Design And Analysis Of Bituminous Construction Mixes For Flexible Pavement By Adding Industrial Waste

Manoj Ahirwar[1], Hitesh Kodwani[2]
[1]Dept of Civil Engineering
2Assistant Professor, Dept of Civil Engineering
[1, 2]Sam Global University, Raisen-464551, Madhya Pradesh, India

Abstract- *The two primary forms of pavement are rigid pavement and flexible pavement. Bituminous is used as the aggregate and binder material in flexible pavements. The gelatinous, viscous mixture of hydrocarbons known as bitumen, which is used for roofing and pavement materialisation, can be obtained naturally or as a byproduct of petroleum refinement. Globally, bitumen is utilised as a binder for flexible pavements. When heated, bitumen turns poisonous and has negative effects on the environment, even though it is not dangerous in normal circumstances. Additionally, the production of bitumen, which comes from petroleum, a non-renewable energy source, will have caused the depletion of petroleum reserves. The highway sector faces a significant challenge in reducing its reliance on fossil fuels and recycling its trash. With bitumen, a binder made from petroleum, being one of its primary constituents, the asphalt industry is certainly one with a sustainable environmental impact. The production of bitumen contributes to massive emissions of carbon dioxide, which harm the environment. Utilising waste oils as substitute binders is the subject of this research project. Waste cooking oil and waste engine oil are the waste oils used. These are investigated and evaluated to create a sustainable environment. This project will offer a substitute or modified binder and a more effective method for the secure disposal of waste oils produced. Therefore, this initiative is advantageous in terms of the safe disposal of waste oils as well as the environmental elements of the alternative binder.*

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

I. INTRODUCTION

The economics of a nation and, consequently, the standard of our lives are determined by the condition of its roads. Since the late 1990s, India has been building roads at a rapid rate by prioritising the construction of highways. The nation's road system has been undergoing significant modernisation. With 5.5 million km, India has the second-largest road network in the world, which includes major district roads, state highways, motorways, national highways, other district roads, and village roads. The last several years have witnessed a steady improvement in India's road infrastructure. Road transport is now the subject of significant development, and connectivity has improved. Roads are giving individuals easier access to services, more mobility, and ease of transportation. The Ministry of Road Transport and Highways (MORTH) has assumed responsibility for constructing high-quality roads and highways throughout the nation in recognition of the significance of a dependable and seamless road network and the role it plays in impacting the nation's economic development.

In addition, sustainability has emerged as a key global development paradigm that has an impact on every facet of society. According to some, sustainable development is a way of using resources that seeks to satisfy human needs while protecting the environment so that these needs can be satisfied for both the present and the future. The term "sustainability" would encompass a variety of concepts, such as the preservation of natural resources for future generations and the sustainability of profits for businesses and the environment. Therefore, it is imperative to find ways to lessen the influence on the environment. Reducing reliance on fossil fuels and recycling garbage from highways are major challenges for the highway sector. The binder, bitumen, which is made from petroleum, is one of the primary ingredients in the asphalt business, a sector with a sustainable environmental impact. The production of bitumen results in massive carbon dioxide emissions, which have a negative influence on the environment.

Commercial modifiers have been added to bitumen to enhance its performance, including fillers, extenders, polymers, fibres, antioxidants, and more. Commercial modifiers may be useful in enhancing bitumen performance, but their application may result in higher asphalt mix costs. Therefore, it is necessary to create substitute low-cost modifiers that can improve bitumen's qualities without

compromising its cost-benefit ratio. As a result, using wastes as bitumen modification modifiers is a far more appealing research goal. India's highway network is growing in length every year as a result of recent social and economic changes. Since many flexible pavements experience various sorts of damage over the course of their service lives, they need various types of maintenance less than 15 years after construction or operation. Additionally, a significant amount of recycled asphalt pavement materials has been produced as a result of highway maintenance. The proper disposal of such waste asphalt pavement concrete is a major cause of pollution in the environment and presents a significant problem to society. Thus, the demand for ways to recycle and reuse this kind of trash is becoming a global focus in terms of environmental and energy conservation as well as the creation of a sustainable ecosystem.

