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EFFECTS OF WASTE CROSSED-LINKED POLYETHYLENE ELECTRICAL WASTE COATING ON THE PROPERTIES OF BITUMEN

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ABSTRACT

The high cost of construction materials and increased axle loads has motivated researchers to seek alternative cost-effective materials for road construction. Studies on the use of waste thermoplastic polyethylene material to improve bitumen properties have been investigated. However, few studies on the use of thermoset polyethylene (cross-linked polyethylene) to modify bitumen have been carried out. This research investigated the use of waste cross-linked polyethylene (XLPE) cable coating on bitumen properties. An FTIR analysis carried out on waste XLPE cable coating revealed that it is predominantly composed of XLPE material. A comparative study carried out on the bitumen properties revealed that the modifier had a decreasing effect on its penetration and ductility but, had an increasing effect on softening point and specific gravity; Hence, a considerable improvement in the temperature susceptibility and stability of the bitumen. The short-term ageing analysis carried out revealed that the modified bitumen can withstand short-term ageing requirements at 2% and 4% by weight of pure bitumen. FTIR analysis carried out on the pure and modified bitumen revealed that changes observed in bitumen properties with increasing modifier content were a result of physical changes and not chemical changes. A one-way ANOVA carried out on the properties of various bitumen content revealed that the modifier had a significant effect on the properties of pure bitumen with increasing bitumen content. The regression models developed properly described the relationship between the modifier content and the bitumen properties as they expressed very good R^2 values.

Keywords: XLPE electrical cable coatings, Consistency, Short term ageing, FTIR analysis

INTRODUCTION

The rising trend in road traffic, increased axle load from heavier vehicles, and inadequate maintenance from inadequate financing resulted in rapid road deterioration. This has resulted in roads failing to serve their intended purpose within the design life. To address these issues, researchers and road professionals have looked into using higher-quality alternative materials, cost-effective construction methods, adequate funding for road maintenance, and improved and innovative design methods to ensure that roads serve their design purpose throughout their design life. The performance of flexible course, which is a widely used road type is significantly affected by the properties of its constituent materials, such as binder, aggregates, additives, and their proportion in the mix (Subagio and Kosasih, 2005). Research conducted by (Shbeeb, 2007; Subagio and Kosasih, 2005) discovered that polymers may be utilized as one of the additives to modified asphalt to increase the performance of flexible asphalt courses.

Polymers are made up of macromolecules, which are made up of numerous smaller chemical components called monomers (Britannica, 2020). (Robinson, 2005; Zoorob and Suparma, 2000) discovered that polymers can be added to asphalt mixtures either in a wet process as bitumen modifier or in a dry method as partial substitute for aggregate. The wet approach is the most popular since it uses less polymer, which raises the price of binder greatly in its virgin state (Kalantar et al., 2012). The dry technique has also sparked a lot of curiosity in a recent study. (Kalantar et al., 2012) directly mixed recycled and virgin polymers into the aggregates. This method may reduce pavement deformation while also boosting fatigue resistance and improving bitumen-aggregate adhesion.(Shbeeb, 2007; Vasudevan et al., 2012; Zoorob and Suparma, 2000).

Cross-linked polyethylene (XLPE) is a high-voltage cable insulating material that has been widely utilized in electrical cable coating for over 50 years due to its strong electrical insulation and heat resistance. Every year, a substantial volume of waste from high-voltage electrical wires is produced around the world. Because of their non-biodegradable components, limited fluidity, and poor moldability, XLPE waste is rarely recycled. The majority of XLPE waste is either burned as fuel or buried. However, burning XLPE pollutes the environment and necessitates huge initial investments (Costa et al., 2017). Therefore, research has been ongoing on how to use this XLPE waste in asphalt production. (Shamsaei et al., 2017) investigated the use of XLPE waste as aggregate in a roller compacted concrete pavement mixes. A number of percentages by volume were used to substitute coarse aggregate and its effect on compressive strength, splitting tensile strength and flexural strength were evaluated. The results depicted that XLPE waste affects the properties of fresh and hardened concrete. (Sun et al., 2021) evaluated the chances of using peroxide cross-linked polyethylene (P-XLPE) cable dust of modified asphalt using solid-state shear milling technology. The test P-XLPE powder and asphalt mix melted together formed a special twisted continuous phase. A storage stability experiment reaffirmed that P-XLPE modified asphalt to perform better due to its stability in high temperature from the stronger intermolecular interface of the two realms. (Liao et al., 2021) also discovered a new a new use of XLPE waste in asphalt production. The XLPE waste was first de-crosslinked using a solid-state shear milling with the asphalt harnessed plasticizers in the thermoplastic dispensation. The result show that the viscosity of the mix was found to reduce immensely. (Aghayan et al., 2022) replaced fine aggregate with XLPE waste in porous asphalt as various percentage replacement. The results show that as a result of the low absorption tendencies of XLPE waste, it increases the chances of resistance to moisture impairment in porous asphalt mix. (Sarkari et al., 2021).

Since little research have been carried out on the effect of waste XLPE on bitumen, this study aim to evaluate the effect of waste cross-linked polyethylene electrical cable coating (XLPE) on the properties of bitumen. This will take advantage of the some of the benefits of XLPE to modify 60/70 penetration grade bitumen in hot-mix asphalt wearing course preparation to improve its properties, since this could present both engineering and environmental benefits.

