iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Influence of Waste Materials on the Performance and Durability of Bituminous Mixes

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Abstract: In the present scenario, roads play a crucial role in enhancing connectivity between urban and rural areas, linking them to national and state highways. However, the high cost of road construction remains a significant challenge. To address this issue, it is essential to explore alternative materials that can replace conventional ones, thereby reducing costs without compromising structural integrity and performance. India has the second-largest road network globally, after China, and is also among the top waste-producing countries. Therefore, utilizing waste materials in flexible pavement construction presents a cost-effective and sustainable approach.

Several studies worldwide have investigated the potential use of various waste materials, such as plastic waste (polythene, PET bottles, plastic bags, and wrappers), waste tire rubber, granite sludge, and waste engine oil, in bituminous mixes. Research findings indicate that incorporating waste materials in flexible pavements can enhance durability, improve resistance to rutting and moisture damage, and reduce environmental pollution. Previous studies suggest that up to 30% waste material can be used without compromising essential pavement properties. Particularly in rural areas, integrating waste-based materials into road construction can significantly lower costs while promoting better infrastructure development. In the current context of sustainable development, adopting waste materials in pavement construction aligns with environmental and economic objectives, making it a viable solution for future road networks.

Keywords: Flexible pavement, Waste Plastic, Crumb Rubber Modified Bitumen (CRMB), Waste Engine Oil, Sustainable Road Construction.

I. INTRODUCTION

With the continuous rise in population and the increased use of plastic polymers and automobiles, waste accumulation and pollution have become significant environmental concerns. These non-degradable materials persist for centuries, highlighting the urgent need for effective disposal methods. Recycling and repurposing waste into useful applications, such as road construction, offer a sustainable solution. Recent research and successful initiatives by private firms and highway agencies have shown that incorporating waste polymers in pavements not only addresses disposal issues but also improves performance and cost-efficiency. This has opened new avenues for innovative and eco-friendly construction practices.

II. LITERATURE REVIEW

Shaikh et al. (2017) conducted a study on the Use of Plastic Waste in Road Construction. The materials used in the study were bitumen 60/70, aggregates, cement, and shredded plastic waste of 2.36 mm size. Marshall Stability test was performed on both the modified and unmodified bituminous mix. On aggregate the tests performed were aggregate impact value, los angeles abrasion test, water absorption test, specific gravity test, stripping value test. On bitumen the tests performed were penetration value test, ductility test, flashpoint test, fire point test, Softening point test. Marshall Stability test was then performed by adding plastic waste. The specific gravity increased from 2.5 to 2.66 and 2.77 on the addition of 10% and 15% plastic content respectively. Aggregate impact value decreased from 10.79% to 8.94% on addition of 15% plastic. Los Angeles abrasion value declined from 12.85% to 10.65% on addition of 15% plastic waste. Water absorption value decreased to 1.1% at the plastic waste of 15% and stripping value was decreased to nil by adding 15% plastic waste. On addition of 15%, plastic waste by wt. of bitumen the Marshall Stability value increased from 950kg to 1980kg, and the flow value increased from 3.1mm to 5mm at plastic waste of15% by wt. of bitumen.

Thus, the study conducted that modified mix improved the Marshall characteristics. With the addition of plastic waste Marshall Stability value increased, flow value decreased, thus it could withstand heavy loads, hence, increasing the durability of roads and also preserving the environment.

Vashisht and Saini (2017) utilized waste plastic and CRMB in the flexible pavement. In this study, the wet and dry process was adopted for preparing the modified bitumen. Samples were prepared according to the ministry of road transport and highway (MORT&H) specification. In the wet process, first bitumen was heated at the temperature of 160°C and temperature was recorded at the time of softening of material. Later, waste material was added in the mix for avoiding agglomeration in the material. In this % of modified agent vary from 1% to 16 %. In the dry process, it was only done with plastic waste by cutting it into small size of around 3mm-6mm and mixed with the aggregate at the temperature of 165°C. On the other hand, bitumen was heated at a temperature of 160°C for having good binding strength. After that sample was made with 8% of plastic waste and 16% of plastic waste. In the present study, CRMB was not utilized in order to make the sample because of the poor bonding quality (i.e. b/w CRMB and aggregates).

