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Study the Properties of Bituminous Mix and Binder Using Waste Cooking Oil as Modifier

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ABSTRACT: The most important aspect of a nation's socioeconomic and physical development is its road system. Additionally, it shows how far a place has come in terms of development. The majority of the roads in India are bituminous. But these roads are subjected to many distresses like cracking, rutting etc due to overloading and temperature conditions. Bituminous Binder is an adhesive material which holds aggregates together. Virgin binders are less durable, poor in rheological properties. Binder modification helps in enhancing properties which improve the performance of binder. Waste Cooking Oil (WCO) is left over oil after frying activities. It cannot be reused or disposed into environment. WCO can form a film over the water bodies which reduces amount of dissolved oxygen. It can also percolate into ground water and cause contamination. FSSAI (Food Safety and Standards Authority of India) estimates India generates around 3 million metric tons of WCO annually. In this study, Bitumen is partially replacing with waste cooking oil and the basic tests conducting to evaluate the physical performance of modified binder with the virgin bitumen

KEYWORDS: waste cooking oil, Bitumen, asphalt pavement, Binder

I. INTRODUCTION

Flexible pavement consists of various layers in which bituminous mix is used in the surface and base courses. Bitumen is a visco-elastic material obtained from refining of crude oil. It has a smooth surface to ride, less sound emission, initial and overall maintenance cost is less as compared to concrete pavement. Bituminous roads are widely used in India. The design of thickness of different layers affects the serviceability throughout the design life. The kind, quality, and quantity of binder employed has a significant impact on the mechanical qualities of bituminous mixes. Flexible pavement defects such as rutting, crack initiation, and propagation are caused by bituminous binder's environmental vulnerability in addition to traffic stresses. Availability of materials for construction is reducing day by day. So, it is important to identify potential replacements of virgin materials. Here comes the role of modified binders to increase pavement performance. Modified binders which increase physical and rheological properties of pavement have great importance in pavement technology.

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Waste Cooking Oil (WCO) is left over oil after frying activities. It cannot be reused or disposed into environment. WCO contains many chemical compounds which are harmful to human life. It cannot be disposed into water bodies or ground without treatment. WCO can form a film over the water bodies which reduces amount of dissolved oxygen. It can also percolate into ground water and cause contamination. After rendering of WCO, residue can be used for many purposes.

Recent research revealed that the hot mix asphalt (HMA) industry has a great potential for using WCO as a good rejuvenator. Use of WCO in road construction reduces maintenance cost. It can be either used as a partial or full replacement.

Bitumen is mainly composed of hydrogen (8–12% by weight) and carbon (80–88% by weight), which together give a hydrocarbon content of about 90%, heteroatom as nitrogen (0–2% by weight), oxygen (0–2% by weight), and sulphur (0–9% by weight) are also present. Bitumen contains four fractions they are saturates, aromatic, resins, and asphaltenes (SARA). Asphaltenes represent about 5–20% by weight of bitumen and consist of a dark powder. It contains many aromatic rings and polar compounds. These are the main component associated with bitumen stiffness and viscosity.

WCO contains complex organic compounds like acid, aldehyde, ester after certain treatments it leads to low saturation and bonding increases with bitumen. The volatile evaporation causes the unbalancing of the SARA fractions, determining the predominance of resins and asphaltenes over saturates and aromatics.

WCO rebalance the SARA fractions of the aged binder, characterized by a lower concentration of maltene. The softening agent allows an increase in bitumen ductility and a decrease in viscosity and brittleness by merely supplying oily components to maltene fraction, but does not achieve any change in the complex structure. The real rejuvenators are additives that allow restoring both the physical and chemical properties of bitumen. In particular, it is able to restore the agglomeration condition of asphaltenes to their original state by promoting the re-dispersion.

II. OBJECTIVE AND SCOPE

This project paper is helpful for an alternate method for the construction of flexible pavement. It is helpful to find the modification of bitumen using untreated Waste Frying Oil. The main priority was to reduce the optimum bitumen content in asphalt binder without significantly changing its current qualities

The basic objectives of this project are:

1. To identify the effect of treated WCO on the physical performance of the binder.
2. To improve the existing methods for pre-treatment of WCO.
3. To find optimum bitumen content of WCO modified bitumen mix
4. To reduce bitumen usage in road construction.
5. Increases self-healing thereby reduces maintenance.

