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Improving the Bearing Capacity of Road Soil by Treatment with Cement and Lime: Case of National Road No. 4 in the City of Ouagadougou in Burkina Faso

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Abstract

Nowadays, the question of the availability of good quality materials is increasingly raised in road projects. This has led us to techniques for improving the performance of materials that can be used in road layers. Cement and lime treatment is a well-known technique for improving materials in road construction. The test is done by adding a small amount of cement or lime to the material to be improved. This amount is determined at various percentages in order to obtain a good result. To carry out our study, it is necessary to study the raw material to see if it meets the standards, otherwise it must be improved. Indeed, for a material to be used in road layers, a minimum bearing capacity of 80% to 98% of OPM is required. Also, in order to understand the evolution of the CBR bearing capacity, we will make our materials suitable for road construction by mixing them with lime and cement.

Keywords

CBR Bearing Capacity, Improvement, GAL, Cement, Lime

1. Introduction

For decades, the study of lateritic soils has been a key concern for engineers and scientists in the field of Civil Engineering. Indeed, it has been noted in Burkina Faso an increase in road traffic and a scarcity of good quality lateritic materials, which limits the availability of these materials, which are used in road construction, especially in the base layer [1]. On the other hand, lateritic gravel that does not meet the criteria of a base layer, in particular, the CBR bearing index, can be used in the foundation layer. Based on this observation, it is necessary to improve the lateritic gravel used in the base layer. It is in this sense that most countries with the same problems have provided technical and economic solutions to meet the needs encountered, namely:

- ✓ The improvement of laterites with cement in order to reduce the use of natural reserves;
- ✓ Improvement with crushed granite gravel (Burkina Faso) or with sand (Senegal and Cameroon): litho stabilization [2];
- ✓ Improvement with lime.

All these improvement techniques have been developed rapidly in recent years thanks to technological progress, increased traffic and interest in the environment. In order to enhance local materials, tests will be carried out on each mixture at a percentage of stabilizer (cement, lime; the cement used is CPA45 and the lime used is slaked lime of dolomitic nature from COVEMI in ABOBO) in order to diversify the technical solutions provided for the realization and to understand the evolution of their CBR bearing capacity.

The objective will be to study the characteristics of the raw material and then improve it at percentages in order to understand the evolution of the CBR bearing capacity.

2. Materials and Method

2.1. Sampling Section

The sampling section is the mother section of any laboratory test, that is to say, the section through which all the samples taken from the different sites pass before the test. The samples taken must be representative of the materials that the company needs.

Sampling is the process of obtaining the quantity of materials needed to carry out the tests. Each sample contains a label that constitutes its identity document. Sampling is done in two stages:

- ✓ The first sampling is done on the project site in order to obtain a representative sample of the entire material. The quantity of material brought must be significantly greater than the quantity needed in order to be able to reuse it in the event of a fault or error.
- ✓ The second sampling is done in the laboratory in the sampling section to obtain the quantity necessary to carry out the requested tests. It can be done in two (2) stages:
  - By quartering or manual splitting when the material used is large.
  - By means of the divider or sampler when the quantity of material used is less.

2.1.1. Materials Used for Sampling

- ✓ A tarpaulin or mat to avoid direct contact of the material with the ground.

- ✓ A sampler or divider to divide the material into two equal and homogeneous parts.
- ✓ Bins to collect the materials from the divider.
- ✓ Hand shovels to collect the material under test.
- ✓ Sieves 44 with a diameter of 20 mm and 38 with a diameter of 5 mm, these sieves are used for sieving materials such as clay and lateritic gravelly clay (GAL).
- ✓ Hammers to crush rejects during sieving.
- ✓ Dishes to collect the sample needed to carry out the test after sampling.
- ✓ A bag to keep the sample reserves.
- ✓ A broom and a trowel.

