Stabilization of bituminous concrete intended for wearing courses by adding dune sand

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ABSTRACT

The semi grained bituminous concrete BBSG intended for wearing layers, known by the name BB 0/14, generally is prepared by mixing two components: aggregates and bitumen. The design of this material considers several criteria related to one hand to the aggregates, namely mechanical characteristics, shape, and cleanliness of stones, the blue value of the fine, the particle size of the mixture (% passing through), the choice of the bitumen grade and mechanical performance as well the water resistance of asphalt concrete 0/14.

The present work aims to study the influence of the substitution of the fraction 0/3 mm of the crushed sand (usually used in this type of materials) by fine dune sand, on the mechanical performance including Duriez and Marshall Stability and water resistance.

I. Introduction

The aggregates used in the wearing courses in regions of the great south of Algeria, have resistance to shocks or attrition far exceeding the values required by the specifications in force [1], [2] and [3]

A preliminary experimental study carried out on aggregates from the Adrar and Ghardaïa region showed that the values of LA; MDE are just at the recommended thresholds for wearing courses [2], [4] and [5].

Subsequently, formulation trials of asphalt concrete with aggregates (classes: 0/3 - 3/8 - 8/15) will be carried out without the addition of dune sand to compare their mechanical performance (Durièz and Marshall saturation) to those obtained with bituminous mixes from formulations containing sand dune levels.

This procedure is very useful in order to highlight the possibility of the exploitation of sand dunes in the Saharan road construction.

The study highlights an optimal value of adding dune sand.

II. Characteristics of Materials

II.1. Gravel

For gravel, it is the classes 3/8 and 8/15 used in Algeria for semi-grinded bituminous concretes that are studied. The percent flattening (AP), Los Angeles (LA), Dicro Deval in the presence of water (MDE), cleanliness, and absolute density values are shown in Table 1.

Table 1. Characteristics of the aggregates – classes 3/8 and 8/15

Aggregates	LA (%)	MDE (%)	AP (%)	P (%)	Density (kN/m^3)
3/8	21	22	10	1,1	26,5
8/15	19	21	9	0,7	26,7

The values of the intrinsic characteristics of the two classes of gravel used in the preparation of semi-gritted bituminous concrete (BBSG) 0/14 are acceptable with regard to the Algerian specifications [2], [6] and [7] which respectively recommend a threshold of 25 and 20% for the results of Los Angeles (LA) and Micro Deval (MDE) trial in the presence of water. The manufacturing characteristics - flattening coefficient and cleanliness also revealed acceptable values: AP ≤ 20%; P ≤ 2% [2], [6] and [7]. The summary chemical analysis of the gravel used is provided in Table 2.

Table 2. Chemical compositions of the aggregates and crushed sand

Minerals	$CaCO_3$	NaCl	SO_3	Insoluble	Others
%	93	0.03	0.01	1.3	5.66

According to the chemical composition, the aggregates have high carbonate content.

II.2. Sands

For sands, class 0/3 crushed sand and dune sands are considered. The values of absolute density, sand equivalent and fines are given in Table 3.

Table 3. Characteristics of the crushed sand and sand from dunes.

Sands	Density (kN/m^3)	E.S	% < 0.08 (mm)
Crushed sand 0/3	26.9	81	22
Sand from dunes 0/0.4	27.1	85	4

The crushed sand has an ES much greater than 60 and contains an acceptable fine level [2], [8], [9], [10] and [11].The sand of the dunes has a narrow grain size (0 / 0.4) and the percentage of fines shows a poverty of fine elements <0.08 mm. Figure 1 shows the particle size curves of the gravel used (classes 3/8 and 8/15) and the sands (crushed sand 0/3 - dune sand 0 / 0.4).

II.3. Binder

The binder used is 40/50 bitumen. The bitumen used is brought back from the NAFTAL unit (Ghardaïa in south of Algeria).

