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STUDY ON REPLACEMENT OF BITUMEN PARTIALLY WITH WASTE COOKING OIL AND ENGINE OIL IN BITUMINOUS CONCRETE - REVIEW

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Abstract - *Pavements have mainly two types i.e. rigid pavement and flexible pavement. Flexible pavements constructed with bituminous as binder and aggregate materials. Bitumen is a viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation, used for road surfacing and roofing. Bitumen is non-hazardous under normal conditions but when heated it becomes toxic and has consequences of environmental degradation. Also being a non-renewable source of energy, will lead to depletion of petroleum reserves. It is a key challenge in highway industry to reduce the dependence on fossil fuels & to recycle the highway waste. The asphalt industry is a sector that has a sustainable environmental impact, one of the main components being binder, i.e. bitumen, which is produced from petroleum. Bitumen generation leads to enormous amounts of carbon dioxide emission which causes hazardous environmental impact. This research is about to reduce the load on environment by the use of waste material i.e. waste cooking oil and waste engine oil. This research will help to find out the optimum addition percentage of waste material to bituminous concrete mix. This research is a way towards sustainable environment.*

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

INTRODUCTION

The quality of roads dictate the economy of a country & hence forth the quality of our lives. India has embarked on a rapid pace of road development since after late 1990s by giving a high priority to the development of highways. Major efforts have been underway to modernize the country's road infrastructure. The Indian road network, comprising of National Highways, Expressways, State Highways, Major District Roads, Other District Roads and Village Roads, is globally the 2nd largest spanning 5.5 million kilometres. India's road infrastructure has seen consistent improvement in the last few years. Connectivity has improved and road transportation has become a focus of rapid development. Roads are providing better access to services, ease of transportation and freedom of movement to people. Recognizing the importance of a reliable and smooth road network in the country and the role it plays in influencing its economic development, the Ministry of Road Transport and Highways (MORTH) has taken up the responsibility of building quality roads and highways across the country.

At the same time sustainability has been the major principle of development across the globe, and all the aspects of the society are somehow affected by the concept. Sustainable development is said to be a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. The term sustainability would include a number of aspects - for business it would mean sustainability of profits and for environment it would mean sustainability of natural resources which can be used by the future generations. Thus there is utter need to look for the solutions to reduce the environmental impact. It is a key challenge in highway industry to reduce the dependence on fossil fuels & to recycle the highway waste. The asphalt industry is a sector that has a sustainable environmental impact, one of the main components being binder, bitumen, which is produced from petroleum. Bitumen generation leads to enormous amounts of carbon dioxide emission which causes hazardous environmental impact.

Commercial modifiers such as fillers, extenders, polymers, fibers, antioxidants, etc. have been incorporated in bitumen for improved performance. Though commercial modifiers could be effective in improving the performance of bitumen, the cost of asphalt mixes could increase, as a result of their use. Thus there is need to develop alternative low-cost modifiers which could enhance the properties of bitumen and also does not affect the cost benefit ratio of the same. Thus, the use of wastes as modifiers for bitumen modification is way more attractive research objective. Recent societal and economic developments have resulted in an annual increase in the total mileage of highways in India. Less than 15 years after construction or operation, many flexible pavements require different types of maintenance due to the different damages sustained during their service lives. Also the maintenance of highways have led to the generation of the large quantities of reclaimed asphalt pavement materials. The disposal of such waste asphalt pavement concrete is a big challenge to society, and the improper disposal of same is a big source of environmental pollution. Therefore the need for solution of recycling and reusing such waste is becoming the centre of attraction in the world with regard to energy and environmental protection and development of sustainable environment in the world.

In the present world, to look for substitute of bitumen and the regeneration of aged bitumen serves as a key goal to

sustainable environment. Modified Bitumen and regeneration of aged Bitumen not only helps in reduction of the use of non-renewable and finite resources but also helps in safe disposal of asphalt pavement waste, thus is becoming more and more attractive from the perspective of energy and environmental protection in the world. In the same world, on the other hand with the development 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 types of modified bitumen and bitumen rejenuvators, the present research work is also aimed to study and analyse the use of waste cooking oil (WCO) and waste engine oil (WEO) as modified bitumen and as bitumen rejenuvators and their impact on the properties of modified as well aged bitumen. It has been seen that the molecular structure of waste cooking oil (WCO) and waste engine oil (WEO) is somewhat similar to that of bitumen and thus can be favourably used to enhance the properties of bitumen and also rejenuvate the properties of aged bitumen. Based on the compatibility theory of rejuvenation, WCO and WEO can be used as a low viscosity component to recycle aged asphalt. Compared with other low viscosity components, flash points of WCO and WEO were above 200°C, which showed that the use of WCO and WEO in hot mix asphalt mixes had high structural safety. The effective treatment or reuse of these materials not only reduced environmental pollution and conserves energy, but also represented an innovative method of recycling waste. The proposed method could recover or improve the properties of aged asphalt and provide an effective method to regenerate the aged asphalt using waste oils. Therefore, it was practically significant and would provide a broad application prospect for WEO and WCO in the asphalt pavement recycling field.