Finding alternatives to bitumen and regenerating old bitumen are important objectives for a sustainable environment in the modern world. In addition to assisting in the safe disposal of asphalt pavement waste, modified bitumen and the regeneration of older bitumen also contribute to the reduction of the use of nonrenewable and limited resources, making them increasingly appealing from an energy and environmental protection standpoint globally. Waste Cooking Oil (WCO) and Waste Engine Oil (WEO) are two examples of the massive amounts of waste oils that are produced in the same world as a result of the advancement of living standards and the car industry. A lot of research has been done to create different kinds of bitumen rejuvenators and modified bitumen. An additional goal of the current research project is to examine and evaluate the effects of using waste cooking oil (WCO) and waste engine oil (WEO) as bitumen rejuvenators and modified bitumen on the characteristics of both aged and modified bitumen. Waste cooking oil (WCO) and waste engine oil (WEO) have been shown to have a molecular structure that is fairly similar to bitumen. As a result, they can be utilised to improve bitumen's qualities and revitalise bitumen that has aged. Old asphalt can be recycled using WCO and WEO as a low viscosity component, according to the compatibility hypothesis of rejuvenation. The usage of WCO and WEO in hot mix asphalt mixtures demonstrated great structural safety because their flash points were higher than 200°C when compared to other low viscosity components. Effectively handling or reusing these materials not only saves energy and lessens pollution in the environment, but it also demonstrates a creative approach to waste recycling. The suggested technique offers an efficient way to rejuvenate ageing asphalt utilising waste oils and may help restore or enhance its qualities. It was therefore realistically significant and would offer WEO and WCO a wide range of application opportunities in the field of asphalt pavement recycling.

OBJECTIVES OF THE RESERCH

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.

II. LITERATURE REVIEW

The viscoelastic qualities of bitumen, a hydrocarbon-based binder, are essential to the functionality of road pavement. The following are essential mechanical parameters: viscosity, ductility (flexibility), softening point (temperature susceptibility), penetration (softness), and ageing resistance. Chemical or physical modification may be necessary because unmodified bitumen, despite its widespread use, may not be resilient to growing traffic and climate stressors.

Shidhi swarupa Nayak et.al (2025) In order to serve society, the project's main goal is to effectively use non-biodegradable plastic for beneficial purposes. Examining the characteristics of bitumen modified with polymers and containing different amounts of polypropylene (between 2% and 8%) is the main goal of the study. The Optimum Binder Content (OBC) and Optimum Plastic Content (OPC) that give the bitumen mix the required strength are found using Marshall Analysis, which guarantees improved performance and sustainability in pavement building.

According to the study's findings, bituminous concrete treated with polypropylene has improved Marshall properties and an ideal plastic concentration of 3.03% by weight, which lowers bitumen consumption and associated building expenses. When polypropylene was added up to 4%, Marshall stability rose while flow values dropped, suggesting greater resistance to deformation. VMA, VA, and VFB were among the parameters that stayed within reasonable bounds, indicating a stable and long-lasting mix appropriate for

flexible pavements. This change not only increases pavement longevity and strength, especially in India's hot and muggy climate, but it also offers a sustainable way to manage non-biodegradable plastic trash by lowering voids, stopping moisture absorption, and enhancing pavement performance in general.

Jisha G S et.al (2024) intended to carry out experimental studies by adding plastic to the bitumen and partially substituting cast iron slag for coarse aggregates to create a better bituminous mixture. The goal is to determine the best mix design that provides the lowest temperature susceptibility and maximum mechanical strength. Furthermore, the research aims to offer a sustainable and efficient way to dispose of plastic trash and make good use of cast iron slag in pavement construction.

While improving pavement strength, performance, and durability, the use of plastic in bituminous pavement construction lowers material costs. Sustainable environmental practices and efficient waste management are facilitated by the incorporation of waste materials. Additionally, there is less cracking in the amended pavement, which results in less maintenance and better long-term performance.

