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Investigation to enhanced Physical and Mechanical Properties of Road Pavement in Asphalt Incorporating Low-Density Waste Plastic Bags

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Abstract

The aim of the study is to formulate a new composite material for road pavement by combining asphalt concrete with waste plastic bags (WPB). The study focused on enhancing the physical and mechanical properties of the composite materials by adding varying proportion of WPB. WPB is prepared simply by cleaning and melting them at 300 °C. Then, the melted WPB is mixed with asphalt at 170 °C for 2 to 3 minutes. The resulting mixtures contained different content of WPB by weight such as 0wt%, 5wt%, 10wt%,15wt% and 20wt%. The homogenized mixtures underwent penetration and softening point tests. Additionally, Marshall stability tests were conducted with 0/14 aggregates, along with asphalt concrete (AC) flow tests, Duriez stability reports, and AC compacity tests. The water content of AC was also examined. The results show that as the content of WPB increased, penetration values exhibited a consistent linear decrease. The incorporation of WPB resulted in an average increase of 22.64% in the softening point of asphalt. Increasing the content of WPB led to an average 72.07% rise in Marshall stability, accompanied by a concurrent 29.47% decrease in AC flow. In addition, at 10wt% WPB incorporation, there was an optimal Voids in Mineral Aggregates (VIM) value of 2.07%. The Duriez test revealed an average increase of 15.18% in the stability of asphalt concrete. The compacity of asphalt concrete (AC) experienced an increase, and concurrently, the AC water content also increased. Conclusively, the incorporation of melted WPB effectively improved the physical and mechanical properties of asphalt, showcasing promising prospects for road pavement applications. The study suggests that the polymer-modified asphalt is achieved with WPB loading optimal ranging from 5wt% to 10wt%. This innovative approach holds potential significance, especially in underdeveloped countries where there is an abundant supply of waste plastic bags.

Keywords: asphalt mixes, waste plastics bags, physicals and mechanicals properties, road pavement

Nomenclature

G	*particle size more than 6,3 mm*
S	*particle size between 6.3 mm and 0,315 mm*
s	*Particle size between 0,315 mm and 0,08 mm*
f	*particle size between 0,08 mm*
K	*Asphalt wealth modulus*
α	*corrector coefficient*
R'	*Immersion resistance of immersed test specimens in MPa*
Rc	*Immersion resistance of non-immersed specimens in MPa*

1. Introduction

The construction of roads needs large quantities of construction materials, including cement concrete, bitumen gravel, asphalt mix and bituminous concrete. The increasingly impact of traffic, coupled with high temperatures induce deformation to the upper layers of the road pavements. The need for high-quality, and sustainable road infrastructure is partly due to the new load configurations of heavy goods vehicles, and partly to the need to improve the durability of road pavements (Junod & Dumont, 2004). Road damage is attributed to excessive loads, natural disasters, and construction quality, wherein the composition and design of construction material play a big role (Yanuar et al., 2021). Asphalt in its traditional configuration no longer provides satisfactory resistance to rutting under theses constraints (Allah et al., 2015; Cuisinier et al., 2007). Previous international research show that high-modulus asphalt mixes offer a potential solution to rutting issues on heavily loaded road. They can show a considerable gain in layer thickness, a high modulus of rigidity, a reduced percentage of voids and outstanding fatigue behavior, which explains the numerous applications in developed countries (Bendimerad & Zadjaoui, 2015). In this context, local raw material such as Bemolanga tar sand was investigated offering technical possibility for tar road, as a substitute of conventional Bitumen (Rakotoarison et al., 2016). In the study addressing the challenges of overlaying old concrete pavement with asphalt by introducing a new trackless tack coat material containing polymer, the results indicated the newly developed polymer-modified trackless tack coat has been shown to effectively enhance the adhesion performance between pavement layers without process delay, the durability of asphalt concrete overlay pavement on old cement concrete pavement (Kim & Le, 2023).

Asphalt, one of the oldest engineering materials (Behnood & Gharehveran, 2019), is typically composed of aggregates and asphalt cement (Amri et al., 2023). Nowadays, asphalt is mainly used as a binder for mineral aggregates in the paving industry (Behnood & Gharehveran, 2019). Today's road construction systems involve several actions: extraction of raw materials (quarries and sandpits), transformation (cement works, concrete plants, refineries, asphalt plants, construction sites), transport and recycling of materials at the end of their useful life (Kicak & Ménard, 2009).The decision to build or renovate a road is often linked to a set of technical-economic factors which will affect both investment costs and long-term maintenance expenses (Bendimerad & Zadjaoui, 2015). Then, increasing awareness regarding environmental considerations and the benefits of circular economy has prompt the road engineers to use recycled materials in pavement layers (Russo et al., 2022).

The diversification of lifestyles and consumption patterns has led to the widespread use of plastics, which end up as plastic waste in the environment (Traore et al., 2016; De Bock et al., 2020; Dahou et al., 2018). It represents a significant proportion of municipal solid waste (Samir et al., 2014; Traore B., 2018; Kowanou et al., 2014). As a result, there is a huge proliferation of this plastic waste, leading to environmental problems given its non-biodegradable nature. The introduction of new road-building materials with advanced physical and mechanical properties is the trend in contemporary civil engineering, which aims to increase the quality of road surfaces (Bieliatynskyi et al., 2022) and safety (St-Jacques et al., 2009). According to previous research work, the mixtures modified with recycled-plastic additives (Russo et al., 2022; Pugin et al., 2022), the addition of fiber from the fly ash of thermal power plants (Bieliatynskyi et al., 2022), the glass particle, showed higher stiffness and tenacity and as expected though, with specified physical, mechanical and operational properties in line with the literature. And asphalt with an added polymer material which is elastomeric can increase the durability of road pavements and the stability of the asphalt concrete mixture (Yanuar et al., 2021; Hadidane et al., 2015). (Endimerad & Zadjaoui, 2015) studied the use of Road Product (PR) industry named polymer plastomere in 95 % (PLAST) in a mixture bituminous concrete to high module. The authors noted on the coated an important improvement of the performances of roads (the rutting and the module of elasticity) and of their service life and deduced an economy bound to the considerable reductions of the thicknesses, the content and high mechanical performances, corresponding to the NF P 98 141 standard (Bendimerad & Zadjaoui, 2015). In addition, in order to achieve the purpose of recycling waste resources, many scholars have conducted a lot of research on the performance of recycled asphalt concrete (Zhang et al., 2023). For example, the Cold-in-Place Recycling (CIR) asphalt material is gaining increased popularity due to its innovative properties, performance and recycling values (Islam et al., 2021). Studying the reinforcement of recycled concrete aggregates in road, the results reveled that the used of waste plastic fibers combined with concrete aggregates absorb all tensile stresses in pavement layers, preventing them from cracking (Belmouchi, 2009).