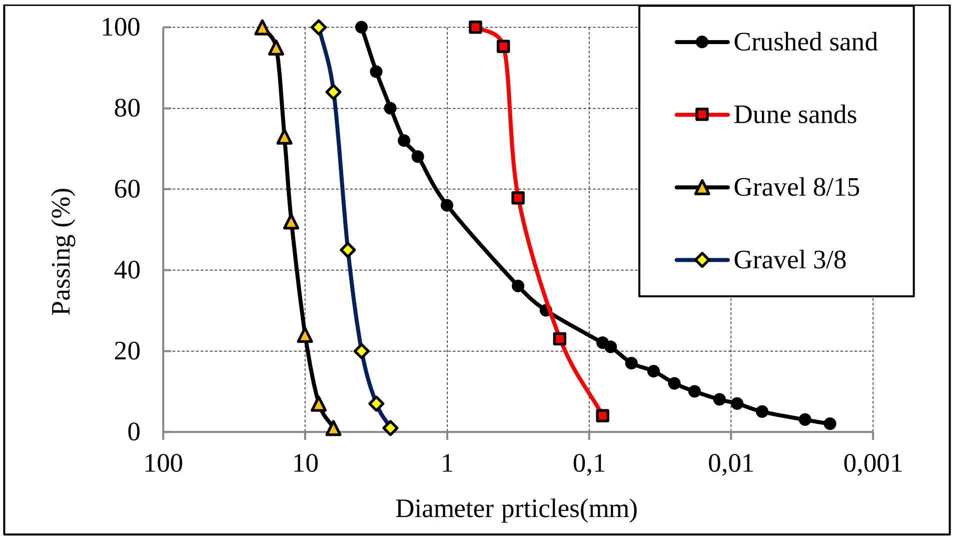

Figure 1. Particle size curves of gravel and sand used

III. Study of the Mixture

III.1. Granular composition

On the basis of the particle size obtained from the different fractions studied, a mixture was prepared in such a way that it was inscribed in the reference zone 0/14 [2], [8], [12], [13] and [14]. The percentages retained are the following:

- 45% of the 0/3 class; - 25% of class 3/8; - 30% of the class 8/15.

The Particle size curve of the mixture of the three classes 0/3 - 3/8 and 8/15 without the addition of dune sands is given in figure 2

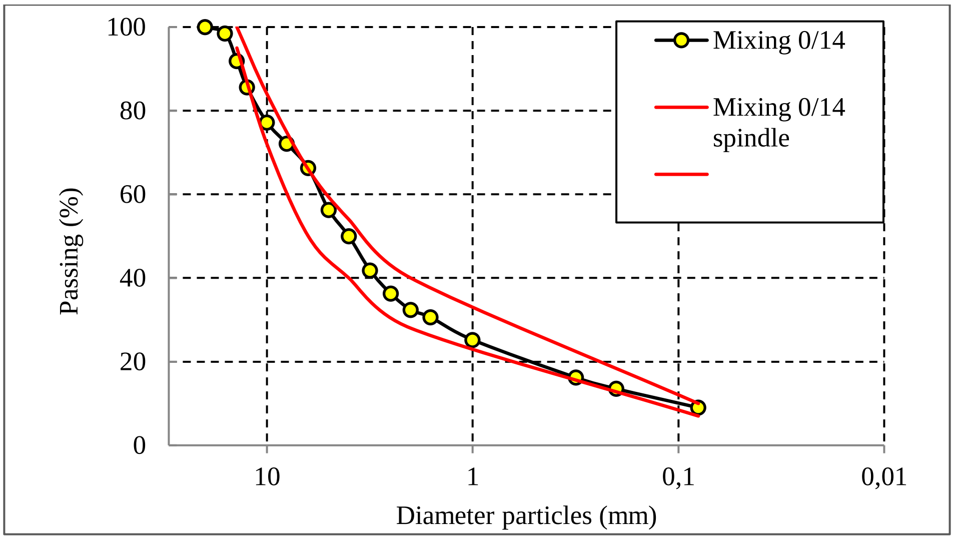

Figure 2. Particle size curve 0/14 without adding dune sands

III.2. Binding dosage calculation

The bitumen content represents the ratio of the mass of binder to the mass of dry aggregates expressed as a percentage, for which the following formula is used [4], [15] and [16]:

Content bitumen (%):

$$(\%) = K.\alpha.\Sigma^{1/5} \qquad (1)$$

Σ: conventional surface area:

$$\Sigma = 0.25G + 2.3S + 12s + 135f \qquad (m^2/kg) \qquad (2)$$

With:
G: proportion of elements greater than 6.3 mm;
S: proportion of the elements between 6.3 and 0.315;
s: proportion of the elements between 0.315 and 0.08;
f: proportion of elements less than 0.08 mm;
K: richness module that characterizes the average thickness of the film around the aggregates;
α: coefficient intended to take into account the real density of the aggregates ($MVRg$), if this differs from 2.65 kN / m^3, one uses the following formula:

$$\alpha = \frac{2.65}{MVRg} \qquad (3)$$

The binder dosage is calculated with three wealth modules, so we will have three formulations. For each formulation, the real density of the bituminous mix (MVR) is calculated from the densities of the components by the following formula [2], [17] and [18] :

$$MVR = \frac{100}{[(\frac{\%G1}{\rho 1} + \frac{\%G2}{\rho 2} + \frac{\%G3}{\rho 3} + \cdots + \frac{Pb}{Db})]} \qquad (4)$$

$\%Gi$: Percentages of granular fractions;
ρi: Densities of aggregates;
Pb: Percentage by weight of the bitumen;
Db: Density of the bitumen.