MIX DESIGN

Table 1: Mix Proportion

% of Replacement	Waste Cooking Oil (gm)	Waste Engine Oil (gm)	Weight of Bitumen (gm)
0.5	1.72	1.72	60.72
1	2.18	2.18	59.01
1.5	2.64	2.64	56.83
2	3.1	3.1	54.19
2.5	3.56	3.56	51.09
3	4.02	4.02	47.53
3.5	4.48	4.48	43.51
4	4.94	4.94	38.57
4.5	5.4	5.4	33.17
5	5.86	5.86	27.31

III. RESULTS AND DISCUSSION

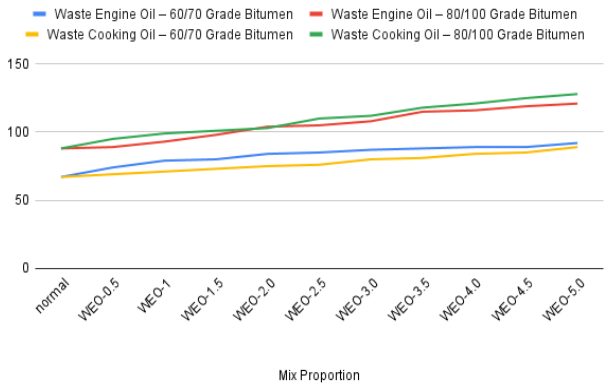

Fig 1: Penetration Value

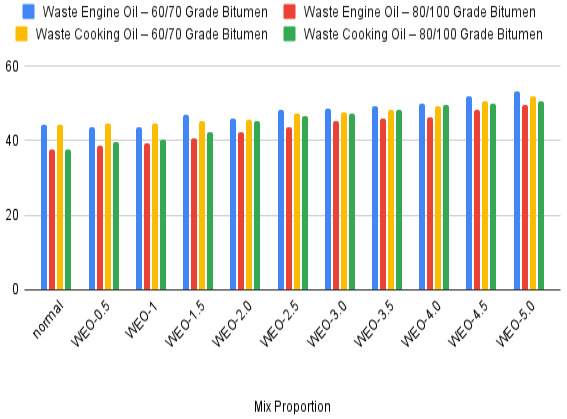

Fig 2: Softening Point

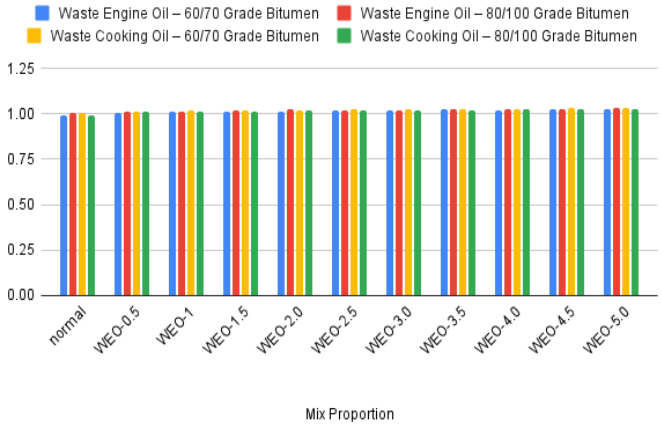

Fig 3: Specific Gravity

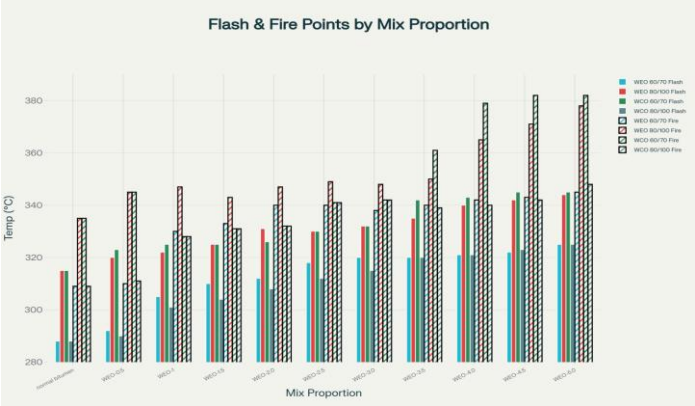

Fig 4: Flash and Fire Point

IV. CONCLUSION

Significant new information regarding the mechanical properties of modified bitumen incorporating waste cooking oil and motor oil is provided by the experimental results. The primary findings are as follows:

- Density: The higher density of modified bitumen, including WEO and WCO, indicates improved strength and durability when compared to traditional bitumen.
- Penetration: The initial penetration value increases in tandem with the overall concentrations of bitumen, waste engine oil, and waste cooking oil. Nevertheless, beyond a certain point, the penetration value usually starts to decrease. A penetration test value of 2% is the ideal one.
- Softening Point: The softening point value first rises and subsequently falls as bitumen, used motor oil, and used cooking oil are added in greater quantities. It is proven that 2% is the ideal number for the softening point test.
- Ductility: The ductility value exhibits an increasing trend when bitumen, used motor oil, and used cooking oil concentrations increase. However, like the penetration and softening stages, it ultimately falls off. It is determined that 2% is the ideal number for the ductility test.
- Specific Gravity: Before beginning to rise, the specific gravity value first decreases as the quantity of bitumen, used motor oil, and used cooking oil increases. We find that the optimal specific gravity value is 2%.
