Experimental Study of Lime Treatment Compacted Swelling Bentonite

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Abstract

Expansive soils are characterized by volumetric changes caused by variations in moisture. They can cause several damages to civil constructions, especially to lightweight structures, including cracks and fissures. Chemical stabilization through the addition of lime is one of the most effective techniques used to treat this type of soil. Due to cation exchanges, lime can significantly reduce swell potential. This report presents a laboratory study of lime treatment of compacted bentonite, through the following laboratory tests: Atterberg Limits, compaction, free swell, and swell pressure. In order, to evaluate the effect of lime, the tests were conducted on bentonite-lime mixtures, using lime contents of 0%, 3%, 5%, and 10%. The results confirmed the efficiency of lime stabilization. It was noticed that, as lime content increased, there was a reduction of the plasticity index. The free swell and swell pressure are also reduced significantly.

Problem Statement

Expansive clays are one of the problematic soils that can cause significant damage to structures, roads, and other constructions due to its tendency to swell and shrink with changes in moisture content. When expansive clay gets wet, it absorbs water and expands, creating pressure against anything it is in contact with, including foundations, walls, and roads. When it dries, it shrinks, which can result in cracks and damage.

Current practices indicate that there are many expansive clays that are, a priori, not reusable in their natural state because they do not meet the technical requirements imposed for the intended applications. They frequently have a natural water content that is too high, and are often too plastic, which complicates their reuse (difficulties in execution, in supporting site traffic, in obtaining the desired compaction rate, high swelling potential and pressure, low shear strength,). To be compatible with the requirements of sustainable development, it is imperative to use soil treatment techniques to improve local problematic soils before reusing them. Currently, the technique of treating soil with lime and/or hydraulic binders is widely used to improve the mechanical properties of soil throughout the world. Soil treatment with lime is a potential technique to achieve the objective of “zero borrowing, zero deposit” during earthworks as part of infrastructure projects.

Objectives

- Understand the properties of the expansive clays, including its mineralogy, chemical composition, and geotechnical characteristics.
- Identify the physicochemical complexity of the system water-quicklime-clay minerals.
- Develop and conduct a laboratory experimental program established according to the parameters to be measured and the objectives to be identified.
- Interpret the test results and assess the effectiveness of lime treatment on the bentonite properties.
- Recommend effective dosage for reduction of swelling potential and pressure.

Methodology

The laboratory experimental program was established to analyze the effect of lime percentage addition on compacted bentonite samples. The material used in this study is a commercial bentonite manufactured in Saudi-Arabia Kingdom and quick lime.

The laboratory tests performed:

➢ Identification Test:
- Specific gravity test according to ASTM D 854.
- pH meter test.
- Atterberg limits according to ASTM D 4318 .
- Compaction test according to ASTM D 698.

➢ Swelling tests:
- Free sell test Indian standard (IS: 2720, Part XL, – 1977).
- Consolidometer free swell test.
- Consolidometer under-loads swelling test.

Result

The specific gravity measured of the studied bentonite and the quicklime used are respectively 2.72, and 3.13.

