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A Study On Replacement of Bitumen Partially with Waste Cooking Oil and Engine Oil in Bituminous Concrete

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***Abstract*: Bitumen is defined as a gelatinous viscid mixture of hydrocarbons attained naturally or as a residue from petroleum refinement which is used for pavement materialisation and roofing. Bitumen is employed as a binder for flexible pavements throughout the globe. Though bitumen is non-hazardous under normal conditions but when heated it becomes toxic and has consequences of environmental degradation. Also bitumen being a product of non-renewable source of energy i.e. petroleum will have led to depletion of petroleum reserves. It is a key challenge in highway industry to scale back the dependence on fossil fuels & to recycle the highway waste. The asphalt industry is undoubtedly a sector that contains a sustainable environmental impact, one amongst the main component being binder, bitumen, which is produced from petroleum. Bitumen generation results in enormous amounts of carbon dioxide emission which causes hazardous environmental impact. This research work is about the employment of waste oils as the alternative binders. The waste oils employed are waste cooking and waste engine oil. These are studied and analysed as a step towards sustainable environment. This project work will provide an alternative or modified binder as well as will serve with the better way for safe disposal of waste oils generated. Thus this project is beneficial concerning both the environmental aspects of alternative binder and safe disposal of waste oils.**

***Keywords*: pavements, bitumen, engine oil, cooking oil, addition percentage, highway industry.**

1. Introduction

The eminence of highways dictates the frugality of a republic and hence forth the standard of our survival. India has kicked off a rapid pace of road development since after late 1990s by giving a high priority to the event of highways. Major exertions are on-going to revolutionize the nation's road structure. The Indian highways or road network, encompassing Expressways, National Highways, State Highways, District Roads, Low volume roads and Village Roads, is the second leading network. Our country's road network has seen unswerving enhancement within the previous couple of eons. Connectivity has been upgraded and transportation via roads has become a spotlight of swift growth. With the up gradation of transportation via roads, country is being provided with better access to services, transportation with low costs and freedom of movement to the society. Identifying the importance of a consistent and freely working road network within the nation and also its importance with regard to its overall development, the Ministry of Road Transport and Highways (MORTH) has preoccupied the responsibility of construction of good quality pavements and highways across the India. At the identical time sustainability has been the most important principle of development across the world, and all the aspects of the society are somehow stricken by the concept. In order to have preservation of environmental resources, such that not only the demands of the present generation but also the future generations are met, sustainable development should be the pattern of resource use. Sustainability includes variety of aspects, concerning business development it means that of profits and with regard to environmental growth it indicates that of natural reserves which are to be utilized by the long run peers. Thus there is utter need to rummage around for the solutions to cut back the environmental impact. It is a key challenge in highway industry to scale back the dependence on fossil fuels and to recycle the highway waste. The bitumen industry undoubtedly is a sector that incorporates a sustainable environmental impact, one of the most important component being binder, bitumen, which is produced from petroleum. Bitumen generation results in enormous amounts of carbon dioxide emission which causes hazardous environmental impact. Commercial modifiers like fillers, extenders, polymers, fibres, antioxidants, etc. are incorporated in bitumen for improved performance. There are varied commercial modifiers which can be effectively used for improving the bituminous performance, however the cost benefit ratio of such bitumen mixes decrease on their use. Thus there is utter need to have substitute modifiers which could enhance the properties of bitumen and which will not hike the price of bitumen mixes and also does not affect the value benefit ratio of the same. Thus, the employment of wastes as modifiers for bitumen modification is much more attractive research objective. Contemporary developments in country's economy have resulted in an overall hike within the total usage and extent of highways in India. Not more than fifteen years after highways are constructed and allowed for the connectivity,

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many flexible type of pavements require differing kinds of maintenance thanks to the varied damages occurred to the pavements during their serviceability. Also the upkeep of highways has led to the production of the massive quantities of reclaimed bituminous highway materials. The disposal of such waste bitumen pavement concrete could be a big challenge to society, and therefore the improper disposal of same could be a big source of environmental pollution. Therefore, the requirement for solution of recycling and reusing such waste is becoming the centre of attraction within the world with respect to energy and environmental protection and development of sustainable environment within the world. In the present world, to look for substitute of bitumen and also the regeneration of aged bitumen is a key goal to sustainable environment. Modified bitumen and regeneration of aged bitumen not only helps in reduction of the employment of non-renewable and finite resources but also helps in safe disposal of bitumen pavement waste, thus is becoming more and more attractive concerning sustainable development of the world. In the same world, on the other hand with the event of living conditions and automobile sector enormous quantities of waste oils are generated, waste oils may broadly include, Waste cooking oil (WCO) and Waste Engine Oil (WEO). Lot of research work has been done to develop various kinds of modified bitumen and bitumen rejenuvators, the current research work is aimed to review and analyse the employment of WCO and WEO as modified bitumen and as bitumen rejenuvators and their impact on the properties of modified moreover aged bitumen. It has been seen that the molecular structure of WCO and WEO is somewhat the same as that of bitumen and thus will be favourably accustomed to improve the properties of bitumen and also rejenuvate the properties of aged bitumen. Supported by the compatibility theory of rejuvenation, WCO and WEO can be used to recycle aged bitumen. Compared to other possible components, the results for flash points of WCO and WEO were above 200°C, thus compatible in hot mix bitumen mixes as they will have high structural safety. The use of these waste oils will not only reduce environmental pollution and conserves energy, but they have also signified a ground-breaking method of recycling of the waste. This methodology proposed could rejenuvate the properties of aged bitumen and supply an efficient method to rejenuvate the aged bitumen using these waste oils. Therefore, it has been practically significant and would supply a broad application of waste cooking oil and waste engine oil in the field of bituminous pavement recycling.

2. Literature Review

A lot of research work has been done associated with the research work I have opted. I explored various research papers which were associated with use of varied waste products in partial replacement of bitumen particularly associated with waste cooking oil and waste engine or automobile oil or similar products having closer properties and molecular structure to it of waste oils. Before the commencement of methodology and various credentials of my research work, following are some researches that were closely associated with my work.

Herrington, and Hamilton, (1998) [1] investigated the potential, as bitumen extenders in road pavements, of the distillation residues or "bottoms" produced during the re-refining of waste motor lubricating oils. The tests were conducted on simple and air blown blends of the residues and 180/200 and 80/100 safaniya bitumen. The simplest results got by air-blowing blends to provide 80/100 binders to be used in bitumen manufacture. The research also showed that 10% and in some cases 20% blends of 180/200 bitumen and waste oil distillation bottoms may be air blown to convey 80/100 penetration binder.

