International Information and Engineering Technology Association

Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials
Vol. 34, No. 3, June, 2024, pp. 357-362
Journal homepage: http://iieta.org/journals/rcma

Effect of Treatment with Different Classes of Cement on the Geotechnical Properties of Soils: Case Study of Red Soil in the M'sila Region, Algeria

Lakhdar Mekki[1*], Ahmed Seddiki[1], Abderrachid Amriou[1], Larbi Belagraa[2]

[1] Geomaterials Development Laboratory, Faculty of Technology, University of M'sila, PO Box 166 Ichebilia, M'sila 2800, Algeria
[2] Faculty of Technology, University of M'sila, PO Box 166 Ichebilia, M'sila 2800, Algeria

Corresponding Author Email: lakhdar.mekki@univ-msila.dz

https://doi.org/10.18280/rcma.340311

Received: 14 February 2024
Revised: 18 April 2024
Accepted: 7 May 2024
Available online: 22 June 2024

Keywords:
class of cement, treatment, silt-clayey, compaction, unconfined compression, CBR test

ABSTRACT

This article showcases the findings of an experimental study conducted on a red silt-clayey taken from the site of Chaaba Elhamra (M'sila region, Algeria) for the purpose of being used for the building of road embankments and pavement layers. This experimental research aims to evaluate the geotechnical characteristics of this red soil, both before and after being treated with two classes of cement (CEM-II/B-L 32.5 N and CEM-II/B-L 42.5 N), and to analyse the impact of the cement class on its geotechnical properties. The experimental program included identification tests as well as Proctor compaction, CBR, and unconfined compression tests. The interpretation of the results has taken into account knowledge acquired from the literature. The findings showed that the percentage of cement had a beneficial effect on the geotechnical characteristics of this red silt-clay. Moreover, they highlighted that the type of cement did not have a great influence on the physical parameters, the compaction parameters, and the CBR indices. However, it was observed that class 42.5 cement had a much greater effect on UCS values than lower class 32.5 cement.

1. INTRODUCTION

The increase in the costs of geotechnical projects due to the utilization of quality soils has led to the need to use local materials, which do not meet the requirements, after their treatments. The use of cement to improve the geotechnical characteristics of soils is a widely employed technique. This method has shown efficiency and cost-effectiveness for the purpose of building road embankments, road sub-bases, and load-bearing soils for geotechnical projects including retaining walls, dams, tunnels, and reservoirs [1-5].

The chemical processes that lead to the formation of resistance in soils treated with cement are hydration, cation exchange, and pozzolanic reactions [6]. The main processes that contribute to the development of the resistance of soil-cement mixtures are, firstly, the hydration that happens when cement and water mix, which leads the initial cementitious products to be formed, and secondly, the pozzolanic reactions, which contribute to the development of long-term resistance by dint of the interactions between soil minerals and the lime released by the cement [7-9].

Many investigations have examined the influence of fundamental characteristics on the resistance of cement treated soils, including the amount of cement used [10-12], chemical components of cement [3, 13], curing conditions [14, 15], curing time [16-18], hydration level and/or ratio of water to cement (w/c) [12, 19-21], fine content [8, 22, 23], and the component mixing method [24].

The literature research reveals a scarcity of information regarding the impact of classes of cement on the geotechnical parameters of soils treated with cement. Although there is a substantial amount of information available on soils treated with cement, research explicitly focused on this aspect seems to be limited.Mollamahmutoglu and Avcı [23] studied the effect of calcium aluminate cement and sulphate resistant cement on the mechanical characteristics of low plasticity clay. Van Nguyen et al. [25] investigated the impact of high-strength Portland cement and ordinary Portland cement on the process of strength enhancement of clay treated with cement through the hardening process at different temperatures.

The purpose of this experimental investigation is to evaluate the geotechnical characteristics of the Chaaba Elhamra soil before and after it has been treated with two classes of Portland cement (CEM-II/B-L 32.5 N and CEM-II/B-L 42.5 N) at different percentages (0%, 2%, 4%, 6%, 8%, and 10%), and analyse the impact of the cement class on its geotechnical properties, later.

