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Stripping Resistance and Storage Stability of Waste Pure Water Sachet Modified Bitumen

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ABSTRACT

Flexible pavements are vital to Nigeria's transportation system. Their materials undergo thorough mixing in line with specifications before production and placement. When exposed to loads exceeding design axle weight, excessive strain can lead to pavement failure. Additionally, improper design of Hot Mix Asphalt (HMA) with non-conventional materials can results in stripping, causing further malfunction and degradation. The study examined the effects of incorporating waste pure water sachets (WPS) made from polyethylene (PE) in bitumen at varying percentages (2.5%, 5.0%, 7.5%, 10.0%, and 12.5%). To ascertained stripping resistance of both bitumen and modified bitumen, boiling and static immersion tests were adopted. Whereas the optical microscope was explored to identified the morphology of the modified bitumen at x40 magnification. Furthermore, the softening point technique was used to assessed the stability of binders. The findings revealed that incorporation of WPS in bitumen improved the stripping resistance of the mix and the modified bitumen exhibited homogeneous micrographs, with improved storage stability falling within acceptable values of softening point difference (0°C to 5°C) between top and bottom samples. But 7.5% modification of WPS better give a promising results compared with the control in terms of the bonding strength and stability. This can be deduced that WPS-modified bitumen has prospective enhancement of pavement against failure mechanism.

Keywords: Keywords: Hot mix Asphalt, Waste pure water sachet, Microscopy, Stabiity, Stripping

1. Introduction

The combination of aggregate constituents, asphalt binders, and fillers, which undergo mixing and heating according to the design enveloped in conformity with general specifications, produces a hot mix called asphaltic concrete binder, which is known as flexible pavement. Flexible pavement structure is a major means of land-based transportation. Good structural components of the road should be very durable and have high-quality pavement. The Nigerian Road component is subjected to heavier loads than designed axle loads due to the increase in the number of commercial trucks, resulting in excessive loading, which is attributed to pavement failure. However, ageing and deterioration may be induced by climatic and environmental factors, which include moisture, temperature, radiation, and chemical attack. Therefore, there is a significant need for high demand to strengthen and extend pavement service life, because of the daily increase in traffic on the highway pavements [1]. Modified mixture has a higher stability and voids in mineral aggregate when compared to non-modified mixtures and, as a result, enhances the rutting resistance of this mixture [2-3]. The National Centre for Asphalt Technology described two processes of incorporating recycled plastics in asphalt pavements [4]. The wet process recycled waste is added to the asphalt binder as a polymer modifier, where homogenous mixing is required through mechanical means to achieve a good homogenous mixture blended modified binder. The limitation of the wet process is the storage stability of the modified binders, in which the recycled binder tends to separate from the Asphalt binder due to density and viscosity differences as well as incompatibility between the two components [5].

The rate of stripping due to water and poor mix design can be improved with the incorporation of polyethene waste thereby enhancing resistance to cracking, pothole formation and rutting by increasing its hardness [6]. It also enhances the general performance of the road for a long time [7]. WPS from polyethene as a modifier in hot mix asphalt design through Marshall Procedure determined that the stability, flow and void in mineral aggregate showed that stability and bulk density increases significantly as the WPS content increases from 2-8% [1]. In this study, the rate of stripping between the binder and aggregate with and without WPS from polyethene waste and morphology at the micro level of the binder with and without WPS were assessed based on the boiling test, static immersion test and optical X40 microscope.

2.0 Materials and Methods

Penetration grade 60/70 bitumen was used in the preparation of both the samples for the control and modified bitumen. The bitumen was obtained from the supply company in Nigeria (ASCA). The polyethene from the waste pure water sachet (WPS) was used as a modifier at various percentages which was obtained from the dustbin, drainage system and pure water producers' outlet. Crushed aggregates of different sizes used in this research were obtained from the quarry at Shira in Bauchi State, Nigeria. Figure 1 shows the physical appearance of materials WPS modifier, PEN60/70 and aggregate.

