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STABILIZATION OF SOIL BY MIXING WITH DIFFERENT PERCENTAGES OF LIME

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ABSTRACT

Increasing urbanization in our cities has created a tremendous demand for developable land especially in the periphery of our cities and towns. We have found several researches dealing with soil-cement and soil-lime stabilization but none has dealt with the specific type of soils which are found in and around the city of Chittagong. We have found from the past researches that cement performs better with sandy soil while lime performs better with silty/clayey soil. In this research, we have tried to check the performance of lime with two different types of soils: hilly soil from Khulshi area and paddy land soil from South Salimpur within the city. Lime-stones were procured from local market. For the ease of measurement and for easy and uniform spreading over soil before mixing, it was converted into powder by sprinkling water on it. It was found that the lime stone procured from the local market had a lime content of 63.2%. Lime-powder in variable percentages of 0%, 2%, 4%, 6%, 8%, 10%, 12%, and 14% were used as stabilizer. The compressive strengths of lime stabilized soil were evaluated for different curing period: 7 days, 14 days, 28 days and 60 days. It was found that the load bearing capacity of soil increased with the increase in percentage of lime to a certain limit. It was, also, found that strength increases with the increase in curing period. At 8% lime content, maximum compressive strength were found in paddy land soil while at 6% lime content maximum compressive strength were found in hilly soil. Hilly soils are generally sandy while the paddy land soils are silty / clayey. It was found that less limes were necessary for stabilizing sandy hilly soil compared to silty paddy land soil. Since lime is cheaper compared to cement, it may become a viable alternative of cement for soil stabilization. Before arriving at a definite conclusion on the use of lime stabilized soil, further researches with lime using all different varieties of soils in and around the City of Chittagong will be necessary.

Keywords: *Quick Lime, hydrated lime; curing period; soil compressive strength, soil-lime stabilization*

1. INTRODUCTION

1.1 Background Information

In the last few decades, world population has increased rapidly especially in developing countries like Bangladesh. Buildings are being built and roads are constructed by encroaching into paddy land. Hills in Chittagong are continuously being lebelled to build houses on it. We like it or not buildings are built on paddy land and the hills. Since paddy land soils are mostly silt with some clay and the hill soils are generally loose fine sand with a small percentage of silt and clay, engineers often had to go for costly foundation like deep foundation in these type of soils. Construction is risky in these soils due to uneven settlement, land slides and or shear failure. Deep foundations are, sometimes, beyond the financial capacity of average home builders trying to build a three or four story building to be claimed and taken pride of as their own house.

Therefore, a suitable and low cost alternative to deep foundation is to be identified for the average home owners going for a low rise building. Soil stabilization techniques might become the cheap alternatives against the conventional technique of deep foundation using pre cast or cast in situ piles. Improvements in engineering properties of soil such as increases in soil strength (shear resistance), stiffness (resistance to deformation) and durability (wear resistance), reduction in swelling potential of wet clay soils can be done by soil stabilization(Sultan et al. 2014).

Soil stabilization involves the blending of natural soils with chemical agents such as lime, cement (OPC or PPC) and asphalt (Rogers et al.). These agents are generally potential binders which effectively bind together the soil aggregates. As a result, load carrying and stress distribution characteristics of soil improve; excessive shrinkage and swelling in soil come under control.. A very common and cheap technique to improve the soft clay soil is to add a certain percentage of lime with the soil (Farooq et al. 2011). Lime in the form of quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca[OH]2), or lime slurry can be used to treat the soils. Hydrated lime is created when the quicklime chemically reacts with water. It is hydrated lime that reacts with particles of clay and permanently transform them into a strong cementious matrix (Ajayi 2012) .

