Performance Improvement of Dune Sand Asphalt Concrete With Two Different Types of Fillers

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ABSTRACT.
This paper shows the results of an experimental study aboutthe contribution to the valorization of dune sands in hot mix asphaltin road pavements. Toward compensate for the lack of filler in dune sands, fivemixtures were improved by two types of filler: limestone filler and crushed dune sand.The experimental testing plancomprisesMarshall test, moisture sensitivity and uniaxial tension test. The addition of crushed dune sand and limestone fines to hot mix asphalt based in dune sand has a positive effect. The results of the tests show that the mixtures with of crushed dune sand give better characteristic than the mixtures with limestone filler.

KEY WORDS. Bituminous concrete; Dune sand; Marshall test; Moisture sensitivity; Modulus.

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INTRODUCTION

The cost of constructing and maintaining roads in desert areas is high, and this is mainlydue to construction materials with not sufficient mechanical properties to withstand natural factors and traffic volume, which makes it inevitable to bring them from other regions. In arid and hot regions, such as in North African or Middle Eastern countries, roads frequently deteriorate more rapidly than in temperate climates[4]. Where daytime air temperatures can reach 55 °C, resulting in road surface temperatures exceeding 70 °C [5] with low humidity and a minimum of 0 ◦C in winter [7].

Dune sand is a plentiful material in several universal regions. Due to its mineralogical composition and fineness, it has various motivating mechanical characteristics [18], is usually almost spherical, well rounded [15,17,21], and fine grained [16].Several studies have been conducted to introduce dune sand into hot asphalt mixtures. Akacem et al.[1] proposed a system to improve the skid resistance of bituminous concrete prepared with limestone aggregates by the addition of dune sand up to 20%.Other studies show that mixing 33% of dune sand with 63% of sand manufactured with appropriate asphalt binders would improve the stability of the hot asphalt concrete by 55%[6].Neji et al.found that the addition of dune sand showed an optimum at the rate of 10% for stability[18]. Akacem et al. [2]prove thattheincorporation of dune sand up to rate a 20% improve the stability, the compressive strength for booth modes dry and immersion and an encouraging improvement for water resistance.

The effectiveness of asphalt mixtures generally depends on the adhesion and bond between binder and aggregate. Stripping is a key failure of asphalt mixtures due to the penetration of water between bituminous binder and aggregate, which happens as a result of damage of adhesion between asphalt and aggregate [13]. The aggregate form and texture influence the interlock level of asphalt mixtures. It is mostly recognized that rough cubical aggregates pay to better performance than those even rounded aggregates due to the high interlock level presented by rough cubical aggregates.Furthermore, air void is regarded as a main factor in the moisture damage of asphalt mixtures[19]. There have been a great number of techniques to make asphalt mixtures perform well. A common technique is to incorporate fillers to reinforce asphalt pavement [14].Suitable quantities of filler make, a lower volume of voids, the mixture denser and impermeable and decrease,Zoulikha et al. [22] and Sami et Kaouther[20]improve that the increase in the percentage of the filler makes decrease the stability on the slopes under the influence of the temperature.

MATERIALS AND METHODS

The materials used in this study are the same as those usually used in ordinary asphalt concrete, such as 3/8 and 8/15 gravel, virgin bitumen 35/50, moreover dune sand, crushed dune sand and limestone filler.

Asphalt Binder

The bitumen used in this study come from SDIRA Melter asphalt El-Oued imported from Spain, it is a virgin grade bitumen (35/50) often used in Algeria for the manufacture of bituminous concrete in layers rolling. Characterization tests were carried out on the latter; these are the needle penetrability tests (PEN at 25°C), the ball and ring softening test (TBA) as well as the determination of the relative density.

The usual characteristics of the bitumen are summarized in table.1.

Test	Test Standard Value	Value
Penetration at 25°C, 0.1(mm)	EN-1426[8]	43.5
Softening Point, °C	EN-1427[9]	54
Specific Gravity	NA-5224[3]	1.015
Flash Point	EN-12591[10]	285

Table 1: Basic characteristics of the asphaltbinder used.

