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Characterization of 0/20 Silexite Material for Use in Bedding or Bonding Layer

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Abstract: ***There is a growing demand in Senegal for road building materials. Moreover, in the face of a scarcity of materials satisfying the technical specifications and overexploitation of the basaltic material normally used, this article was intended to initiate studies on the possibility of using the existing silexite material as an alternative in order to anticipate the problem of exhaustion of basaltic deposits. Indeed, this article has referred to the possibility of using as a bedding or bonding layer of the limexite material from industrial waste from phosphate recovery at Mboro in association with the bituminous binder to form severe bitumen. 20 to determine its physical and mechanical performance and then note their limits in relation to the minimum requirements of the road technical specifications. For this purpose, the physical and mechanical identification of the silexite material is carried out initially. It turns out that the silexite material has good mechanical properties with Los Angeles and Micro Deval values in accordance with the requested requirements. Regarding the granularity, nonconformities are noted on the sieve D and d refusals and can be corrected during the crushing because of the manufacturing parameters. Then, the performances of the bituminous mixture, in particular the severe bitumen GB 0/20, are studied. At the end of this study, the results obtained are satisfactory in terms of stability, creep and Marshall compactness while the Duriez test denotes some nonconformities on the immersion compression ratio below the threshold value of 0.70 for certain values of binder content. .Nevertheless, the silexite material can be used as a bedding or bonding layer in the form of severe 0/20 bitumen, given the conclusive results obtained.***

Keywords: Silexite - Basalt - Serious bitumen - Los Angeles - Micro Deval - Marshall – Duriez

1. Introduction

Road construction remains a major lever in a country's economic growth. In other words, the economic development process in any place requires the establishment of an adequate road network. Thus, the roadway must have properties that allow users to circulate under optimal conditions of safety and comfort. The satisfaction of these conditions of use implies at first certain qualities for the materials of the roadway.

In Senegal, with the urbanization of the regions and the densification of the road network, it has been noted an increasing exploitation of basaltic granulate commonly and usually used in road construction. This material considered noble and precious in Senegal is becoming scarce day by day and tends to increase the cost of construction because there is mainly a career very exploited in Senegal which is that of Diack located in the region of Thiès 70 km of Dakar. As a result, supply is decreasing and demand is increasing, resulting in frequent stops at road construction sites. Aware of this situation, researchers that we are have made inventories of materials available regionally. This is how the silexite material caught our attention. Silexites are hypersilicating sedimentary rocks in the form of kidneys or grouped in more or less horizontal passes in the phosphate levels [1]. They are residues of phosphate mining, located in Mboro in the region of Thiès 70 km from Dakar.

A sample of a silexite all-out shows that the rock consists of: 91% flint; 6% phosphated indurated; 3% fine with phosphated and clay elements [2].

Thus, in the context of this article, the physical and mechanical performance of the silexite material in association with a hydraulic binder will be studied to form a severe 0/20 bitumen for a bedding or bonding layer. The heavy bitumen is a hydrocarbon asphalt that was developed in the 1970s. It is the first technique created for the base layers on the high traffic network following the first findings of rutting. Optimum formulation of the bituminous mixture will be based notably on the Marshall and Duriez tests after studying the physical and mechanical aspects of the silexite material such as granularity, flattening, resistance to fragmentation determined by the Los Angeles coefficient and the wear resistance determined by the coefficient Micro Deval to water ect. With traditional mechanical tests, we can establish optimal binding levels and reject asphalt with visibly poor behavior [3].

2. Materials and Method

2.1 Materials

The materials used are mainly aggregates and bitumen. The aggregates come from Mboro silexite waste rock in the Thiès region located 70 km from Dakar in Senegal. They are collected by our good care and received at the laboratory of

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the Experimental Center for Research and Studies for Equipment of Senegal (CEREEQ).

Bitumen is marketed in Senegal by the EUROPEAN RAILROAD ESTABLISHED SERVICES (ERES S.A.) company.

Aggregates
An identification of aggregates is made to verify if the proposed silexite aggregates are in accordance with the technical recommendations. They have been listed as follows:
Silexite 8/20.
Silexite 3/8.
Silexite 8/14.
Silexite 14/20.

To do this, the aggregates are subjected to the following identification tests:

Particle size analysis, Specific gravity, Sand equivalent

Table 1 hereinafter gives the results obtained on the particle size analysis, the specific gravity and the sand equivalent of the silexite used according to the standards NF P 94056 [4], NF EN 1097-6 [5], EN 933- 8 [6].