1.2 Chemistry of Lime Treatment

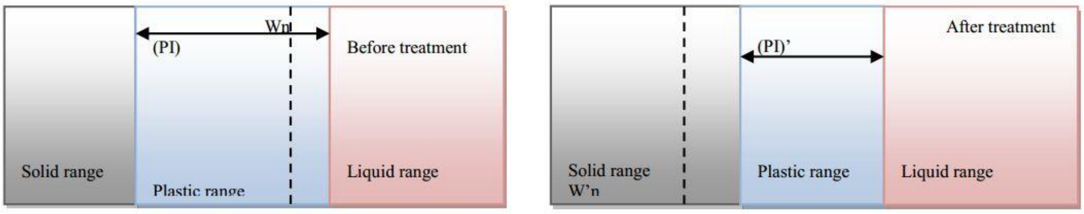
The chemical reactions between clay and lime particles can be grouped under two distinct types of changes; one is a short term change termed as modification and the other is a long term change termed as stabilization. In modification, the process of ion exchange makes the clay minerals flocculate and agglomerate leading to a reduction in plasticity, swell and moisture content. In stabilization, pozzolanic reaction takes place over a long period of time that creates cementitious products which are responsible for long-term gain in strength (Bozbey et al. 2016).

1.3 **Drying**:

If quicklime is used, it immediately hydrates (i.e., chemically combines with water) and releases heat. As a result, soil dries quickly, because part of the water present in the soil participates in the reaction, and the rest evaporates due to heat of hydration. The hydrated lime produced thus will subsequently react with clay particles. These subsequent reactions will slowly cause additional drying because of a reduction in soil's moisture holding capacity by way of modification in soil structure known as floculation. Floculation increases drainage capability of the soil and reduces the soil's moisture holding capacity. If hydrated lime or hydrated lime slurry is used instead of quicklime, drying occurs only through changes in the soil structure. This, in fact, increases the draining capability of of the soil; reduces the water holding capacity of the soil and increases its stability. In fig.1, it can be seen that water content Wn is reduced to W'n after treatment with lime.

1.4 **Modification**:

After initial mixing, the calcium ions (Ca++) from hydrated lime migrate to the surface of the clay particles and displace water and other ions. The soil becomes friable and granular, making it easier to work and compact. At this stage the Plasticity Index of the soil as shown in Figure 1 decreases dramatically, as does its tendency to swell and shrink. The process, which is called "flocculation and agglomeration," generally occurs in a matter of hours.



(Kerni, Sonthwal, and Jan 2015)

Figure 1**:** Effect of lime addition on the consistency of soil

1.5 Stabilization:

When adequate quantities of lime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and alumina are released and react with calcium from the lime to form calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates(CAH). Both CSA and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to the strength of lime-stabilized soil layers. As this matrix forms, the soil is transformed from a sandy, granular material to a hard, relatively impermeable layer with significant load bearing capacity. The process begins within hours of lime addition and can continue for years in a properly designed system. The matrix formed is permanent, durable, and significantly impermeable, producing a structural layer that is both strong and flexible.

Therefore the purposes of binder addition to soft clays can be stated briefly (Bozbey et al. 2016) as:

• To increase the strength and stiffness of soft soil
• To improve the differential deformation properties of the soft soil
• To increase dynamic stiffness of the soft soil
• To remediate contaminated soil

The aim of this study is to determine the engineering properties and unconfined compressive strength of paddy land soil and hill soil. Additionally, this study investigates the improvement of the unconfined compressive strength of soil by mixing different percentages of lime with soil. Finally, it gives information about optimum lime content for this particular types of soil for improving the unconfined compressive strength of the soil . Four different time periods for curing were considered.

2. LITERATURE REVIEW

Soil stabilization is a procedure where natural or synthesized additives are used to improve the engineering properties of weak soil. Several reinforcing methods are available for stabilizing soils. Therefore, the techniques of soil stabilization can be classified into a number of categories such as physical stabilization, chemical stabilization and mechanical stabilization. There is a rich history of the use of soil stabilization admixtures to improve poor sub grade soil. Improvement in performance by controlling volume change and by increasing strength was in practice (Navale et al. 2016).

