THE EFFECT OF SOAKING IN WATER ON CBR OF LIMESTONE

Dr. Riyadh A. Al-Gurah
Lecturer
Civil Engineering Department
University of Baghdad

Noorance A. Razzaq
Assistant Lecturer
Building and Construction Engineering Department
University of Technology

ABSTRACT

This study presents utilizing additive, such as limestone to treat clay soil in the southern parts of Iraq. Roadways and parking areas need to be designed to accommodate the expected vehicle traffic. Ignoring the nature of the underlying soils creates the potential for pavement failures. A laboratory study concerning the strength behaviour in terms of the California Bearing Ratio (CBR) of a lime roadbed soil. The paper reveals that the CBR decreased with the increasing number of cycles until equilibrium was achieved at the end of the fifth cycle of soaking.

Keywords: Lime stabilization/ soil improvement/ pavement design/ roads and highways.

1. INTRODUCTION:

Lime has a number of effects when added to react pozzolanically with soil, which can be generally categorized as soil drying, soil modification, and soil stabilization. Lime stabilization occurs in soils containing a suitable amount of clay and the proper mineralogy to produce long-term strength; and permanent reduction in shrinking and swelling. This causes cracking and breaking up of

pavements, railways, highways, roadways, embankments, foundations and channel or reservoir linings [8].

Therefore, clay soils need to be improved to make them suitable types of construction. Soils can often be economically improved by the use of admixtures. Lime, either alone or in combination with other materials, can be used to treat a range of soil types. Some of the more widely used admixtures include lime, Portland cement and asphalt [7].

Lime stabilization can provide sound pavement foundations and reduce the thickness of the overlying layers. The treated soils may be in-place (sub-grade) or borrow materials. Sub-grade stabilization usually involves in-place “road mixing” and generally requires adding 3 to 6 percent lime by weight of the dry soil. Also, lime has an extensive history as a soil treatment option for several non-highway applications such as housing, embankment soils, airport construction and parking areas [8].

Several studies have been performed on soil improvement using lime for improving clay soil.

Akawwi and Alkharabsheh studied the effect of lime stabilization on the geotechnical properties of different types of soils, especially clay soils in Amman (Jordan) [1].

In 1999, the National Lime Association commissioned Dr. Dallas Little to evaluate various procedures and develop a definitive lime stabilization mixture design and testing procedure that specifying agencies, design engineers, and laboratory personnel could use with confidence for soil conditions and environmental exposures throughout the United States. The resulting series of reports summarize the literature on lime stabilization; describe mix proportioning and testing procedures for lime stabilized soil; and present a field validation of the protocol [4,5].

In 2001, Lopez and Castano used calcium oxide as a stabilization technique on clay soils, in order to inhibit its expansion contraction properties [6]. Mahasneh presented utilizing different additives, such as cement, silty sand (Dead Sea soil), ziolite, oil shale and sand to treat soft clay soil in Al-Kerak area (Jordan) [7].

The assessment of roadbed soils for highway and airfield pavements is usually expressed through the California Bearing Ratio (CBR) that is still used in much of the world [3,9].

In this study, the authors used quicklime (calcium oxide CaO) to improve clay soil in the southern parts of Iraq, using lime. Strengthening the existing soil with lime, rather than removing and replacing it with granular material can be resulted in substantial cost savings.

2. CHEMICAL COMPOSITION:

Lime in the form of 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 CaCO3) into calcium oxide. It can be produced by direct calcination of crushed limestones (calcium carbonate $CaCO_3$) in either shaft kilns or rotary kiln [9]. The following reaction takes place:

$$CaCO_3 + heat \longrightarrow CaO + CO_2$$

Quicklime has, however, the economic advantage over hydrated lime of being cheaper while at the same time containing as much as 25% more CaO [9].

Hydrated lime is created when quicklime chemically reacts with water. It is hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix [9].

Most lime used for soil treatment is “high calcium” lime, which contains no more than 5% magnesium oxide or hydroxide. On some occasions, however, "dolomitic" lime is used. Dolomitic lime contains 35% to 46% magnesium oxide or hydroxide. Dolomitic lime can perform well in soil stabilization, although the magnesium fraction reacts more slowly than the calcium fraction [9].

Sometimes the term “lime” is used to describe agricultural lime which is generally finely ground limestone, a useful soil amendment but not chemically active enough to lead to soil stabilization [9].