Table 1: Particle size analysis, Specific gravity, Sand equivalent

Granular class	Silexite 14/20		Silexite 8/14		Silexite 3/8		Silexite 0/3	
Initial weight	5000g		5000g		5000g		500g	
opening (mm)	Cumulative weight refusal	% Passing	Cumulative weight refusal	% Passing	Cumulative weight refusal	Cumulative weight refusal	Cumulative weight refusal	% Passing
25	0	100						
20	2368	52,64						
16	3737	25,26	0	100				
14	4387	12,26	135	97,3				
12,5	4733	5,34	404	91,92				
10	4961	0,78	2686	46,28	0	100		
8	4964	0,72	3969	20,62	325	93,5		
6,3	4964	0,72	4873	2,54	1721	65,58		
5			4978	0,44	2969	40,62		
4			4981	0,38	4208	15,84	0	100
3,15					4883	2,34	22	95,6
2					4964	0,72	98	80,4
1,25							186	62,8
0,63							294	41,2
0,5							312	37,6
0,315							348	30,4
0,16							384	23,2
0,08							410	18
MVA (t/m^3)	1,27		1,3		1,32		1,33	
Specific weight (t/m^3)	2,503		2,413		2,421		2,353	
Sand equivalent (%)							41	

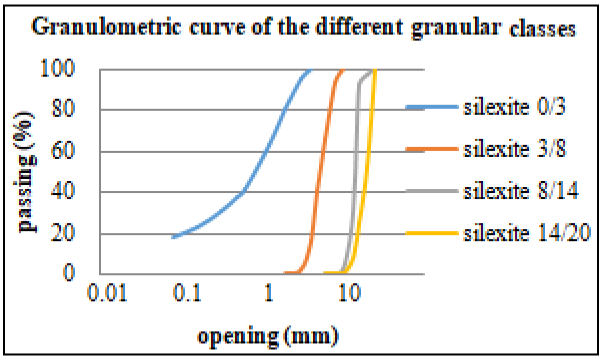

Figure 1 : Particle size analysis of silexite on different fractions

Flattening test
The shape of aggregates is characterized by the flattening coefficient according to the European standard EN 933-10 [7].

Table 2: Characterization of silexite with the flattening test

Classe granulaire		Silexite 14/20		Silexite 8/14		Silexite 3/8	
Poids initial		5000g		5000g		5000g	
M_O (g)		4994		4995		4166	
Opening d/D (mm)	Grids spacing (mm)	M_{gi} (g) (Tamis)	M_{ei}(g) (Grille)	M_{gi} (g) (Tamis)	M_{ei} (g) (Grille)	M_{gi} (g) (Tamis)	M_{ei} (g) (Grille)
31,5 / 40	20						
25 / 31,5	16	0	0				
20 / 25	12,5	2346	503				
16 / 20	10	1357	276	11	0		
12,5 / 16	8	942	121	824	121		
10 / 12,5	6,3	318	15	2460	482	0	0
08-oct	5	3	0	904	154	347	82
6,3 / 8	4			701	87	1436	243
5 / 6,3	3,15			73	7	1146	157
04-mai	2,5			2	0	1166	149
$\sum(M_{gi})$		4966		4975		4095	
	$\sum(M_{ei})$		915		851		631
$\frac{\sum(M_{ei})}{\sum(M_{gi})}$		18,43%		17,11%		11,41%	

Essai Los Angeles

La dureté des granulats silexite est appréciée selon la norme européenne EN 1097-2 [8] par l'essai Los Angeles qui a pour but de mesurer la résistance à la fragmentation par chocs des éléments d'un échantillon de granulats.

Table 3 : Caractérisation mécaniques du silexite avec l'essai Los Angeles

Coefficient Los Angeles : LA (%)					
Nature of the sample	Granular class	Initial weight Po (g)	Weight after wash P1 (g)	Weight of elements < 1.6 mm P_2 (g)	Coefficient LA (%)
Silexite 14/20	10/25	5000	3966	1034	20,68
Silexite 8/14	10/14	5000	3870	1130	22,6
Silexite 3/8	4/6,3	5000	3825	1175	23,5

Micro Deval Trial

The micro-Deval test carried out according to the European standard EN 1097-1 [9] allowed in the framework of this study to determine the micro-Deval coefficient which gives information on the resistance to wear by the mutual friction of the elements. a granulate.