The Federal Highway Administration, (2011) [2] states, RAP is a treasured waste material that can be used replace precious virgin aggregates and binders. The foremost utilization of RAP can be done economically in bitumen mixtures. Reclaimed asphalt pavement can be effectively used as an alternative to virgin materials as it can be used in place of aggregates and also the quantity of virgin bitumen binder required. The utilization of RAP will be useful in the conservation of energy, will preserve aggregate and bitumen resources. Also the transportation charges in order to get materials to the site will be reduced. The employment of reclaimed asphalt pavement is principally determined by the prices of virgin materials and transportation.

Dr. Kemas et al., (2011) [3] studied technical viability of utilizing used oil as rejuvenating agent in reclaimed asphalt pavement. Motor oil which is employed as a emollient in varied sorts of engines of automobiles, boats, lawn mowers, trains, airplanes, etc. In engines contacting parts glide over each other at very high speeds, often for persistent phases. Friction erodes away the surfaces of these parts in contact, which may lead to lower efficiency and degradation of the motor. Oil makes a movie between surfaces of parts moving against one another to attenuate direct contact between them decreasing friction, wear, and production of excessive heat. Materials tend to become softer and fewer abrasion-resistant at high temperatures. Some engines have an extra oil cooler.

Majid Zargar, et al., (2012) [4] tested applied bitumen (80/100 grad) and evaluated the properties of same. to organize aged bitumen, the initial 80/100 bitumen was heated within the oven at a relentless temperature of 160 ◦C for about one and a half hours to 2h until it had been fluid enough to pour. Then, the melted bitumen was placed on the recent plate and mixed using the propeller mixer. The ageing process was continued for 7 h at a speed of 350 rpm to supply aged bitumen 40/50 penetration group. After the ageing process was completed, the aged bitumen was tested using the penetration test to see the group of aged bitumen. The 40/50 aged bitumen was then blended with 1%, 2%, 3%, 4% and 5% of waste oil using the propeller mixer for 30 min at 160 ◦C with a continuing speed of 200 rpm. The 40/50 aged bitumen was rejuvenated with WCO at 1%, 2%, 3%, 4% and 5% by weight of bitumen. Approximately 3% of added waste vegetable oil rejuvenates the aged bitumen of the 40/50 penetration group to an identical condition to the first bitumen. When approximately 1% of waste oil is added into the aged bitumen penetration groups of 50/60, they resemble the first bitumen value. Moreover, the first softening point value of 46 C is achieved when 2% of waste oil is added into the aged bitumen penetration group of 40/50. At the identical time, adding around 4% of WCO changed the aged bitumen to resemble the first bitumen.

Hallizza Asli et al., (2012) [5] investigated physical properties of waste oil on Rejuvenated bitumen binder. The penetration grade 80/100 of bitumen was employed in this study and supplied from one source to confirm the consistency of the initial bitumen properties. This pen-grade bitumen has been used extensively for bituminous pavement in Malaysia. The Physical and rheological properties of the initial bitumen were ascertained utilizing a penetration test, softening point test, viscosity test, and ductility test, etc. The aged bitumen were classified into several categories, namely, 50/60, 40/50 and 30/40, which have penetration values starting from 50 to 60, 40 to 50 and 30 to 40, respectively. Subsequently, a series of three aged bitumen binders were rejuvenated with WCO at 1%, 2%, 3%, 4% and 5% by weight of bitumen. It had been observed that the penetration value increases linearly because the amount of added waste oil into aged bitumen increases. Increasing the penetration value for various degrees of ageing is caused by changes to the bitumen by the chemical groups (asphaltenes and maltenes), thanks to the addition of WCO, which result in having a softer binder. However, when it reached an optimum percentage of WCO, the lower penetration value resembled that of the first bitumen. Traditional methods to work out the share of the rejuvenator are predominantly supported blending charts of either penetration or viscosity.

Nurul Hidayah, et al., (2013) [6] gave a brief review of waste oil application in pavement materials. Their review concluded because the effects of WEO and WCO are commonly produced both of the adverse and good effects to the pavement. The acceptable amount of waste oil depends on the constituent of aged mixture material. The high stiffness of mixture also require high amount of waste oil. In cold mix, it absolutely was reported that the performance was affected like stability, strength and weakening the bonding between aggregate and binder. However, in hot mix bitumen where the oil was integrated into the RAP, it offered the stiffness reduction and so improved resistance to cracking. The temperature, amount of waste oil and RAP are notable to allow significant influence on the performance properties. Therefore, these factors are an intriguing which may be usefully explored in further sustainable research.

Meizhu Chen, et al., (2014) [7] used two matrix bitumen binders (referred to as A0 and B0) and one SBS modified bitumen (referred to as C0) as control binders. The penetration grad of A0 and B0 were 60–80 grad and 40–60 grad, respectively. It is observed that penetration values of various bitumen binders are all increased with the rise of W dosages, which suggests that the addition of waste edible oil can soften aged bitumen by reducing its consistency. Physical properties including penetration, softening point, viscosity, ductility, penetration index and penetration ratio of aged bitumens is improved to the amount of its virgin bitumens at an optimum dosage of waste edible fat, which is different for various bitumens. During this study, the samples including A4 (6.0%W), B3 (5.0%W) and C2 (4.0%W) have similar physical properties with their virgin binders. However, cold flexibility of aged bitumens with waste edible oil have to be further improved, especially for virgin bitumen with a greater ductility like SBS modified bitumen.

Reena Patra, (2014) [8] explored the moral dimensions of environmental sustainability. Sustainable Development is that the development that meets the wants of the current without compromising the flexibility of future generations to fulfill their own needs. Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges facing humanity. In our modern world, we've somehow lost the deeper metaphysical dimension of sustainability as we've got lost the meaning of sustainable living. Proponents of sustainable living aim to conduct their lives in manners that are consistent with sustainability such as in natural balance and respectful of humanity‘s symbolic relationship with the Earth‘s natural ecology and cycles.