3. DISCRIPTION OF LIMESTONE SAMPLE:

Several tests have been made to figure out the physical properties of limestones. These tests are stated as follows: Atterberge limits were found according

to ASTM D4318-00. Liquid Limit test; is to determine the dividing line between liquid and plastic states. It was found to be 32.7 %. Plastic limit test; was determined to be 27.1 % which could be represented the dividing line between the plastic and semisolid state. Specific gravity test; it is useful to compute the density and occasionally the specific gravity. It was calculated and found to be 2.72. Sieve Analysis test; to determine the grain size distribution using ASTM D422-98. Compaction test; using the ASTM D1883-99; is necessary to improve its strength.

Water content determination test; to determine the amount of water present in a quantity of limestones in terms of its dry mass. The compaction curve of modified AASHTO compaction [2] (AASHTO T180-88) revealed an optimum moisture content (OMC) of 15.08 % and the corresponding dry unit weight of 18.58 kN/m^3.

4. EXPERIMENTS METHODS:

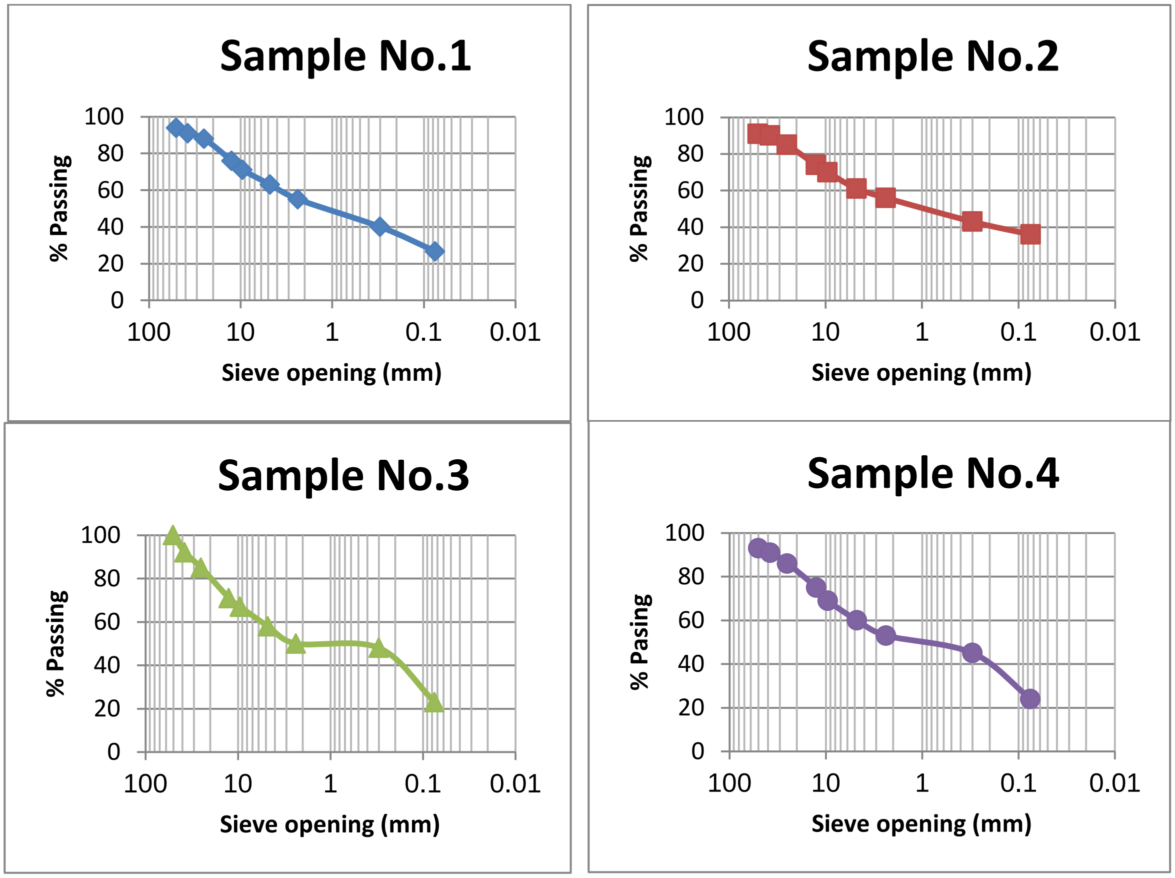
Four limestone samples were prepared in this study. The one sample was divided into six specimens. Each specimen should be compacted to the density required by specification, typically at least 95% of the maximum density obtained in the AASHTO T 99 (Standard Proctor) test.

