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CONTRIBUTION TO THE IMPROVEMENT OF BITUMINOUS OVERLAIN: APPLICATION TO THE DEVELOPMENT WORKS OF THE YAOUNDE-DOUALA MOTORWAY IN CAMEROON.

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Abstract

The frequent closure of roads for the sake of maintenance and refurbishment is an increasing problem for the road administrators and users, because of induced high costs, restrictions and influence they impose, traffic jam, and the many other disruptions such interventions have on traffic. In these circumstances, carriageways with long life span, with adapted tar, have much to offer, especially if they can exhibit optimum performances without requiring major repairs for over 30 years. On high traffic roads, research has shown that binders with elevated modules are a reliable and credible alternative to render their life span more sustainable and durable. In this context, the advantages presented by the absence of important repairs and refurbishing can be enough to justify the initial high costs of these advanced carriageway coatings. Studies on the different binders to be used were done, which have permitted in accordance with the performance of the layers, the required tests and the different study levels. Also, this has permitted us to analyze the obtained results and conclude that due to the expected needs, the LA and MDE tests, the PSV tests are the criteria that determine the selection of aggregates; The complexes modular methods, fatigue resistance (level IV), is to be necessary for the forecasting of the mechanical behavior of bituminous materials.

Key words: Formulation test, Coated sands, Elevated module, Performance, Implementation.

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1. Introduction

Transport infrastructure, including roads, airports, ports and railways, is the foundation on which the development and competitiveness of a country's economy must be built. They reduce production and transaction costs, facilitate activity, increase the volume of production and drive social progress. Indeed, the road provides the link between the zones of complementary economy, production, import, export and consumption within the states but also between the states. Also, it ensures human and social links of capital importance because it allows the establishment of cultural, social, political and administrative exchanges which also prove to be one of the elements promoting any development. Roads therefore constitute a heritage that must be preserved since they are both an investment, an accumulated capital and a collective working tool that must be monitored and evaluated periodically once they are put into service [1-7].

Despite the work in progress, Cameroon still suffers from the insufficient level of development of its transport infrastructure. The road sub-sector is the most important of all, as it alone accounts for nearly 85% of national transport. Of the country's 50,000 km of roads, only 24% are in good condition and nearly 8,000 km are paved or 14% [5, 11-14]

"Where the road passes, development follows." As long as this old saying goes, it finds its full meaning in the less affluent countries in road infrastructure like Cameroon. The development project for the Yaounde-Douala Highway Phase I, Tranche 2 is therefore part of the infrastructure development policy. Road managers, in the policy of opening up and the development of transport infrastructure, aspire for long-life pavements; especially for roads with high traffic and in view of new tire configurations and climatic variations [4-8]. The use of perennial pavements would considerably reduce the cost of maintenance campaigns as well as the costs of delay caused to users in the event of traffic congestion but also accidents that are very often fatal on our most in-demand roads. It is accepted that pavement layers participate and influence their behavior over time. The components and mixes must therefore be characterized by design methods and laboratory tests that will make it possible to evaluate long-term performance with a view to optimizing their lifetime [7, 11].

The purpose of this study is to present the main work carried out on the formulation study of EME 0/20 class 2 and BBME 0/14 class 1 mixes for the pavement body and the wearing course respectively; the overall objective is to make an optimal study of the components involved in the structural constitution of a roadway in order to meet the durability criteria for road surfaces.

2. Project context

So far, the direct interconnection between the cities of Yaoundé and Douala is by the national road N°.3 (Yaounde-Douala heavy axis, 240 km long) commissioned in 1984 which has benefited over the years from operations routine and periodic maintenance as part of the paved road and priority network maintenance program. However, the intensity of the maintenance actions is insufficient given the level of degradation (potholes, generalized crazing observed along the route) due to high overloads, poor lateral sanitation and fatigue of the roadway, causing many accidents including loss of life [9].

The governments of the developing countries, in their growth policy, have as their main objective, the improvement of the living conditions of the populations and this through the development of communication infrastructures (roads, bridges, etc ...). It is in this impetus that the Yaoundé-Douala motorway project was initiated. The implementation of this project will strengthen the capacity for concentration and deconcentration of the main networks of national roads, thereby accelerating the speed of exchange of goods and services nationally and internationally [12].

1.1. Location and consistency of work

The highway is located almost 1km north-west of the old road Yaoundé-Douala in the locality of Nkolkoumou (PK0 + 00), starting point of the project; and to the North-East, 8.5km from Douala International Airport (PK194 + 500), the final point of the project joining the present P14 regional corridor in the form of a T.

This motorway axis starts at Yaoundé, about 1 km northwest of the Nkolkoumou junction, and goes west through Nkongmessa, Nkongkarak, Lobo and Pan Makana villages to arrive at Sépé south of Bot Makak. , and continues on the D54 towards the city of Dibang, and ends at Bodmon in its first phase [9, 13].

1.2. Consistency of the work

This contract includes the ODA studies of the first 100 km and all the works necessary for the realization of the first phase of the works of the Yaoundé - Douala Motorway on a linear to be specified by the execution studies: (earthworks , structures, roadways, drainage, equipment, signage, etc.).

The current section of Linear 68.3 km and 25 km of recovery path (definitive linear to stop after the results of the execution study). Figure 1 illustrates the study area of our project.

2. Materials and methods

The realization of a formulation test for high-modulus bituminous mixes requires adequate equipment and at least ten days for level I, with 60 kg of materials and around one month to reach level 4 with approximately 400 kg of materials.

The durations of the tests by level are indicated in the following table. These estimates are based on the assumption of the density measurement on hydrocarbon mixture according to NF EN 12697-5, method A with water and the measurement of the water resistance according to NF EN 12697-12, method B in compression.