Meizhu Chen et al., (2014) [9] studied Physical, chemical and rheological properties of waste edible oil rejuvenated asphalt binders. Two matrix asphalt binders and one SBS modified asphalt were used as control binders. The penetration grad of A0 and B0 are 60–80 grad and 40–60 grad, respectively. They were widely applied in China. Waste edible fat employed in this study was repeatedly fried scraps oil, which was processed employing a simple filtering process that filtered water and solid impurities which can influence regeneration effect. The viscosity (25 C) and density (25 C) of waste edible fat are 0.05 Pa s and 0.896 g/cm3, respectively. Physical properties including penetration, softening point, viscosity, ductility, penetration index and penetration ratio of aged asphalts may be improved to the extent of its virgin asphalts at an optimum dosage of waste edible oil, which is different for various asphalts. During this study, the samples including A4 (6.0%W), B3 (5.0%W) and C2 (4.0%W) have similar physical properties with their virgin binders. However, vasoconstrictive flexibility of aged asphalts with waste edible oil must be further improved, especially for virgin asphalt with a greater ductility like SBS modified asphalt.

Md. Maniruzzaman A. Aziz, et al., (2015) [10] conducted study to explore the likelihood of using waste oil as a rejuvenating agent for aged bitumen. Result was very promising because the successful application of waste vegetable oil with bitumen as revivifying agent for used or aged bitumen result in an economic and environment friendly solution. Further modification and research are needed to induce more efficient and effective results.

Md Tareq Rahman A, et al., (2016) [11] used bitumen 60/70 to organize the samples and was provided by Shell Singapore. Bitumen was stored at temperature in air sealed condition. Waste vegetable oil (WCO) was collected from local restaurants. It absolutely was filtered to get rid of all dirt and other suspended materials. . An optimum and efficient mixing ratio is determined by physical test which consists of penetration test and softening point test. After these tests, it had been found that fifty replacement of bitumen by waste vegetable oil is that the optimum ratio among all the blending ratios. Quite 5% of waste vegetable oil makes the sample softer and not eligible for application within the construction of flexible pavement in warmer region. With the employment of all modifiers up to fifteen of replacement of bitumen has been successfully done.

Aghazadeh Dokandari, et al., (2017) [12] investigated the implementation of Waste Oils with Reclaimed Bitumen Pavement. Mary bitumen with a 50/70 penetration grade obtained from Aliaga/Izmir Oil Terminal of Turkish oil refinery Corporation was utilized in this study. During this study, 5.4% of WEO by weight of binder and 5.1% of WVO by weight of binder are found adequate supported penetration values.

Bamidele, et al., (2017) [13] investigated the properties of bitumen modified with waste cooking oil and high density polyethylene for applications in flexible pavement. Penetration grade bitumen which formed the bottom bitumen employed in this study is of grade 60-70 and was sourced from the fabric lab of a construction company in Nigeria. The bottom bitumen was black in colour. The waste oil used for the study was sourced from households in Ibadan, Nigeria. The color of the WCO was yellowish-brown. HDPE plastic wastes sourced from households in Ibadan and shredded into powdery form for an efficient blend was utilized in the research. The bottom bitumen was replaced with WCO at 5% percentage to make WCO modified bitumen. Then, HDPE was added at different percentages to the WCO modified bitumen to create WCO-HDPE modified bitumen. Tests including relative density, penetration and softening point were conducted on the modified bitumen. . It absolutely was observed that the replacement of bitumen with WCO reduces the precise gravity of the resulting binder. The reduction within the relative density of the WCO modified bitumen is attributed to the lower density of WCO compared to the bottom bitumen. Replacement of bitumen with WCO led to softer blends (as apparent within the reduction within the viscosity and a rise within the flow of the WCO modified bitumen) with lower relative density. However, the addition of HDPE increases the precise gravity of the binder. This will be attributed to the upper density of the HDPE including the very fact that HDPE was added to the WCO modified bitumen and not accustomed replace any component. HDPE added at 2.5%, 5% and 7.5% resulted in modified bitumen with higher relative density in comparison to the bottom bitumen. Modified bitumen B95-WCO-5-HDPE7.5 was found to be of the best relative density.

Shengjie Liu, et al., (2018) [14] evaluated rheological characteristics of bitumen modified with waste engine oil (WEO). One pure binder (AH-70, named Binder-PB) and one SBS modified binders (named Binder-PMB) were selected because the matrix bitumen. PB has penetration of 71.9 (0.1 mm) at 25°C, softening point of 50.6°C. Master curve of WEO modified bitumen were obtained using time–temperature superposition at the reference temperature was 50°C. It's found that the values of master curve of complex modulus for WEO modified bitumen are not up to that of control binders. Especially, the influence levels of WEO on $|G*|$ values of both binders were different. for instance, the $|G*|$ values of Binder-PB with 2%, 4%, 6%, 8% and 10% WEO were 22.5%, 38.9%, 66.6%, 74.8%, and 78.4% under that of control binders (0% WEO), respectively and therefore the Binder-PMB with 2%, 4%, 6%, 8% and 10% WEO had 13.2%, 33.5%, 56.3%, 61.9%, and 71.9% not up to that of control binder, respectively.

Sara R.M. et al., (2018) [15] worked on modified bitumens with waste engine oil products combined with polymers. The bottom bitumen (B35/50) was partially replaced by the waste engine oil (EO) or recycled engine oil bottoms (RB) during a proportion of 10% by weight. These binders modified with EO or RB shall be compared to the commercial base bitumen utilized in their modification and with an advert modified bitumen (PMB45-80/60) so as to judge the effect of EO and RB incorporation. The new modified binders (EO10 and RB10) showed increased penetration values and lower softening point temperatures than both commercial bitumens. Additionally, among the modified binders, the RB10 presented very cheap penetration value and therefore the highest softening point temperature, which can be explained by the upper viscosity of RB when put next to EO. This might indicate that a better amount of RB will be employed in order to get an identical binder employing a lower amount of EO. As compared to the commercial bitumens, EO10 and RB10 binders presented lower viscosity values within the temperature range evaluated. Again, the absolute viscosity of RB10 is slightly on top of that of EO10. The incorporation of both EO and RB decreased the binder production temperature, as may be easily observed when comparing the coefficient of viscosity values at 150 C to the reference mixing viscosity. Although the incorporation of EO or RB in bitumen is used with some advantages already presented, the corresponding binders might not present the required properties to be directly employed in asphalt mixtures, particularly at high service temperatures, because of their low viscosity and softening point temperatures, which could lead to high permanent deformations. Thus, this kind of binders should be combined with polymers, which are called materials that improve the permanent deformation resistance and thermal susceptibility of bitumen.