Figure 1. The physical appearance of WPS, aggregate, and binder

2.1 Preparation of Binder-WPS Modified Binders.

The PEN 60/70 asphalt binder was pre-heated in an oven at 160°C for two hours. The asphalt binder and WPS were blended for 10-16 minutes manually at 160°C using a stirrer for the sample to attain homogeneity.

2.2 Binder Test

Basic properties of the asphalt binder as obtained and tested from the manufacturer certificate, such as penetration test, specific gravity test, density at 150°C S1-Clavel and Flashpoint (Open cup), were all found to be within the general specification. The softening point test is to confirm the binder's durability when subjected to a high temperature before it starts melting, while the penetration test was carried out to evaluate the penetration grades which were confirmed to be within the general specification.

Table 1: Physical Properties of an Asphalt Binder

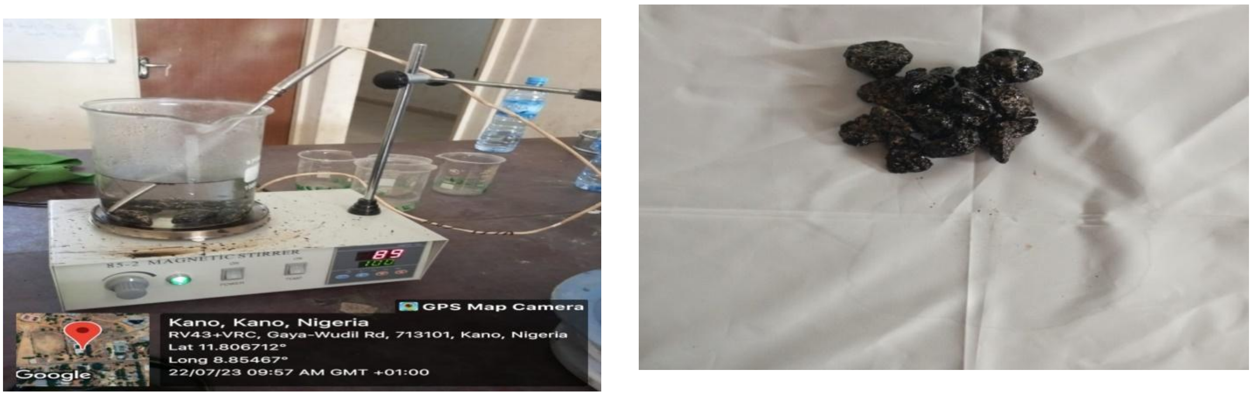
Properties	Test Specifications	Test Results
Penetration (25°C,100g 5s)	ASTMD6	61
Specific. G(Relative density at 25/25°C	ASTMD70	1.026
Density at 15°C	ASTMD70	1025
Softening point	ASTMD36	51.6
S1-claveland Flash point (Open cup)	ASTMD92	240

2.3 Stripping Test of Loose Mixture

The stripping phenomenon is caused by moisture damage from the loss of adhesion, and it adversely affects the strength of an asphalt mixture dramatically. Therefore, in this study, the boiling and static immersion tests were employed to evaluate the rate at which the WPS modified bitumen was coated with aggregate with and without WPS incorporation.

2.3.1 Boiling Test

Figure 2a shows the boiling water test assembly consisting of a 1000-2000 ml glass beaker and a thermometer placed on top of a hot plate for the boiling process. Subsequently, the prepared loose mixture of aggregate coated with binder as shown in Figure 2b was placed into the boiling water for 10 min ± 5 s. After the designated time, the water was drained and the wet mixture was placed on a paper towel and allowed to dry. Images of the loose mix were captured immediately with a digital camera after the placement on the paper towel as well as after 24 hrs to assess the level of stripping via physical assessment of both control and WPS modified mixtures.



a b

Figure 2.0 Boiling Water Test: (a) Boiling Water Test Assembly and (b) the Prepared loose Mixture