pH meter test result shown in figure 1

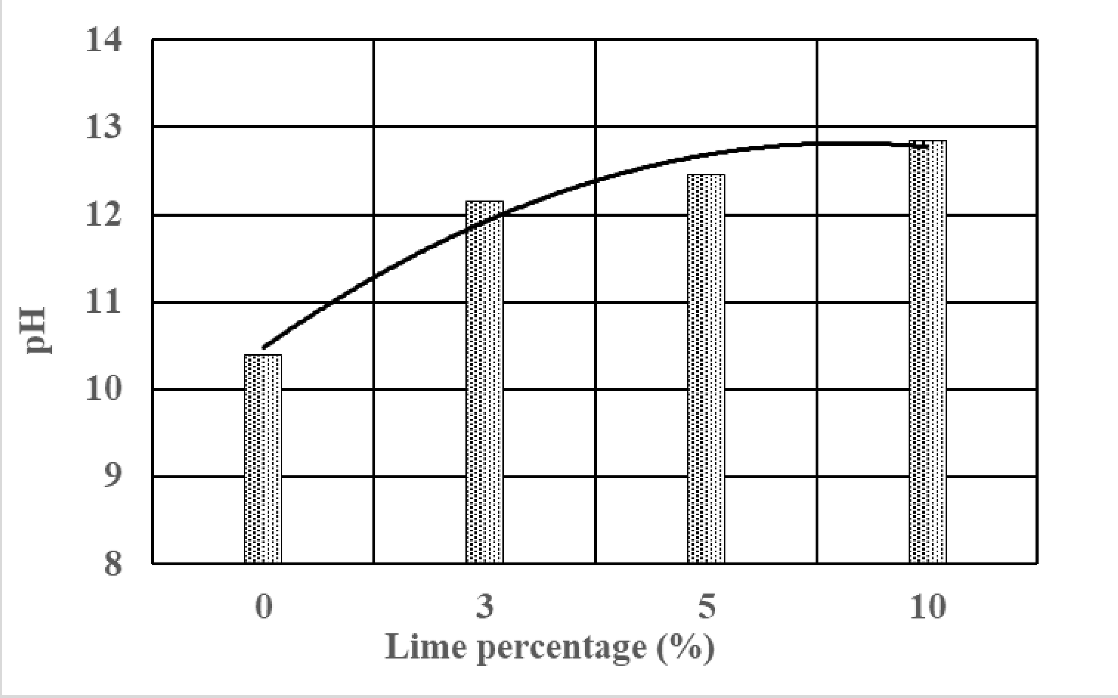

Figure 1

From figure 1, it is noticed that initially the pH of the bentonite is 10.4 and this value increases by adding the percentage of quicklime with a tendency to stabilize around a value of 12.85 corresponding to a strongly alkaline solution.

Atterberg's Limits, Liquid limit result shown in figure 2

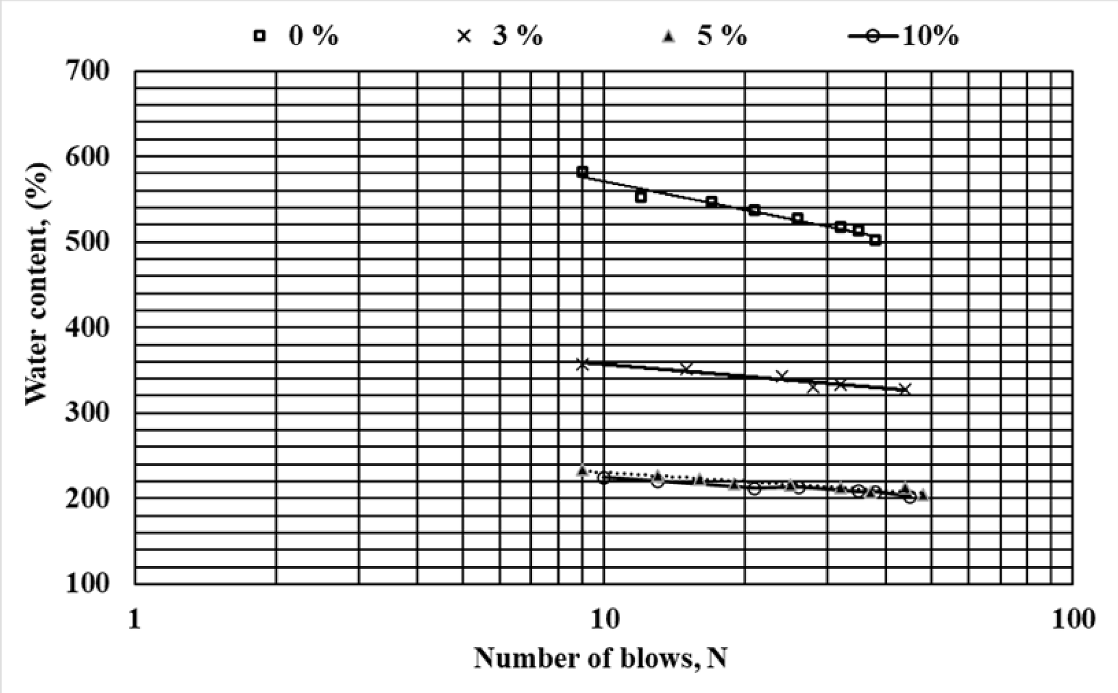

Figure 2

Plastic limit result

% Lime	Ref.	Mass of can (gr)	Total mass (gr)	Dry mass (gr)	Water content (%)	Plastic limit (%)
0	1	20.7	26.7	24.8	47.1	47
	2	20.7	27.8	25.5	47.5	
3	1	21.1	30.3	26.9	57.8	60
	2	20.9	28.7	25.7	61.6	
5	1	21.2	28.9	26	58.8	59
	2	21	34.6	29.5	59	
10	1	20.9	33.3	29.2	48.6	49
	2	21.1	31.2	27.9	49.1	

Table 1

Summary of Atterberg limits and plasticity index shown in table 2.