The compacted specimens were soaked in water to arrive the CBR at the end of each soaking period. In this study, it was revealed that about six soaking cycles are necessary to achieve "equilibrium" which it is reflected the same behaviour in two consecutive soaking period time. The length of soaking cycle was chosen to be seven days under room temperature. The specimens were subjected to 7, 14, 21, 28, 35 and 42 days of soaking period time. At the end of each period, the CBR test was carried out to determine CBR_t where t is soaking period.

5. RESULTS AND ANALYSIS:

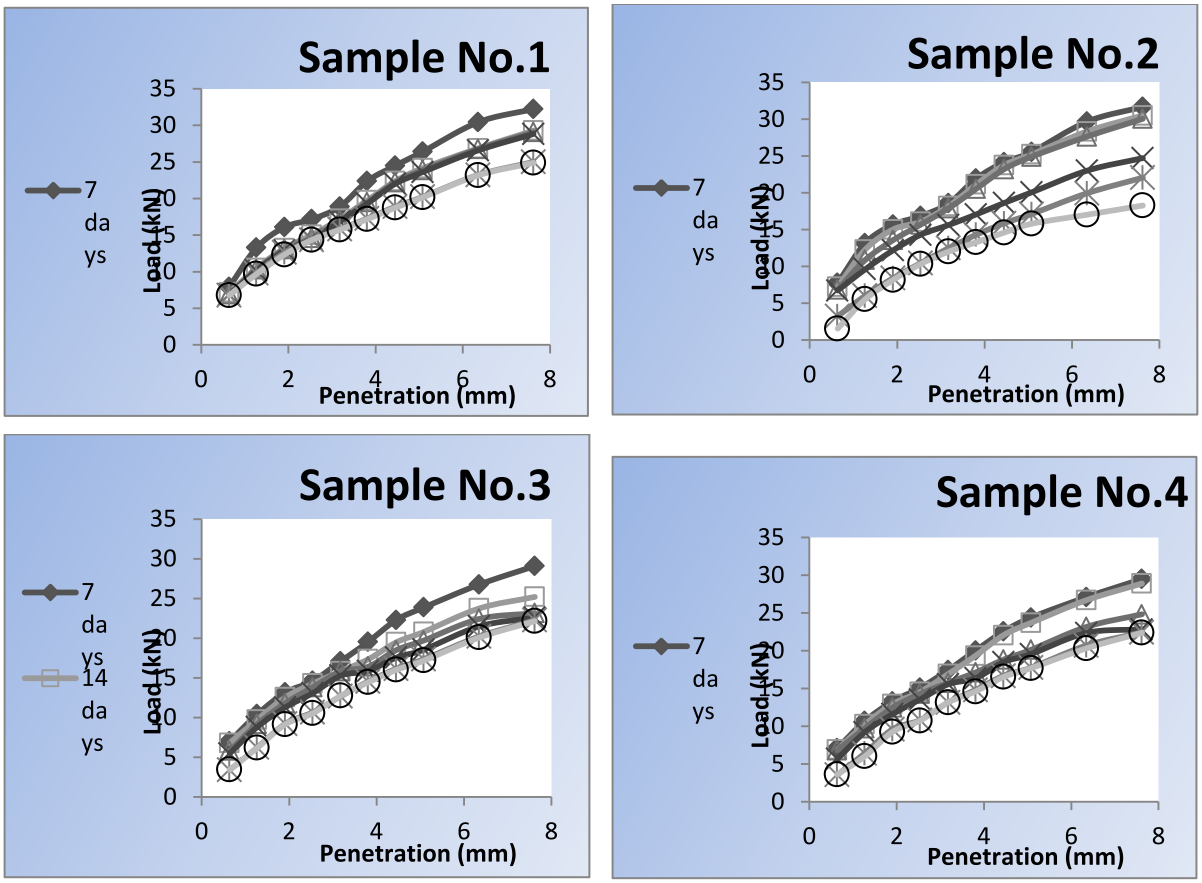
When samples are soaked in water, chemical reactions begin to occur almost immediately to produce long-term permanent strength and stability.

Figures (1) show different grain size distribution of the four samples. It could be mentioned that there is small difference in the percentages of passing sieve No.200 in the curves of samples No.1 and 2. However, the percentages of passing sieve No.8, 50, and 200 of samples No.3 and 4 were similar.



