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Research Article

Evaluation of the uses of treated sawdust as a partial replacement for aggregate in hot mix asphalt

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Abstract: Undoubtedly, the damage to the upper layer of the road pavement caused by a tremendous load of vehicles and climate factors is an alarming and challenging fact to both government and researchers in the respective field. Thus, and with the aim to come up with a remedy, the potential of sawdust, as a renewable material for replacing aggregate in hot-mix asphalt, was examined. Therefore, a full factorial design of experiment (DOE) was conducted to evaluate the effects of sawdust content (5%, 10%, and 15% of total aggregate volume) on Marshall stability flow values and density. The range of binder from (5.77% to 6.45% means from low level to high level) and the temperature of mixing (140°C to 180°C) and the time of mixing (2 minutes to 4 minutes) as well. Also, to improve its durability, the sawdust was treated with an established emulsion coating. Accordingly, it has been demonstrated in this study that sawdust can be utilized as a partial replacement for (3/8) aggregate. Indeed, the use of this renewable material resulted in an increase in Marshall stability, a decrease in density, and flow values within the accepted range, leading to a positive environmental impact. Additionally, sawdust is considered a waste material, making it cost-effective. Ultimately, the acceptance criterion allows for the replacement of up to 7% of the aggregate for both low and high-level values; however, if more than 7% is replaced, only the highest-level value is considered acceptable. Thus, an economically and technically efficient solution may have been provided by this study.

Keywords: sawdust, Marshall test, full factorial DOE, mixing time, mixing temperature.

1. Introduction

Roads are a key to develop any country in almost any field. Therefore, their pavement should meet the engineering requirements. Accordingly, the hot mix asphalt which is the most used mix in Algeria and other countries is witnessing several modifications by adding or replacing materials. Two main categories of additive materials can be said to exist, namely valuable materials and waste materials. Indeed, (Hamid et al., (2020)) have proved the positive effect of adding the Rock Wool in the hot mix asphalt, and the terms they controlled were Fatigue life and Stiffness modulus, and the optimum percentage of rockwool is 0.8% by weight of mixture. In another article there was possibility to improve the rutting resistance of asphalt pavement by using the carbon nanotubes as an additive. this improvement consists of an increase in rutting resistance by 61.0% and stability by 35.0% at 1.5% of the carbon nanotubes (Mohammed Q. et al., 2021). Also, other study shows the benefit of Nano Sb2O3 on early and long-term aging behavior of bitumen and asphalt mixtures and the best rutting performance was determined for 3% Sb_2O_3 modified bitumen with 4.3 mm rut depth (Mustafa Y. et al., 2021).

One of the most evident choices for additive or replacement materials is waste materials or natural materials because they are environmentally friendly and economically efficient. Valerio and Jorge Rodriguez (2018) used tetra pak material in porous asphalt mixtures and compare it to porous asphalt mixtures with cellulose fibers, the comparison was in terms of drain-down and air void and permeability and indirect tensile strength (ITS) (Valerio et al.,2018). Besides, the use of waste polymers was determined as percentage of optimum bitumen content and as result bitumen that has been polymer-modified showed an increased rigidity and less sensitivity to the effects of high temperatures. In comparison to unmodified asphalt mix, polymer-modified asphalt mix is found to have greater stability, rutting resistance, and load bearing capability (Muhammad B K et al., 2019). Another study also investigated the engineering properties modified binder with waste plastic polymer, and posited that 6-8% of waste plastic should be present in order to increase aging and rutting resistance. Additionally, 8% PET Polyethylene Terephthalate increases the resistance to fatigue cracking (Nuha et al., 2020). Other 2022 study by Mustafa Akpolat compares crumb rubber (CR) and Sasobit-modified asphalt, revealing that CR + Sasobit enhances rutting resistance but diminishes rheological benefits at low temperatures, increasing stiffness and lowering fatigue parameters, particularly at high strain values (> 6%) (Mustafa Akpolat.,2022).

In contrast, natural fibers and materials were used by other researchers such as Laiana et al (2019) who used banana fibers in SMA mixtures, and then indirect tensile strength, resilient and dynamic modulus, flow number, and fatigue life tests were conducted, and as a result, the fibers improved the mechanical properties (Laian et al.,2019). Within the same context, burned sawdust was used as a replacement for filler in asphalt concrete with different percentages. this use of sawdust gave an improvement in terms of Marshall stability and flow and bulk density (Osuya.,2017). In a recent study by Ali et al (2018), waste materials were used to modify hot mix Asphalt and the results have showed reducing the final strain of asphalt mixtures (Ali et al.,2018). One of the common waste materials used in asphalt mixes is waste plastic, which resists to moisture damage and shows improvement (Rajan et al.,2018) another study explores using basalt fiber to modify porous asphalt mixtures, aiming for economic and environmental benefits through ferrochrome slag recycling. Adding 0.2% basalt fiber significantly enhances mechanical performance, as indicated by various tests (Altan Çetin and Gökhan Oral.,2022).

In the review of the analysis of the use of natural fibers and asphalt rubber binder in discontinuous asphalt mixtures by Sandra Oda et al (2011), many types of natural fibers were evaluated such as cellulose and coconut also sisal, and the results of mechanical tests were accepted. Also, sawdust can be used in ordinary concrete as a replacement for fine aggregate (Tomas and Ganiron., 2014). Date palm fibers were employed in asphaltic concrete, and the test results demonstrated a positive aspect of their addition, leading to the amelioration of the mechanical performance (the modulus), of course, with a well-defined percentage and length of date palm fibers (Zidouk, 2019). Other studies consider Marshall Stability and indirect tensile strength (ITS) and moister susceptibility for dense graded bituminous mixes with sisal fibers and coal ash (Saswat and Mahabir.,2016).