Table 4 : Mechanical characterization of silexite with the Micro Deval test

Micro Deval Coefficient to Water: MDE (%)						
Nature of the sample	Granular class	Initial weight Po (g)	Weight after wash P_1 (g)	Weight of elements < 1.6 mm P_2 (g)	Micro Deval Coefficient to Water: MDE (%)	Moyenne MDE (%)
Silexite 8/16	10*14	500	434	66	13,2	
			438	62	12,4	12,8
Silexite 3/8	4/6,3	500	448	52	10,4	
			448	52	10,4	10,4

Table 5 : Comparison of the identification results against the specifications

Measured Parameters	Silexite de Mboro				Spécification. GB 0/20	Conformity
	0/3	3/8	8/14	14/20		
% refusal to D for chippings	-	6,5	2,7	47,36	< 15 %	Suitable for all classes except 14/20 silexite
% passing from d to gravel	-	2,34	20,62	12,26	< 15 %	Suitable for all classes except for 8/14.
% of refusal to D for sands (on curves)	4,4	-	-	-	< 15 %	Suitable.
Specific weight	2,342	2,421	2,413	2,503	-	-
Sand equivalent	41	-	-	-	> 55 % (a)	non conforming.
Aplatissement	-	15,41	17,11	18,43	<25 (III)	Suitable for all classes.
Coefficients LA (%)	-	23,5	22,6	20,68	≤ 30 (C for T ≥T0) et ≤ 35 (D for T < T0)	Conforme pour tous les échantillons.
MDE (%)	-	10,4	12,8	-	≤ 25 (C for T ≥T0) et ≤ 30 (D for T < T0)	Suitable for all classes
LA + MDE	-	33,9	35,4	-	≤ 45 (C for T ≥T0) et ≤ 55 (D for T < T0)	non Conforming

Bitumen

The identification of the binder used, which is from ERES SA, is based on the penetration tests on bitumen (EN 1426) [10] and the ball and ring softening point (EN 1427) [11]. The values obtained in this study are shown in Table 6 below. It reveals a grade 35/50 bitumen and a softening temperature of 54.2 ° C.

Table 6: Characteristics of bitumen

Trial	Bitumen tested	Spécifications	Conformity
Point of softening	54,2 °C	50-58 (°C)	conforme
Penetration at 25 ° C	43,7 (1/10 mm)	35–50 (1/10 mm)	conforme

Particle size curve of the mixture

The granulometric curve of the mixture is not indicated in the standards, however, a prescription is given concerning the envelope of the granularity of the mixture [12].

It is used the SETRA-LCPC spindle for the framing of the mixture curve. This is the 0/20 spindle for severe bitumen. From the granulometric curve of the different granular classes, a mixture is chosen whose curve is inscribed within the limits of the spindle defined for the severe bitumen.

Table 7 : Composition of mixtures according to different granular classes

granular Class	Grave bitumen 0/20
granular Class	(%) silexite
0/3	44
03-Aug	16
8//14	20
14/20	20

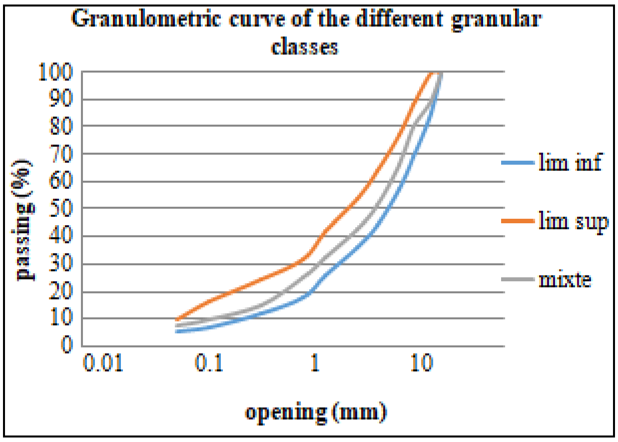

Figure 2: GB 0/20 mix curve for Mboro silexite

Determination of the binder content

An amount of the minimum bituminous binder (Table 8) is defined to ensure good durability of the mixture by the W richness modulus method. This quantity is a function of K and the specific surface area of the aggregates Σ.

$$TLext = K\alpha\sqrt[5]{\Sigma} \quad [13].$$

Tlext : Teneur en liant extérieur

K : Module de richesse
Σ : Surface spécifique
Tlext: Binder content outside
K: Wealth module
Σ: Specific surface area
$\alpha = 2.65/MVRg$: Corrective coefficient relating to the density of the aggregates .
$MVRg$: Actual density of aggregates in g / cm3
$.\Sigma = \frac{1}{100}(0{,}25G + 2{,}30S + 12s + 150f)$

- G: proportion of elements greater than 6.3 mm
- S: proportion of elements between 6.3 mm and 0.315 mm
- s: proportion of elements between 0.315 mm and 0.08 mm
- f: proportion of elements smaller than 0.08 mm

Table 8 : Bitumen content (TL) according to the richness module K

Wealth module K	Binder content (%) GB 0/20	New Binder Content (%) GB 0/20	
	Silexite	K	Silexite
2,5	4,56	3,2	5,84
2,6	4,74	3,3	6,02
2,7	4,93	3,4	6,2
2,8	5,11	3,5	6,38
2,9	5,29	3,6	6,57

2.2 Method

The method used is based on the methodological principle of the Marshall and Duriez test.