As per the result, impact value was found to be increased up to 10% due to the addition of plastic waste (i.e. worked as a coating material for aggregate). The specific gravity of plain and modified aggregates was found to be same while penetration value and ductility value of modified bitumen was lower than the conventional one.

Kawade et al. (2018) investigated a study on design and qualitative analysis of flexible pavement containing waste materials. The waste materials utilised in this study as the replacement of natural aggregates were namely crushed stone, steel slag, recycled concrete and CRMB (by cutting waste rubber tires in pieces that could pass through 2.36 mm sieve and were retained on 1.18mm sieve. Marshall Stability test was performed for each type of mixes containing different waste material as the replacement of aggregates and VG-30 bitumen mix. In the case of steel slag, the impact value and crushing value was found to be around 9.33% and 15.42% respectively which is appropriate for highways construction as per to Indian road congress (IRC). While impact value and crushing value of recycled concrete aggregate was 24.69% and 31.47% respectively which are not as per the IRC's specifications? Marshall Stability and the flow value of mix containing steel slag were found to be 990.6kg and 2.1mm respectively, which satisfies the IRC's guidelines.

Sharma et al. (2018) examined the performance of bituminous paving mix containing waste plastic. The material used was crushed basalt type of course aggregate 20 mm, crushed basalt type of fine aggregate 2.36 and down,80/100 penetration grade bitumen, basalt stone dust, and cement as a mineral filler. While the waste plastics namely polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), low-density polyethylene (LDPE), high-density polyethylene (HDPE) was used in the shredded form. Marshall Stability test was carried out with varying % of plastic waste in order to check the stability of the mix. Later, a comparison b/w the results of BC (Bituminous concrete) mix with waste plastic and plain BC mix was made. Consequently, the stability value of optimum plastic content OPC (optimum plastic content) was found to be 30.1, which was much higher than the optimum bitumen content OBC (optimum bitumen content). The volume of voids in BC mix containing plastic waste was found lower than the plain BC mix. These results were within the parameters of MORT&H-2001 specifications.

The test concluded that the OPC mix showed higher stability as compared to OBC mix and intermolecular binding b/w bitumen and waste plastic enhances the strength, durability, and life of roads.

Sarma and Srikanth (2018) utilised waste polythene in the bituminous paving mix design. The materials used in the study were bitumen, aggregate and waste plastic. Marshall Stability test was performed and carried out in two parts to determine optimum bitumen content (OBC) and optimum plastic content (OPC). Different samples were made with different ratio of bitumen, aggregates, and plastic. After that test was conducted at the temperature of 60°c to check the OBC which was found to be 5.8%. Later, disposed milk packets were used to determine OPC. The specific gravity and softening point were taken from the report of milk packets manufacturer and report specified the specific gravity and softening point value around 0.92 and 115°C respectively. So according to the result, the value for plastic content corresponding to maximum stability was equal to 10%. The value of binder content corresponding to maximum bulk specific gravity was found to be equal to 7.5%. Average of the above values came out to be 8.75%.

The results from the test stated that, the OBC was 5.8% and the OPC was concluded to be 8.75%. Thus, it was concluded that addition of plastic waste material content in bitumen increases the stability as comparison to conventional bituminous mix.

Anand & Raju (2024) conducted a study on the utilization of waste plastic in bituminous concrete mix for road construction. They examined the mechanical properties of bituminous mix modified with two different plastic wastes (thickness more than 40 microns and less than 40 microns) using the dry process. The study evaluated parameters such as Marshall Stability, Flow, Indirect Tensile Strength (ITS), and Retained Stability. Their findings revealed that waste plastic-modified bituminous mixes performed better than conventional mixes, exhibiting improved abrasion value, crushing strength, impact value, and water absorption resistance. The research also emphasized the economic and environmental benefits of utilizing locally available aggregates and reducing plastic waste through road construction.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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The study concluded that replacing base bitumen with **waste plastic** is **both economical and environmentally friendly.**
Garg & Duggal (2024) investigated the use of waste plastic in bituminous mixes to enhance pavement durability and resistance to moisture damage. The study highlights that while waste plastic improves anti-stripping properties; its widespread adoption faces challenges such as financial constraints, technological limitations in hot mix plants, and inconsistent supply of high-quality waste plastic. They identified key obstacles, including high initial costs, lack of awareness, and difficulties in integrating plastic into current production processes. The authors emphasized that overcoming these barriers requires supportive regulations, technological advancements, and improved supply chain mechanisms to facilitate broader use of waste plastic in road construction.
Chaturvedi et al. (2025) conducted a laboratory investigation on the modification of bituminous mix design using plastic waste and crumb rubber. The study aimed to evaluate the mechanical properties of Stone Mastic Asphalt (SMA) mixes by incorporating plastic waste (PET bottles) and crumb rubber as modifiers. The experimental analysis included Marshall Stability, flow value, voids in mineral aggregates (VMA), and indirect tensile strength (ITS). The results indicated that the optimum plastic waste content was 6.3%, which provided higher stability, improved fatigue life, and enhanced rutting resistance compared to conventional bituminous mixes. The study concluded that modifying SMA with plastic waste and rubber can enhance pavement durability while promoting sustainable road construction practices.