2.1.2. Method of Operation

Sampling is the operation of taking a quantity of material such that the part taken is representative of the whole material. The sample taken on the site must be spread on a tarpaulin and dried in the open air if it is too wet; the largest elements must be crushed in order to facilitate the drying of the material. Also, the material must not be completely dry to avoid the departure of fines during sieving.

Sampling is done by quartering or using the sampler:

- ✓ **Quartering:** on the tarpaulin, the material is divided into 4 substantially equal parts then grouped into two parts, consisting of opposite tars of the fourth part. This selection is homogenized and another quartering is carried out in order to obtain 8 points, that is to say, 8 equal parts of the material including 5 points for the Proctor and 3 points for the CBR.
- ✓ **Sampling:** it is a device that divides the material into two equal parts and each half is collected in two separate bins. This operation is repeated 4 times for each bin to obtain the quantity of materials necessary for the requested test. We thus obtained the 8 points sought, including 5 points for the Proctor test and 3 points for the CBR test.

These two operations make it possible to obtain the same results, that is to say, the homogeneity of the material subjected to the test.

2.1.3. Sampling of Soils of the GAL Type (Grave Argyle Lateritic) and the Clayey Type

Before sampling the GAL or clay, its water content must be checked, and the material must be moistened so as not to lose the fines during sieving. The distribution of points from the GAL and clay is as follows:

- 5 points for the modified Proctor;
- 3 points for the CBR;
- One point for the Atterberg limit;
- One point for the sieving (Particle Size Analysis);
- One point for sedimentometry.

2.1.4. Quartz and Crushed Stone Sampling

The sampling of crushed rock and quartz is done as follows:

- One point for sieving (AG);
- One point for Cleanliness;
- One point for flattening;
- One point for Specific Weight [3].

2.2. Carrying out the Tests

2.2.1. Atterberg Limit Test

1) PURPOSE OF THE TEST

The purpose of the Atterberg limit test is to determine the water content of the soil when it passes from the liquid state to the plastic state of the soil. At the end of this test, it is necessary to determine:

- The liquidity limits;
- The plasticity limits;
- The plasticity indexes;
- The Consistency Index (if the natural water content (Wn) is determined).

2) PRINCIPLE OF THE TEST

After sampling, the material obtained must be soaked in water in a container at room temperature for 24 hours. The material is then washed with sieve 27 and the wash water (passing sieve 27) obtained is collected in a container and left to settle for 12 hours, after decantation the clear water is siphoned off without touching the solid deposits (**Figure 1** shows what we get). Excess water is evaporated at a temperature not exceeding 50˚C. In fact, the test is carried out in two stages:

- The search for water content when using the Casagrande apparatus;
- The search for water content by rolling the material to fixed dimensions in order to obtain cracks [4].

Figure 1. Operation of obtaining the leg.

3) MATERIALS USED

The equipment used to perform the limit test is:

- A CASAGRANDE apparatus: this is the apparatus used to perform the test; it is composed of a wooden base mounted on four rubber feet, a cup that has the shape of a portion of a sphere, a metal support holding a cup and a cane operated by a crank to lift the cup;

- A scale to weigh the material in order to determine its water content;
- Spatulas to knead the paste to make it homogeneous and capsules to collect the paste in order to determine the water content;
- A 400 µm sieve (module 27 sieve) with square mesh for washing the material;
- A smooth plate for kneading and rolling the material subjected to the test;
- An oven with a temperature adjustable to 150˚C to dry the paste obtained during the test;
- A groove allows the leg spread out in the cup to be divided in two.

