CONSTRUCTION
e-ISSN: 2785-8731
VOL. 2, ISSUE 1, 10 – 21
DOI: https://doi.org/10.15282/cons.v2i1.7367

ORIGINAL ARTICLE

Performance of Asphalt Mixture Incorporated Encapsulated Cigarette Butts as Bitumen Modifier

H. AL-A. Nader Ameen[1]* and P.J. Ramadhansyah[1,2]

[1]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Pahang, Malaysia.
[2]Institute for Infrastructure Engineering and Sustainability Management, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

ABSTRACT – Cigarette butts are non-biodegradable waste, and the difficulties in dealing with cigarette waste is a big concern for communities and environmental groups all over the world. In past years, cigarette butts has been increasingly used on flexible pavement and has become one of the causes that increases pavement strength and reduces environmental challenges. Environmental factors are external influences that affect the performance of flexible pavements. These include snow, chemicals, water, and ageing issues. The aim of this research is to evaluate the mechanical and physical properties of asphalt mixture incorporating encapsulated cigarette butts. Asphalt concrete has a number of problems, including rutting, moisture removal, and binder drain. The use of asphalt is restricted due to high temperatures that cause rutting cracking of the asphalt or coating layer. Therefore, it is necessary to modify asphalt and improve its quality with less affects to environment. In this research, experiments were carried out to compare two types of asphalt which are unmodified asphalt and modified asphalt mixture. For modified asphalt, various percentages of encapsulated cigarette butts were added to the mixtures. The additive used was encapsulated cigarette butts with increment 0%, 0.2%, 1% and 3% for the bitumen and 0%, 5%, 10% and 15% for asphalt mixture. Penetration test, softening point, ductility test, penetration index, los angeles (LA) abrasion test, marshall tests, indirect tensile strength test and dynamic creep test were performed. The findings of the studies performed in this project reveal that varying the percentages of cigarette butts in the asphalt concrete mixture obviously differs in the mechanical and physical characteristics of asphalt mixture. As a result, the addition of CBs to AC resulted in a different abrasion loss value when compared to unmodified AC. At 10% CBs put into the asphalt mixture, the abrasion loss was chosen as the most advantageous level for increasing the performance of AC mixture. Based on the results of the mechanical and physical tests we can infer that 5% of CBs is the best percentage of cigarette butts to add in asphalt mixture. So this study proved that cigarette butts to be an effective material is used as an addition to asphalt binder because it improves performance by increasing paving strength and stiffness.

ARTICLE HISTORY
Received: 27th Jan 2022
Revised: 11th Mar 2022
Accepted: 28th Mar 2022

KEYWORDS
Cigarette butts modifier
Asphalt concrete
Marshall
Indirect tensile strength
Dynamic creep
Stability
Abrasion

INTRODUCTION

A road is a broad path that connects two points, particularly one having a paved surface for vehicles to go on. The most upper surface of the road is referred to as the pavement. Road, runway and street are the best examples of hard-surfaced road pavement. Asphalt concrete is a common road design tool in Malaysia. Concrete asphalt is a mixture of two principal aggregate elements and asphalted cement. Aggregates typically constitute 90-95% (w/w) of a combined average and bituminous cement (binding asphalt) accounts for 5-10% (w/w) of a total blend to be asphalt concrete [1]. Asphalt concrete is a combination of asphalt and aggregation that is a sensitive substance compared with other materials used in structural engineering. The most significant method of covering is asphalt concrete. It has been widely used around the world due to its excellent road performance and simple maintenance steps. Bituminous binder is thought to have an important impact as a binder in paving and contribute to paving results. According to [2], Asphalt concrete (AC) is one of the most commonly used materials on the planet. It consists of a mixture of asphalt, aggregate pellets, and pores, formed at an incredibly high temperature of around 180°C. The hardness of asphalt concrete improves after years of use and its ability to relax decreases. Asphalt concrete (AC) adhesive then creates micro-cracks and breaks the interface between the aggregate and the stick. During the shelf-life, the product continues to become fragile, rigid and exposed to sun, oxygen and ultraviolet rays during packaging, blending, transportation and positioning [3].

The unit price of concrete asphalt is thought to be low. Because it can be used as it cools and at same time the building is frequently less time consuming and has high drainage and quietness a few hours after construction because of the durability and smoothness of asphalt concrete. Asphalt concrete (AC) differs by its surface water drainage, foot regulation of noise, spray avoidance and wet season increase of skid resistance. In addition, the floor surface has a lack of light as well as a decrease in tyre wear because of lower rolling power. For a dense smooth surface, a combination of thick-graded and bituminous added matter, or without mineral filler, is compacted hot which is known to be a standard and lasting

*CORRESPONDING AUTHOR | H. AL-A. Nader Ameen | ✉ nd.alameri5@gmail.com
© The Authors 2022. Published by University Malaysia Pahang Publishing. This is an open access article under the CC BY license.

paving substance for the use of rails and structural pillars, trails and floor coverings. It can be designed for a variety of applications [2]. Decrease the force of the plank. This means that the structural layer of the sidewalk needs to be supported more. Low durability, so it is easy to crack and dent. Often needs repairs. When touched accidentally, like in the middle of a summer day, it gets hot enough to burn you. Reducing resistance will also limit the application of the substance in low stress areas, which can lead to an increase in total cargo volume. In addition, compared to other materials, the service life of the coating is shortened, since the oxidation of the liver is most likely due to the vacuum in the material. In addition, due to the increased exposure of materials to adverse temperature and weather conditions, it results in higher construction costs. Finally, the fact that paver repair methods are more difficult than other more traditional materials increases maintenance costs for a cause [4].

The AC method determines the optimum aggregate gradation, optimum asphalt binder, and optimum aggregate and asphalt binder mix. As the pavement's underlying skeleton, the minerals mixture is made up of course and fine crystals. Bitumen is widely used in road and highway building to tie graded minerals together [5]. In general, at the desired temperature, the asphalt binder is combined with the aggregate to thoroughly coat the aggregate and binder and prepare for paving. In comparison to what is typically expected in Asphalt concrete (AC) processing, the viscosity would be lower at lower temperatures, allowing the aggregate to be completely coated [6]. These would lead to the mastic's overall weakening and the aggregate-mastic bond's weakening.