2.3.2 Static Immersion Test

The ASTM D1664 (AASHTO T182) standard was adopted to carry out the static immersion test to determine the rate of stripping of aggregates coated with asphalt binders. Before testing, 100g of aggregates was batched with sizes ranging from 5 to 9.5 mm. During the test, the batched samples were coated with 5.5g bitumen and immersed in distilled water at a temperature of 25◦C for 16 – 18 hrs in a 500 ml glass bottle. Physical observation of the samples was carried out through the glass to estimate the percentage of total visible area of aggregates that remain coated above or below 95%. Figure 3 presents the two replicates of 100g aggregates coated with bitumen immersed in water.

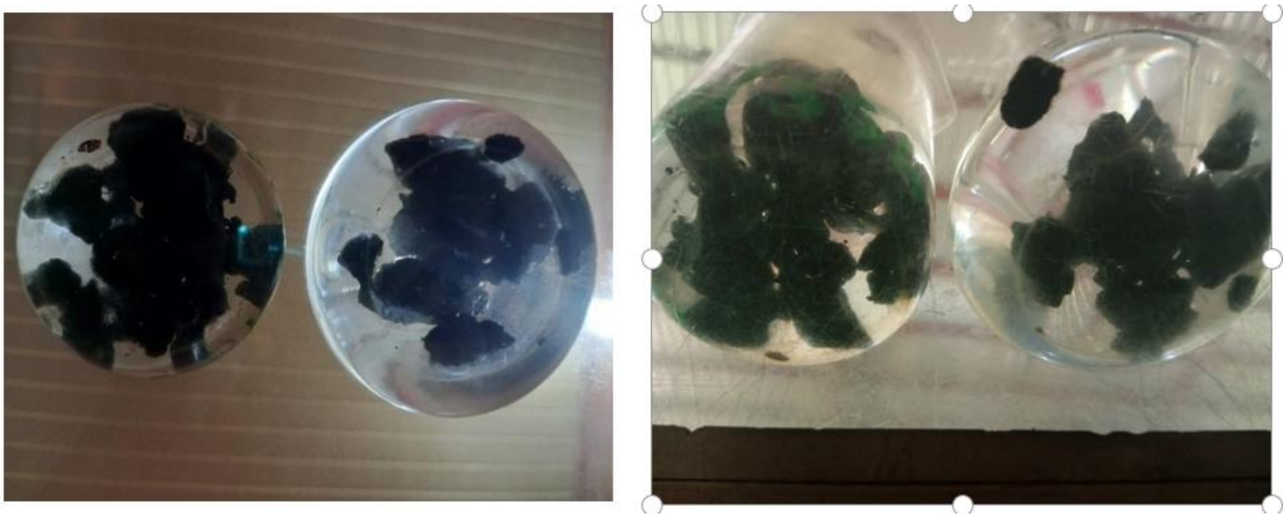


Figure 3 Static Immersion Test samples

2.4 Microstructural Morphology of Asphalt Binders

The storage, mixing, and placement processes typically lead to changes in the stability of modified bitumen, potentially influencing the strength of the HMA. The optical microscope was used to observed the morphology of WPS modified bitumen.

2.4.1 Optical Microscope

The storage stability of both the modified (WPS) and conventional asphalt binders were evaluated through a tube test experiment as per BS EN 13399 (BS 2000-517: 2003) standards. This involved pouring the conventional and modified asphalt binders into aluminium tubes, which were then placed in an oven at 180°C for three days (72 hours). After 72-hours conditioning period, the aluminium tubes were placed in a freezer for a minimum duration of four hours. This was followed by the cooling of the samples at ambient temperature. The cooled aluminium tubes were then horizontally cut into three equal sections. Only the top and bottom parts of the samples were used for analysis, while the middle sections of the samples were discarded. The difference in surface morphology between the top and the bottom sections of the samples was observed. Before observations, thin film samples were prepared by quickly spreading a drop of each sample on separate microscope glass slides at a certain temperature. Before observation, the prepared samples were allowed to cool down to room temperature. Micrographs of the control and WPS modified bitumen were captured using an optical microscope. Visible light of 40X magnification was used to examine the control and WPS modified asphalt binders. The optical microscope used for the observation and the prepared thin film samples are as shown in figure 4.