4) DETERMINATION OF THE LIQUIDITY LIMIT

a) PROCEDURE

The operations described below are to be carried out successively:

- ✓ Make a quartering to obtain a representative soil sample;
- ✓ Determine the initial water content of the sample if the consistency index (Ic) needs to be calculated;
- ✓ Pass the representative soil sample through a 0.4 mm sieve. Sieving is preferably done by washing, in order to ensure complete recovery of particles smaller than 0.4 mm;
- ✓ After a settling time of at least 12 hours, the clear water is siphoned off without causing any solid deposits;
- ✓ Dry the sample at a temperature not exceeding 50˚C;
- ✓ Weigh the weight of the dry residue, the weight of the dry passer (P), and calculate the weight proportion C of the 0/0.4 mm fraction

$$\boldsymbol{C} = \frac{\text{mass passing the 0.4 mm sieve}}{\text{sample mass}} \quad (1)$$

- ✓ Place the sample in a porcelain bowl and saturate it with water (weight of water required ≈ weight of sample) by completely reworking it using a spatula to obtain a homogeneous mixture;
- ✓ Leave the paste to rest in an oven for 4 to 8 hours;
- ✓ Calibrate the drop height of the cup using the calibration shim: 1 cm ± 0.5 mm;
- ✓ After having homogenized the paste well, distribute it in the cup in a symmetrical manner, the thickness in the center must be 15 to 20 mm. It is at the point of impact (center of the cup) that this maximum thickness must be found.

Divide the dough in two using the groove tool. The groove will be made in one movement.

- ✓ Using the device, subject the cup to a series of regular shocks: two blows per second;
- ✓ Stop the series when the two lips of the groove have closed over a length of 12 to 13 mm, as judged by eye;
- ✓ Note the number of blows;
- ✓ Take a sample from the vicinity of the groove (where it has been enclosed) to determine the water content.

The entire test is repeated 3 to 5 times, varying the water contents either by drying or by adding water, so as to cover a range of blows from 15 to 35.

b) EXPERIMENTATION OF THE LIQUIDITY LIMIT TEST

The previously obtained paste must be used to search for the 5 points. Using the spatula, the paste is homogenized by kneading and then spread in a clean and dry cup to avoid air bubbles. The spread paste is then divided symmetrically with the groove for an opening of approximately 20 mm (Figure 2); the cup is fixed on the metal support of the Casagrande apparatus. Using the cane of the Casagrande apparatus, a series of shocks is actuated at a rate of 2 strokes per second. The shocks require a closure of approximately 1 cm long, or N, the number of shocks necessary for the closure of the 5 points. This closure is included in a series of shocks spaced 4 times apart:

- 15 < N > 19
- 19 < N > 23
- 23 < N > 27
- 27 < N > 31
- 31 < N > 35

NB: if N is less than 15, the paste is very liquid, so it is necessary to knead to reduce the water content and if N is greater than 35, the paste is too dry, so it is necessary to add a little water and repeat the kneading procedure to homogenize the paste.

Figure 2. Test sample taken and placed in the oven.

Then using the spatula, the material is taken symmetrically at the level of the closure in two capsules or petri dishes of known mass and weighed before being placed in the oven at 105˚C for 4 hours. After the 4 hours, we let the capsules cool and then weighed them. The result obtained makes it possible to determine the water content of each material contained in the different capsules. We average the water content in order to obtain the 5 points for tracing the line, which means it is necessary to have at least 3 points. This line makes it possible to obtain the liquidity limit at 25 strokes.

2.2.2. Granulometric Analysis

1) Purpose of the test

The purpose of the test is to determine the weight proportions of grains of different sizes that make up the soil. The percentages thus obtained are expressed in the form of a graph called a granulometric curve.

2) Principle of the test

The test consists of washing a material of known mass with a modulus 19 sieve in order to detach the clay coatings that contain it from the solid grains. Once dried, the material is sieved using a series of sieves and the cumulative rejects are successively weighed on each sieve, allowing us to obtain the passers-by by calculation [5].

3) MATERIALS USED

The materials used to perform the AG test are:

- A series of sieves with an opening in mm to sieve the material;
- An oven for drying the material;
- A precision balance for weighing the rejects;
- A dish for washing the material and collecting the rejects in order to weigh them.