2.2.1 Marshall Methodology

Several standards frame the process such as the European standard EN 12697-34 [14]. The purpose of this test is to determine the mechanical characteristics (stability, creep) as well as the percentage of voids of the compacted bituminous mixture under standardized conditions.

Five sets of specimens are made for mixing with binder contents ranging from 5.84 to 6.57.

Since the granular mixture gave satisfactory results with an insertion of its granularity in the reference zone, it is admissible and chosen for the continuation of the study.

This phase is followed by a determination of theoretical optimal bitumen contents. The results obtained lead us to draw up a Marshall test program with variable binding contents. The test program is transmitted in Table 10.

Table 10: Marshall Test Program

Granular composition	Variation in TL bitumen content (%)
44 % de 8/20	5.84 – 6.02 – 6.2 – 6.38 – 6.57
16 % de 8/14	
20 % de 3/8	
20 % de 0/3	

Duriez Methodology

The test is described according to standard NF P 98-251-1 of September 2002 [15] on hot hydrocarbon mixtures. The principle of the Duriez test is manufactured by double-acting static compaction, specimens some of which are subjected to the compression test after storage at 18 ° C under defined conditions (in air and in water). Others are intended for the measurement of the density by hydrostatic weighing to calculate the compactness.

For the mixture, 07 test pieces were made and distributed as follows:

02 tested in single compression after 24 hours;
02 tested in simple compression after 07 days of storage in air at 18 ° C;
02 tested in simple compression after 07 days of storage in water 18 ° C;

One reserved to determine the compactness of the mixture. For each parameter, a figure is presented with the values obtained and the limit values generally retained by the technical prescriptions.

3. Results and Discussions

After compaction, the samples are subjected to a stability and creep test. Stability is the maximum force that the sample can withstand and creep is the resulting plastic deformation. The compactness is deduced from the test of apparent density or bulk density. The values obtained are very indicative and allow to decide on the performance of the mix. The following Marshall curves reveal that the GB 0/20 exhibits good stability, acceptable creep and acceptable compactness.

Following the analysis of the Marshall results, an evaluation of the water sensitivity by the Duriez test is made on the silexite with the same contents in binder. These grades are the bitumen grades that best meet all Marshall criteria.

The study is pursued by water resistance analysis, which is the ability of the asphalt to resist stripping under the action of water. It is characterized by the ratio immersion / compression (R'c / Rc) between the resistance to compression after immersion (R'c) and that after conservation air (Rc).

GB 0/20			Spécification et conformity	
Matérials		Silexite	Spécification GB 0/20	Conformity
Bitumen content %		5,84	-	-
	Stability (kgf)	1007	$\geq$ 900	Conforme
	Creep (mm)	3,41	< 4	Conforme
	MVA (t/m^3)	2,123	-	-
Marshall Test	Compacity (C%)	94,77	[94 - 97]	Conforme
Essai Duriez	Imm.(R'c) / Comp.(Rc)	0,71 0,705 0,69 0,68 0,65	$\geq$ 0,70	Conforme pour les deux teneurs
	MVA (t/m^3)	2,137	-	-
	Compacity (C%)	95,4	[92 - 96]	Conforme

Stabilité Marshall

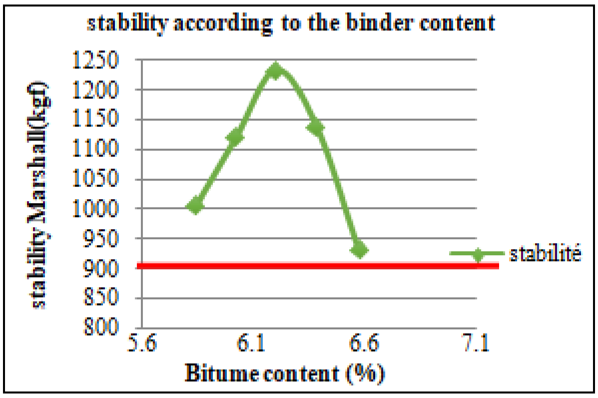

Figure 3 : Marshall GB stability 0/20 depending on the binder content.

