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Research Article

STUDY ON THE ABILITY TO USE MATERIALS IN ROADWAY LAYERS

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ABSTRACT

The present study bill exclusively on the choice of quality road materials case of three road infrastructural projects, namely: the Sangmelima-Bikula, N'joura-Bilala roads and the NGaoundéré cliff. In this experimental study, we make laboratory tests at LABOGENIE. The principal's results are: Lateritic gravels represent the mostly used soil category in road projects in Cameroon, have outstanding geotechnical and mechanical characteristics in most cases, that is why it is widely used as forming layer and foundation layer. However, these types of soil do not generally have the necessary characteristics to be used as underlying layer: it is therefore necessary to improve them or stabilize them with LHR or to resort to Tar Gravel; Concerning surface layers made of bituminous concrete, in addition to the fact that the formulation phase in laboratory must be validated for all levels of studies carried out, it is also primordial to choose the final formulation on the basis of economic and weather conditions of use.

INTRODUCTION

Problematics

During its lifespan, a roadway is subjected to separate modes of constraints: those resulting from traffic and those resulting from weather conditions. Under traffic action, the body of the roadway undergoes various types of compression, shear and traction constraints through flexion and efforts due to the braking and acceleration of vehicles or the grip of tires. With the increase in the number of heavy-duty vehicles (generalized increase in traffic both from the point of view of the number of vehicles and the axle load) constraints due to traffic are becoming more and more important, thus increasing the need for more and more performing roadways.

The quality of a roadway is determined by two aspects: the choice of quality road materials and a good use of these materials, especially during the compacting phase. This study will deal exclusively on the first aspect.

However, the overall quality of roads in Cameroon is being more and more questioned, both in terms of their poor comfort and practicability and their short lifespan. This is partly due to the fact that the materials chosen do not often offer the geotechnical and mechanical characteristics necessary to be able to bear all the constraints the roadway is exposed to.

In this experimental study, we are presenting laboratory tests carried out by LABOGENIE on lateritic soil whose performances would be improved by a cement treatment and a formulation of bituminous tar. This study is applied to three road infrastructural projects, namely: the Sangmelima-Bikula, N'joura-Bilala roads and the NGaoundéré cliff.

Soil Treatement with Binding Materials

The treatment of soil with lime, cement or road hydraulic binding materials helps to add value to these materials of low quality characteristics: alluvium, clay and sand in order to use them as earthworks constructions and roadway foundation. This is a method that has been widely developed for the past twenty years: in the same time, knowledge of mechanical performances of soil treated and the behaviour of structures developed, while the performance and reliability of treating materials improved.

Immediate actions

Lime helps to reduce the water content of treated soil. As a matter of fact, this treatment property is due to a supply of dry materials, water consumption during the hydration of quick-

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lime, water evaporation due to the heat produced during the same reaction. Generally, for 1% of lime used, water content in the medium reduces between 1% and 3%[4].

It also modifies the clayey portion of the medium as it brings together a large number of fine clayey particles to form bigger and crumbly elements: that is flocculation. This evolution reduces the plasticity index PI, increases the immediate carrying index ICI, and produces a flattening of the Proctor curve with reduction of the Proctor optimum density and an increase in optimal water content.

Long term actions

Given that lime acts as strong base, it increases the soil Ph.and causes the destruction of soil constituents (silica and alumina). Hydrated calcium aluminates and silicates are ten created (pouzzolane reaction) which, through crystallization, act as binding element between grains.

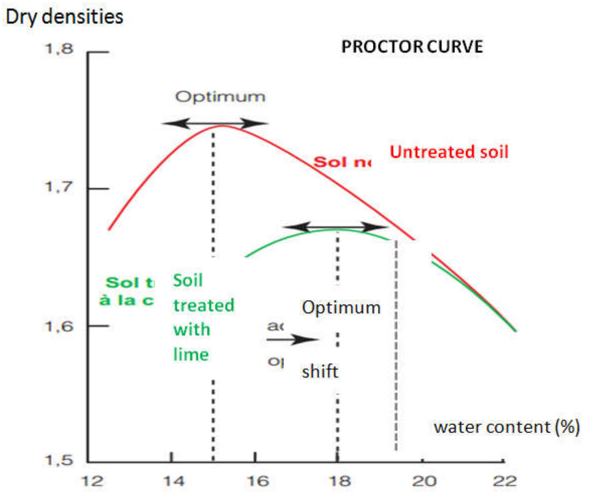

Figure 1 Influence of lime treatment on soil characteristics[4]

Treatment of soil with cement or with hydraulic binding materials (HBM) is used to improve the mechanical resistance of materials and applies to fine soils previously treated with lime or to pebble soil with low alluvium content.

Immediate actions

One can note the decrease in water content resulting from the addition of dry materials, water consumption necessary for the hydraulic setting of cement or of the IBM and water evaporation through soil ventilation during mixing.

Application

The aim is to carry out a study for all the roadway layers, from the forming layer up to the surface, and the studies carried out involve three road infrastructure projects:

- The foundation layer of the Sangmelima–Bikula road: This is a gravelly lateritic soil. We will test the ability to use this soil as foundation layer. Thereafter, we will even propose to extend its use as foundation layer through stabilization with cement.
- The foundation layer of the NGaoundérécliff was made with 0/20 Bitumen Grave
- The surface of the N'joura-Bilalaroad in the Far-North Region is made of BBSG Semi-C-grained bituminous concrete.