In most cases of using vegetal materials in asphaltic concrete, the vegetal material should be treated with heating treatments (Sandra et al.,2012; Martina et al.,2010), chemical treatments (Abderrezak et al.,2015), and coating treatments with a thin film of coal ash or polyethylene terephthalate (Saswat and Mahabir.,2016; Mojtaba et al.,2021), with a lot of other ways of treatment. The experimental designs of full factorial DOE allow for better-organized tests that are involved in scientific studies or industrial studies (Bordjiba et al.,2016). The sawdust and waste materials were used to replace aggregates in concrete hollow blocks in a study in 2022 and the results of the study show promising applications for these materials (BARBUȚĂ et al.,2022). Also using natural additives for warm asphaltic mix such as the natural zeolites of the Tasajera and the sugar cane wax resulted in an acceptable performance plus a good impact on the environment by using the renewable resource (Rosa et al.,2018).

The utilization of sawdust in hot mix asphalt (HMA) is infrequently observed, particularly in roles involving filler replacement or as a broad additive. Sawdust is implemented in a powdered state to exert control over various factors, including binder content, mixing duration, and manufacturing temperature. Notably, the primary objective in incorporating natural fibers is to mitigate issues related to drain-down. However, its application as a substitute for coarse aggregate in hot mix asphalt has not been previously explored. This substitution serves the overarching purpose of conserving non-renewable resources. This study is principally focused on enhancing specific engineering criteria, such as Marshall Stability and flow properties.

2. Methods

2.1. *Sawdust treatment*

Generally, vegetal materials used in any construction need to be treated to protect them from external conditions and then to extend their service life. Therefore, three types of treatments in terms of absorption, as defined by the norm NF EN 772-21, were opted to be compared, which are the chemical treatment, heating treatment, and coating treatment.

2.1.1. Chemical treatment

Chemical treatments were done with NaOH solution with three concentrations of 5% and 10% and 15% and three times of immersion for each concentration during 24 hours and 48 hours and 72 hours. Figure 1 shows sawdust during immersion. The best result of this treatment is that of 8.5 % which is better than the control sample.

Figure 1. Sawdust treated with NaOH.

Table 1. Weight of absorbed water after chemical treatment with NaOH.

Concentrate	5%	10%	15%
Weight of absorbed water after 24 hours of treatment (g)	188.8	185.3	181.3
Weight of absorbed water after 48 hours of treatment (g)	182.7	183.9	181.2
Weight of absorbed water after 72 hours of treatment (g)	182.9	185.9	180.7

NB: The weight of absorbed water in 100 grams of sawdust in the control sample is 196.1 g.

2.1.2. Heating treatment

The second type of treatment is a heating treatment which is heating the sawdust to the degrees of 140°C, 160°C, and 180°C for 24 hours, the best result of this treatment is 7.3% better than the control sample. Figure 2 shows sawdust after heating.

Figure 2. Sawdust treated with heating.

Table 2. Weight of absorbed water after heating treatment.

Degree of heating	140°C	160°C	180°C
Weight of absorbed water after 24 hours of treatment (g)	185.3	184.1	181.8

NB: The weight of absorbed water in 100 g of sawdust in the control sample is 196.1 g.

2.1.3 Coating treatment

The treatment of coating consists of using the over-established emulsion to coat the sawdust; the result of this treatment indicates that the sample of 40% is better than the control sample. Figure 3 shows sawdust after coating.

Figure 3. Sawdust treated with coating.

Table 3. Weight of absorbed water after coating treatment

Concentrate of emulsion	50%	33%	25%
Weight of absorbed water after 24 hours of treatment (g)	117.7	147	166.7

NB: The weight of absorbed water in 100 grams of sawdust in the control sample is 196.1 g.

2.2. Experimental design

The full factorial design uses all possible combinations at all levels of all factors. Given that, there are four factors with two levels for each factor. The factors are the sawdust percentage, the binder content, time of mixing, and the temperature of manufacturing with 5% and 15% levels for the sawdust, 5.77%, and 6.45% levels for the binder content, 2 minutes and 4 minutes levels for the mixing time, 140°C and 180°C levels for temperature. In fact, the number of experiments having been accomplished in this study is 16 and one is for a central point with 10% of sawdust, 6.11% binder content, 3 minutes mixing time, and 160°C temperature.

Table 4. Design summary.

Factors:	4	Base Design:	4; 16
Runs:	17	Replicates:	1
Blocks:	1	Center points (total):	1

Table 5. Full factorial design details.

	Factors			
Test	Binder percentage (%)	Sawdust percentage (%)	Mixing temperature (°C)	Mixing time (minutes)
1	5,77	5	140	4
2	6,45	5	180	4
3	5,77	15	180	2
4	6,45	5	140	4
5	6,11	10	160	3
6	5,77	5	140	2
7	5,77	5	180	4
8	6,45	15	180	2
9	5,77	15	140	2
10	6,45	15	180	4
11	6,45	5	140	2
12	5,77	5	180	2
13	6,45	5	180	2
14	6,45	15	140	2
15	5,77	15	140	4
16	5,77	15	180	4
17	6,45	15	140	4

3. Materials

3.1. Bitumen

The used bitumen is 40/50 class manufactured by NAFTAL, a branch of the Algerian oil company Sonatrach. Table 6 summarizes the physical and mechanical properties of the base bitumen. The analyzed bitumen meets the requirements of the 40/50 class according to the NFT65-001 standard.

Table 6. Binder characteristics.

Test type	Result	Mean	Specifications
Penetrability at 25 ◦C (1/10mm)	42.7	40	35–50
Temperature ring and ball (TRB ◦C)	56	53	50–58
Relative density (g/cm^3)	1.041	1.01	1.0–1.05

3.2. Aggregates

The aggregates 0/15 used in this study is coming from ALCO-GAZ METLILE quarry in GHARDAIA, with Los Angeles results test, Micro Deval results from test, Flakiness results test, and Aggregate property are shown in Table 7. As for the sand equivalent, it is presented in Table 8. Figure 4 displays the granulometry curve of the aggregates.

Table 7. Coarse aggregate characteristics.

Class (d/D)	Flakiness (%)	Los Angeles (%)	Micro Deval (%)	Property (%)
3/8	17	36	10	3.67
8/15	15	33	22	0.56

Table 8. Sand equivalent.