III. RELATED WORK

Bitumen is mainly composed of hydrogen (8–12% by weight) and carbon (80–88% by weight), which together give a hydrocarbon content of about 90%, heteroatom as nitrogen (0–2% by weight), oxygen (0–2% by weight), and sulphur (0–9% by weight) are also present. Bitumen contains four fractions they are saturates, aromatic, resins, and asphaltenes (SARA). Asphaltenes represent about 5–20% by weight of bitumen and consist of a dark powder. It contains many aromatic rings and polar compounds. These are the main component associated with bitumen stiffness and viscosity.

After undergoing various treatments, WCO's complex organic molecules, such as acid, aldehyde, and ester, lead to low saturation and stronger bonds with bitumen. The SARA fractions become out of balance as a result of the volatile evaporation, favouring asphaltenes and resins over saturates and aromatics.

The SARA portions of the aged binder, which have reduced maltene content, are rebalanced by WCO. By only adding oily components to the maltene portion, the softening agent enables an increase in bitumen ductility and a decrease in viscosity and brittleness while achieving no change in the complicated structure. The true rejuvenators are the bitumen additives that enable repairing both its chemical and physical qualities. In particular, it is able to return asphaltenes to their initial state of aggregation to their original state by promoting the re-dispersion.

Technologies to Minimize FFA from Waste Cooking Oil -The best conventional procedure for lowering the acid value of WCO are transesterification. In this process it converts triglycerides from the oil to esters with help of alcohols. A variety of alcohols can be used such as methanol, ethanol, butanol, and propanol. Due to its widespread availability,

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low cost, and speedy reaction with triglycerides, methanol is a more practical alternative. Since the reaction is taking place in an equilibrium process, to fasten it, there must be too much alcohol in the reaction mixture. Along with that catalyst like sodium hydroxide (NaOH) are frequently used to speed up the transesterification reaction.

Combine 1 g of NaOH and 50 ml of methanol thoroughly in a beaker using a glass rod. Then, using a heating mantle as shown in fig 4.2, heat 200 ml of used cooking oil to a temperature of 55°C to 65°C in the conical flask. Dip a thermometer into the flask to gauge the temperature. The reaction slows down below 55 °C, while oil polymerization occurs beyond 65 °C. Therefore maintain it at 55 to 65°C. Once that temperature is reached, switch off the heat source, add the methanol and NaOH mixture to the conical flask, and stir for the following 30 minutes. Keep it aside for the following 24 hours.

Within 24 hours, used waste oil separates into two layers. The top layer of water is hydrophobic, and the bottom layer is hydrophilic layer. Fatty acids won't be present in the hydrophobic layer, and the bottom layer will contains water, salts, and glycerol. Separate the top layer using a separating funnel.

IV. METHODOLOGY

Waste Cooking Oil was collected from a catering center. The oil is filtered to remove large sized residue after frying. Acidity test was performed to find the acid value of untreated oil. Transesterification was then performed on the filtered oil to reduce free fatty acids. Acidity test was performed on treated oil to check how much free fatty acids have been removed. Bitumen was collected from kalpatta bitumen plant. Basic tests like ductility, softening point, penetration, viscosity were conducted on virgin bitumen. Through these tests we can also determine the properties of virgin bitumen. Impact value test, Los angel abrasion test, flakiness and elongation test are the test that we have to conduct on aggregate to check whether it is suitable to use on mix. Modified bitumen is prepared by adding the waste cooking oil into bitumen in specific temperature. Marshall Mix design is the commonly adopted mix design strategy in India and through this the stability of the mix can be determined.

V. DIFFERENT TESTS THAT ARE DONE FOR STUDY

1. DUCTILITY TEST (IS: 1208-1978)

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27°C temperature. The excess bitumen is cut and the surface is levelled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 45 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm.

2. SOFTENING POINT TEST (IS 1205-1978)

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5°C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below.

