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A Study to Determine the Effects of Organics on the Results of Quicklime Slurries Treatment of Clay Soils

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16. Abstract

1. Select and sample subject clay soil(s) for improvement, and locate a source of suitable heavily organic soil(s). 2. Determine the basic physical properties of both the subject soil and organic soil: 3. Select mixtures of the natural soil and organic soil for testing: suggest 0, 5, 10, 15, 20 and 25 % organic soil as percent of whole sample mixture. 4. Make the mixture of soils and sufficient water to bring to approximately the mixture's plastic limit and allow to equilibrate moisture. 5. Determine the untreated properties of the soil mixtures. 6. Conduct standard lime treatment testing regimen on the natural clay soil and the soil mixtures. 7. Conduct 3-D swell potential tests and wet-dry tests on specimens at LMO and LSO percents lime for each soil mixture. 8. Conduct SEM study of materials tested and taken from the compacted specimens of untreated and treated soil mixtures. 9. Analyze results of testing and provide project report to funding company.

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Preliminary Project Report: The Effect of Organic Content on Lime Treatment of Highly Expansive Clay

EXECUTIVE SUMMARY

The effects that organic material has on swell potential and strength of lime-treated expansive clay were determined thru laboratory testing. Four soils (one natural and three manufactured) subjected to different laboratory tests were used to analysis the effects of organic material in lime treatment. The laboratory testing program consisted of Atterberg limits, Eads and Grim pH, linear shrinkage, standard compaction, one dimensional swell, and unconfined compression were used to identify the differences between untreated and treated soils physical properties. The soils' physical properties were then graphically and statically analyzed for significant changes. The results indicate that swell potential can practically reduced to zero, while strength can only slightly improved. The Final Report will include soil chemical property data and X-Ray diffraction data.

INTRODUCTION

Expansive clays exhibit high potential for volume change because of changes in soil moisture, Jones and Jones (1987) estimated that the annual const of damage to facilities built on expansive clay in the United States exceeded $9 billion. One of the most common and effective chemical treatments of expansive clay is the addition of lime, either calcium hydroxide [$Ca(OH)_2$] or quicklime (CaO), to the soil. Lime treatment has been widely used for many years and is current used for stabilizing clay soils supporting runways, building, roads, and parking lots. Although much is know about the phenomenon of soil-lime reaction in expansive clays, little has been done to investigate the affects of organic content on the effectiveness of lime treatment. The focus of this research is on the effect(s) of organics on the treatment of a highly expansive clay soils with the addition of quicklime. Of particular concern were effects of organic content on the swell potential and unconfined compressive strength of lime treated soil.

PURPOSE

Over the years, rules of thumb have been developed in the treatment of organic clay soils. However, little research has been conducted to determine the precise effects of organic material on the lime treatment process. Thru the financial support of Chemical Lime, Co., and the University Transportation Center of the University of Missouri–Rolla, a research project was develop to test the effects of organics material on the lime treatment of an expansive clay soil. The goals of the project were to determine the amount of lime needed to reduce the swell potential (modify) and increase the unconfined compression strength (stabilize) this clay.

BACKGROUND

Organic matter

Organic matter in general terms comes from the decomposition of plant and or animal organisms. The presence of organics can affect many soil properties. Since most organic soils are relatively young in geologic age and have not bee exposed to large confinement, most organic soil have very low strengths, extremely compressible, and large creep. The degree that the organics affect soil properties depends on the degree of decomposition, chemical composition, organic content, particle charge, and Cation Exchange Capacity (CEC). Properties of organic soils are derived from the source organic material. According to Hartlen & W.Wolski (1996):

> *Organic matter to can be divided into three general categories: peat, dy and Gyttja. Peat originates from plants and denotes the various stages in the humification process where the plant structure can still be discerned. Dy denotes the stage where the plant structure is completely destroyed…Gyttja originates from remains of plants and animals rich in fats and proteins. In contrast to peat which is formed by remain o plants rich in carbohydrates.* (1)

There are a number of different classification systems available for organic and organic soils. However, most systems are not geared toward geotechnical engineering. The most common classification system uses ash/organic carbon content as the basis of soil identification (ASTM D 2972). The particular procedures and nuisances of this method are beyond the scope of this paper. However, a general explanation is helpful since this method was used to determine the organic content of the research soils. The concept stems from the fact that organic matter is assumed to be combustible were as soil minerals are not. The percent organics is determined by placing a soil sample in a muffle furnace at a specified temperature and measuring the weight of it before and after. The percent organics is found by dividing the loss of weight on ignition by the final dry weight of the soil solids.

Lime Treatment

The purpose of lime treatment is to improve existing soil properties to achieve a desired performance level. Soils property improvements normally expected by lime treated include improved strength, improved resistance to fracture, fatigue, and permanent deformation; improved resilient modulus properties; reduced swelling; and improved resistance to the damaging effects of moisture according to TRB State of the Art Report 5. The most substantial improvements in these properties are seen in moderately to highly plastic soils, because of their high cation exchange capacities. Lime treatment can be divided into two categories; modification and stabilization.