2. MATERIALS AND METHODS

The red soil from Chaaba Elhamra was taken from a location situated 10 km north of the city of M'sila (Algeria) at a depth of about 50 cm. Figure 1 presents its particle size curve. Table 1 presents the average values of their geotechnical characteristics, while Table 2 describes its chemical composition. According to the GTR classification, it is a silty clay with low plasticity (class A2).

The two classes of cement used in this study are class CEM-II/B-L 32.5 N and class CEM-II/B-L 42.5 N, manufactured locally in the Lafarge cement plant in Hammam Dalâa (M'sila region, Algeria). Their chemical compositions are described in Table 2.

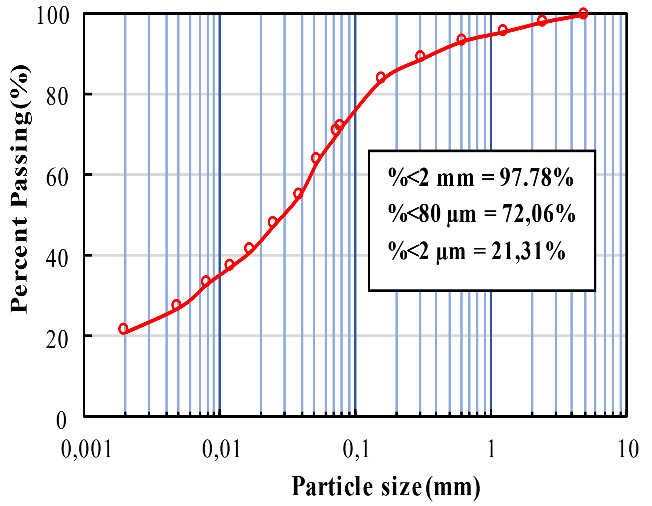


Figure 1. Average grain size distribution of Chaab El Hamra soil

Table 1. Average values of geotechnical parameters of Chaaba Elhamra soil

Parameters	Means Values
Liquid limit, w_L (%)	38.55
Plastic limit, w_P (%)	19.52
Plasticity index, I_P (%)	19.03
Methylene blue value, MBV (%)	3.50
Passing 2 mm (%<2 mm)	97.78
Passing 0.08 mm (%<0.08 mm)	72.06
Clay content, C_2 µm (%)	21.31

The experimental programme included identification tests as well as Proctor compaction tests, immediate CBR and CBR after immersion tests, and unconfined compression strength tests. for the two classes of cement (32.5 and 42.5), we used the weight contents of cement 0%, 2%, 4%, 6%, 8% and 10%.

The soil was dried and then manually mixed with cement according to the required soil/cement ratio, then moistened. carried out for all cement/soil ratios.

To control the density of the samples in the unconfined compression strength tests (UCS), a sufficient quantity of soil-cement mixture was moistened to its optimum moisture content (OMC) and statically compacted to its maximum dry density (MDD) in a specific mould linked to the type of test. This allows the specimens to have a constant volume. The samples were promptly preserved following their preparation in plastic bags at room temperature (25°C) over various durations (7, 14, and 28 days) of hardening. For each type of test and for each soil/cement ratio, at least a set of three specimens were prepared. Experimental test protocols were carried out in compliance with Algerian standards.

