The Effect of Saturated Lime Solution on Increasing the Strength of Silty Sandy Soils

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Abstract

Due to the increase of construction projects, we are faced with the necessity of using lands, having loose and soft soils more than before. Recently a new method for strengthening these soils has been developed, by which saturated lime is intruded into soil. As it penetrates due to the gravity, improves the soil strength through pozzolanic reactions. In this paper, the influence of two key parameters, on the improvement of unconfined strength of sandy soils is studied. Two sets of laboratory tests were conducted on silty sandy soil specimens. In the first set, the saturated lime solution (SLS) was intruded with different volumes through the specimens and then they have been used for uniaxial strength test. In the second set, after passing specific volume of SLS through the specimens, they have spent different curing times under controlled humidity and temperature conditions, then have been used for uniaxial strength test. The first set of tests indicates that the uniaxial strength increases with an increase of the volume of infiltrated solution linearly. And the second indicates, contrarily to clay soils, the curing time, cannot be a contributing factor to the improvement of the silty sandy soils.

Keywords: stabilization, the volume of infiltration, curing time, uniaxial stress, silty sandy soils.

1. INTRODUCTION

Using the Calcium cation is common in civil projects. The main method for having that is by virtue of lime. Adding lime to increase the strength parameters of fine graded soils have been used before. Alongside with environmental issues, the economy of projects should be considered as a significant factor that should be relevant to the importance of site.

Although using lime as a whitewash or dry mixture with soils have been suggested by Puppala et al., (2003) [1], Rao and Shivananda, (2005) [2], Farzaneh and Mosaddegh (2007) [3] and other researchers for fine graded soils, it is not practicable because of not being able to move the rockfill materials. As had been studied by Davoudi (2007) [4], if the lime is soluted in water and infiltrated as a saturated lime solution, the result will be the increase of the friction angle and cohesion in soils. This recently used method by researchers is known as Saturated Lime Solution (SLS).

There has been researches such as Rostami (2010) [5], "Investigation on Effects of Saturated Lime Solution on Uniaxial Compressive Strength of Clayey Soils", that has shown this method is economical comparable in stabilizing the landslides. But there has been no research for this method on silty sandy soils so far. In this research, it has been tried to study the usage of SLS method on silty sandy soils by means of investigating the volume of filtration and the curing time after that.

2. THISIS METHOD

This study has been done on silty sandy soils by virtue of laboratory tests. The soil had 7.5% clay and PI=0, it was categorized due to ASTM-D422 as SM. By standard proctor test, its maximum dry density was 1.92 gr/cm3 while its optimum moisture content was 12%.

A special device has been designed and made for this research including three parts: cylinder molds with 50 mm diameter and 130 mm height, cubic tank with 50*150*150 mm capacity and a big tank with 500*500*80 2 mm capacity. The tanks have been connected by plastic vessels and the filtration was upside down through the soil specimens. All specimens were compacted at 10% moisture content, in 10 cm height, 95% of standard compaction and with dry density of 1.80 gr/cm3. For each specimen, specific volume of saturated lime was passed in 48 hours. After filtration completed, the cylinder was separated from the cubic tank. In 7 specimens, water was penetrated for comparison purpose. In 10 specimens, different volume of saturated lime was penetrated and then they were used for uniaxial strength test. In 16 other specimens, saturated lime was passed through the soil in 48 hours, then they had curing times of 4, 8 and 28 days, then they were used for uniaxial strength test as well. The "controlled stress" uniaxial test has been held in this study.