% of Lime	Liquid limit LL (%)	Plastic limit PL (%)	Plasticity index PI (%)
0	520	47	47.1
3	340	60	47.5
5	220	59	57.8
10	220	49	61.6

Table 2

The variation of Atterberg limits and the plasticity index with the lime percentage addition is shown in figure3.

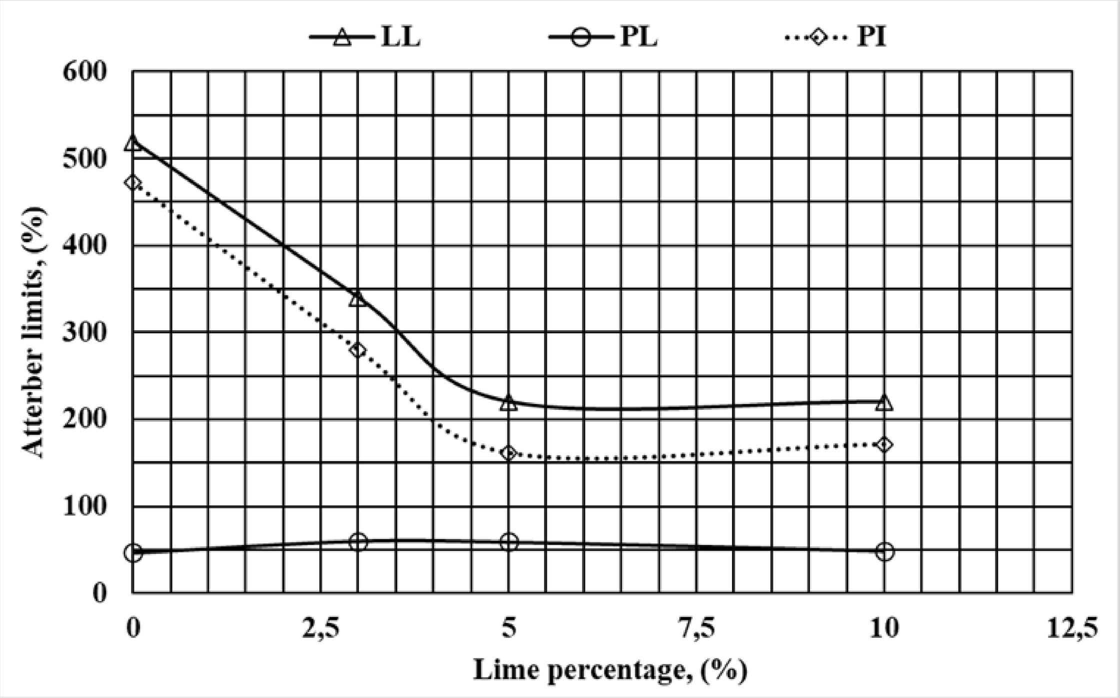

Figure 3

Compaction test result for all studied samples are summarized and presented on the figure 4

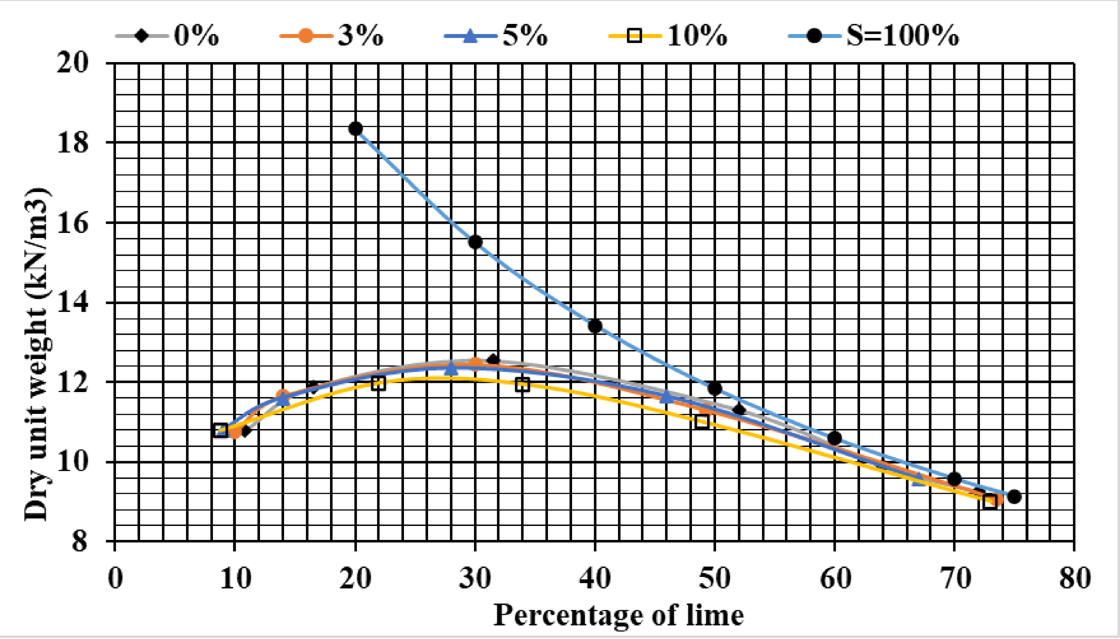

Figure 4

Summary of standard compaction results.