Between the waste plastic, the great proportion (more than 78wt%) corresponds to thermoplastics and the remainder to thermosets, but only the thermoplastics are recyclable (Achilias et al.,2007; Balakrishnan & Guria, 2007; Dahou et al., 2018). By reviewing existing literatures, we noticed many studies focused on the use of the waste plastic as incorporating material in concrete or in modified -asphalt concrete. It’s the case of the most studies focused on the impact of PET type waste on the physical and mechanicals properties (Hama, 2021). Many asphalt modifiers have been introduced and tested in the road pavement industry aiming at improving the properties of asphalt concrete and consequently its service life (Russo et al., 2022). In this context, the right choice of components, such as WPB, aggregates, conventional asphalt class and loading types and rates, is essential. The inclusion of local waste, represented by plastic water drink bottles caps (CPPA), in the concrete as a partial substitute for coarse aggregates at 15wt% and 30wt% were suitable for structural reinforced concrete (Hama, 2021). In fact, the type and level of modification highly depends on the design criteria and climatic conditions (Russo et al., 2022). The present study focuses to produce an ecofriendly asphalt concrete with the addition of Waste Plastics Bag (WPB). Taking into account the aim in mind, the objectives of this study are as following:

- Experimentally investigate the classification of conventional asphalt and the composite based one asphalt and waste plastic bags;
- Experimentally investigate the effect of waste plastic physical and mechanical properties of asphalt concrete.

2. Materials and Methods

2.1 Raw Materials

2.1.1 Aggregate

Coarse and fine used in this study are crushed granite. The aggregates were obtained from Koubri area in Ouagadougou and were in three type of size distribution :0/6 (G1); 4/6 (G2) et 6/10 (G3) showed in Figure 1 below.

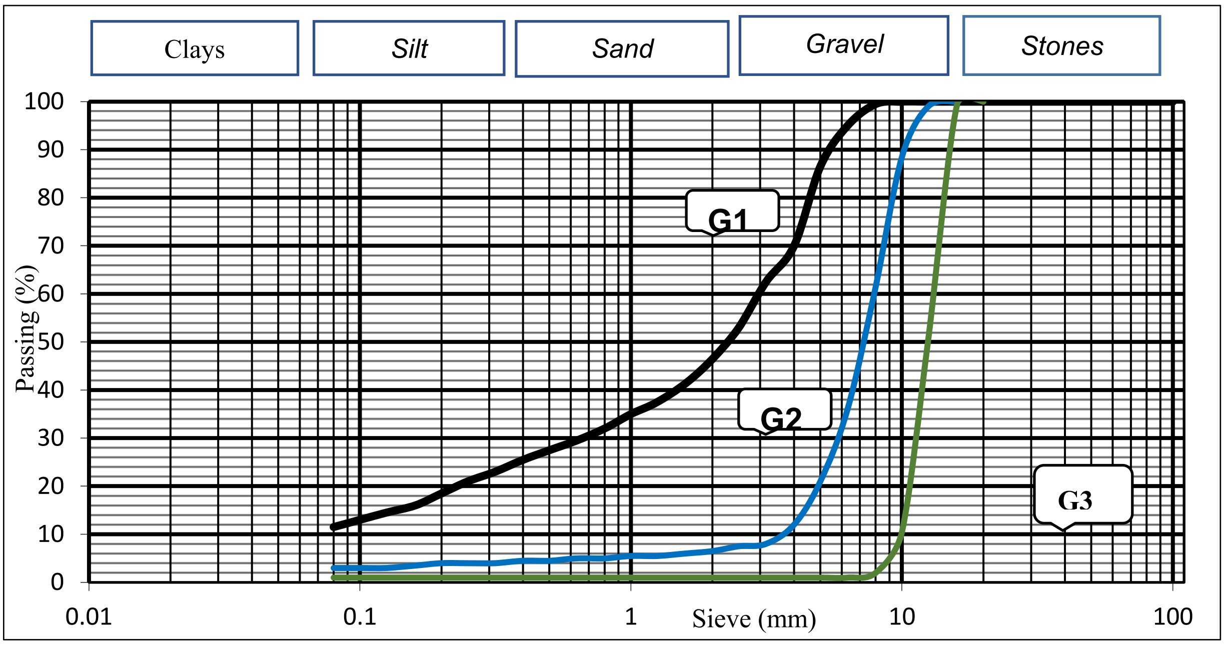


Figure 1. Particle size distribution of the aggregates 0/4, 4/6 and 6/10

The characteristics of the aggregate by LA and MDL tests are summarized in Table 1 below.

Table 1. Summary of the physicals and mechanicals properties of the aggregates

Parameters	Size distribution			*requirement [16]*
	0/6	4/6	6/10	
Specific weight	2.70	-	-	-
Sand equivalent %	46	-	-	>40
Surface cleanness %	-	4,93	0,71	-
Flatness Coefficient	-	17,49	13,38	< 20
Los Angeles Coefficient %	-	23	22	LA ≤ 30
Micro Deval Coefficient %	-	8	6	MDE ≤ 20

This granite crushed present a good property for the mixture in this study with less flatness elements. But to performed the asphalt concrete it's necessary to optimize the crushed granite size distribution by the mix of G1, G2 and G3. To do this, three types of mixtures are applied and the best result is obtained by the mix of 65wt% of G1, 25wt% of G2 et 10wt% of G3 and presented the Figure 2 below.