LITERATURE REVIEW

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

1. **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 best results were given by air-blowing blends to produce 80/100 binders for use in asphalt manufacture. The research also showed that 10% and in some cases 20% blends of 180/200 bitumen and waste oil distillation bottoms could be air blown to give 80/100 penetration binder.
2. **The Federal Highway Administration, (2011) [2]** states, RAP is a valuable, high-quality material that can replace more expensive virgin aggregates and binders. The most economical use of RAP is in asphalt mixtures. RAP is a useful alternative to virgin materials because it reduces the use of virgin aggregate and the amount of virgin asphalt binder required in the production of HMA. The use of RAP also conserves energy, lowers transportation costs required to obtain quality virgin aggregate, and preserves resources. The use of RAP is primarily driven by the costs of virgin materials and transportation. Usage is optional and depends on the contractor to propose its use based on economic considerations, availability of materials, plant site, and production capabilities
3. **Majid Zargar, et al., (2012) [3]** tested applied bitumen (80/100 grad) and evaluated the properties of same. To prepare aged bitumen, the original 80/100 bitumen was heated in the oven at a constant temperature of 160 ◦C for about one and a half hours to 2h until it was fluid enough to pour. Then, the melted bitumen was placed on the hot plate and mixed using the propeller mixer. The ageing process was continued for 7 h at a speed of 350 rpm to produce aged bitumen 40/50 penetration group. After the ageing process was completed, the aged bitumen was tested using the penetration test to determine the group of aged bitumen. The 40/50 aged bitumen was then blended with 1%, 2%, 3%, 4% and 5% of waste cooking oil using the propeller mixer for 30 min at 160 ◦C with a constant 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 cooking oil rejuvenates the aged bitumen of the 40/50 penetration group to a similar condition to the original bitumen. When approximately 1% of waste cooking oil is added into the aged bitumen penetration groups of 50/60, they resemble the original bitumen value. Moreover, the original softening point value of 46 C is achieved when 2% of waste cooking oil is added into the aged bitumen penetration group of 40/50. At the same time, adding around 4% of waste cooking oil changed the aged bitumen to resemble the original bitumen.
4. **Meizhu Chen, et al., (2014) [5]** used two matrix asphalt binders (referred to as A0 and B0) and one SBS modified asphalt (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 clearly observed that penetration values of different asphalt binders are all increased with the increase of W dosages, which implies that the addition of waste edible vegetable oil can soften aged asphalt by reducing its consistency. Physical properties including penetration, softening point, viscosity, ductility, penetration index and penetration ratio of aged asphalts can be improved to

the level of its virgin asphalts at an optimum dosage of waste edible vegetable oil, which is different for different asphalts. In 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, low temperature flexibility of aged asphalts with waste edible vegetable oil need to be further improved, especially for virgin asphalt with a greater ductility such as SBS modified asphalt.

5. **Md. Maniruzzaman A. Aziz, et al., (2015) [6]** conducted study to explore the possibility of using waste cooking oil as a rejuvenating agent for aged bitumen. Result was very promising as the successful application of waste cooking oil with bitumen as revivifying agent for used or aged bitumen lead to an economic and environment friendly solution. Further modification and research are needed to get more efficient and effective results.
6. **Md Tareq Rahman A, et al., (2016) [7]** used bitumen 60/70 to prepare the samples and was provided by Shell Singapore. Bitumen was stored at room temperature in air sealed condition. Waste cooking oil (WCO) was collected from local restaurants. It was filtered to remove all dirt and other suspended materials. . An optimum and efficient mixing ratio can be determined by physical test which consists of penetration test and softening point test. After these tests, it was found that 5% replacement of bitumen by waste cooking oil is the optimum ratio among all the mixing ratios. More than 5% of waste cooking oil makes the sample softer and not eligible for application in the construction of flexible pavement in warmer region. With the use of all modifiers up to 15% of replacement of bitumen has been successfully done.
7. **Aghazadeh Dokandari, et al., (2017) [8]** investigated the implementation of Waste Oils with Reclaimed Asphalt Pavement. The virgin bitumen with a 50/70 penetration grade obtained from Aliaga/Izmir Oil Terminal of Turkish Petroleum Refinery Corporation was used in this study. In this study, 5.4% of WEO by weight of binder and 5.1% of WVO by weight of binder have been found adequate based on penetration values.
8. **Shengjie Liu, et al., (2018) [9]** evaluated rheological characteristics of asphalt modified with waste engine oil (WEO). One pure binder (AH-70, named Binder-PB) and one SBS modified binders (named Binder-PMB) were selected as the matrix asphalt. PB has penetration of 71.9 (0.1 mm) at 25°C, softening point of 50.6°C. Master curve of WEO modified asphalt were obtained using time–temperature superposition at the reference temperature was 50°C. It is found that the values of master curve of complex modulus for WEO modified asphalt are lower than that of control binders. Especially, the influence levels of WEO on |G∗| values of both binders were different. For example, 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% lower than that of control binders (0% WEO), respectively and the Binder-PMB with 2%, 4%, 6%, 8% and 10% WEO had 13.2%, 33.5%, 56.3%, 61.9%, and 71.9% lower than that of control binder, respectively.
9. **Gupta and Kumar, (2019) [12]** 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 increases with polyethylene content up to 9% 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.