While these two treatment levels are closely related, for this paper a distinction between the two needs to be made. Modification is a combination of changes due to cation exchange, agglomeration & flocculation, and ion crowding. The affect of modification can be seen as an nearly immediate reduction of the Plasticity Index (PI) along with increased workability of the soil. Stabilization is long term product of Calcium Aluminate Hydrate (CAH) and Calcium Silicate Hydrate (CSH) formation and is seen as an increase in compressive strength and increase of soil modulii. Both of these procedures are applied to improve the engineering properties of highly expansive clays.

Soil composition and chemistry are integral factors in the amount of lime needed to treat soil. The effectiveness of lime treatment is dependent upon degree of soil weathering, soil-water pH, base cation concentrations, Silica-alumina concentrations, sulfate content, and organic content. Every soil has a particular level of lime needed to achieve modification and stabilization levels of treatment, the Lime Modification Optimum (LMO) and Lime Stabilization Optimum (LSO), respectively. Through the use of a proper laboratory testing program the amount of lime needed to reach a desired improvement level can be achieved. The testing program utitlized for this project included soil manufacturing processes as well as normal testing to provide known levels of organics.

LABORATORY TEST PROGRAM

Soil Manufacture

The soil chosen for the research was weathered clay shale for the Eagle Ford geologic Formation. The soil was provided by the Chemical Lime Co. and shipped to the geotechnical engineering laboratory at the University of Missouri-Rolla. Upon arrival the soil was air dried and processed thru a Number 4 U.S, Series sieve. This soil will be referred to throughout this report as the Natural soil. To insure that a sufficient amount of organic matter was present in subject soils, “organic” soils were manufacture by adding “peat” to the Natural soil. Three soils with differing organic contents were manufactured. These soils will be referred to throughout this report as Soil A, Soil B, and Soil C. The soils were batched by weighing out sixty pound of Natural soil and an amount of peat added to each soil: 6, 12, and 18 pounds, respectively.

Testing Procedure

The eight different laboratory tests were conducted on the natural and 3 subject soils. The laboratory tests were:

- Grain Size Analysis (ASTM D 422)
- Organic content (ASTM D 2974)
- Eads and Grim pH (ASTM D 6276 Rev. A)
- Atterberg Limits (ASTM D 4318)

- Linear Shrinkage (Tex-107-E)
- Standard compaction (ASTM D698)
- Unconfined Compression (ASTM D2166)
- Free Swell (ASTM D2166)
- Determination of Soluble and Exchangeable Salts (In Process)
- X-Ray Diffraction of the Clay Portions (In Process)

Treated and untreated specimens were tested for the properties listed above, where appropriate. Standard procedures were used unless otherwise stated. Small variations form the standards were implemented in some testing procedures. The following is summary of the testing procedure for each test.

Grain Size Analysis - ASTM standard procedure was used on sieve and hydrometer analysis. Sieves used were #4, #10, #40, #100, and #200. The Material for the hydrometer was acquired after washing the soil retained on the #40, #100, and #200 sieves.

Organic content - Determination of organic content was conducted on the 4 subject soils (untreated) and the organic soil. ASTM D 2974 procedure C was followed. The procedure utilizes a 440°C ignition oven to determine the amount of combustible carbon in the soil specimen.

Eads and Grim pH test - The standard ASTM procedure states that a soil is fully modified when the pH has reached a value of 12.45. Our test procedure was modified to state that a soil is fully modified to find the percent lime for the maximum pH.

Atterberg limits – The standard ASTM procedure was followed for Atterberg limits testing. A four point liquid limit test procedure was used to develop the liquid limit curve.

Linear shrinkage – Linear shrinkage was preformed on treated and untreated soils. Treated soil was prepared at 4 different lime treatment levels in accordance with data obtained for the Eads and Grim pH test. Lime treated soil was mellowed for one day before testing.

Standard compaction – Generation of the optimum moisture content vs. dry unit weight curve for untreated soils was constructed using five moisture content/unit weight data points. Treated soil curve generation used 4 moisture content/ unit weight data points. Lime treated soil was mellowed for one day before testing/compaction.

Unconfined Compression – Each subject soil was tested untreated and treated. Treated soil specimens were mixed at differing lime treatment levels in accordance with Eads and Grim pH test and Atterberg limit testing results. Lime treated samples were allowed to mellow one day before compaction. All specimens were statically compacted with target compaction to meet 95 percent of standard proctor maximum dry unit weight at optimum moisture content for the various soil-lime mixtures. After compaction the samples were sealed and cured in a moisture control room for 28days. A total of 29 unconfined compression tests were conducted. Unconfined compressive strengths were determined using a strain rate of 0.5 percent per minute.

Free Swell - Free Swell Tests were preformed with 150psf seating load and allowing the sample to swell vertically for 120 -168hrs (5-7days). Treated and untreated swell test were preformed on all soils. Treated swell test were conducted at LMO of the respective soil. Lime treated sois were mellowed for one day before testing/compaction. All specimens were statically compacted with target compaction to meet 95 percent of standard proctor maximum dry unit weight at optimum moisture content for the various soil-lime mixtures.

Soil chemical testing and X-ray diffraction testing were delayed by equipment availability. The procedures used will be included in the final project report.

RESULTS

Grain Size Analysis

Sieve and hydrometer tests were run on the Natural soil only. The result of the sieve and hydrometer analysis indicates that 35 percent of the natural soil is passing the #200 sieve. The grain size curve is shown in figure 1.