- Flash and Fire Point: Initial increases in flash and fire value are followed by decreases as the total amount of bitumen, waste motor oil, and waste cooking oil is raised. The ideal level for the flash and fire test is found to be 2%.

REFERENCES

[1] Iqra Meerak and Asif Altaf, [Performance of Bitumen Mixes Using E-Waste for Flexible Pavements], International Journal of Innovative Research in Engineering and Management (IJIREM), Volume-10, Issue-4, August, 2023, ISSN https://doi.org/10.55524/ijirem.2023.10.4.22.: 2350-0557.

[2] Pranoti V Pawar and Madhulika Sinha, [Analysis of construction and industrial waste to strengthen flexible pavement], International Advanced Research Journal in Science, Engineering and Technology, Vol. 9, Issue 9, September 2022, ISSN: 2394-1588, DOI: 10.17148/IARJSET.2022.9910.

[3] P Mittal, T Singh, G Kaur and P Mittal, [Design and analysis of bituminous construction mixes for flexible pavement by adding industrial waste], IOP Conf. Series: Earth and Environmental Science 1327 (2024) 012003, doi:10.1088/1755-1315/1327/1/012003.

[4] Balram Singh Yadav and Ankit Kumar, [Use of Waste Material as Filler in Bituminous Mix Design], International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 11 Issue VI Jun 2023, ISSN: 2321-9653.

[5] Sindhu J. Nair, Deepak Chauhan, Sandeep Kumar, Ghanshyam Mandavi, Sanskar Kuldeep and Mukut Mohan Chandra, [MIXING OF HARD PLASTIC WITH BITUMEN FOR FLEXIBLE PAVEMENT DESIGN], International Research Journal of Modernization in Engineering Technology and Science, Volume:05/Issue:04/April-2023, ISSN: 2582-5208.

[6] Jisha G S, A.Abhija S, B.Arabhy Sugunan, C.Ushus U and D. Vaishnavi V, [Study on the Mechanical Properties of Bitumen Plastic Mix Flexible Pavement by Partially Replacing Coarse Aggregate with Cast Iron Slag], INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY, January 2024| IJIRT | Volume 10 Issue 8 | ISSN: 2349-6002.

[7] Mohammed Nayab, Mohammed Shahabuddin, Nazeer Patel, Priyanka Sheshappanava and Shahaji Patil, [Utilization of Industrial Waste in the Construction of Flexible Pavement by Marshall Method], International Journal of Scientific Research and Engineering Development-– Volume 4 Issue 3, May- June 2021, ISSN : 2581-7175.