For evaluation, the volume of penetration is presented based on their void volume (V_V). And also, to ease the comparison between results, the "relative uniaxial strength" is defined as the equation 1 below in which, q_{u0} and q_u are the strength of unreformed and reformed specimens respectively.

$$\Delta q_u = \frac{q_u - q_{uo}}{q_{uo}} \times 100 \qquad (1)$$

In the equation above, q_{u0} is derived from the uniaxial strength plotted versus the specific dry density in unreformed specimens, shown in fig.1 which is presented as equation 2:

$$q_{u0} = 0.0249(\rho_d)^{15.977} \qquad (2)$$

In addition, the "relative failure strain" is presented in equation 3 in which ε_u is the strain of reformed specimens and the ε_{u0} is the strain of the unreformed ones which has been derived from the failure strain plotted versus the specific dry density in unreformed specimens, shown in fig.2 which is presented as equation 4.

$$\Delta\varepsilon = \frac{\varepsilon_{u_0} - \varepsilon_u}{\varepsilon_{u_0}} \times 100 \qquad (3)$$

$$\varepsilon_{u_0} = 0.5916 - 0.984 \ln(\rho_d) \qquad (4)$$

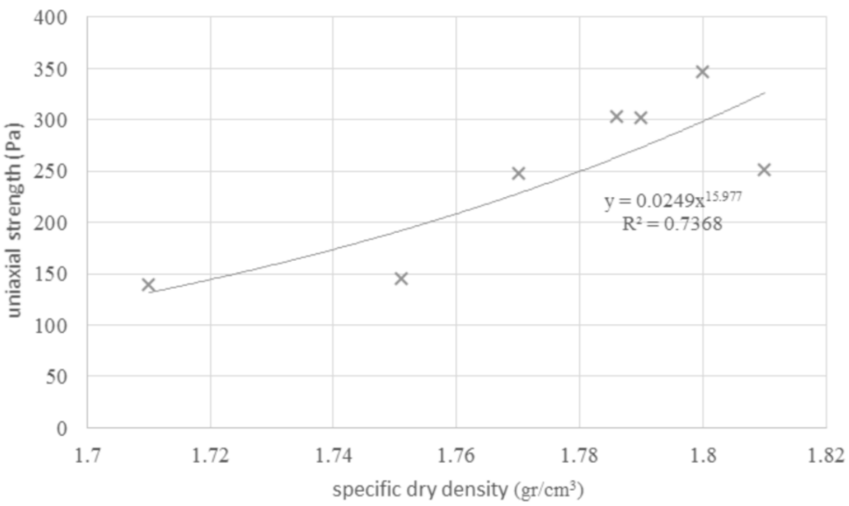


Fig 1: Uniaxial strength versus specific dry density in unreformed specimens

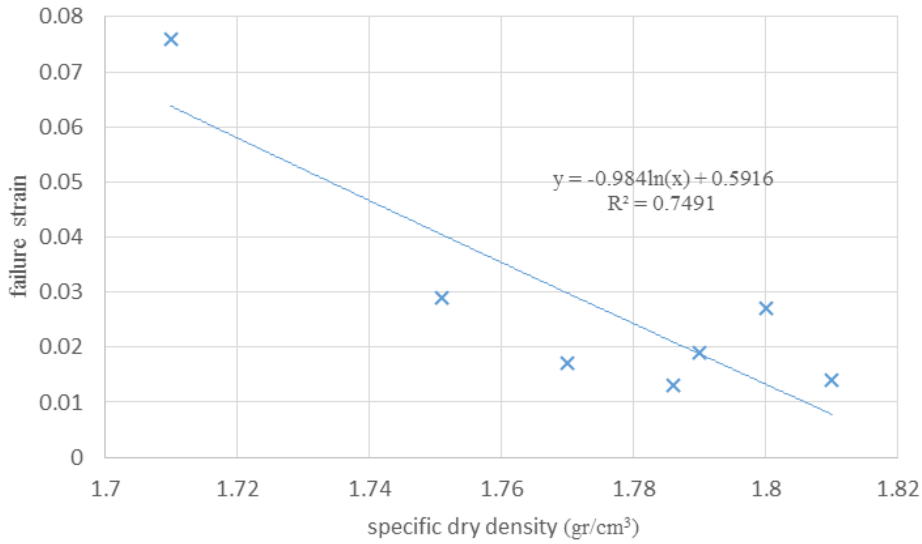


Fig. 2: Failure strain versus specific dry density in unreformed specimens

3. RESULTS AND DISCUSSION

The results of first set of tests are presented in table 1.