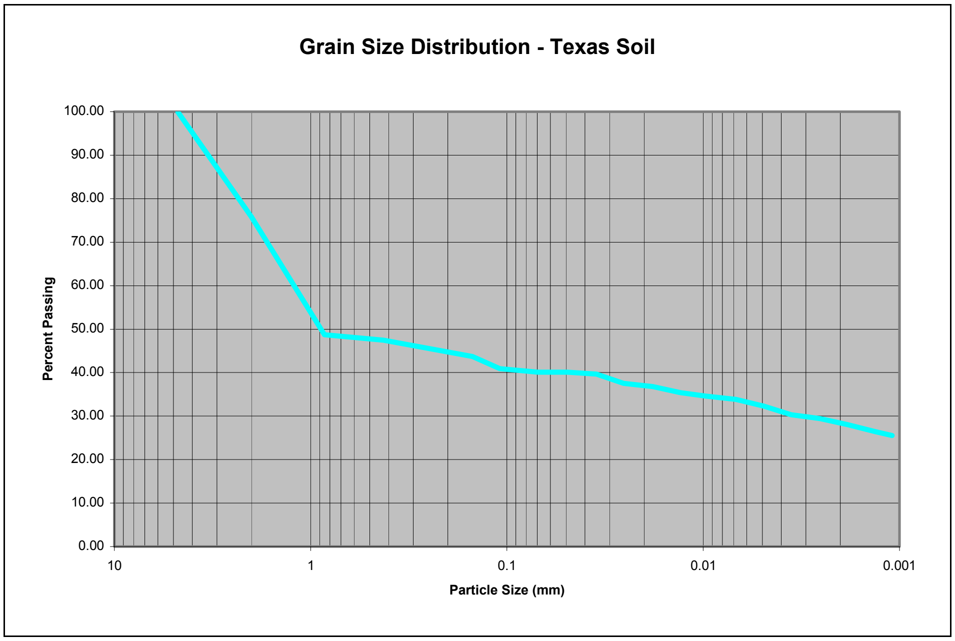

Figure 1: Grain Size Analysis distribution

Organic Content

Organic content was determined for all four subject soils plus the organic Soil. The results of this test can be seen in Table 1.

Soil	% Organics
Natural	0%
Soil A	2%
Soil B	4%
Soil C	6%
Organic Soil	15%

Table 1: Percent Organics for Subject Soils

Eades and Grim

Figure 2 shows a typical results form Eades and Grim. Two tests were run on each soil for a total of eight. Table 2 shows the results obtained for the pH testing. An increase in of approximately 2 percent lime for the LMO was observed as the organic content increased in each case.

	Lime Modification Optimum
Soil	**% Lime**
Natural Soil	4
Soil A	6
Soil B	8
Soil C	10