A. Research Objectives
1) Minimising the use of bitumen by partially replacing the bitumen with waste material like waste LDPE, HDPE, CRMB, motor oil, steel slag.
2) Utilization of waste material in pavement construction to create sustainable environment, cost effectiveness without compromising with the requisite properties.
3) Minimising greenhouse emission and landfill scarcity.

III. METHODOLOGY

A. Methodology Flow Chart

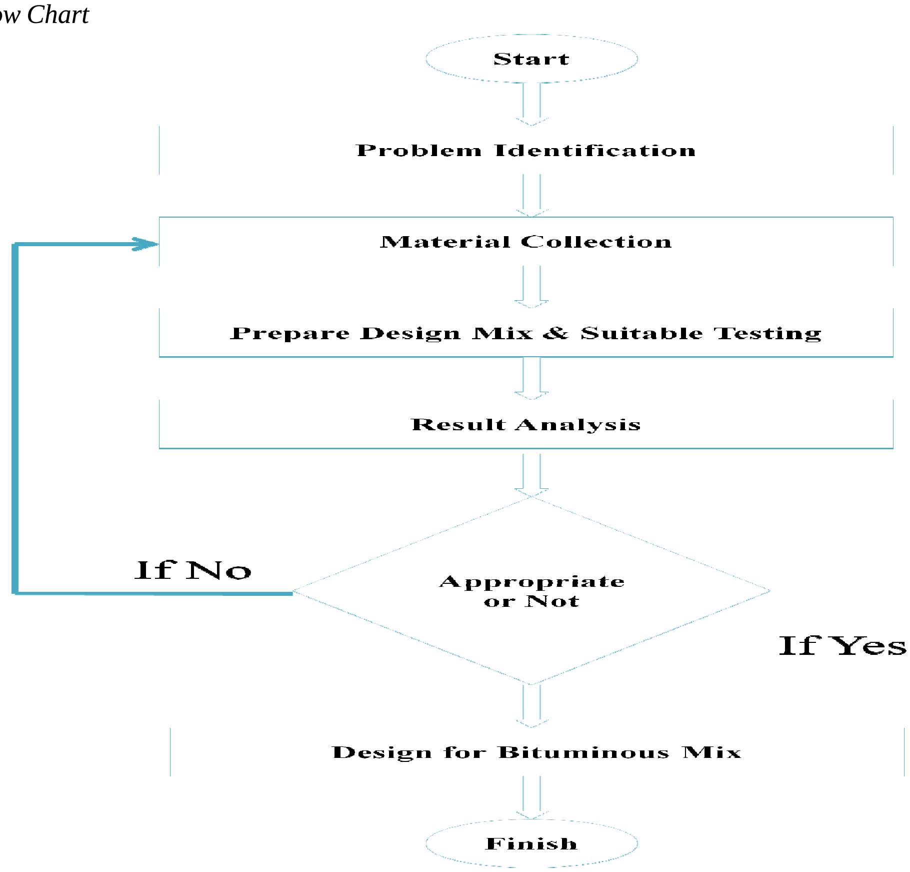

Figure 3.1:- Methodology Flow Chart

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B. Selection of Material

In this study, VG10 or 80/100 penetration grade bitumen was chosen along with various waste materials, including LDPE, HDPE, CRMB, and engine oil, for the testing process. Different samples were prepared with varying compositions. The selection of waste materials was based on their chemical compositions, which are elaborated in the next subsection of this chapter.

Table 3.1 Chemical Composition of Bitumen (Raha Bitumen Co.)