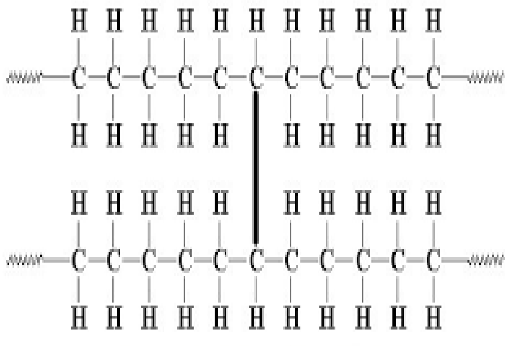

Figure 1: Chemical structure of XLPE

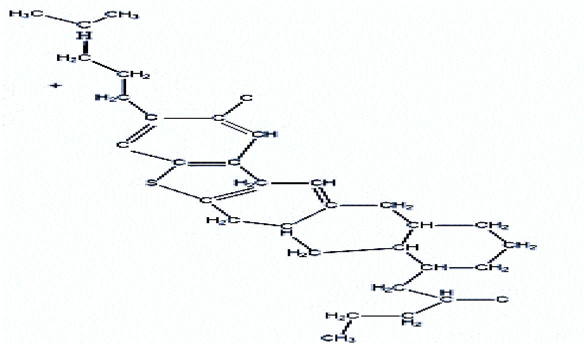

Figure 2: A typical chemical structure of bitumen (Redelius and Soenen, 2015)

MATERIALS AND METHODS

Materials

The 60/70 penetration grade bitumen utilized in this study was sourced from MOTHER-CAT Construction Company Ltd in Zaria, Kaduna state, Nigeria. Electrical cables with XLPE coatings were retrieved from waste and dumps in the Sabon-gari neighborhood of Kano metropolis, Kano State, Nigeria.

Methods

Sample Preparation

The cross-linked polyethylene electrical cable coating was completely washed and dried for 48 hours. With the help of a sole file machine, the modifier material was then filed down to powdered size. The material was subsequently fed into a Thomas Wiley milling laboratory machine type 4 at the Leader Research Institute's quality control laboratory in Zaria, Kaduna State, Nigeria, which was equipped with a 0.1 mm mesh sieve. When combined with bitumen, the material was further broken down into tiny bits to improve the contact surface area. It was then sieved using an ASTM sieve No. 100 (150 mm). The modifier used was the cross-linked polyethylene particles that went through 150 mm sieve.

The modified bitumen was made by slowly heating 600 g of bitumen in five different metal containers for each percentage replacement (2, 4, 6, 8, and 10 %), using a seven-liter camp gas burner. The heat was gradually applied until the temperature reached 160 °C–165 °C, which is within the temperature range for hot mix asphalt production (150-175°C). The modifier was then gradually added to the bitumen and mixed manually while maintaining the temperature range until a homogeneous mix was obtained with respect to each percentage (percent) replacement by weight of bitumen.

Laboratory tests

The XLPE material which is the modifier was first subjected to Fourier Transform Infrared Spectrum (FTIR) examination (ASTM E168, 2015) to determine if it was made of polyethylene. Penetration test (ASTM, 2013); Ductility test (ASTM D113-17, 2017); Softening point of bitumen (ASTM D36/D36M-14, 2020); and Specific gravity test (ASTM D2041 / D2041M-19) were carried out on the pure and modified bitumen to establish the effect of the modifier on the conventional rheological properties of bitumen with respect to temperature susceptibility, hardness and ductility when subjected to stresses. Rolling thin film oven test (ASTM D2872-19, 2019) was conducted to establish the effect of the modifier on short-term aging which takes place on the binder during preparation. Flash and fire point test of bitumen (ASTM D92-16b, 2016) and solubility test (ASTM, 2015) were also conducted on the pure bitumen for quality control and safety purposes.

Table 1: Characteristic Infrared Absorption Band (ICT Progue)

S/No	Frequency Range (cm^{-1})	Bond type	Bond name (family name)	Molecular Motion
1`	2840 - 3000	C - H	methylidyn (Alkanes)	Stretching
2	860 -900	C - H	Methylidyn (Alkane/Aromatic)	Bending
3	1290-1430	C - H	Methylidyn (Alkenes)	Bending in plane
4	1585 - 1600	C - C	Aromatic	Stretching
5	1450 - 1600	C = C	Aromatic	Stretching
4	900 - 860	C - H	Methylidyn	Bending
5	900 - 675	C - H	Aromatic	Out of plane bending
4	1450-1465	CH_2, CH_3	Methyl, Methylene	Bending
5	808	C - C	Alkane	Rocking
6	2922.2	CH_2	Methylene (Alkane)	Assymetric stretching
7	1375.4	CH_3	Methyl (alkanes)	Symmetric bending
8	701 - 600	S - C	From Thiophene group	Stretching

Statistical Analysis

A One-way analysis of variance (ANOVA) was performed between the properties of the pure and modified bitumen to see if the modifier has a significant effect on the attributes at a significance level of 0.05%. The regression analysis was used to describe the relationship between the modifier and bitumen properties.

RESULTS AND DISCUSSION

MODIFIER

The results and analysis conducted on the modifier are as follows:

Fourier Transform Infra-Red spectrum (FTIR) analysis

The chemical formula for the cross-linked polyethylene (XLPE) is [C_2H_4] on tn, with its chemical structure shown in Figure1. The presence of XLPE in the modifier was determined using a correlation of the chemical structure of the XLPE, the standard chart of Characteristic Infrared Absorption Bands (CIAB), and the FTIR test findings of the modifier presented in Table 1.