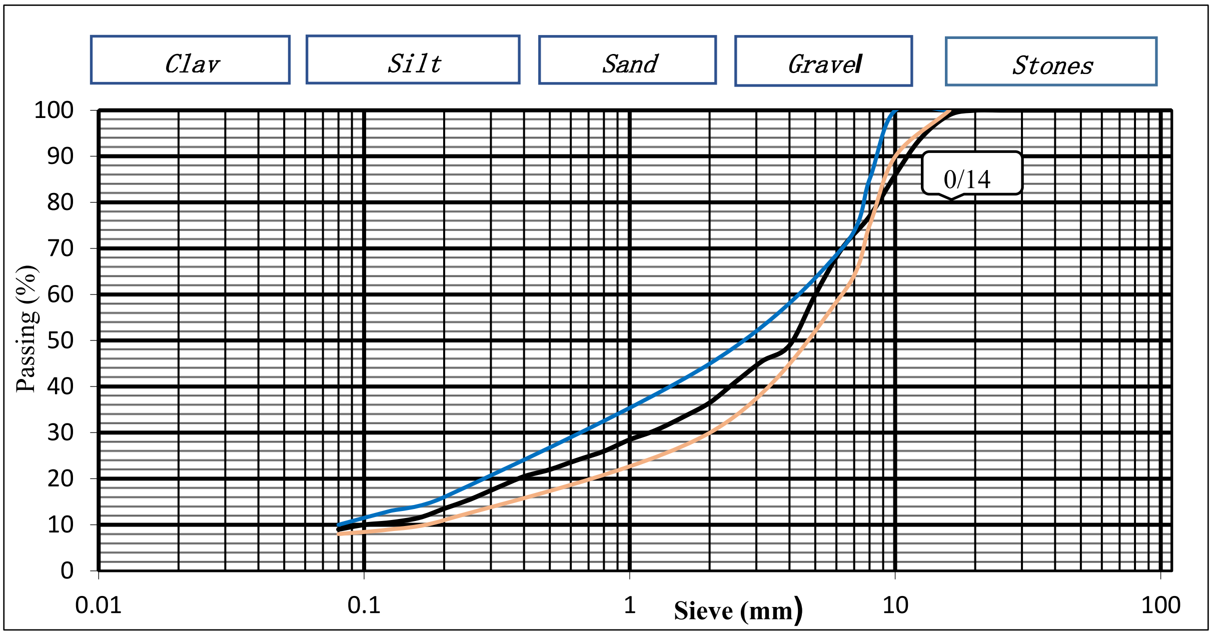


Figure 2. Size distribution of the aggregate optimized

The particle size distribution experiment and the granular flatness index test procedure are according respectively to the NF P 94-056/057 standard (NF P 94-056, 1996) and NF P 18-561 (NF P 18-561, 1990). The particle size distribution is an experiment to acquire the gradation of the aggregate. The gradation of the aggregate is specified on the road works recommended by the CEBTP standards and size distribution 0/14 for the asphalt concrete.

2.1.2 Asphalt

The characteristics of the asphalt of 35/50 according to NF T 66-007 standard (NF T 66-007, 1957) used are summarized in Table 2 below:

Table 2. Physical properties of asphalt used in this study

Asphalt grade	*Relative density at* 25°c – by pycnometer method	*Permeability y pointer at a 25°c, 100 g, 5 s*	*Binder content*
35/50	1.034	45.83	6.2%

To manufacture the asphalt concrete (AC) samples, the formula 1 and 2 are respectively used for the binder content and conventional specific surface.

$$\textbf{Binder content} = \mathbf{K} * \boldsymbol{\alpha} * \sqrt[5]{\sum} \quad \textbf{with } \boldsymbol{\alpha} = \frac{2,65}{MVRg} \tag{1}$$

$$\mathbf{100 \sum = 0,25G + 2,3S + 12s + 135f} \tag{2}$$

where:

- *G: particle size more than 6,3 mm;*
- *S: particle size between 6.3 mm and 0,315 mm;*

- *s: Particle size between 0,315 mm and 0,08 mm;*
- *f: particle size between at 0,08 mm;*
- *K: Asphalt wealth modulus;*
- *α: corrector coefficient*

The Marshall and the Duriez tests results are summarized in Table 3 below.

Table 3. Mechanicals properties of conventional asphalt

N°	Properties	Results	Standards
1	Compaction	96%	96-98 %
2	Flow	23,46 (1/10mm)	2 and 4 mm
3	Stability at 60 °C	1113 daN	> 1000 daN
4	Module de richesse K	3.7	3.5 to 4
4	R' / Rc	0.878	≥ 0,75

The asphalt content obtained is used as a fixe variable in the second phase for the formulation of the asphalt concrete samples.

2.1.3 Waste Plastics Bags

The waste plastics bags (WPB) used in the study is the low-density polyethylene (PEBD) type. These plastics waste is from bottle and bags rejected in environment. They are characterized by a fusion temperature of 200°C, self-inflammation temperature from 330 to 410 °C and a density range 0.91-0.96 g/cm3.

2.2 Methods

The present study used the criteria defined by classicals Marshall and the Duriez tests for the road pavement. These tests allow to evaluate the road pavement mechanical stability and the behavior in contact with the water. The laboratory experiment program consists of third phases, which were conducted in Laboratoire National du Bâtiment et des Travaux Publics (LNBTP). The first phase includes the selection of raw materials, their treatment and the necessary laboratory preliminary test for the basic properties of these selected materials. The second and the third phases include respectively the design and characterization of AC respectively with conventional asphalt and the modified asphalt. The test performed are described in following paragraphs.

2.2.1 Production of Binder Based on WPB

To produce the new asphalt binder, the waste plastic bags (WPB) were first cleaned and then melted at around 300°C in a suitable metal container. The liquid obtained was then cooled in ambient air (temperature: 29-31°C, relative humidity: 67-73%), and the resulting solid finely ground to powder passing at 0.160 mm sieve.

2.2.2 Asphalts Concrete Sample Preparation

This section presents the design of the AC mixtures with conventional asphalt and the modified asphalt by loading of the WPB, to result in an optimal choice of components and proportional composition to meet the requirements performance (Centre de recherches routières, 2022). Table 4 summarize the asphalt concrete samples and the mechanicals tests carried out.

Table 4. Quantity of materials and samples for mechanicals tests

Material	**Unit**	**Marshall test**					**Duriez test**		
Granite crushed	g	7000					12000		
Asphalt	g	620	589	558	527	496	620	558	496
WPB	%	0	5	10	15	20	0	10	20
	g	-	31	62	93	124	-	62	124
AC Samples	u	3	3	3	3	3	13	13	13

The Modified asphalts mixtures were designed based on the optimum asphalt content (OAC) of conventional asphalt. The conventional asphalt was modified using the WPB and the amount of WPB used was varied, namely 0wt%, 5wt%, 10wt%n 15wt% and 20 wt% by the weight of asphalt. Three and thirteen samples were prepared at each percentage of the additives at the OAC respectively for Marshall and Duriez tests. The mixt of melted WPB and asphalt is done at temperature of 170 °C and the mixtures varied between to 2 à 3 minutes, as asphalt is a temperature-sensitive material, and many of its characteristics are related to temperature (Zhang et al., 2023).