Using waste materials to improve the efficiency of asphalt mixtures is not a novel concept in the industry. It is frequently used as an additive ingredient in asphalt mixtures, such as density polyethylene, marble quarry waste, building demolition waste, ground tyre rubber, cooking oil, coconut, sisal, cellulose, starch, plastic bottles, waste glass, waste tile, waste ceramic, waste fly ash, and cigarette butts, among others. Cigarette butts were added to the asphalt concrete to improve its performance [7]. Cigarette filters are made up of heavy metal materials, such as asbestos, chrome, nickel and cadmium. The filters are not biodegradable in particular and can take several years to degrade. Science may be rescued as often. As construction material for buildings, for example, cigarette butts may be repurposed. It also points out that blending into asphalt increases the robustness and heat- absorption of road surfaces [8].

A 28% of adults in Europe still smoke and the continent have some of the highest prevalence for cigarette consumption among teenagers (according to the World Health Organization). And all of those millions are gazillions of smokers who produce cigarette butts. The condition in the rest of the world is not any different. In 2020, worldwide about six trillion cigarette butts have been removed, which surpass 1,2 million tonnes. The total number of smokers around the world could increase to 9 trillion by 2025 [9].

The asphalt fortified with cigarette butts can be able to survive heavy traffic and the mixture also has decreased thermal conductivity. It absorbs less heats from the sun and hence keeps the asphalt surface hotter on hot summer days, a research team at RMIT University in Melbourne, Australia has discovered [7].

Asphalt combined with cigarette butts will help to minimize the influence of urban heat in tropical cities, particularly the temperatures will escalate as the global warming continues. The opinion of Dr Abbas Mohajerani, senior lecturer at RMIT School of Engineering [10], we have encapsulated the cigarette butts with bitumen and paraffin wax to protect chemicals from being leached from asphalt concreted.

The summary of this paper is using cigarette butts to increase the efficiency of asphalt mixtures is not new in industry. Cigarette butts was first used in civil engineering applications in 2017 in Australia [7]. It has been used as an additive to asphalt. It is constantly being introduced as an additive ingredient in asphalt mixtures. To improve the performance of the asphalt concrete, cigarette butts were added. Encapsulated butts of cigarette is therefore offered as one of the finest options to alleviate the problem of large loads because cigarette filters are made up of heavy metal materials, such as asbestos, chrome, nickel and cadmium [11].

MATERIALS AND PREPARATION

Aggregate

Sieve analysis, aggregate impact value (AIV), and aggregate crushing value (ACV) are the three main tests for aggregate attributes. The sample weight was estimated at about 1200g. In the oven the aggregate was dried. The sieve was then put in the mechanical shaker and it lasted 10-15 minutes. In Figure 1, seven ASTM analyses from 14mm to 0.075mm, each of which was of a weight difference, were used for this experiment, while 1200g were used in the sample after a seven-sized test. The unit had been screened and then weighted to make it more flexible and homogeneous to integrate additional materials with a temperature range between 140 and 150 C^{o}.

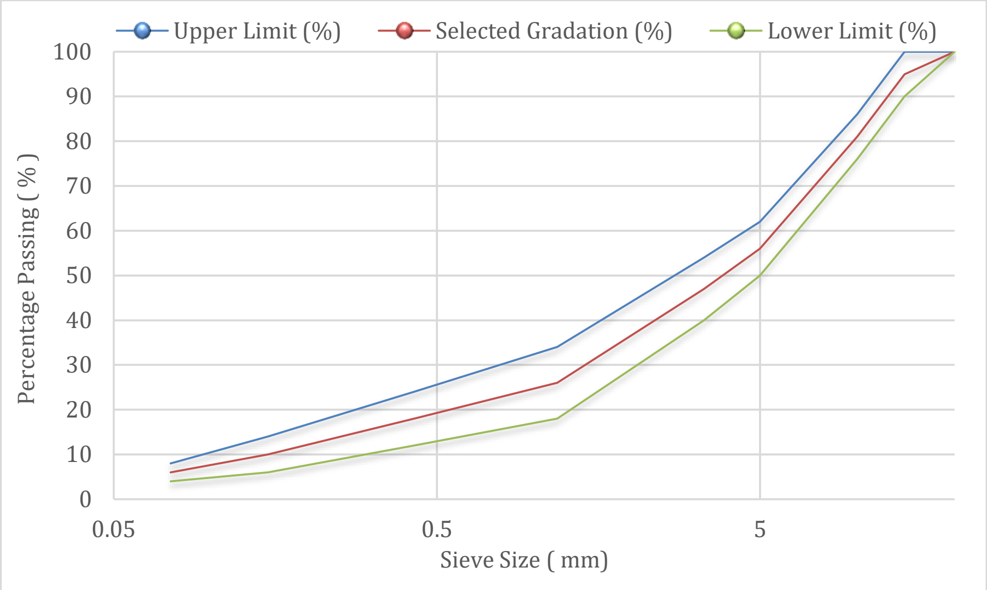

Figure 1. Gradation limit for Asphalt Concrete(AC14)[12].

Bitumen

In this research, a PEN 60/70 grade binder was used. The additive used was encapsulated cigarette butts with increment 0, 0.2, 1 and 3% of CBs.

Encapsulated Cigarette Butts

The process flow below represents the prepration of CBs :-

Step 1: The cigarette butts were collected and kept in a metal container where CBs were dried for 48 hours at 130°C. and any extra tobacco was removed from the CBs during this procedure. Figure 2 (a) depicts the CBs during the drying and cleaning procedure in the oven.

Step 2: Once the CBs is removed from the oven, it keept at room temperature for 5 hours.

Step 3: The dried CBs were ground into fiber using a home grinder as shown in Figure 2 (b & c).

Step 4: Removed the small paper that apperanced because of the CBs filters as shown in Figure 2 (d). Later, the ground CBs were mixed with bitumen samples.

(a) (b) (c) (d)

Figure 2. Processes to form CBs fiber: (a) encapsulated cigarette butts in oven, (b) home blenders, (c & d) ground cigarette butts (CBs).

EXPERIMENTAL METHODS

Aggregate Properties Tests

BS EN 1097-2:2020 was followed during the testing process [13].The sample of aggregates was prepared first and then passed to 14.0mm and was maintained in the 10.0mm range. At steady temperatures of 100 C° to 110 C°, this aggregate was washed up and dried in a laboratory oven not longer than 4 hours. Equation 1 and 2 could be used to compute the proportion of fines as a percentage of aggregate impact value and aggregate crushing value.

$$\textbf{Aggregate Impact Value }(\textbf{AIV}) = \frac{Weight\ Loss\ (M_3)}{Initial\ Weight\ (M_1)} x100\% \tag{1}$$

$$\textbf{Aggregate Crushing Value }(\textbf{ACV}) = \frac{Weight\ Loss\ (M_3)}{Initial\ Weight\ (M_1)} x100\% \tag{2}$$

Table 1. Classification of Aggregate Impact Value Based On JKR/SPJ/2008.