Study of the Sangmelima – Bikula Project Foundation Soil

The soil that was analyzed in this study is a gravelly lateritic soil. Given their abundant nature, the use of lateritic gravelly soil in the form of foundation layers is economically beneficial to Cameroon. The sample analyzed here was taken from PK13+450 at the borrow pit.

Methodology of the study

The objective here is to study the ability to use this laterite as roadway layers. To this end, we will have to determine soil properties through characteristic tests. To this end, soil properties will have to be determined through special tests and compare them with norms presented in previous chapters. For busier traffic, higher performances are requested from different layers, and it may be necessary to increase their rigidity through a treatment with lime and/or cement. Geotechnical and mechanical studies will help to establish the response of the soil so treated.

Material characterization

We need to identify the material to be used and thus carry out a series of operations which are considered as identification tests. These tests involve defining and measuring a number of parameters known as soil characteristics. Within the framework of our study, these will include laboratory tests only: natural water content, granulometric analysis, Atterberg thresholds and bearing capacity tests.

Identification tests

Table1 Identification of tested laterite

Geotechnical characteristics		Values
Natural water content(%)		16.7
Specific weight (KN/m^3)		28.3
Atterberg treshols	W_l	68.4
	W_p	32.7
	I_p	25.3
	I_c	1.4

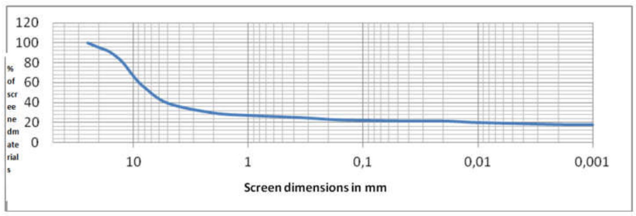

Figure 2 Granulometric analysis of tested laterite

From these results, the GTR classification of this laterite can be derived: **B6**.

Bearing capacity test

Bearing capacity test results are shown in the following graphs:

Modified Proctor test

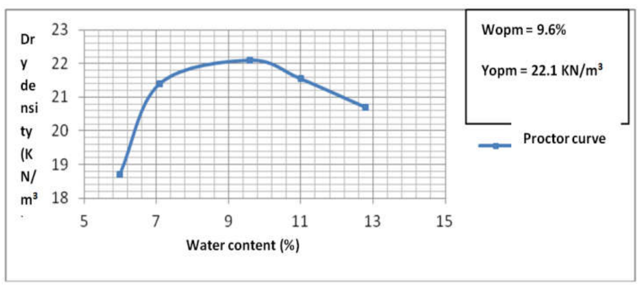

Figure 3 Laterite's Proctor test result

CBR test

Table 2 CBR result of the tested laterite

´Y_d (KN/m^3)		CBR	Wsat (after 4 days of immersion)	CBR after 4 days of immersion
55 strokes	22.1	67	10.2	
25 strokes	20.9	46	11.4	45
10 strokes	19.8	21	12.2	

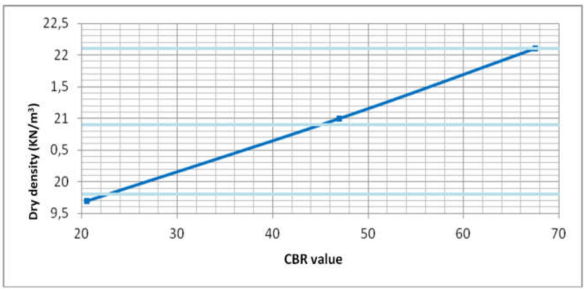

Fig 4 CBR of the tested laterite

Ability to use soil as forming layers

The use of gravels as forming layerscan be envisaged for any type of traffic, provided that some granulometric, plasticity and bearing capacity requirements are fulfilled. Category B6 soils are generally easy to use as forming layers because they fulfill these requirements.

Table 3 Ability to use tested laterite as forming layer

Criteria	Values	Specifications	Comments
Granulometry	D_{max}=25mm	≤80mm	Corresponding
Plasticity	Ip= 25.3	≤ 40	Corresponding
Bearing capacity	CBR= 45	≥ 10	Corresponding

Theminimum CBR of 10 required is widely obtained. Therefore, the tendency will be to endeavour to put in place the best forming layer possible in order to shape the upper layers better.

Conclusion: From these results and interpretations, one could conclude thatthe type of laterite tested have enough features to be used as forming layer.

Ability to use soil as foundation layer

Given the geotechnical characteristics of natural laterite gravels, their privileged use is at the level of the foundation layer for tarred roads destined for traffic ≤ T0 Beyond this limit, it is generally necessary to envisage some improvements when the characteristics of the material can allow doing so.

Granulometry criteria

For the foundation layer, the granular spherical lune below is recommended:

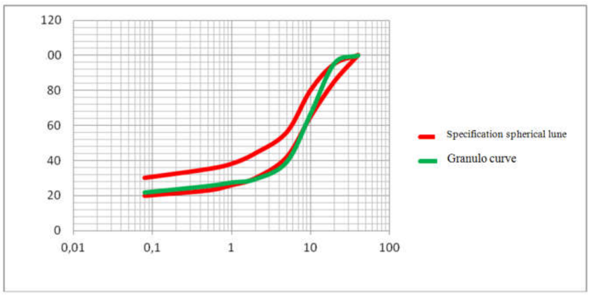

Figure 5 Granulometry criteria in foundation layer[18]

It is noted that the granulometric curve obtained through experiment is situated within the spherical lune, except for the 2mm and 5mm sieve.