Haibin Li, et al., (2019) [16] conducted a groundwork add similar aspect. Mother bitumen (VA) utilized in this research was KLMY Pen70 bitumen (One of the petroleum bitumens types named by the Karamay Oilfield), which was produced in western China. The WEO utilized within the study was collected from auto store. The WCO utilized in this study was vegetable oil, which had been used several times. The rejuvenated bitumen samples were made by mixing six aged bitumens with five WEO and WCO contents viz. 1%, 2%, 3%, 4%, and 5%, by mass of bitumen. The penetration values of the aged bitumens were significantly larger than that of VA. As different aged bitumens could reach or exceed the hardness degree of VA with different oil contents. Compared with the VA, the penetration of 5-h- and 7-h-aged bitumens recovered up to 96.8% and 92.0% with 1% WEO content, 9 h- and 11 h-aged bitumens recovered up to 110.3% and 97.7% with 2% WEO content, while 13-h- and 15-h-aged bitumens recovered up to 105.2% and 99.4% with 3% and 4% WEO contents, respectively. This proved that WEO could soften aged bitumen. The effect of WEO content on bitumen penetration was better for specific aged bitumen. Although WCO had similar effects on penetration, it could achieve the same regeneration effects in lesser contents, thereby confirming its better regeneration efficiency than WEO. With 1%, 2%, and 3% WCO content, the recovery extents for bitumens aged 5 h, 7 h, 9 h, 11 h, 13 h, and 15 h were 102.9%, 87.3%, 93.4%, 98.1%, 107.7%, and 102.9%, respectively.

Gupta and Kumar, (2019) [17] worked on "Use of Waste Polyethylene in Bituminous Paving Mixes". Marshall-samples were prepared and tested for determination of Bulk Density, Air voids content, Percent volume of bitumen, Percent voids in Mineral Aggregates, and Percent Voids Filled with Bitumen. It was found Marshall Stability value increased up to certain percent and thereafter decreases. It is also observed that the Marshall Flow value shows minor changes upon addition of polythene. While, the mean value attained was pretty satisfactory. Percentage of Voids in Mineral Aggregate (VMA), Percentage of Air Voids in Bituminous Mix (VA) and Percentage of Voids Filled with Bitumen (VFB) were within the design requirements of bituminous mixes for pavement layers. It was seen that if regular road requires 10 tonnes of bitumen for each kilometre, plastic road will require only nine tonnes of bitumen and one tonne of waste plastic for coating. Thus for every km, the plastic roads save as much as one tonne of bitumen. Thus plastic roads are economically benefitted. This research will enhance the use of various wastes in construction of road, and mine work is also inspired by this research work.

Hussein, et al., (2020) [18] employed control binder as PEN. 60-70 bitumen. The penetration test was performed on the sample and bitumen samples prepared with 5, 10 and 15% maltene by the weight of total binder. It was analyzed that on increasing the concentration of maltane, penetration value was increased. The penetration value increased by 27%, 69%, and 110% as the maltene percentage was 5%, 10%, and 15%, respectively. Penetration was indirectly correlated with the softening point values of the control mix. As maltene concentration was increased, the softening point value decreased. 15% maltene concentration depressed the softening temperature of rejuvenated bitumen to 49°C, which is near about as that of the (50.5°C) softening point of virgin bitumen. It was observed with the enhancement of softening point, pavement degradation because of fatigue and low-temperature cracking was decreased.

Irtiza and Kumar (2021) [19] gave a review paper about replacement of bitumen partially with waste cooking oil and engine oil in bituminous concrete. As the properties of waste oils was interlinked and interrelated bitumen, thus they can be utilized as a partial replacement of bitumen in bituminous concrete mixes.

These conclusions indicated that WCO or WEO in suitable contents could be used as modifier or to rejuvenate aged bitumen to achieve the properties of original bitumen and meet all physical requirements.

3. Methodology

A. *Selection of Materials*

To develop a modified alternative binder, material selection is the most vital part. Materials were selected as per the availability, cost efficiency. Samples were prepared from the mixture of Bitumen, Coarse Aggregates, Filler (Fly Ash and Lime), WCO and WEO.

The various materials used for carrying out the project work with their particular type used and the source from which they were obtained are given in the table 1.

Table 1

S. No.	Material	Type
1	Bitumen	Vg 40
2	Aggregates	Stone Crushed
3	Filler	Fly Ash & Lime
4	Waste Cooking Oil	Obtained from Local Restaurant
5	Waste Engine Oil	Obtained from Local Automobile Shop

For the conduction of research work, initially the specific gravity of various components were determined using Pycnometer test. The test results obtained are given table 2.

Table 2

S. No.	Component	Specific gravity
1	Coarse	2.75
2	Fine (Stone)	2.6
3	Filler (Lime)	2.7
4	Filler (Fly ash)	2.3
5	Bitumen	1.12
6	WEO	0.94
7	WCO	0.79

To achieve the objective of study, a methodology was devised to investigate the influence of partial replacement of bitumen with waste cooking and engine oil in bituminous concrete for flexible pavement. The flow chart of the same is as under.

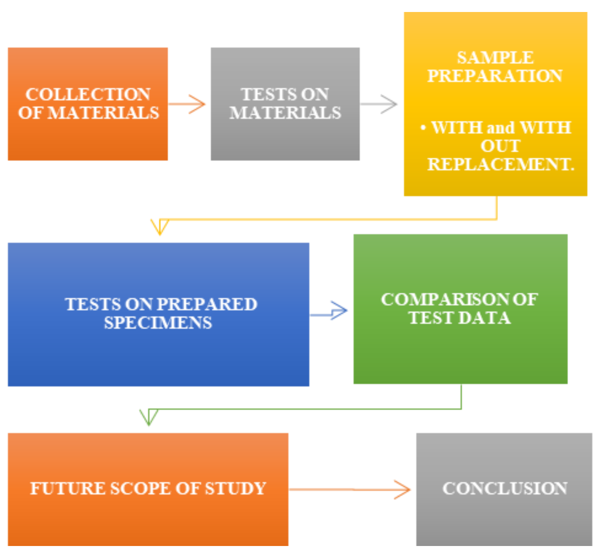

Fig. 1. Methodology Flow Chart

B. *Mix Design*

The mix is designed as per MORTH Section 500. The composition of Bituminous Concrete Pavement Layers is as per following table.