Tedesco (2006) studied soil compressibility before and after lime treatment with respect to the effects of initial moisture content of compacted soil sample, the curing time and the test procedure. He used a unique percentage of lime equal to 3% by weight of soil for all soil specimens. Using standard and modified Proctor tests, the samples were prepared with moisture content corresponding to optimum water content. In addition to the odometer, he developed a delayed procedure, which involved tests with constant curing time of 7 and 28 days. He pointed out that the lime-treated soil samples exhibited lower compressibility; particularly for samples compacted on the dry side and that dramatic over consolidation was obtained by dynamic compaction.

4% addition of lime with Gazipur clay soil increased the unconfined compressive strength at different curing period by four to six times. Strengths with 4% lime were, also, found to be 1.5 to 2 times higher compared to the addition of lime in the range of 2, 6 and 8%.(Farooq et al. 2011). Better strength was recorded when Gazipur soil was combined with 4% lime

By adding 6% lime with sandy clay maximum strength found was 198.44 KPa for 6% addition of lime (Jawad et al. 2014).

It is evident from literature review that lime stabilization is one of the most practical and cost effective techniques of sub grade stabilization. However, it is to be noted that in cold weather, lime stabilization could not give the desired strength in soil. The goal of this research is to clearly understand the behavior of lime in increasing compressive strength of locally available soil.

3. METHODS & PROCEDURES

The soils used in this study were classified according to Unified Soil Classification System (USCS). For the classification Atterberg limit test, Sieve Analysis test as well as Hydrometer Analysis test was conducted. The consistency limit test includes liquid limit and plastic limit tests of soil by using the Casagrande apparatus in accordance with ASTM specification. The ASTM standard procedure was followed in performing particle-size analysis of fine grained soil which was based on the principle of sedimentation of particles, and is measured by flotation of hydrometer for 36 hours. The results associated with the classification of both soil samples were showed in the tabular format in Table 1.

Table1: Classification and Engineering Properties of Soil

Soil Properties (Paddy Land Soil)		
Parameter		Percentages (%)
As Per Unified Soil Classification System(USCS) Group Symbol SM	Sand	68
	Silt & Clay	32
Liquid Limit		47
Plastic Limit		43.5
Plasticity Index		3.5
Optimum Moisture Content(OMC)		16
Salinity		Nil
Soil Properties (Hilly Soil)		
As Per Unified Soil Classification System(USCS) Group Symbol SC	Sand	59
	Silt & Clay	41
Liquid Limit		30.5
Plastic Limit		20
Plasticity Index		10.5
Optimum Moisture Content(OMC)		12
Salinity		Nil

Lime in the form of Lime-stones (CaCo3), quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca $(OH)_2$, or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. In our case, lime-stones were collected from the local market. Properties of lime-stones procured from the local market are given in Table-2.

Table 2: Properties of Lime-stones procured from local market

Lime Properties.		
SL No.	Parameter	Percentages (%)
1	Calcium oxide – CaO	63.2
2	Moisture	22.9
3(1+2)	Calcium Hydroxide $Ca(OH)_2$	86.1
4	Residual Materials	13.9

In this research, performance of lime with two different types of soils: hilly soil from Khulshi area and paddy land soil from South Salimpur within the city were assessed. For the ease of measurement, it was converted into powder by sprinkling water on it. It was found that the lime stone procured from the local market had a lime content of 63.2%(Table 2). Lime-powder in variable percentages of 0%, 2%, 4%, 6%, 8%, 10%, 12%, and 14% were used as binder/stabilizer. The unconfined compressive strengths of lime stabilized soil were evaluated for different curing period: 7 days, 14 days, 28 days and 60 days. The overall working framework is shown in Figure 2.