4) OPERATING MODE

- ✓ After observing the aggregate, choose the finest sieve and the coarsest sieve. Generally, the aggregate passes entirely through the coarsest sieve;
- ✓ Stack the sieves in descending order;
- ✓ Place the column thus formed on the sieve, clamp the column;
- ✓ Pour the aggregate into the column;
- ✓ Set the sieving time to at least 7 minutes;
- ✓ Carry out the sieving;
- ✓ Weigh the rejects. That is to say, weigh the contents of the first sieve, then the contents of the immediately lower sieve, and so on;
- ✓ Enter the results of the rejects in g in a table;
- ✓ Calculate the cumulative rejects in %;
- ✓ Calculate the sieved in %;
- ✓ Plot the curve.

2.2.3. Proctor-CBR Test

1) Purpose of the test

This is one of the most widely used tests in road geotechnics. The purpose of the Proctor test is to determine, for compaction of a given intensity, the water content (ω optm.) at which the material must be compacted to obtain the maximum dry density (γd max.). The test is carried out according to the French standard NF P 94-095 [6].

2) Principle of the test

The principle of the test consists of moistening soil with several water contents and compacting it using a process (56 cuts for each layer) and conventional energy. For each of the water content values considered, the dry density of the soil is determined and the curve of variations of this density is established as a function of the water content. Generally speaking, this curve called the Proctor curve presents a maximum value of the dry density (Yd). It is obtained for a particular value of the water content (W). These two values are called the Modified Proctor compaction characteristic values.

3) Test procedure

To perform the test, the mold must be chosen according to the nature of the test to be performed, *i.e.*, the Modified Proctor mold for the Modified Proctor test. Then, the moistened specimens are compacted by introducing the quantity of material so that the height of the first layer after compaction is slightly greater than one-fifth of the height of the Modified Proctor mold. Compact this layer with the PM tamper, applying 56 strokes per layer (5 layers) (**Figure 3** shows the test process).

Figure 3. The modified proctor test operation.

4) CBR (California Bearing Ratio) bearing test: NF P 94-078 (1997)

Compaction is carried out at a water content corresponding to 95% of the OPM determined during the Proctor test. When the maximum dimension of the soil elements to be studied is less than 20 mm, the entire soil is subjected to the test. If the soil contains elements greater than 20 mm in a proportion of less than 30%, they are eliminated by sieving. The test is then carried out on the remaining fraction. All the CBRs in our study are carried out after imbibition (or immersion). The compacted specimen in the CBR mold is immersed in water for four days, after which punching is carried out. The aim of this operation is to place the soil in the worst hydrometric conditions that it is likely to encounter in practice.

3. Results and Discussions

3.1. Characteristic Study of Gal in Its Natural State (Raw)

In this section, we will present the results of the identification tests (Granulometric Analysis (by Sieving and Sedimentation), Atterberg Limits, Proctor-CBR Tests, Methylene Blue) of the GAL on which the improvement studies will be carried out. At the end, a summary of the results will be presented in order to give an opinion on the characteristics of the materials studied.

3.1.1. Results of the Gal Identification Tests

1) RESULTS OF THE GRANULOMETRY ANALYSIS TEST

The Granulometry Analysis by sedimentation is the complement of the Granulometry Analysis by sieving. The curve below is the result of the AG carried out on the raw material of the GAL (**Figure 4**).

