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Improvement of a plastic clay

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ABSTRACT: The treatment of clayey soils by the addition of lime is an old and recognized technique that is applied in the construction of embankments and subgrades related mainly to road projects. The mixing procedure of clayey soils with lime causes immediate reduction of water content in the soil and thus reduces the plasticity index based on hydration that goes out with a high heat release and causes flattening of the Proctor curve and an increase in CBR value.
This laboratory investigation aims to explore the effect of some parameters such as the particle size distribution, plasticity index, the moistening and flocculation of the lime upon the behaviour of the resulted mixed soils.

1 INTRODUCTION

Projects of road construction are becoming, increasingly, binding and require major soil movements on the site, soils are sometimes difficult to re-use, and natural deposits of fine materials, unevenly distributed, are being depleted. It is therefore necessary to protect the existing resources, as the cost of transportation is becoming high. Fine soils contain significant proportions of clay and silt, which affect their intrinsic and geotechnical properties. They swell and become plastic in the presence of water, shrink with drought, and expand because of freezing. These soils are considered bad or mediocre and do not, respond to the necessary performance to support construction traffic, roadway and future traffic.

Earthworks in road, using the technique of soil treatment, can be done by the immediate improvement of the soils that are too wet by increasing their stability and ensuring their implementation to obtain the rigid and stable platforms, on the of treated subgrades, aiming high mechanical properties. The choice of treatment agent and dosage are determined by the soil type and the moisture content while processing. We have chosen an experimental approach to understand the mechanisms leading to the stabilization of the subgrade of the future road. By this approach we can determine the physico-chemical, mechanical, and characteristics of the soil and also the effect of its consistency before and after treatment with lime.

2 SOIL TREATMENT

In practice, two processing techniques are used to improve the land:

- By compaction (porosity reduction);
- The use of chemical agents (physical and mechanical modification).

In the case of fine soils, these two techniques are used to make the soil ready to fit road structures. Soil treatment with lime is a technique which consists of incorporating within the soil, this supply element lead to reduce quickly the water content and plastic soil, neutralize, and also to flocculate clays. The addition of lime causes significant physicochemical modification of the soil, so to correct this flaw and improves its quality, by reducing the plasticity index (PI), producing a flattening of the Standard Proctor with a decreases in the density of the Proctor optimum and increasing the optimum water content. Lime raises, therefore, the shear stress and transforms the compaction characteristics of the material, Figure 1.

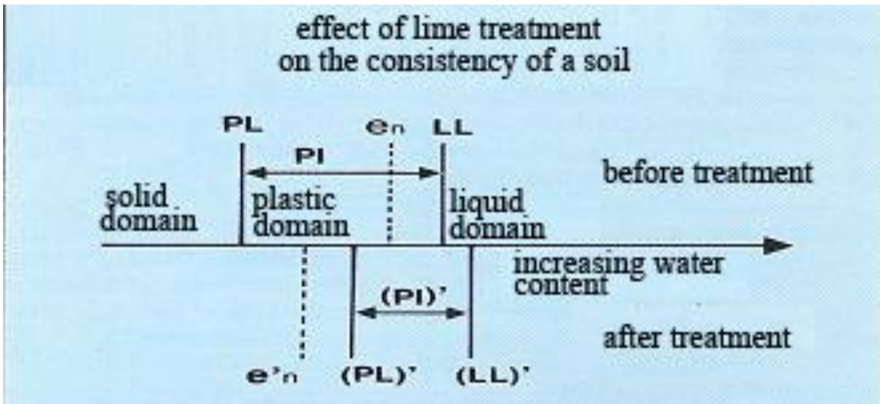

Figure 1. Immediate change of behavior of a moist clay soil caused by the introduction of the quicklime.

The lime treatment improves, sustainably, the bearing capacity of soils and their resistance, so it reduces the total thickness of the pavement (Figure 2), and also helps to reduce the purchase and transportation of additional materials.

