonite).This study used the Harvard miniature method to compact the soils and prepare specimens for the strength test.

2. OBJECTIVES

Investigate the effectiveness of 3% lime and cement treatment on the behavior of soils with varying bentonite content. The behavior of the stabilized soils were investigated after 14 days of curing.

3. MATERIALS AND METHODS

Binders

Ordinary Portland cement Type 1 (ASTM C150) was used. Typical particle size distribution of cement is shown in Fig. 1. The D_{50} for cement is about 100µm and the particle distribution is much higher than the bentonite clay.Calcium oxide (CaO), commonly known as quicklime was also used as a binder. Quicklime produces heat energy by the formation of the hydrate, calcium hydroxide,

$$CaO + H_2O \leftrightarrow Ca(OH)_2 \quad (1)$$

Sand (S)

The grain size distribution of the sand used in this control study is shown in Fig. 1. The coefficient of uniformity (C_u) for the sand was 2.6.The D_{50} for the sand was 0.6 mm

Bentonite (B)

Bentonite clay, also known as the montmorillonite, is common part of the smectite group of clays, which are groups of clays with three layer structure. Numerous types of bentonite clay exist, and while each type has properties that serve to set each clay apart from the other, the clay types all share the common characteristic of being able to absorb water at a significantly higher rate than other forms of clay. Sodium bentonite which is also known as "Swelling Clay," is capable of holding many times its weight in water. This capability makes it usable as a sealant for older, unused oil wells and toxic waste storage areas, as it bonds with the natural surrounding soil to create a barrier where oil and toxins cannot penetrate. The properties of the bentonite used in this study are summarized in Table 1.In this study, bentonite was selected to represent the clay fraction of the soil. Typical particle size distribution for the bentonite clay is shown in Fig.1. The D_{50} for the clay was about 1 µm.

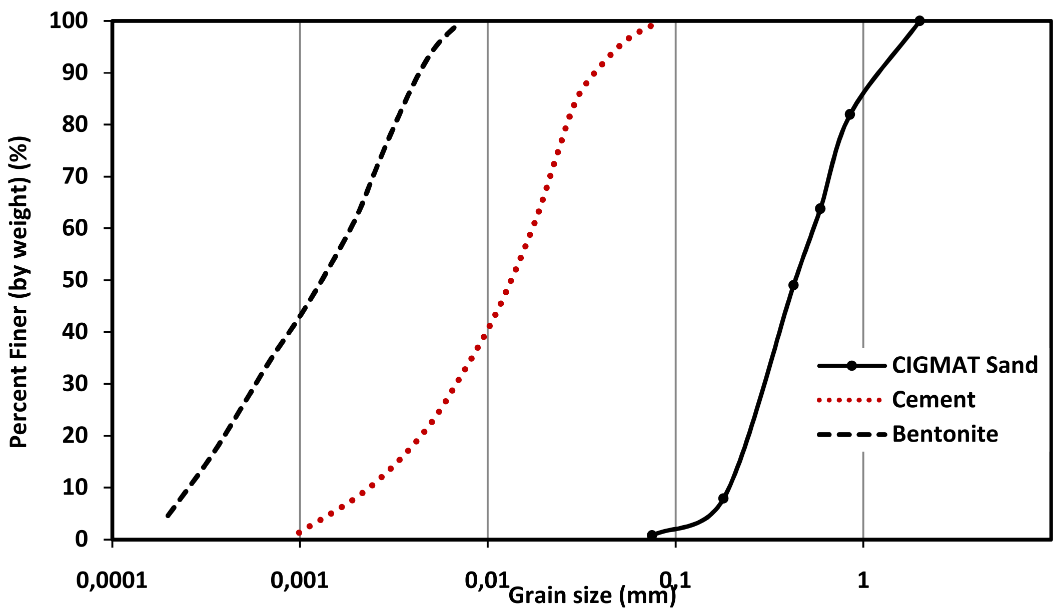

Figure 1. Grain size distribution for sand, cement and bentonite (after Ming Leung, 1990)

Table 1. Properties of bentonite

Type of sample	LL%	PL%	Gs	γ_{dry}	O.M.C%
Remodeled	324	43	2.66	11.45	38.1

Bentonite Soils

The sand-bentonite mixtures were prepared with bentonite contents of 10, 50 and 90% by weight. For the first mixture of soil sand content was 10% with 90% of bentonite. The soil was stabilized with 3% of lime and cement.