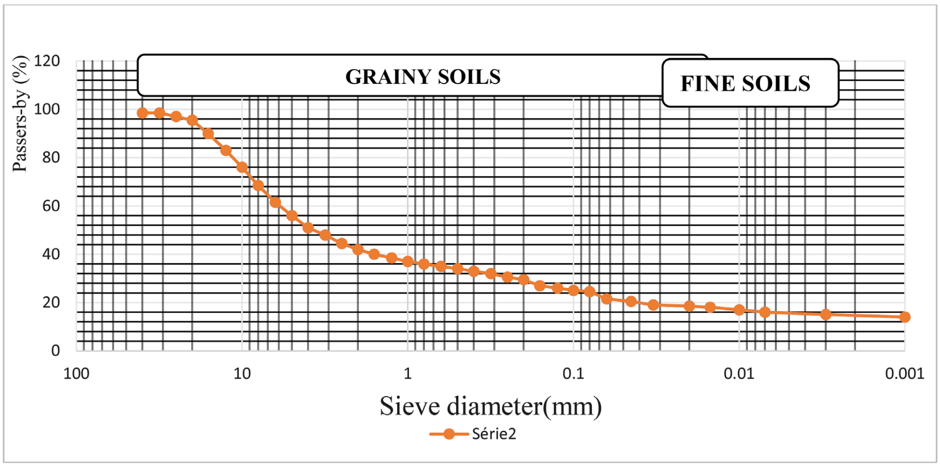

Figure 4. Granulometric curve of raw GAL.

The granulometry curve shows that our material contains more coarse soils (sand, gravel, pebbles) and a small portion of fine.

In order to better see the proportion and nature of the GAL grains, we will summarize the values obtained in the following **Table 1**:

Table 1. Proportion of grains in raw GAL.

Material	Fines	Pebbles	Gravel	Sand	TOTAL
GAL	7%	18%	29%	46%	100%

These results obtained show that our material actually contains more granular elements than fine elements.

For a good realization of the roads, the CEBTP (1984) proposes the granulometric range within which the curve should be inscribed. In order to know if the material really suits the range proposed by the CEBTP we will make a comparison of the results. In the same way for the percentages of grains at the 80µm sieve, the CEBTP (1984) gives a value between 4% - 20% for the base layer and 5% - 35% for the foundation layer; on the other hand, we have 80 µm = 24.5%. So, from the granulometric point of view, the material can be used in foundation layer without improvement but not in the base layer. So, it must be improved to different percentages in order to use it in the base layer.

2) RESULT OF THE ATTERBERG LIMIT TEST (Table 2)

Table 2. The Atterberg limits of the GAL.

Liquidity limit W_L (%)	62
Plasticity limit W_P (%)	32.7
Plasticity index I_P	29.5

These parameters characterize the clayiness of the material; according to the LCPC classification (Central Laboratory of Bridges and Roads) our material has very plastic silt with liquidity limit WL = 62% and IP = 29.5%. The plasticity limit allows us to calculate the plasticity index: $I_P = W_L - W_p$.

The Atterberg limits are water contents by weight corresponding to particular states of soil. Also, in this parameter, we determine the clayiness of the material through the value of the plasticity index, which must comply with the CEBTP standards for use in a base layer. According to the CEBTP (1984), a base layer material must have an IP of 15. On the other hand, we have an IP (Plasticity Index) equal to 29.5, which means that our material contains a lot of fines. It is in this sense that after analysis of our results, we note that the material is not usable as a base layer, so it must be improved [7].

3) RESULT OF THE PROCTOR TEST MODIFIED

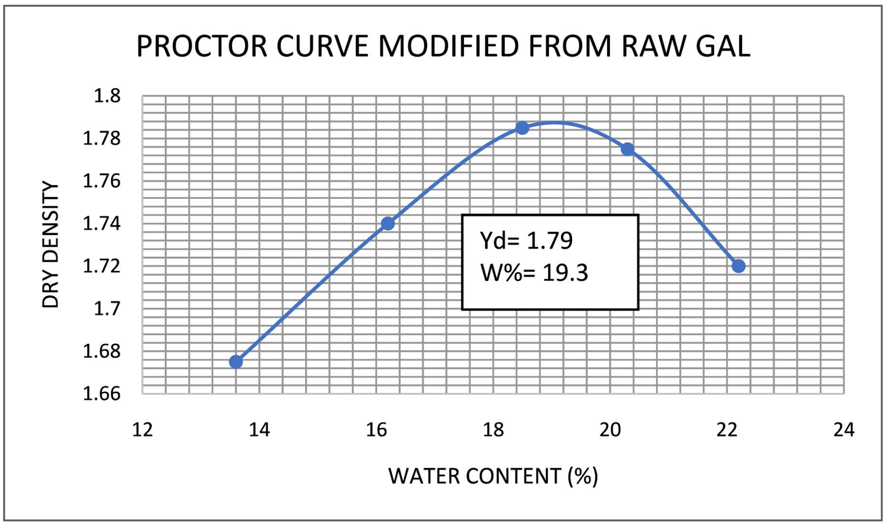

Figure 5. Modified Proctor Curve GAL raw.