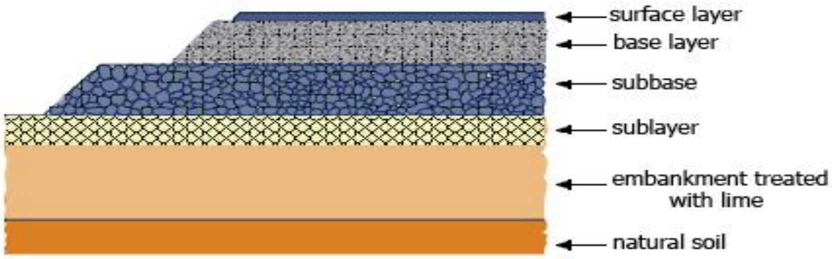

Figure 2. Cross section of the road

3 LIME

Lime is a natural material, organic, and is environmentally friendly. Lime is generally a powdery and white material, obtained by thermal decomposition of limestone. It is used since antiquity, particularly in construction. It has a special place in the building sector and in construction materials. Lime occurs at different stages of soil treatment, and its quality has a direct influence on the effectiveness of soil treatment. Some properties of lime have special advantages for treatment of soil:

a- Alkalinity

Lime is strongly basic, solutions have a pH greater than 12 (reduce the acidity of the soil).

b-Hydration

Quicklime has strong affinity to water. Upon hydration, it goes out with a high heat release according to the following chemical reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2 + 64.8 \text{ KJoule / kg of lime}$$

This property is used for very dry soils that are waterlogged.

c-Flocculation

The flocculation phenomenon is explained by the bridging $Ca(OH)_2$ or $CaOH^+$ between the clay layers, which changes the consistency of the environment and the act of placing a plastic state to a stable, crumb structure which allows good compaction. The lime used in this study is a lime produced per unit of Umm Djerane (State of Saida) ERCO affiliated group (of Cement Company and Derivatives West) west of Algeria. Table1. gives the chemical and physical characteristics of the lime used in this study.

Table 1. Physico-chemical characteristics of lime used

Basic characteristics	Lime sheet
Physical apparence	Dry white powder
Calcium oxide CaO (%)	> 73.3
Magnesium oxide MgO (%)	< 0.5
Iron oxide Fe2O3 (%)	< 2
Aluminium oxide Al2O3 (%)	< 1.5
Silicon dioxide SiO2 (%)	< 2.5
Sulfur trioxide SO3 (%)	< 0.5
Sodium oxide Na2O (%)	0.4 - 0.5
Carbon dioxide CO2 (%)	< 5
Calcium carbonate CaCO3 (%)	< 10
Specific Gravity	2.0
More than 90 µm (%)	< 10
More than 630 µm (%)	0
Insoluble material (%)	< 1
Bulk density (g/l)	600-900

Lime has to be thin enough to respond quickly with the ground (This feature is secured with a size of 0-1 mm). During the processing of clay soils with lime two important reactions occur simultaneously:

a- hydration reaction, highly exothermic, the quicklime with water in the soil by decreasing the water content thereof. This reaction releases heat, which warms the soil and causes the evaporation of water. Hydrated lime can then react with clay minerals, causing flocculation of the clays.

b- a second slow reaction, which gradually hardens the mixture compacted soil-lime, responsible for long-term effects (soil stabilization).

Lime increases the pH of the soil, releasing silicates and aluminates. This latter can then react with the calcium supplied by lime and water in the soil. Then starts the hardening of the soil. Then, the ground lift depends on the nature and reactivity of clay minerals in soil treated with and the amount of lime added.

4 SOIL TESTING

To determine the suitability of a soil treatment, we have to take representative samples for laboratory tests. The preliminary study of these samples in the laboratory will focus on the condition and characteristics of soils to be treated. To determine soil characteristics, an experimental program was conducted at the Soil Mechanics Laboratory at the University of Tebessa. Chemical and mineralogical analysis, and tests of physical identification were performed on the type of selected soil and lime. The soil used in this study was obtained from a site crossed by a new route (avoiding Tebessa).