a b

Figure 4 Morphology: (a) Thin film samples and (b) Optical Microscope Assembly

2.4.2 Storage Stability Test

Phase separation of the polymer-modified asphalt binder is a common consequence of high temperatures during the production and storage stages. According to Cong et al. [8], phase separation may result from the differences between the polymer modifier and bitumen as well as insoluble rubber particles. The tube test experiment was used to evaluate the instability tendency in accordance with BS EN 13399 (BS 2000-517: 2003). It basically involves evaluating the possibility of bitumen-modifier separation to improve the modified bitumen's storage stability and service life.

3.0 Results and Discussion

3.1 Boiling Test

The images of the boiling water test samples were captured using a camera. Estimations on the percentage of bitumen coverage were made after 10 min of boiling and the subsequent 24 hrs room temperature conditioning. Figures 3 represent the images of granite aggregate coated with asphalt binders. In Figure 3 (a), it can be seen that control exhibited the low bonding property, whereas the mixtures with the incorporation of WPS promoted reduction in the rate of stripping effect. Figure 4 shows the subjective assessment of granite aggregate coated with asphalt binders after boiling test and 24 hrs room temperature conditioning. Similar trends are also observed in comparison with the image assessment. The WPS modified HMA mixtures efficiently enhance stripping rate of resistant. The stripping rate reduction is attributed to the increase in the dosage of WPS in the PEN 60/70 binder. However, the 7.5% WPS exhibited a better stripping resistance than all the considered mixtures.

Control 2.5% WPS

5% WPS

7.5% WPS

10% WPS

12.5% WPS

Fig 3. Images of Granite Aggregate Coated with Asphalt binders after 10 minutes of Boiling and 24 hours conditioning

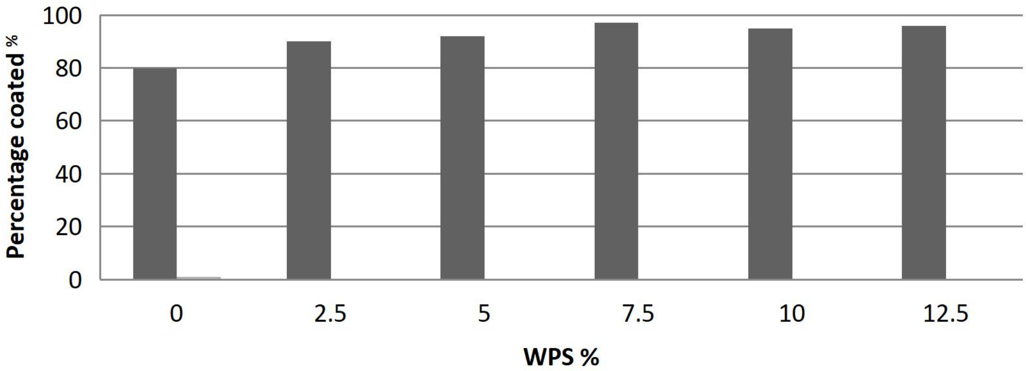


Fig 4 Percentage remains coated with Asphalt binders after 24 hours Conditioning.

3.2 Static Immersion

The percentage of the total visible area of granite aggregate that remained coated after 16–18 hrs of immersion was estimated as above or below 95%. Figure 5 presents the results of static immersion of the control and WPS-modified binders. The results show that the incorporation of WPS improves the moisture sensitivity of PEN 60/70. However, the addition of WPS has better improved the coat ability rate of the binder with almost 100% retained coated aggregate. The highest retained coated binder is the 7.5% WPS, whereas the lowest retained coated binder is the 5.0%. The 5.0% binder shows the weakest moisture sensitivity behaviour. This indicates that the presence of polyethene in the PEN60/70 binder may better improve asphalt mixture properties.