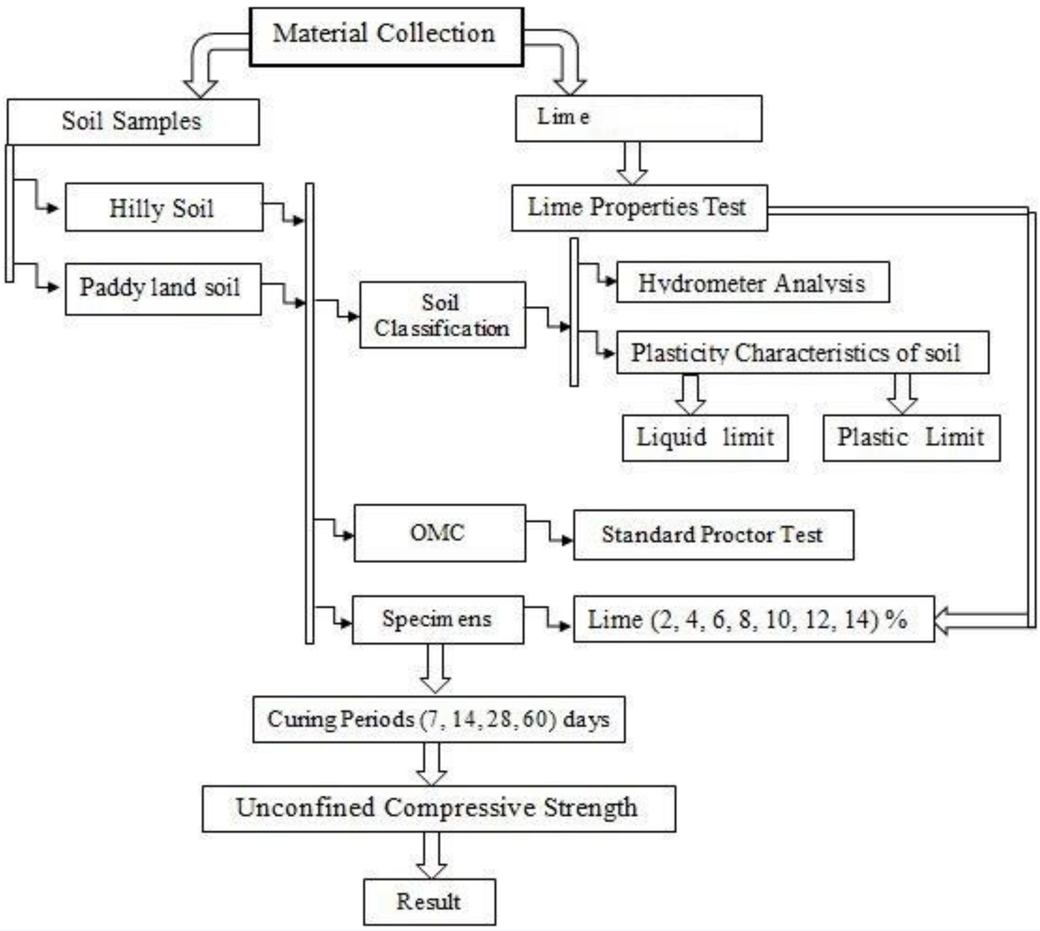
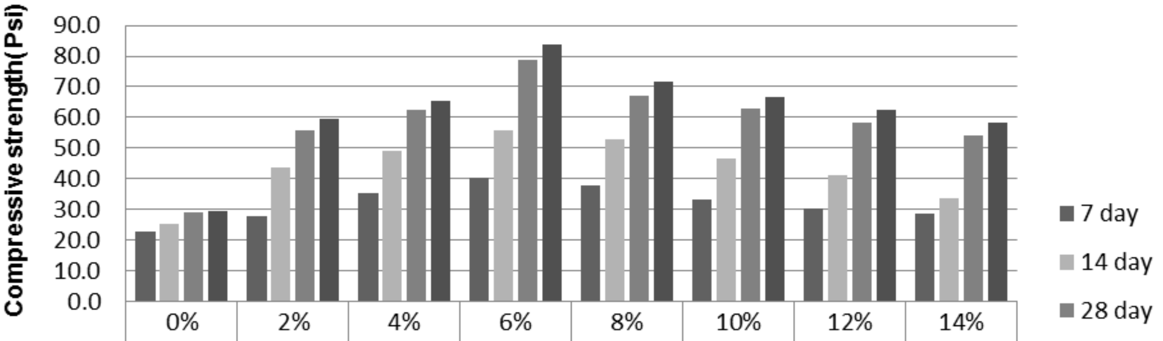