Chemical Elements	Elements Range	Unit
Carbon	80.2-84.3	%
Nitrogen	0.2-1.2	%
Hydrogen	9.7-10.7	%
Sulphur	0.8-6.8	%
Oxygen	0.5-1.1	%
Nickel	11-137	Ppm
Vanadium	8-1595	Ppm
Iron	6-149	Ppm
Manganese	0.1-3.8	Ppm
Calcium	1-335	Ppm
Magnesium	1-134	Ppm
Sodium	6-157	ppm

Table 3.2 Chemical Composition of Polyethylene (CHEMIK 2013, 67, 5, 435?445)

Chemical Elements	Elements %
Carbon	81.90
Nitrogen	0.45
Hydrogen	12.38
Sulphur	1.94
Oxygen	0.0
Calcium	0.98

Table 3.3 Chemical Composition of Waste Engine Oil (Ikhajiagbe, et.al P.,2024)

Chemical Elements	Weight (mg/kg)
Iron	3253.65
Manganese	12.36
Zinc	54.13
Copper	33.53
Chromium	23.23
Lead	12.45
Nickel	11.84
Vanadium	8.21
Cadmium	24.85

Table 3.4 Physical Composition of CRMB (Behnia, A et.al ., 2017.)

Elements	Elements %
Acetone	9.3
Ash Cement	8.5
Carbon	28.1
Rubber Hydro Carbon	50.2
Heat Loss	0.9
Metal Content	0.8
Fibre Content	1.5

Table 3.5 Chemical Composition of CRMB (Donga et.al., 2016.)

Elements	Elements %	Unit
Carbon	87.53	%
Oxygen	9.25	%
Zinc	1.75	%
Sulphur	1.07	%
Silicon	0.21	%
Manganese	0.13	%
Aluminum	0.09	%

C. Waste Production in India

Various studies and reports indicate that India generates significant amounts of waste materials, many of which can be effectively utilized in road construction. According to a report by FICCI, India produces approximately 3.5 million tonnes of plastic waste annually, with a large portion originating from household sources such as plastic bags, bottles, and packaging materials. Most of this waste consists of single-use plastics, which are difficult to decompose without recycling. These plastic wastes contribute significantly to environmental pollution, affecting both land and marine ecosystems. However, innovative approaches, such as their use in road construction, have shown promising results. The National Rural Road Development Agency reported that in 2016, **7,**600 km of roads were built using waste plastic, demonstrating the feasibility of this method.

Additionally, India is one of the largest producers of waste tyres. According to research by Lalatendu Mishra, around 1.5 billion tyres are manufactured globally each year, with an almost equal number being discarded. In India, approximately **6-7%** of the world's total waste tyres are generated annually. Despite efforts to recycle tyres over the last three decades, only **8-10%** of discarded tyres are recycled, while 10-12**%** are incinerated for fuel. A significant **70% or more** end up in illegal dumping sites and landfills, leading to serious environmental hazards. The incorporation of waste tyres in road construction can effectively address landfill shortages and provide an eco-friendly alternative to disposal.

In addition to plastic and rubber waste, a substantial quantity of waste engine oil is generated by vehicles across the country. Although numerous waste oil recycling plants operate in India, they are only capable of recycling up to 50-55**%** of the total waste oil produced. The remaining 45-50% is often discarded, leading to environmental contamination. Research suggests that blending processed waste oil with bituminous mixtures can enhance road durability while simultaneously reducing construction costs. This method presents a sustainable and economically viable solution for managing waste oil.

1) Plastic Waste: According to a study by the University of Leeds published in September 2024, India leads globally in plastic waste generation, producing approximately 10.2 million tonnes annually. This figure has more than doubled compared to previous estimates, highlighting a significant increase in plastic consumption and disposal. The majority of this waste originates from household items such as plastic bags, bottles, and packaging materials, predominantly single-use plastics that are challenging to decompose without recycling. These plastics contribute extensively to environmental pollution, affecting both terrestrial and marine ecosystems. Innovative approaches, like incorporating plastic waste into road construction, have demonstrated potential in mitigating this issue. For instance, in 2016, the National Rural Road Development Agency reported constructing 7,600 km of roads using waste plastic, showcasing the feasibility of this method.