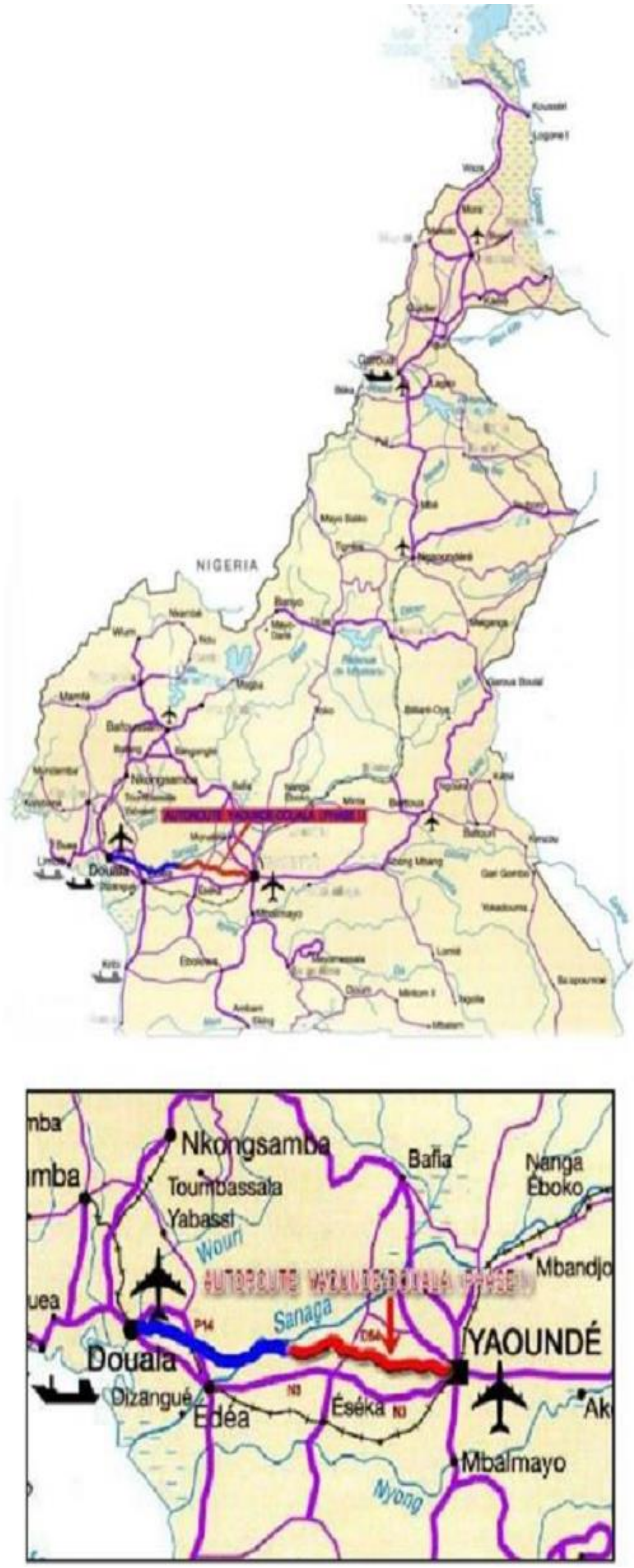

Figure 1: Location of Yaounde-Douala highway development project [10].

Table 1: Presentation of asphalt formulation procedure [12].

Level of difficulty	Trial	Quantity of material	Duration		Overall duration including preparation	Necessary equipment
			Trial	Preparation and related operations		
Preparation Identification of constituents	Actual density of the mixture	5 kg for mixing	1 day	Drying + test	2 days	
	Particle size analysis	3 kg per granular fraction	1 day	Drying + test	2 days	Series of sieves, bowls and scales
1	Duriez	20 kg (ϕ80) 40 kg (ϕ120)	8 days	Drying + mixing + testing	10 days	Duriez molds, molding press, Duriez press
	PCG	30 kg	1 day	Drying + mixing + testing	2 days	PCG molds, PCG device
Total level 1		40 kg à 50 kg			12 days	
2	Rutting (2 plates)	50 kg	2pl. 30000 cycles 3 days	Confection + ripening + MVA	7 days	Orniéreur LCPC
Total level 2		110 kg			15 days	
3	Direct traction module	80 kg	3 temperatures 3 or 4 charging times 4 days	Making + coring + ripening + MVa + gluing + test	21 days	Machine de compression
	Complex module	80 kg	1 temperature 3 or 4 frequencies 4 days	Confection + drying + ripening + MVa + gluing + test	18 days	Machine de fatigue mlpc

Total level 3		200 kg			21 days	
4	Trapezoid fatigue 2 points	200 kg	15 days	Making + sawing + ripening + MVa + gluing + testing	25 days	Machine de fatigue mlpc
Total level 4		400 kg			30 days	

The tests and test methods used in the context of the standard tests for the formulation of bituminous mixes in European standards are set out in standard NF EN 13108-20, standard laboratory formulation test. They are presented in the following table:

Table 2: Formulation test for bituminous mixes [12].

Characteristic	Test method	Observations
Binder content (prescription)	NF EN 12697-1, soluble bitumen content	When the formulation test is carried out using materials made in the laboratory, the bitumen content considered is the quantity of bitumen incorporated in the mixture.
Granularity (prescription)	NF EN 12697-2, particle size analysis	/
Percentage of voids, including voids filled with binder and voids in the granular skeleton, void content 7 <Vmax <10% (prescription)	NF EN 12697-8, Determination of void percentage of test specimens NF EN 12697-6 (bulk density), method C, paraffin-sealed NF EN 12697-5 (maximum density-MVR-), Method A in water	/
Percentage of PCG voids (prescription)	NF EN 12697-31, Gyratory shear press test	The standard includes the determination of the void percentage from the measurement of the height of the specimen.
Sensitivity to water (connected performance)	NF EN 12697-12, water sensitivity	Method B in compression
Resistance to permanent deformation	NF EN 12697-22, large model, in air at specified temperature	Corresponds to the LPC switchgear. By choosing a temperature of 60 ° C and a number of cycles of 3000, 10 000 or 30 000.