Aggregate Impact Value (AIV)	Classification
< 20%	Exceptionally Strong
10 – 20%	Strong
20 – 30%	Satisfactory for Road Surfacing
> 35%	Weak for Road Surfacing

In Table 1, shows the classification of the aggregate impact value (AIV) based on JKR 2008, where if the percentage of AIV is between the 10-20% that means the classification of that aggregate is striong which is prefered.

Bitumen Properties Test

The bitumen fortified with cigarette butts was mixing with a high shear mixer at speeds of 1500 rpm for 60 minutes at a temperature of 160°C resulted in a consistent mixing condition [14].

Penetration, Softening Point and Ductility Tests

For the specimen preparation, the asphalt binder was diluted in the oven for 15 to 20 minutes at temperatures ranging from 75 to 100 degrees Celsius. After that the asphalt binder was added to the penetration container. The specimens were kept cool between one and two hours in the open air at room temperature. The standard penetration needle was cleaned before being placed in the needle holder, and the needle was slowly lowered until the tip of the needle touched the surface of the specimen. Meanwhile, the dial reading of the penetrometer was reset to zero, and an electric timer was connected to the penetrometer. After that, the timer button was pressed to start releasing the needle holder for 5 seconds. The penetration value would be used to calculate the depth of penetration. To achieve the average penetration score, the procedure was repeated three times on the same specimen. Finally, the needle was washed for each application. This test was carried out in compliance with ASTM C131. The depth of penetration is measured in tenths of a millimetre (deci-millimeter, dmm).

For softening point test, the ring moulds was the asphalt binder which was still sweetened. At least thirty minutes at room temperature, the specimens were cool open-air. The water was in the meantime poured into the beaker and placed in the water bath afterwards. The beaker was put on the magnet stirrer. Then a thermometer was used to determine the water temperature. The water temperature was held for 15 minutes at a temperature of 5 C° ± 2 C°. After the temperature was stabilised, the specimens were put in the ring holder. The steel balls were put in the ball-center guides with forceps after 15 minutes. The water was then heated by the electric heater at 5 C° ± 2 C° per minute. Finally, after a drop in the ball on the base plate of the suspended ring holder the temperature and the time were registered. The procedure was performed in compliance with the ASTM D36. The depth of penetration is measured in tenths of a millimetre (deci-millimeter, dmm).

For ductility test, it aimed at ensuring that bitumen is not too fragile to cause cracking on the bituminous surface of the lane. At 25 degree, the bitumen sample is elongated by 5cm per minute. The sample elongation of at least 100cm is referred to as bitumen ductility, according to ASTM D 113 [15]. In order to form the standard bitumen material, the asphalt bitumen that was already softened was transferred to the standard briquette models for the production. Then the sample mould is cooled for at least 30 minutes at room temperature. The ductility specimen will be dipped in the bath and the temperature also will be held for 30 minutes at 25 degrees ± 0.5 degrees. The ductility specimens put in a ductilimeter then reached the target temperature after the ductility specimens had reached.

Penetration Index

Penetration index (PI) is the relationship between the Penetration Test and Softening Point Test for bitumen PEN 60/70 [16]. The penetration index is a quantitative measure of bitumen's reaction to temperature changes. It is feasible to anticipate the behavior of a given bitumen in an application by knowing its penetration index. Asphalt binders with high penetration numbers (referred to as "soft") are used in cold regions, whilst asphalt binders with low penetration numbers (referred to as "hard") are utilized in warm areas [17].

$$\boldsymbol{PI} = \frac{(1951.4 - 500logP - 20SP)}{(50logP - SP - 120.14)} \tag{3}$$

Where: P = penetration Value (dmm) & SP = Softening Point Value (C°)

Mix Design

Sample preparation and performance evaluation

The asphalt binder was mixed with 0, 5, 10, and 15% encapsulated cigarette butts, respectively. The sum of each addictive was calculated by the weight of the aggregate. The aggregate and asphalt bitumen were combined with the inclusion of cigarette butts before compacting the asphalt binder at 180 C°. Asphalt Concrete was the asphalt mixture used in this analysis. Cigarette butts were used as a modified asphalt binder to improve the properties of AC's modified asphalt binder.

Step 1: CBs were dried for 48 hours at 140 °C. CBs are sanitised and the moisture content is removed during this procedure. Figure 3 (a) depicts the CBs before and after the drying and cleaning procedure in the oven.

Step 2: Bitumen was chosen depending on the type of bitumen that will be utilised on the road. Bitumen grade 60/70, which is typically utilised in the construction of AC, was employed in this study to encapsulate CBs. Because encapsulation requires a liquid form of bitumen, a container of bitumen was put in the oven for 3 hours at 140°C to promote workability.

Step 3: Liquid bitumen was collected in a thick metal tray, and CBs were left in the tray with the bitumen. This tray was then placed in a 140°C oven for 3 hours. During this time, the bitumen was stirred every 30 minutes with a steel rod. Figure 3 depicts the encapsulation of CBs with bitumen 60/70. As seen in Fig. 3, (b), during this procedure, bitumen replaced the air in the pores of the CBs, and bitumen coated all of the CBs' surfaces.

Step 4: The encapsulated CBs were recovered from the bitumen filled tray in this step. Encapsulated CBs were collected, and surplus bitumen was removed using a 5 mm sieve. As seen in Fig. 3, (c), the encapsulated CBs were then placed in a baking dish and kept at room temperature. Because the bitumen does not adhere to the baking tray surface, the encapsulated CBs may be easily stored and collected for future use. Bitumen-encapsulated CBs comprise around 70% bituminous content by weight[7].

(a) (b) (c) (d)

Figure 3. Processes to form CBs: (a) encapsulated cigarette butts in oven, (b) bitumen mixed with CBs, (c) cigarette butts in baking tray and (d) mix design.

Asphalt Concrete Sample Preparation

Marshall mixing was used for the modified and unmodified asphalt concrete blend. The mixture was mixed until the entire aggregate was coated. Meanwhile, a layer of filter paper was placed at the bottom of the mould. When the mix was placed in the mould, it was spaded 15 times around the perimeter and 10 times in the center with a spatula. The mould was put in the pedestal and immediately compressed with the desired number of 50 [3]. The mould was promptly removed and flipped over, and the other mixtures received the same number of blows.