Sand 0/3	Sand equivalent (at 10% fine) (%)	<0.08mm (%)
(01)	63	27

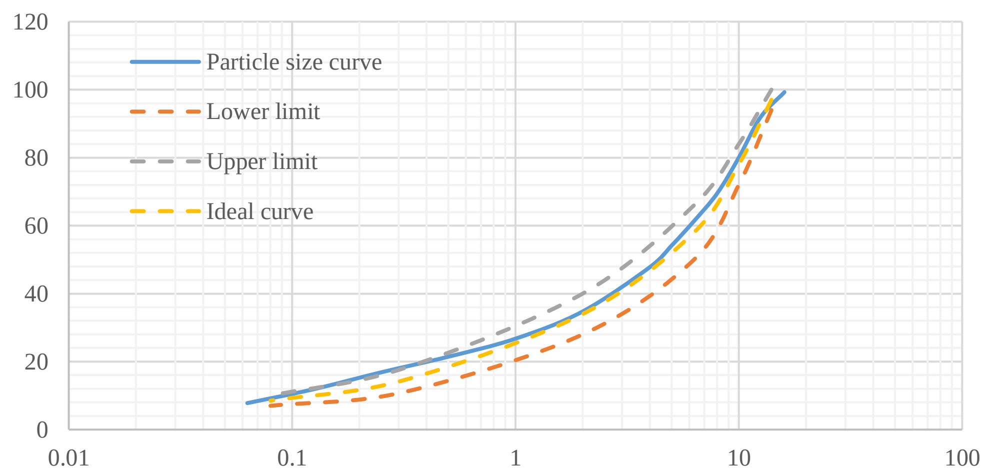

Figure 4. Granulometric analysis curve of the aggregates.

3.3. Sawdust

The sawdust used in this research was gathered from a carpentry shop, the redwood is the source of our sawdust. The size of sawdust particles after coating treatment varies from 2.5 mm to 9 mm with a density of 0.65 g/cm³. The coating treatment done with an over established emulsion.

3.4. Control of asphalt mixture properties

To determine this optimal binder content, the concept of specific surface area of the aggregates, denoted (Σ) and expressed in m²/kg, is introduced, meaning the surface area the aggregates would have if they were considered as spheres. For a given gradation mix, the following formula provides an approximation of the specific surface area (Σ): $100\ \Sigma=0.17G+0.33g+2.3S+2.3s+135f$.

With

G: percentage of large gravels (ø > 11)

g: percentage of small gravels (ø > 6/11)

S: percentage of coarse sand (ø > 0.3/6)

s: percentage of fine sand (ø > 0.08/0.3)

f: percentage of filler (ø < 0.08)

In our study the specific surface area (Σ) = 13,893 m²/kg

The optimal binder content, as a function of the specific surface area of the aggregates, is given by the following experimental formula: P = $\alpha k\sqrt[5]{\Sigma}$

With:

P: binder content (%)

α: factor dependent on the type of aggregates (2.65/bulk density of aggregates)

Σ: specific surface area of aggregates (m^2/kg)

k: stiffness modulus (K ranging from 2.75 for the mixes giving the maximum resistance to deformation, to 3.5 for the more flexible mixes).

In this study a=2.65/MVRg with MVRg is the density of the mix of aggregate for our mix MVRg=2.643 so a=1.003.

Table 9. Stiffness modulus with binder content.

K	3,4	3,6	3,8
P	5,77	6,11	6,45

In this case, the three possible binder content values are displayed in table 4, and the best binder content was chosen after comparing the results of Marshall tests. In our case, the best binder content is 6.11%, with a mixing time of 3 minutes and a mixing temperature of 160°C.

4. Results and discussion

4.1. Marshall compactness

According to the results shown in figure 5, the sawdust percentage, mixing temperature, binder percentage, and mixing time have a main effect on the compactness. The PARETO chart of the effects helps to order these last four factors by their effect on the Marshall compactness. Figure 6 shows four plots for the effect of the four factors on the result of Marshall compactness.

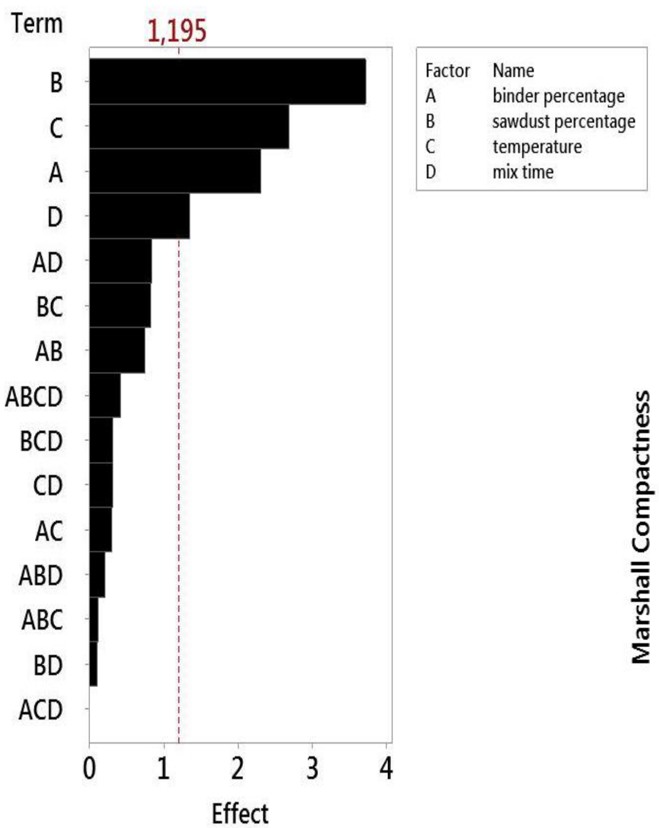

Figure 5. Pareto chart of the effects of Marshall compactness.