Table 2: Results of Eades and Grim pH testing to determine soil LMO

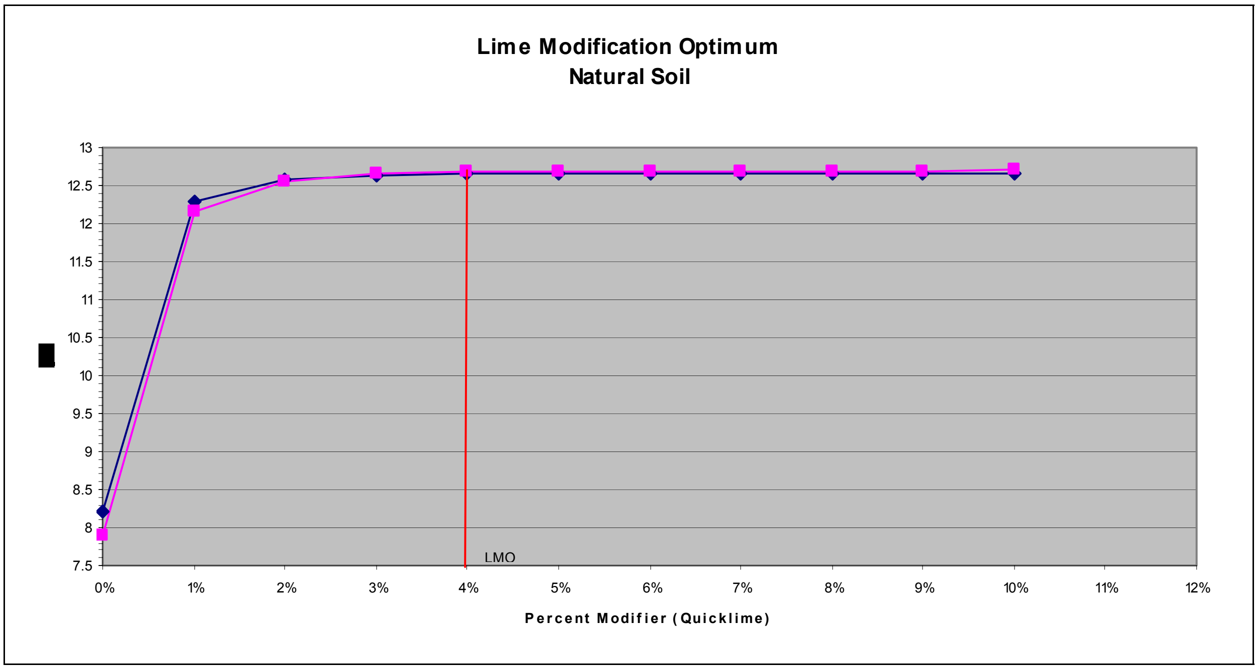

Figure 2: Eades and Grim Test Results

Atterberg limits

The Atterberg limits test results were used in soil classification along with grain size analysis and, in addition, to determine the LMO of the subject soils. Four sets of Atterberg Limits (AL's) were preformed on each subject soil. One test with untreated soil and three with treated soil of differing lime contents. Figure 3 shows a typical reduction in liquid limit as a result of lime treated. As more lime was added to the subject soil the liquid limit (LL) decreased while the plastic limit (PL) increased. This can also be seen as a reduction in the plasticity index (PI). When the PI of the soil is at a minimum the soil is said to be fully modified. Table 3 is a summary of Atterberg limits test results. As seen in Table 3 the untreated natural soil had the highest plastic limit (PI) while untreated Soil C the lowest PI. Results indicate that all soils showed a reduction of PI with the addition of lime, of the type seen in Figure 4. The greatest decrease is seen in the natural soil and the smallest in Soil C.

Besides being used for LMO determination the Atterberg limits were used in the identification of the soil type. All untreated soils were identified as CH according to ASTM D2487. After lime treatment Natural, B, and C soils were classified as ML.

Soil	% Organics	Quicklime %	PL	LL	PI
Natural	0	0	24	65	41
Natural	0	2	42	51	9
Natural	0	4	42	51	9
Natural	0	6	42	49	7
A	2	0	26	61	35
A	2	4	41	55	14
A	2	6	40	48	7
A	2	8	39	46	7
B	4	0	26	59	33
B	4	6	43	54	11
B	4	8	40	50	10
B	4	10	40	50	10
C	6	0	26	57	31
C	6	6	39	54	15
C	6	8	37	49	12
C	6	10	38	51	13

Table 3: Results form Atterberg limits testing.