Figure 2: Flowchart of Methods and Procedures

4. RESULTS AND DISCUSSIONS

The results of the unconfined compressive strength tests are given in this section. Unconfined compressive strengths were estimated from stress strain diagram and plotted against eight different percentages of lime content for four different curing periods and are shown in figure 3**.** It shows that unconfined compressive strength increases as the curing period increases for all the hilly soil samples tested in this study. It also shows that unconfined compressive strength increases for (0% - 6%) lime content and decreases for further increment of lime content in the samples. The initial increment of unconfined compressive strength for using (0%-6%) percent of lime is due to the hydration of lime in the hilly soil sample and the later decrement of unconfined compressive strength for using (8 to 14 %) percent of lime is due to the presence of excessive lime, having less compressive strength compared to soil, in the hilly soil sample. It is clear from the Figure that 6% lime content in the hilly soil gives highest unconfined compressive strength after each curing period. The compressive strength is highest after a curing period of sixty days. It is clear that compared to cement lime takes more time in curing for gaining adequate strength.



	0%	2%	4%	6%	8%	10%	12%	14%
7 day	22.89	27.87	35.08	40.25	37.93	33.15	30.27	28.73
14 day	25.3	43.83	48.94	55.94	52.98	46.75	40.95	33.52
28 day	28.87	55.63	62.3	78.8	67.02	62.86	58.45	54.07
60 day	29.52	59.63	65.32	83.87	71.53	66.65	62.56	58.32

% of Lime

Figure 3**:** Unconfined Compressive strength (UCS) of hilly Soil with different percentages of lime and different curing period

Figure 4 shows that unconfined compressive strength against four different curing periods for eight different percentages of lime soil mixture. It showed that that with 0% limes content, unconfined compressive strength is almost similar for all four curing periods. That means when no lime is used, increase in curing period will have no appreciable effect on the strength of soil. However, for varying percentages of lime in lime soil mixture, considerable variations of unconfined compressive strengths were observed. The optimum lime content required to produce maximum strength depends on curing temperature and curing period. From the figure:4, it is also found that soil without lime gives the lowest unconfined compressive strength and addition of 6% lime content with hilly soil showed largest values of unconfined compressive strength for all curing periods.