IV. Tests on Mixtures

In order to verify the mechanical properties of the mixes, blends were made in the laboratory and subjected to the following tests:
- DURIEZ test (Normal for BB0 / 14);
- MARSHALL test with 50 shots.

IV.1. Duriez Test

This test makes it possible to evaluate the water resistance of an asphalt mixture by measuring the drop in compressive strength, after a 7-days immersion period.
In our case, for a bituminous concrete 0/14, and in accordance with the standard (NF P 98-251-1) [18], [19] and [20] 12 cylindrical specimens of diameter 80 mm, 1000 grs are manufactured for each specimen, statically compacted with a force of 60 kN;

- 2 test pieces for the measurement of bulk density by hydrostatic weighing;
- 5 specimens for preservation without immersion at 18 ° C,
- 5 test pieces intended for immersion preservation at 18 ° C;

After 7 days of storage, the simple compression test is carried out
The average compressive strength of the five specimens kept in the air is measured: R,
The average compressive strength of the test pieces preserved with water is measured:
- We calculate the ratio r / R.
The stages of manufacture and storage of specimens intended for the Duriez test are presented in Figure 3.

(a) *Molds and materials in the oven* (b) *Weighing* (c) *Mold filling*
(d) *Static compaction: 60 kN* (e) *Preservation after demolding* (f) *Simple compression test*

Figure 3. Stages of manufacture and storage of specimens intended for the Duriez test

IV.2. Marshall Test

The test consists in making test pieces of hydrocarbon mixtures by impact compactor according to a determined process [21], [22] and [23].
The specimens of bituminous mixes of cylindrical shape with a diameter of 101.6 mm and a target height of 63.5 mm are molded using impact compactor.
The standardized compaction lady is constituted of a sliding mass on a guide rod and falling freely on the foot of the lady in direct contact with one of the faces of the mixture contained in the mold. The number of strokes per side (compaction energy) is generally taken as 50. The minimum number of test pieces per tested formula is 4.
After compaction and before demolding, the test pieces must be kept at least 4 hours at room temperature, then, the apparent density of each specimen is determined.
After having immersed the test pieces in water at 60 ° C for 40 minutes, the diameter compression test is carried out using a constant compression deformation press 50 mm / min, equipped with a device to measure the effort during the test.
The results of the test are as follows:
Marshall S stability which corresponds to the maximum resistance of the specimen expressed in (kN),
Creep F, which represents the sagging of the test piece according to its vertical diameter at the moment of rupture, expressed in (mm),
The Marshall quotient which represents the S/F ratio between the stability S and the creep F expressed in (kN/ mm).
The stages of manufacture and storage of specimens intended for the Marshall test are presented in figure 4.

IV.3. Test Results

Three mixtures with different binder dosages for the hot mix grade (BB 0/14) were made.
The formulation retained is given in table 4.

(a) Molds in the oven (up) *(b) Mixing* *(c) Mold filled*

(d) Immersion (60°C) *(e) Compaction (50 strokes per side)* *(f) Overwrite sample*

Figure 4. Stages of manufacture and storage of specimens intended for the Marshall test

Table 4. Formulation retained of the asphalt mix (in %)

Sand 0/3 (%)	Gravel (%)		Bitumen 40/50 (%)	Density (kN/m^3)
	3/8	8/15		
45	25	30	6	22.1

The results obtained for Duriez and Marshall Tests are summarized in Tables 5 and 6.

Table 5. Results Duriez Test performance

Reference asphalt mix (without dune sands)		Algerian specifications
Dry compressive stress (Mpa) R	8.84	> 7 MPa
Compressive stress after immersion (Mpa) r	7.54	
r/R	0.85	> 0.75

Table 6. Results Marshall Test performance

Reference asphalt mix (without dune sands)		Algerian specifications
Stabilité value S (kN)	13.88	> 10.5
Flow value F(mm)	1.35	< 4

V. Study of Mixtures with Sand Dunes

The study of the effect of sand dune incorporation in the formulation of asphalt concrete 0/14 for the wearing course is done by partial substitution of crushed sand with increasing rates of sand dune ranging from 10% up to 40% .
For each dune sand addition rate (10, 20, 30 and 40%), three mixtures were studied in the laboratory with different bitumen contents in order to choose the formulation that gives the best performance. Table 7 groups the stopped formulations.

