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# CHEMICAL STABILIZATION OF A LOW PLASTICITY NATURAL SOIL

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**ABSTRACT**

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It is recognized that the chemical soil stabilization by lime and/or cement, offers a comprehensive, economical and technically advanced solution for many earthworks applications. Better understanding the performances of low plasticity soils, when binders are used simultaneously, remains a challenging issue. The present investigation concerns the stabilization of a natural soil, obtained from a site situated on the Eastern layout of the East-West Algerian highway project. In order to ensure the pavement stability and durability, it was decided to re-use this soil, after treatment, for the construction of the working plat-form. Proctor compaction tests and CBR tests were performed, to find out the necessary binders as type and proportions, and their eventual effects on the variation of the optimum water content, the dry density and the mechanical strength. The results show that the optimum water content is more sensitive to the amount of lime used in the mixture, the lime fixation point found is around 3% for the soil considered, which is in good agreement with previous researches. Simultaneous use of binders, with respect to an optimum mixing protocol (3% of lime with 10% of cement), enhances considerably the mechanical properties of the soil considered, by further reducing its plasticity and increasing its $CBR_{index}$ up to 6 times.

***Key words:*** *natural soil, stabilization, lime, cement, proctor, CBR*

## INTRODUCTION

The construction of pavement layers and embankments usually involves the re-use of in-situ soils, which, as natural conglomerate, might contains proportions of soft clays and organic materials, with insufficient strength to meet design specifications. A ground treatment is often required to increase the in-situ soil shear strength and reduce its compressibility. Many procedures have been developed to achieve this goal, incorporating a wide range of stabilization techniques. Several methods of soil stabilization are reported in the literature (Makusa 2012), those methods could be summarized into two broad categories namely; mechanical stabilization and chemical stabilization. Mechanical stabilization is used to enhance soil–particles interlock through compaction, blending, and/or the use of reinforcements (geogrids / geotextiles), however, chemical soil stabilization concerns the introduction of chemical additives and binders in order to create a cementation of the soil particles. The most common binder agents used in geotechnical practice are lime and cement.

Use of lime and cement is widely documented in the literature, a review by Onyelowe and Okafor (2012), Jones *et al.* (2010) and many others, shows that stabilization primarily results in cementation, with a secondary reaction related to the calcium hydroxide generated during hydration. The end product is a cemented material consisting of the original soil, in which any clay minerals are altered, resulting in reduced plasticity and providing significantly increase in strength. In addition to lime, cement has been found to be effective in stabilizing a wide variety of soils, including granular materials, silts and clays and was largely used in pavement base, sub base, and sub grade construction (Dallas and Syam, 2009).

Despite many years of soil stabilization and experience with binder materials, challenges remain in the optimal use of these materials within an evolving mechanistic design framework. These challenges include developing a better understanding of granular soils (with low plasticity) performances when both lime and cement were used simultaneously as a binders, referred to in some literature as the dry method of deep mixing (Jacobson *et al*. 2005). Various parameters were found to affect the mechanical characteristics of treated soils such as amount of binder agents, initial water content, grain size distribution of the natural soil, curing time etc. Thus, numerous studies have been performed recently to figure out these effects (Omid *et al*. 2012).

The most common parameter used to evaluate pavement layer strength is the Californian Bearing Ratio (CBR). Even though the CBR is not a fundamental soil property, its significance lies in the fact that it is the basis of pavement design methods actually in use in most countries. The CBR is known to be influenced by the water content and the dry density as well as the texture of the soil (Ampadu 2007).

Laboratory testing is performed on samples of an in-situ granular soil mixed with various binders proportions (lime, cement or lime plus cement) in order to investigate the influence of this materials on the maximum dry density ($\gamma_{dmax}$), the corresponding optimum moisture ($W_{OPN}$), and the eventual $CBR_{index}$ values, used as an index of soil strength and bearing capacity. The present research is aimed to find the optimum mixing option as type and proportion for the stabilization and improvement of the soil considered.

## MATERIALS AND TESTING

### Soil characteristics

Bulk samples of a natural soil were obtained from a site situated on the Eastern layout of the East-West Algerian highway project (in the area of Béni-Béchir- Wilaya of Skikda, north of Algeria). The most important characteristics of the soil are listed in Table 1. Particle size analysis of this soil indicates grading values of the uniformity coefficient $C_u$=60 and the gradation $C_c$=0,8. The high value of $C_u$ is a clear indication that the soil mass consists of a conglomerate of different range of particle sizes. This soil was classified (LPC classification system) as a well graded sandy gravel containing a fraction of about 17% of low plasticity clay ($D$ < 80µm).