Table 2. Chemical composition of the cements and the soil used

Constituents (%)	Chaaba Elhamra Soil	CEM II/B-L 32.5 N	CEM II/B-L 42.5 N
SiO_2	26.58	13,13	16,02
Al_2O_3	6.24	3,20	3,69
Fe_2O_3	2.31	2,23	2,67
CaO	32.38	64,07	62,29
MgO	2.60	1,81	1,78
SO_3	4.04	2,41	2,14
K_2O	1.27	0,44	0,51
Na_2O	0.03	0,05	0,06

3. RESULTS AND DISCUSSIONS

3.1 Plasticity and activity parameters

Figures 2, 3 and 4 show the effect of treatment with different classes of cement (32.5 and 42.5) on the plasticity parameters of the studied soil. It can be noted that unlike the plastic limit, which increases as a function of cement content, the liquidity limit and the plasticity index decrease proportionally with the cement content. Also, it can be noted that there is no remarkable difference between the two classes of cement. Consequently, the plasticity of the studied soil diminishes, rendering it less sensitive to water. These results are in good agreement with almost all published research on soil treatment with cement [11, 16, 26, 27].

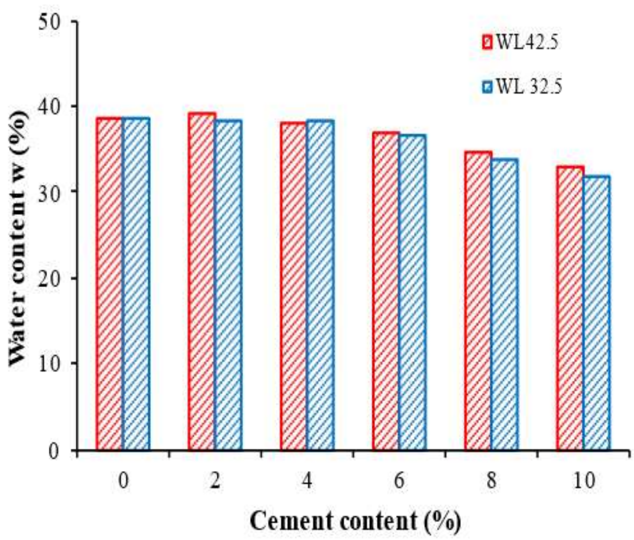


Figure 2. Effect of treatment with two classes of cement (32.5 and 42.5) on the plasticity parameters of the soil studied

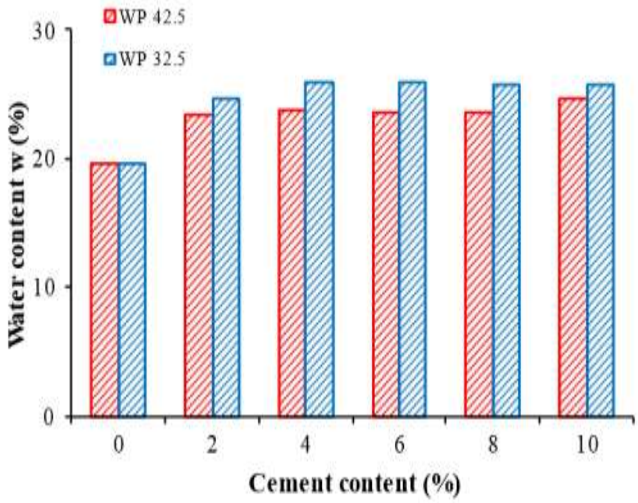


Figure 3. Effect of treatment with two classes of cement (32.5 and 42.5) on the plastic limit of the soil studied

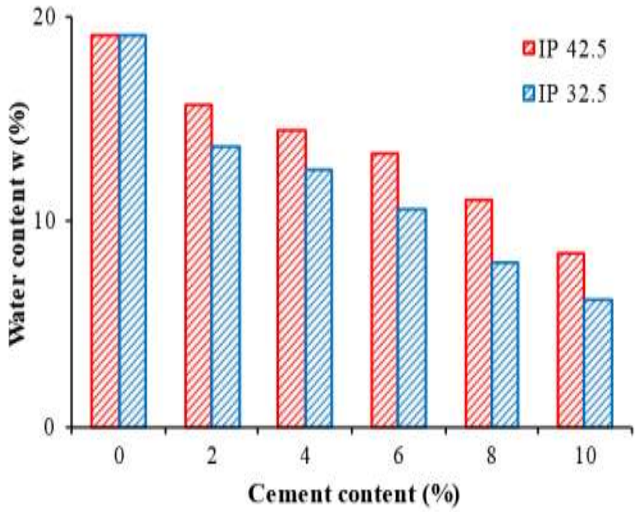


Figure 4. Effect of treatment with two classes of cement (32.5 and 42.5) on the plasticity index of the soil studied