Table 3

Grading	1	2
Nominal aggregate size*	19 mm	13.2 mm
Layer thickness	50 mm	30–40 mm
IS Sieve¹ (mm)	Cumulative % by weight of total aggregate passing	
45		
37.5		
26.5	100	
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	Min 5.2*	Min 5.4**

4. Results and Discussions

The properties of the different samples were characterized using various tests viz., Ductility test, Flash and Fire point test, Float test, Loss on heating test, Penetration test, Softening point test, Viscosity test, Water content test and most importantly Marshall Stability test.

For carrying out the Marshall Stability test on the prepared samples Fly Ash and Lime were used as fillers. Chemical composition of fly ash and Lime in percentage (by weight) are given in the following table.

Table 4

S. No.	Constituents of Fly Ash	Percentage of Constituents
1	Fe_2O_3	2.30%
2	CaO	4.20%
3	MgO	3.00%
4	Silica	56.40%
5	Al_2O_3	28.08%
6	Carbon	6.02%

Table 5

S. No.	Constituents of Lime	Percentage of Composition
1	Al_2O_3 (aluminum oxide)	0.01
2	Fe_2O_3 (Iron Oxide)	0.11
3	CaO (Calcium Oxide)	65.25
4	MgO (Magnesium Oxide)	0.50
5	K_2O (Potassium Oxide)	0.01
6	Na_2O (Sodium Oxide)	0.01
7	S (Sulphur)	0.13
8	C (Carbon)	4.50
9	Loss on ignition	33.25

Aggregates were tested for various physical requirements and were put to various tests such as, Aggregates Impact Test, Aggregate Crushing Test, Abrasion Test, Shape Tests and Water Absorption Test. These tests were performed as per different parts of IS: 2386. The test results for the various tests conducted are given in the table below.

Table 6

S. No	Test Property	Test method	Test result
1	Aggregate Impact Value (%)	IS: 2386 (P IV)	14.3
2	Aggregate Crushing Value (%)	IS: 2386 (P IV)	13.02
3	Los Angeles Abrasion Value (%)	IS: 2386 (P IV)	18
4	Flakiness Index (%)	IS: 2386 (P I)	18.83
5	Elongation Index (%)	IS: 2386 (P I)	21.5
6	Water Absorption (%)	IS: 2386 (P III)	0.1

Various lab tests were also done on the virgin bitumen in order to check the physical properties of virgin bitumen to be used. This was also necessary in order to have comparative analysis. The results of various tests performed are presented below in a table.

Table 7

Sr. No.	Characteristic	Unit	Result	Test Method
1	Ductility at 25° C	Cm	35 cm	IS 1208 : 1978
2	Penetration at 25° C	1/10mm	54 mm	IS 1203 : 1978
3	Absolute Viscosity at 60° C	Poise	3300	IS 1206 : 1978
4	Softening Point	°C	53°C	IS 1205:1978
5	Flash Point Test	°C	250°C	IS 1209 : 1978
6	Fire Point Test	°C	300°C	IS 1209 : 1978

Specimens with varying percentages of waste engine oil and waste cooking oil were prepared by partial replacement of bitumen with the oils and were tested for various bituminous properties viz, penetration, Softening point, Viscosity, Flash and Fire point and ductility. Also for the same percentages of replacement of bitumen by oils specimens for Marshall Stability test were prepared. The replacement percentages by weight of bitumen considered for the study were, 8% 12% 16% 20% and 24% (partial being that of cooking oil and partial that of engine oil). The detailed percentage of replacement of waste engine oil and waste cooking oil is presented below.

Table 8

S.No.	% of replacement				Weight of Bitumen
	Waste cooking oil		Waste Engine oil		
	%	gm.	%	gm.	gm.
1	4	2.64	4	2.64	60.72
2	6	3.96	6	3.96	58.08
3	8	5.28	8	5.28	55.44
4	10	6.6	10	6.6	52.8
5	12	7.92	12	7.92	50.16
6	14	9.24	14	9.24	47.52

A. Penetration

Penetration indicates degree of softness and consistency as well as the relative viscosity of bitumen. Specimens prepared with different percentages of WCO and WEO were tested for penetration and it was observed that when 8% 12% 16% 20% and 24% of bitumen was replaced with WCO and WEO penetration values were 62, 65, 69, 72, and 80 respectively. The results clearly showed hike in the penetration value corresponding to the penetration value of 54 for virgin bitumen with zero content of waste oils. This showed that incorporation of WEO and WCO in the bitumen increased the penetration values significantly.

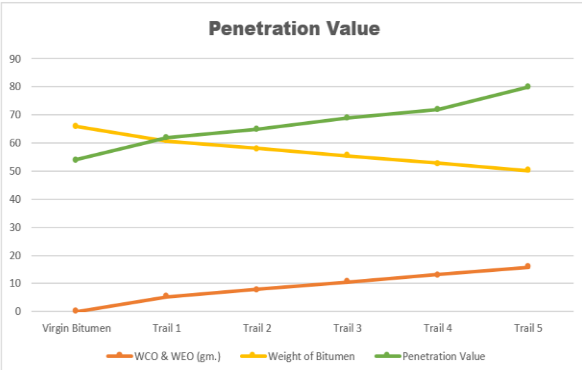

Fig. 2.

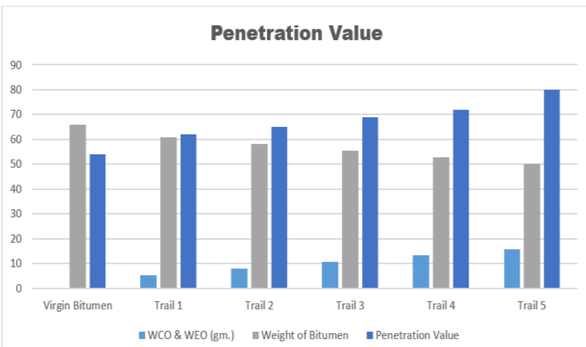

Fig. 3.