These conclusions indicated that WCO or WEO in suitable contents could rejuvenate aged asphalt to achieve the properties of original asphalt and meet all physical requirements. In summary, WEO and WCO could both have positive effects on recovering aged asphalts properties to the original asphalt level with addition of a suitable content.
All my research work will be attributed to above mentioned research works and my work will be in accordance to these research works.

METHODOLOGY

The research will comprise of two parts

- GENERATION OF MODIFIED BITUMEN
- IMPROVING THE PROPERTIES OF RECLAIMED/AGED BITUMEN

In both the parts of research, properties of bitumen and that of aged bitumen will be enhanced by the use of waste oils viz, waste cooking oil (WCO) and waste engine oil (WEO).

MATERIALS TO BE USED

Material selection is the most vital part in the research study. The preparation of sample for the investigation of various properties of modified bitumen shall include:

- **Bitumen**: This is also known as Asphalt in United States, is a substance produced by the distillation of crude oil that is known for its water proofing and adhesive properties. Bitumen production through distillation removes lighter crude oil components viz gasoline and diesel, leaving the heavier bitumen behind.
- **Aggregates**: The coarse aggregates are known for their abrasion resistance and toughness. These aggregates offer compressive and shear strength to the mix. These also facilitates good interlocking properties between aggregates. Examples for this type of aggregates are granites.
  The fine aggregates fill the voids in the mix created by the coarse aggregates and provide stiffening to the binder. Examples of fine aggregates used are sand and rock dust.

- **Fillers**: Fillers play the role of filling the voids, they help in stiffening the binder and offer higher permeability. Example for this type of fillers are cement, lime and rock dust
- **Modifiers:** The following modifiers will be used to enhance the properties of bituminous concrete
  1 Waste Cooking Oil 2 Waste Engine Oil.

OBJECTIVE OF STUDY

The objective of present study is a step towards the sustainable environment. The major objectives of the work are;

- To investigate the effect of waste cooking oil and waste engine oil on the properties of fresh and aged bitumen.
- To determine the optimum content of replacement of bitumen by waste cooking oil, waste engine oil, reclaimed bitumen treated with the waste oils.
- To promote the use of waste materials in order to safeguard the environment and also the finite sources of fossil fuels.
- To find out the effect of replacement of bitumen by waste oils in bituminous concrete in the aspects of cost.

IMPORTANCE OF RESEARCH

The mentioned research title i.e. the effect of use of waste cooking oil and waste engine oil for improving the properties of both virgin bitumen and that of reclaimed bitumen is of great importance with regard to the green and sustainable environment. The objective of present study is a step towards the sustainable environment. As we know India is currently going at a rapid pace towards development, in which the major contribution is of highways. India is having one of the largest road network comprising of urban as well as rural roads. With the development of highways, the need of natural, non-renewable and finite resources is increasing, with in turn, increasing impact on the sustainability of environment. On the other hand after the service life of pavements is over or in case of various failures to pavements, there is a need for maintenance of pavements. The maintenance of pavements, generates tremendous quantities of asphalt pavement wastes which need to be disposed of and thus causing environmental pollution. The present research work is aimed at to reduce the demand of non-renewable and finite resources i.e. bitumen and also how we can use the reclaimed bitumen, out of the pavement waste, which can reduce the environmental pollution and promote the reuse of recycled pavement wastes. The research will help us to give a solution for the reduced use of finite and non-renewable source of petroleum i.e. bitumen and also will help in safe disposal of various wastes i.e. waste oils, and asphaltic pavement wastes. Bitumen is non-hazardous at room temperature but when heated to 165– 200 C to coat all the aggregates it generates hazardous fume which is severely detrimental to health. Consequences such as environmental degradation, depleting petroleum reserves and price spiking, led researchers to explore alternative sources of obtaining binder for flexible pavement. From the review of literature it is clear that there was decreased effect of cracking, formation of potholes in the modified bituminous pavements. This research focused on the effect of adding waste cooking oil and waste engine oil to reduce the percentage of bitumen in the mixture. These modifiers are sourced from waste materials, easily available in the market and cheap in price.

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