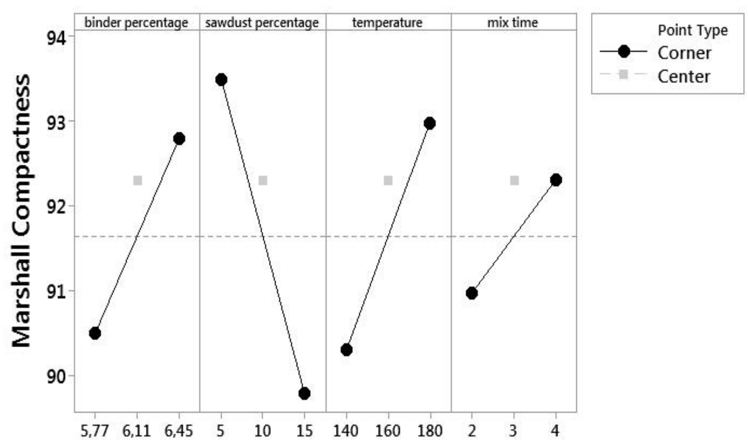

Figure 6. Main effects plot for results Marshall compactness.

The first main factor affecting compactness can be observed as the sawdust percentage because sawdust possesses a very low density and greater binder absorption than the aggregates. The second main factor is the mixing temperature, the temperature, indeed, it has a high effect because high temperature makes sawdust shrink more and the shrinking reduces the binder absorption and elevates the density by reducing the volume. The third main factor is the binder because voids fill with excessive binder. The fourth main factor is mixing time because the more the sawdust mixes the less void the sawdust keeps which consequently increases the compactness. By fixing the temperature at 160°C and the mixing time in 3 minutes, Figure 7 shows the relation between sawdust percentage, binder percentage, and the result of Marshall compactness.

Table 10. Results of Marshall compactness

	Factors				Results
Runs	Binder percentage (%)	Sawdust percentage (%)	Temperature(°C)	Mix time (minutes)	Compactness (%)
1	5,77	5	140	4	91,06
2	6,45	5	180	4	96,36
3	5,77	15	180	2	90,65
4	6,45	5	140	4	95,95
5	6,11	10	160	3	92,3
6	5,77	5	140	2	90,65
7	5,77	5	180	4	93,11
8	6,45	15	180	2	90,98
9	5,77	15	140	2	86,55
10	6,45	15	180	4	93,47
11	6,45	5	140	2	92,64
12	5,77	5	180	2	93,11
13	6,45	5	180	2	95,12
14	6,45	15	140	2	88,09
15	5,77	15	140	4	87,78
16	5,77	15	180	4	91,06
17	6,45	15	140	4	89,74

NB: Table 10 is the source of data exhibited and illustrated in figure 5, figure 6, figure 7, and figure 8.

The surface plot presented in Figure 8 allows us to predict the direction of variation of Marshall compactness, in terms of sawdust percentage and binder percentage by fixing the temperature at 160°C and the mixing time in 3 minutes.

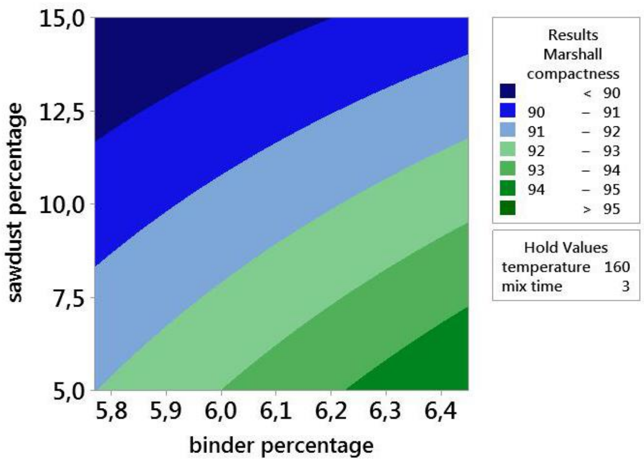

Figure 7. Contour plot of result of Marshall compactness VS sawdust percentage; binder percentage.

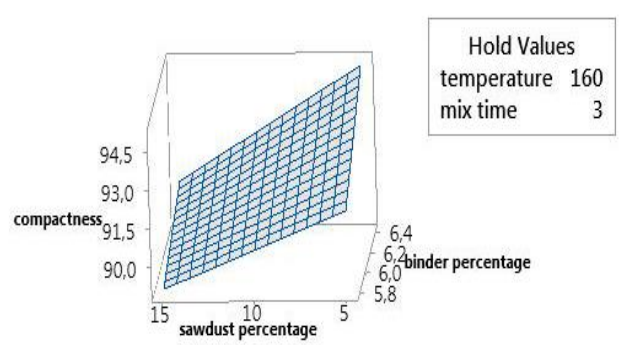

Figure 8. Surface plot Marshall compactness VS sawdust percentage; binder percentage.

After when observing Figure 7 and Figure 8, a balance is struck between the sawdust percentage and the binder content in order to achieve the desired levels of compactness or void ratio, whether they are high or low.

The higher the binder content, the greater the compactness, and the lower the void ratio, leading to conclude that an increase in binder content results in increased compactness and reduced void ratio.

4.2. Marshall stability

As can be observed in Figure 9, the PARETO chart of the effects of factors on Marshall stability, none of the controlled factors has a direct main effect on the result.