Sample Preparation

The samples were prepared by dry mixing sand with bentonite and cement or lime with varying amount of water. The Harvard Miniature compaction mold was used to prepare the specimens.

4. RESULTS AND DISCUSSIONS

Observations from Harvard Miniature compaction test and unconfined compaction tests have been analyzed to study the effect of lime and cement on compaction characteristics and stress-strain behavior of the different mixtures of soil. The results are summarized in Table 2.

Table 2. Summary of test results

Mixture	Sand (%)	Clay (%)	Lime (%)	Cement (%)	OMC %	γ_{dry} (g/cm^3)	q_u (psi)	ε_u	Curing days
I	10	90	0	0	28.9	1.54	119	1.76	14
	10	90	3	0	30.6	1.63	466	3.15	14
	10	90	0	3	27.5	1.72	325	2.2	14
II	50	50	0	0	18.5	1.97	143	2.21	14
	50	50	3	0	19.2	1.96	182	2.31	14
	50	50	0	3	20.1	1.97	290	2.54	14
III	90	10	0	0	12.7	2.08	85	1.16	14
	90	10	3	0	10	1.93	172	1.7	14
	90	10	0	3	9.8	1.87	78	0.4	14

Compaction characteristics

Bentonite Clay (90/10)

As shown in Figure 2 for the untreated soil (B90% ; S10%) the optimum moisture content was 28.9% while the dry density was 1.54g/cm^3. The treatment of this type of soil gave the following results:

1. Addition of 3% of lime to this mixture increased the OMC by 6% while the dry density was increased by 5.5% compared to the untreated soil.

2. Addition of 3 % of cement increased the dry density by 11% compared to the untreated soil while the OMC was not changed compared to the untreated soil . Hence the addition of cement was more effective in modifying compaction properties(density and optimum moisture content) of the bentonite clay soil.