Aggregate

The gravels used in this study come from the Ain Touta quarry 80 km from Biskra. The two fractions used in the different mixtures are 3/8 and 8/15. The nominal maximumaggregate size was selected as 14 mm.

The dune sand was taken from the three sides of a dune called Touareg. The Touareg dune is one of the thousands of dunes of the Grand Erg Oriental, it is located southwest of Ouargla about 25km, its geographical coordinates are latitude 31° 48'53'' is 5° 14' 06''.

Table.2 presents the recorded average geotechnical characteristics of the aggregates. The particle size curves are shown in figure.1.

Test	3/8	8/15	DS
Real density (g/cm3)	2.61	2.62	2.66
Cleanliness	0.80	0.50	-
Flatness	17.60	16.80	-
Los Angeles Test	18.60	19.50	-
Micro-Deval Test	16.50	18.20	-
ES (%)	-	-	86.40

Table 2: Geotechnical characteristics of aggregates.

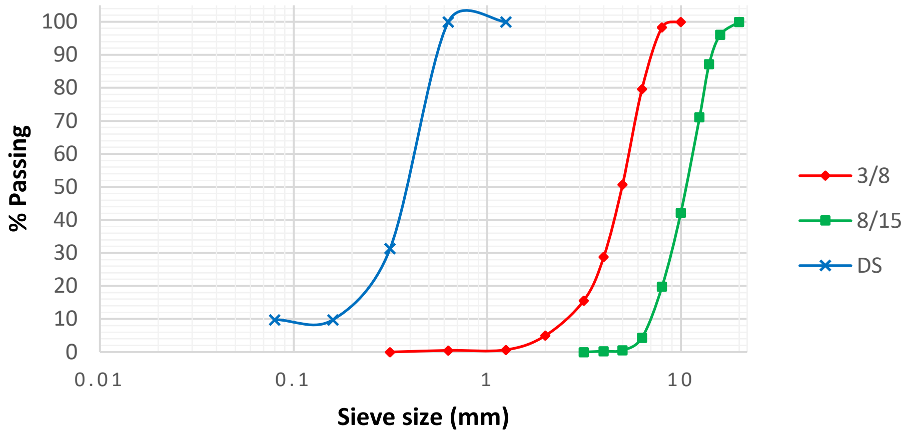

Figure 1:Grains size distribution.

Figure 2: Filler used in study; A: limestone filler, B: rushed dune sand.

Fillers

Limestone Filler

The mineral filler used in this study is a filler pulverized limestone produced by the CALCO company, it is commonly used, in low levels, for the improvement of bituminous mixes as well as other uses, particularly agricultural.

Crushed Dune Sand

In order to provide the necessary quantity of fines for the mixtures, we ground the dune sand using the Micro Deval Dry Machine (grinding process without water). Its mechanism provides an excellent environment to produce crushed sands. The grinding process consists of putting in each cylinder 1500 g of 1 mm sieve sand with 3000 g of spherical balls of 10 mm ±0.5 mm in stainless steel, the grinding time is set at 03 hours with a speed of 100 rev /min ± 5 rpm for a total of 18000 rpm.

The physico-chemical characteristics of limestone filler and crushed dune sand are presented in

Table 3.

Chemical analysis	Limestone Filler (%)	Crashed dune sand (%)
MgO	0.52	-
$Ab0_3$	0.40	-
$Fe20_3$	0.42	0.21
$CaC0_3$	97.9	1.28
SO_4 Ca, $2H_2O$	-	2.72
SO_4	-	0.61
Insoluble	-	93.07
Real density (g/cm^3)	2.72	2.65

Table 3: Physico-chemical characteristics of limestone filler and crushed dune sand.

Tests

Marshall Test

Marshall Test was carried out in order to find the preliminary composition of the mixture. Furthermore, this made it possible to respect the mechanical and physical characteristics considered in the European specifications EN 12697-34[11].Cylindrical Marshall specimens were prepared using different percentage of binder and grain size of aggregates corresponding to asphalt concrete as shown in Table 4. Based on the granulometry of the mixtures and the ratio of fines, the optimum percentage of binderresulted B (by weight of aggregate) was between 5 and 6%.