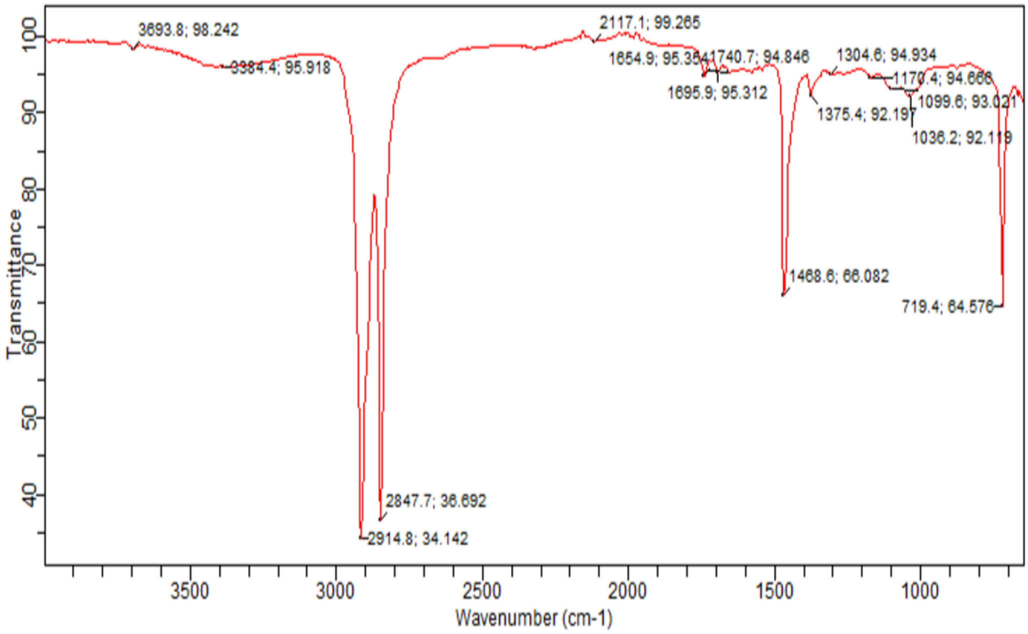

Figure 3: FTIR spectrum of the modifier (waste crosslinked polyethylene XLPE)

The properties of infra-red transmittance peaks as described by the intensity of the peak and wave numbers are as shown in the FTIR illustrated in Figure3. The XLPE molecule is usually characterized by transmittance peaks located at 2914.8 cm^{-1}, 2847.7 cm^{-1}, 1468.6 cm^{-1} and 719.4 cm^{-1}. These peaks are identical to those observed by (D'Amelia et al., 2016), who discovered that the typical absorbance bands for XLPE are at 2914 cm^{-1}, 2847 cm^{-1}, 1470 cm^{-1}, and 718 cm^{-1}. A very sharp transmittance peaks was detected at 2847.7 cm^{-1} and 2914.8 cm^{-1} wave numbers suggest a substantial presence of (C - H) group bond stretching of CH_2 group present in XLPE. The peaks at 1468.6 cm^{-1} and 719.4 cm^{-1} observed at the finger print region indicates the presence of methylene (CH_2) group bond in the ethylene molecule. This demonstrates that the material utilized in this study was none other than polyethylene, although in its thermoset (crosslinked) form. Other peaks could be due to colors used in fabricating XLPE electrical cable coating material, which are minor compared to the amount of XLPE and were thus ignored in this investigation.

Specific gravity test

The result of specific gravity test conducted on the modifier according to (ASTM, 2011; ASTM, 2000), yielded a result of 0.94. This implies the material used as modifier is approximately 2.6 times lighter than the weight of water. (Awwad and Shbeeb, 2007) observed specific gravities of 0.92 and 0.95 for LDPE and HDPE respectively.

Pure Bitumen

Other general tests conducted on the pure bitumen yielded findings that were consistent with expectations of (FMWH, 2016), for 60/70 penetration grade bitumen.

Table 2: The results of consistency and other general tests of the pure bitumen

S/N	Test Conducted	Unit	Result	Specification
1	Penetration	0.1 mm	67.9	60 -70
2	Softening point	ºC	48.9	48-56
3	Ductility @ 25 ºC	cm	119	100 (Minimum)
4	Specific gravity	NIL	1.013	1.01-1.06
5	Flash-point	ºC	256	250 (Minimum)
6	Fire-point	ºC	221	NIL
7	Solubility in C_2S	%	100	99 min

Modified bitumen

Effects of modifier on the penetration

Figure 4 shows the influence of the modifier (XLPE) material on the penetration property of the 60/70 grade bitumen.

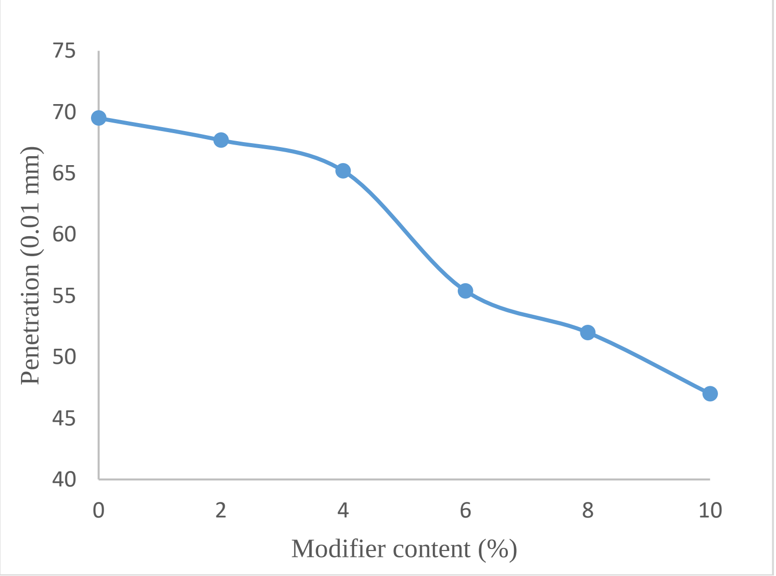

Figure 4: Effect of the modifier on the penetration property

From Figure 4, it can be seen that the as the modifier content (2%, 4%, 6%, 8% and 10%) is increased, the penetration of the material was clearly observed to decrease. The decrease is as a result of increased hardening of the mix which can visibly be observed by the increasing thickness as shown in plate 1, 2, 3, 4 and 5. This trend is in tandem with the works of (Jan et al., 2018) which examined the efficiency of modified hot mix asphalt using waste polymeric polyethylene.