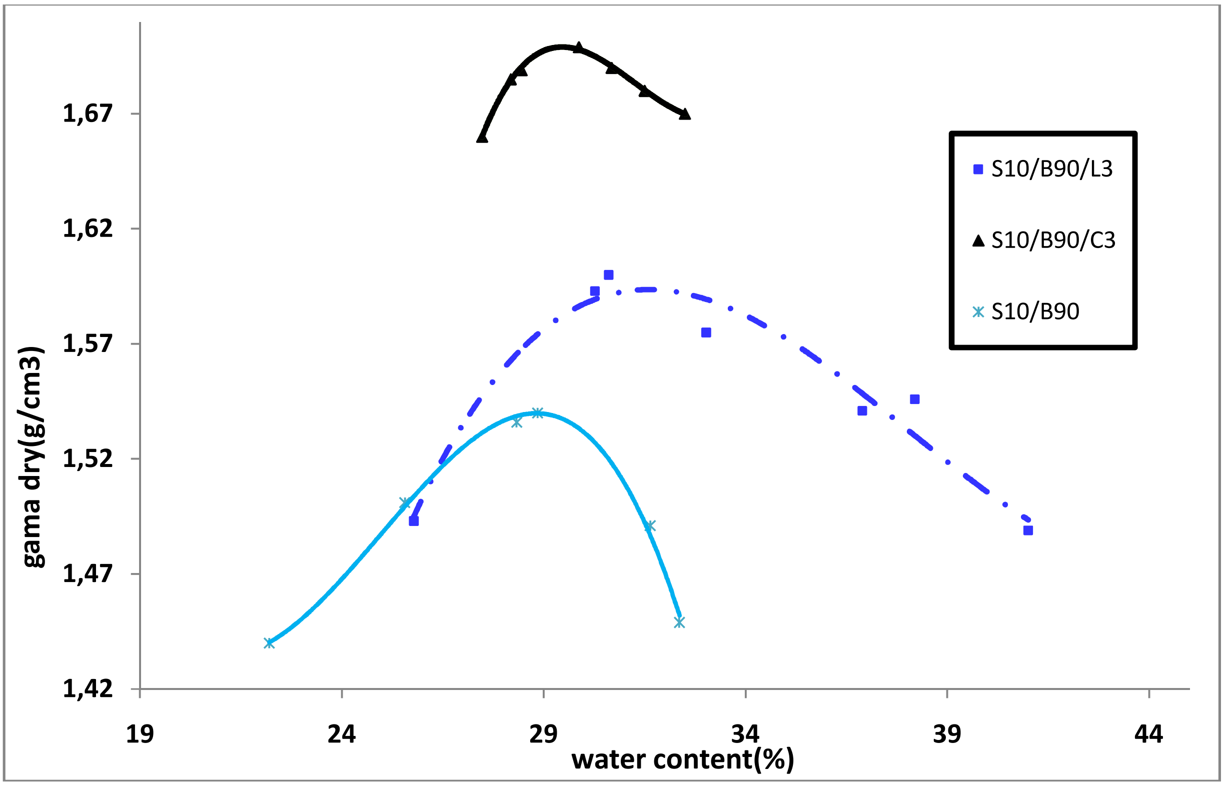

Figure 2. Dry Density vs. Water Content for the Clayey Sand

Bentonite Clayey Sand (50/50)

The maximum dry density and optimum moisture content for the soil were 1.97 g/cm^3 (123 pcf) and 18.5% respectively.

1. Addition of 3% of lime decreased the maximum dry density by 0.4% while the OMC increased by 4%.
2. The treatment of the soil with 3% cement decreased the dry density slightly .While the optimum moisture content increased by 9%.
   Hence the addition of 3% lime and cement had minimal effect on the compaction properties(dry density and optimum moisture content)

Bentonite Sandy-Clay (90/10)

The maximum dry density and optimum moisture content for the untreated soil were 2.08 g/cm^3 and 12.7% respectively.

1. Addition of 3% of lime caused a decrease of 21% in optimum moisture content and7% in dry density.
2. Addition of 3% of cement caused a decrease on both dry density and optimum water content by 10% and 23% respectively.

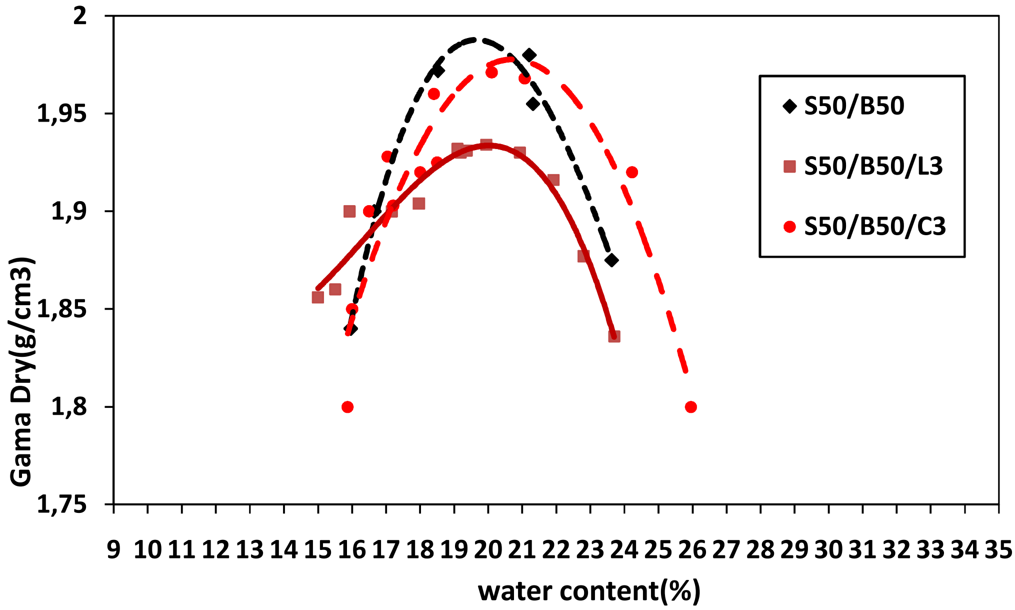

Figure 3. Dry density vs. Water Content for the Clayey Sand

Hence the addition of 3% of cement and lime reduced the maximum dry density and optimum content of the sand clay.

Compressive Strength

Specimens were tested at a deformation rate of 0.05 in/mn. After a curing period of 14 days for each combination of bentonite clay and sand, The results were as follow for:

Bentonite Clay (90/10)

The unconfined compressive strength of the untreated soil near optimum moisture content was 119 psi as shown in Fig. 5.

1. Addition of 3% lime increased the U C S by 292% compared to the untreated soil
2. Soil stabilized with 3% of cement show an increase of 173% compared to the control soil.
3. Based on these tests, it was noticed that specimens stabilized by lime ($\varepsilon_u = 3.15\%$) were less brittle than those stabilized using cement ($\varepsilon_u = 2.2\%$).