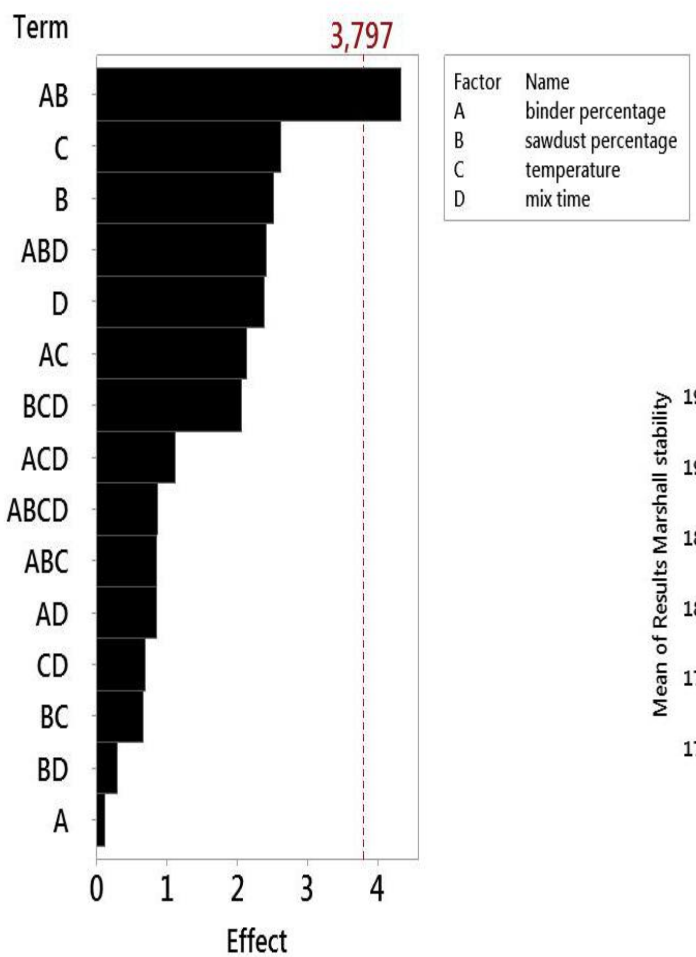

Figure 9. Effects Pareto for results Marshall stability.

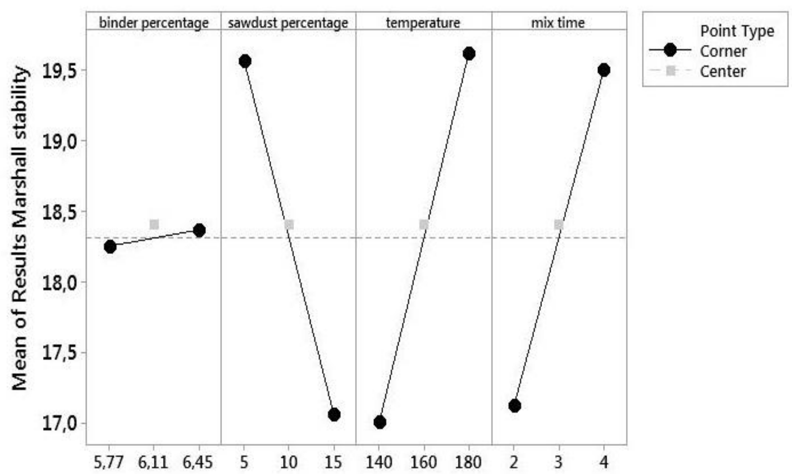

Figure 10. Main effects plot for results Marshall stability.

However, the interaction between the binder content and the sawdust percentage has the main effect on the Marshall stability (Figure 9) because the sawdust has more absorption capacity of binder than the aggregates. This means on the one hand, more sawdust with less binder equals great stability; and on the other hand, more sawdust with more binder will lowers the stability. Considering the elastic nature of sawdust, elasticity helps extend elastic and plastic deformation before the rupture point. In addition, Figure 9 exhibits the ranking of the factors that have a noncritical effect on stability. The first one of the noncritical factors is temperature, then the sawdust. Furthermore, in Figure 10, the effect of each factor on Marshall stability is depicted. In fact, the order of the factors in terms of their effect on results can be observed to be increasing as follows: temperature, sawdust percentage, and mixing time.

Table 11. Results of Marshall stability.

	Factors				Results
Tests	Binder percentage (%)	Sawdust percentage (%)	Temperature(°C)	Mix time(minutes)	Stability (kN)
1	5,77	5	140	4	17,125
2	6,45	5	180	4	23,642
3	5,77	15	180	2	19,261
4	6,45	5	140	4	24,151
5	6,11	10	160	3	18,41
6	5,77	5	140	2	13,018
7	5,77	5	180	4	18,674
8	6,45	15	180	2	13,36
9	5,77	15	140	2	13,702
10	6,45	15	180	4	15,529
11	6,45	5	140	2	17,431
12	5,77	5	180	2	20,578
13	6,45	5	180	2	21,923
14	6,45	15	140	2	17,72
15	5,77	15	140	4	19,666
16	5,77	15	180	4	24,024
17	6,45	15	140	4	13,212

NB: Table 11 is source of data shown in Figure 9, Figure 10, Figure 11, and Figure 12.

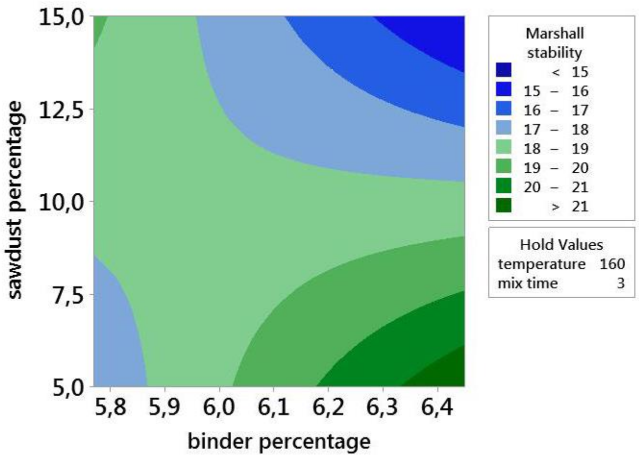

Figure 11. Contour plot of Marshall stability VS sawdust percentage; binder percentage.