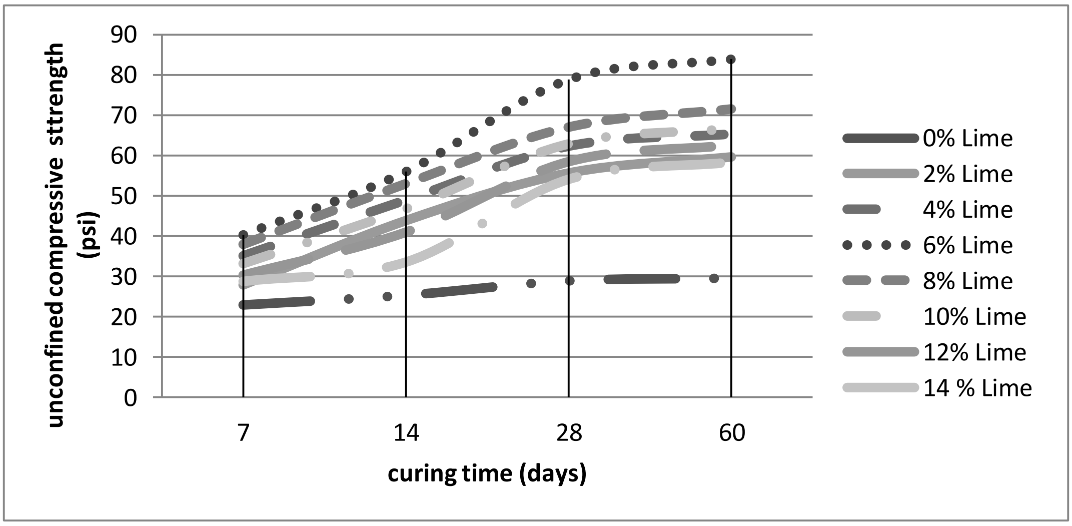


Figure 4: Unconfined compressive strength of Hilly soil as a function of curing period for eight different lime soil mixtures

In figure 5 it is shown that unconfined compressive strength increases with the increase in the length of curing period, even when the percentage of lime remained unchanged. It also showed that with further increase in lime, in all curing periods, strength decreases.

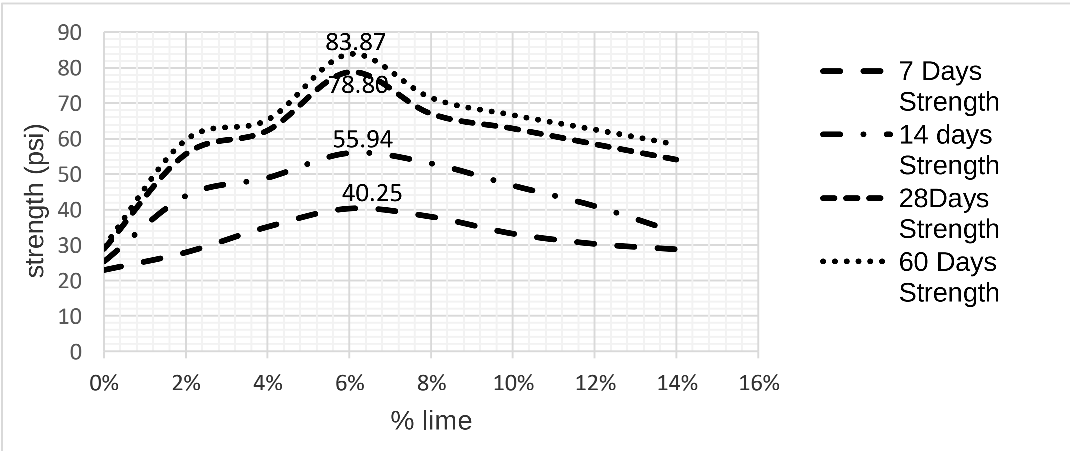


Figure 5: Unconfined compressive strength of hilly soil against percentages of lime for 7, 14, 28, 60 days of curing period.

Unconfined compressive strength was estimated from stress strain diagram and plotted against eight different percentages of lime content for four different curing periods. In figure 6, it shows that unconfined compressive strength increases as the curing period increases for all the paddy land soil samples tested in this study. It also shows that unconfined compressive strength increases for (0% - 8%) lime content and decreases for further increment of lime in the samples. The initial increment of unconfined compressive strength for using (0%-8%) percent of lime is due to the hydration of lime in the paddy land soil sample and the later decrement of unconfined compressive strength for using (10 to 14 %) percent of lime due to the presence of excess lime (having less compressive strength compared to soil) in the paddy land soil sample. It is clear from the Figure that 8% lime content in the paddy land soil gives highest unconfined compressive strength at each curing period used in this study.