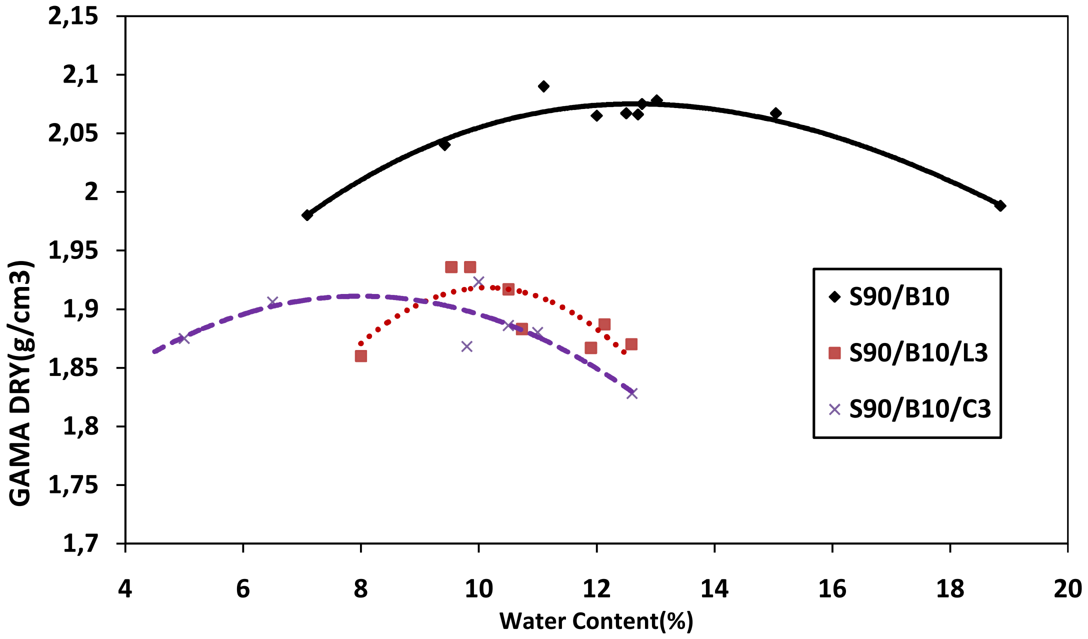

Figure 4. Dry density vs. Water content for the sandy clay

Bentonite Clayey Sand (50/50)

Figure 6 showed stress-strain relationship for the control soil near the optimum control a value of 143 psi.

1. By comparing UCS of the different mixtures, it was observed that lime stabilized specimens had 28% higher strength than the untreated soil (S50B50)
2. Soil treated with 3% cement showed an improvement of 102% in UCS compared to the control soil.
3. The specimens stabilized with lime (ε_u = 2.3%) and cement (ε_u = 2.5%) had comparable failure strains.
4. In this case, the specimens stabilized by cement exhibited better performance.