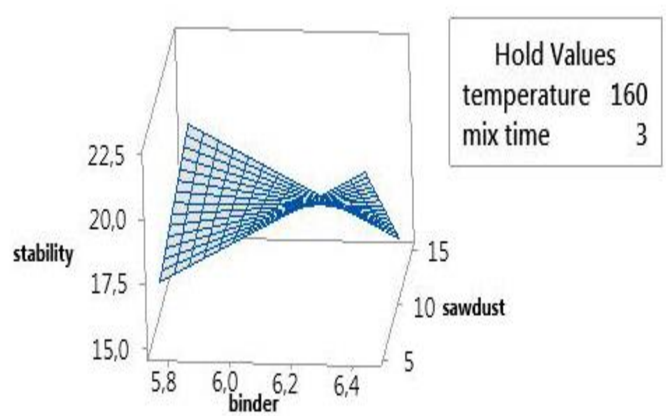

Figure 12. Surface plot of Marshall stability VS sawdust percentage; binder percentage.

Data proved in figure11, explain the reason why the interaction between binder content and sawdust percentage has the main effect on the Marshall stability. Moreover, Figure 12 helps to predict the results within the limit of the value of the inputs, and gives an idea about the result out of the limits of the inputs value. Figure 11 shows that the lowest percentage of sawdust (5%) can give a high stability value with highest binder percentage of 6.45 %. this would be explained by the absorption of sawdust and its relation with the excessive binder in the mix. In addition, with the highest sawdust percentage (15%), the fragility of sawdust in the mixture must be considered.

4.3. Flow test

The flow value is affected mainly by the sawdust percentage as shown in the Effects Pareto for flow value chart (Figure13).

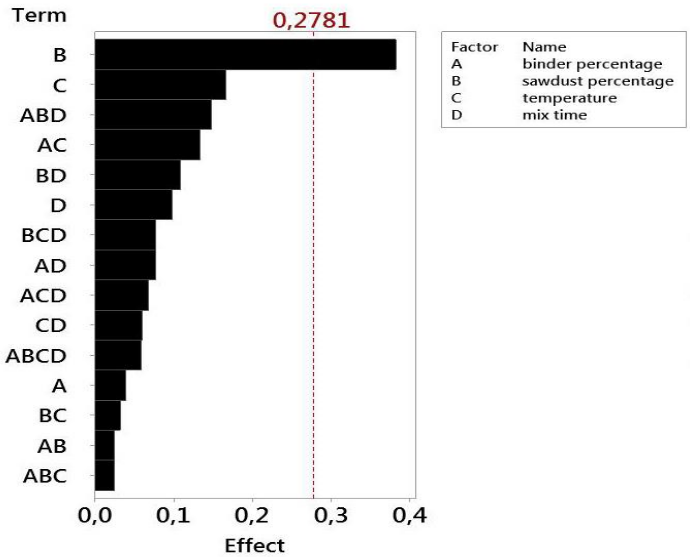

Figure 13. The effects Pareto for flow value.

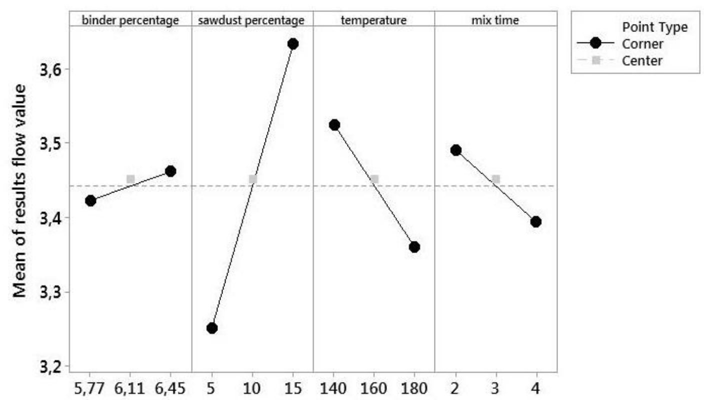

Figure 14. Main effects plot for flow value.

As illustrated by Figure14 hand with Figure 13, the major effective is the sawdust percentage, the second effective is temperature and the third effective factor is mixing time. Accordingly, the flow increases proportionally with the sawdust percentage because of the low density and elastic nature of sawdust. Additionally, the high temperature assists in reducing the elasticity of sawdust and increasing its density, resulting in a consequent decrease in the flow value. According to Figure 15, the flow can be reduced by reducing the amount of binder or reducing the sawdust amount. Furthermore, Figure 16 can help predicting the direction of the flow value inside and outside of the limits of the controlled factors. Therefore, decreasing the quantity of sawdust and decreasing the binder to the minimum allowed decreasing the flow value.

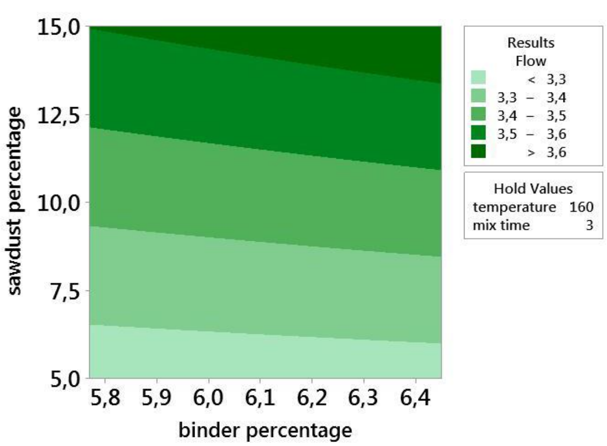

Figure 15. Contour plot of flow.
VS sawdust percentage; binder percentage.

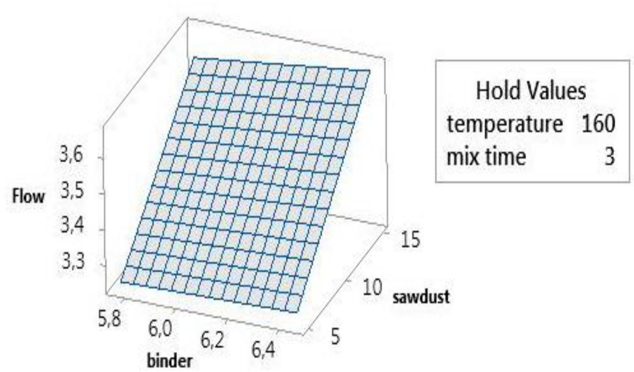

Figure 16. Surface plot of flow value.
VS sawdust percentage; binder percentage.