Plate 1: Modified bitumen at 2% modifier content.

Plate 2: Modified bitumen at 4% modifier content.

Plate 3: Modified bitumen at 6% modifier content.

Plate 4: Modified bitumen at 8% modifier content

Plate 5: Modified bitumen at 10% modifier content.

The increased hardening from the decrease in penetration of the material from increase in the modifier content signifies an overall improvement in the material's high-temperature susceptibility, which, if lacking, might result in failures such as bleeding and rutting. The cause of the observed trend, as reported by (Airey, 2002; Kumar and Garg, 2011; Panda and Mazumdar, 1999; Sadeque and Patil, 2014) can be attributed to fact that when polymers mix with bitumen at certain temperature (usually above 150ºC), they swell absorbing lower molecular fractions such as maltenes oils from pure bitumen. Absorbing low molecular weight maltenes oils increases the amount of high molecular weight asphaltene micelles. Bitumen with a lower and harder penetration grade is caused by asphaltene micelles (O'Flaherty, 2002). The modified bitumen at 2% and 4% by weight of pure bitumen was also observed to meet up with the Nigerian Federal Ministry of Work Specification for penetration property.

Effects of modifier on the softening point

Figure 5 shows the influence of the modifier (XLPE) material on the softening point property of 60/70 grade bitumen.

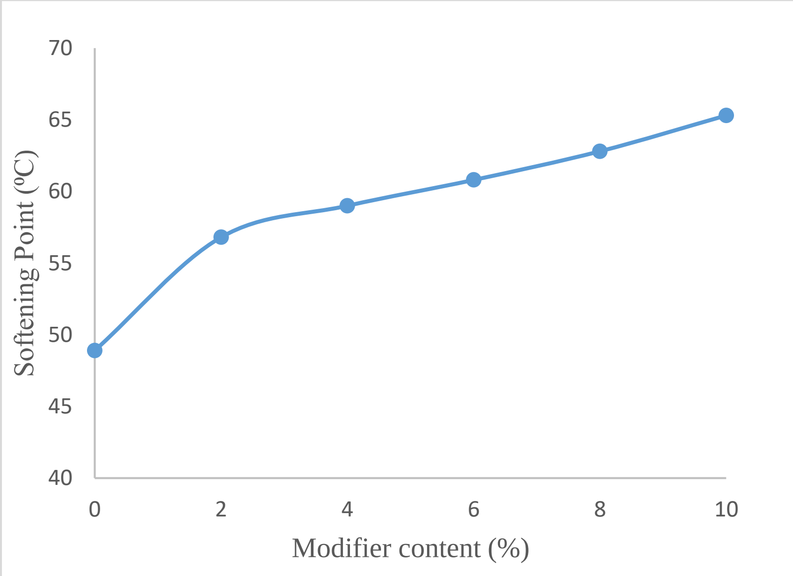

Figure 5: Effect of the modifier on the softening point property

The softening point, like penetration property of bitumen, is a useful indicator of increased resistance to failures which are expected to develop as a result of high temperature susceptibility of bitumen binder material. Figure 5 shows the increasing trend of temperature of softening point with increasing modifier content. This finding is in agreement with previous study by (Eme and Nwaobakata, 2019) that the softening point of asphalt mix increases with increase in plastic content up to a weight of 10%. This tendency is caused by a phenomenon similar to that of the penetrating property, which is caused by increase in high molecular weight asphaltene micelles. The softening point temperature for the modified bitumen met with the Nigerian specification for road construction at 2% and 4% modifier content by weight of pure bitumen.

Effects of modifier on the ductility

Figure 6 shows the influence of the modifier (XLPE) material on the ductility property of 60/70 grade bitumen.

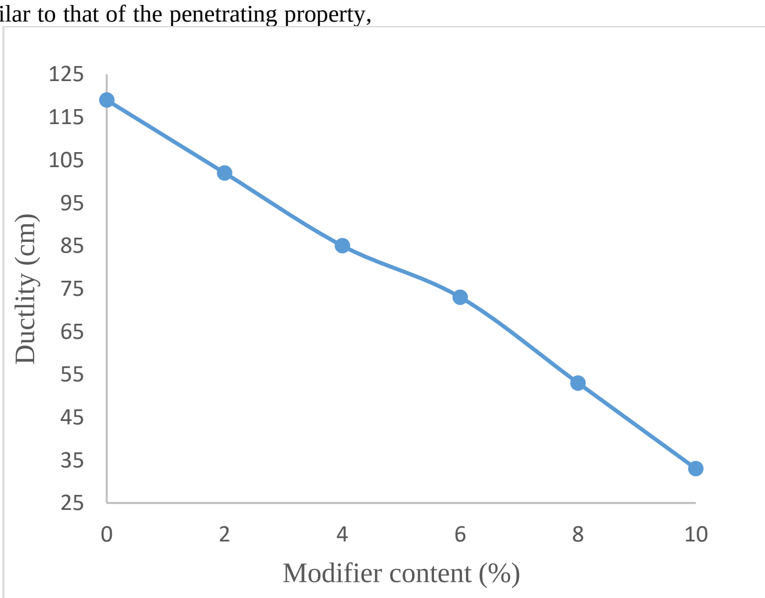

Figure 6: Effect of the modifier on the ductility property.