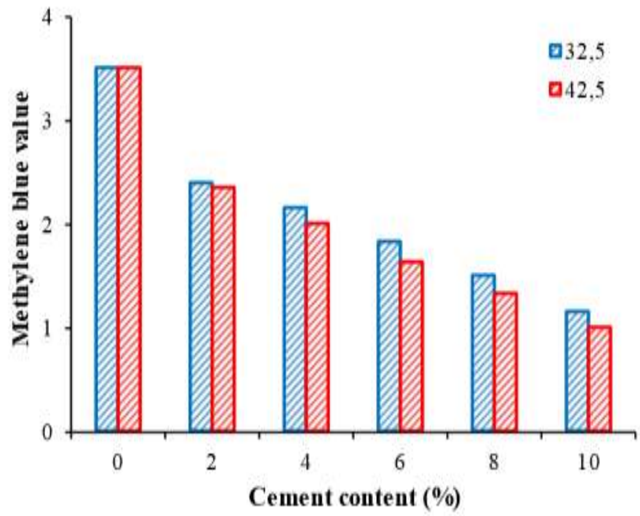


Figure 5. Effect of treatment with two classes of cement (32.5 and 42.5) on the activity of the soil studied

Figure 5 presents the effect of treatment with different classes of cement (32.5 and 42.5) on the activity of the soil object of this study. The value of methylene blue (MBV) drops dramatically with higher cement percentage. These results show a decline in the water sensitivity of the soil studied, so far.

3.2 Compaction parameters

Figures 6 and 7 show the compaction curves for the soil studied treated with cement classes 32.5 and 42.5 respectively. Figures 8 and 9 present the evolution of MDD (maximum dry density) and OMC (optimal moisture content). It can be noted that, for the two classes of cement, the different dosages do not lead to a fundamental difference in (MDD) between the treated soil and the untreated soil. However, the optimal moisture content (OMC) increases with cement content. These results agree well with previous studies conducted by several researchers [5, 28, 29].