The above result can be explained by the high ductility of sawdust particles and the high ductile of the binder, added to that, the low density of the sawdust. Those properties lead to a high flow value. The temperature has also great effect on flow value because the high temperature increases the absorption of binder, which then decreases the flow value.

Table 12. Results of flow.

	Factors				Results
Runs	Binder percentage (%)	Sawdust percentage (%)	Temperature (°C)	Mix time (minutes)	Flow value (mm)
1	5,77	5	140	4	3,244
2	6,45	5	180	4	3,037
3	5,77	15	180	2	3,459
4	6,45	5	140	4	3,051
5	6,11	10	160	3	3,452
6	5,77	5	140	2	3,488
7	5,77	5	180	4	3,265
8	6,45	15	180	2	3,618
9	5,77	15	140	2	3,805
10	6,45	15	180	4	3,674
11	6,45	5	140	2	3,493
12	5,77	5	180	2	2,983
13	6,45	5	180	2	3,456
14	6,45	15	140	2	3,631
15	5,77	15	140	4	3,753
16	5,77	15	180	4	3,391
17	6,45	15	140	4	3,74

NB: Table 12 is source of data shown in figure 13 and figure 14 and figure 15 and figure 16.

4.4. Comparison

4.4.1 Comparison of the results to control samples

The control sample is a sample made without partially replacing the (3/8) aggregate with the treated sawdust, table 12 shows Marshall compactness and Marshall stability and the flow value for the control sample. The control samples were prepared with 6.11% binder content, 3 minutes of mixing time, and 160°C mixing temperature.

Table 12. Results of the control samples

Control sample	Marshall compactness (%)	Marshall stability (kN)	the flow value (mm)
1	96.26	18.12	3.32
2	95.41	17.61	3.51
3	96.9	17.69	3.42
Mean	96.19	17.8	3.41

According to the recommendation on the use of bitumen and hot bituminous mixes for Algerian roads which were authored by the Algerian ministry of public works, table 13 below gives the accepted ranges for Marshall compactness, Marshall stability, and the flow value.

Table 13. The recommended values

Marshall mix criteria	Light traffic		Medium traffic		Heavy traffic	
	min	max	min	max	min	max
Marshall compactness (%)	93	97	93	97	93	97
Marshall stability (kN)	9.5	-	10.5	-	12.5	-
the flow value (mm)	-	4	-	4	-	4

The adding of sawdust in the mix with high percentage with low time mix, and low temperature may disturb the compactness by a given value of compactness out of recommended values.

4.4.2 Comparison of the results to other studies

Table 14. Results compared to other studies

additive	percentage of additive	Marshall compactness	Marshall stability	the flow value
blast furnace slag	4.5	95.39	11.75	3.96
	5.0	96.04	12.86	3.81
	5.5	96.91	13.13	3.84
	6.0	99.15	12.30	4.14
carbon nanotubes	0.05	82.20	11.95	3.87
	0.10	86.30	13.25	3.95
	0.15	90.40	13.63	3.91
	0.20	92.90	14.15	3.89
	0.25	96.10	15.00	3.84

Table 14 shows in the first column two previous studies, the first named behavior of a warm mix asphalt containing a blast furnace slag (Jairo F et al., 2019), and the second under the name of performance evaluation of carbon nanotubes as a binder modifier for asphalt mixtures (Van B L et Van P L., 2020). The two studies were chosen because they provide the Marshall test results and with two types of additives, the first is considered as waste material and the second is non-waste materials.

As a conclusion, this comparison has demonstrated that our study offers better results in term of Marshall compactness and Marshall stability. However, in terms of flow, our study does not offer better results, but they still are in an acceptable range.

5. Conclusions

With a main aim to contribute efficiently to the sustainable development of road pavement, this present research gave the opportunity to numerous significant results which were discussed and interpreted in detail to come up with the following relevant conclusions:

1. Including the sawdust in the hot mix asphalt HMA improves the Marshall stability compared to control samples.
2. Including the sawdust in the hot mix asphalt HMA keeps the flow value in the accepted range.
3. In case of compactness, the use of sawdust in HMA with more than 7% of the total volume of aggregate (regardless of the mixing time, the temperature, and the binder content) makes the compactness value unaccepted according to recommendations.
4. In terms of compactness, a high percentage of sawdust requires the augmentation of the binder content.

Thus, the possibility to partially replace the aggregates with treated sawdust has been demonstrated. Furthermore, major roles are played by the temperature and mixing time. However, a high percentage of more than 15% of sawdust is neither recommended nor desirable, even with high levels of the factors, especially concerning compactness and flow value.

Future scope

After the optimum range of sawdust replacement is defended in this study, other tests can be conducted to further understand the effect of sawdust, such as:

1. Rutting tests for the optimum range.
2. The resilient modulus test for the optimum range.
3. The fatigue test for the optimum range.
4. Modifying the binder contents proposed before starting the Marshall test.

Combining two sawdust treatments such as heat treatment and coat treatment, this combination looks promising.

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References

Hamid, B., Vahid, NMG. , Reza, S., Daniel, S. (2020). Evaluation of Fatigue and Rutting Behaviour of Hot Mix Asphalt Containing Rock Wool. International Journal of Civil Engineering. https://doi.org/10.1007/s40999-020-00532-5

Mohammed, QI. , Mohammed, YF. , Abbas, FJ. (2021). Improving the rutting resistance of asphalt pavement modified with the carbon nanotubes additive. Ain Shams Engineering Journal .Volume 12 (2021) 3619–3627. https://doi.org/10.1016/j.asej.2021.02.038

Mustafa, YA.,Sebnem, K., Mahmoud, E.(2021). Study on the effects of nano Sb2O3 on early and long-term aging behaviour of bitumen and asphalt mixtures. Ain Shams Engineering Journal .Volume 12 (2021) 3531–3542. https://doi.org/10.1016/j.asej.2021.02.041