3. PENETRATION TEST (IS: 1203-1978)

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25°C .



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4. VISCOSITY TEST ((IS: 1206-1978)

The tar cup is properly leveled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test. Stirring is also continued. The sample material is heated at the temperature 20°C above the specified test temperature, and the material is allowed to cool. During this the material is continuously, stirred. When material reaches slightly above test temperature, the same is poured in the tar cup. until the leveling peg on the valve rod is just immersed. In the graduated receiver (cylinder), 25ml of mineral oil or one percent by weight solution of soft soap is poured. The receiver is placed under the orifice. When the sample material reaches the specified testing temperature within +/- 0.1°C and is maintained for 5 minutes, the valve is opened. The stopwatch is started, when cylinder records 25ml. The time is recorded for flow up to a mark of 75ml (ie 50ml of test sample to flow through the orifice).

5. MARSHAL MIX DESIGN

The objective of a mix design is to determine the combination of asphalt cement and aggregate that will give long-lasting performance as part of the pavement structure. Mix design involves laboratory procedures developed to establish the necessary proportions of materials for use in the asphalt mixture. These procedures include determining an appropriate blend of aggregate sources to produce proper gradation of mineral aggregate and selecting the type and amount of asphalt cement to be used as the binder for that gradation. Well-designed asphalt mixtures can be expected to serve successfully for many years under a variety of loading and environmental conditions.

Marshal Mix design is the commonly adopted mix design strategy in India. The gradation of the aggregate is one of the factors that must be carefully considered in the design of asphalt paving mixtures. The purpose for establishing and controlling aggregate gradation is to provide a sufficient volume of voids in the asphalt-aggregate mixture to accommodate the proper asphalt film thickness on each particle and provide the design air void system to allow for thermal expansion of the asphalt within the mix. As per Ministry of Road Transport Highway Officials (MORTH), there are two gradations for aggregate namely, BC 1 and BC 2, in which BC 2 was selected for mix design because it is the commonly used wearing course.

Binder content selected for sample preparation were 1%, 2%, 3%, 4%, 5%. Samples were prepared for each binder content. The aggregate are selected according to IRC specified. 1200 gram aggregates were taken for each sample preparation. Heat the aggregates in cauldron up to a temperature 170°C-180°C as shown in figure 5.1. Add modified binder to cauldron. Again heat it till all aggregates are coated with modified binder. Cool it up to 140°C-150°C by keeping it out of the stove, and then compact it in Marshall Compactor with 75 blows on each side as shown in figure 5.2. After compaction keep the sample with mould in rest for 24 hours (figure 5.3), then extract the sample from mould by using sample extractor shown in figure 5.4. Keep the extracted sample in water bath for 20 minutes in 60°C . After that place the sample inbreaking head to test the stability and flow value of prepared sample

VI. EXPERIMENTAL RESULTS

Table 1 and 2 shows the test results on virgin bitumen and also test results on modified bitumen

SL NO.	TEST	TEST RESULTS	STANDARD VALUE (MINIMUM) AS PER IRC: 105-2019
1	Ductility (cm)(IS: 1208-1978)	>100	25
2	Softening point (°C)(IS: 1205-1978)	65	50
3	Viscosity (cSt)(IS 1206-1978)	434	400
4	Penetration test (mm)(IS: 1203-1978)	6.8	4

Table 1 shows the test results conducted on virgin bitumen



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SL NO	TESTS	VIRGIN BITUMEN	1% WCO ADDED	2% WCO ADDED	3% WCO ADDED	4% WCO ADDED	5% WCO ADDED
1	Ductility (cm)	>100	>100	>100	>100	98	93
2	Softening Point (°C)	65	65	65	64	60	58
3	Penetration (mm)	6.8	6.9	7	7.2	7.4	7.9
4	Viscosity(cSt)	434	435	435	436	440	445

Table 2 shows the test results on modified bitumen by adding 1%, 2%, 3%, 4%, 5% of waste cooking oil

The study is mainly conducted to increase the utilization of waste cooking oil and minimizing the usage bitumen in road construction.