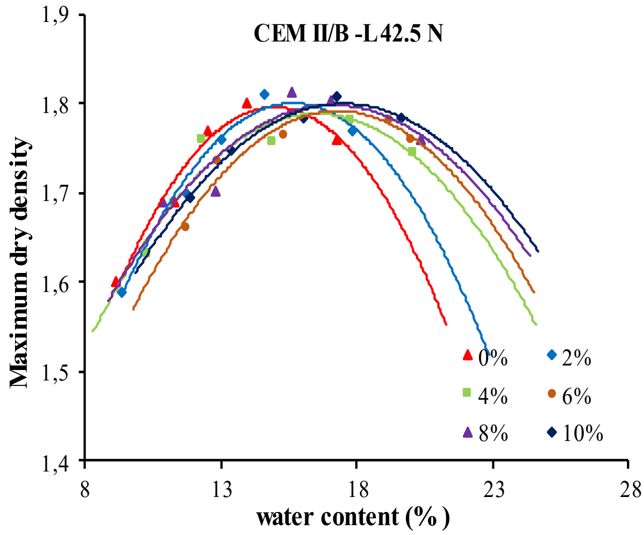


Figure 6. Compaction curves of the soil studied treated with cement class 32.5

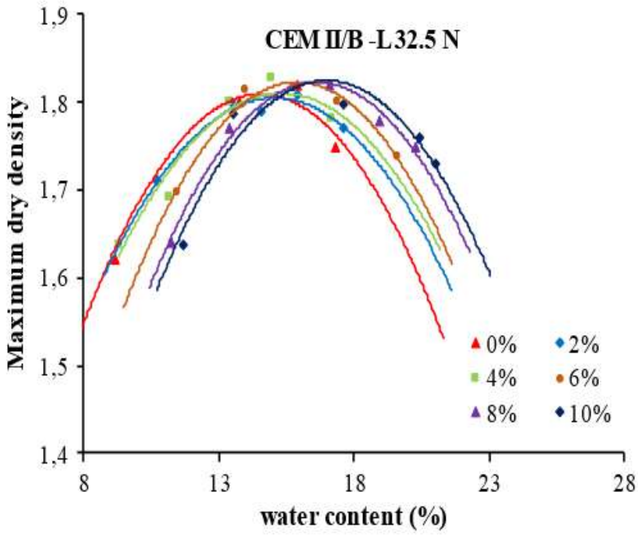


Figure 7. Compaction curves of the soil studied treated with cement class 42.5

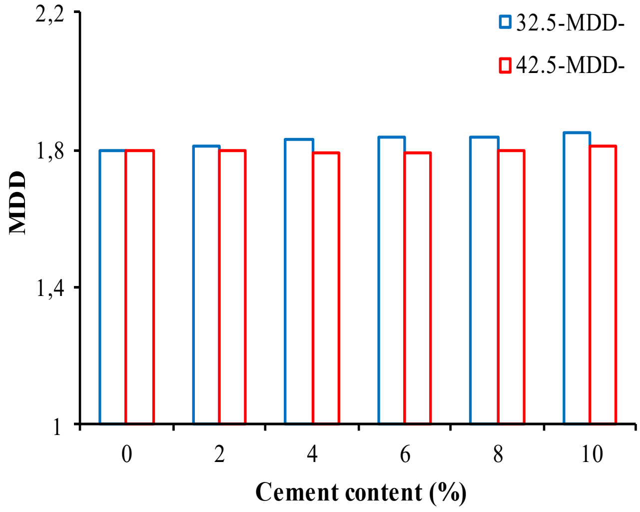


Figure 8. Effect of treatment with two classes of cement (32.5 and 42.5) on the MDD

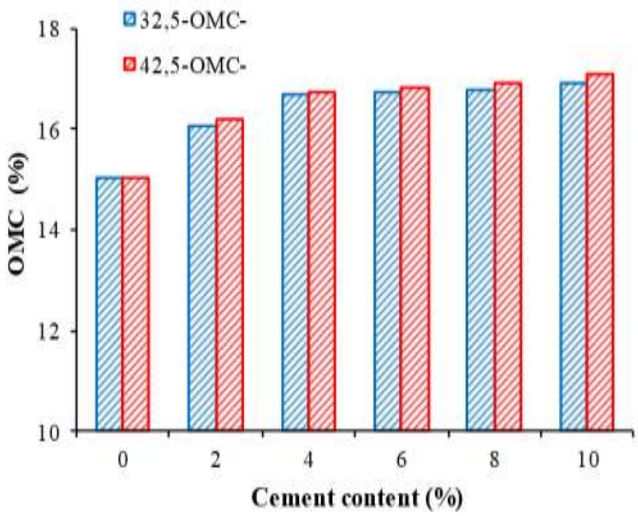


Figure 9. Effect of treatment with two classes of cement (32.5 and 42.5) on the OMC

3.3 Bearing capacity parameters

The CBR (California Bearing Ratio) test provides information on the stiffness and puncture resistance of the floor. Figure 10 shows the evolution of the immediate CBR and CBR after immersion (for 4 days) indices of used soil treated with different classes of cement and compacted at normal Proctor densities.

It can be noted that the class of cement has a significant impact on the CBR indices after immersion, while its effect on the immediate CBR index values is relatively minimal. It is worth mentioning that the percentage of cement does not have a substantial impact on the immediate CBR indices for both cement class. However, it influences the CBR index values after immersion, markedly. But the effect of cement class 42.5 is much greater than that of cement class 32.5. This can be justified by the hydration reaction products as well as by the pozzolanic reactions during the immersion time. Which, led to a decrease in the deformability of the soil and an improvement in its bearing capacity.