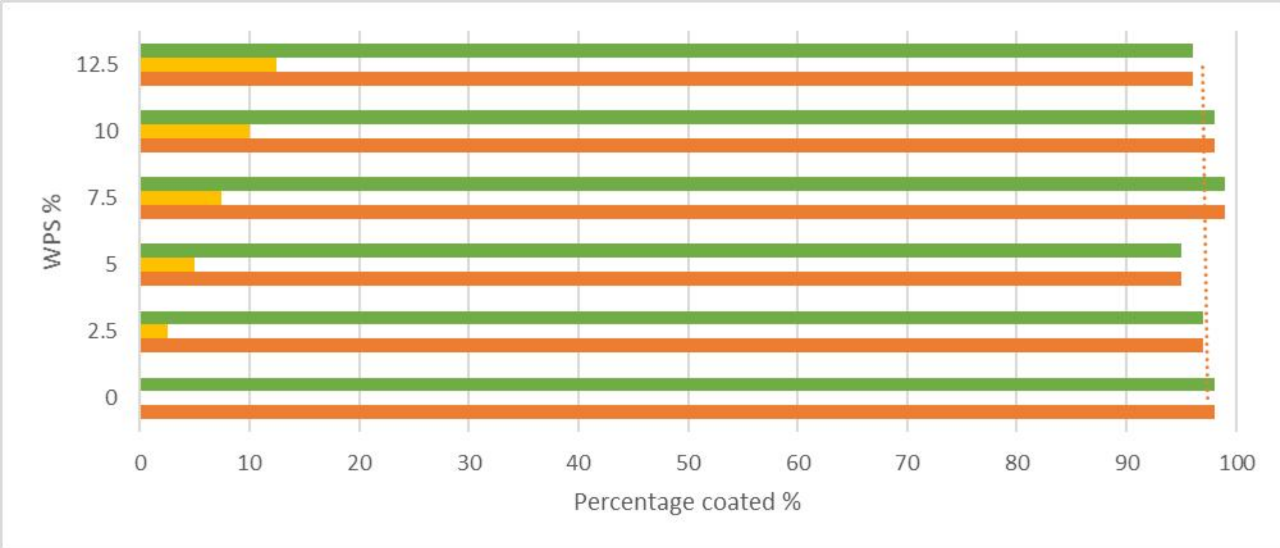
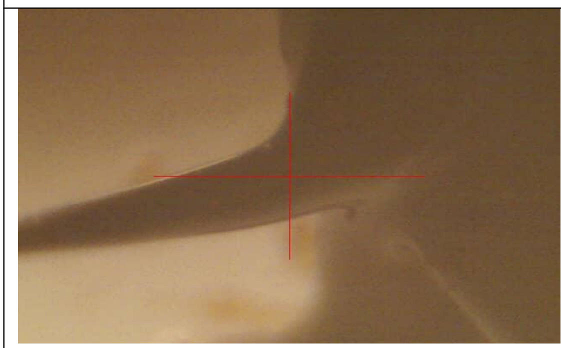
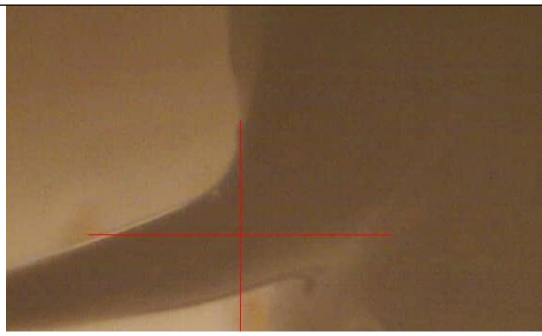
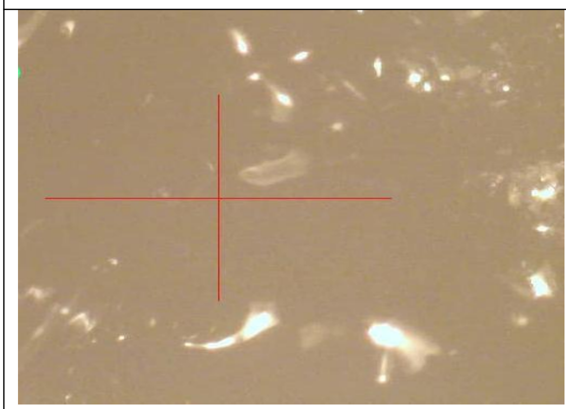
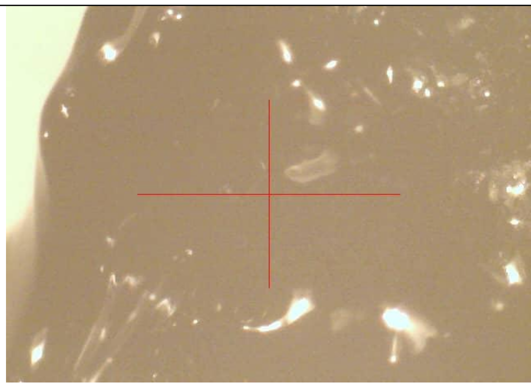