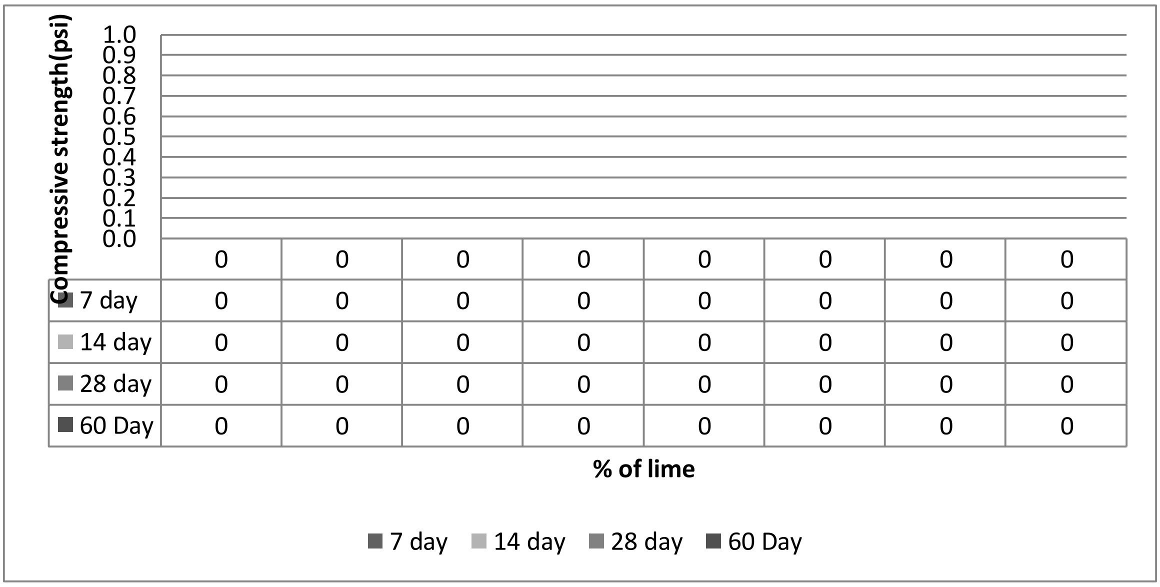


Figure 6: Unconfined Compressive strength (UCS) of Paddy Land Soil with the different percentages of lime

Figure 7 shows the plotting of unconfined compressive strength against four different curing periods for eight different percentages of lime soil mixture. It shows that (0% lime content) unconfined compressive strength is almost similar for all four curing periods indicating no effect of curing period on unconfined compressive strength for 100 percent sample soil. However, for other cases (lime soil mixture) considerable variation of unconfined compressive strength was observed with varying percentage of lime content in soil indicating the effect of lime content on unconfined compressive strength. From the Figure 7**,** it is also found that soil without lime gives the lowest unconfined compressive strength and 8% lime content in paddy land soil gave largest values of unconfined compressive strength for all curing periods. Therefore, adding only 8% of lime with paddy soil gives considerable improvement in the strength of soil.