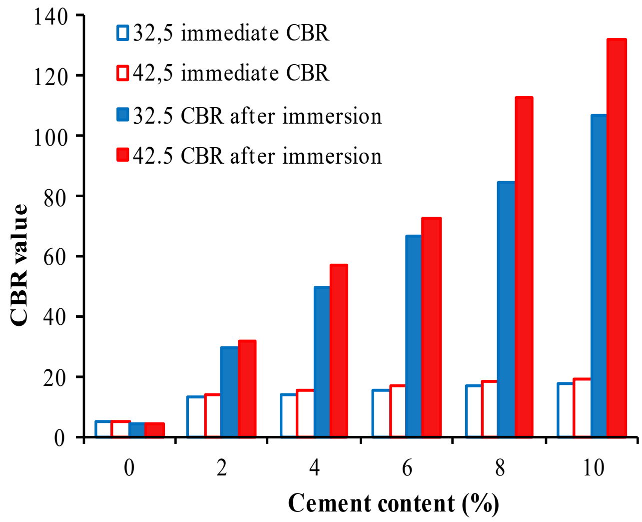
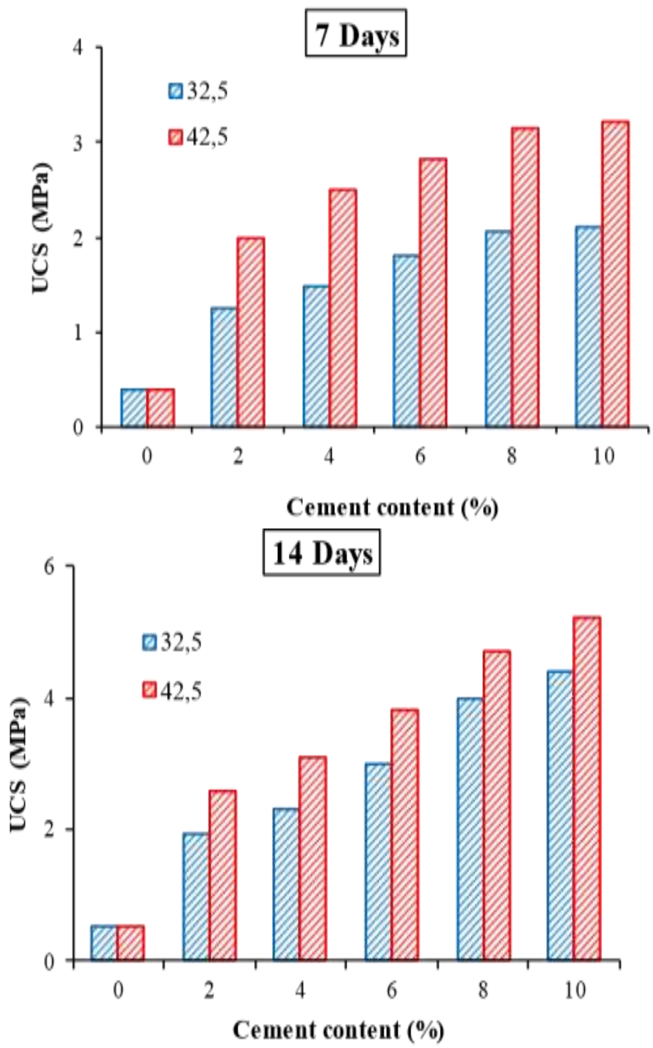


Figure 10. Effect of treatment with two classes of cement (32.5 and 42.5) on the CBR value

3.4 Unconfined compressive strength parameters

The unconfined compressive strength (UCS) is a crucial factor that dictates the effectiveness of soil treatment [5]. Many researchers have noticed a substantial rise in the resistivity of soils treated with cement all along as the curing period progresses [9, 27, 30, 31].