The Modified Proctor curve gives us a water content W% OPM equal to 19.3 and a dry density Yd equal to 1.79 (**Figure 5**). The values obtained will be used to mold the CBR.

The results obtained are summarized in **Table 3** below:

Table 3. Maximum water content and maximum dry density value of the GAL raw material.

Proctor Couple	$\omega\%$	γ_d
Raw material	19.3	1.79

For the material to be usable as a base layer, the CEBTP gives us an OPM density of at least 2, which is not our case. Also, we have a very low CBR bearing capacity to be used as a base layer, which requires improvement [8].

4) RESULT OF THE CBR TEST

These values present in **Table 4** were calculated by projection on the stress-deformation curve taking into account the F(div) references at 2.5 and 5 from the depression (Figure 6); the CBR Index is therefore the highest value obtained, *i.e.*, 24, 47 and 67 [9].

Table 4. Table for determining the CBR Index.

	IP Bearing Index (2.5)	IP Bearing Index (5)
10 SHOTS	13 = 319/13.35 = **24**	16 = 368/20 = 18
25 SHOTS	32 = 625/13.35 = **47**	43 = 802/20 = 40
56 SHOTS	49 = 899/13.35 = **67**	75 = 1318/20 = 66

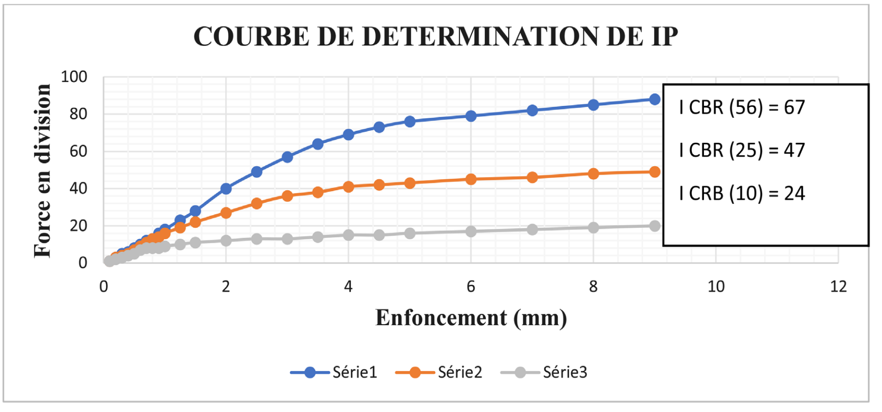

Figure 6. Stress-strain curve.

The stress-deformation curve allows us to obtain the values of the CBR indices at 10 strokes, 25 strokes and 56 strokes. These values allow us to plot the index-dry density curve.

The index-dry density curve for determining the CBR bearing capacity was plotted from the data of the stress-deformation curve (Figure 7).