2.2.3 Tests Performed

A part of the homogenized asphalt improved by adding of Waste Platics Bags (WPB) mixture was taken for penetration test using an automatic needle penetrometer (NF T 66-004, 1999) and softening point test (NF T 66-008, 1979). Another part of the asphalt mixture was then mixed with aggregate and compacted. The compacted asphalt concrete mixture was submitted to Marshal and Duriez tests.

The Marshall test was carried out according to NF P 98-251-2 standard with the equipment in Figure 3 on the Asphalt concrete specimens of size 6,3 cm high and 10 cm diameter presented in Figure 4 below. This test permit to evaluation the optimum asphalt content for conventional asphalts and the road pavement mechanical stability.

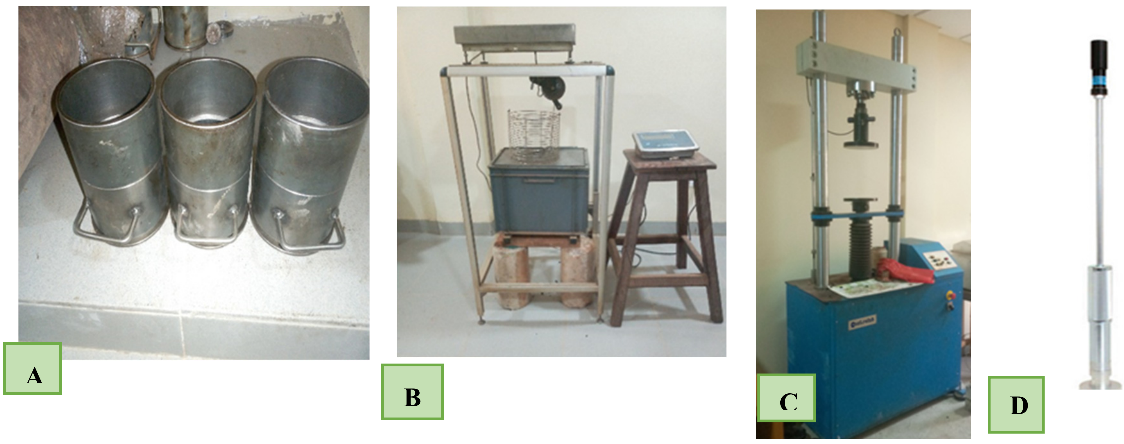


Figure 3. Equipment for Marshall test a) Mold, b) Scale, c) Press d) Manual compaction tamper

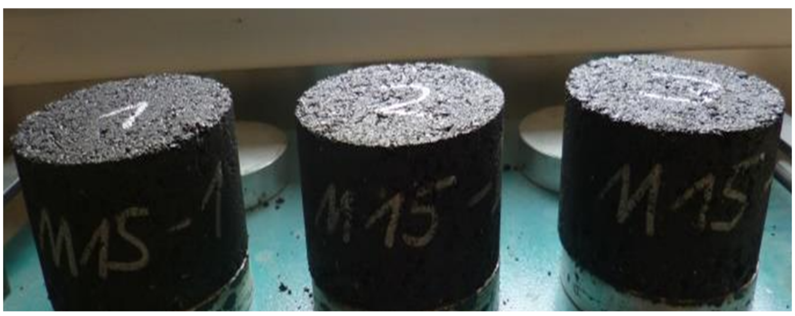
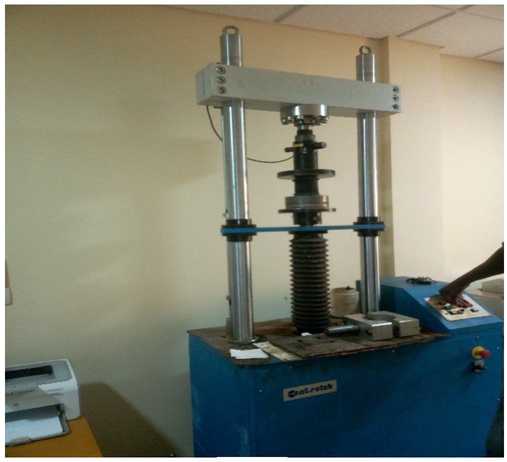


Figure 4. Asphalt concrete samples for Marshall test

The Duriez test were caried out according to NF P 98-251-1 standard with the equipment in Figure 5 below. The sample are cured conditions at 8±0,5 °C during 8 days and the test progress at 1mm/s.

a



b

Figure 6. Equipment for the Duriez test of the AC samples a) storage and b) Press

3. Results and discussion

3.1 Asphalt Penetration Analysis

The asphalt penetration test at 25 °C is caried out following the NF T 66-007 standard (NF T 66-004, 1999) and the result are used for classifying asphalt's grade and quality for road pavement.

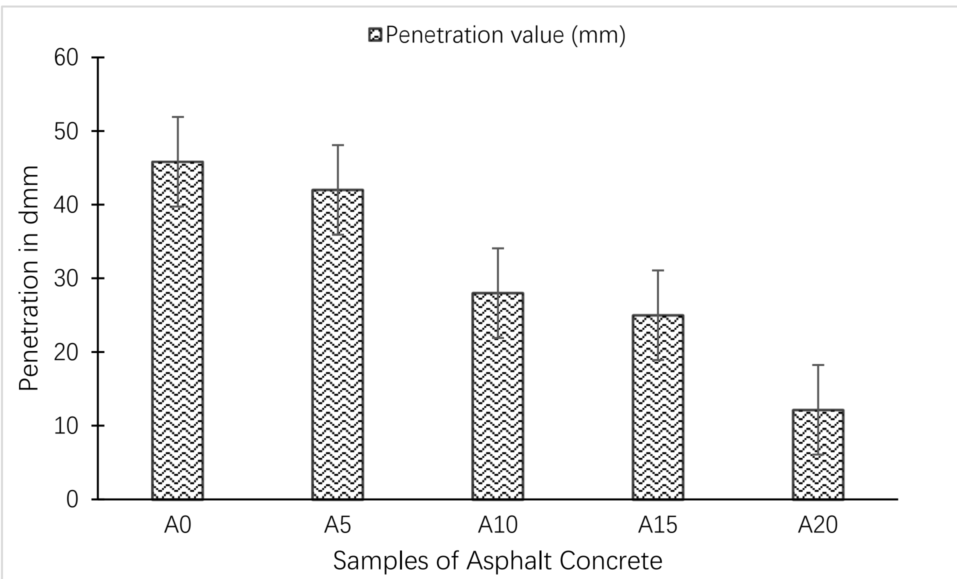


Figure 7. Penetration values of conventional asphalt with WPB addition

Figure 6 shows the penetration values of conventional asphalt with WPB addition in various weight percentages in asphalt. Analysis of these values has shown that the introduction of melted plastic significantly influences binders' penetrability. Mixes indexed as A5, A10, A15 and A20 correspond to bituminous binders of classes 30-45,20-30 respectively, while A15 and A20 are outside the norm.