Mixtures	8/15(%)	3/8 (%)	DS(%)	LF(%)	CDS(%)	B (%)
M1	33	33	34	0	-	5.30
M2	30	30	38	2	-	5.76
M3	31	31	34	4	-	6.00
M4	30	30	38	-	2	5.76
M5	31	31	34	-	4	6.00

Table 4: Mixturescompositions.

Moisture Sensitivity

Moisture sensitivity was studied by means ofEuropean standard for moisture damage NF EN 12697-12 method B[12]:compressive strength after conditioning 7 days at 18°C in air (R) or in a water bath (r), to determine r/R, the objective of this test is to determine, at 18°C for a given compaction, the water resistance of a hot hydrocarbon mixture from the ratio of the compressive strengths with and without immersion of the specimens.

Stiffness Test

The principle of the test consists of applying uniaxial sinusoidal tension on cylindrical specimens in strain control mode, levels lower than about 50 μm. The cylindrical specimens are 100mm in diameter and between 62mm and 67mm in height depending on each mixture. A series of strain amplitude sweep tests are performed at different temperatures (10, 15 and 20°C) and 10^{-3} Hz frequency.

RESULTS AND DISCUSSION

Marshall Test

T est results for Marshal stability for various mixes tested represented graphically in figure 3.

A steady rise in the stability value is initially observed with increasing any type of filler content.In general, the stabilities increase almost linearly between 0 and 2% of filler from the average value of 956.47 Kg up to 1223.57 Kg almost 28%.

Crushed dune sand has the same influence on asphalt behavior with respect to Marshall stability. The stability increases almost linearly between 0 and 2% load from the value of 956.47Kg up to a maximum stability value of 1317.18Kg, i.e. nearly 38%.

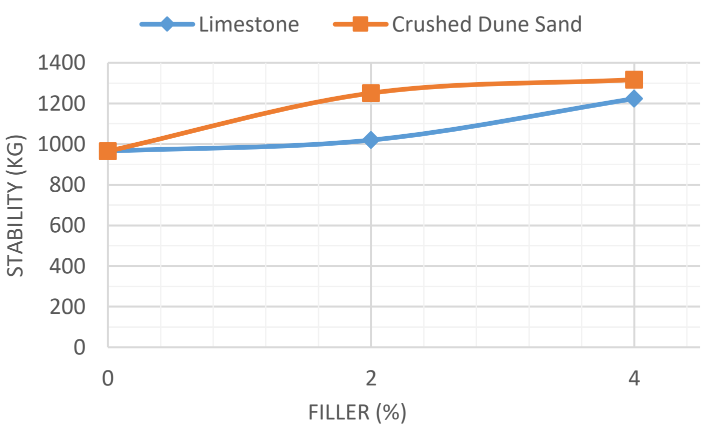

Figure 3: Evolution of the Marshall stability according to the quantity of filler.

The incorporation of filler leads a variation in the level of flow in a way not similar to the bi-filler type, the limestone filler having a negative influence on the bituminous mixture based on dune sand in flow. According to the figure4, we noticed an increase in throughput from 2.68 mm to 5.13 mm, or almost 91.5%. In contrast, crushed dune sand fillers show a relatively small improvement in flow from 2.68 mm to 2.45 mm.

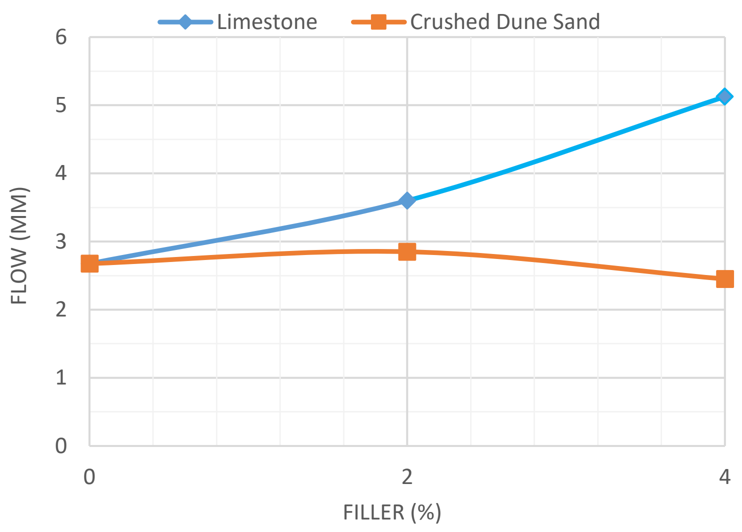

Figure 4: Evolution of the Flow according to the quantity of filler.