Bearing capacity and plasticity criteria

Table 4 Ability to use laterite as foundation layer

Criteria	Values	Specifications	Comments
Plasticity	Ip= 25.3	≤ 30	Corresponding
Bearing capacity	CBR= 45	≥ 30	Corresponding
Consistency	W_l= 68.4	≤ 70	Corresponding

Conclusion: On the basis of these remarks, one can conclude that the use of this type of soil as foundation layer is well consistent and it is up to the field teams to ensure that the implementation requirements are abided to.

Then, we will propose that the use of this soil be extended to the underlying layer. In principle, it is not advised to use natural lateritic soil as underlying layer. Through stabilization with cement, we shall significantly improve the properties of this soil so that it can be also be used as underlying layer.

Ability to use the material as underlying layer

Generally, underlying layers are built with 0/31.5 gravel. Due to very strict requirements imposed for the underlying layer, natural lateritic gravel will be used only for low traffic levels(≤ T3).

Granulometry criterion

The granulometric spherical lune to be respected for the underlying layer is shown below:

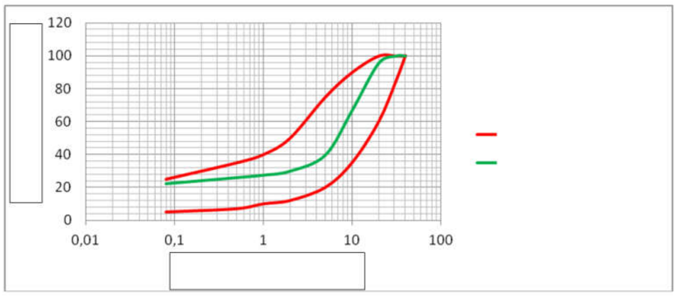

Figure 6 Granulometry criterion for laterite used as underlying layer[18]

It is clear that the granulometric curve corresponds to the specification spherical lune.

Bearing capacity and plasticity criteria

Table 5 Ability to use laterite as underlying layer

Criteria	Values	Specifications	Comments
Plasticity	Ip=25.3	≤ 20	Notcorresponding
Bearing capacity	CBR= 45	≥ 80	Notcorresponding

***Conclusion**:* Therefore, laterite does not offer the necessary characteristics to be used as underlying layer. It needs to undergo some treatment before use.

Soil stabilization with cement

Previous studies have enabled us to highlight the material’s ability to be used as forming layer and foundation layer, but not as underlying layer, as it could have been quite well envisaged. As a matter of fact, gravelly lateritic types of soil found in Cameroon generally have CBR lower than 80, the minimum value requested for the underlying layer. And even when this is the case they have a very high abrasion proportion and are not suit for high traffic. It is thus necessary to treat them before use as underlying layer. In this vein, we shall use specifications and requirements defined previously.

Preliminary and formulation studies

In this section, it is necessary to make sure that soil properties classify them among those that could be stabilized with cement. Identification tests primarily carried out helped us to establish soil GTR: B6. For this category, granulometry usually helps to avoid pre-treatment with lime.

Table 6 Etude préalable au traitement

Criteria		Values	Specifications	Comments
	Dmax	25	< 31.5	Corresponding
granulometry	D	12.5	< 20	Corresponding
	% à 80µm	22.3	< 35	Corresponding
Plasticity	Ip	25.3	< 30	Corresponding
Bearing capacity	CBR	45	≥ 40	Corresponding

In principle, all conditions are satisfactory. The percentage of cement to be used will be determined by laboratory tests. Dosages are generally situated between 4 and 6%. For the purpose of this study, two stabilization formulations will be tested: à 3%and5 %.

Performancesto be obtained after treatment

Soil ability to treatment

Soil ability to treatment is assessed through volumic creep and resistance to diametric compression measures after 7 days of immersion. Tube tests are produced through compression at (w_{opm} ; 95%΄Yd_{opm}). Resistance to diametriccompression is obtained at breaking point after simple compression test, having placed the cylindrical test tubes along their height. Resistance is then calculated using the formula below:

$R_{it} = \frac{2F}{HD\pi}$ with

- F: Load at breaking point
- H : test tube height
- D : test tube diameter

The following results were obtained:

Table 7 Results of soil ability to treatment

Dosage	Volumic creep Gv (%)		Resistance to diametralcompression Rit (Mpa)		Comments
	Values	Specifications	Values	Specifications	
3%	3.2	≤5	0.16	≥ 0.2	Doubtful
5%	4.8		0.25		Able

Soil formulation at 5% fulfills the ability criteria (low volumic creep Gv and good resistance development Rit), and this is not the case for a 3% formulation whose ability test results are considered as doubtful. This example shows the importance and selectiveness of this test, which quickly enabled (within 7 days) to guide the next steps of the study.