Table 1. Properties of the used soil

| **Properties** | **Value** |
|---|---|
| Moisture content $Wn$ (%) | 4,00 |
| Liquid limit $LL$ (%) | 35,12 |
| Plastic limit $PL$ (%) | 20,85 |
| Plasticity Index $PI$ (%) | 14,28 |
| Activity | 0.84 |
| Consistency Index $CI$ (%) | 2,18 |
| Methylene Blue value ($VBS$) | 1,58 |
| Carbonate content $CaCo_3$ (%) | 0,2 |

The maximum particle size and the clay content are the two principal criteria that limit the re-use of natural soils as pavement base layers or platform. According to the Setra (2008) and the earthworks-classification of materials for use in the construction of road embankments and capping layers (Standard 1992), the soil covered in this research was classified as *B6*, and fulfill the required criteria. Since stabilization operations involve mixing and compaction operations that destroy the original soil fabric, disturbance of samples during extraction does not normally compromise the quality of neither the sample nor its acceptability for testing (Dallas and Syam, 2009).

The compaction characteristics of the soil investigated were examined by Standard Proctor tests and its strength by corresponding CBR Tests. Fig. 1 shows the obtained compaction curve. The highest maximum dry density and corresponding optimum moisture content ($W_{opn}$) are 2,06 (g/cm3) and 9.2% respectively.

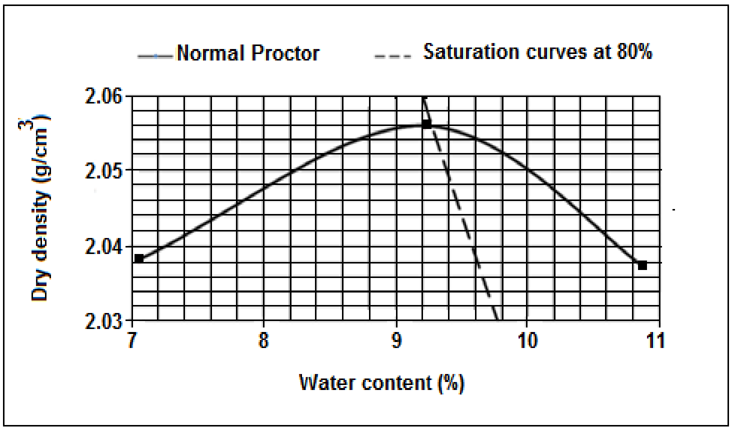


Fig. 1. Compaction curve of the soil

Each soil sample is tested for its soaked CBR and unsoaked CBR strength. The value of the immediate bearing capacity ratio is 10,9%, with an immediate $CRB_{index}$ of 10,7%. The CBR strength after being soaked in water for 4 days, gives a swelling index of 0,54%. The load-penetration curve of the soil is shown in Fig. 2.

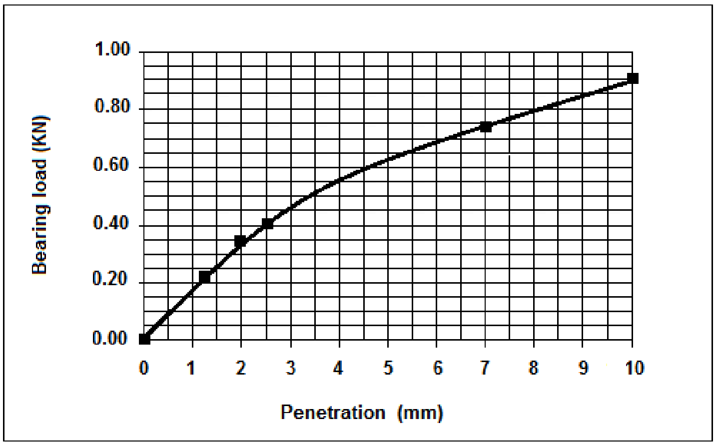


Fig. 2. Load-penetration curve after soaking

**Soil mixing with benders**

Dallas and Scullion (2005) provide a decision tree to select the appropriate additive (s) for the stabilization of soils. For the case of our soil with $PI \geq 12\%$ and the proportion of fine soil is less than 25%, lime and cement could be used as binder agents for this soil. Although, the decision tree serves as a good rule for obtaining an initial additive, the mixing proportion needs to be further investigated and validated to verify whether the selected additive (lime or/and cement) accomplishes the goals and requirements of the treated soil.