Table 1: Results of uniaxial strength test in first set of specimens

Volume of penetration (V_v)	Relative failure strain (%)	Relative uniaxial srength (%)	Failure strain mm/mm	Maximum uniaxial strength Pa	NO.
1.5	559.48	3.5	0.014	402.09	L-4-5-10
4.53	9.21	1.71	0.012	303.43	L-1-1-14
4.95	-12.3	45.03	0.021	395.8	L-1-12-9
6.26	-93.14	8.72	0.015	354.37	L-1-4-26
6.47	53.59	110.3	0.019	400	L-4-5-2
6.95	3.74	65.07	0.018	450.5	L-2-5-20
7.87	-111.83	15.1	0.028	343.38	L-3-5-10
7.88	16.78	0.34	0.011	299.33	L-3-4-26
9.27	36.15	76.03	0.019	401.47	L-2-4-26
10.5	54.57	82.49	0.011	455.4	L-1-4-14
11.6	2.29	78.57	0.040	339.64	L-1-5-17
13.27	34.90	184.55	0.023	592.81	L-1-5-2
16	25.66	343.32	0.018	1106.32	L-1-3-19
16.51	-15.64	75.19	0.028	437.18	L-1-5-20
21.77	49.59	275.6	0.015	856.64	L-2-4-14
24.37	15.09	179.2	0.030	581.67	L-3-5-2

The purpose of first set was identifying the effect of the volume of solution penetrated on uniaxial strength as it is shown in figure 3.