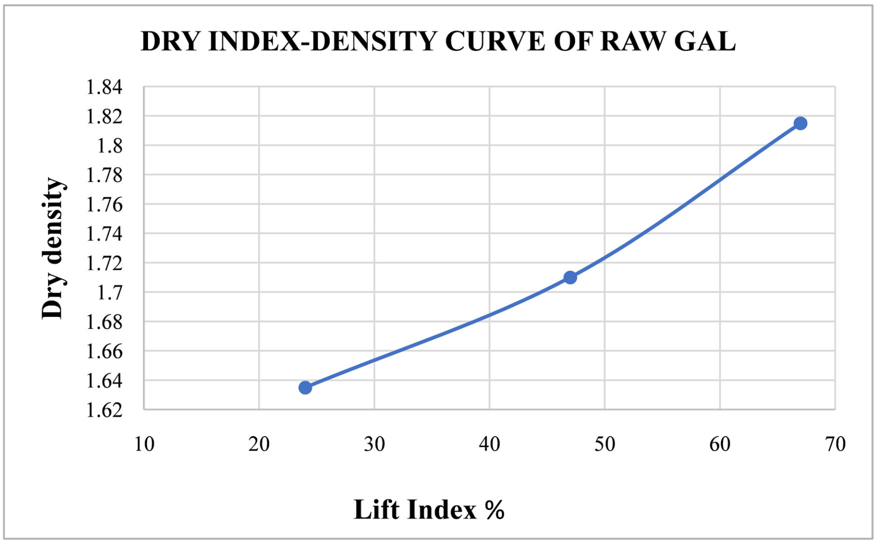

Figure 7. CBR lift curve of raw GAL%.

The CBR bearing curve shows us the evolution of the CBR bearing capacity from 90% to 98%, allowing us to see if the material can be used in road construction.

Thus, we can say that these values obtained do not meet the CEBTP requirements for a base layer, so it must be improved.

The data from these two (2) curves are summarized in Table 5 below:

Table 5. Value obtained after the CBR test of raw GAL.

Numbers of shots	Dry density	IP (Load Index)	CBR lift determined	Water content % of molding	Water content % after test
56 hits (100%)	1.815	67	57% to 98%	17.3	19.6
25 hits (95%)	1.71	47	45% to 95%	18.2	22.6
10 hits (90%)	1.635	24	24% to 90%	17.8	25.1

Knowing that the CBR molding water is obtained after the Proctor test according to the 56 strokes per layer process, which refers to 56 CBR strokes, we must obtain results similar to 56 CBR strokes or more or less equal to 2. This observation is made in Table 3 and Table 5.

The obtained bearing capacities do not meet the CEBTP conditions because at 98% a CBR bearing capacity of 80 is required, which is not the case, so it must be improved.

3.1.2. Analysis of the Results of the Improvement of Gal with Cement and Lime

Soil improvement can be explained as changing its properties by using chemicals or physical means to increase its quality. The main objective of soil improvement is to increase its bearing capacity, resistance to weathering and permeability [10].

Since the quality of materials has a significant influence on the proper functioning of the road, we will improve our material at different dosages of cement and lime. In order to optimally improve the mechanical characteristics of lower bearing materials used in the structure of pavements, we will improve our materials at the following dosages:

Proctor Modifier test: 2%, 4% and 6% and that of CBR at 2%, 4% and 6% according to the recommendation of the laboratory of bridges and roads for the construction of economic and durable pavement layers; the test was carried out at the 100 KN ring [11].

1) Modified Proctor

Modified Proctor test was conducted to determine the effect of cement and lime on compaction parameters such as maximum dry density and optimum water content (Figure 8). For improvement, the quantity of cement or lime is weighed while considering the improvement rate. The materials are well mixed and covered to avoid an increase or decrease in water content of the materials subjected to Modified Proctor test. The results of water content (W%) and density (Yd) are reported in Table 6 below:

Table 6. OPM values (W% and Yd).

Proctor couple	W%	Yd
Raw Materials	19.3	1.79
2% lime	13.8	1.80
4% lime	14.5	1.77
6% lime	12.1	1.76
2% cement	9.6	1.875
4% cement	9.7	1.87
6% cement	10.5	1.87

Figure 8. Principle of sample preparation for the Proctor test.

- **Lime results:**

The maximum dry densities of lateritic gravel treated with 2% and 4% lime decrease while the optimum water contents increase. The decrease in maximum dry densities is explained by the fact that the addition of lime to soil causes an agglomeration of its particles, which then occupy large volumes. The increase in optimum water contents, on the other hand, is due to the high demand for water in the materials after the addition of lime and also to the high affinity of lime for water. However, we note an increase in density when improving the material to 4% and 6% lime; this can be explained by a decrease in water content. This decrease is due to the consumption of water necessary for the hydration of lime and the evaporation of water following the hydration reaction, as well as the aeration caused by mixing.