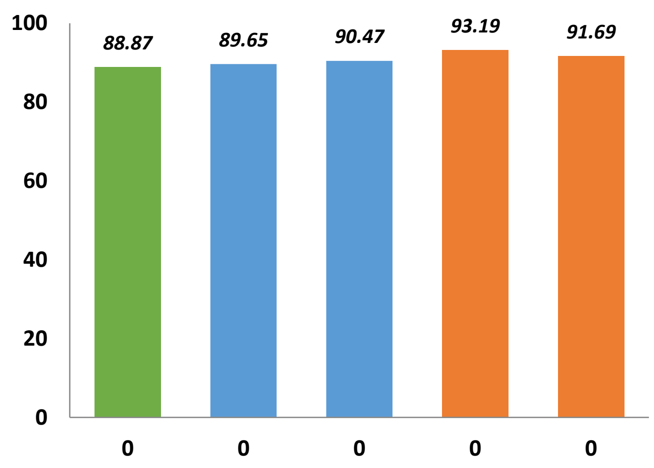

Figure 5: Effect of filler on compactness.

According to figure 5, the addition of limestone filler or crushed dune sand to the bituminous concrete based dune sand improves compactness therefore reduction in air voids, however the influence of this is relatively weak and remains below 2.5% for limestone filler and almost 3% for crushed dune sand. The addition of 2% crushed dune sand gave a maximum compactness value.The maximum compactness value is 90.47% for 4% limestone filler and 93.19% for 2% crushed dune sand.

Moisture sensitivity

The results of resistance to moisture damage are show in table 5. Based on these results all mixtures studied have acceptable characteristics for Duriez test. The addition of fillers has a positive effect on the resistance to air compression and after imbibition as well the r/R ratio, this is essentially due to the closed surface of the test specimen which gives us a more water-resistant mixture. Because the proportion of voids in the M1 mixture is high, the results were the worse it is compared to other mixtures.

It should be noted that the type of fines has also influences the moisture damage, obtaining the highest improvements when crushes dune sand are used.Obviously that the highest improvement when adding 2% of crushed dune sand.

Mixtures	R (MPa)	r (MPa)	i
M1	7.853	6.351	0.809
M2	8.009	7.090	0.885
M3	8.815	8.130	0.922
M4	11.856	11.267	0.950
M5	10.709	9.996	0.933

Table 5: Compressive strength of dry (R) / wet (r) specimens and retained resistance (i) according tostandard “Duriez” storage conditions (7 days in a 18°C water bath)