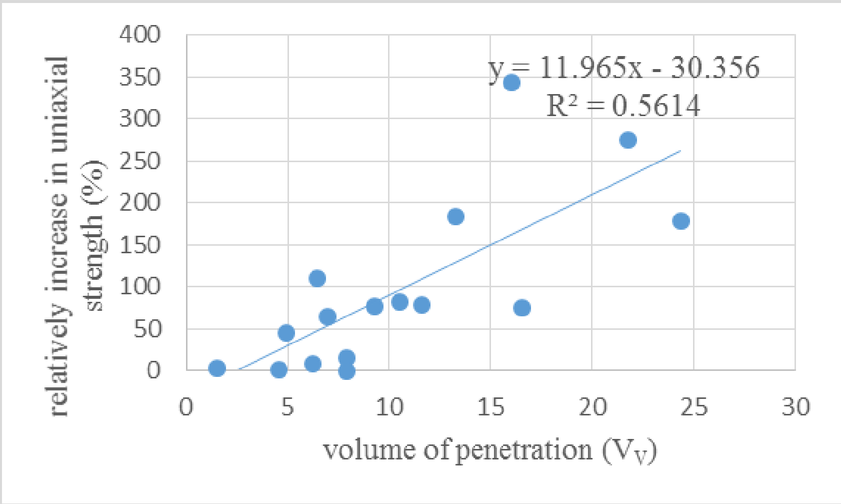


Fig 3-1: All specimens of the first set

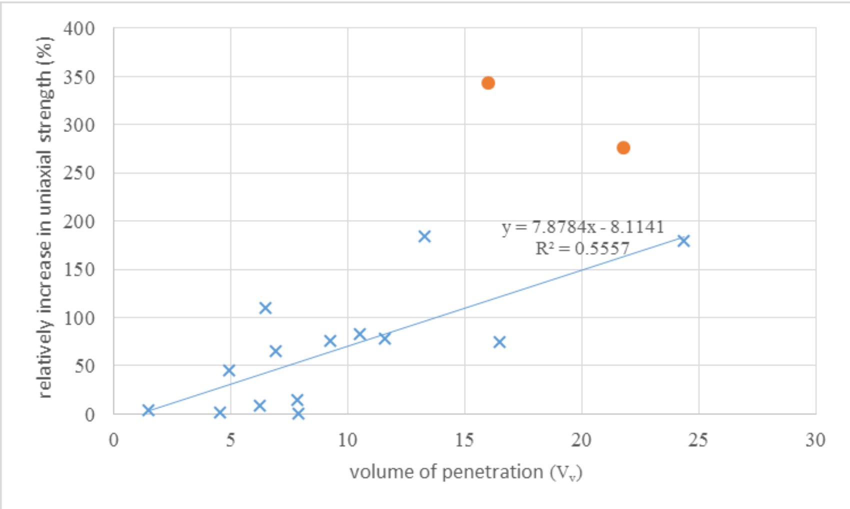


Fig. 3-2: All specimens in first set without considering L-2-4-14 and L-1-3-19

Fig 3: Relative uniaxial strength versus volume of penetration in first set without considering L-2-4-14 and L-1-3-19

Specimens L-12-4-14 and L-1-3-19 had different behavior in comparison with others. Without considering these two specimens, the correlation will not get better, but considering that, without any solution the relative uniaxial strength would be equal to zero, the graph in which the correlation is close to zero would be acceptable. Therefore, according to Fig 3-2, the equation can be derived for the "volume of penetrated solution" and the "relative uniaxial strength" as presented in equation 5.

$$\Delta q_u = 7.8784V - 8.1141 \qquad (5)$$

In case of comparison between this study and the same on CL-ML soils (Rostami, 2010, [5]), figure 4 is presented.

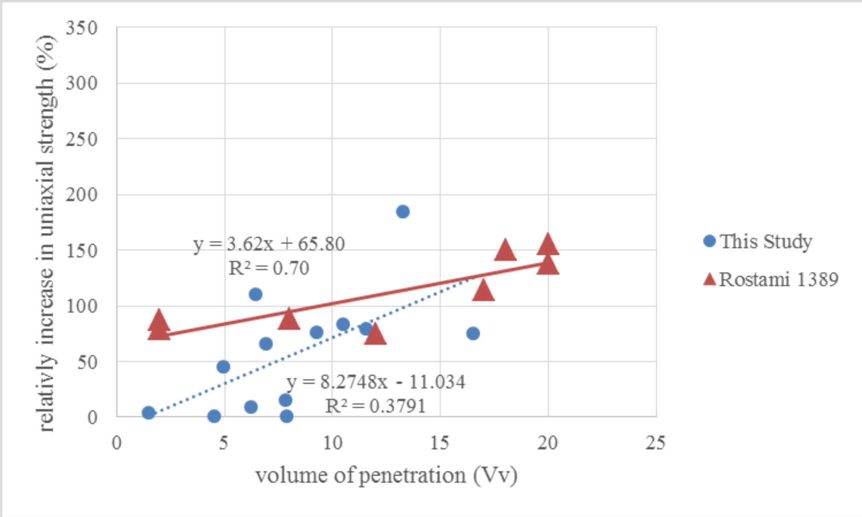


Fig. 4: Comparison in relative uniaxial strength versus volume of penetration between this study and Rostami 2010 [5]

Figure 4 illustrates that in case of less than $20V_v$ of penetrated solution, the increase in relative uniaxial strength in CL-ML is much more than in SM. This might be a reason of the soil nature that the passing of sieve NO.200 in CL-ML was around 65% while it was almost 29% in SM. The uniaxial strength between these two soil types are different as well, in CL-ML with 80% of compaction, it is around 40 kPa while in SM with 95% of compaction it is around 0.3 kPa, that might be a result of cohesion in clays. This cohesion causes chemical reaction between Ca^{++} and clay minerals. Table 2 shows the uniaxial strength after filtration of different volume of solution in specimens. Consequently, by increase of the volume of filtration in specimens, the effect of this method will be more noticeable.