Lime (%)	0	3	5	10
OWC (%)	31	30	28	26
MDD (kN/m3)	12.5	12.45	12.35	12.12

Table 3

Free swell test result shown in table 4.

Lime (%)	0	3	5	10
FSI (%)	230	120	80	50
MFSI	3.3	2.2	1.8	1.5

Table 4

Expansion soil classification based on FSI shown in table 5

Degree of expansion	Low	Medium	High	Very high
FSI (%)	<50	50-100	100-200	>200

Table 5

Free swell consolidometer test result shown in figure 5 & 6.

Free swell potential versus lime percentage

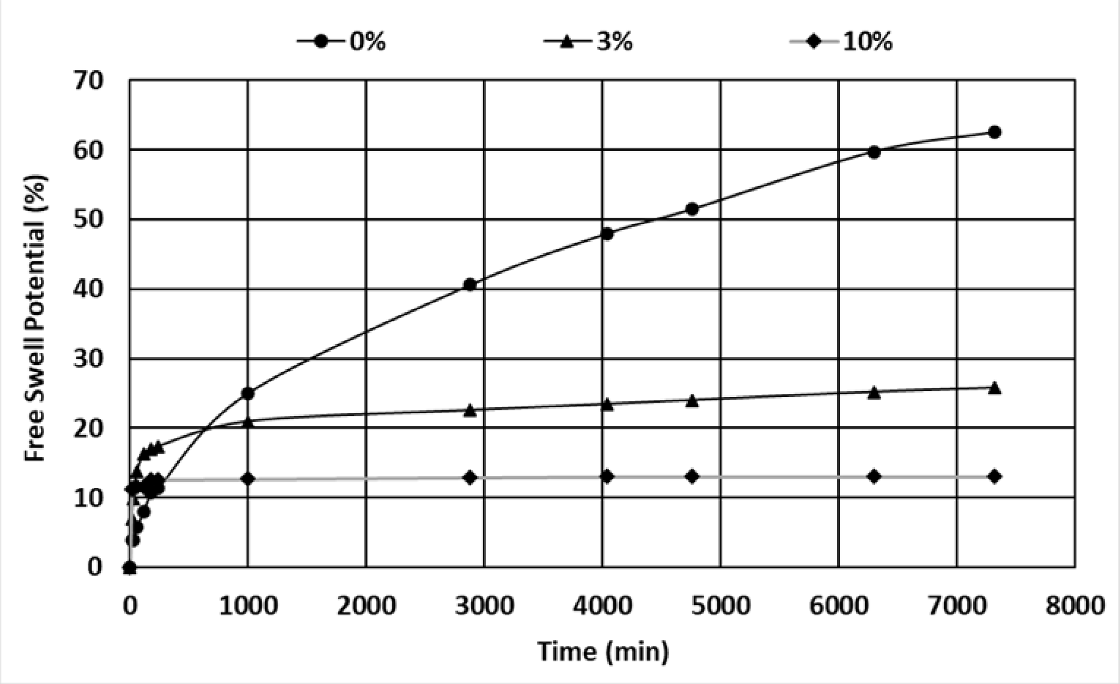

Figure 5

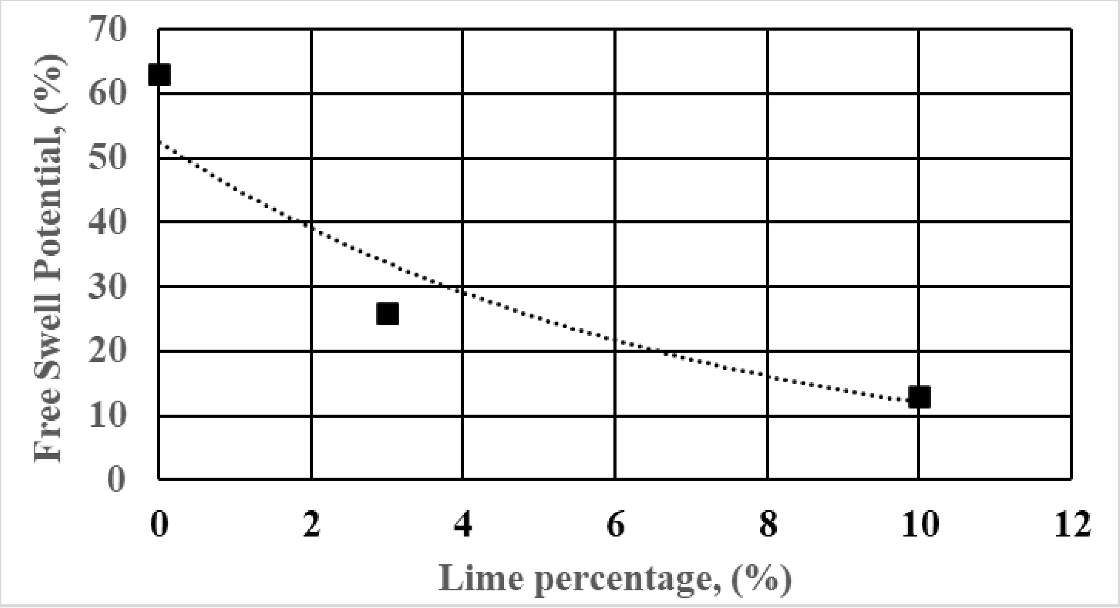