Rigidity modulus	NF EN 12697-26, Rigidity modulus Appendices A and C	modalities for determining the module are considered equivalent. However the specifications concern modules at 15 ° C, 10Hz or 0.02 s.
Fatigue - 2 points	NF EN 12697-24, Fatigue strength - Annex A	Annex A describes the 2-point bending fatigue test compatible with the design method applied in France. The specifications at 10 ° C, 25Hz are identical to those of the current repository.

2.1. Calculation and choice of the pavement structure

2.1.1. Characteristics of the road

The general characteristics of the development of the Yaoundé-Douala motorway are presented below:

Table 3: General characteristics of the project

Road grade	**highway**
Reference speed	110km/h
Standard	French standard
way	2X2 channels (internal extensible to 2X3 channels)
Platform width	33.5m
Pavement structure	Pavement made of bituminous concrete 0/14

2.1.2. Geometric characteristics of the roadway

A. Drawing in plan

The plan layout consists of representing the axis of the road by a succession of broken lines called general alignments. It is normal for reasons of comfort and safety to connect these line segments by a suitable curve giving the maximum comfort without forgetting the economic impact of the type of connection chosen.

Table 4: Characteristics of the Yaounde-Douala motorway connection

N°	Designation	Unité	PK 0 – PK 10	PK 10 – PK 50	PK 50 – PK 100
1	Length of the route	km	10.0	40.0	50.0
2	Number of curves	-	11	33	31
3	Total length of circulars and clothoids	Km	7.935	26.654	28.017
4	Minimal circular radius	R (m)	875	1000	1010
5	Maximum straight line	L (m)	956.4	1872.78	1863.72
6	Minimum straight line	L (m)	351.6	202.38	201.65

The characteristics of the plan layout meet the requirements of ICTAAL 2000

B- Longitudinal profile

The long profile consists of a succession of ramps and slopes (declivities) connected by circular or parabolic elements (clothoids). It is conceived after the final choice of the plan layout.

Table 5: Characteristics of the profile along the Yaounde-Douala highway

N°	Designation	Unit	PK 0 – PK 10	PK 10 – PK 50	PK 50 – PK 100
1	Number of slope changes	-	11	79	94
2	Total length of vertical curves	Km	3.685	22.091	27.097
3	Max Slope	(%)	5.0	5.75	5.8
4	Slope min	(%)	0.5	0.3	0.3
5	Vertical curve protruding min	m	6100	7100	7000
6	Incoming vertical curve min	m	7500	6100	6940.67

B- Crosswise profile

The cross section is the cross section perpendicular to the project axis. The characteristics of the cross section selected for the Yaoundé-Douala motorway project are given in the following table:

Table 6: Profile characteristics across the Yaoundé-Douala highway

N°	Characteristics	Unit	Value	Observations
1	Embankment width of berm	m	1.0	OK
2	Width of berm in CU	m	1.0	OK
3	Width of BAU	m	3.0	OK
4	Width of TPC in current section	m	3.0	OK
5	Width of roadway	m	3.75	OK

3.2. Accelerated Polishing Stone (APS) or Polished Stone Value (PSV) NF EN 1097-8

3.2.1. Description of tests by European standard

The APS test described in the European standard is rigorously equivalent to the PSV test.

It is connected to the old French APS test (XP P 18-575) according to the relation:

New APS = 100 x old APS + 1.5

3.2.2. Principle of the test

The Accelerated Polishing Factor is intended to simulate in the laboratory the polishing action of chippings by automobile tires. The sample (mosaic of aggregates 6.3 / 10 mm) undergoes double polishing by the action of two abrasive powders made of corundum (one coarse, the other fine), aluminous silicate, hardness just below that of diamond (9 / 10 at the Mohs hardness scale).

The residual roughness of each polished mosaic, saturated with water, is measured using a pendulum of friction (pendulum S.R.T) which translates the kinetic energy loss of the pendulum when this last traverse the mosaic.

Figures 5 (a) and 5 (b) are the representations of the polishing machine and the sample wheel (b), while Figures 6 (a) and 6 (b) show the residual roughness measurements. after polishing and mosaic grit 6.3 / 10 mm

(a) **(b)**

Figure 6: Polishing Machine **(a),** Sample Wheel **(b)**

The residual roughness of each polished mosaic, saturated with water, is measured using a pendulum of friction (pendulum S.R.T) which translates the kinetic energy loss of the pendulum when this last traverses the mosaic.

(a) (b)

Figure 7: Measurement of the residual roughness after polishing (a), gravel mosaic 6.3 / 10 mm (b)

3.3. Marshall test

The minimum binder content is obtained by the equation:

$$TL = K \times \alpha \times \sqrt[5]{\Sigma} \quad (1)$$

- Calculation of characteristics required for briquettes

The main features are:

- The real density $$\text{MVRe} = \frac{(100+TL)}{\left(\frac{100}{MVRg} + \frac{TL}{MVRb}\right)} \quad (2)$$

- The apparent density MVA calculated after an immersion weighing;

- The percentages:

- Empty: $$\text{Vi} = \left(1 - \frac{MVA}{MVRe}\right) \times 100 \quad (3)$$
- Intergranular void:
$$\text{VAM} = (MVRg - MVR) \times \frac{100}{MVRb} \quad (4)$$
- Vacuum filled with bitumen:
$$\text{VRB} = \frac{(VAM - Vi)}{VAM} \times 100 \quad (5)$$

- The richness module K is presented by the following equation.

$$\text{TL} = K \times \alpha \times \sqrt[5]{\Sigma} \quad (6)$$

- The compactness is give by equation:

$$\text{C} = \frac{MVA}{MVRe} \quad (7)$$

3.4. The PCG test

The PCG test is the Marshall test with varied compaction energy. The procedure is as follows

- Maximum density of the asphalt

The maximum density test makes it possible to obtain the maximum experimental density of the bit prepared so as to adjust more precisely the quantity of bitumen to be inserted into the mixture intended for the PCG test. It is determined by hydrostatic weighing where we determine the mass of the asphalt in the open air (A) and the mass of the asphalt in water (E).