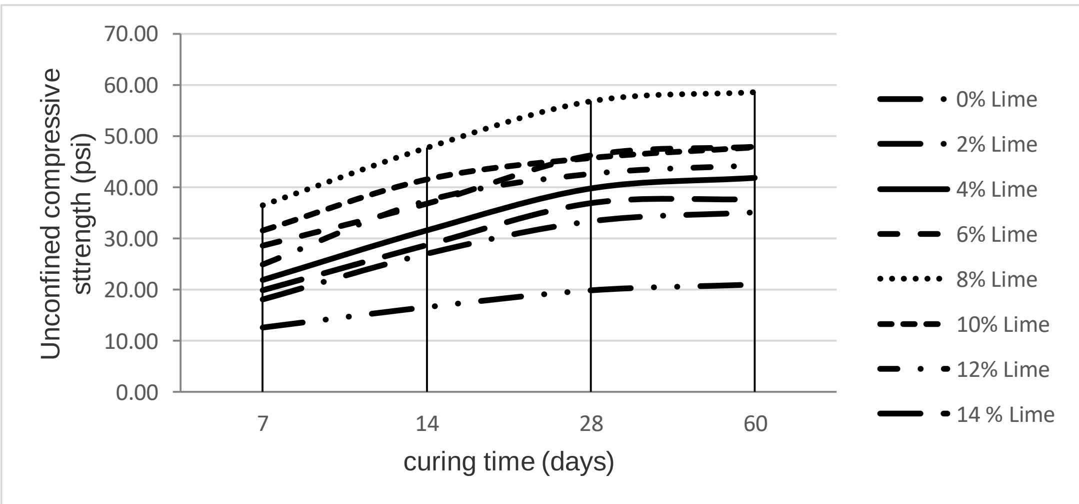


Figure 7: Unconfined compressive strength of Paddy Land Soil as a function of curing period for eight different lime soil mixtures

In figure 8 it is shown that the unconfined compressive strength increases in respect of curing period when the percentage of lime is constant. It also showed that with further increase of lime in all curing period, strength decreases.

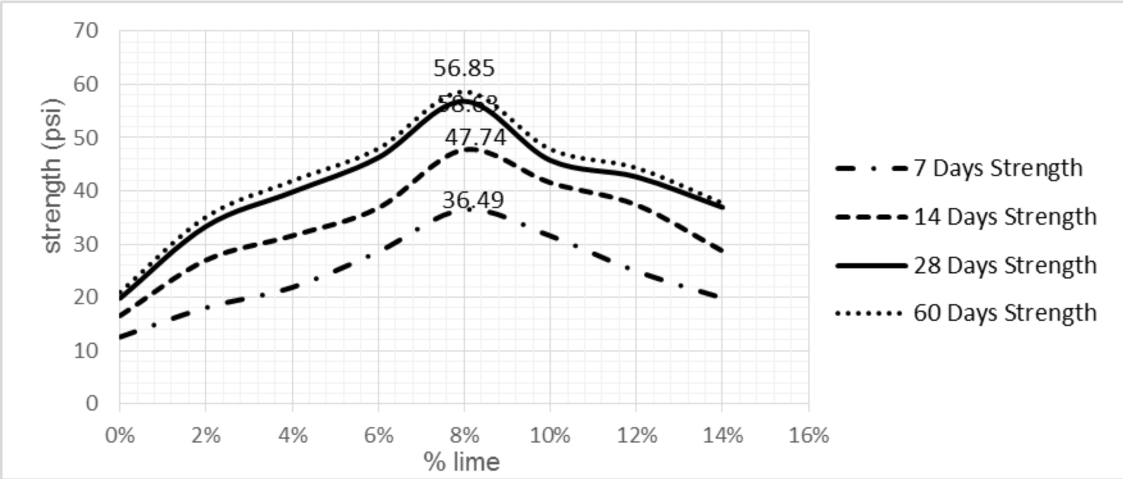


Figure 8: Unconfined compressive strength of Paddy Land Soil against percentages of lime content for 7, 14 and 28 days curing period.

5. CONCLUSIONS

It was found that the soil strength increased with the increase in percentage of lime to a certain limit. It was, also, found that strength increases with the increase in curing period. At 8% lime content, maximum compressive strength was found in paddy land soil while at 6 % lime content maximum compressive strength was found in hilly soil. Hilly soils are generally sandy while the paddy land soils are silty/clayey. It was found that less limes were necessary for stabilizing sandy hilly soil compared to silty paddy land soil.

RECOMMENDATIONS

The following recommendations are suggested for further research work.

- ❑ Different varieties of soil sample, especially soils frequently found and used in the locality, can be analyzed for same and similar percentages of lime used in this study.
- ❑ Impact of cyclic wetting–drying on swelling behavior of lime-stabilized soil is to be investigated.

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