Asphalt Mixture Performance Tests

Los Angeles (LA) Abrasion, Marshall Stability, Indirect Tensile Strength and Dynamic Creep

For LA test was intended to assess the abrasion resistance to travelling traffic loads of AC asphalt specimens. The samples were calculated as a percentage loss after 300 revolutions [18]. For every percentage of the cigarette butts content, two collections of asphalt concrete are used. Before the measurement was performed, the samples were weighed. The sample was then put without a steel ball in the LA abrasion system. The drum was then rotated for the revolution of 100, 200 and 300. The drum has been stopped and the specimen weighted after every 100 revolutions. A LA abrasion test is conducted on two specimens for each percent of the substance of the butt cigarette.

$$\textbf{\% Abrasion} = (W1-W2)/W1\times 100\% \tag{4}$$

Where: W1 = the weight before abrasion & W2 = the weight after abrasion

ASTM D6927-15 was used to conduct the marshall stability test[19]. The Marshall stability test was marginally associated to determine the reliability of the mixture. Marshall stabilisation is responsible for traction strength, and Marshall flow is responsible for the specimen's low resistance to rutting [6]. In air, water, and saturated surface dry (SSD) conditions, the specimens were weighted. The weight of the specimens in air condition was registered. The specimens were fully immersed in a water bath at a temperature of 25°C for 3 to 5 minutes in the water state. The weight was then measured by measuring in water. The sample was then removed and cleaned quickly with a wet towel until the weight of air was calculated. The specimens were then submerged in a water bath at 60°C for 30 to 40 minutes. The sample was stripped and gently cleaned with a towel before being put between the breaking head's lower and upper segments. This investigation yielded data such as stability, flow, stiffness, bulk density, Voids Filled with Asphalt (VFA), and Voids in Total Mix (VTM). As stated in Table 2, each parameter has a defined range that must be satisfied in order to comply with the Malaysian Standard Specification for Road Works [12].

Table 2. Malaysian Standard Specification for Road Works[12].

Parameter	Wearing Course
Stability, S	> 8000 N
Flow, F	2.0 - 4.0 mm
Stiffness, S	> 2000 N/mm
Air voids in mix (VIM)	3.0 - 5.0%

Indirect tensile strength measure for assessing the tensile properties of the bituminous mixture. A tensile strength test indirectly tests prior to and after water exposure shall verify the stability and resistance of the mixed asphalt slice. Indirect tensile strength changes will be monitored in six tests: 3 dry samples and 3 water-exposed samples. The sample is connected between two load strips and radially loaded at 50mm/min during the indirect strength evaluation [20]. The maximum burden is estimated at fracturing. According to ASTM-4123 [21], the ITS can be calculated as equation (5).

$$\boldsymbol{ITS} = \frac{2 \times P}{\pi t D} \tag{5}$$

To assess the effect of cigarette butts on the changed AC asphalt binder, a dynamic creep test was conducted. This test necessitated the use of a universal test machine (UTM). The reaction of the specimen was determined by loading the cylindrical specimen with the Universal Measuring Machine (UTM) Two specimens were checked for each cigarette butts modified asphalt binder content (0%, 5%, 10%, and 15%). Both samples were analysed at temperature 40°C in compliance with ASTM D4123 [22]. Before the specimens could be tested, The sample height and diameter were measured, and the samples were conditioned for 15 minutes at 40°C in the Universal Testing Machine (UTM). After that, the specimens were loaded into the loading apparatus with the loading strips in place. The electronic measurement device was adjusted and balanced as needed, and the LVDTs were adjusted and balanced to operate within their ranges as shown on the level and closed level displays. The jogged loading ram was then lowered to make contact with the top loading platen of the creep jig, but without adding any loading strength. The sample was then subjected to a series of loading pulses after pressing the start button. As the test progressed, the stress and deformation data were catalogued and tabulated. Finally, close the valve after the mechanism has completed 3600 cycles. For each percentage of cigarette butts content, two specimens were tested for dynamic creep [23].

RESULTS AND DISCUSSIONS

Aggregate Properties

According to Table 3, the aggregate material's AIV test value is 15.63 %. As a result of Table 1, the aggregate may be classified as strong for pavement surface course. The smaller the proportion of loss, the greater the collective strength. Aggregate Impact Value testing has a loss percentage of 15.63 %. The achieved result met the MS 30 criteria that the value of percent loss be less than 25.00 %. Aggregate that has AIV % value less than 50% is preferable to use in building, however having value greater than 50% is negative for construction. Calculating the AIV percent of aggregate usage as road metal is trustworthy since it gives us the ability of the road to sustain the load on it. Aggregate with an AIV percent equal to or more than 35% is not recommended for use in road building[24]. The obtained result satisfies the criteria of MS30, where the percent loss value should be in the range provided in Table 3.

Table 3. Results of Aggregate Impact.

Aggregate test	Aggregate size (mm)	Weight of Aggregate (g)			%Loss
		Before Test (M1)	Retain at 2.36mm sieve (M2)	Passing at 2.36mm sieve (M3)	
AIV	14-10	283.37	238.29	44.3	15.63
ACV	14-10	2361.54	1876.33	493.98	20.92

The aggregate material's ACV test value is 20.92 %, which is less than the acceptable limit of less than 35 percent. Table 3 shows the detailed results.The smaller the proportion of aggregate crushing value loss, the stronger the aggregate. According to Table 3, the percentage of loss for Aggregate Crushing Value testing is 20.92%. The obtained result met the criteria of MS 30, where the value of percent loss should be less than 35.00 %. As a consequence of the ACV test, a good grade of pavement was attained, as aggregate with a low crushing value was favoured. The ACV may be used to determine the acceptability of aggregates in terms of crushing strength for various types of pavement components. The aggregates used for the surface course of pavements must be robust enough to withstand the strains caused by wheel loads, especially the steel tyres of heavy bullock carts. The obtained result satisfies the criteria of MS30 which is less than 35.00 %.

Bituminous Binder Properties

The consistency of bituminous materials varies according to a variety of elements such as components and temperature. By measuring the depth to which a standard needle will penetrate vertically under defined conditions of standard load, time, and temperature, the penetration test evaluates the consistency of these materials for the purpose of grading them. The higher the penetration, the softer the bitumen[25]. According to Table 5, the value of penetration for 0% was 60 mm/10, which was within the standard range and met the criteria. From table 4, the results show that, in the case of bitumen 60/70, the control sample with no Cigarettes Butts present has a penetration value of 64 mm on average. When 0.2 % of cigarettes butts was introduced as fibre, the penetration value decreased. The penetration levels began to fall when more CBs (0.2 %,1 % and 3 %) were introduced. The results indicated that the usage of CBs fibres in bitumen is adverse to penetrating performance, with 0.2 %, 1%, and 3% additions of CBs compromising the normal penetration range of bitumen.The bitumen penetration test, used to measure the hardness of the material, was mostly successful. The use of bitumen with varying degrees of penetration is dependent on the 62 climatic situation and structure type. Higher penetration levels of bitumen are employed in colder climates, whereas lower penetration levels are favoured in warmer regions [26].