**Binder's characteristics**

- Lime: The lime used in this research is the quicklime, this commercial type of lime is fine aggregated, its content in free lime ($CaO$) is ≥ 80% and in magnesium oxide ($MgO$) is ≤ 8. This quicklime is thoroughly suitable for blending and stabilization procedure.
- Cement: The hydraulic cement used is the Algerian cement of the Portland type (*CPJ-C EMII* 42, 5), made up with 80-90% of finally grind Portland clinker, 6-20% of limestone and 0-5% of calcium sulfate. The mechanical resistances to compression test determined after 28 days is 44 MPa, with an initial setting time of 60min. This cement is known to satisfy all the mechanical specifications and limits according to most relevant standards.

**Soil mixing and testing program**

To investigate the effect of binder types and proportions upon the behaviour of the resulting soil mixture (stabilized soil), a comprehensive testing program was realized in the laboratory. For the mixing of soil with lime and cement the literature shows that the amount of cement used for soil stabilization is generally small (less than 15%) but should be sufficient to allow cation exchange of clay. The range of lime to use is normally 4 to 6% based on the soil types.

In this investigation, three series of tests were realized; each series corresponds to a particular mixture with varying proportions of the additive binders. The samples were prepared in a mechanical mixer, capable of producing uniform and homogeneous mixtures.

The first *Series-SC* stands for a mixture of the soil with 3 proportions of cement (4%, 8% and 12% by dry weight of the natural soil), the S*eries-SL* stands for the mixture of the soil with 3 different proportions of lime (2%, 3% and 5%) and finally the S*eries-SLC* stands for the mixing of the soil with different proportions of lime and cement following a ratio $R_{L/C}$. See Table 2.

Table 2. Values of the Ratio $R_{L/C}$

| | | **Lime (%)** | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 5 | |
| **Cement (%)** | 4 | 0.50 | 0.75 | 1.25 | $\boldsymbol{R_{L/C}}$ |
| | 8 | 0.25 | 0.37 | 0.62 | |
| | 12 | 0.16 | 0.25 | 0.41 | |

The mixing program is summarized in the chart of Fig. 3.

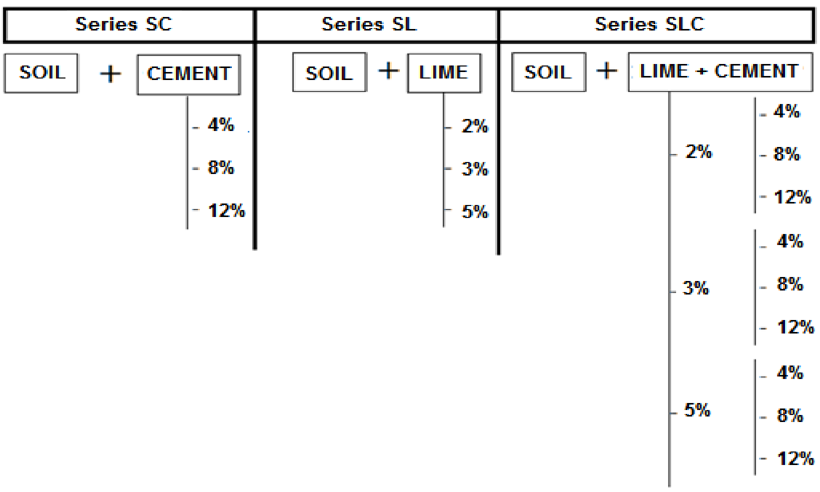


Fig. 3. Chart of mixing program

For each mixing variant the compaction characteristics of the resulting mixture (stabilized soil) was examined by Standard Proctor tests and its strength by the corresponding CBR Tests. The dry density ($\gamma_{dmax}$) and corresponding optimum moisture content ($W_{OPN}$) and the $CBR_{index}$ were determined. The $CBR_{index}$ value of a compacted soil is a powerful indicator of its strength and bearing capacity and one of the common tests frequently used to evaluate the strength of stabilized soils.