2) Waste Tyres: India's tyre industry has experienced significant growth, leading to increased production of waste tyres. While exact figures for waste tyre generation are not specified in the available sources, the global production of tyres and subsequent waste has been substantial. For example, a recent report highlighted that human’s discard millions of tyres daily, contributing to environmental challenges. Incorporating waste tyres into road construction can effectively address landfill shortages and provide an eco-friendly alternative to disposal. However, specific data on the recycling rates and utilization of waste tyres in India remain limited.
3) Waste Engine Oil: The generation of waste engine oil in India has been on the rise due to the increasing number of vehicles. Although numerous waste oil recycling plants operate across the country, they can only recycle up to 50-55% of the total waste oil produced. The remaining 45-50% is often discarded improperly, leading to environmental contamination. Research suggests that blending processed waste oil with bituminous mixtures can enhance road durability while simultaneously reducing construction costs. This method presents a sustainable and economically viable solution for managing waste oil.

By effectively utilizing plastic waste, waste tyres, and waste engine oil in road construction, India can significantly reduce landfill accumulation, lower pollution levels, and promote sustainable infrastructure development.

D. Methods for Testing Samples or Construction of Roads

1) Dry Process
2) Wet Process

Dry Process: In dry process aggregates are heated up at particular temperature and shredded pieces or liquid of waste material added in hot aggregates chamber for giving them glossy look when covers the aggregates then bitumen will add to the hot aggregates for making bituminous mix. Generally, this process is use for constructing of roads.