Table 7 Asphalt mixes with various percentage of sand from dunes (in%)

Dune sands (%)	Sand 0/3 (%)	Gravel (%)		Bitumen 40/50 (%)	Density (kN/m^3)
		3/8	8/15		
10	38	20	32	5.9	22.3
20	28	20	32	5.8	22.6
30	15	20	35	5.7	23.0
40	10	20	30	5.6	23.3

For each of the formulations stopped, Table 8 gives the compressive strengths of the test specimens after one week of storage in air and water as well as the values of the ratio (r / R) reflecting the water resistance of bituminous mix.

Table 8 Results of Duriez test on asphalt mixes with various percentages of dune sands

Dune sands (%)	0	10	20	30	40
Dry compressive stress (Mpa) R	8.84	9.10	9.10	9.10	8.84
Compressive Stress after immersion (Mpa) r	7.54	8.32	8.58	7.80	7.02
r/R	0.85	0.91	0.94	0.86	0.79

Note: R> 7 MPa; r/R > 0.75 (according to Algerian specifications).

The Marshall Stability values as well as the creep - of the Marshall test carried out on specimens of each optimal formulation - are presented in Table 9

Table 9 Results of Marshall test on asphalt mixes with various percentages of dune sands

Dune sands (%)	0	10	20	30	40
Stability Value (kN)	13.5	14.0	13.6	11.1	9.3
Flow value (mm)	1.35	1.36	1.38	1.42	1.44

Note: Flow value < 4 mm (according to Algerian specifications).

V.1. Discussion

Firstly, classical mechanical tests for the characterization of asphalt mixes (Marshall, Duriez) showed that the addition of dune sand modified the performance levels while remaining in conformity with the Algerian normative requirements.
Referring to Table 7, it can be seen that the incorporation of dune sand up to a rate of 30% improves the compressive strength (Duriez Stability), and that for both modes of conservation: dry and in immersion (respectively 3 and 12%), figure 5.

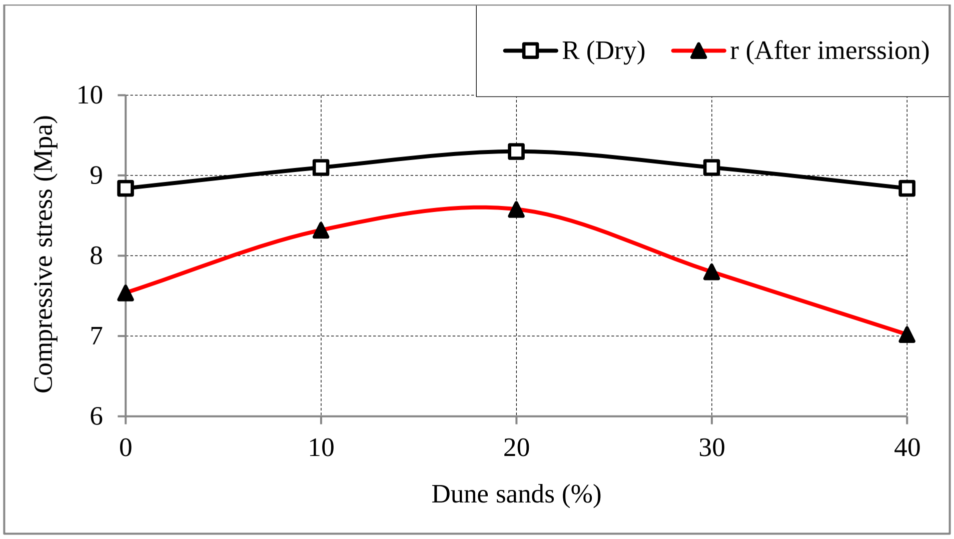

Figure 5. Evolution of the stability Duriez according to the % sand dunes

Similarly, for the water resistance characterized by the immersion / compression ratio, it shows an encouraging improvement of up to 20% in the addition of sand dunes, Figure 6.
This is explained by the fact that the addition of sand up to at these rates contributes to the decrease of the voids while increasing the compactness and the actual density of the bituminous mix.
Beyond this value, the effect becomes negative and the mechanical performances tend to degrade.