As can be seen in Figure 6, the ductility of the modified bitumen decreases as the modifier amount increases. This is as a result of the absorption of lighter molecular weight oil fractions from pure bitumen, the binder has become harder and more brittle (Becker et al., 2001). The ductility values of modified bitumen at all of the modifier contents did not meet up with the Nigerian specification for road construction. Even though, the ductility of the modified bitumen did not meet up with the specified criteria (>100cm), authors such as (Saal, 1955) debated it importance to practical application to HMA. Their justification is that rutting and fatigue resistance of binders have been investigated in a set of polymer modified binders. The results showed no correlations with binder ductility. A test protocol was designed employing a dynamic shear rheometer (DSR) as a surrogate for traditional ductility test (which is outside the scope of this work). Even when traditional ductility revealed a loss of ductility, the results demonstrated that both modified binders are substantially more ductile than conventional binders. Furthermore, it was discovered that the plastic elongation witnessed during ductility testing is caused by thixotropic breakdown in the bitumen and a specific sort of temperature rise, both of which are not observed in practice.

Effects of modifier on the specific gravity

Figure 7 shows the influence of modified (XLPE) material on the specific gravity of 60/70 grade bitumen.

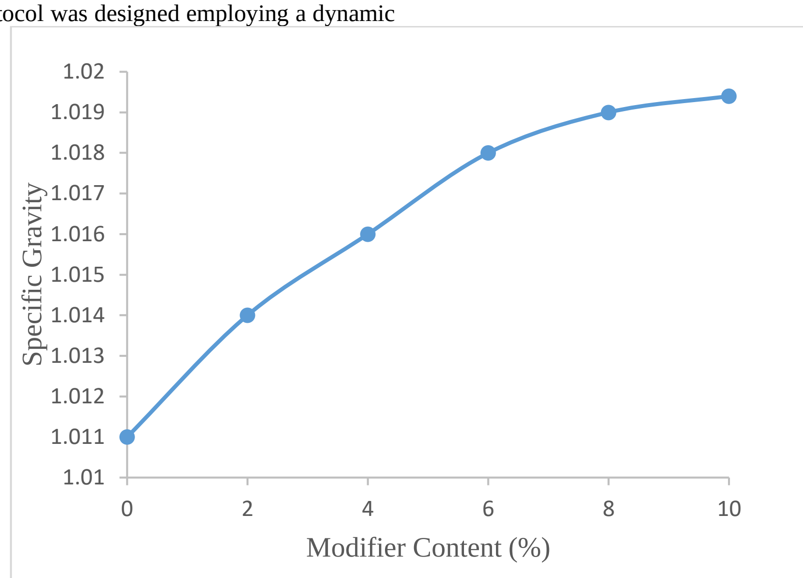

Figure 7: Effect of the modifier on the specific gravity property.

The trend in the specific gravity is attributed to an increase in weight due to the modifier material being added to the pure bitumen. This results to an increase in weight of the modified bitumen with increasing modifier content. This trend is in line with the works of (Eme and Nwaobakata, 2019) which also observed that specific gravity increases with increase in LDPE content up to 10%. The specific gravity of the modified bitumen meets the specification of 60/70 penetration grade bitumen.

Rolling thin film oven (RTFO) test

Table 3 presents the results of the rolling thin film oven (RTFO) test.

Table 3: Results of Rolling Thin Film Oven tests

Modifier content (%)	Mass of binder before RTFO test (g)	Mass of binder after RTFO test (g)	Percent loss after RTFO test (%)	Specification (%)
0	55.605	55.271	0.6	≤ 1
2	55.770	55.324	0.8	≤ 1
4	55.880	55.394	0.95	≤ 1
6	55.990	55.150	1.5	≤ 1
8	56.045	53.669	2.5	≤ 1
10	56.067	54.385	3	≤ 1

The percent loss in mass after the RTFO test is within the specified limits for pure bitumen, and 2% and 4% modified bitumen. However, the 6%, 8% and 10% modified bitumen fell out of the specified limits. This implies the modified bitumen will be able to withstand short-term aging experienced during production of up to 4% modifier added by weight of pure bitumen. This buttress the finding by (Addissie et al., 2018) that adding 3% PVC and 5% LDPE modifies on pure 40/50 and 85/100 penetration grade bitumen reduces the effect of short aging of mastic asphalt in the process of mixing and compacting.

Fourier Transform Infra-Red spectrum (FTIR) analysis

Figure 8 depicts the infrared (IR) spectrum of the pure bitumen documented in the range of 4000 – 650 cm^{-1}.

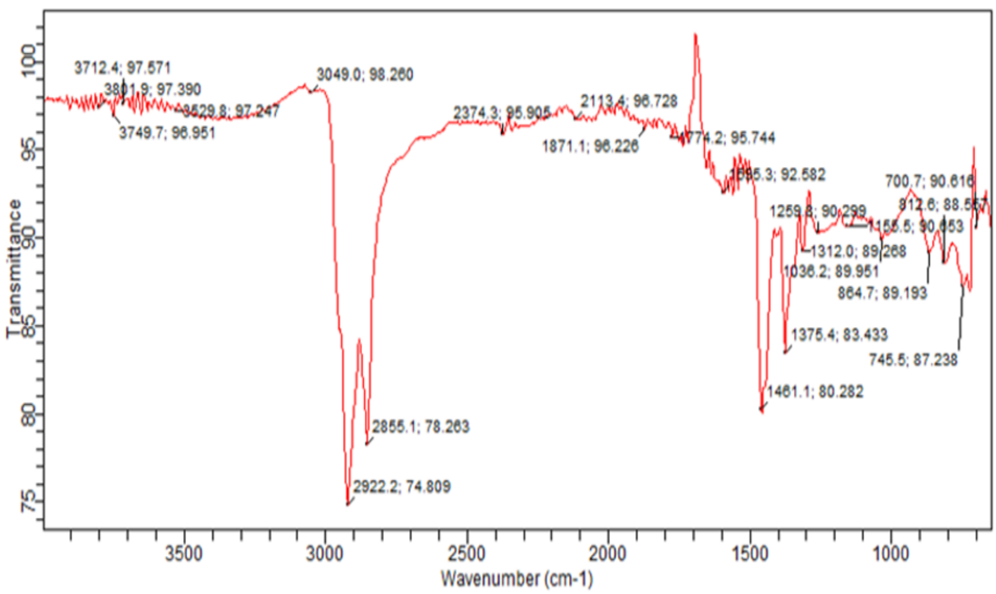

Figure 8: FTIR spectrum of the pure bitumen (0% modifier by weight of bitumen)