Table 3 shows marshall test result of virgin bitumen

SL. NO.	% OF BITUMEN	STABILITY (KG)	FLOW (mm)	Va (%)	VMA (%)	VFB (%)
1	1%	682	3.10	3.90	11.52	65.90
2	2%	750	3.26	3.16	11.80	67.68
3	3%	820	3.80	2.45	12.08	78.44
4	4%	670	4.2	1.46	11.81	85.60

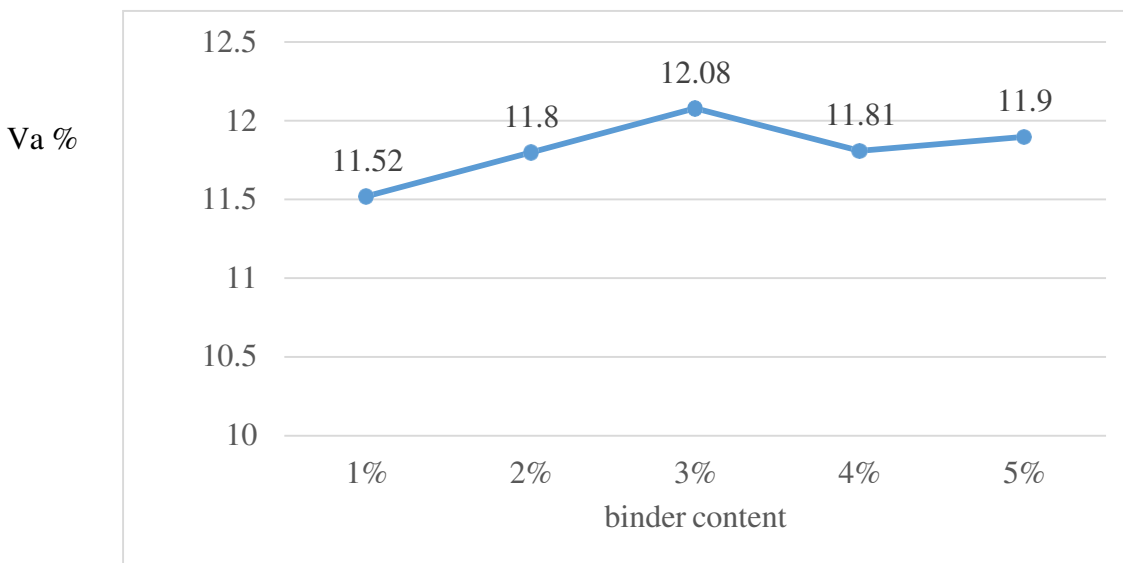
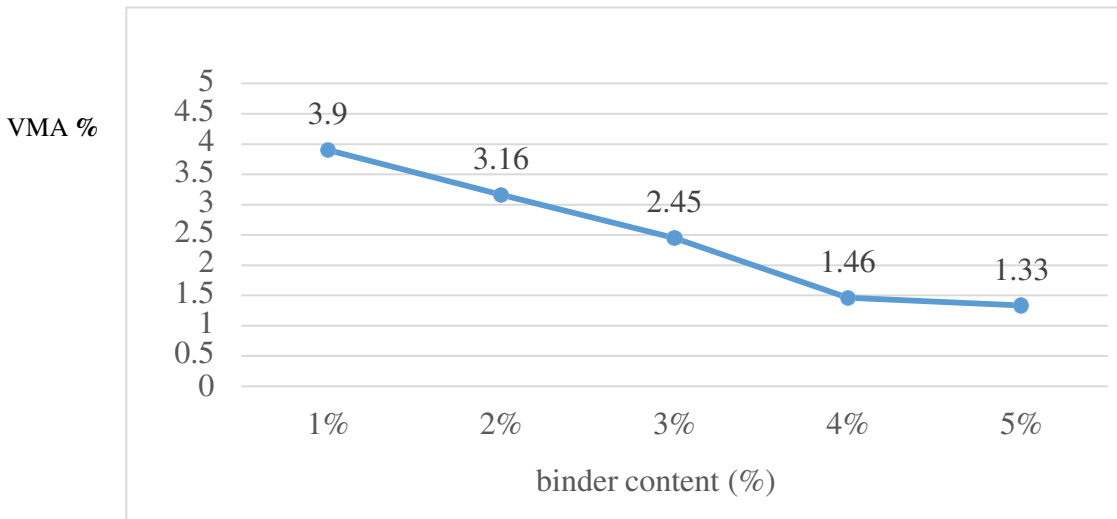