Fig 5. Percentages remain coated after static immersion of the WPS modified loose mix samples.

3.3 Surface Morphological Observation of WPS Modified Bitumen

The spreadability and dispersion of the asphalt binders matrix were assessed by examining the surface

morphology of PEN 60/70 asphalt binder and modified asphalt binders using optical microscope. Moreover, the homogeneity of different WPS modified asphalt binders was detected by observing the microstructure of the top and bottom parts of the samples from the storage stability test. Both the control and WPS-modified asphalt binders' micrographs are displayed in Figure 6. The top and bottom micrographs showed the same surface morphology, which was comparable. Excellent storage stability is demonstrated by the comparison of the samples' pictorial views for the control and modified asphalt binders. All the samples displayed small integrated spots of phase, which indicates the higher homogeneity and enhanced compatibility between asphalt binder and WPS [9-11].

Top	Bottom
	
PEN 60/70 Control	
	
2.5% WPS	

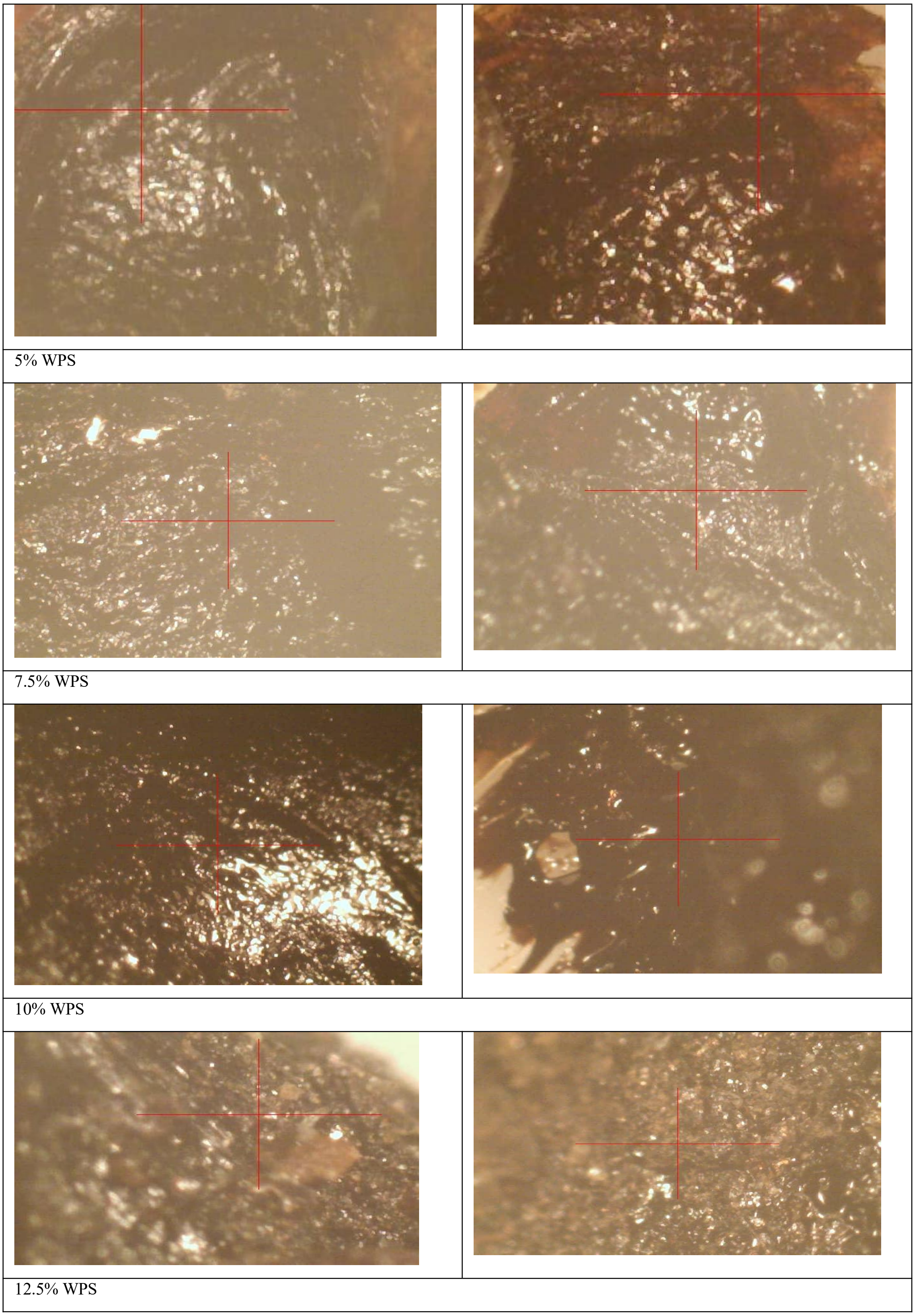


Figure 6 Micrographs of the Top and Bottom Storage Specimens

3.4 Storage Stability

The results of the softening point values of the binder's top and bottom section samples after they were exposed to a high temperature are displayed in Table 2. The control binder's top and bottom section samples showed precisely the same softening point values, as was expected. On the other hand, the modified binders demonstrated a nearly identical pattern, with the bottom part's softening point value being significantly greater than the sample from the top. Moreover, the bottom portion of the