## RESULTS AND DISCUSSION

### Proctor test

The rate of binders content (lime or cement) from *Series-SC* and *Series-SL* are plotted together versus the corresponding values of the maximum dry density ($\gamma_{dmax}$) and the optimum moisture content, are shown in Fig. 4 and Fig. 5 respectively. Fig. 4 shows that the maximum dry density ($\gamma_{dmax}$) decreases as the lime concentration increases, with a rate of reduction more pronounced between 0% and 2.5%. However, the maximum dry density ($\gamma_{dmax}$) increases with the content of cement which indicates strength gain and hence stronger soil samples. This is in good agreement with other investigations like Oyediran and Kalejaiye (2011) and Ajayi (2012).

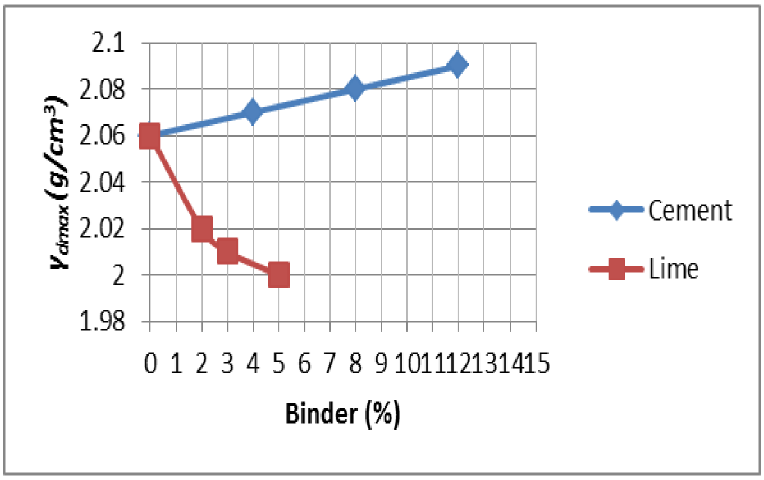


Fig. 4. Variation of ($\gamma_{dmax}$) with Binders content (%)

The variation of the optimum moisture content ($W_{OPN}$) plotted versus the percentage of binders used for each sample is depicted in Fig. 5. As expected the optimum moisture content ($W_{OPN}$) was found to increase with the percentage of lime content (the reaction generates heat). From this figure it is evident that, the percentage of cement content does not affect significantly the initial value of the optimum moisture content ($W_{OPN}$).

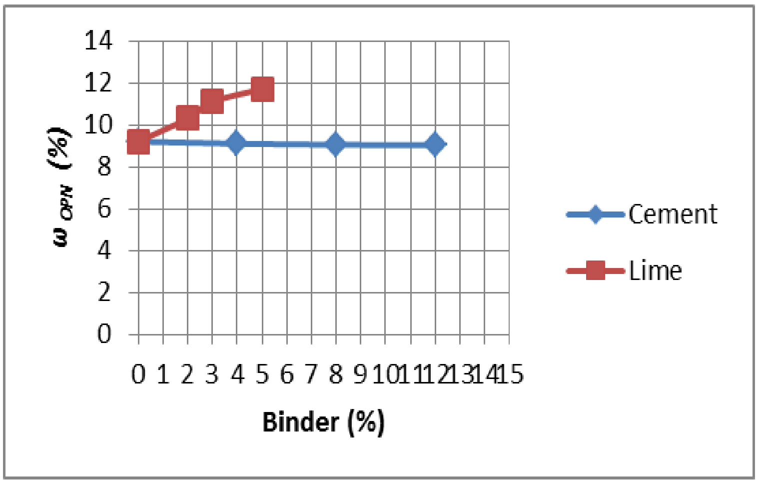


Fig. 5. $W_{OPN}$ vs. the binders content (%)

In Fig. 6 and Fig. 7, the Proctor test results of the *Series (SLC)* is shown, where the samples of soil are mixed simultaneously with both lime and cement. The maximum dry density is plotted against the Ratio of lime percentage to cement percentage noted $R_{L/C}$, for the three percentage of lime content (2%, 3% and 5%) considered. From this figure it is evident that for a percentage of 2% of lime there is an increase in the maximum dry density of the soil, however, this increase is much less pronounced for sample with 3% of lime concentration. Beyond this limit (3% of lime) or lime fixation point, there is a sharp decrease in the maximum dry density of the soil with the increase in the ratio $R_{L/C}$ as it the case for the sample with 5% concentration in lime content (Fig. 6).