The lithology of the wells made in the field, shows some heterogeneity is represented in the majority by brownish clays, clay loams and silty clays blackish brown, Figure 3.

Depth (m)	Description Lithological
0.60	Topsoil
7.00	Brown silty clay
17.00	Brownish gray marly clay

Figure 3. Lithological description

After extraction, the soils were placed in sealed plastic bags to maintain moisture intact. The remoulded samples were collected to determine of the natural water content of 0.1 m to 3.0 m is depth. It is essential, before startes any work to get a sense of physical and chemical characteristics of soil in the presence (Table.2) and thus to understand its mechanical behavior, because the knowledge soil quality of the makes it possible: assess the potential for treatment of soil (Figure.4 and Figure.5), to determine the hydraulic binder of treatment to use, and get an idea of the amount of binder added to land treatment.

Table 2. Physicochemical characteristics of the studied soil

Water content w%		15.80
Dry density ρ_d t/m^3		1.50
Saturation Sr %		53
Wet density γ_h t/m^3		1.75
Particle Size Analysis	D_{max} (mm)	2
	2mm	100
	0.080mm	98.4
Atterberg limits	LL %	58
	PI %	36
Value of Methylene Blue	VBS %	8.67
Chemical analyzes	Content $CaCO_3$	47.69
Modified Proctor	W_{opt} %	18
	$\gamma_{d\ opt}$ t/m^3	1.85
CBR soaked to 4 days	%	4.47

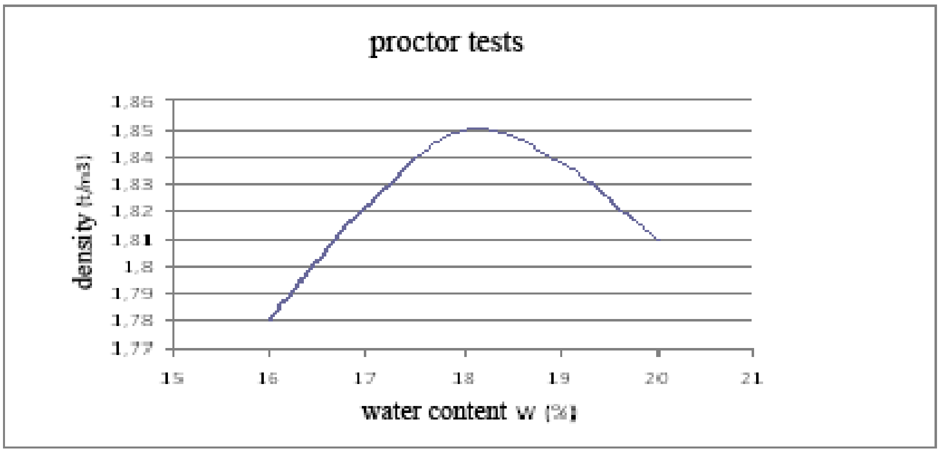

Figure 4. Proctor compaction test

There are two main types of parameters which are crucial to know for a ground characterization facing its lime treatment:

1) The parameters of nature: they indicate what does not vary (or not) over time or during handling that can undergo the ground (grain size, the clay content, and the presence of specific chemical constituents);

2) The state parameters of soil: water status (water content) determines the agent's choice of best treatment and the dosage needed to apply.