It can be seen that, generally the penetration values decrease (or asphalt hardness increase) linearly with the increase of weight percentage of WPB in asphalt. These tendence was observed with FLG addition in asphalt by (Amri et al., 2023). These results suggest that the mechanical behavior of the asphalt-WBP mix will very quickly be dominated by the properties of the WBP, especially above 20% doping.

The penetrability index obtained with 15% and 20% WPB content leads to the conclusion that these mixtures deviate from conventional asphalt, instead falling into the categories of special asphalt, specifically 10-20 and 15-25, as identified by standard (NF EN 13924). These specialized asphalt compositions are designed to address challenges posed by the unforeseen increase in heavy traffic, offering a solution in the form of high modulus asphalt concrete. Considering the recorded penetrability values, it can be observed that the incorporation of melted plastic bags progressively downgrades the grades of doped bitumen towards the classification of harder bitumen. Starting from class 35-50 at 0%, doped bitumen with a 5% plastic bag content shifts to class 30-45 and then to 20-30 at 10%. At 15% and 20% doping, the binder completely falls outside the classification of conventional road pavement.

3.2 Effect of Melted WPB Addition on Softening Point of Asphalt

Figure 7 shows the softening point temperatures of asphalt with and without the addition of WPB in various percentages in asphalt. Generally, it can be seen that the softening point temperatures of asphalt increase with the increasing of WPB contents in asphalt.

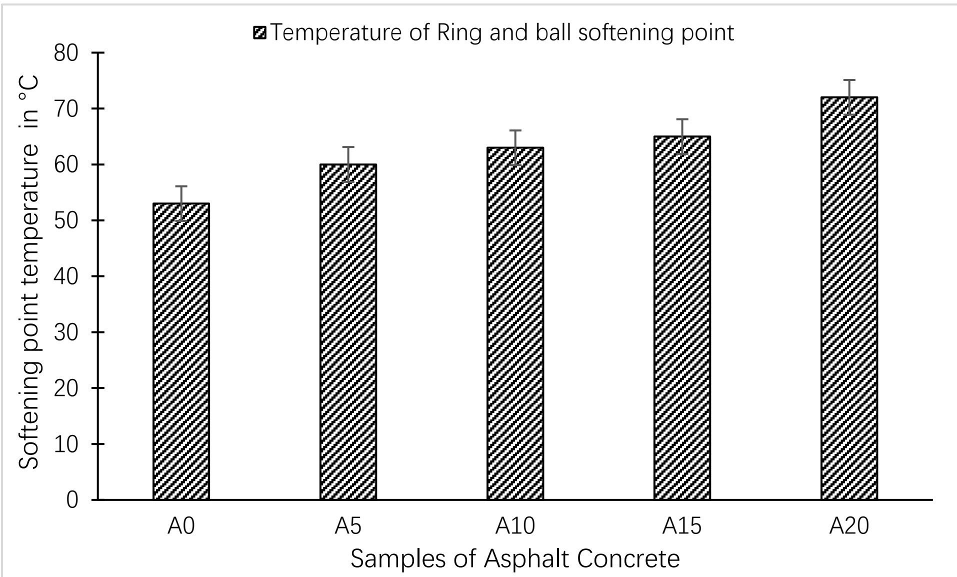


Figure 8. Effects of WPB addition on the Softening point temperature of AC

The tests carried out for plastic bag contents of 15% and 20% show that the softening point values exceed the conventional limits admissible with regard to the experimental device. In fact, the temperature rose to 65 °C and 72 °C, with the classic water bath device. They correspond rather to the (NF EN 13924) which ranges from 60°-76° and 55°- 71°. From A0, A5, A10 including 53°, 60° and 63° respectively, the almost simultaneous fall of the two almost naked balls onto their respective plateaus was observed. We note that as the rate of dope incorporated into the 35-50 bitumen increases, the softening point of the binder increases. This effect was funded by (Amri et al., 2023) with FLG concentrations and FLG contents in asphalt. They reported that the increase of asphalt-FLG softening point towards the softening point of asphalt without the addition of FLG averagely is about 5%.

3.3 Effect of Melted WPB Addition on the Marshall Stability, the Asphalt Concrete Flow and Void Contents

3.3.1 Effect of Melted WPB Addition on the Marshall Stability

Figure 8 shows the marshal stability values versus WPB addition in various ratio. We funded the relationship between Marshall stability values and the addition of Waste Plastic Bags (WPB) in different weight percentages. These findings conclusively demonstrate that the Marshall stability of bituminous concrete experiences an enhancement with the escalating content of melted WPB employed as an additive.