Figure 6

Consolidometer under loads swelling test result shown if figure 7

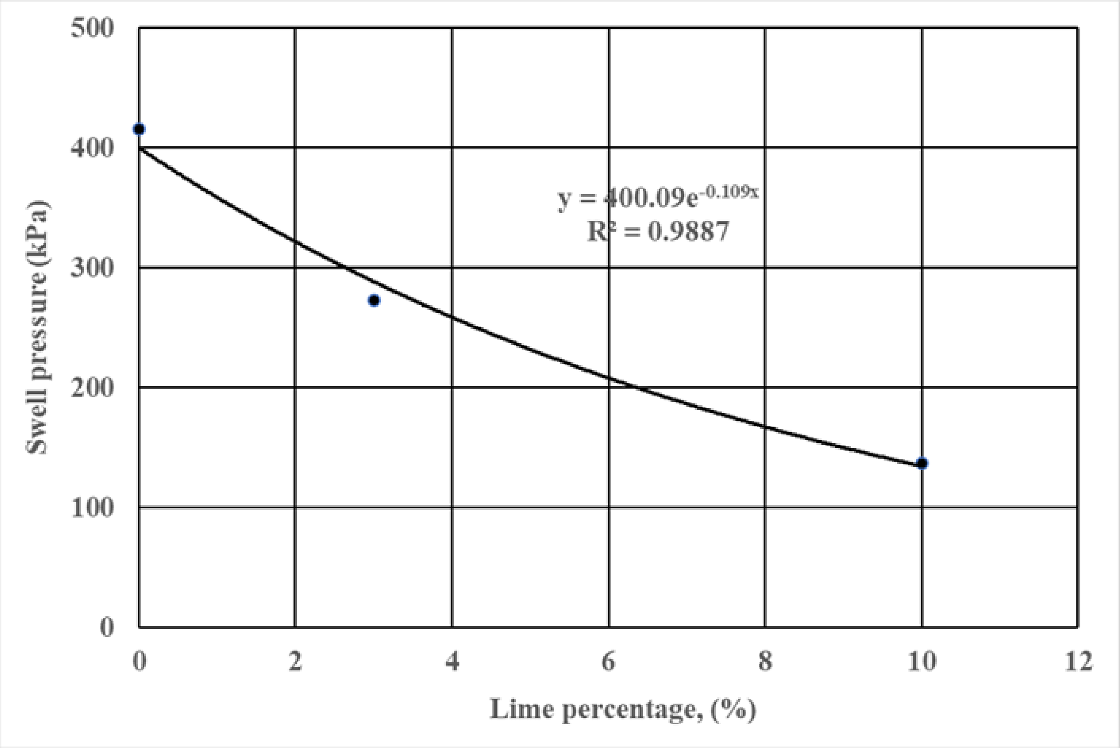

Figure 7 Free swell pressure versus lime percentage

Conclusion

- Swelling potential and pressure significantly decrease after treatment.
- Long-term behaviour of treated samples needs further evaluation.
- Treated samples tend to be drier than untreated samples at a constant water content.
- pH measurements can help optimize the amount of quicklime to add.
- Quicklime can be used to treat swelling clays.