- The maximum density is obtained through the formula:

$$dm = \frac{\mathrm{A}}{\mathrm{A-E}} \qquad (8)$$

- The percentage of voids is determined by:

$$V_i = 100 \times \frac{H_g - h_0}{H_g} \qquad (9)$$

With $H_g\,(in\ mm)$, the height at a given number of gyration.

- The mass of the mix to be used for the test is determined as follows:

$$m = dm \times \rho_{eau} \times h_0 \times \frac{\pi \times \emptyset^2}{4} \qquad (10)$$

with h_0 : height of the specimen at 0% vacuum

3.5. Rutting test

The test consists of measuring the depth of the rut (without bead) as a function of the number of cycles (round trip) in% of the slab thickness at a temperature of (60 ± 2) ° C.

3.6. Complex module

The module test is carried out on four trapezoidal asphalt specimens embedded in their bases and on the free ends. From the resulting force, the module is calculated in a temperature range of -10 to 40 ° C, and for each temperature, four levels of frequency which are: 1, 3, 10 and 30 Hz. We present on the figure 4 the materials allowing the execution of the stiffness modulus

Figure 4: Execution of stiffness modulus

The test was carried out in diametric compression and bending at two points.

3.7. Fatigue test

The fatigue test in the laboratory consists in imposing repeated demands on the specimen of material to be tested. This stress is in displacement imposed at the free edge of a trapezoidal specimen of asphalt from the complex module, recessed at its base. The test was carried out at a temperature of 10 ° C, at a frequency of 25 Hz; the criterion of rupture is conventional. The figure 5 is the representation of the equipment enabling the fatigue test to be carried out

Figure 8: Execution of the fatigue test on 20-EME

4. Results and discussion

4.1. Formulation of 20-EME 2

4.1.1. Choice of aggregates

The mechanical parameters used to select the aggregates are given in the following table:

Table 3: Intrinsic Characteristics of Aggregates

Sample	LA	MDW	LA+MDW
1	28.4	14.9	43.3
2	31.0	14.0	45.0
3	29.9	14.0	43.9
Average	29.8	14.3	44.1
Required values	≤ 25	≤ 20	≤ 45 ± 5

The table 3 presents the values of characteristics such as: Los Angeles (LA), the Micro-Deval in the presence of Water (MDW). However, we find that the results do not meet the requirements (LA = 29.8 ≥ 25 required). However, by applying the compensation law according to standard NFP 18 545; for 25 <LA ≤ 30, MDW ≤ 15 and LA + MDW ≤ 45 we have: LA = 29.8, MDW = 14.3, LA + MDW = 44.1 ≤ 45; therefore these materials can be used as a foundation and base coat. In order to increase their performance, and prevent the premature appearance of large-radius rutting, PR PLAST additive will be used in 20-EME bituminous mixtures.

High Modulus Asphalt (20-EME 2) will be developed from a crushed gravel supplied in four fractions that are 0/3, 3/5, 5/10 and 10/20 for the base and base coat. These samples were identified and a blank mixture was performed:

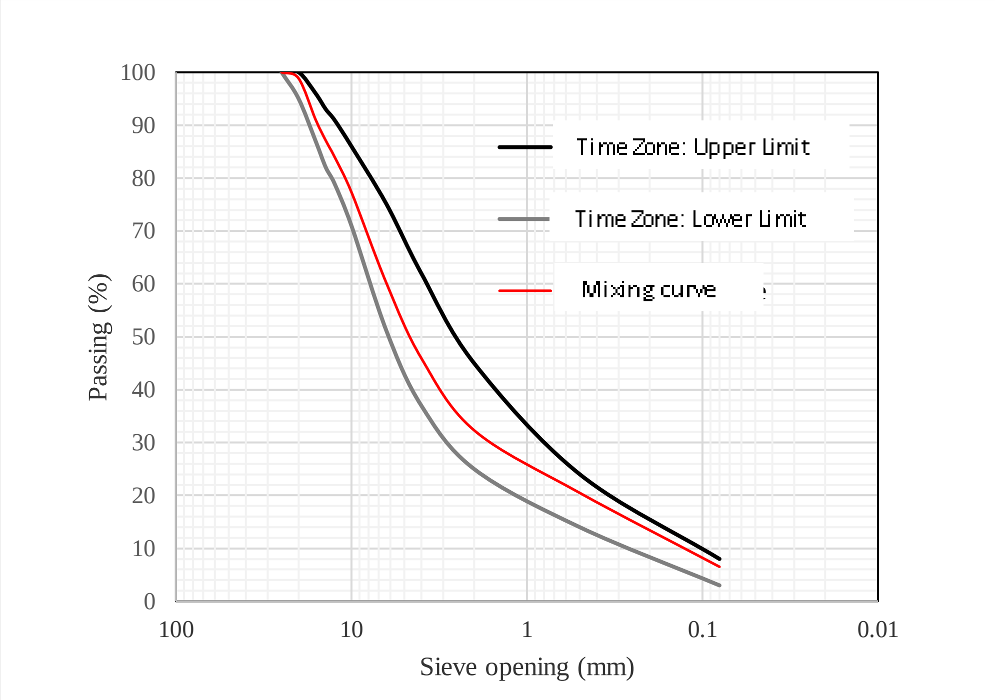

Figure 1: Particle size curve of 0/20 fraction aggregates

The granulometric curve of the mixture fits perfectly into the specification zone

4.1.2.Choice of binder

The binder is chosen based on the traffic, geomorphology and climatic conditions of the project area. The choice was therefore made on a hard bitumen whose identification tests have defined that it is 35/50 [13-16].