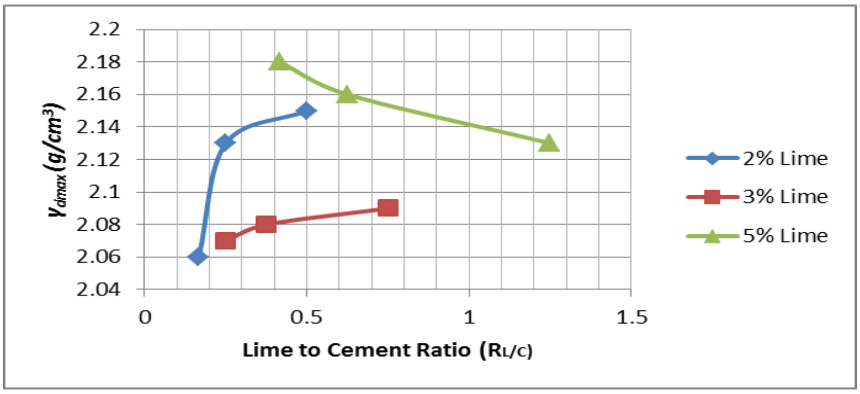


Fig. 6. Variation of ($\gamma_{dmax}$) *with* $R_{L/C}$

In Fig. 7, the optimum moisture content is plotted against the Ratio $R_{L/C}$ for different levels of lime content. For values of 2% and 3% lime content, a small decrease in the optimum moisture content is obtained, which is more visible for values of $R_{L/C} \leq 0.3$. The optimum moisture content increases with the ratio $R_{L/C}$ for samples with 5% of lime content.

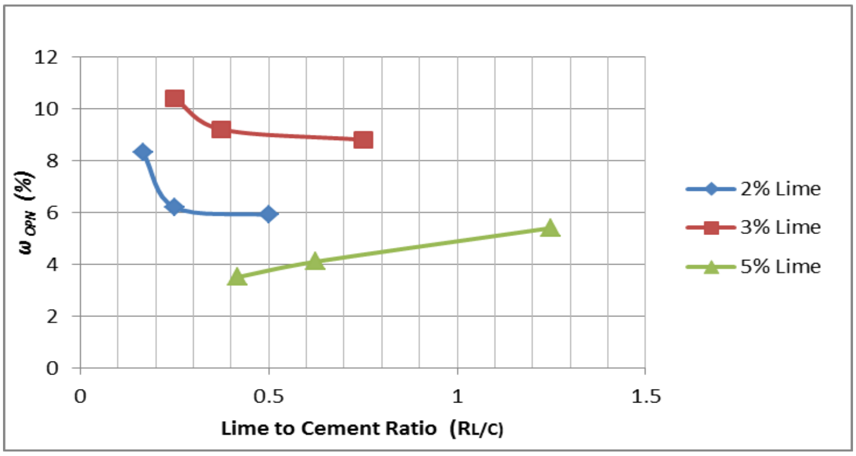


Fig. 7. Variation of the $W_{OPN}$ *with* $R_{L/C}$

**CBR test**

In Fig. 8, the variation of the $CBR_{index}$ with increase in $R_{L/C}$ ratio is presented, with specific percentages of lime content, for the *Series-SC* and *Series-SL*. This figure indicates clearly the increase in the strength of the soil with both binders content, in the case of the mixing with lime (*Series-SL*), the strength increases up to a limit corresponding to 3% of lime content, however, strength of the soil keep increasing almost linearly with the increase in cement content which contributes in inter-particles bonding.

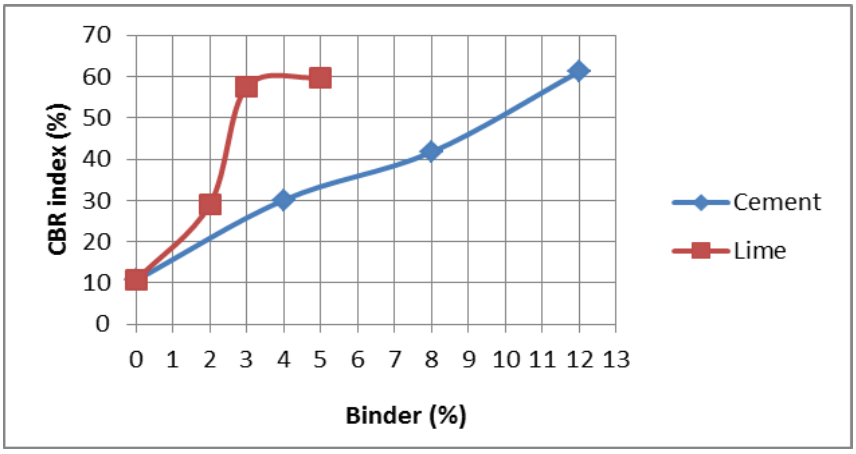


Fig. 8. Increase of the $CBR_{index}$ with binders content (%)