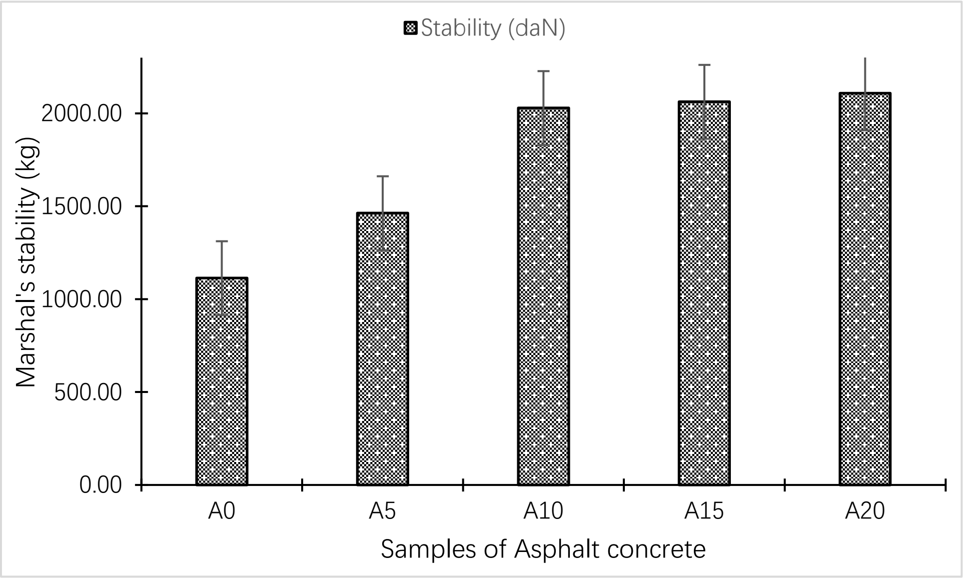


Figure 9. Effects of WPB addition on the Marshall stability of AC

Specifically, the Marshall stability of bituminous concrete at 0% additive registers at 1113.33 daN, and at 20%, it increases to 2103 daN, consistently adhering to the established reference parameters outlined in the Marshall stability tests recommended by the CEBTP. The Marshall stability increased with increasing of WPB content ratio. The increases of Marshall stability compared to the conventional asphalt stability without WPB addition are about 88,89% when 0 to 20% WPB are added. (Amri et al., 2023) reported that their FLG could increase the Marshal stability value of asphalt are about 5.1% to 17.6% when 3 to 9% FLG are added at concentrations of 10 to 30 mg/ml. This effect was also observed by (Yanuar et al., 2021). In fact, the stability value of the polymer asphalt mixture has a higher stability value than the stability of conventional asphalt mixture and the difference in the stability value was about 113% higher. So, according to this, WPB can provide additional strength and stability to the asphalt matrix, thereby increasing the ability of asphalt to withstand loads and reducing susceptibility to damage.

3.3.2 Effect of Melted WPB Addition on the Asphalt Concrete Flow

The results of the different asphalts concrete samples flow are presented in Figure 9. It shows the relationship between the ratio of WPB in asphalt on the asphalt concrete ow properties.

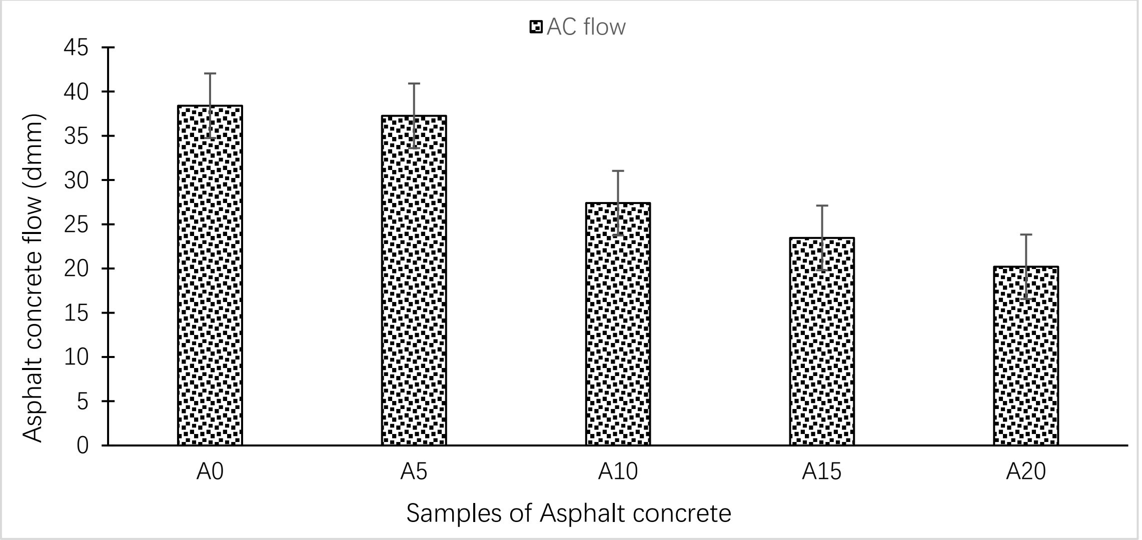


Figure 10. Effects of WPB addition on the asphalt concrete flow

These results clearly indicate a discernible variation in the flow of asphalt concrete corresponding to the content of melted WPB. In Figure 8, we noticed that the asphalt concrete flow value decreases with the increase in WPB content in the mixtures, with an average decrease of around 2.95% to 47.4% compared to conventional asphalt witch itself has a flow value of 3.84 mm. Indeed, the flow value, for this range of binder contents, varies between 2 and 4x1/10 (mm) as recommended criteria for good performance. From a flow perspective, the binder rate of 6.2% remains a good value for the formulation of asphalt concrete. (Amri et al., 2023) found that the asphalt concrete flow value increases with the increase in FLG content, with an average increase of around 3.5% to 17.7% compared to conventional asphalt without the addition of FLG which has a ow value of 3.8 mm. This indicated that, contrary to FLG, WPB causes a decrease in the elasticity of asphalt. A progressive reduction in creep and an improvement in stability was observed depending on the percentage of additive.

3.3.3 Effect of Melted WPB Addition the Void Content in Mixtures of AC

Filling voids is useful to increase the stability and strength of the road, as well as to reduce erosion and water damage (Amri et al., 2023). Figure 10, shows the effect of WPB addition on the void value. It can be seen the incorporating melted WPB into the asphalt concrete produces a composite material (aggregate-bitumen-bag) whose compactness reaches an optimum at a polymer content of 10%, and then starts to fall rapidly as soon as this content is exceeded, leading to an increase in void volume. Marshall compaction is performed manually.