Table 4: Identification of Class 35/50 bitumen

Relative density (C)	Penetration at (25 °)	Softening point	Ductility
Test performed before RTFOT			
1.03	41.5	53.3	> 150
Test carried out after RTFOT			
≥ 1	26.6	60.3	> 120

The results obtained meet the specifications and allow us to conclude that the bitumen identified is class 35/50

4.1.3. Minimum rate in binder

The choice of the initial binder content was made for a minimum richness module of 3.4.

For $\alpha = \frac{2.65}{MVRg}$= 0.9198 MVRg = 2.881 $\sqrt[5]{\Sigma}$= 1.540 m^2/kg

TL = 4.8

4.1.4. Preparation of briquettes

For the test, four groups of specimens with a binder content of 0.2% relative to the initial binder content were defined. The following table represents the different values:

Table 5: Preparation of test pieces

	Mixed 1	**Mixed 2**	**Mixed 3**	**Mixed 4**
K	3.3	3.4	3.5	3.7
TL	4.6	4.8	5.0	5.2

To each group of samples, 04 briquettes are made for the test, identified and then demolded after 12 hours at room temperature.

4.1.5. Realization of stability test and creep

The briquettes are soaked in a thermostat bath for 30 to 40 minutes at 60 ° C. it follows a crash at constant speed. The crushing is stopped when the maximum loads are reached. The values of the different loads and deformations obtained are recorded in the following table:

Table 6: Marshall Results

	Mixed 1	**Mixed 2**	**Mixed 3**	**Mixed 4**
Stability (KN)	12.0	13.9	17.4	21.6
Fluage (mm)	1.3	2.4	3.3	4.4
Marshall Quotient	9.23	5.79	5.27	4.91

4.1.6. Calculation of characteristics required for briquettes

The main characteristics have been determined and the results obtained are represented in the following table:

Table 7: Required characteristics of the asphalt

	MVRe	MVA	Vi	VAM	VRB	K	C
Mixed 1	2.635	2.425	8.0	26.63	70.06	3.3	92.0
Mixed 2	2.626	2.46	6.3	27.64	77.15	3.4	93.7
Mixed 3	2.617	2.47	5.6	28.64	80.43	3.5	94.4
Mixed 4	2.608	2.5	4.1	29.62	86.07	3.7	95.9

Tables 6 and 7 should be explained it

4.1.7. Optimum binder content

The graphing of the various parameters (Marshall stability, void percentage, density) made it possible to obtain the optimum binder content as a function of the binder content of the briquettes.

Table 8: Optimum binder content

	Stability max	Density max	% vacuum desired
Optimal values	17.4	2.5	6.0
TL	5.0	5.2	4.9
Optimal TL	5.0		

From this optimal binder content, compliance checks were performed on other graphs (VAM, K, creep) to ensure that it meets the requirements and the results of the analysis show:

Table 9: Mixture Compliance Checks

	VAM	K	VRB	Creep	C
Optimal TL	5.0				
Read values	28.6	3.5	80.4	3.3	94.4
Specifications	-	3.4 - 4	≤ 85	2 - 4	94 – 97

The interpretation of these different tables implies that the value retained TL = 5.0 satisfies the requirements formulated.

4.1.8. Duriez test

The test is performed with test pieces from the Marshall test. The results obtained following the crushing of the test pieces after 7 days of maturation gave:

- Specimens kept in the open air, R = 16.02 MPa
- The specimens immersed in water, r = 14.91 MPa

We obtain a water resistance r / R = 0.93; result in accordance with the specifications which require a ratio ≥ 0.7 and a LCPC compactness of 96.4% for a void percentage equal to 3.6%.

4.1.9. Trial at PCG

A test with the optimum binder content was performed and the results were recorded in the following table:

Table 10: Results of the PCG Test

Number of gyration	5	10	15	20	25	30	40	50	60	80	100	120	150	200
% of empty	10.8	9.1	8.0	7.1	6.5	5.9	5.1	4.4	3.9	3.1	2.5	2.0	1.4	0.6

The analysis of the different results obtained shows that the behavior of the asphalt at 120 girations with a percentage of vacuum equal to 2.0%, meets the specifications (Vmax = 6% at 120 girations).

4.1.10. Rutting test

The test is carried out on asphalt plates made from asphalt collected during the execution of the test strip at PK 0 + 600 - PK 0 + 840. The results obtained are represented in the following table:

Table 11: Results of the rutting test

Number of cycles	**PR PLAST**	**30**	**100**	**300**	**1000**	**3000**	**10000**	**30000**	**Test temperature (° C)**
Witness	0%	2.3	3.2	4.8	6.9	8.6	10.4	14.0	60.2
Plate 1 (%)	0.6%	1.31	1.88	2.42	3.02	3.62	4.19	4.69	60.4
Plate 2 (%)	0.6%	0.38	1.99	2.59	3.23	3.88	4.49	4.81	60.7

Average (%)		0.84	1.93	2.50	3.12	3.75	4.34	4.75	/

The results obtained comply with the specifications with 4.75 ≤ 7.5 required.