Stiffness Test

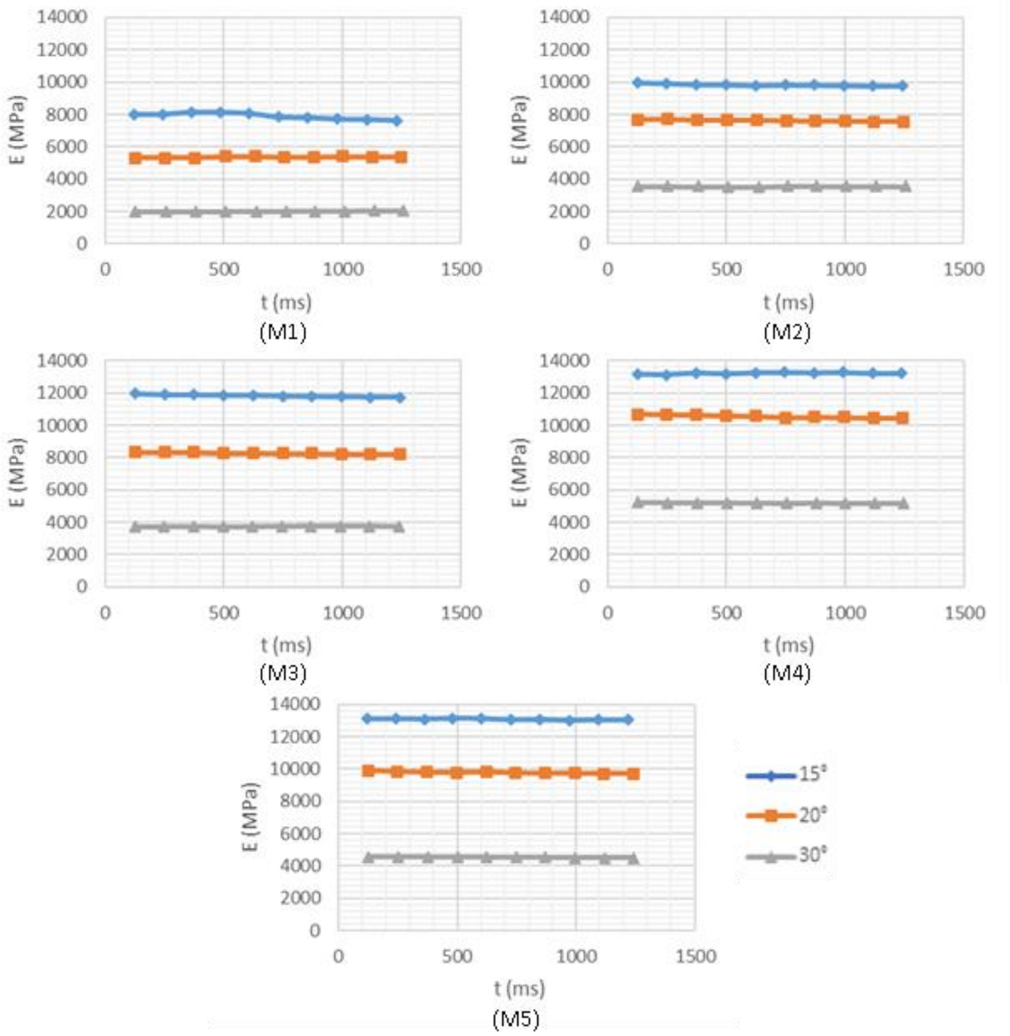

Figure 6: Normalized modulus master curve at 15, 20 and 30°C

Figure 6show the experimental results of modulus for the uniaxial tension test on cylindrical specimens. The addition of crushed dune sand and limestone fines to hot mix asphalt basedin dune sand has a positive effect on the resultsfor the uniaxial tension test.The results also showed that the effect of crushed dune sand was more effective than limestonefiller on the bituminous mixture based on dune sand, as the maximum value of the modulus was noted when adding 2% of crushed dune sand, and it hopped from 7902 MPa to 13219 MPa, i.e. 67% at 15° C, from 5366 MPa to 10552 MPa i.e. 96%at 20°C and from 2023 MPa to 5194 MPa i.e. 156% at 30°C.

CONCLUSION

This research aimed to improvement of dune sand asphalt concrete with two different types of fillers, limestone filler and crushed dune sand. Five mixes were tested by changing the amount of filler. The contribution of filler has a great influence on the characteristics of bituminous concrete based on dune sand. The results found allow us to conclude the following points:

- A gain in stability greater than 28% for limestone filler and 38% for crushed dune sand.
- A strong increase in flow reaches 91.5% for limestone filler and a slight decrease or even an almost constant flow for the crushed dune sand.
- An increase in compactness of 2.3% for limestone filler and 3% for crushed dune sand.
- Positive effect on the resistance to air compression 12% for limestone filler and 50%for crushed dune sand.
- Improvementon the resistance to compression after imbibition 28% for limestone filler and 77% for crushed dune sand.
- Enhancement on the uniaxial tension testresultswherethe value of the model has improved at very encouraging rates.

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