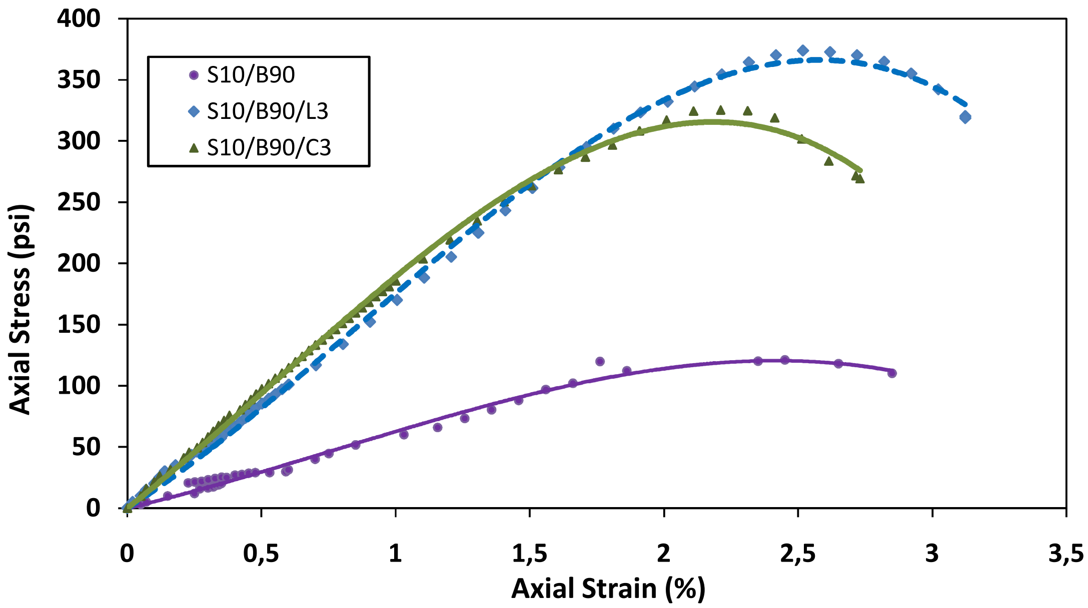

Figure 5. Compressive stress-strain relationship for clay soil

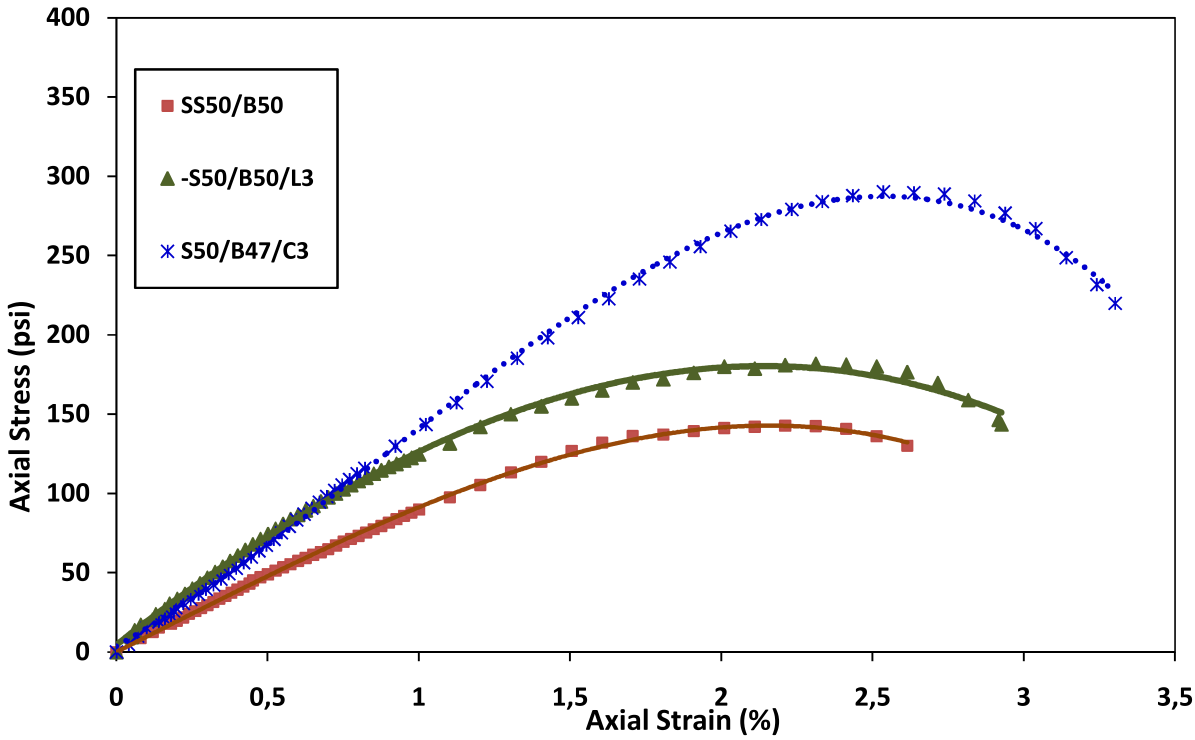

Figure 6. Compressive stress-strain relationship for clayey sand

Bentonite Sandy-Clay (90/10)

As seen in Fig. 7 for these combinations, the USC for the control soil is 85 psi.

1. The soil treated with 3% of lime gave a UCS 102% higher than the value of the untreated soil with an improvement in failure strain of 48%.
2. Addition of 3% cement had no effect on the strength but the failure strain was 0.4%.The failure strain of the control soil (ε_u =1.16%) was substantially reduced by the addition of 3% cement.