4.1.11. Rigidity test

The test was carried out in diametric compression and bending at two points. The results obtained are recorded in the following tables:

Table 12: Results of diametric compression stiffness test

	Geometric MVA (Mg / m3)	**Vacuum %**	**Test Temperature (° C)**	**Force (KN)**	**Charge time (ms)**	**Deformation (µm)**	**Modulus of stiffness in diametric compression (Ecd in MPa)**
Average	2.508	4.1	15	8.36	124	7.0	13859
	Estimation of the complex module 15 ° C-15 Hz						14199

The results obtained conform to the specifications: Ecd = 14199 MPa

4.1.12. Fatigue test

. The test was carried out at a temperature of 10 ° C, at a frequency of 25 Hz, and the results obtained are satisfying the requirements: Ɛ6 = 132 µdef ≥ 130 µdef.

4.2. Formulation of 14-BBME 1

4.2.1. Choice of aggregates

The first section of the highway has unfavorable track conditions due to the geomorphology of the Central Region (average elevation of 750 m). We observe a large number of clothoids and declivities. For heavy traffic and a high traffic speed (Vr = 110 km / h), the aggregates recommended for the wearing course must have good mechanical properties (LA, MDE, CPA) [8, 13].

The results obtained are recorded in the following table:

Table 14: Mechanical characteristics of the 0/14

	LA	MDE	LA+MDE	CPA
1	27.2	13.9	41.1	54
2	27.4	13.9	41.3	53
3	28.3	15.2	43.5	/
Average	27.6	14.6	42.0	53.5
Required values	≤ 25	≤ 20	≤ 45 ± 5	≥ 50

We find that the Los Angeles results do not meet the requirements (LA = 27.6 ≥ 25 required). However, by applying the compensation law according to standard NF P 18 545; for 25 <LA ≤ 30, MDE ≤ 15 and LA + MDE ≤ 45 we have: LA = 27.6, MDE = 14.6, LA + MDE = 42.0 ≤ 45, more than CPA = 54 ≥ 50 therefore these materials can be used in wearing course.

In order to increase their performance, the PR FLEX 20 anti-rut additive will be used in BBME 0/14 bituminous mixes.

The aggregates for BBME class 1 will have to be supplied in four fractions (04) namely: 0/3, 3/5, 5/10 and 10/14, the fractions will have to be recombined in order to obtain the imposed granulometric curves.

The vof the different particle size analyzes yielded the following result:

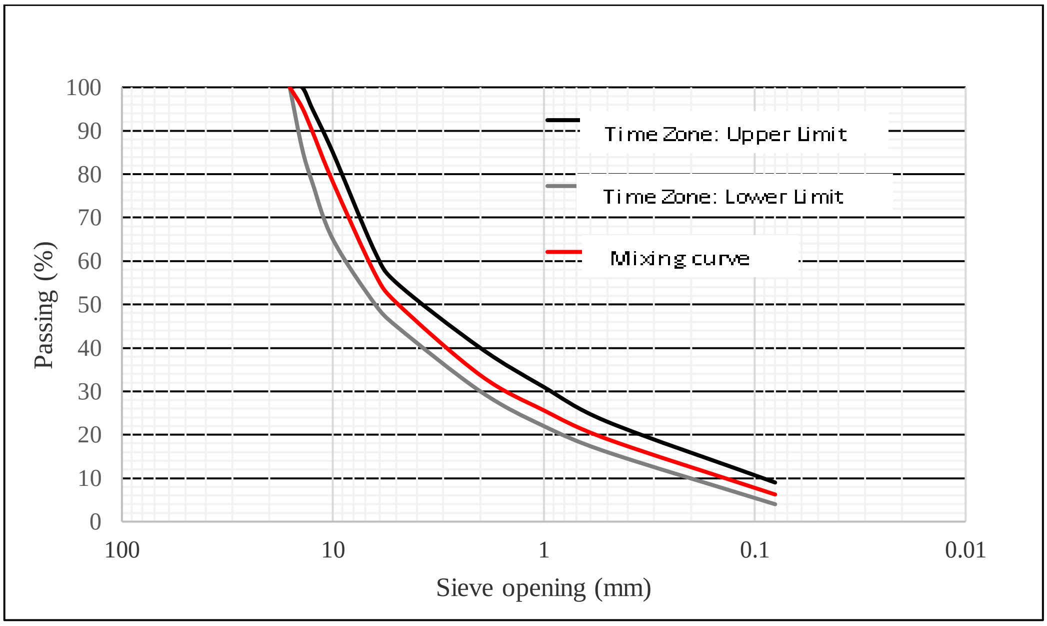

Figure 2: Particle Size Curve 0/14

The granulometric curve of the mixture fits perfectly into the specification zone.

5. Choice of binder

In addition to the traffic and climatic conditions of the environment, the aging behavior and its susceptibility to temperature have been decisive parameters in the choice of binder [13, 16].

The analysis of the results of identification tests made it possible to define that the bitumen studied is of grade 50/70.

Table 15: Identification of pure bitumen

Relative density	Penetration at 25 ° C	Softening point	Ductility
Test performed before RTFOT			
1.04	57.4	51.8	> 100
Test carried out after RTFOT			
≥ 1	38.3	53.4	> 100

The results obtained satisfy the specifications and allow us to conclude that the identified bitumen is of class 50/70

6. Initial binder content

The choice of the initial binder content was for a minimum richness modulus of 3.21.

We have: = 0.9298 MVRg = 2.85 = 1.5458

TL = 4.7

7. Determination of stability and creep

The results obtained for the Marshall test are shown in the following table.

Table 16: Marshall Characteristics of 14-BBME

	Max Stability	Creep	Max Density	Actual density	% of desired vacuum	Marshall Quotient
Optimal values	19.6	2.3	2.47	2.609	5-8	8.5
Optimal TL	5.0					

In accordance with market requirements and normative specifications, the results are satisfactory.

8. Maximum density of asphalt mix: PCG test

The maximum density test made it possible to obtain the maximum experimental density of the asphalt mix.