Bearing capacity properties of treated soil

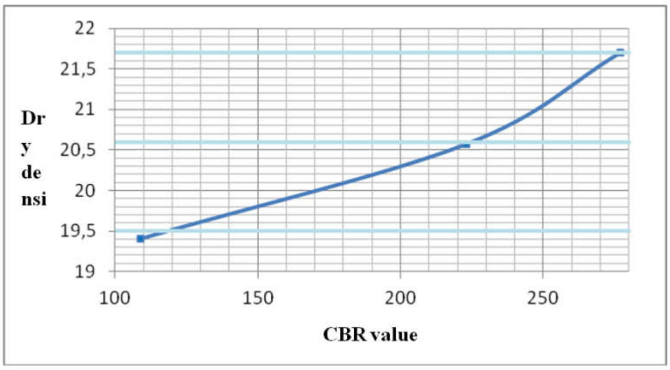

Figure 7 CBR value of laterite treated at 3%

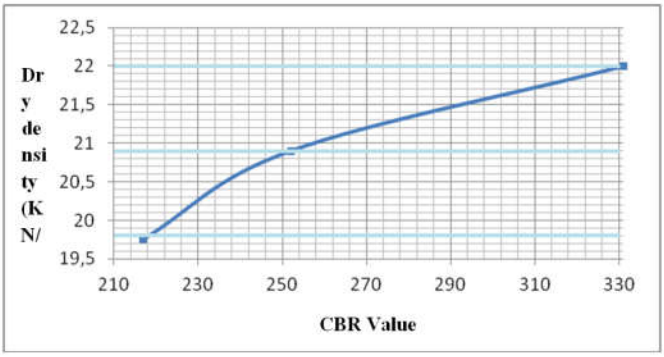

Figure 8 CBR value of laterite treated at5%

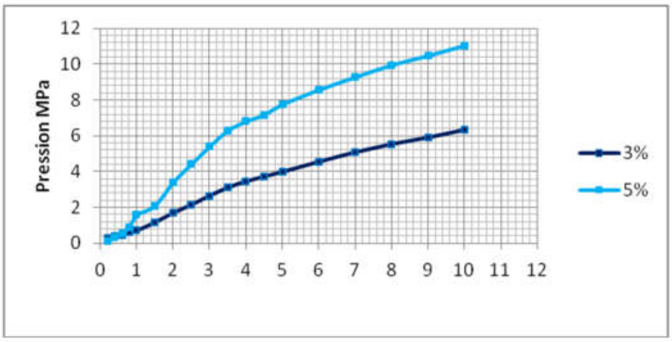

Figure 9 IPI of treated laterite

Table 8 Bearing capacity properties and IPI of treated soil

DOSAGE	IPI		CBR a 3 day de cure by air and 4 day immersion into water		Comments
	Values	Specifications	Values	Specifications	
3%	38	[≥50]	225	[160 ; 300]	Not corresponding
5%	73.85		252		Corresponding

As concerns immediate bearing capacity, the norm sets the bearing capacity level to be obtained for B6 class soil at 50. It is noticed that the 3% content does not represent the desired immediate bearing capacity level, which confirms the doubt created during the soil ability to treatment.

The other bearing capacity criteria to be validated for treated soil is the CBR after a 3 day treatment with air and 4 days of immersion into water, which must be comprised between 160 and 300: That is the case for each of our formulations.

Resistance to water

In this case, the indicator is resistance to simple compression. Soil test tubes are compacted at OPM 95%, then follows a treatment period with air and/or water during which resistances are developed. Treatment periods are as follows:

- 7 day treatment with air ▪ 3 day treatment with air and 4 day immersion in water
- 60-day treatment with air▪ 28 day treatment with air, followed by 32 days with water.

Test tubes are crushed at the end of this period, and the corresponding resistance is $Rc = \frac{F}{S}$. Compression test results are provided by

Table 9 Compression resistances of treated soil

Deadlines (days)	Rc (MPa) 7 days		7days immersion		60days	60 daysimmersion	Rci/Rc60		Comments
	Results	Specification	Results	Specification	Results	Results	Results	Specification	
3%	0.72	[≤3]	0.59	[≥0.5]	1.19	1.05	0.88	[≥0.8]	Corresponding
5%	1.18		0.8		1.70	1.41	0.83		Corresponding

Using an improvement with cement, and through a laboratory experiment, we tried to make this soil, which initially had insufficient properties for underlying layer, usable for this purpose. At the end of this experiment, we can conclude that soil obtained after treatment presents satisfactory properties for the formulation at 5% of stabilizing material, be it in terms of bearing capacity or resistance. Subject to a long term study that will help us to classify the soil and cement compound; its use as underlying layer can thus be well envisaged.

Analysis of the Underlying Soil of The N'gaoundere Cliff

In this section, we will carry out a level 2 formulation study for a Bitumen Grave. Requirement level 2 is the one in force in Cameroon. As a matter of fact, technical module and fatigue equipment are not yet available. The study was carried out in LABOGENIE. Materials taken and conveyed are from the TCHABAAL quarry in North Cameroon.

Formulation methodology

The study includes the following steps.

- Identification of constituents (gravel and binding material) and verification of their conformity with thresholds: a coating is made up of aggregates and binding material which in this case is tar. The behaviour of the coating, be it during the construction phase or during traffic conditions will therefore be largely linked to the constituent's properties. From the onset, it will be necessary therefore to identify these constituents through special tests in order to make sure that they fall within the various values set by standards in force.
- Definition of granularities and binding material contents to be adopted: after having checked the conformity of the various constituents, the next step will be to determine the quantity of each of them in the final compound.
- Resistance and stability tests of the compound: once the formulations for the coating have been defined, they are verified through tests corresponding to each formulation level in order to anticipate its behavior in actual situation of use. The standard sets results expected for which a formulation will be deemed satisfactory.
- Choice of formula: Finally, a formulation is chosen among those that were previously retained, based on geographic, climate and economic condition of use of the material.