From Table 5, the softening point value reached was 49.5 C° with 0 % CBs, which is within the specification range and meets the criteria. The specification limit, like with the other bitumen physical tests, is critical. From Table 4, the results show that the softening point of the samples increased somewhat after being modified with CBs (0.2 %, 1% and 3 %). However, even after the increase, the findings were determined to be identical to the control sample and within the normal range. Impurities such as water or glycerin have been found, which can have a substantial influence on the outcome. If the ball's weight is excessive and the gap between the bottom of the ring and the bottom plate increases the softening point, it indicates a lower softening point. The temperature at which the viscosity of the bituminous binders is equal is effectively the softening point. Bitumen with a greater softening point can be used in warmer climates.

From Table 5, the ductility result of 0 % of CBs in asphalt bitumen was 102 cm / s, which is greater than the standard of 100 cm / s. For Table 4, the results demonstrate that after being changed with CBs (0.2 %, 1 %, and 3 %), the ductility of the samples reduced somewhat (0.2 %, 1 %, and 3 %). Because of the continuous cross-head speed circumstances in the asphalt ductility test, the real strain-rate decreases with time and elongation. This drop causes the strain rate to alter by more than an order of magnitude merely after a few centimetres of elongation. The greater the temperature of the test, the higher the ductility value, since higher levels of stress of failure correlate to lower temperatures of the believed that a better and higher stress rates [27].

Table 4. Results Asphalt Binder Testing of PEN 60/70.

Samples	Penetration (mm/10)	Softening Point (C°)	Ductility in 25 C°(cm/s)	PI
Control	64	49.5	102	-0.74
Modified 0.2%	29	51.0	87.5	-2.00
Modified 1%	23	54.25	38.5	-1.75
Modified 3%	14	56.7	30	-2.00

Table 5. Asphalt Binder Testing Based On ASTM.

Bitumen Test	Observed Test Result	Limit	Status	Reference Standard
Penetration (25 C°)	64 mm/10	60-70 mm/10	PASS	ASTM D244 &ASTM D5
Softening Point C°	49.5	49-56 C°	PASS	ASTM D244 &ASTM D 36
Ductilit Test C°	102 cm/s	>100 cm/s	PASS	ASTM D113

Table 6. Relationship between Characteristics of Bituminous Material and PI value [27].

PI Range	Classifications
PI ≤ -2	Temperature Susceptible Bituminous Materials (Tars)
-2 < PI < +2	Conventional Paving Bituminous Material
PI ≥ +2	Blown Bituminous Material

According to the Table 6, the bitumen PEN 60/70 when it is unmodified with cigarettes butts (0 % CBs) can be classified as conventional paving bituminous material. Also, for the bitumen PEN 60/70 when it's modified with cigarettes butts (0.2 %,1 % and 3 % of CBs) can be classified as conventional paving bituminous material.

Mechanical Properties

Los Angeles (LA) Abrasion

The average % abrasion for unmodified AC and modified AC-CBs is shown in figure 4. In general, the smaller the abrasion loss, the better the abrasion loss performance.

According to the Figure 4, in 300 reps, 0 % cigarette butts content showed the maximum value for abrasion and 10% cigarette butts content indicated the lowest value of abrasion loss. This is due to the fact that the lower the abrasion, the higher the tensile strength of the AC. The cigarette butts aid in the hardening of modified asphalt binder, which can increase AC performance. The cigarette butts content of 10% had the lowest loss abrasion and was chosen as the most beneficial level for improving the performance of AC mixure. The cigarette butts modified asphalt binder performs well in pavement. It is sufficiently hard to withstand abrasion and is highly resistant to traffic crushing for a long length of time[4].

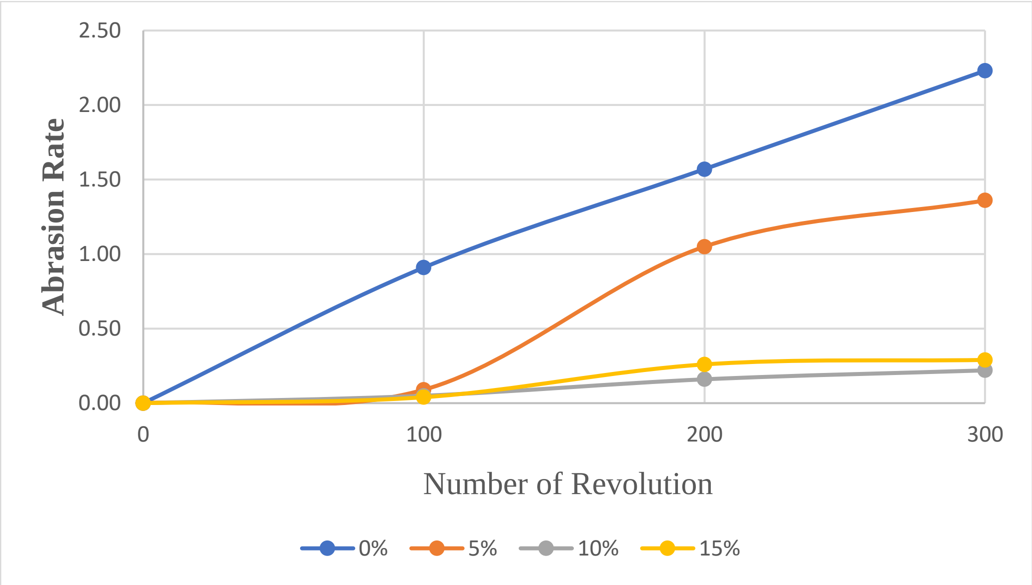

Figure 4. Graph of (LA) Abrasion Loss Vs CBs.

Volumetric properties, stability and flow

The results shown in Figure 5 show the average stability of two samples, one unmodified and one modified. In general, stability refers to the greatest stress applied before sample failure occurs. According to the graph, all modified samples have lesser stability than unmodified samples. When compared to changed samples, the maximum stability was at 0% CBs, which is 12.019 KN. According to Malaysian Standard Specification for Road Works [12] in Table 2, The findings in Figure 5 show that 0, 5 and 10% of CBs with stability values of 12.019, 9.888, and 9.305 kN passed the criteria, whereas 15% of CBs with stability value of 7.071 KN did not pass the criterion, where the stability values observed were larger than 8kN. It demonstrated that CBs could withstand deformation caused by induced loads. So from the results, the stability reduced with increment of CBs and the blue line indicates the range of the stability according to Malaysian Standard Specification for Road Works.