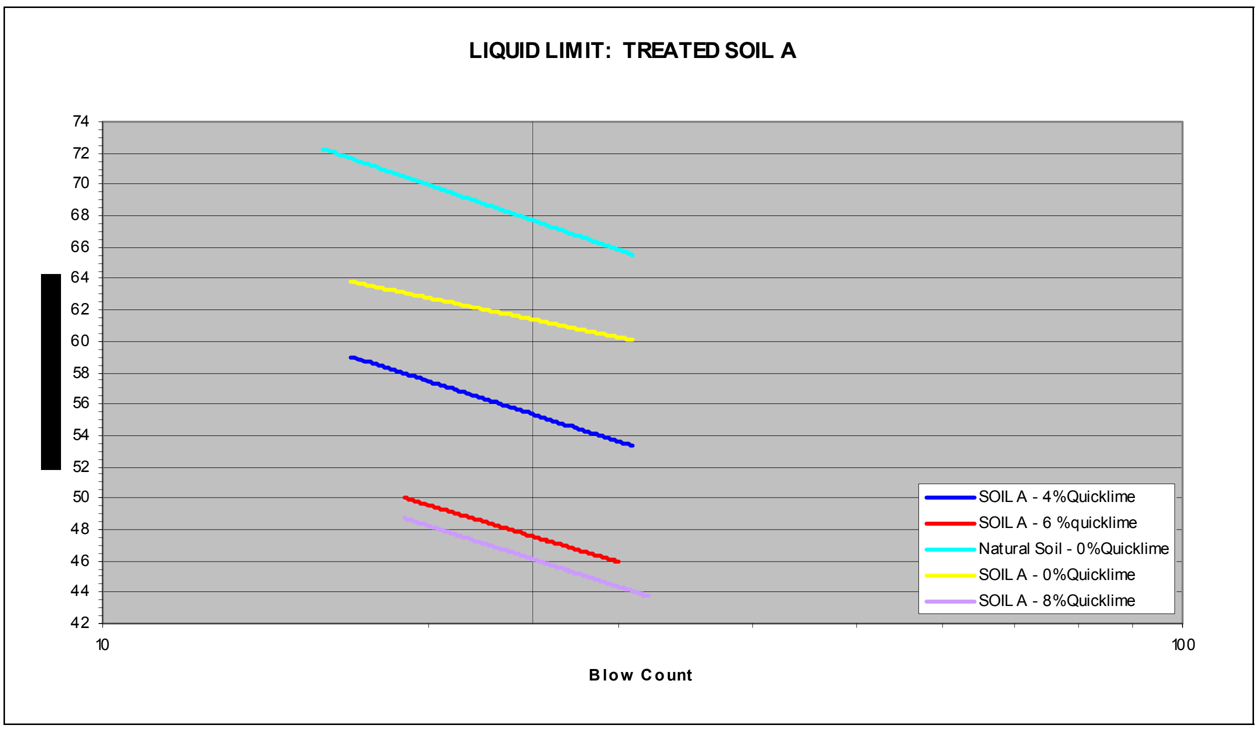

Figure 3: Liquid Limit Results for Soil A

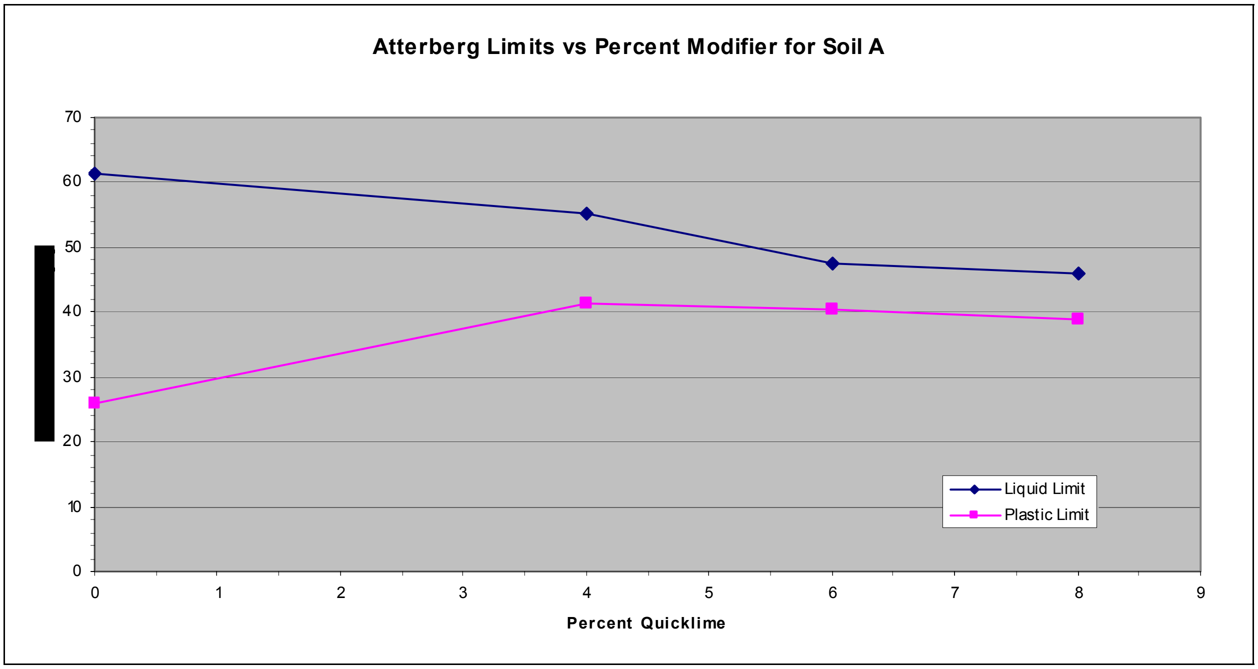

Figure 4: Liquid and Plastic Limit of Soil A vs. Percent Modifier

Linear Shrinkage

The purpose of using the linear shrinkage test was to observe the effects of organic content on shrinkage with respect to different levels of lime treatment. Four linear shrinkage (LS) tests were preformed on each subject soil. One test with untreated soil and three with treated soil at differing lime contents. A diagram depicturing the effect of organics on linear shrinkage is shown in Figure 5. For untreated soil specimens the addition of organics increased the shrinkage of the soil. Maximum shrinkage was observed in Soil C to be 17% while 13% was measured in the natural soil. As lime was added to each soil, a reduction in LS was observed. A maximum reduction, for all soils, occurred with the addition 6% lime. The LS for lime treated soils varied from a low of about 6% for Soil B, to the highest of about 9% for the Natural Soil.