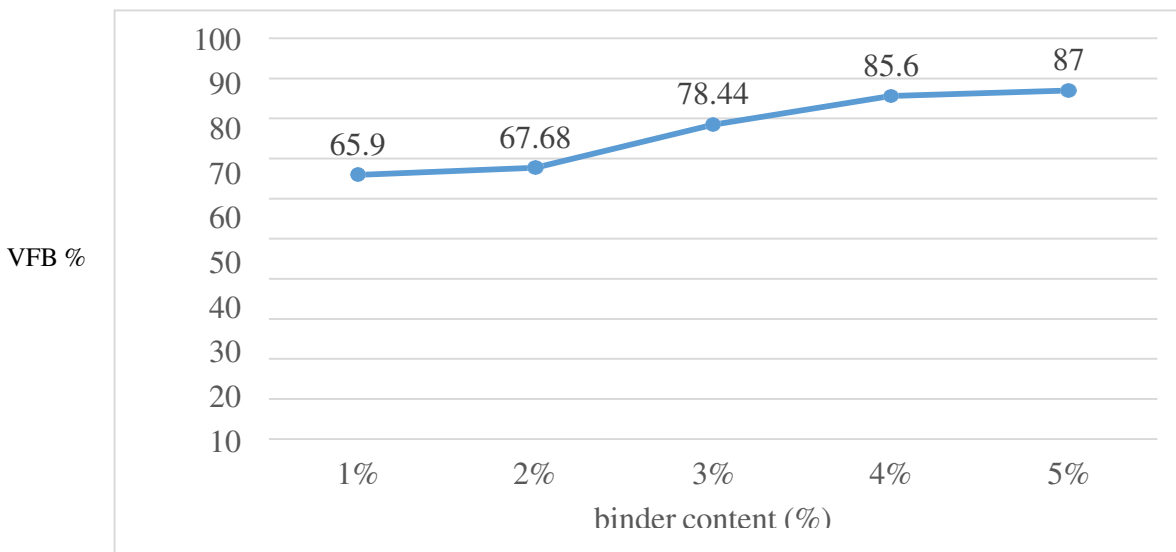
Fig 4(a) Va vs Binder content



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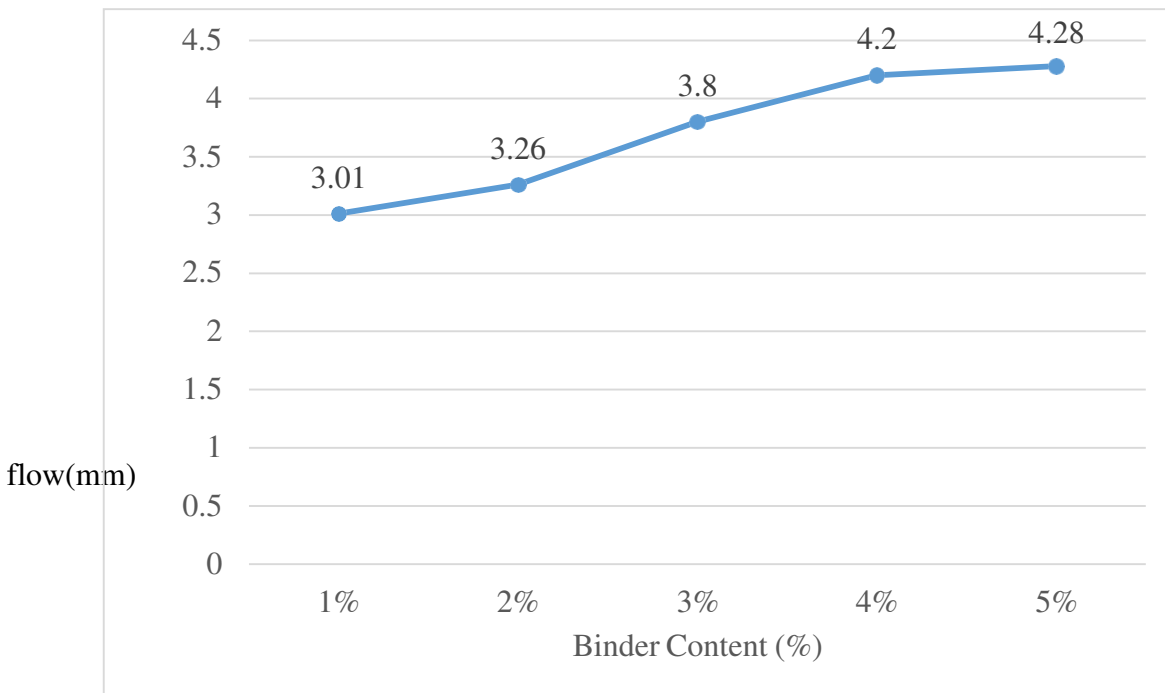
(b) VMA vs Binder content