According to Figure 5, the cigarette content of 0% which is 5.119 mm, was the best flow value and was chosen as the most effective quantity for improving the performance of AC mixure. According to Table 2 of the Malaysian Standard Specification for Road Works [12], the result for flow must be between 2.0 mm and 4.0 mm. The standard was not met by any of the modified or unmodified mixes. So from the results, the flow increased with increment of CBs and the red lines indicates the range of the flow according to Malaysian Standard Specification for Road Works.

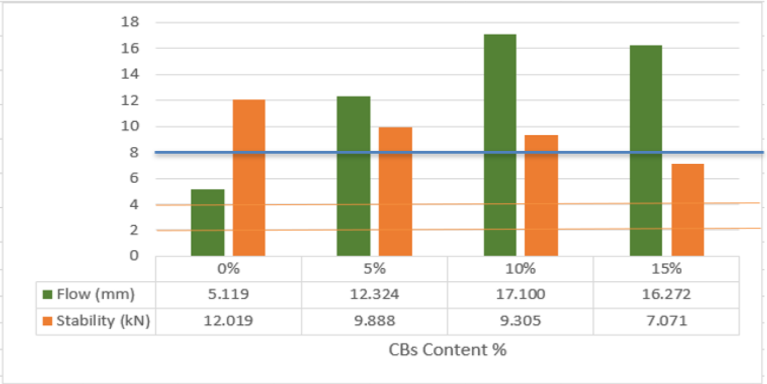

Figure 5. Stability and Flow value Vs CBs.

The stiffness can bear a load without causing considerable distortion in the sample. Thus, more stiffness leads to better pavement strength, but the stiffness should be at its maximum since brittleness will occur, resulting in cracking. According to Figure 6, the highest stiffness was at 0% CBs, which was 2.348 KN/mm, and the lowest stiffness was at 15% CBs, which was 0.435 KN/mm. According to the Malaysian Standard Specification for Road Works [12] in Table 2, the results in Figure 6 show that 5, 10 and 15% of CBs with stiffness values of 0.802, 0.544, and 0.435 kN/mm did not pass the criteria, whereas 0% of CBs with stiffness value of 2.348 KN/mm passed the criterion, where the stiffness values observed were larger than 2kN/mm. Black line indicates the range of the stifness according to Malaysian Standard Specification for Road Works.

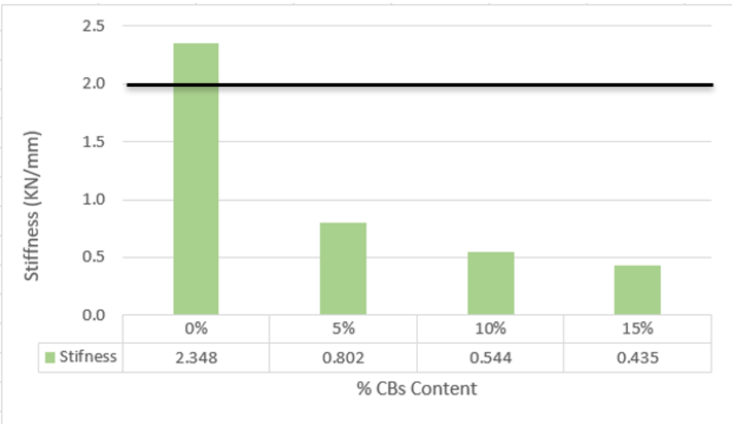

Figure 6. Stiffness Vs CBs Content

Figure 7 depicts the density of unmodified and modified samples containing CBs. The definition of density is mass per unit volume. According to the hypothesis, increasing the density of the pavement will increase its fatigue life, rutting resistance, and durability. As a result, a higher sample density is required to prevent water from penetrating the subgrade layer and causing degradation. As a result in Figure 7, the bar chart revealed that the maximum density occurred at 0% CBs that is 2.287 g and the lowest density occurred at 15% CBs that is 1.813 g. The results demonstrated that the presence of CBs in AC does not increase its performance. However for the modified samples, the best presentage which gives a great performance to Ac was 5% of CBs. In Malaysian Standard Specification for Road Works [12], there are no precise bulk density limitations for asphaltic concrete using waste components. So from the results, the density reduced with increment of CBs.

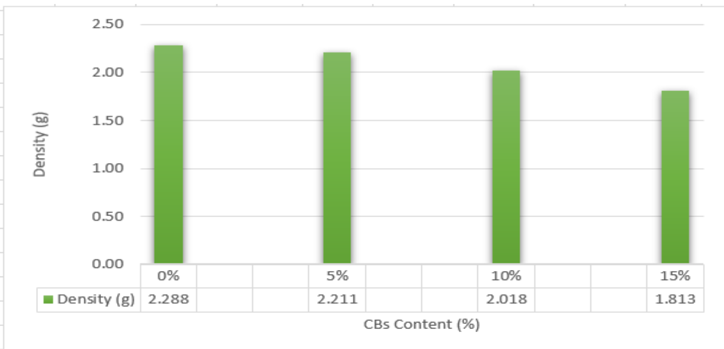

Figure 7. Density Vs CBs Content.

According to Figure 8, the cigarette butts content of 15% which is 25.0 %, was the greatest percentage of voids in total mix (VTM) value but wasn't chosen as the most effective level for AC mixture performance augmentation. In Malaysian Standard Specification for Road Works [12], the findings in Figure 8 show that 0,5, 10 and 15% of CBs with VTM values of 5.3,8.5, 16.5 and 25% did not pass the criteria. The VTM for wearing course should be between 3.0 and 5.0 %. The rule, however, does not define any limiting values for asphalt mixture integrated waste materials, particularly cigarettes butts. So from the results, the void increased with increment of CBs and the red lines indicates the range of the VTM according to Malaysian Standard Specification for Road Works.

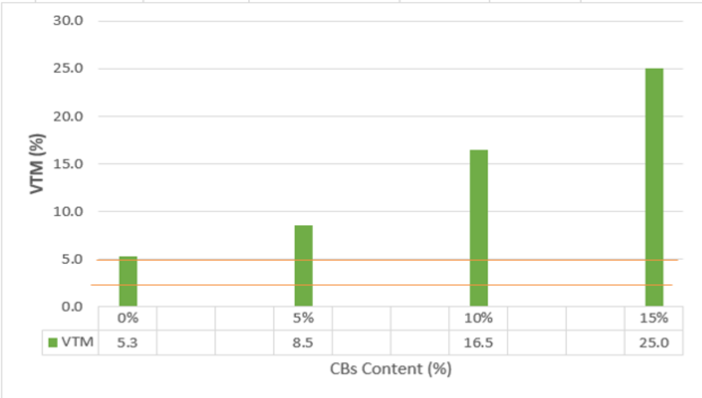

Figure 8. VTM Vs CBs content.