B. Softening point

Softening point is measure of viscosity of bitumen. The viscosity of bitumen decreases with decreasing softening point. Specimens prepared with different percentages of WCO and WEO were tested for Softening point and it was observed that when 8% 12% 16% 20% and 24% of bitumen was replaced with WCO and WEO Softening point values were 46, 43, 42, 37, and 35 respectively in terms of °C. The results showed significant decrease in softening point, which means on addition of WEO and WCO to bitumen, viscosity of bitumen decreases as compared to the softening point of virgin bitumen i.e. 53. This property will help in liquefying the bitumen which is necessary for road construction purposes.

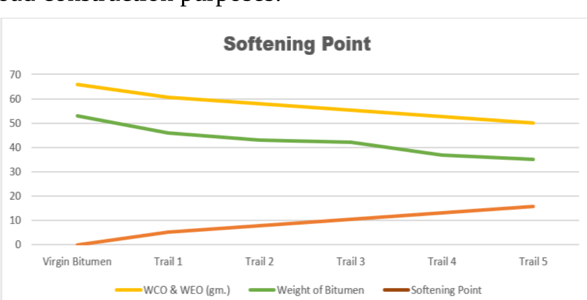

Fig. 4.

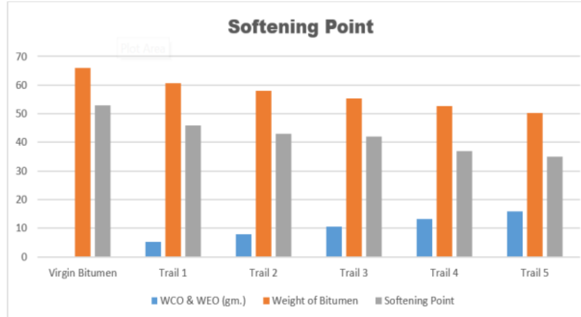

Fig. 5.

C. Ductility

It gives us the measure of stiffness of bitumen i.e. how much elongation can bitumen undergo because of traffic loads without getting cracked in road construction works. Ductility of virgin bitumen was determined and was compared to the ductility measured for different trials carried out by adding varied percentages of WCO and WEO. Specimens prepared with different percentages of WCO and WEO were tested for Ductility and it was observed that when 8% 12% 16% 20% and 24% of bitumen was replaced with WCO and WEO Ductility values were 47, 53, 69, 81, and 109 mm respectively. The results showed significant increase in ductility value in comparison to that of virgin bitumen having ductility value of 35 mm. It implies that on increasing the content of WCO and WEO in bitumen ductility of bitumen is enhanced. Or in other words that bitumen added with the WCO and WEO will help roads to sustain more traffic load before cracking.

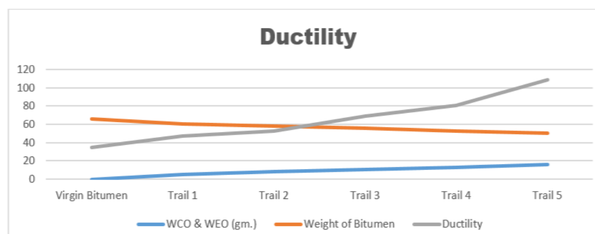

Fig. 6.

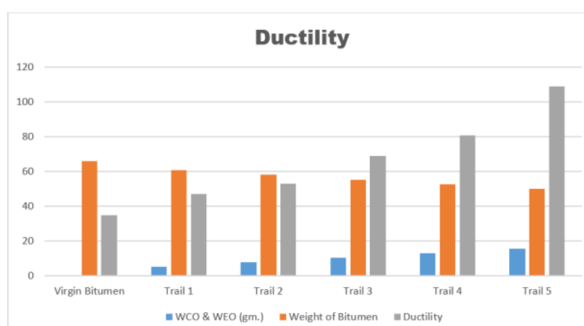

Fig. 7.

D. Viscosity

Viscosity is defined as the property of bitumen which indicates its ability to flow, spread, penetrate into the voids and also how it in binds with the aggregates. That is, it is the measure of fluid property of bitumen. Higher the viscosity of bitumen, lesser will be the compactive effort of bitumen and heterogeneous mixture arises. However, if the viscosity of bitumen will be lower, it will lubricate the aggregates. Specimens prepared with different percentages of WCO and WEO were tested for Viscosity and it was observed that when 8% 12% 16% 20% and 24% of bitumen was replaced with WCO and WEO Viscosity values were 3000, 2750, 2540, 2250 and 1960 poise respectively. The results showed significant decrease in Viscosity value in comparison to that of virgin bitumen having Viscosity value of 3300 poise. It implies that on increasing the content of WCO and WEO in bitumen viscosity of bitumen is decreases. Or in other words that bitumen added with the WCO and WEO will enhance fluidity of bitumen, which will help in road construction works.

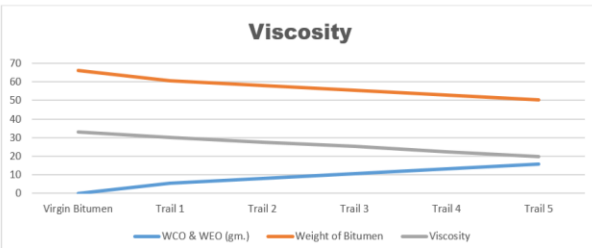

Fig. 8.

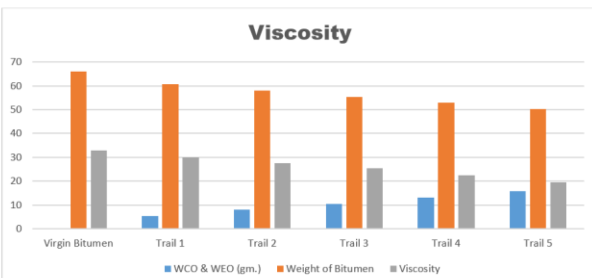

Fig. 9.

E. *Marshall Stability Test*

In order to conduct the Marshall Stability test, the aggregates were first sieved as per requirements of the Marshall Mix design with reference to MORTH Section 500 for bituminous concrete. The coarse aggregates plus filler material weighing 1200 grams were sieved through the following sieves of sizes 19, 13.2, 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15, 0.07 and pan. The results are provided in the following table.