[8] Anil N. Kawade, Ashwini S. Chalke, Sanchita N. Dawale, Surendra U. Jangam and G.Parulekar, [DESIGN AND QUALITATIVE ANALYSIS OF FLEXIBLE PAVEMENT BY USING WASTE MATERIAL], International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 04 | Apr-2018, ISSN: 2395-0056.

[9] Shidhi swarupa Nayak, Snehal Ramdas Kshirsagar and Sangita Nayak, [EXPERIMENTAL STUDY OF BITUMINOUS CONCRETE MIX BY USING POLYPROPYLENE PLASTIC], International Research Journal of Engineering and Technology (IRJET), Volume: 12 Issue: 07 | Jul 2025, ISSN: 2395-0072.

[10] Abdel-Rahman Megahid, Hassan Younis, Talaat Abdel-Wahed and Eman Abdel-Sabour, [UTILIZATION OF INDUSTRIAL WASTE MATERIAL IN HIGHWAY CONSTRUCTION], Journal of Engineering Sciences Assiut University Faculty of Engineering Vol. 48 No. 3 May 2020 PP. 373–382.

[11] Primož Jeluši˘c, Süleyman Gücek, Bojan Žlender, Cahit Gürer, Rok Varga, Murat V. Taciro˘glu, Burak E. Korkmaz, ¸Sule Yarcı and Borut Macuh, [Potential of Using Waste Materials in Flexible Pavement Structures Identified by Optimization Design Approach], Sustainability 2023, 15, 13141. https://doi.org/10.3390/su151713141.

[12] Rajneesh Kumar and Maaz Allah Khan, [Use of Plastic Waste Along with Bitumen in Construction of Flexible Pavements], International Journal of Engineering Research & Technology (IJERT), Vol. 9 Issue 03, March-2020, ISSN: 2278-0181.

[13] OYEDEPO J. Olugbenga, [UTILIZATION OF INDUSTRIAL WASTE PRODUCTS IN THE PRODUCTION OF ASPHALT CONCRETE FOR ROAD CONSTRUCTION], Slovak Journal of Civil Engineering, Vol. 27, 2019, No. 4, 11 – 17 DOI: 10.2478/sjce-2019-0026.

[14] Bhadane Rupesh Umrao, [Use of waste plastic and crumb rubber in construction of flexible pavement], International Journal of Advance Research, Ideas and Innovations in Technology, Volume 5, Issue 2, ISSN: 2454-132X, 2019.

[15] Sonia Deshmukh, Rajshekhar Rathod and Bhagyashree Rathod, [Experimental Analysis of Flexible Pavement Structure Using Waste Plastic], International Journal of Research in Engineering, Science and Management Volume 4, Issue 9, September 2021, ISSN: 2581-5792.

[16] Subhajit Dutta, Sabyasachi Nandi, Biswapriya Bandyopadhyay and Anupam Kumar Biswas, [OPTIMAL UTILIZATION OF PLASTIC WASTE AS A BITUMEN SUBSTITUTE IN FLEXIBLE PAVEMENT: AN EXPERIMENTAL STUDY], International Journal of Creative Research Thoughts (IJCRT), Volume 12, Issue 6 June 2024 | ISSN: 2320-2882.

[17] Shailendra Singh Gurjar, Vipul Sharma, Sanjeev Barar, Kuldeep Dohare and Kuldeep Pathak, [Comparative Analysis of Bitumen Content in Flexible Pavements of Sub-tropical Climate Zone of India], International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 8 Issue VI June 2020, ISSN: 2321-9653.

[18] Md Shah Azam, Rachana Verma, Anuj Kumar Sharma and Mukesh Kumar, [CONSTRUCTION OF HIGHWAY USING INDUSTRIAL WASTE], International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 07 | July 2020, ISSN: 2395-0072.