Identification of constituents

Identification of aggregates

The identification of aggregates involves the definition of their Intrinsic and production characteristics. Granular cuts tested are as follows: 0/2 ; 2/10 ; 0/20

Intrinsic Characteristics

Results from Los Angeles and Micro Deval tests are provided in the following table:

Table10 Intrinsic Characteristics of aggregates for Tar Gravel

TEST	10/14	6/10	Specification	Comment
Los Angeles(%)	27	29	<30	Corresponding
Damp Micro Deval (%)	18	15	<25	Corresponding

Production features

They include granularity, cleanness, shape and angularity and are summarizes in the following table:

Table 11 Production features of Tar Gravel aggregates

Characteristics	0/2	2/10	10/14	Specifications	Comments
Specific weight (KN/m^3)	25.8	26.0	25.9	-	-
Apparent density (KN/m^3)	14.0	12.9	13.0	-	-
Outer cleanness(%)		0.8	0.1	< 2	Corresponding
Flattening coefficient (%)		20	18	≤20	Corresponding
Sand equivalent	Visual=66				Corresponding
	Piston=64			≥ 60	

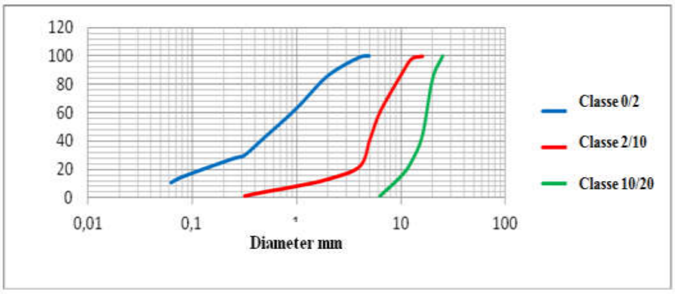

Figure 10 Analyse Granulométrique des différentes fractions de la Grave Bitume

Identification of the binding material

Tests carried out to identify the binding material are as follows: Penetration at 25°C, Relative densityat 25°C, Loss of density at heating and Bille-Anneau softening point.

Table 12 Tar identification for the Tar Gravel

TEST	Results	Specifications	Comments
Initial penetration at 25^0c (1/10ème mm)	45	35-50	Corresponding
Relative densityat 25°C (KN/m3)	1.01	1-1.1	Corresponding
Bille and anneau softening point(°C)	47.1	50-58	Corresponding
Loss of density at heating (%)	0.17	<1	Corresponding

Interpretation

Aggregates

Intrinsic and production characteristics obtained help us to carry out a codification of aggregates according to the standard presented earlier:

- Intrinsic characteristics**:**

LA<30and MDE<25↔ Code C

- Production characteristics of loose chippings:

Granularity; Cleanness f_2 ; Flattening A_{20} ↔Code III

- Production characteristics of sand:

Granularity; ES= 64 ↔ Code a

It is evident that these results are in line with the requirements set previously.

- Binding material

As concerns tar, its classification is determined by the penetration test. In this case, we have pure tar of 35-50 category. The other tests are used to validate his classification.

Definition of granularities and binding material content of the compound

Granularity of the compound

After a granulometric analysis of aggregates available, it is necessary to determine the quantity of each of the fractions (0/2, 2/10, 10/20)in the compound. The operation is aimed at solving a matric equation A X= Bin which:

A: matrix of screened material(n×m) n representing the number of sieves and m the number of parts
X: unknown matrix (m×1) representing each granulometric fraction's proportion
B: matrix (n×1) representing the specification mean granular spherical lune for a 0/20 GB
For the production of our tar gravel, we chose the following formulation:
Class 10/20: 35%; Class 2/10: 25%; Class 0/2: 40%

Bindingmaterial content

Pursuant to specifications provided for the formulation of tar gravels, tests will be carried out with the following binding material contents: 4.2%; 4.4% and 4.6%.

Results and interpretations

Level0: Granulometric recombining

At this formulation stage, we must make sure that the resulting granulometric curve after having done the complete mixing (mixing of various components in chosen quantities) actually corresponds to the specification spherical lune for tar gravels. The figure below shows the blank compound's granulometry and the reference spherical lune.

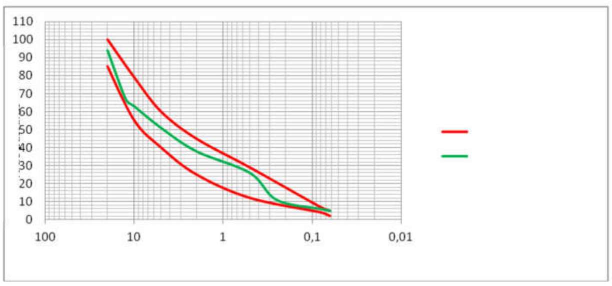

Figure 11 Granulometric reconstitution of the Tar Gravels [17]

The resulting granulometric curve corresponds to the specification spherical lune.

Level 1: PCG and water-holding qualities

PCG

The hydrocarbonic compound prepared in the laboratory is placed and expanded at test temperature (130 °Cto about160 °C) in a cylindrical mold 150 mm or160 mm. A 0.6 MPa vertical pressure is exerted on top of the test tube. At the same time, the test tube is slightly tilted by about 1° (external) or 0.82° (internal) and subjected to a circular movement. These various actions exert a compacting action through moulding. It is observed that compactness increases (reduction of the vacuums) according to the number of revolutions.