According to Figure 9, the cigarette butts content of 15 % which is 75.2 %, was the greatest percentage of air voids filled with asphalt (VFA) value and was chosen as the most beneficial quantity for performance enhancement in AC mixes. In the JKR standard [12], for asphaltic concrete incorporating waste elements, there are no specified VFA limiting levels in JKR.

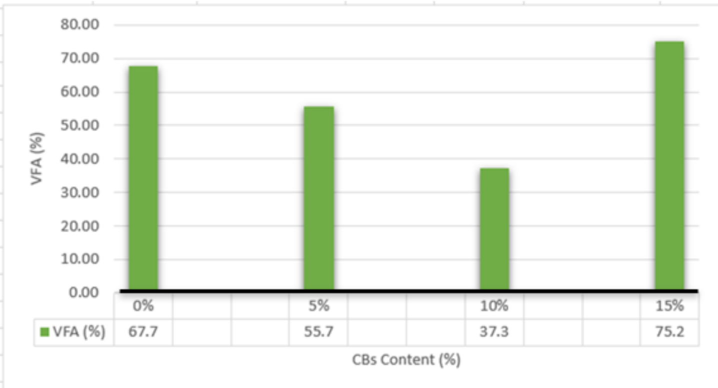

Figure 9. VFA Vs CBs content.

Indirect Tensile Strength

The sample is connected between two load stripes and loaded radially at a speed of 50mm/min during the indirect tensile strength test[6][20]. The maximal force at fracture is determined. According to Figure 10, 0 % of the cigarette butts which is 0.541 KN/mm^2, was the greatest percentage of indirect tensile strength (ITS) value and was chosen as the most beneficial quantity for performance enhancement in AC mixure. So from the results, ITS values reduced with increment of CBs.

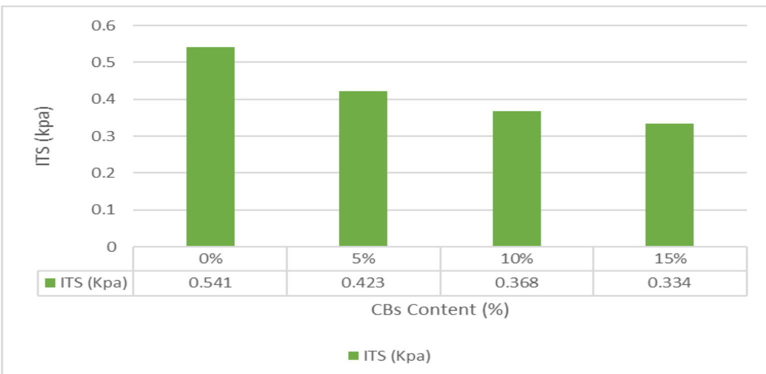

Figure 10. ITS Vs CBs Content.

Dynamic Creep

Figure 11 depicts the connection between cycle and strain for unmodified and modified samples at 40 degrees Celsius. According to the Figure 11, the presence of CBs at 0% and 15% in AC results in the lowest strain when compared to unaltered percentages of 10% and 5%. In comparison to another changed sample, the lowest value of dynamic creep in table 11 was 3.40 MPa at 0% CBs content. Thus, the improved value of AC was 67.73 % when comparing 15 % CBs content to the control sample in terms of dynamic creep when CBs were present in AC. So from the results, Strain increased with increment of CBs.

Table 11. Result of dynamic creep.

Cigarettes butts Content (%)	**Creep Modulus (MPA)**
0%	3.40
5%	7.26
10%	9.53
15%	5.02

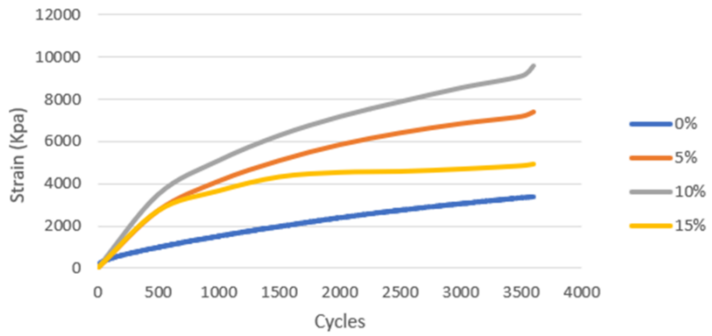

Figure 11. Dynamic Creep at 40˚C.

CONCLUSION

This project has done to evaluate two types of studies which are the properties of modified asphalt binders with cigarette butts as fiber and to evaluate the mechanical and physical properties of asphalt mixture incorporating encapsulated cigarette butts. The addition of CBs to AC resulted in a different abrasion loss value when compared to unmodified AC. At 10% CBs put into the asphalt mixture, the abrasion loss is 0.22 % compared to the unmodified sample, which is 2.23 %, and this level was chosen as the most advantageous level for increasing the performance of AC mixture. Based on Marshall Stability and Flow, the performance of AC incorporating CBs varies at different percentages. Stability and density have greater values at 0% CBs concentration, whereas stiffness has a lower value at 15% CBs content. The result for indirect tensile strength shows that at 0% CBs, the maximum load was greater compared to modified AC, and it was chosen as the most advantageous quantity for performance enhancement in AC mixtures. According to the results of the dynamic creep testing, the sample for 0 % CBs is preferable to the other modified samples since it has a lower value of micro-strain when compared to the modified samples. As a result, we may conclude that that 5% of CBs is the best percentage of cigarette butts to add in asphalt mixture. So this study have declared cigarette butts to be an effective material to be used as an addition to asphalt binder because it improves performance by increasing paving strength and stiffness for future development.

ACKNOWLEDGEMENT

The support provided by Universiti Malaysia Pahang in the form of a research grant vote number PGRS2003172 for this study is highly appreciated.

REFERENCES

[1] J. Jin, Z. Wu, J. Song, and X. Liu, “Research on the road performance of cigarette butts modified asphalt mixture,” *J. Phys. Conf. Ser.*, vol. 1168, no. 2, 2019, doi: 10.1088/1742-6596/1168/2/022053.

[2] P. Pereira and J. Pais, “Main flexible pavement and mix design methods in Europe and challenges for the development of an European method,” *J. Traffic Transp. Eng. (English Ed.*, vol. 4, no. 4, pp. 316–346, 2017, doi: 10.1016/j.jtte.2017.06.001.