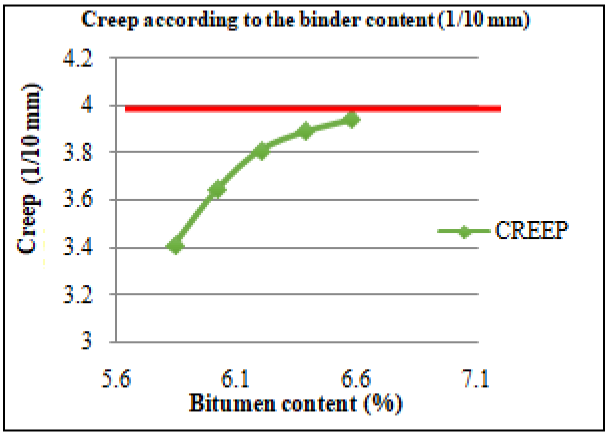

Figure 4: Creep GB / 0/20 as a function of binder content

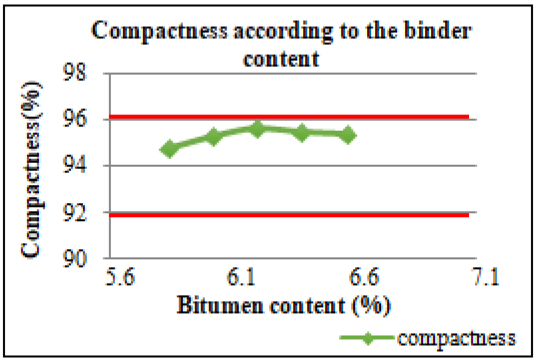

Figure 5 : GB / 0/20 compactness as a function of binder content

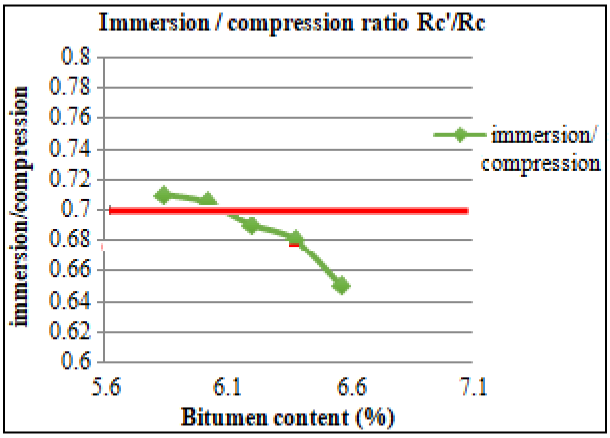

Figure 5 : Immersion / compression ratio GB / 0/20 as a function of the binder content.

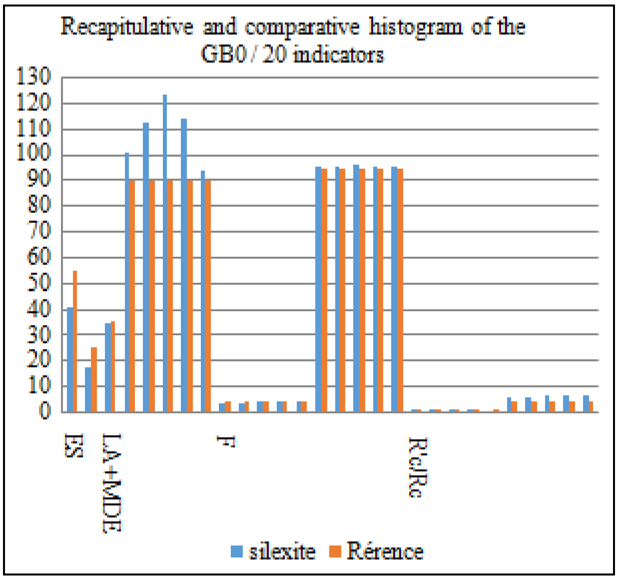

Figure 5 : Summary and comparative indicators for GB0 / 20

4. Conclusion

At the end of our analysis, it remains to be understood that the silexite material has acceptable physical and mechanical characteristics for its use in road construction, particularly in the base or bonding layers. Its association with the hydraulic binder to form the severe bitumen 0/20 is possible and has provided conclusive results with respect to the results obtained in this analysis. However, some of the characteristics of silexite do not meet requirements such as 14/20 and 8/14 granularity. These parameters are related to manufacturing and can be corrected during crushing. Compared to the water sensitivity of nonconformities are noted for certain levels of binder. This would require further testing with use of adhesive dope.

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