This is done for binding material contents 4.2% 4.4% et 4.6%. We obtain:

Table 13 Results for the Tar Gravel's PCG

Number of revolutions	vacuum% 4.2%	4.4%	4.6%	Specifications	Comments
10	14.3	15.2	16.3	14 <vacuum%	Conforme
120	7.6	8.2	10.2	vacuum% < 9	Not correspoding to 4.6%

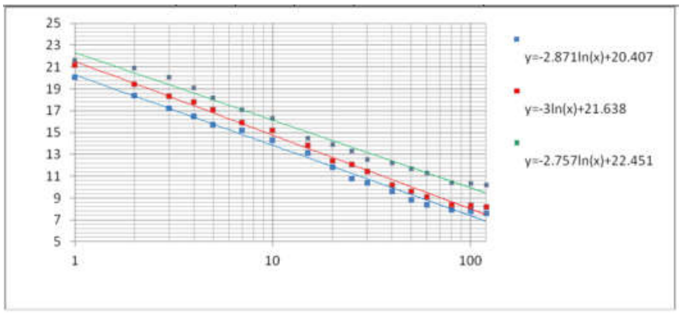

Figure 12 Results for the Tar Gravel's PCG

The gyratory shear equipment validated formulations at 4.2% and 4.4% which show a corresponding vacuum percentage. Conversely, formulation at 4.6% shows a very high vacuum percentage at 120 gyrations; it should therefore be discarded for the next steps of the study. The DURIEZ test can therefore be carried out.

The Duriez

The hydrocarbonic compound is compacted in a cylindrical mould by double effect static pressure for 5 minutes. Part of the test tubes is kept without immersion at a temperature of 18 °C and at controlled et hygrometry; the other part is immerged for 7 days. Each group of test tubes is crushed by simple compression.

Results provided for the Duriez are provided by table 14:

Table 14 Duriez Resultsfor the Tar Gravel

Binding material content	4.2%	4.4%	Specification	Comment
r (water) at 18°C (Mpa)	4.6	5.1		
R (air) at 18°C (Mpa)	5.6	6.1	≥ 6	Notcorrespondingat 4.2%
Relation (r / R)	0.82	0.84	≥ 0.7	Corresponding

It is noted that the compound at 4.4% of the binding material present satisfactory duriez characteristics. This is not the case for the compound at 4.2% whose resistance to air is not satisfactory.

Level2: Potholing

The test body is a 10 cm thick parallelepipedic plate. This plate is subjected to the traffic of a wheel equipped with a tyre (frequency: 1 Hz, load: 5 kN, pressure: 6 bars), in rough weather conditions des conditions (60 °C).The depth of the distortion resulting from the passing of the wheel is noted according to cycles. Specifications relate to a pothole percentage for a given number of cycles, which depend on the type of material and on its class.

Table 15 Results from the Tar Gravel potholing

Binding material content(%)	4.4	Specifications	Comments
Pothole depth at10000 cycles (%)	4.75	< 10	Corresponding

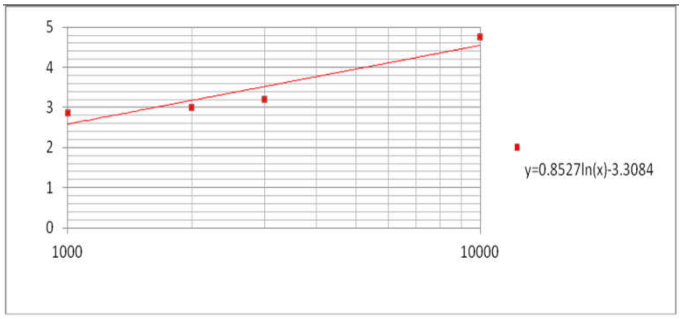

Figure 13 Potholing Results for the Tar Gravels

The standard setting the potholing percentage at 10% at 10000 cyclesfor tar gravels, potholing results are therefore satisfactory for this binding content.

Choice of formula and justification

Finally, the formulation tests confirm the good behaviour of the following formula that will therefore be adopted:
Class 10/20: 35% ; Class 2/10: 25% ; Class 0/2: 40%
Concerning the binding material content, the formulation shows the good behaviour of the 4.4% binding material content.

Study of the Surface of the N'joura – Bilala Road

The formulation presented in this study is a 0/14Semi-Grany Bituminous Concrete. The formulation and the laboratory test were carried out at the LABOGENIE. Aggregates used in this formulation are those used on the N'joura – Bilala road in the Far-North of Cameroon. They were taken and conveyed to the laboratory.

Methodology of the formulation

The study will follow the same protocol as earlier, that is:

- Identification of constituents (aggregates and binding material) and verification of their conformity with set thresholds.
- Definition of granularities and of binding material contents to be adopted
- Resistance and stability test of the compound
- Choice of the formula:Finally, a formulation is chosen among those identified based on geographic, weather and economic conditions of use of the material.

Identification of constituents

Identification of aggregates

Classes studied are 0/2 ; 2/6.3 ; 5/10 and 8/14 fillers.