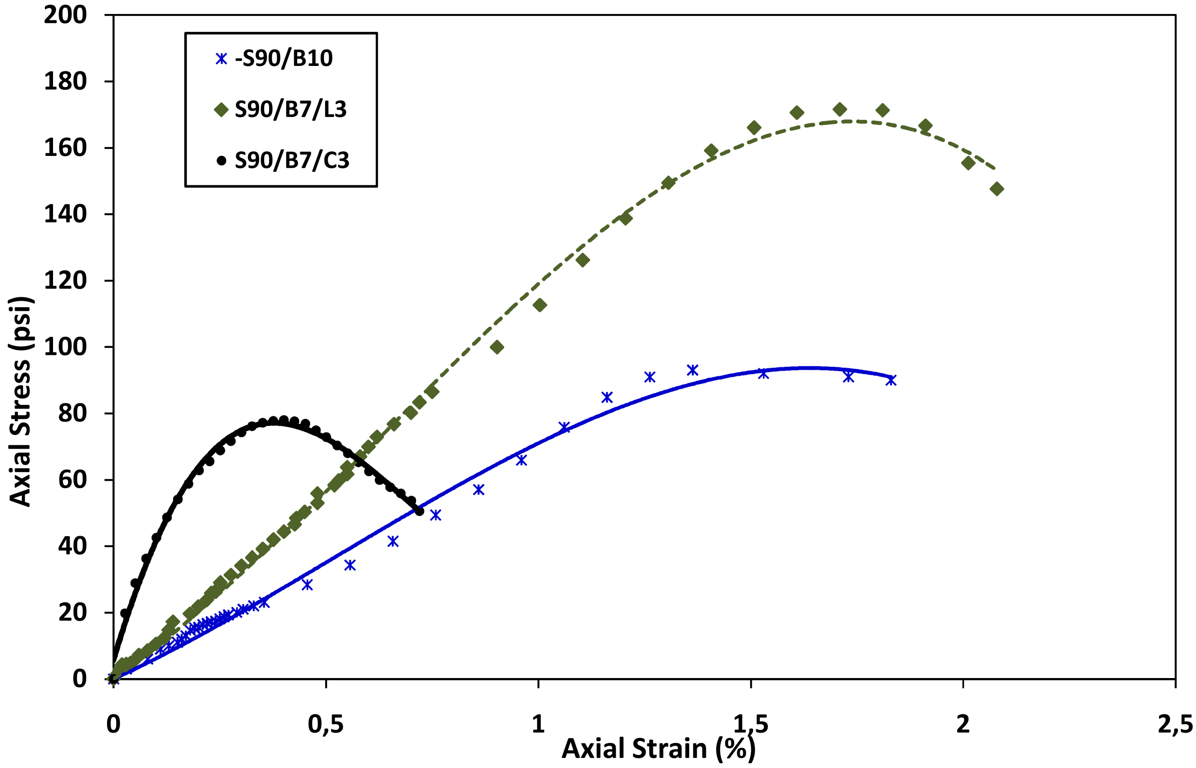

Figure 7. Compressive stress-strain relationship for clay –soil

5. CONCLUSION

Addition of cement and lime had varying effects on the soils studied and the properties of interest such as the unconfined compressive strength, failure strain, dry density and optimum water content. Based on the experimental study the following observations are advanced:

1. For the sandy- clay (10%sand 90% bentonite) addition of 3% lime increased the UCS by 292% and the treated soil with cement had an increase in UCS of 173% compared to the control soil . Based on these tests, it was noticed that specimens stabilized by lime showed higher failure strain than those stabilized by cement .
2. Addition of 3% of cement and lime increased the maximum dry density. The optimum water content of the sand clay showed an increase(6%) for the treated soil with lime while a decrease (5%)was noticed in treating the soil with cement.
3. For the clayey sand (S50%B50%) by comparing UCS of the different mixtures, it was seen that lime stabilized soils (3%) are 28% higher than the untreated soil. The addition of 3% cement showed an improvement of 102% in UCS compared to the control soil. Soils stabilized with cement had a higher failure strain(10%) compared to the soil treated with lime .
   Lime or cement had slight effect on the compaction properties(dry density and moisture content)

4. For the sandy clay soil (S90%B10%) addition of 3% lime to the soil improved the UCS by102% compared to the untreated soil,while the failure strain increased by 47% also.
5. For this group of combination, soil treated with 3% cement had no effect on the control soil.
6. The addition of 3% of cement and lime reduced the maximum dry density by10% and 7% respectively, while the optimum water content decreased by 23% and 21% respectively for the sand clay.

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