Figures (1) Grain Size Distribution of the Samples

Figures (2) show load-penetration curves of samples for the CBR test. Maximum load was detected after 7 days soaking in all samples then it decreases as soaking time increases. The first limestone sample was given the same behaviour in 14, 21, and 28 days and in 35, and 42 days.



Figures (2) Load-Penetration Curves for the CBR Samples Tested

Figure (3) show the relationship of maximum penetration load of the CBR samples versus the soaking period time. It is obvious from this figure that the penetration loads are decreased as the soaking period increased.

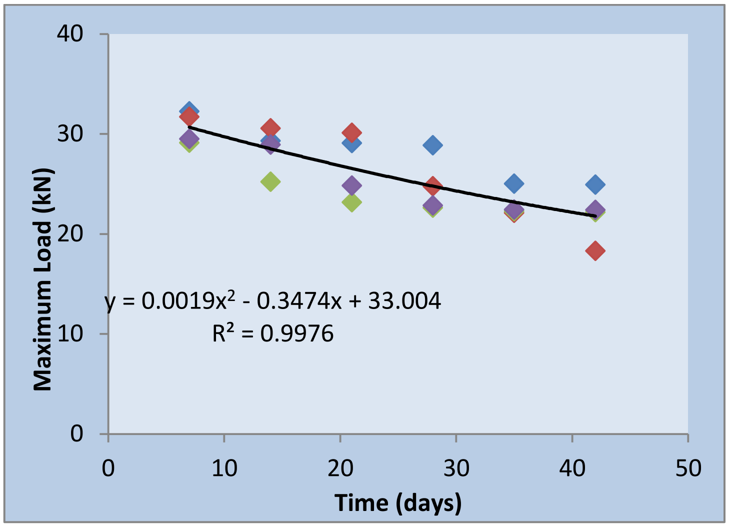
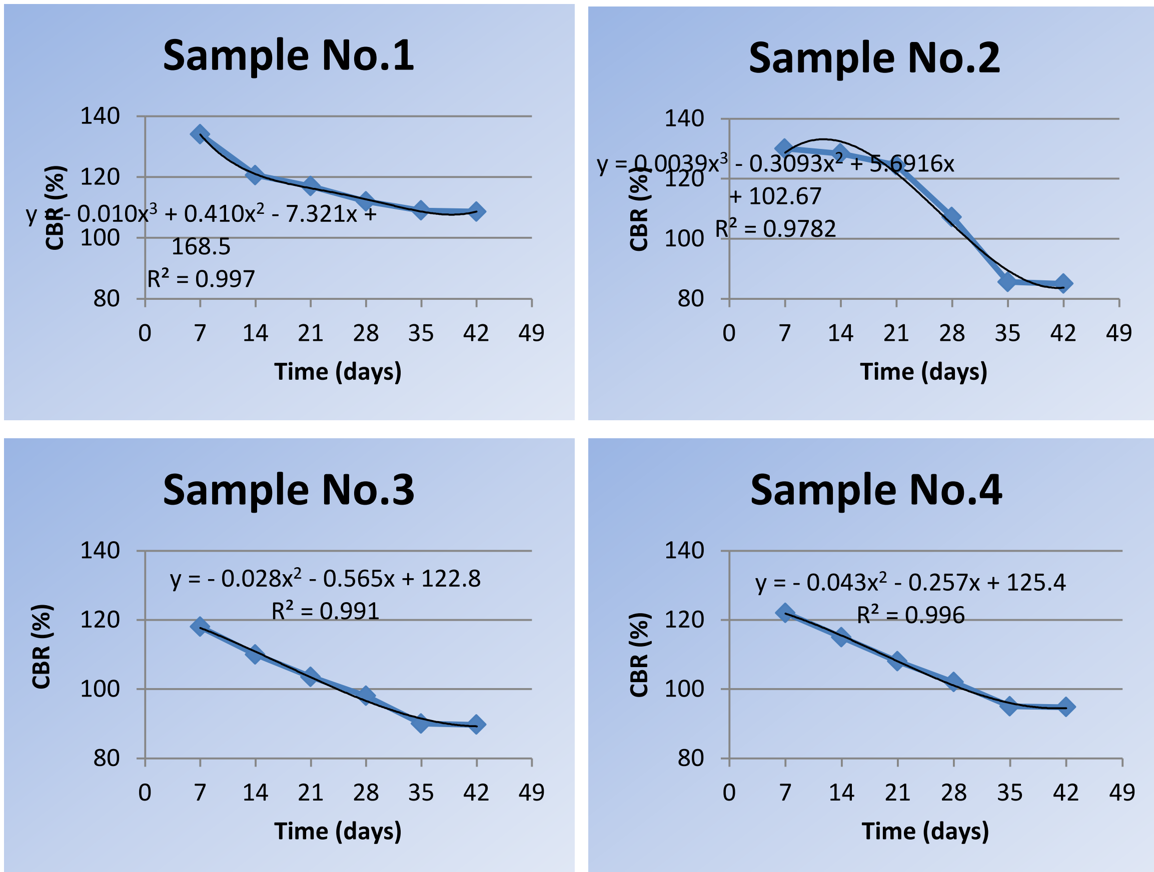