The variation of the $CBR_{index}$ for the *Series-(SLC)*, where the samples of soil are mixed simultaneously with both lime and cement is shown in Fig. 9. In this figure, the $CBR_{index}$ is plotted against the Ratio $R_{L/C}$, for three levels (percentages) of lime content (2%, 3% and 5%) considered. Out of this figure, it is evident that: for a percentage of 2% of lime there is a decrease of the $CBR_{index}$ and hence, in the samples strength, however, this decrease is much less pronounced for samples with 3% of lime concentration, corresponding to a ratio $R_{L/C}$ of about 0.3. Beyond this limit (3% of lime content), there is a decrease trend in the strength of the samples with increasing values of the ratio $R_{L/C}$.

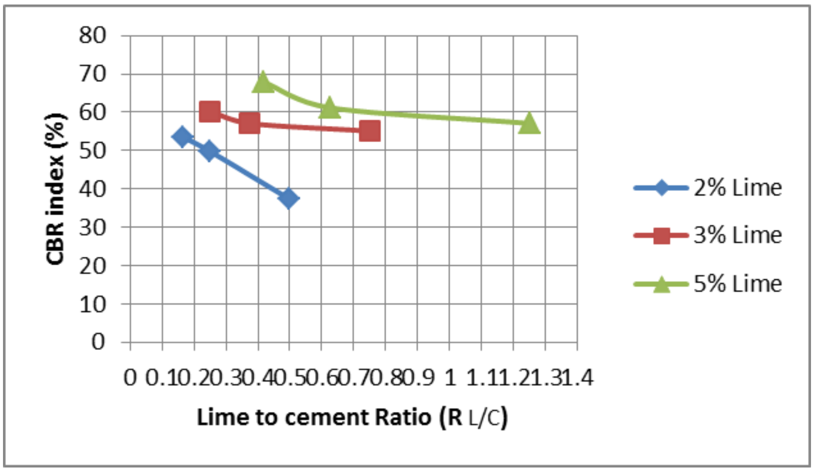


Fig. 9. Variation of the $CBR_{index}$ with the ratio $R_{L/C}$.

The results obtained out of this experimental investigation are summarized in Table 3, where the variation of the compaction (Proctor) and strength (CBR) parameters are indicated, following the mixing program and corresponding testing Series.

Table 3. Summary of the results obtained

| | **Proctor Test** | **CBR Test** |
|---|---|---|
| | $\gamma_{dmax}$, $W_{OPN}$ | $CBR_{index}$ |
| **Series -SC (Soil + Cement)** | - $\gamma_{dmax}$ increase with cement content<br>- $W_{OPN}$ constant | - $CBR_{index}$ increases with cement content |
| **Series-SL (Soil + Lime)** | - $\gamma_{dmax}$ decreases with lime content<br>- $W_{OPN}$ increases up to 3% of lime | - $CBR_{index}$ increase with lime content up to 3% then steady. |
| **Series -SLC (Soil + Lime + Cement)** | - $\gamma_{dmax}$ increases with $R_{L/C}$ for 2-3% of lime content<br>- $\gamma_{dmax}$ decreases with $R_{L/C}$ for 5% of lime content<br>- $W_{OPN}$ decreases for 2-3% of lime, steady for $R_{L/C}$ >0,3<br>- $W_{OPN}$ increases for 5% of lime | - $CBR_{index}$ decreases, then steady.<br>- $CBR_{index}$ steady for $R_{L/C} \geq 0,3$ and 3% lime content |

Research by Ankit *et al*. (2013) confirms that lime causes a decrease in plasticity and an increase in the compressibility and strength properties, however, cement with its compounds (silicates and aluminates) hydrate upon the contact with water, resulting in cementation products that bond soil particles together and develop strength. From the results obtained, it is evident that the combination of lime and cement as binders, within a defined proportion (Ratio $R_{L/C}$=0,3) enhances the mechanical properties of the low plasticity soil considered, by further reducing its plasticity and increasing its $CBR_{index}$ up to 6 times.