Comparing Figure 2 and Figure 8 divulges that pure bitumen transmittance peaks at 3049 cm^{-1}, which indicated stretching of O-H group. Wave numbers 2922 cm^{-1} and 2855.1 cm^{-1} shows a presence of (C – H) group bond and stretching of CH_2 and CH_3 group. Wave numbers 2374 cm^{-1} and 2113.4 cm^{-1}signifies a presence of P-H phosphine and HC ≡ CH stretching respectively. Likewise, wave numbers 1774 cm^{-1}, 1699 cm^{-1} and 1596.3 cm^{-1} also signifies the presence of C=O stretching, C=O bond from a conjugate aldehyde, and aromatic stretching respectively. In addition, wave number 1461 cm^{-1} indicates presence of methyl and methylene bending; 1375.4 cm^{-1} reveals O-H bending from a phenol group; and 1036.2 cm^{-1} indicates presence of C-F stretching from a flouro-compound. The peak at 1259.8 cm^{-1} indicates the presence of C-O strong stretching from an akyl-aryl ether. Likewise, peak at 1312 cm^{-1} indicates presence of C-N stretching of an aromatic amine, and peaks in the region 864.7 cm^{-1} and 812.6 cm^{-1} indicates m-substitution benzene. The 745.5 cm^{-1} indicates mono-substitution out of plane bending in benzene; 700.7 cm^{-1} is an indication of the presence of S-C bond. The infrared absorption peaks are similar to the submission of (Kamal et al., 2017), whom identified absorption bands related to pure bitumen to include 2922 cm^{-1} (υasCH2 CH3), 2862 cm^{-1}(υsCH2 CH3), 1601 cm^{-1}(υ C=C), 1455 cm^{-1}, 1376 cm^{-1}, 1031 cm^{-1}(υ SO2), 868 cm^{-1},813 cm^{-1} (C=C), 747 cm^{-1}, and 722 cm^{-1}). Figures 9, 10, 11, 12 and 13 shows the FTIR analysis conducted on the modified bitumen at 2%, 4%, 6% 8% and 10%.