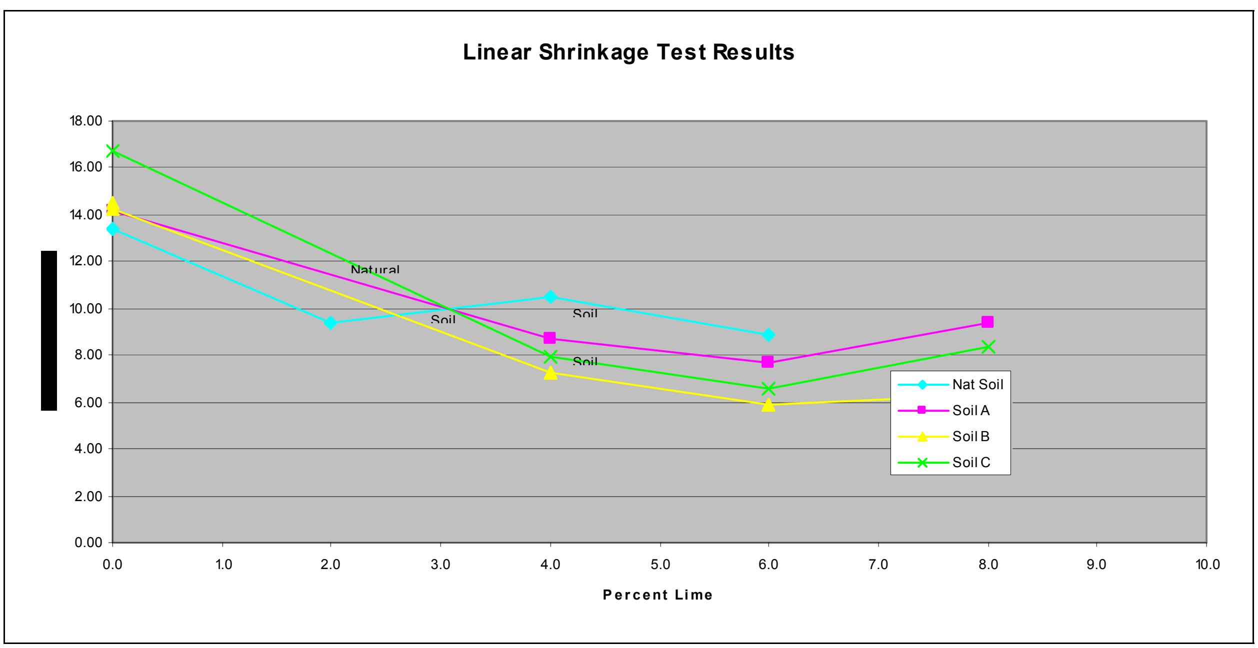

Figure 5: Linear shrinkage vs. Percent Modifier

Compaction (Proctor)

Standard Proctor compaction was used to determine the max dry unit weight and optimum moisture content (OMC) of each subject soil. A test was performed on each of the untreated soils. Do to a limitation in available soil, only two tests were conducted on treated soil. Soil A and Soil C were chosen for the treated soil compaction tests. . Figure 6 and Figure 7 show the moisture-unit weight compaction curve for the untreated and treated soils, respectively. As seen in Figure 6, as the organic content increases, the maximum dry unit weight deceases and the OMC increases. When lime was added the subject soils, the maximum dry unit weight is decreased and the OMC is increased as shown in Figure 7.