Table 2: Comparison of uniaxial strength (kPa) between CL-ML and SM after filtration of different volumes of solution

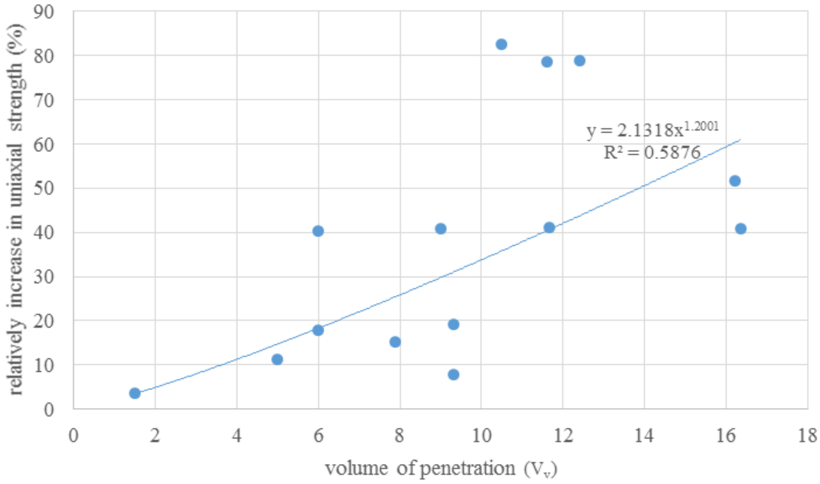
	Volume of filtration (V_v)	0	5	10	15	20
Soil Type	(This Study) SM	0.32	0.37	0.42	0.47	0.52
	(Rostami, 2010 [5]) CL-ML	41.45	46	46	55.1	59.65

The results of the second set of tests are shown in table 3. Also, in figure 5 the relative uniaxial strength versus volume of penetration without considering the curing time, is presented.

Table 3: Results of uniaxial strength test in second set of specimens

Volume of penetration (V_v)	Curing time (day)	Relative failure strain (%)	Relative uniaxial srength (%)	Failure strain mm/mm	Maximum uniaxial strength Pa	NO.
1.5	4	559.48	3.5	0.014	402.09	L-4-5-10
5	28	-1435.26	11.22	0.036	395.82	L-3-6-14
6	28	-36.18	17.83	0.018	351.50	L-4-6-14
6	8	17.40	40.26	0.020	350.03	L-2-5-27
7.87	4	-36.18	15.1	0.018	343.38	L-3-5-10
9	8	54.57	40.92	0.011	249.55	L-2-6-10
9.3	28	-144.64	7.89	0.019	351.65	L-2-5-31
9.3	28	17.40	19.25	0.020	297.59	L-1-5-31
10.5	4	54.57	82.49	0.011	455.4	L-1-4-14
11.6	4	2.29	78.57	0.040	339.64	L-1-5-17
11.65	8	33.92	41.17	0.016	352.2	L-2-5-24
12.4	28	-210.85	78.78	0.041	533.36	L-1-6-14
16.22	8	26.06	51.69	0.022	345.97	L-1-5-24
16.35	28	-27.37	40.72	0.045	293.17	L-2-6-7

Fig. 5: Relative uniaxial strength versus volume of penetration in second set without considering the curing time



The results are shown in figure 6

This figure (5) illustrates the effect of volume of filtration on increase in uniaxial strength even without considering the curing time.

To evaluate the effect of "curing time" on "uniaxial strength", specimens are divided in two groups based on the volume of filtration:

1. first group, which less than $10V_v$ of solution is passed
2. second group, which more than $10V_v$ is passed