sample's softening point value increases in tandem with the percentage of WPS increase. However, the results of this investigation are consistent with those of the prior study [12-13], which employed an identical testing methodology. The temperature difference between the samples of both top and bottom sections falls within the permitted range of 0°C to 5°C. Thus, WPS modified bitumen exhibits good thermal storage stability in comparison to the one without modifier.

Table 2 Effect of WPS on Storage Stability of Bitumen

S/NO	Percentage (%)	Top SP*	Bottom SP*	Temperature Diff. °C
1	Control	50	50	0
2	2.5	58	60	2
3	5.0	60	62	2
4	7.5	62	64	2
5	10.0	64	66	2
6	12.5	63	66	3

SP* denote softening point

Conclusion

The effects of WPS dosage used at different percentages on the stripping, morphological and stability properties of the asphalt binders were evaluated. Observations were made using loose mix assessment, optical microscope and softening point tests, respectively. According to the results, the conclusions that can be drawn from this study as follows:

1. The result obtained of the rate of stripping between the binder and aggregates with the incorporation of WPS improved the bonding in the HMA based on the boiling and static immersion test conducted
2. The WPS-modified asphalt binder based on the microstructural appearance indicated that there is homogeneity and stability between the two components.
3. The softening point test result indicated that the WPS modifier binder offers strong storage stability looking at the temperature difference between the top and bottom sections is within the allowable range of 0°C -5°C.

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