Table 9

S.No.	Sieve size (mm)	Percentage finer range	Percentage finer passed	Percentage Retained	Percentage retained per sieve	Weight retained on each sieve (gm.)	Cumulative weight (gm.)
1	19	**100**	100	0	0	0	0
2	13.2	**79-100**	91.25	8.75	8.75	105	105
3	9.5	**70-88**	76.25	23.75	15	180	285
4	4.75	**53-71**	53.7	43.3	19.55	234.6	519.6
5	2.36	**42-58**	45.35	54.65	11.35	136.2	655.8
6	1.18	**34-48**	37.14	62.86	8.21	98.4	754.2
7	0.6	**26-38**	29.04	70.96	8.10	97.2	851.4
8	0.3	**18-28**	21.8	78.20	7.24	86.88	938.28
9	0.15	**12-20**	13.66	86.34	8.14	97.68	1035.96
10	0.07	**4-10**	4.42	95.58	9.24	110.88	1146.84
11	Pan	**0**	0	100	4.42	53.04	1200

In order to find out the optimum bitumen content three samples were prepared with bitumen content ranging 5% to 6% by weight of total mix of Aggregate & filler. Weight of Aggregates along with Filler was taken as 1200 mg.

Table 10

S. No	% of Bitumen, (Pb)	% of Aggregates, [Ps=(100-Pb)]
1	5.00	95.00
2	5.50	94.50
3	6.00	94.00

F. *Optimum Bitumen Content*

Specimens for Marshall Stability test were prepared using virgin bitumen i.e. in this trial zero content of waste engine oil and waste cooking oil was used and different parameters evaluated were, weight in air, weight in water, Bulk volume, Bulk specific gravity, theoretical specific gravity, Voids in mineral aggregates, Air voids, voids filled with bitumen, Stability, and Flow Value. The results along with graphical representations of the Marshall Stability test conducted on specimen with virgin bitumen and zero content of waste oils are presented below.

Table 11

S.No.	A			B			C		
% of Bitumen Pb	5			5.5			6		
% of Aggregates Ps = 100- Pb	95			94.5			94		
Aggregate Specific Gravity Gsb	2.58								
Sample No.	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
Wt. in Air (gm) Wa	1236.6	1235.5	1239.8	1236.4	1243.8	1247.1	1241.3	1235.5	1236.2
Wt. in water (gm) Ww	705.2	700.1	704.8	708.5	707.1	707.5	713.4	711.7	712.7
SSD Weight (gm) W_{SSD}	1237.4	1236.4	1240	1237.5	1242.6	1245.3	1242	1237.2	1239.7
Bulk Volume Bv= WssD-Ww	532.2	536.3	535.2	529	540.5	535.8	528.6	525.5	527
Bulk Sp. Gr. Of specimen Gmb	2.324	2.304	2.317	2.332	2.307	2.328	2.348	2.351	2.35
Avg. Sp. Gr. Of Specimen Gmb	2.315			2.322			2.349		
Theoretical Sp. Gr. Of Mix Gmm	2.43			2.4			2.39		
Va	4.73			3.25			1.715		
VMA	14.76			14.95			14.42		
VFB	67.95			78.26			88.11		
Stability (KN)	14.9	15.6	16	16.8	17.7	18	15.9	16.3	15.8
Avg. Stability (KN)	15.5			**17.5**			16		
Flow Value (mm)	2.9	3.1	3.2	3.5	3.1	3.2	3.4	3.5	3.6
Avg. Flow Value (mm)	3.05			3.26			3.55		

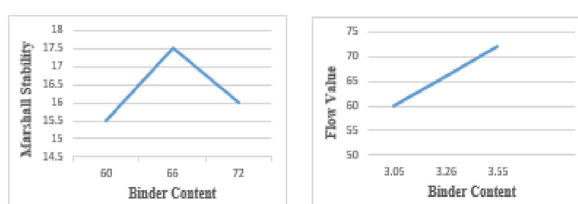

Fig. 10.

As per the results carried out on control mix with three different contents of bitumen, it was observed that 5.5 % of bitumen to the weight of aggregates is optimum. Thus to carry out further trials bitumen content as taken as 5.5% to the weight of aggregates. Specimens with varying percentages (three samples for each percent) of waste engine oil and waste cooking oil were prepared by partial replacement of bitumen with the oils and were tested for Marshall Stability. The replacement percentages by weight of bitumen considered for the study were, 8% 12% 16% 20% and 24%. The results for all the trials along comparative analysis and with the graphical representations of the Marshall Stability test conducted on specimens of virgin bitumen (0% waste oils) and those having 8% 12% 16% 20% and 24% content of waste oils are presented below.

Table 12

S.No.	A			B			C			D			E			F		
% of WEO and WCO by wt. of bitumen	0			8			12			16			20			24		
Sample No.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Wt. in Air (gm) Wa	1236.4	1243.8	1247.1	1252	1246	1240	1238	1249	1256	1252	1261	1270	1260	1258	1264	1268	1263	1258
Wt. in water (gm) Ww	708.5	707.1	707.5	706	703	700	703	707	705	713	718	720	718	730	722	728	724	728
SSD Weight (gm) WssD	1237.5	1242.6	1245.3	1256	1250	1244	1241	1252	1259	1256	1263	1275	1265	1265	1269	1272	1269	1268
Bulk Volume Bv	529	540.5	535.8	550	547	544	538	545	554	543	545	555	547	535	547	544	545	540
Bulk Sp. Gr. Of specimen Gmb	2.332	2.307	2.328	2.28	2.28	2.28	2.3	2.29	2.27	2.31	2.31	2.29	2.3	2.35	2.31	2.33	2.52	2.33
Avg. Sp. Gr. Of Specimen Gmb	2.322			2.28			2.29			2.3			2.32			2.33		
Stability (KN)	16.8	17.7	18	17.2	15.6	16.1	16.1	15.9	15.7	15.6	15.4	15.3	15	15.2	14.9	14.8	14.6	14.8
Avg. Stability (KN)	17.5			16.3			15.9			15.43			15.03			14.73		
Flow Value (mm)	3.5	3.1	3.2	4.21	4.29	4.55	4.34	4.45	4.55	4.65	4.52	4.45	4.2	4.69	5.1	4.5	5.1	4.8
Avg. Flow Value (mm)	3.27			4.35			4.45			4.54			4.66			4.8		

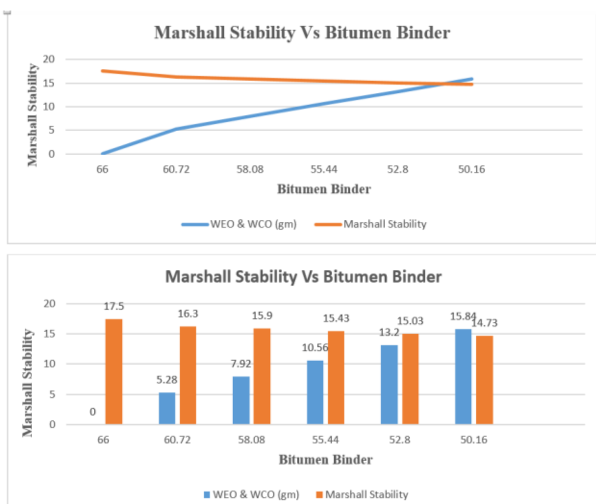

Fig. 11.