- Ground of the asphalt in the open air A = 1309 g
- Weight of the mix in water E = 778.3 g

The maximum density obtained is:

dm = 2.467 Kg / m3

The mass of the mix to be used for test a is:

m = 6539.32 g

Subsequently, the PCG trial was conducted, the results of which are recorded in the table below:

Table 17: PCG test results on 14-BBME

Number of gyration	5	10	15	20	25	30	40	50	60	80	100	120	150	200
% of empty	13.1	11.1	9.8	8.9	8.2	7.6	6.7	6.0	5.4	4.5	3.9	3.4	2.8	2.1

The results obtained were represented on the following semi-logarithmic graph:

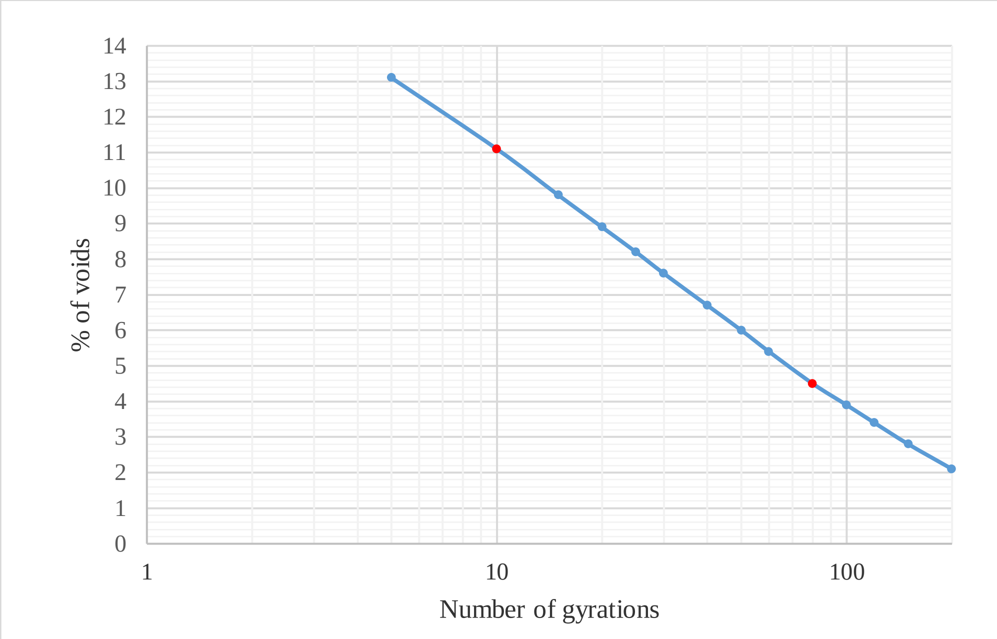

Figure 3: Variation curve of void percentage

The curve analysis shows that it meets the requirements of the specifications.

9. Duriez test

The Duriez test is carried out on specimens which contain an optimal bitumen dosage corresponding to the best Marshall stability. The results obtained following the crushing of the test pieces after 7 days of maturation gave:

- Specimens kept in the open air, R = 8.31 MPa
- The specimens immersed in water, r = 7.31 MPa

We obtain a water resistance r / R = 0.88; result in accordance with specifications that require a ratio ≥ 0.8.

The LCPC compactness is C = 92.8% for a void percentage, empty% = 7.2%

With MVA = 2.461 and MVRe = 2.609

10. Rutting test

The test is carried out on asphalt plates taken from the test plate of PK 0 + 600 - PK 0 + 840, at a temperature of 60 ° C. The results obtained are represented in the following table:

Table 18: Summary of rutting test results

Number of cycles	PR FLEX	30	100	300	1000	3000	10000	30000	Test Temperature (°C)
Witness	0%	2.6	3.4	4.2	5.8	8.3	9.7	11.8	60.1
Plate 1 (%)	0.3%	0.98	1.27	1.53	1.82	2.09	2.43	2.78	59.8
Plate 2 (%)	0.3%	1.02	1.31	1.57	1.87	2.19	2.58	2.85	60.2
Average (%)		1.0	1.29	1.55	1.84	2.14	2.5	2.81	

The results obtained are represented by the following graph:

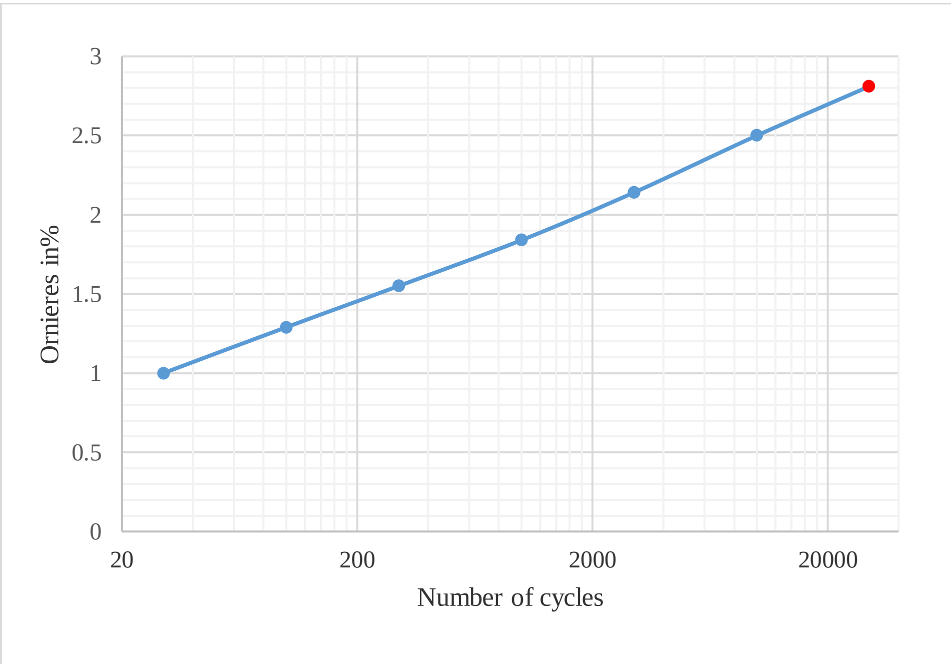

Figure 4: Deformation variation curve

The results are in accordance with specifications that require:

- For the validation of the rutting test, a deformation <10% at 30,000 cycles,
- For the validation of the asphalt formulation, a deformation <7.5% at 30,000 cycles.