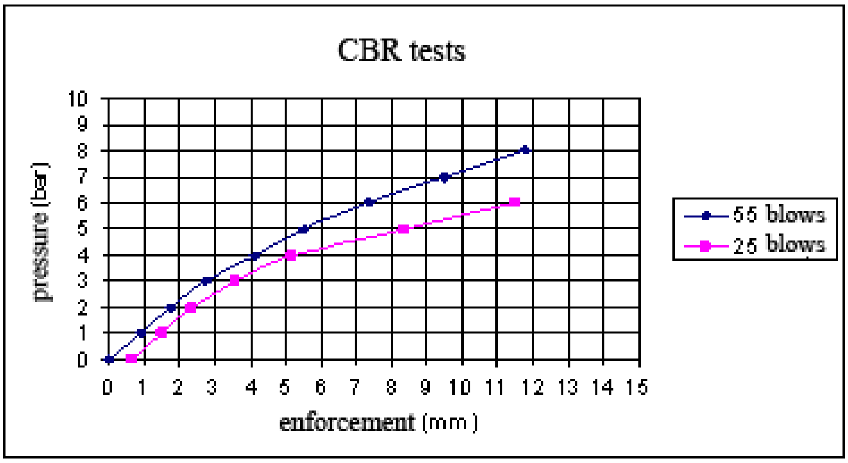

Figure 5. CBR tests

5 FORMULATION STUDY

The formulation study conducted in the laboratory was to specify the percentage of lime to add in counterpart of water content encountered. It has also made it possible to directly test the effectiveness of a treatment in order to achieve the desired performance in an application described by fixing the amount of treatment agent to use, Table.3. This study was, in general, to measure the sensitivity to water, by CBR test.

Table 3. Use of floor area of treaty with lime

Soil lime	Dosage of lime	Field of use for the treated Soil
Medium to fine soils Heavy	clay Quicklime: 1 à 3 % Slaked lime: 3 à 5 %	Used embankment used in Layers

We have to setup in order to verify the behavior of the treated soil and determine the optimal dosage to be applied. However, if a study is not desired, we can apply the maximum dosages, but we have to the risks (water content less than optimal, lack of frost resistance, swelling, ...). A small percentage of lime (1-3%) is usually sufficient to improve the behavior of plastic or clay soils.

6 TESTS ON THE TREATED SOIL

According to its properties, lime significantly alters the behavior of fine soil clay and silt, with three distinct actions:

a-A decrease in water content of clay soils;

b-Immediate changes geotechnical properties of the soil, by reducing the plasticity index PI, an increase in the immediate bearing ratio CBR, and a decrease in the optimum Proctor density (with an increase of the content optimum water) ;

C-Changes to occur in a long term, because lime raises the pH of the soil we notice its decreases acidity and causes the attack of soil constituents (silica and alumina). This forms aluminates and calcium silicate hydrates (pozzolanic reaction) which, crystallizing, acts as a binder between the soil grains (increasing pH contributes to a good basement).
The complexity of this study identification varies with the geological diversity of the terrain and the target application (backfill, ground-support, and subgrade).

6.1 The Influence of Treatment on the Proctor Optimum

The Proctor test is to determine the optimum on the base of dry density measurements, performed on soils having increasing water content.
Clays are sensitive to water while the lime treatment can limit its effect: the curve is flattered as the same time the Proctor optimum is shifted to higher water contents, Figure.6.