- **Cement results:**

The results obtained show that the addition of cement to BAMA lateritic gravel increases the optimum water content while decreasing the maximum dry density. The evolution of these properties is linked to an increasing affinity of cement for water. Also, the density and water content of cement and lime are generally lower than that of soils. We thus obtain a similar evolution of OPM parameters on lateritic soils treated with cement and lime [12].

2) CBR TEST

To perform the CBR test, the material must be weighed beforehand while respecting the improvement rate of the cement or lime, just like the PM test. After the CBR test, the material remains in the open air for three days and is immersed for four days, and then, we proceed to punch the molds (Figure 9).

Figure 9. Principle of sample preparation for CBR test.

Finally, the CBR curves are plotted for the different samples of laterite improved at 2%, 4% and 6%. The CBR indices were determined at 90%, 95% and 98% of the Optimum Proctor Modified (OPM). The results are recorded in Table 7 below:

Table 7. CBR lifts at 90%, 95%, and 98%.

Proctor couple	90%	95%	98%
Raw Materials	24	45	57
2% lime	10	32	47
4% lime	19	38	57
6% lime	32	76	112
2% cement	26	75	85
4% cement	110	225	340
6% cement	160	360	495

The addition of lime or cement to clayey or lateritic soil improves mechanical performance, mainly CBR bearing capacity.

The bearing capacities of the materials increase with the lime content. A similar evolution of the CBR indices according to the percentage of lime treatment is obtained by the cement treatment. The CBR indices of the materials increase with the cement content. This improvement in the bearing capacities would be due to the hydration reactions of the cement and the lime [13].

3.1.3. Discussion of the Results

The addition of lime or cement to a clayey or lateritic soil increases the optimum water content and consequently the maximum dry density decreases. The increase in the optimum water content is due to the high demand for water after the addition of binders.

The addition of lime or cement to clayey or lateritic soil improves mechanical performance, mainly CBR bearing capacity.

From the bearing capacity point of view, natural samples are suitable materials for the construction of foundation layers. However, their use in the base layer requires improvement. The study of the improvement shows that the material improved with 4% cement has optimal geotechnical characteristics and economic advantages for road construction. On the other hand, with lime, we need 6% lime to have an adequate result for road construction (base layer) [14].

Economically, it would be preferable to use cement to improve our material.

Research on the quality of local materials is a great challenge that engineers must take care of in order to enhance the materials and obtain standards adapted to our climates. Also, despite the poor quality of the GAL, we have been able to obtain satisfactory results, and perhaps if we deepen the research, we will have results that are in line with our climates.

4. Conclusions

Generally speaking, for a material to be usable as a base layer and foundation layer in Burkina Faso, it must have a CBR bearing index greater than or equal to 80% to 98% and greater than or equal to 30% to 95% of the OPM respectively. However, the scarcity of natural materials meeting this requirement has led to the development of a technique for improving natural lateritic gravel with cement and lime. This work was carried out in order to observe the influence of cement and lime on the evolution of the CBR bearing index. The studies carried out in the laboratory concerned lateritic clayey gravel that cannot be used in its natural state as a base layer. Indeed, its CBR bearing index is 57% to 98% of the Optimum Proctor Modified [15]. This material was improved with cement and lime at different percentages. In addition, these tests provide information on the granulometry, the Atterberg limit and the bearing capacity of lateritic soils.

The geotechnical properties of the soils deduced from the tests were interpreted with reference to the threshold values recommended in the practical guide for the design of lateritic pavements in tropical Africa. This document, established by the CEBTP (1984), is currently used as a guide for the design of pavements in many African countries.

We can say that cement-improved laterite is more resistant than lime-improved or natural laterite.

Nevertheless, the disadvantages of cement- and lime-improved lateritic gravel tip the balance in favour of the stabilizing litho because, in addition to being a local and natural material, it has a higher resistance over time.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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