11. Module tests

The test was carried out in diametric compression and bending at two points. The results obtained are recorded in the following tables:

Table 19: Synthesis of the results of the modulus of stiffness in diametric compression

	Geometric MVA (Mg / m^3)	Vacuum%	Test Temperature (° C)	Force (KN)	Charge time (ms)	Deformation (µm)	Modulus of stiffness in diametric compression (Ecd in MPa)
Average	2.453	5.8	15	8.36	124	7.0	7576
	Estimation of the complex module 15 ° C-15 Hz						9430

The results obtained conform to the specifications: Ecd = 9430 MPa ≥ 9000 MPa required.

Table 20: Synthesis of the modulus of stiffness in bending 2 points

	Geometric MVA (Mg / m^3)	Vacuum%	Test Temperature (° C)	Force (KN)	Deformation (µdéf)	Flexural stiffness modulus for 2 points (Efl in MPa)
Average	2.434	6.0	15	0.0154	30	9588

The results are conclusive, Efl = 9588 MPa ≥ 9000 MPa required.

In the light of the experimental results, it is found that the mechanical performances obtained on the various high-modulus mixes formulated, are satisfactory and comply with the specifications required in level 4 of formulation by the standard NF EN 13108-1 for a 20-EME 2 and a 14-BBME 1.

12. Conclusion

Road infrastructure plays a vital role in the development of a country as it serves the national and international transit of goods and services, facilitating the easy introduction of investment programs to various economic sectors. They must therefore be given special attention because their implementation requires very high investments.

In this context, our study was interested in the formulation study and its optimization and at the end of this study, we came to the conclusion that; in order to optimize the service life of our roads and for high traffic roads such as motorways and national roads. Traffic, climatic conditions, the geotechnical context and a selection of materials with high intrinsic characteristics for the different layers of the road structure must be taken into account. As for the determination of the mechanical characteristics of the aggregates, the LA and MDE tests must be systematically coupled to the PSV test which is one of the main intrinsic characteristics of the aggregate which contributes to the maintenance of adhesion in the same way as the formula and the maximum dimension D of the coating under traffic [7, 8]. Some compensation seems to be possible between the different mechanical characteristics: thus, one could admit a lower impact resistance if the grit has a PSV or a higher wear resistance, this compensation must not exceed certain limits. And therefore the mechanical performance of asphalt can be improved by the addition of additives optimizing their service life [10]. This parameter is all the more important because, so far, it has not been selected among the characterization tests for pavement aggregates and many traffic accidents are observed on our roads.As part of our study, the intrinsic characteristics of the aggregates that make up the different types of mixes EME and BBME have been defined in terms of resistance to fragmentation, wear and polishing; results satisfactory to the requirements.

The formulation study of high modulus asphalt pavements revealed that, to obtain congruent information on their mechanical behavior (performance) from the relevant tests, for high traffic pavements, a level 4 formulation is required and results satisfactory were obtained in accordance with the specified requirements.

Tests	**Results**		**Specifications**	
	20-EME 2	14-BBME 1		
PSV/CPA	/	54	/	≥ 50
Percentage of PCG voids	2.0 % à 120 gyration	11.1 % à 10 gyration et 4.5 % à 80 gyration	6 %	
Duriez	R = 16.02 Mpa r = 14.91 Mpa r/R = 0.93	R = 8.31 Mpa r = 7.31 Mpa r/R = 0.88	≥ 0.7	≥ 0.8
Rutting tests	4.75 %	2.81 %	≤ 7.5 à 30000 cycles	
Ecd rigidity module	14199 Mpa	9430 Mpa	≥ 14000 Mpa	≥ 9000 Mpa
Efl stiffness modulus	14325 Mpa	9588		
Fatigue test	132 µdéf	/	≥ 130 µdéf	/
Marshall trial	Creep = 3.3 Stability = 17.4	Creep = 2.3 Stability= 19.6	2-4	2-4

Any reflection made on the choice of aggregates for wearing course, we realize that aggregates have a significant impact on the adhesion of pavements and therefore on traffic safety. The adhesion of a pavement is largely the result of two parameters: the formula of the coating material and the aggregates that make it up. It requires very high demands on the polishing resistance of chippings, which is considered to be the paramount parameter, even almost exclusive, for obtaining a good and durable adhesion [6, 9, 10, 11-18].

To obtain a long-lasting pavement, it is not enough to improve the properties of the wearing course itself. If the lower layers are not properly designed and constructed, they will lose their structural strength which will reduce the service life of the wearing course, regardless of whether the wearing course has been properly designed and constructed. Also a good implementation according to the specifications is crucial for the successful execution of a roadway [13, 14].

For high-traffic roads, in the case of basecoats and foundations, the use of high-modulus asphalt (EME) instead of severe bitumen (GB) or untreated gravity (GNT) allows, for same level of performance, increase durability (high resistance to rutting), significantly reduce the thickness applied, or even save the implementation of a bonding layer before application of the wearing course [2 , 3, 4].

In the case of the wearing course, a high-modulus asphalt concrete (BBME) used as a replacement for an asphalt concrete (BB) would have superior performance in terms of fatigue strength and stiffness modulus. It participates more actively in structuring power by significantly reducing the fatigue damage of the bound layers of the pavement [1, 5].

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