Figure (3) Penetration Load Versus Cyclic Soaking Period

Figures (4) show the relationship of CBR values with soaking period time. The curve of sample No.2 that has concaved down while other curves of other samples have concaved up. This is because of the percentage of passing sieve No.200 (about 36%) was greater than the percentages of passing of the sample No.1, 3, and 4. Also, the percentages of retained material on sieve No.8, 50, and 200 of sample No.1, 3, and 4 were similar and greater than the percentages of retained material of sample No.2.

It was mentioning that the maximum CBR could be obtained after 7 days soaking and decreases within each soaking period until the change in CBR becomes constant when equilibrium was achieved at the end of the fifth cycle (42 days)



Figures (4) CBR Versus Cyclic Soaking Period

6. CONCLUSIONS AND RECOMMENDATIONS:

Results in this study of using limestone to treat the clay soil in the southern parts of Iraq lead to the following conclusions:

1. **The penetration loads of CBR samples that had 7 days soaking time curve are greater than other penetration loads.**
2. **After each cycle of soaking period for the samples tested, the penetration load and CBR values decrease during soaking periods increase.**
3. **In addition to cost savings, benefits of limestone stabilization include soil drying and soil modification properties, substantial increase in subgrade strength. Therefore, the weak soil can not be replacement and this is contribution in lessees the time and cost.**

4. **Limestone is recommended to be added to the clay soil that enhances strength over long periods of time, and long-term durability to withstand heavy traffic.**

REFERENCES:

1. **Akawwi, E. & Alkharabsheh, A. "The Effect of Lime Stabilization on the Geotechnical Properties of Expansive Soils in Amman". Electronic Journal of Geotechnical Engineering, 2000.**
2. **American Association of State Highway and Transportation Officials AASHTO 1986. Standard Specification for Transportation Materials and Methods of Sampling and Testing. Part II, 14th Edition, Washington D.C.**
   - **AASHTO T180-88. Moisture–Density Relations of Soils Using a 10-lb [4.54 kg] Rammer and an 18-in [457 mm] Drop.**
3. **American Society for Testing and Materials ASTM 2003. Soil and Rock, Building Stones, Geotextile.Vol.04-08.**
   - **ASTM D2487-00. Classification of Soils for Engineering Purposes. (Unified Soil Classification System)**
   - **ASTM D422-98. Particle-Size Analysis of Soils.**
   - **ASTM D4318-00. Liquid Limit, Plastic Limit, and Plasticity Index of Soils.**
   - **ASTM D1883-99. CBR (California Bearing Ratio) of Laboratory Compacted Soils.**
4. **Little, Dallas N. "Evaluation of Structural Properties of Lime Stabilized Soils and Aggregates, Vol. 1: Summary of Findings", 1999. http://www.lime.org/SOIL.pdf**
5. **Little, Dallas N. & F.A.M. Shafee Yusuf "Example Problem Illustrating the Application of the NLAMDTP to Ascertain Engineering Properties of Lime-Treated Subgrades for Mechanistic Pavement Design/Analysis", 2001. http://www.lime.org/AMDTP.pdf**
6. **Lopez and Castano, "Time Dependency of CaO Treated Expansive Soil". Electronic Journal of Geotechnical Engineering, 2001.**
7. **Mahasneh, B. Z. "Improvement of Soft Clay Soil in Al-Karek Area Using Different Additives". Paper submitted in Fourth Jordanian Civil Engineering Conference, April 2006.**
8. **National Lime Association "Lime-Treated Soil Construction Manual: Lime Stabilization and Lime Modification", 2004. http://www.lime.org/Construct104.pdf**
9. **O`Flaherty C.A. "Highways, Third Edition Vol.2, Highway Engineering". Edward Arnold. London, 1988.**