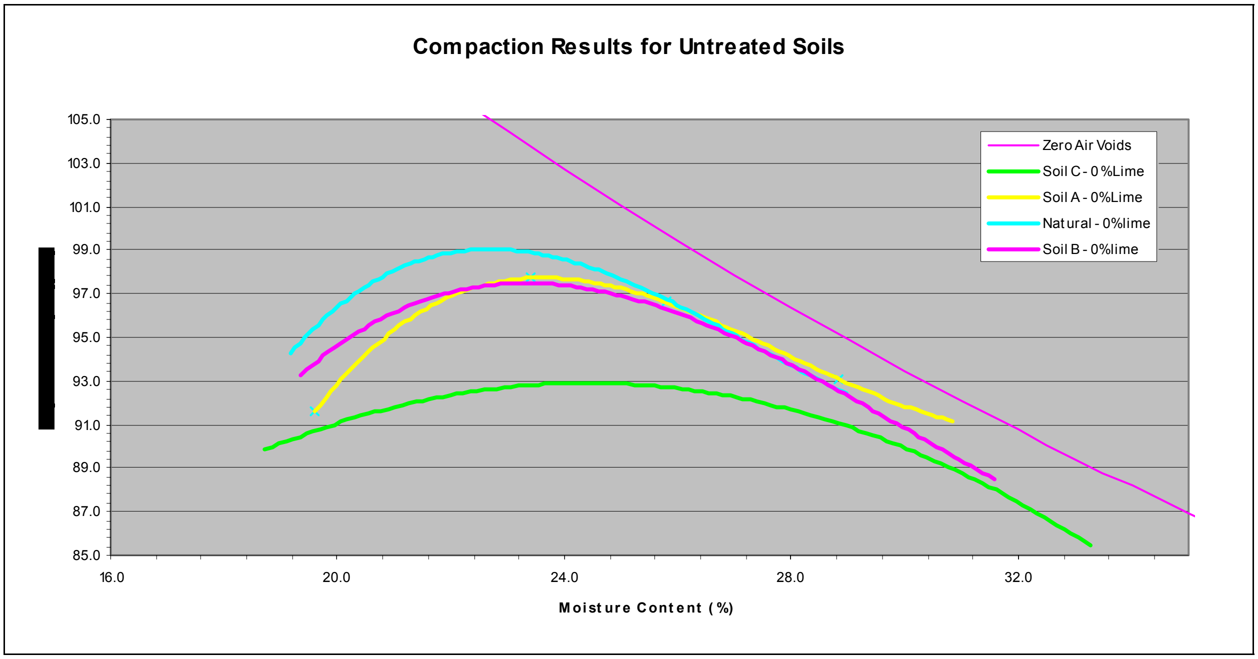

Figure 6: Compaction Results for Untreated Soils

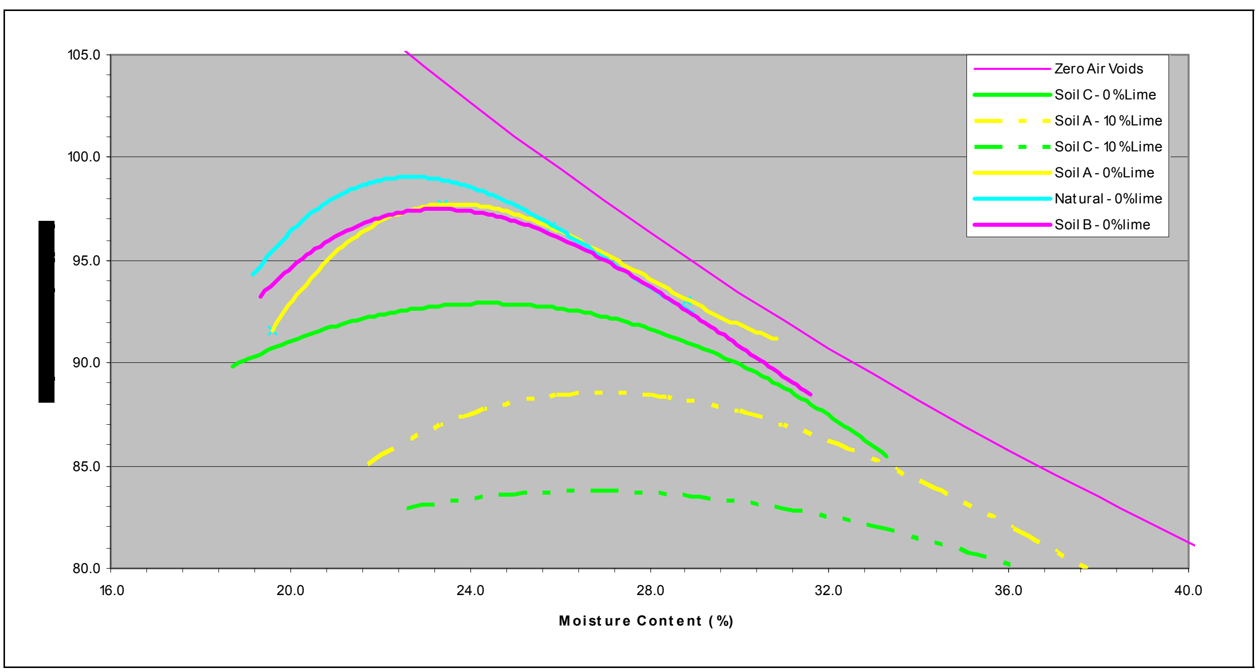

Figure 7: Compaction Results for Treated Soils

Free Swell

The purpose of the swell test was to determine if the swell potential of the subject soils could be reduced. Two swell tests were run on each soil, one with untreated soil and one with treated soil. As seen in Figure 8, as the organic content increased the swell decreased. The untreated natural soil had the most swell with 3.4% and Soil C had the lowest swell at 2%. The treated as compared with the untreated subject soils, showed no indication of swelling. The swell tests indicate that the organic soil can be effectively treated to reduce swelling.

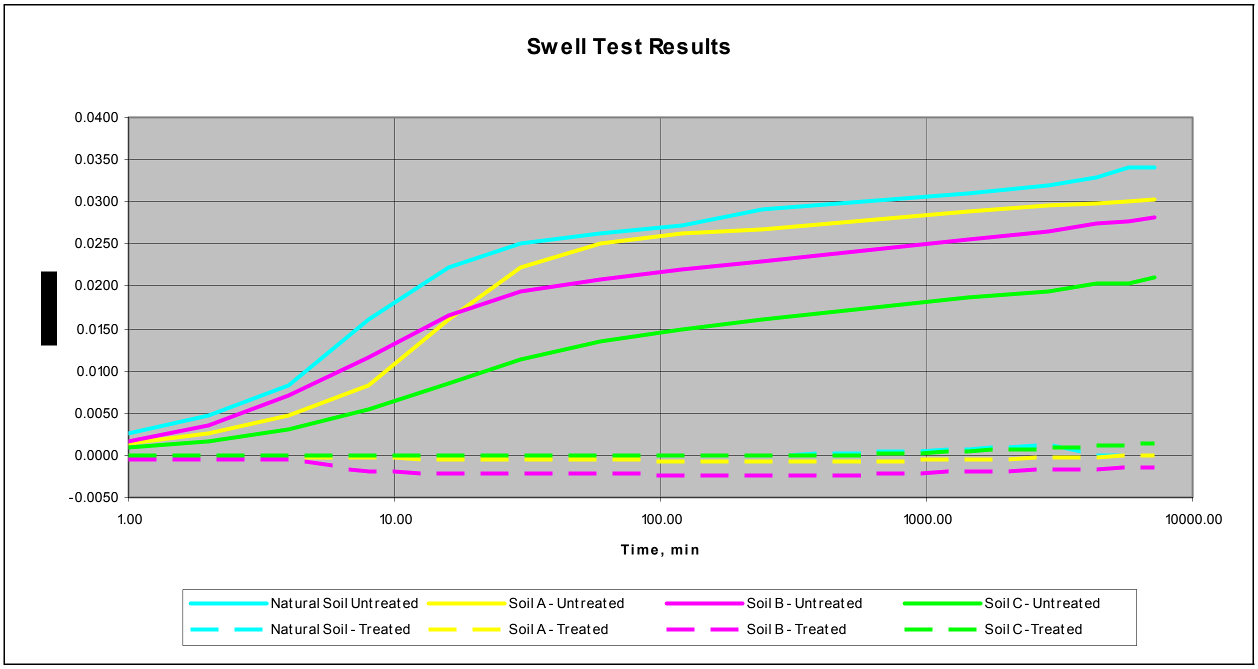

Figure 8: Free Swell Test Results

Unconfined Compressive Strength

Unconfined compressive strength test was conducted to determine the Lime Stabilization Optimum (LSO) for each soil. Figure 9 shows the unconfined compressive strength verses lime content of 28 statically compacted samples. Seven samples were manufacatured for each soil. One untreated and 6 at varying degrees of lime content. Lime contents were determined by analyzing the LMO. The lower bound was the LMO and the upper was 2 % percent lime above 2 times the LMO. The greatest strength of untreated material was seen in the natural soil, with Soil C having the lowest strength. As seen in Figure 9 the maximum for the treated subject soils occurred at 8%, 12%, 14% lime for Natural soil, Soil A, Soil B, respectively. The maximum compressive strength value observed for Soil C occurred at 18% lime. While this may be the LSO for this soil, a definite conclusion can not be made due to data restrictions.