Intrinsic characteristics

Results from Los Angeles and Micro Deval tests are provided in the table below:

Table16 Intrinsic characteristics of aggregates studied for the BBSG

TEST	10/14	6/10	4/6	Specifications	comments
Los Angeles (%)	27	28	30	[< 30]	Corresponding
Damp Micro Deval (%)	6	7	13	[< 15]	Corresponding

Production characteristics

They include granularity, cleanness, shape and angularity, and are summarized un the table below:

Table 17 Production characteristics of aggregates for the BBSG

Characteristics	8/14	5/10	2/6.3	0/2	Specifications	Comments
Specific weight (KN/m^3)	28.6	28.4	28.2	27.6	-	-
Apparent density (KN/m^3)	13.6	13.6	13.5	15.4	-	-
Outer cleanness(%)	0.1	0.4	1.1	-	< 2	Corresponding
Flattening coefficient (%)	3	3.9	6	-	< 20	Corresponding
Sand equivalent		-		Visual=97	≥ 60	Conforme

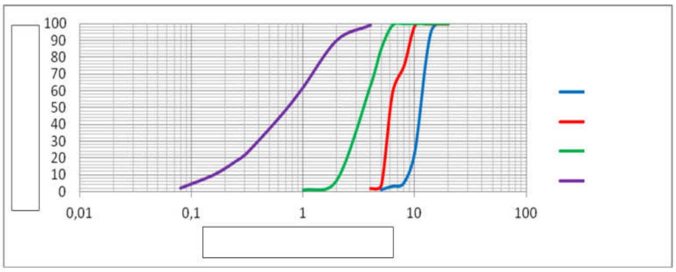

Figure 14 Granulometric curve of the various fractions for the BBSG

Identification of the binding material

Table 18 Identification of the binding material used for the BBSG

TEST	Results	Specifications	Comments
Initial penetration at 25^{0}c (1/10ème mm)	39	35-50	Corresponding
Relative densityat 25°C (KN/m3)	1.01	1-1.1	Corresponding
Bille et anneausoftening point (°C)	48.5	50-58	Corresponding
Loss of density at heating (%)	1.01	<1	Corresponding

Interpretation

Aggregates

Concerning aggregates, from results obtained and bead on the codification established previously, we can obtain the aggregates classification below:

- Intrinsic characteristics

LA<30 and MDE<15↔ Code B

- Loose chippings production characteristics:

Granularity; Cleanness f_2 ; Flattening A_{20}↔Code III

- Sand production characteristics:

Granularity; ES= 93↔ Code a

It is noted that these results are congruent with the thresholds st by the standard as indicated previously.

- Tar

The type of tar used is class 35-50 class pure tar.

Definition of granularities and binding material content of the compound

Granularity of the compound

For the production of our BBSG, we chose the following formulation:
32% of 8/14 - 20% of 5/10 - 8% of 2/6.3 - 33% of 0/2 - 7% of fillers

Binding material content of compound

As the standard establishes the binding material content of bituminous concrete between 5 and 5.5%, we shall test the liability of our coating using**5%,5.2%,5.4%**binding material contents**.**

Results and interpretations

Level 0: Granulometric Recombination

We must ascertain that the compound obtained is within the specification zone.

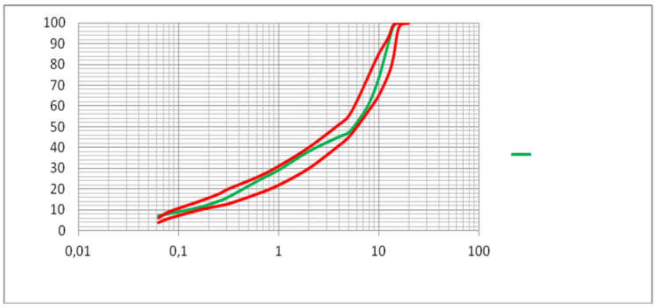

Figure 15 Granulometric curve obtained for the BBSG [16]

From this result, it appears that at 0 formulation level, aggregates have necessary granulometric characteristics in that the real compound obtained fits in the spherical lune. Consequently, we can proceed to the next level of requirement.

Level 1: La PCG et la tenue à l'eau

PCG

PCG results are provided in table 48:

Table19 PCG results for the BBSG

Number of gyrations	Vacuum %			Specifications	Comments
	5	5.2	5.4		
10	15	13.1	11.7	11 < %vides	Corresponding
80	8.6	7.2	7.1	4< %vides < 9	Corresponding

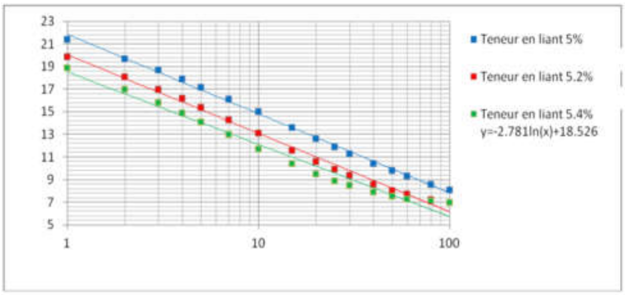

Figure 16 PCG results for the Bituminous Concrete

For each binding material content, PCG results for this formulation study were all validated by gyratory shear pressure. As a matter of fact, they correspond to specifications provided earlier on bituminous concrete. Nevertheless, for a binding material content ranging from 5.4%, a strong drying up phenomenon was observed and that could be detrimental during the coating phase. Therefore, to avoid this phenomenon, the following binding material contents are considered: 5%, 5.2% et 5.3%.

DURIEZ test

The DURIEZ test results are summarized in the table below:

Table 20 DURIEZ test results for the BBSG

Binding material content (%)	5	5.2	5.3	Specification	Comments
r (water) at 18°C (Mpa)	5	6	5.5		
R (air) at 18°C (Mpa)	5.5	6.5	6.1	≥ 6	Not corresponding at 5%
Relation (r / R)	0.90	0.92	0.91	≥ 0.75	Corresponding

Interpretation

For all binding material contents used for this test, it appears that contents 5.2% and 5.3%have satisfactory duriez characteristics (R≥ 6; r/R≥ 0.75). Consequently, we can move to the next formulation step, that is potholing.