Valerio, C., Jorge, R.T., Miguel, A., Jorge, R.H. (2018). EXPLORATORY STUDY OF POROUS ASPHALT MIXTURES WITH ADDITIONS OF RECLAIMED TETRA PAK MATERIAL. Construction and Building Materials. Volume 160. Pages 233-239. DOI:10.1016/j.conbuildmat.2017.11.067

Muhammad, BK., Nadeem, AQ., Arshad, H., Muhammad, JI. (2019). Enhancement of Hot Mix Asphalt (HMA) Properties Using Waste Polymers. Arabian Journal for Science and Engineering. https://doi.org/10.1007/s13369-019-03748-3

Nuha, SM., Amin, C., Hamid, N., Alireza, R. (2021). Investigating the engineering properties of asphalt binder modified with waste plastic polymer. Ain Shams Engineering Journal .Volume 12(2021) 1569–1574. https://doi.org/10.1016/j.asej.2020.08.035

Akpolat, M. (2022). Investigation of rutting, fatigue and cracking resistance parameters of CR modified warm asphalt binders compare with SBS modified binders. Revista de la Construcción. Journal of Construction, 21(2), 309-328. https://doi.org/10.7764/RDLC.21.2.309.

Laiana, F., Lêda, C., Adriano, E., Ablenya, G.(2019). Use of Banana Fibers in SMA Mixtures, Journal of Materials in Civil Engineering. 32(1), 04019341-1-04019341-10 page DOI:10.1061/(ASCE)MT.1943-5533.0002994.

Osuya, D., Mohammed, H.(2017). EVALUATION OF SAWDUST ASH AS A PARTIAL REPLACEMENT FOR MINERAL FILLER IN ASPHALTIC CONCRETE. Ife Journal of Science. vol. 19, no. 2. https://dx.doi.org/10.4314/ijs.v19i2.23

Ali, R.A., Gholam, H.H., Hossein, F. A.(2018). Providing Laboratory Rutting Models for Modified Asphalt Mixes with Different Waste Materials. PeriodicaPolytechnica Civil Engineering, 62(2), pp. 308–317. https://doi.org/10.3311/PPci.10684

Rajan, C., Abhinay, K., Kishori, M. (2018). Properties ofWaste Polyethylene Terephthalate (PET) Modified Asphalt Mixes: Dependence on PET Size, PET Content, and Mixing Process. PeriodicaPolytechnica Civil Engineering. paper10797. https://doi.org/10.3311/PPci.10797

Cetin, A., and Oral, G. (2022). Performance evaluation of porous asphalt mixtures modified with basalt fiber. Revista de la Construcción. Journal of Construction, 21(1), 93-104. https://doi.org/10.7764/RDLC.21.1.93.

Sandra, O., José, L., Jesner, S. (2012). Analysis of use of natural fibers and asphalt rubber binder in discontinuous asphalt mixtures, Construction and Building Materials, 26 13–20p. doi:10.1016/j.conbuildmat.2011.06.030

Tomas, U., Ganiron, J. (2014). Effect of Sawdust as Fine Aggregate in Concrete Mixture for Building Construction. International Journal of Advanced Science and Technology. Vol.63, pp.73-82. http://dx.doi.org/10.14257/ijast.2014.63.07

ZIDOUK, A.(2019).ÉTUDE DE L'INFLUNCE DE L'AJOUT DES FIBRES DU PALMIER DATTIER SUR LE MODULE DES ENROBÉS BITUMINEUX. Thesis Presented for obtaining the diploma of ACADEMIC MASTER.KASDI MERBAH OUARGLA UNIVERSITY.

Saswat, B.D., Mahabir, P.(2016) A Study on Use of Natural Fiber for Improvement in Engineering Properties of Dense Graded Bituminous Mixes with Coal Ash. Transportation in developing economies.2:4. DOI 10.1007/s40890-015-0008-z

Martina, M., Norman, H.S., Dieter, S.(2010) Physical properties of burnt timber with special focus on the drying performance. european journal of wood and wood products. DOI 10.1007/s00107-009-0388-z

Abderrezak, B., Salah, A., Fabrizo, S.(2015). Statistical analysis and effect of chemical treatment on the physic mechanical behavior of fibers from date-palm fruit branches. Synthèse Revue des Sciences et de la Technologie, Rev. Sci. Technol, Synthèse, 31: 108 -120.

Mojtaba, K., Alireza, A., Ali K. (2021).Influence of Polymeric Coating the Aggregate Surface on Moisture Damage of Hot Mix Asphalt. PeriodicaPolytechnica Civil Engineering, 65(2), pp. 376–384. https://doi.org/10.3311/PPci.14340

Bordjiba, A., Hacen, C.A., Guenfoud, H., Guenfoud, M. (2016). INFLUENCE OF RECYCLED AGGREGATES ON THE RESISTANCE OF BITUMINOUS CONCRETE IN THE PRESENCE OF ADDITIVES. Romanian Journal of Materials, 46 (1), 89 – 94.

BARBUȚĂ, M., MIHAI, P., PRECUL, A., BEJAN, L., ȚĂRANU, N., BANU, O. (2022). CONCRETE HOLLOW BLOCKS WITH WASTE MATERIALS REPLACING THE NATURAL AGGREGATES. Romanian Journal of Materials. 52 (1), 83-89

Rosa, H.R., Anadelys, A.A., Nelson, V.M. (2018). Evaluation of natural additives for warm asphalt mix. Revista de la Construcción. 1071. DOI:10.7764/RDLC.17.2.330

Jairo, FRL., Hugo, ARQ. , Saieth, BCP.(2019). Behavior of a Warm Mix Asphalt Containing a Blast Furnace Slag. International Journal of Civil Engineering. https://doi.org/10.1007/s40999-019-00475-6

Van, BL., Van, PL. (2021). Performance Evaluation of Carbon Nanotubes as a Binder Modifier for Asphalt Mixtures. International Journal of Civil Engineering. https://doi.org/10.1007/s40999-020-00599-0