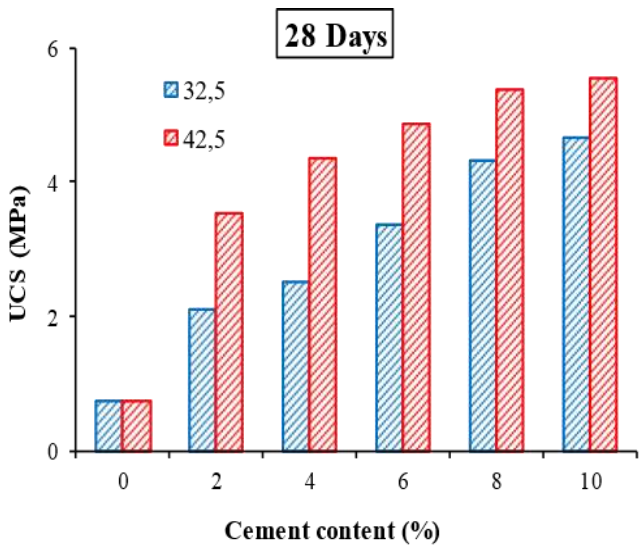


Figure 11. Effect of treatment with two classes of cement (32.5 and 42.5) on the UCS

Figure 11 presents the variation of unconfined compressive strength (UCS) as a function of percentage of cement during various curing periods (7, 14 and 28 days) on soil specimens from Chaaba Elhamra treated with two classes of cement and compacted with standard Proctor densities. It can be noted that the UCS increases with curing time and cement content, but at a content above 8%, a decline of the slope is noticed. Also, it can be observed that class 42.5 cement has a much greater influence on UCS values than class 32.5 cement for both types of cement. This increase can be explained by the hydration of the cement as well as by the pozzolanic reaction which will continue over time [8, 9]. Moreover, this leads to an enhancement in the load-bearing capability of the treated soil.

4. CONCLUSIONS

This experimental research aims to evaluate the geotechnical parameters of Chaaba Elhamra soil, both before and after being treated with two classes of Portland cement (CEM-II/B-L 32.5 N and CEM-II/B-L 42.5 N). Secondly, the analysis of the impact of the class of cement on the geotechnical characteristics of studied red soil is undertaken.

The present study lets the following important conclusions to be drawn;

- A notable reduction in plasticity index and methylene blue value (MBV) with increasing cement content is noticed. As a result, the soil's sensitivity to water decreases.
- Regardless of the kind and proportion of cement used, the treatment does not significantly affect the maximum dry density (MDD). Inversely, the ideal moisture content (OMC) rises as the cement concentration increases.
- The amount of the cement has a much greater influence on the values of the CBR indices after immersion than that of the values of the immediate CBR index. The Cement content has significantly affects the CBR index values after immersion, unlike direct CBR index values. However, cement content does not lead to a big difference in the values of the immediate CBR indices. On the other hand, it is very remarkable for the values of the CBR index after immersion, but more with class 42.5 cement than with class cement 32.5. This can be justified by the hydration process, as well as by the pozzolanic reactions during the immersion time.
- The impact of cement content on the CBR index values is particularly pronounced after immersion. While, there is not a significant difference in the immediate CBR indices. It becomes quite notable for the values of the CBR index after immersion, especially with class 42.5 cement compared to class 32.5 cement. We can attribute this to the process of hydration and the occurrence of pozzolanic reactions that take place throughout the duration of immersion, which are more prominent with higher cement classes.
- The unconfined compressive strength (UCS) rises as the proportion of cement and cure time increase, but above 8% a weak increase of the slope could be noted. This increase can be explained by the process of hydration of the cement as well as the pozzolanic reaction, which will continue over time.
- The class of cement does not lead to a significant impact on the physical parameters, compaction parameters and immediate CBR index values. However, it's noteworthy that class 42.5 cement has a much greater influence on UCS values than class 32.5 cement.

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