Level 2: Potholing

Results obtained during potholing at 30000 cycles at 60^{0}c:

Table 21 BBSG Potholing results

Binding material content	5.2	5.3	Specifications	Comments
Potholes' depth at 30000 cycles (%)	3.6	3.8	< 5	Corresponding

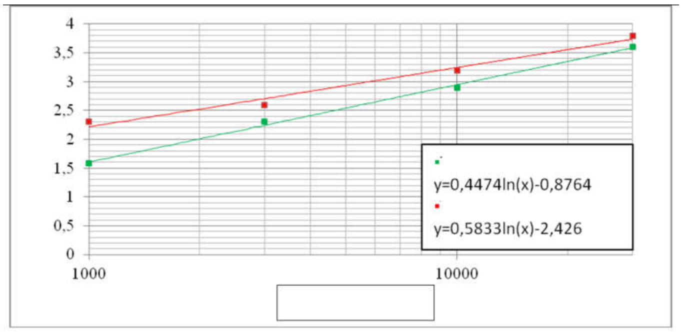

Figure.17. BBSG potholing results

These results reveal that 5.2% and 5.3% contents satisfactorily react to potholing.

Choice of the optimum formula and justification

At the end of this formulation study, the content retained for the BBSG is as follows: 32% of 8/14 - 20% of 5/10 - 8% of 2/6.3 -33% of 0/2 -7% of fillers.

This content successfully went through all formulation tests carried out.

As concerns tar content, 2 values were retained, that is 5,2% and 5,3%. We would advise that for this case the 5.2% content should be adopted and this for 2 reasons. First for economic reasons, and secondly due to the drying out phenomenon mentioned earlier which entails the use of the minimal binding material content possible.

CONCLUSION

Given the diversity and the variety of types of material and soil that can be used in road construction, studies and laboratory tests are very important in order to anticipate their behaviour in real situation. The aim here was to determine the features of various road projects' materials through laboratory tests.

We can conclude that lateritic gravels, which represent the mostly used soil category in road projects in Cameroon, have outstanding geotechnical and mechanical characteristics in most cases, that is why it is widely used as forming layer and foundation layer. However, these types of soil do not generally have the necessary characteristics to be used as underlying layer: it is therefore necessary to improve them or stabilize them with LHR or to resort to Tar Gravel.

Concerning surface layers made of bituminous concrete, in addition to the fact that the formulation phase in laboratory must be validated for all levels of studies carried out, it is also primordial to choose the final formulation on the basis of economic and weather conditions of use.

GENERAL CONCLUSION

All in all, our task has been to present the characteristics of materials to be used for all layers of the roadway, either for the forming soil, the body and the roadway or surface layers, with the objective of building roads that can withstand traffic and weather conditions to which they will be submitted.

To that end, we briefly reviewed the various layers of the roadway, then we presented road materials and their characteristics before giving the specifications of all these materials, which specifications depend on the layer to be put in place. Finally, we ended with a laboratory study which enabled us to actually get acquainted with the job of road engineer in the way that it highlighted the various difficulties encountered in obtaining and using quality road materials.

Road engineers should do well to follow the guidelines and specifications put forward, because the construction of quality roads has many benefits:

- Economic benefit: Firstly, the high level of requirements will definitely lead to a reduction in the quantity of materials to be used in most cases, and therefore cutting down the overall costs. Then in the long run, there will be substantial savings in maintaining the roads.
- Technical benefit: Improvement of soil bearing capacity and mechanical characteristics, increase in the lifespan of roads and reduction of roadway thickness.
- Environmental benefits with a better management of aggregates ores (quarries) which are non-renewable natural resources.

Prospects

With this work, we now have a tool for the choice of road materials at our disposal. However, it is essential for all actors in the sector to note that guidelines and recommendations put forward are essentially based on French standards; test operational modes, test conditions and specifications for use are derived from these standards. Yet, these standards were set in specific traffic and weather conditions which are not always adapted to Cameroonian realities. Of course, the Government of Cameroon, through various entities such as the Ministry of Public Works and even LABOGENIE, has already taken steps in this sense, especially in matters such as soil bearing capacity and granulometry; however, many adaptations are still necessary.

LISTOF ABBREVIATIONS

BBSG*: Béton Bitumineux Semi Grenu*
CBR*: Californian Bearing Ratio*
CEBTP*: Centre d'Etude des Bâtiments et des Travaux Publics*
ES: *Equivalent de sable*
GB*: Grave Bitume*
GNT*: Grave Non Traitée*
GTR*: Guide des Terrassements Routiers*
IPI*: Indice Portant Immédiat*
LA: *Los Angeles*
LABOGENIE*: Laboratoire National de Génie-Civil*
LCPC: Laboratoire Central des Ponts et Chaussées
LHR: Liants Hydrauliques Routiers
MDE: Micro Derval à l'eau
MTB: Matériaux traités aux Liants Hydrocarbonés
MTLH: Matériaux Traités aux Liants Hydrauliques
OPM: Optimum Proctor Modifié
PCG*: Presse de Cisaillement Giratoire*
PSV*: Résistance au polissage accéléré*
SETRA*: Service d'Etudes Techniques des Routes et Autoroutes*
VB_F: Valeur de Bleu de Méthylène

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