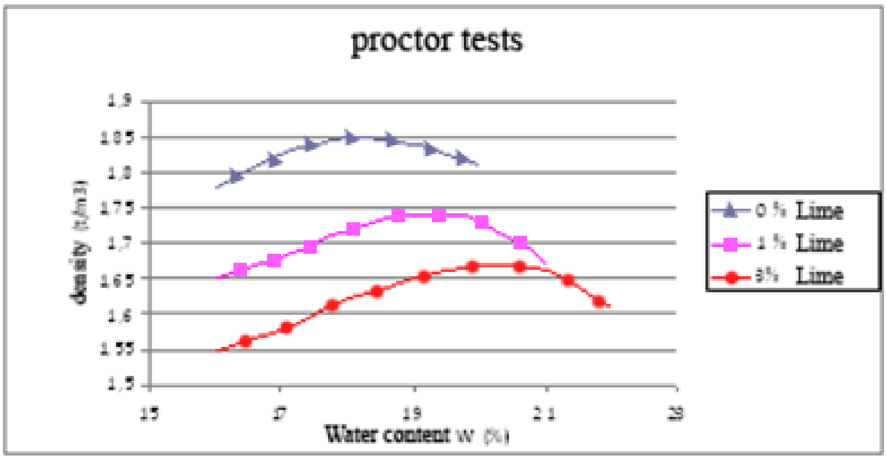

Figure 6. Proctor compaction test before and after treatment

6.2. Influence of Treatment on the CBR

The determination of the CBR, depending on the water content of the soil for varying percentages of lime, show the very rapid increase of the index as a function of treatment with increasing cohesion. A compact and equal water content of the CBR of soil-lime mixture is, at the age of two hours, 4 to 10 times greater than that of untreated soil. In our example it was observed after two hours, for an initial water content of 18%, the CBR of 8 before treatment, increased to 28 to 1% lime and 64 for approximately 3% lime, Figure.7.

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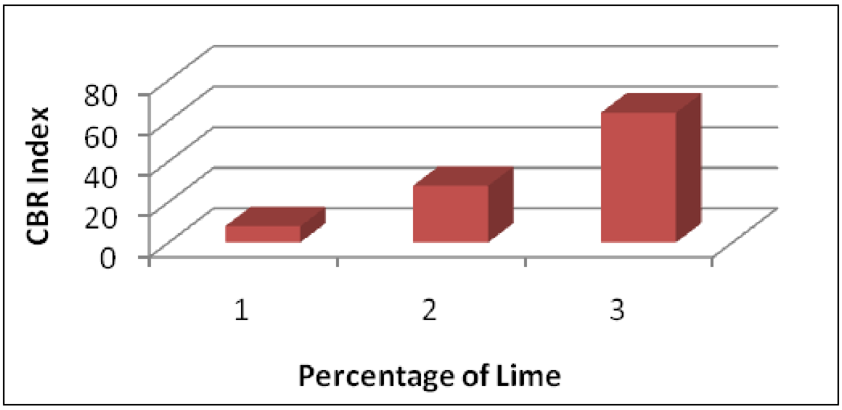

Figure 7. The CBR index based on the percentage of lime

6.3. Influence of Treatment on the Plasticity

We can notice after the addition of lime to our soil, that the plasticity index PI and the value of methylene blue (VBS) are reduced (see Table 4).

Table 4. Variation of Atterberg limits and the blue value of the soil studied by the percentage of lime

Percentage of lime	Plasticity index PI	Value of Methylene Blue VBS
0	36	8.67
1	32	8.04
3	21	6.80

A slight Increase in the CBR value is due to some samples because of some disturbing elements (organic matter and sulfates).

7 CONCLUSION

Construction of embankments and layers represents an important part of the overall cost of implementation of road projects. This importance justifies a search for global optimization, to minimize costs. The addition of lime has many advantages, including: energy conservation (cold treatment), the economics of transporting materials (work in situ), the aggregate saving inputs (preservation of environment), and the economy on the total cost of road projects. But in some cases, this treatment is ineffective due to the presence in the soil to treat disruptive, especially organic matter and sulfates, because organic matter can delay the effect of treatment by consuming an amount of treatment agent, and also sulfates can result in the swelling of the soil. To better predict the long-term behavior of the treated soils, follow the research, especially on the sustainability of treatment effects.

Proper treatment of problem soils and the preparation of the foundation are important to ensure a long-lasting pavement structure that does not require excessive maintenance. Such soils can be stabilized to form a construction pad or a long-term subsurface layer capable of carrying pavement applied loads.

In general, the stabilized soil is built up in layers of 30 to 40 cm thick. The exact thickness of the layer depends on the compaction equipment used. There are good reasons for avoiding dust formation on site. A closed installation limits dust formation during treatment. It is possible to work on a storage site where the soils which have been treated with lime can be stored for weeks or even months without any loss of quality.

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