The results showed that when samples were prepared upon addition of WEO and WCO along with bitumen binder Marshall Stability of samples was decreased as the content of WEO and WCO was increased. This indicates that partial replacement of bitumen with WEO and WCO decreased the load carrying capacity of mix. The results of Marshall Stability at 0% 8% 12% 16% 20% and 24% were 17.5, 16.3, 15.9, 15.43, 15.03 and 14.73 respectively. Also results showed that when samples were prepared upon addition of WEO and WCO along with bitumen binder Flow Value of samples was increased as the content of WEO and WCO was increased. This indicates that upon addition of WEO and WCO fluidity of bitumen was enhanced. The results of Flow Value at 0% 8% 12% 16% 20% and 24% were 3.27, 4.35, 4.45, 4.54, 4.66, and 4.8 respectively. This indicates that partial replacement of bitumen with WEO and WCO increased the workability of mix.

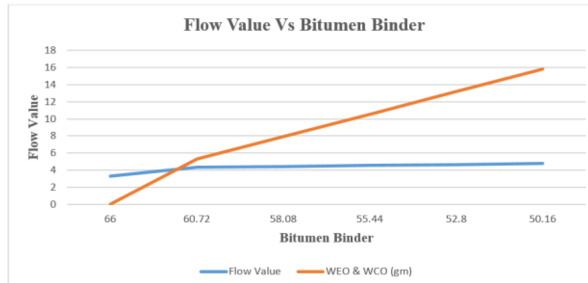

Fig. 12.

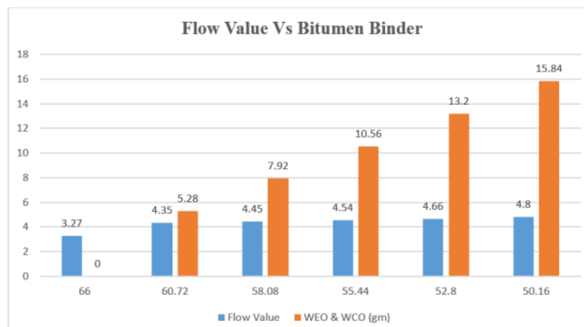

Fig. 13.

5. Conclusion and Future Scope

This dissertation was about studying the influence of partial replacement of bitumen by WEO and WCO in bituminous concrete. This research was inspired by two concepts i.e. to reduce the use of bitumen and to achieve the beneficial disposal of waste oils. In this study, bitumen (VG 40) was partially replaced by WEO and WCO and specimens were tested for various physical properties, viz. Penetration, Softening Point, Ductility, Viscosity, Marshall Stability and Flow value. The samples were prepared with varying contents of WEO and WCO and were compared to the samples prepared using virgin bitumen. The results indicated that when 8% 12% 16% 20% and 24% of bitumen was replaced with WCO and WEO penetration values were 62, 65, 69, 72, and 80 respectively. The results clearly showed hike in the penetration value corresponding to the penetration value of 54 for virgin bitumen with zero content of waste oils. This showed that incorporation of WEO and WCO in the bitumen increased the penetration values significantly. Specimens were tested for Softening point values were 46, 43, 42, 37, and 35 respectively in terms of °C. The results showed significant decrease in softening point, which means on addition of WEO and WCO to bitumen, viscosity of bitumen decreases as compared to the softening point of virgin bitumen i.e. 53 °C. Ductility values were 47, 53, 69, 81, and 109 mm respectively. There was increase in ductility value in comparison to that of virgin bitumen having ductility value of 35 mm. It implies that on increasing the content of WCO and WEO in bitumen ductility of bitumen is enhanced. Or in other words that bitumen added with the WCO and WEO will help roads to sustain more traffic load before cracking. Viscosity values were 3000, 2750, 2540, 2250 and 1960 poise respectively. The decrease in Viscosity value in comparison to that of virgin bitumen having Viscosity value of 3300 poise could be seen. It implies that on increasing the content of WCO and WEO in bitumen viscosity of bitumen is decreases. Or in other words that bitumen added with the WCO and WEO will enhance fluidity of bitumen, which will help in road construction works.

When samples were prepared upon addition of WEO and WCO along with bitumen binder Marshall Stability of samples was decreased as the content of WEO and WCO was increased. This indicates that partial replacement of bitumen with WEO and WCO decreased the load carrying capacity of mix. The results of Marshall Stability at 0% 8% 12% 16% 20% and 24% were 17.5, 16.3, 15.9, 15.43, 15.03 and 14.73 respectively. Also results showed that when samples were prepared upon addition of WEO and WCO along with bitumen binder Flow Value of samples was increased as the content of WEO and WCO was increased. This indicates that upon addition of WEO and WCO fluidity of bitumen was enhanced. The results of Flow Value at 0% 8% 12% 16% 20% and 24% were 3.27, 4.35, 4.45, 4.54, 4.66, and 4.8 respectively. This indicates that partial replacement of bitumen with WEO and WCO increased the workability of mix. The analysis of test results indicates that if we have provision to compromise on load carrying capacity of roads e.g. Low Volume Roads, Rural Roads, Foot paths, Cycle tracks, then partial replacement of bitumen by WEO and WCO will be beneficial.

Future scope of the study includes the partial replacement of bitumen by WEO and WCO in addition to some stability enhancer. If we will be able to find out an economical stabilizer, then the mixes created by partial replacement of bitumen by waste oils and stabilizer can prove as most beneficial mix with regard to both sustainable environment and as well as cost benefit ratio. Also the influence of WEO and WCO in rejenuvating the aged bitumen or reclaimed bitumen pavements can be studied. This idea can introduce an efficient, economic and environment friendly alternative in pavement industry.

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