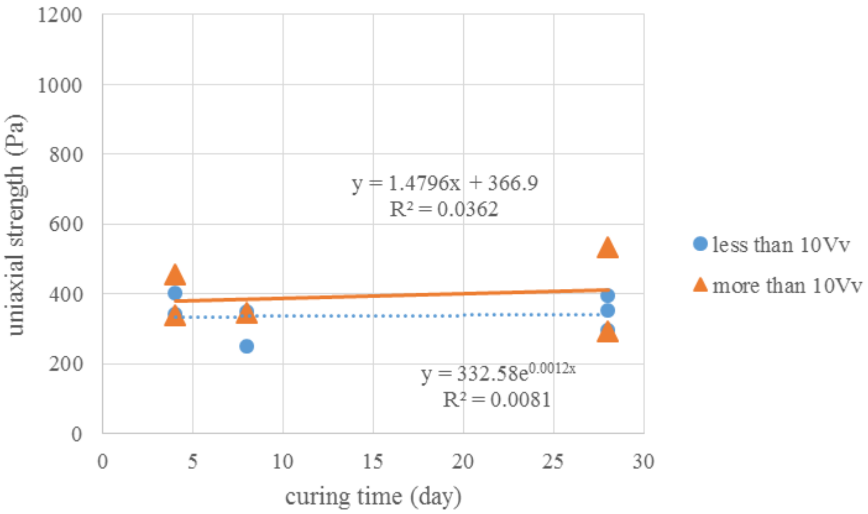


Fig. 6: Uniaxial strength versus curing time in all specimens of second set

As it can be seen, curing time does not affect uniaxial strength of specimens that might be as a result of lack of clay minerals in SM to reach the goal in this method. In other words, the access of the increase in strength in this method requires clay minerals for pozzolanic reactions which is around 7.5% in the tested soil in this study. Also, due to passing more saturated lime in second group, we can see an increase in uniaxial strength in comparison with the first group.

In the research had been done by Rostamiy (2010) [5], for three groups of $19V_v$, $28V_v$ and $40V_v$, as it is shown in figure 7, correlations between uniaxial strength versus curing time, have been found.

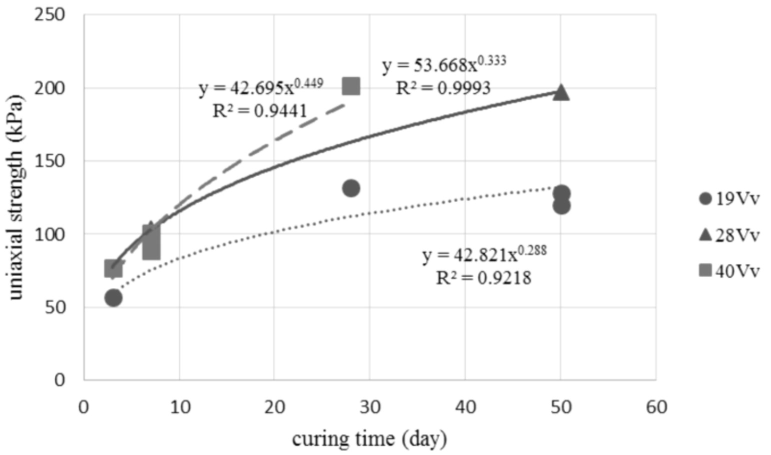


Fig. 7: Comparing the uniaxial strength of three CL-ML groups treated with different volume of solution versus curing time (Rostami, 2010 [5])

Comparing these two figures (6 and 7) illustrates that due to lack of clay minerals in SM soils, curing time is not as effective as it is in increasing the relative uniaxial strength in CL-ML soils, which has a relation with the volume of filtration, as the more volume of solution passed, the more effectiveness of this method by passing curing time can be seen.

4. CONCLUSIONS

The study has been shown that there is no correlation between the volume of filtration and failure strain in SM soils. Also because of the difference of soil natures in CL-ML and SM, in case of the volume of less than $20V_v$ of filtration, the relative uniaxial strength in SM is much less than it is in CL-ML due to less clay minerals in SM, that causes less cohesion. In addition, by increasing the volume of saturated lime solution passed through SM, the uniaxial strength can be more affected. The studies have been shown that in case of the $17V_v$ of filtration, the increase of relative uniaxial strength in both SM and CL-ML soils are the same considerable value of 129%. In CL-ML specimens due to the presence of clay minerals, noticeable increase of relative uniaxial strength can be seen after curing time.

5. REFERENCES

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