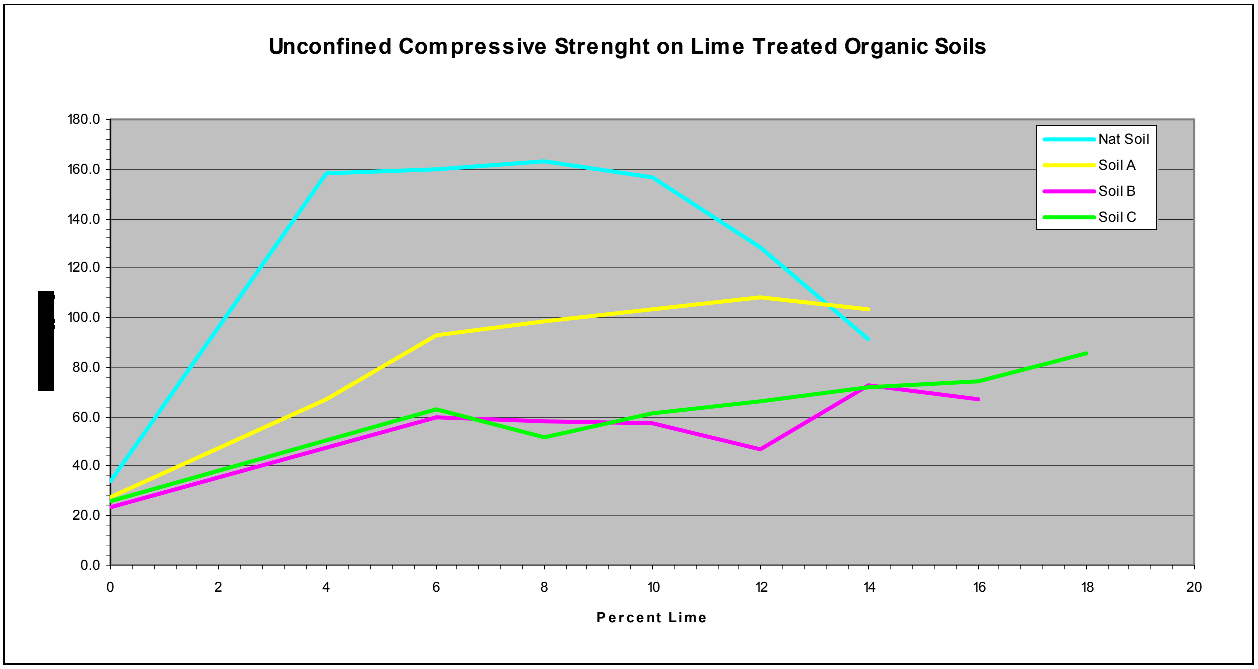

Figure 9: Unconfined Compression Strength Plot

CURRENT TESTING

Additional testing is being conducted on the exchange and soluble salts behavior of each of the subject soils and the organic matter. This information will help to provide valuable information about the physico-chemical behavior of the soil-organic-lime complex.

CONCLUSIONS

A laboratory testing program was used to classify the soil, observe swell and compaction behavior, and identify the amount of lime treatment needed to achieve Lime Modification Optimum and Lime Stabilization Optimum. The sieve and hydrometer analysis, Atterberg limits were used to classify the soil as a CH according to ASTM D2487. The LMO was identified by using the data from Atterberg limits, linear shrinkage, and Eades and Grim pH Testing. Unconfined compression test was used to determine the LSO for each subject soil.

One of the main interests of this research was on the swell behavior of lime treated organic soils. The use of lime to reduce swell potential or modification of organic soil proved successful. All LMO treatment levels reduced the swell of subject soils to essentially zero. However, the LMO increased as more organic soil was added to the natural soil. Although the LMO is increased, the amounts of lime needed to achieve the LMO are within reasonable economic values.

The Lime Stabilization Optimum was the other interest of this research. Although lime treatment was successful in improving the unconfined strength of a soil, the strength increases comes at a high cost. Very large amounts of lime are needed to achieve a small gain in strength for small percentage of organic soil. Lime treatment to achieve the LSO for organic soils is, in most situations, unfeasible due to economic and construction factors.

The intent of this research was to test the effects of organic content on a lime-treated expansive clay. Physical property testing was conducted on treated and untreated soils for changes in lime reactive characteristics. In all physical property tests conducted, addition of organic matter was detrimental on the modification/stabilization attributes of thid lime-treated clay when Peat was added. The organic constituents have there own physico-chemical phenomenon associated with them. As a result the manufactured soil is a conglomerate of the two base materials. Hence, the soils behavior is dependent on the amount of organic/soil material present. The organic matter present in the soil alters the physico-chemical phenomenon of lime treatment.

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