(c) VFB VS BINDER CONTENT



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(d) Flow vs binder content

From figure (a) the graph shows that the percentage in air voids (V_a) is gradually decreasing with increasing the binder content. It indicates reduction in the volume of air voids. Maximum air voids is present at 1% of binder content.

From figure (b) the graph show that a sudden increase is seen in the percentage of voids in the mineral aggregate (VMA) with increase in the binder content. from the graph the maximum value of voids in mineral aggregate is 12.08% upto adding of 3% of binder content. After the binder content reaches up to 4% the percentage in voids starts decreasing.

From figure (c) the percentage of voids filled with bitumen (VFB) is increasing with binder content. Because the voids are getting filled with binder with increase in binder content.

From figure (d) the flow increases with increase in binder content. Flow is the deflection of mix corresponds to maximum stability.

From the table 5.1 the maximum value of stability is 820 kg by adding of 3% of binder content. after that it starts a reduction in the stability while increasing the binder content. Stability is the maximum load that can be sustained by the mix. From this table stability increases up to a limit and then decreases



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Table 4 shows the Volumetric Properties of WCO Modified Binder

SL. NO.	% OF BITUMEN	WCO CONTENT (%)	STABILITY (KG)	FLOW (mm)	Va (%)	VMA (%)	VFB (%)
1	3%	1%	845	3.73	2.008	12.10	79.4
2	3%	2%	827	3.78	2.021	11.90	79.99
3	3%	3%	802	3.82	2.024	11.50	80.01
4	3%	4%	784	3.9	2.027	11.43	80.21
5	3%	5%	757	3.98	2.03	11.20	80.32

VII. CONCLUSION

Remaining cooking oil was blended with five various levels of binder (1%, 2%, 3%, 4%, and 5%) as a bitumen modifier in order to create sustainable pavement. This study aims to reduce bitumen content in asphalt mix while preserving virgin bitumen's properties by incorporating used cooking oil. To lessen the acidic content of WCO, transesterification is utilised. Testing bitumen containing up to 3% WCO did not appreciably alter the findings from testing virgin bitumen. This study examines the possibility of using waste cooking to replace bitumen. Bitumen is a viscoelastic substance produced during the refinement of crude oil. On virgin bitumen, we have performed the fundamental tests for ductility, softening point, penetration, and viscosity. Additionally, cooking oil was tested for acidity both before and after the treatment. All the test results on virgin bitumen were within the range (as per Indian Standards) and Through transesterification we could lower acidity from 2 ml/g to 0.16 ml/g. aggregate tests, creating modified bitumen, Marshall test, modified bitumen test, and mix preparation. According to the Marshall Stability Test, adding 3% bitumen increases flow value up to a certain point before gradually decreasing. And the stability is increasing up to 3% of the binder content. The mix exhibits superior stability values at limiting flow values as the binder concentration is increased above 3%. Bitumen does not significantly alter when waste cooking oil is added at a rate of up to 3%. It suggests replacing used cooking oil by 3%.

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