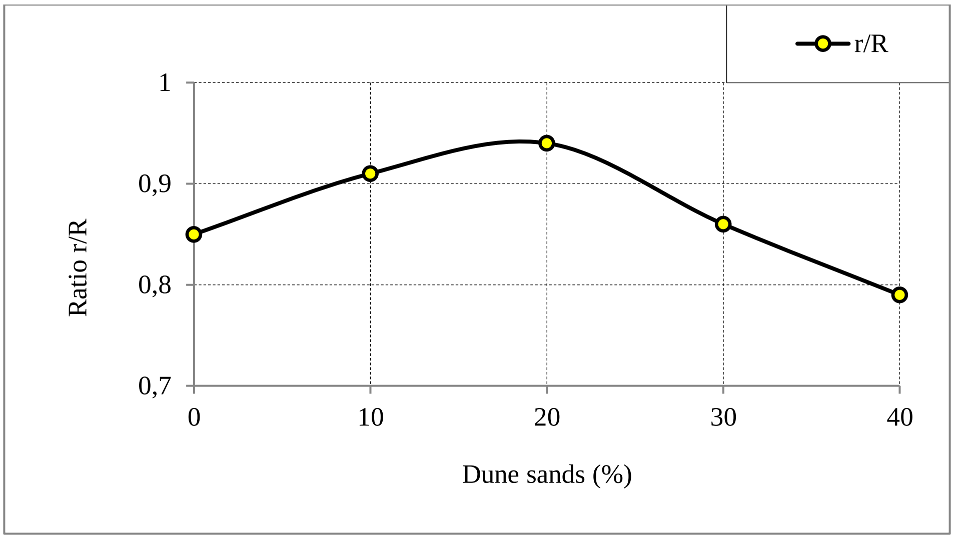

Figure 6. Effect of adding dune sands on the water resistance of asphalt mix

Regarding Marshall stability, and despite the fact that the latter is decreasing as we add dune sand to the formulation of 0/14 bituminous concrete, we see that it remains in the standards (≥ 10.5 kN) to a dune sands percentage of 20%, Figure 7.

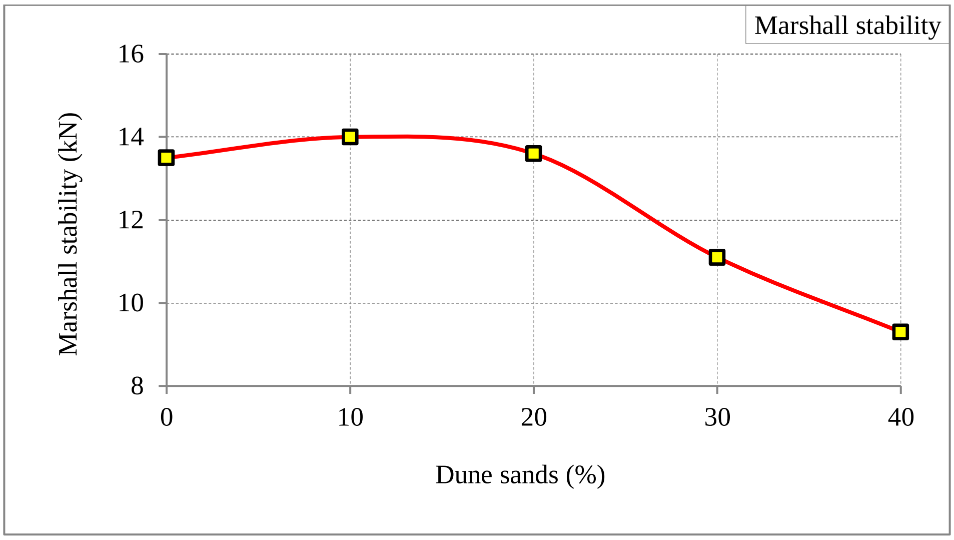

Figure 7. Influence of adding dune sands on Marshall Stability

VI. Conclusion

Asphalt mix production always aims to choose the optimal formulation that ensures good mechanical performance.
Several factors influence the final result of a formulation, namely the particle size of the mixture and the different mechanical characteristics, intrinsic and manufacturing characteristics of the aggregates on the one hand, and the choice of the bitumen class and its content.
In this work, we have chosen to study the influence of the incorporation of dune sand into the granular composition of bituminous mix by replacing crushed sand (class 0/3) with dune sands and this in a gradual way.
Taking into account the results of this study in terms of mechanical performance, and in order to valorize this local material available in abundance in the south of Algeria, one can retain for formulation of the 0/14 bituminous concrete a formulation containing a rate of dune sands up to 20%.

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