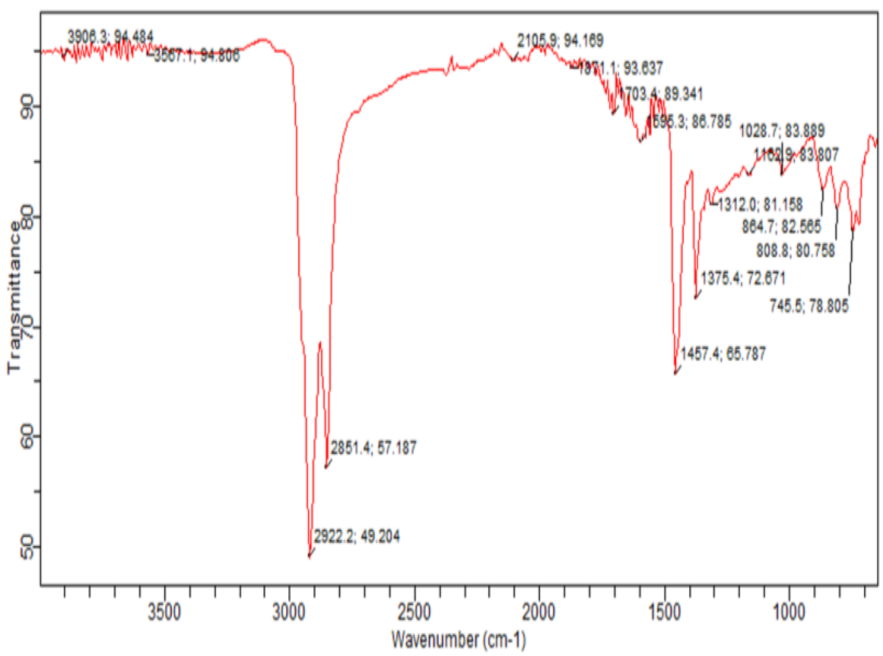

Figure 9: FTIR spectrum of 2% modifier by weight of pure bitumen

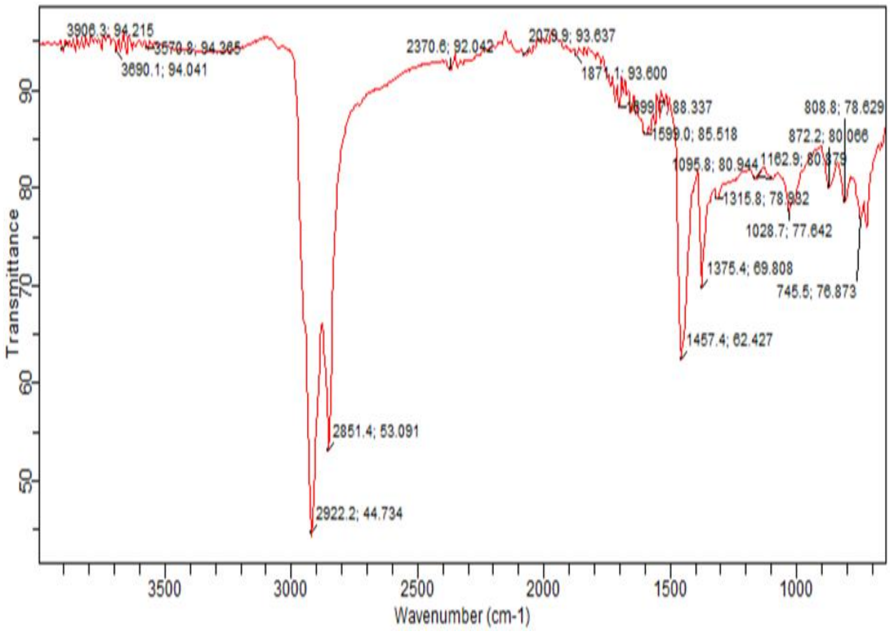

Figure 10: FTIR spectrum at 4% modifier by weight of pure bitumen

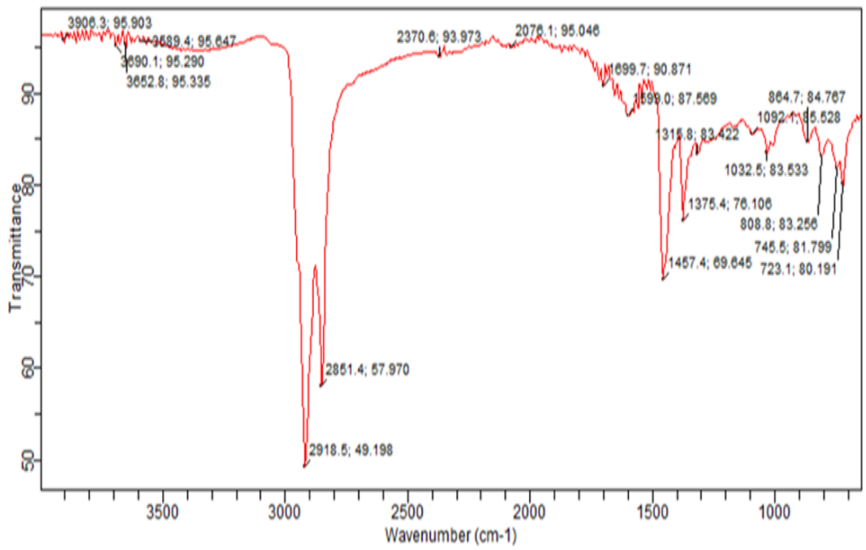

Figure 11: FTIR spectrum at 6% modifier by weight of pure bitumen

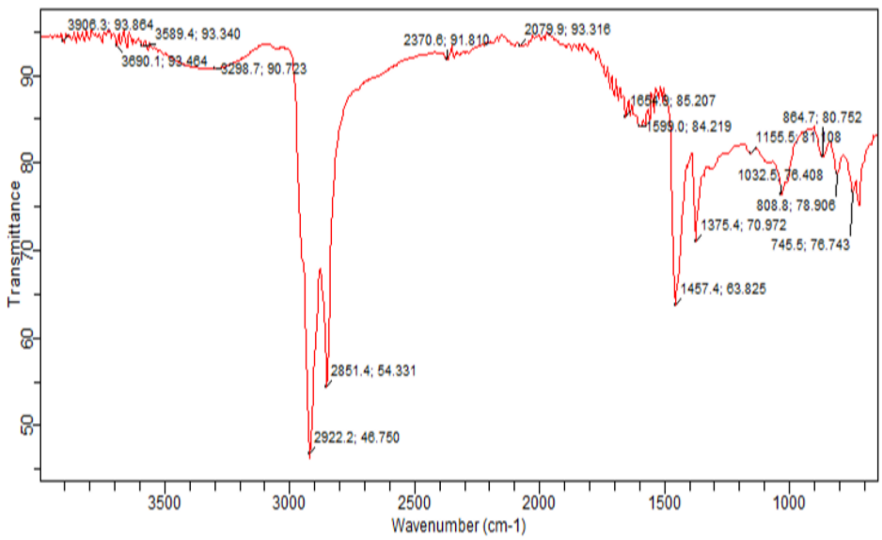

Figure 12: FTIR spectrum at 8% modifier by weight of pure bitumen

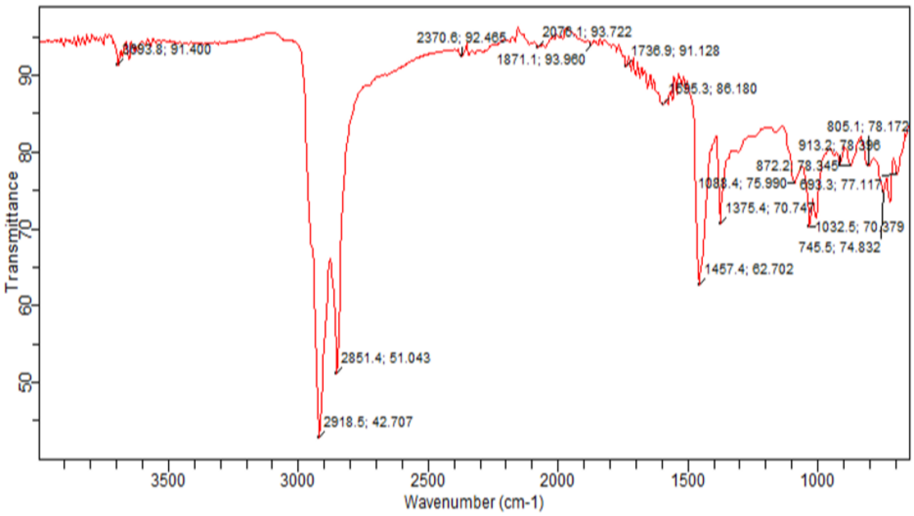

Figure 13: FTIR spectrum of 10% modifier by weight of pure bitumen

A comparative analysis between the FTIR spectra of the modifier, pure and modified bitumen shows that most Infra-red spectrum transmittance peaks of the modifier material and pure bitumen are present in the modified bitumen, with the measure of transmittance increasing with increasing modifier content. However, no appearance or disappearance of any known functional group peaks. (Olabemiwo et al., 2019) revealed that no additional peaks in the spectra of HDPE modified base samples since the four main peaks in the spectrum of polyethylene, for example methylene stretches at 2920 cm^{-1} and 2850 cm^{-1} with deformations at 1464 cm^{-1} and 719cm^{-1} also existing in the base of the spectrum. This establishes that bitumen modification occurs as a result of a physical contact between the modifier and the bitumen, resulting in the absorption of low molecular weight fractions in pure bitumen.