[3] S. M. R. Shah, N. I. Zainuddin, N. Tutur, S. Ismail, T. L. Sian, and N. A. I. Nasaruddin, “Strength properties of polyethylene in bituminous mixtures for flexible pavement,” in *AIP Conference Proceedings*, 2018, vol. 2031. doi: 10.1063/1.5066985.

[4] Yi CUI, Zhao-rong WU, Yali LI, and Hang YANG, "Experimental Study on Determining the Optimum Cigarette Butt Content of Modified Bituminous Mixture of Cigarette Butts," *J. Civ. Eng. Archit.*, vol. 12, no. 6, pp. 447–453, 2018, doi: 10.17265/1934-7359/2018.06.005.

[5] A. Al-Hdabi, "Laboratory investigation on the properties of asphalt concrete mixture with Rice Husk Ash as filler," *Constr. Build. Mater.*, vol. 126, pp. 544–551, 2016, doi: 10.1016/j.conbuildmat.2016.09.070.

[6] A. Vaitkus, M. Kilas, F. Tuminiene, and Z. Perveneckas, "Experience of use of warm mix asphalt in Lithuania," *8th Int. Conf. Environ. Eng. ICEE 2011*, pp. 1227–1234, 2011.

[7] A. Mohajerani *et al.*, "Physico-mechanical properties of asphalt concrete incorporated with encapsulated cigarette butts," *Constr. Build. Mater.*, vol. 153, pp. 69–80, Oct. 2017, doi: 10.1016/j.conbuildmat.2017.07.091.

[8] M. T. Rahman and A. Mohajerani, "Thermal conductivity and environmental aspects of cigarette butt modified asphalt," *Case Stud. Constr. Mater.*, vol. 15, no. March, p. e00569, 2021, doi: 10.1016/j.cscm.2021.e00569.

[9] T. E. Novotny, K. Lum, E. Smith, V. Wang, and R. Barnes, "Cigarettes butts and the case for an environmental policy on hazardous cigarette waste," *Int. J. Environ. Res. Public Health*, vol. 6, no. 5, pp. 1691–1705, 2009, doi: 10.3390/ijerph6051691.

[10] T. Rahman, A. Mohajerani, and F. Giustozzi, "Possible use of cigarette butt fiber modified bitumen in stone mastic asphalt," *Constr. Build. Mater.*, vol. 263, p. 120134, 2020, doi: 10.1016/j.conbuildmat.2020.120134.

[11] M. T. Rahman, A. Mohajerani, and F. Giustozzi, "Possible recycling of cigarette butts as fiber modifier in bitumen for asphalt concrete," *Materials (Basel).*, vol. 13, no. 3, pp. 1–20, 2020, doi: 10.3390/ma13030734.

[12] Malaysian Standard Specification for Road Works, *JKR/SPJ/2008-S4 Standard Specification for Road Works Part4 Flexible Pavement*. JKR Specification for Road Works Part4 Flexible Pavement, 07(Reapproved), 1–187, 2008.

[13] BS EN 1097-2, *Tests for mechanical and physical properties of aggregates. Part 2: Methods for the determination of resistance to fragmentation*. British Standards Institution, 2020.

[14] I. O. P. C. Series and M. Science, "Investigation on rheology and physical properties of asphalt binder blended with waste cooking oil Investigation on rheology and physical properties of asphalt binder blended with waste cooking oil," 2019, doi: 10.1088/1757-899X/527/1/012045.

[15] O. Felode, G. Jonathan, and O. Ohinola, "Softening point and Penetration Index of bitumen from parts of Southwestern Nigeria," *Nafta*, vol. 63, no. 9–10, pp. 319–323, 2012.

[16] S. H. Firoozifar, S. Foroutan, and S. Foroutan, "Chemical Engineering Research and Design The effect of asphaltene on thermal properties of bitumen," *Chem. Eng. Res. Des.*, vol. 89, no. 10, pp. 2044–2048, 2011, doi: 10.1016/j.cherd.2011.01.025.

[17] O. Felode, G. Jonathan, and O. Ohinola, "Softening point and Penetration Index of bitumen from parts of Southwestern Nigeria," *Nafta*, vol. 63, no. 9–10, 2012.

[18] E. Science, "Volumetric Properties and Abrasion Resistance of Stone Mastic Asphalt Incorporating Eggshell Powder Volumetric Properties and Abrasion Resistance of Stone Mastic Asphalt Incorporating Eggshell Powder," 2021, doi: 10.1088/1755-1315/682/1/012058.

[19] ASTM D6927, *Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures*. ASTM International, West Conshohocken, PA, 2015, 2015.

[20] S. Wu, J. Zhu, J. Zhong, and D. Wang, "Experimental investigation on related properties of asphalt mastic containing recycled red brick powder," *Constr. Build. Mater.*, vol. 25, no. 6, pp. 2883–2887, 2011, doi: 10.1016/j.conbuildmat.2010.12.040.

[21] M. A. H. Al-shaybani, "Investigation on Tensile Strength Ratio (TSR) Specimen to Predict Moisture Sensitivity of Asphalt Pavements Mixture and Using Polymer to Reduce Moisture Damage," no. 2, pp. 732–743, 2017.

[22] I. Hafeez and M. A. Kamal, "Repeated Load Permanent Deformation Behavior of Mixes With and Wihtout Modified Bituments," vol. 30, no. 1, pp. 15–22, 2011.

[23] N. Barazi, M. Fakhri, and M. Reza, "Determining the optimum amount of recycled asphalt pavement (RAP) in warm stone matrix asphalt using dynamic creep test," *Constr. Build. Mater.*, vol. 228, p. 116736, 2019, doi: 10.1016/j.conbuildmat.2019.116736.

[24] A. K. Yadava and S. A. Ahmad, "Characterization of Classified Indian Reclaimed Asphalt Pavement RAP Aggregate Impact Value and Aggregate Abrasion Value of Rap Aggregates," *Int. J. Eng. Adv. Technol.*, vol. 9, no. 3, pp. 3913–3921, 2020, doi: 10.35940/ijeat.c6443.029320.

[25] A. H. Norhidayah *et al.*, "The influence of nano kaolin clay as alternative binder on the penetration properties," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 682, no. 1, 2021, doi: 10.1088/1755-1315/682/1/012063.

[26] BS EN 1426, *Bitumen and bituminous binders-Determination of needle penetration*. British Standards Institution, 2015.

[27] J. Read and D. Whiteoak, "The Shell bitumen handbook," *Read, J., & Whiteoak, D. (2003). The Shell bitumen handbook. Thomas Telford*. 2003.