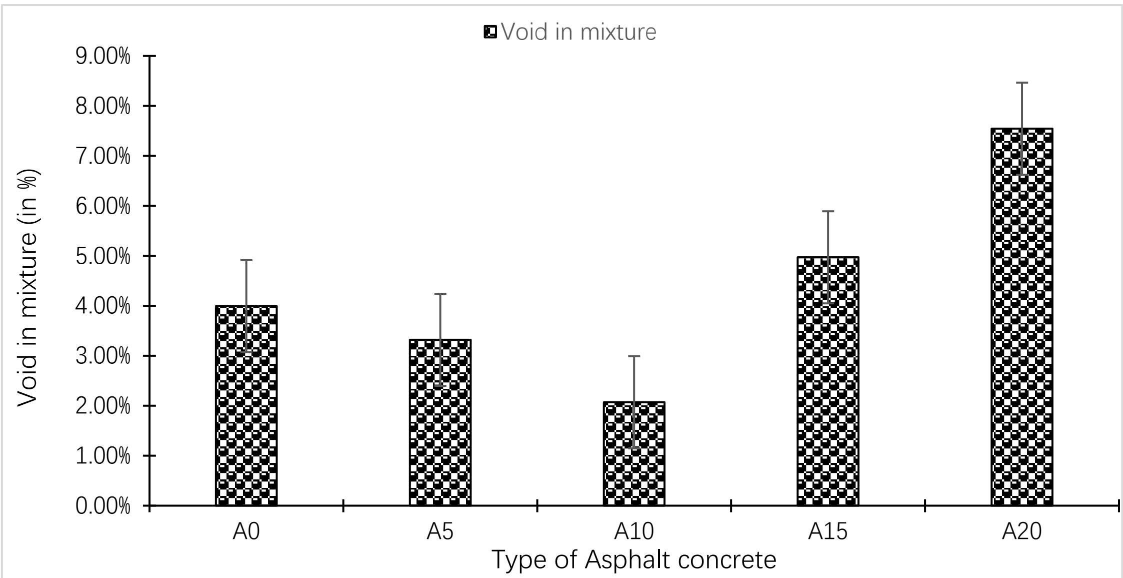


Figure 11. Effect of WPB addition on void in mix of AC

Figure 10 also shows the void volume results for doped asphalt concrete. The void volume in the AC rises from 3.99% without doping (0%), to 2.06% at 10% doping, then to 7.54% at 20% doping. However, from 0% to 10% spiking, the volume of voids is still within the range of rates that offer good performance, i.e., 2 to 4%. Similar effect was observed with the addition of FLG by (Amri et al., 2023). In conclusion, void volume is significantly related to Marshall compactness, i.e. as compactness increases, void volume decreases.

3.4 Effect of Melted WPB on the Duriez Stability, AC Compacity and Water Absorption

3.4.1 Effect of Melted WPB Addition on the Duriez Stability Report

Figures 11 and 12 present respectively the Duriez stability report and the AC compressive strength.

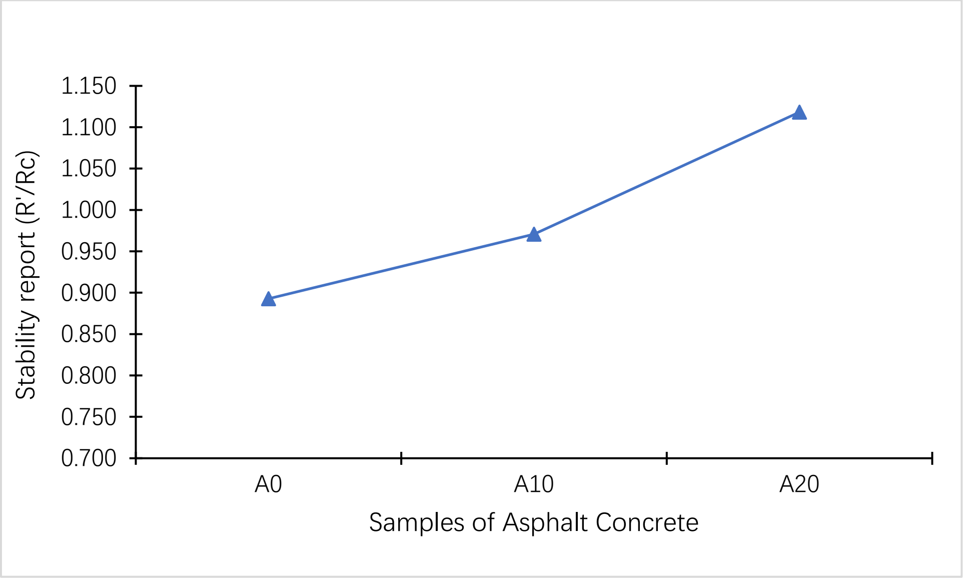


Figure 12. Effect of WPB addition on Duriez stability report of AC

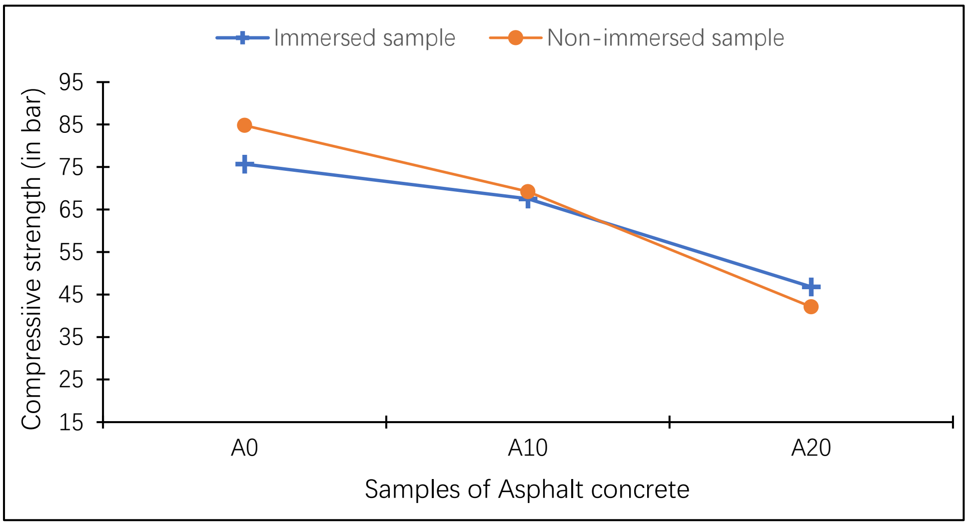


Figure 13. Evolution of Compressive strength of Asphalt concrete

The WPB addition in the mixture affected the asphalt concrete stability with an average value of increasing of 15,18%. Indeed, the compressive strength of the AC with WPB loading at 20wt% for AC immersed sample is more than those of non-immersed samples of AC but under requirement value(60bars) as shown in Figure 11 below. The same effects were observed by mass of incorporation of plastic bag powder until 20w% by (Ratsifaherandahy et al., 2022).

3.4.2 Effect of Melted WPB Addition on the Duriez Compacity of the AC Mixtures

Figure 13 shows the Duriez compacity values versus WPB addition in various Percentages of weight. The compacity value of (AC) mixtures are 92% for AC mixtures without WPB and 91,65%, and 93,5% for AC mixtures with WPB loading respectively at 10wt% and 20wt%.