Statistical Analysis

Analysis of variance (ANOVA)

The following are the results of a one-way ANOVA statistical analysis of the properties of modified bitumen:

Table 4: ANOVA of Specific gravity Property at Various Bitumen and Modifier Contents

Bitumen content	Polymer Content (J)	Mean	Mean Difference (I-J)	P_{value}.	Comment
0% (I)	2%	1.0140	-0.00300*	0.000	Significant effect
CONTROL	4%	1.0160	-0.00500*	0.000	Significant effect
(1.0110)	6%	1.0180	-0.00700*	0.000	Significant effect
	8%	1.0190	-0.00800*	0.000	Significant effect
	10%	1.0194	-0.00840*	0.000	Significant effect

From Table 4, the ANOVA results showed that the modifier had significant effect on the specific-gravity at 2%, 4%, 6%, 8% and 10% modifier contents when compared with the control i.e. (Sig-values <0.05).

Table 5: ANOVA of Penetration Property at Various Bitumen and Modifier Contents

Bitumen content	Polymer Content (J)	Mean	Mean Difference (I-J)	P_{value}.	Comment
0% (I)	2%	67.7000	1.80000*	0.003	Significant effect
CONTROL	4%	65.2000	4.30000*	0.000	Significant effect
(69.5000)	6%	55.4000	14.10000*	0.000	Significant effect
	8%	52.0000	17.50000*	0.000	Significant effect
	10%	46.6667	22.83333*	0.000	Significant effect

From Table 5, the ANOVA result shows that the modifier had significant effect on the penetration property at 2%, 4%, 6%, 8% and 10% modifier contents when compared with the control i.e. (Sig-values <0.05).

Table 6: ANOVA of Ductility Property at Various Bitumen and Modifier Contents

Bitumen content	Polymer Content (J)	Mean	Mean Difference (I-J)	P_{value}.	Comment
0% (I)	2%	102.0000	0.88192	0.000	Significant effect
CONTROL	4%	85.0000	0.88192	0.000	Significant effect
(119.0000)	6%	73.0000	0.88192	0.000	Significant effect
	8%	53.0000	0.88192	0.000	Significant effect
	10%	33.0000	0.88192	0.000	Significant effect

From Table 6, the ANOVA result shows that the modifier had significant effect on the Ductility property at 2%, 4%, 6%, 8% and 10% modifier contents when compared with the control i.e. (Sig-values <0.05).

Table 7: ANOVA of Softening-point Property at Various Bitumen and Modifier Contents

Bitumen content	Polymer Content (J)	Mean	Mean Difference (I-J)	P_{value}.	Comment
0% (I)	2%	56.8000	-7.90000*	0.000	Significant effect
CONTROL	4%	59.0000	-10.10000*	0.000	Significant effect
(48.9000)	6%	60.8000	-11.90000*	0.000	Significant effect
	8%	62.8000	-13.90000*	0.000	Significant effect
	10%	65.3000	-16.40000*	0.000	Significant effect

Table 7 ANOVA result shows that the modifier had significant effect on the Softening-point property at 2%, 4%, 6%, 8% and 10% modifier contents when compared with the control i.e. (Sig-values <0.05).

Regression Analysis

Table 8 shows the regression analysis used to establish a relationship between modifier content and properties of modified bitumen:

Table 8: Regression models of the various HMA property

Property	Regression Model	R^2 Value
Penetration	$Y_1 = -2.4551X + 71.586$	0.9496 (94.96%)
Softening Point	$Y_2 = 1.492X + 51.393$	0.9062 (90.62%)
Ductility	$Y_3 = -8.4143X + 119.37$	0.9937 (99.37%)
Specific-Gravity	$Y_4 = -0.000075X^2 - 0.0015X + 1.0113$	0.9478 (94.78%)

Table 8 depicts the several regression models for each property that describe the relationship between the properties of modified bitumen and modifier. Consequently, the value of any attribute for a specific modifier content can be predicted to the degree of the R^2 value, as shown Table 8, using the models.

CONCLUSION

This research aim at evaluating the effect of waste cross-linked polyethylene electrical cable coating (XLPE) on the properties of bitumen. First, a Fourier Transform Infra-Red (FTIR) spectra analysis conducted on the waste XLPE cable coating compared with Characteristic Infra-red Absorption Band of Function Group (CIABFG), confirmed the predominance of XLPE in the cable coatings. A comparative evaluation between pure and modified bitumen at various modifier contents revealed that increasing the modifier content reduces the penetration and ductility although, had an increasing effect on the softening point and specific gravity. RTFO test revealed that the modified bitumen at 2% and 4% modifier content can withstand short-term aging which occur during manufacturing of hot-mix asphalt. In addition, comparative evaluation between pure and modified bitumen using FTIR spectra analysis show that no new wave number (cm^{-1}) transmittance peaks appeared in the modified bitumen (at 2%, 4%, 6%, 8% and 10% modifier content) that were not present already in the pure bitumen. Hence changes experienced in the bitumen properties with respect to increase in the modifier content was as a result of physical change and not chemical change. Furthermore, a one-way ANOVA carried out revealed that the modifier had a significant effect on all properties of the bitumen at all modifier contents. Lastly, regression models are developed to describe the relationship between the modifier and bitumen properties showed good R^2 values which therefore, validated the models.

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