The optimum water content is found to be more sensitive to the amount of lime used in the mixture. Portelinha *et al*. (2012), in an investigation on the stabilization of Brazilian Lateritic soil using lime, reported that the lime fixation point is around 3% for the soil considered, which is in good agreement with the present research work. The optimum mixing protocol proposed (3% of lime with 10% of cement), investigated in *Series-SLC*, is in fact the optimum combination of the chemical effect of the lime, at the fixation point (3%) and the amount of cement (10%) necessary to the cementation of the soil particles, consequently, the soil treated exhibit a crumbly state, which make it is easy to excavate, load, compact and level.

## CONCLUSION

A comprehensive testing program was realized to investigate the effect of chemical binders as types and proportions, used to stabilize bulk samples of a natural soil, used for the construction of a highway project in Algeria. The compaction characteristics of the resulting mixtures were examined by Standard Proctor tests and the strength by the corresponding CBR Tests.

The optimum water content is found to be more sensitive to the amount of lime used in the mixture. The lime fixation point found is around 3% for the soil considered, which is in good agreement with previous researches. The mixing protocol proposed which is: 3% of lime with 10% of cement (corresponding to a $R_{L/C}$=0,3), is in fact, the optimum combination of the chemical effect of the lime, at the fixation point (3%) and the amount of cement (10%) necessary to the cementation of the soil particles.

Simultaneous use of lime and cement (referred to as the dry method of deep mixing), and with respect to the optimum mixing option proposed in the present investigation, was found to enhances considerably the mechanical properties of the natural soil considered, by further reducing its plasticity and increasing its strength up to 6 times.

Other necessary findings are outlined in this paper, which could be of interest to geotechnical designers dealing with stabilization of natural granular soils having a low plasticity.

**REFERENCES**

Ajayi ES (2012) Effect of lime variation on the moisture content and dry density of Lateritic soil in Ilorin, Nigeria. *Int. J. Forest, Soil and Erosion.* 2(4), 165-168.

Ampadu SIK (2007) A laboratory investigation into the effect of water content on the CBR of a subgrade soil. Experimental Unsaturated Soil Mechanics, Springer Proceedings in Physics, Volume 112. p.137-144.

Ankit SN, Faizan M, Devashish PS, Rehanjot S (2013) Soil stabilization using lime. *Int. J. of Innovative Research in Science, Engineering and Technology.* 2(2), 448-453.

Dallas L, Scullion T (2005) Guidelines for modification and stabilization of soils and base for use in pavement structures. Document of the Texas Department of Transportation, TxDot 09.

Dallas NL, Syam N (2009) Recommended practice for stabilization of sub grade soils and base materials. NCHRP document 144. 137-144.

Jacobson JR, Filz GM, Mitchell JK (2005) Factors affecting strength of lime-cement columns based on a laboratory study of three organic soils. International Conference on Deep Mixing, Best Practice and Recent Advances. Deep Mixing 05, Stockholm, Sweden.

Jones D, Rahim A, Saadeh S, Harvey J (2010) Guidelines for the stabilization of sub grade soils in California. Institute of Transportation Studies. University of California. Research report -UCD-ITS-RR-10-38.

Makusa GP (2012) Soil stabilization methods and materials in engineering practice, state of the art review. Lulea University of Technology, Sweden.

Omid A, Jafari SH, Jie L (2012) Compaction characteristics and mechanical properties of lime/cement treated granular soils. *The Electronic Journal of Geotechnical Engineering.* Vol. 17, 2275-2284.

Onyelowe KC, Okafor FO (2012) A comparative review of soil modification methods. *ARPN Journal of Earth Sciences*, 1(2), 36-41.

Oyediran IA, Kalejaiye M (2011) Effect of Increasing cement content on strength and compaction parameters of some Lateritic soils from southwestern Nigeria. *EJGE.* Vol. 16, 1501-1514.

Portelinha FHM, Lima DC, Fontes MPF, Carvalho CAB (2012) Modification of a Lateritic soil with lime and cement: An economical alternative for flexible pavement layers. *Soils and Rocks,* 35(1), 51-63.

Setra S (2008) Treatment of soils with lime and / or binders - application to the construction of pavement base layers. *Technical guide. Reference: 0857w-ISRN: EQ-SETRA-08*.

Standard NF (1992) Earthworks-classification of materials for use in the construction of road embankments and capping layers. NF 11-300.