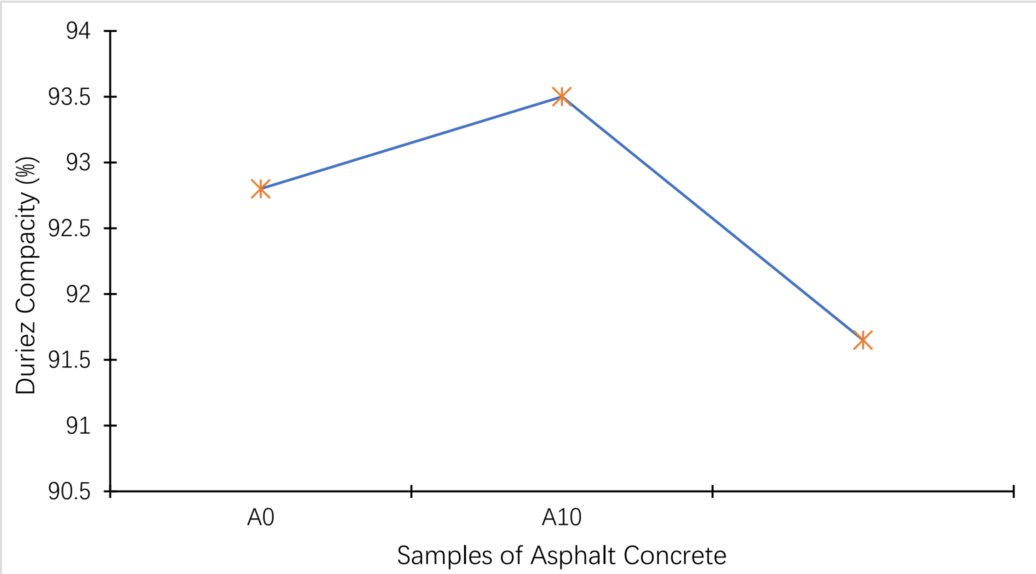


Figure 14. Effect of WPB addition on Duriez compacity of AC

In Figure 13, we noted that only the sample of AC with WPB loading at 10wt% conformed the requirement of CEBTP. The similarly result was funded by (Ratsifaherandahy et al., 2022) according to SETRA-LCP norms.

3.4.2 Effect of Melted WPB Addition on the Water Content of the AC Mixtures

Figure 14 presents the effect of melted WPB addition on the AC water content. We noticed that the AC with WPB loading at 0wt% and 10wt% meted the NF P 98-251-4 (NF P 98-251-4, 1992), with respectively water content of 2.25 and 2.47%. Then, the addition of WPB in the asphalt mixtures increased the AC water content.

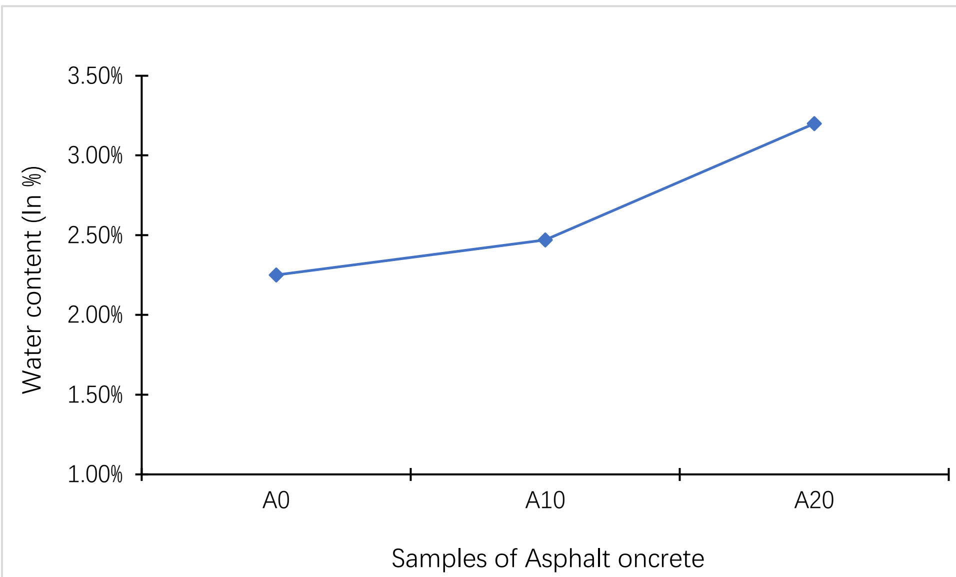


Figure 15. Effect of WPB addition on AC water content

3.5 Summary of the Incorporating of WPB

The application of polymer in an asphalt concrete (AC) mixture has reached wide popularity lately to deal with the increasing demand for higher quality roads with heavier traffic. The thermoplastic is one of the of the most popular polymers employed (Daniel et al.,2022). The present study focused on the use of WPB in an AC mixture.

The mechanicals tests on AC such as Marshal and Duriez indicated that the incorporating of WPB modified the performances. The results show that the WBP loading at convenable rate is suitable for asphalt improvement for road pavement and the best polymer-modified asphalt are obtained at the WBP loading of 5wt% to 10wt%. This study can be compared to the inclusion of thermoplastic ethylene-vinyl acetate (EVA) with the optimum content of approximately 5–6% of the bitumen weight (Daniel et al., 2022). These effects were observed by (Boukhari et al., 2015) which recommended the addition content between 2% to 8%. Furthermore, the optimal amount of fiber from fly ash in cast hot asphalt concrete is 4.0% of the mass (Bieliatynskyi et al., 2022) and 10wt% with waste plastic bags (Kowanou, 2014). The incorporation of glass particles at 10wt% in the mixtures increase the performance of bituminous coating of type ESG10 and GB20 (Bachand, 2018).

4. Conclusions

The physical and Mechanical properties of asphalt with addition of waste plastic bags (WPB) were investigated, leading with the following mains conclusions:

- penetration values decrease linearly with increasing WPB percentages or content in asphalts. The decreasing rate varies from 8.36% to 73.47% as following the WPB loading at 10% to 20%;
- softening point increases corresponding to the loading rate of WPB in asphalt, resulting in an average softening point increase of 22.64% after the addition of WPB;
- Marshall stability shows a consistent increase, while the flow of asphalt concrete decreases with the rise in WPB content, with average values of 72.07% and 29.47%, respectively. Indeed, the flow value, for this range of binder contents, varies between 2 and 4x1/10 (mm) as recommended in the good performance criteria. However, the addition of WPB affected the VIM with an optimum of 2.07% with 10wt% of WPB incorporation in asphalt.
- Incorporating melted WPB impacts the Duriez stability report of asphalt concrete, resulting in an average increase of 15.18%. Additionally, it enhances the compacity of asphalt concrete and increases its water content.

In summary, the addition of melted WPB improves the physical and mechanical properties of asphalt concrete. The abundance and availability of WPB in undeveloped countries offer promising prospects.

The study highlights that a suitable loading rate of WPB can held to asphalt improvement for road pavement, and the most favorable polymer-modified asphalt results from loading WPB in the range of 5wt% to 10wt%.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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