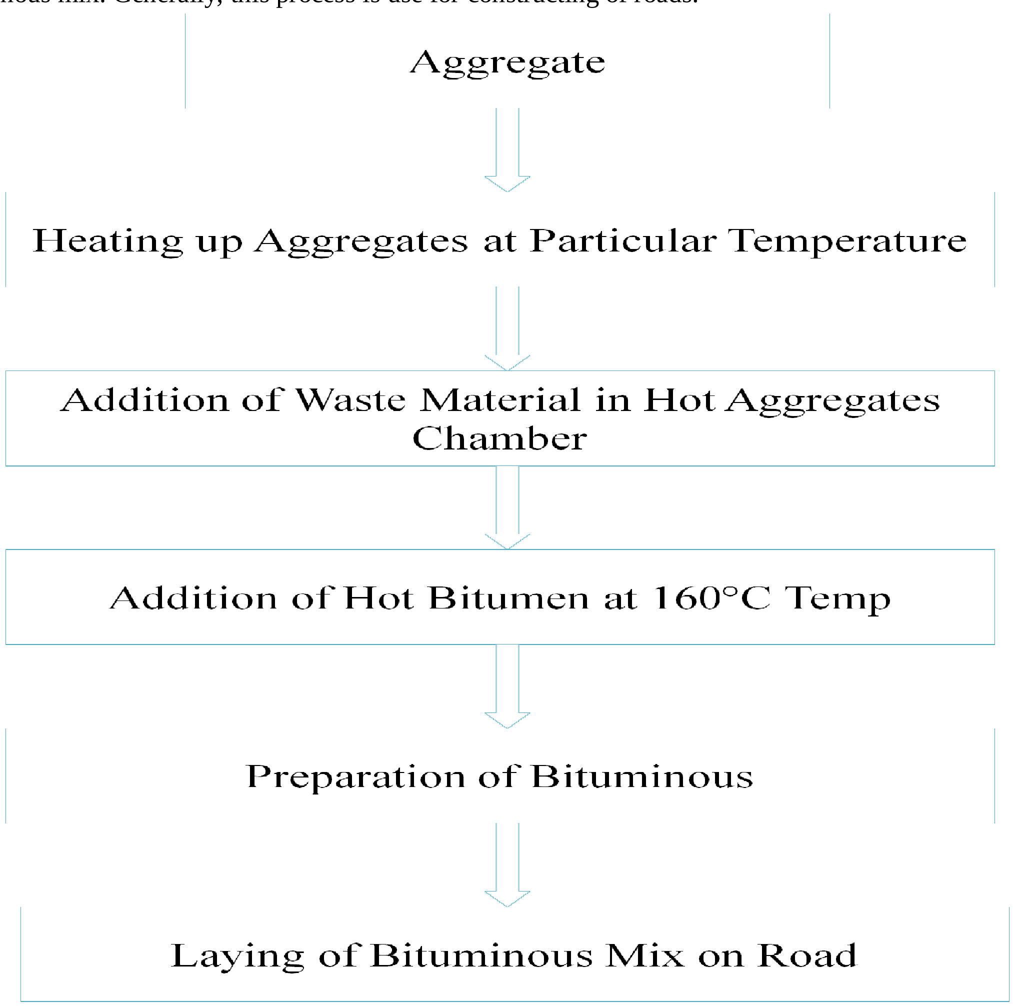

Figure 3.2:- Flow Chart of Dry Process

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Wet Process: In this process bitumen is heat up at around 160°C and shredded pieces of waste material is added in hot bitumen for mixing waste with bitumen after that aggregates added in bitumen mix with aggregates. Generally, this process of construction of road is rarely use.

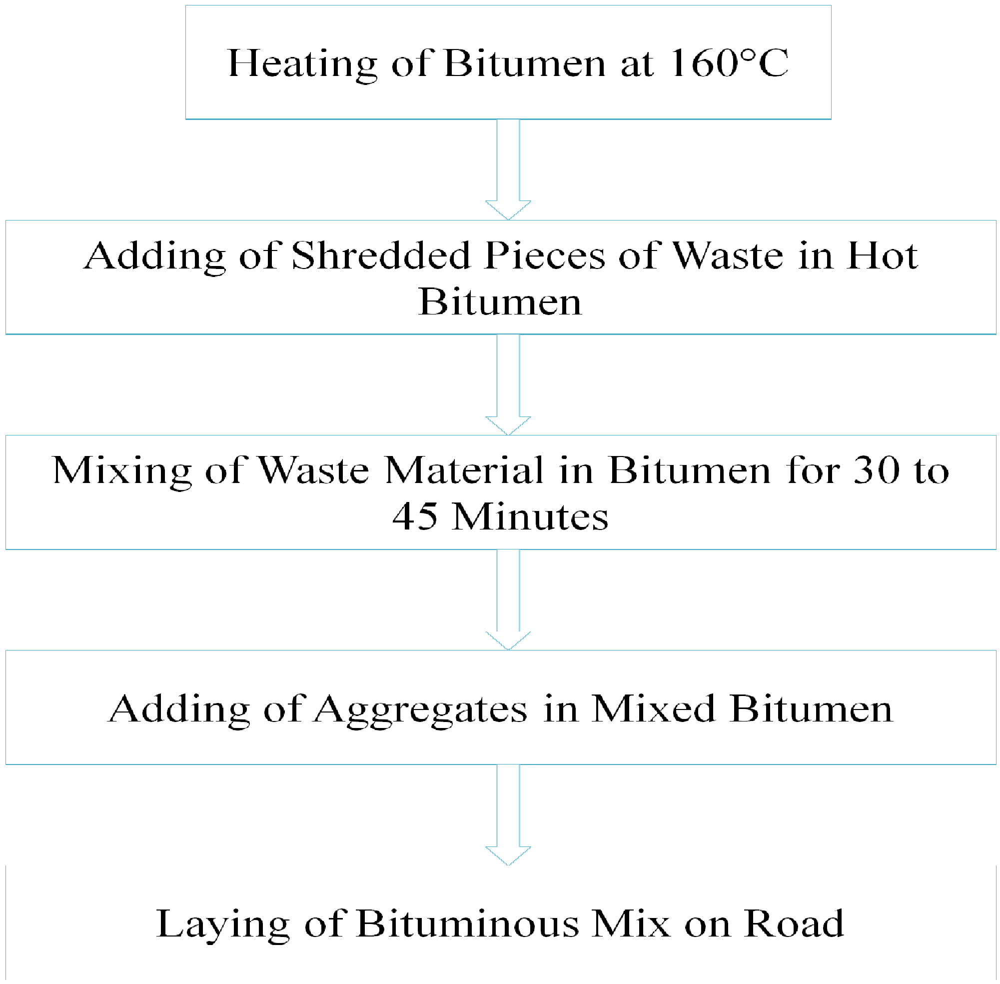

Figure 3.3:- Flow Chart of Wet Process

E. Test Conducted on Bitumen with Different Waste by Using Wet Process

1) Penetration Test (IS 1203:1978):- The device penetrometer is used to assess bitumen penetration. It is accomplished by adhering to the correct IS 1203 guidelines. A penetration test is used to determine the bituminous mix's consistency or hardness. Bitumen comes in various grades, each with a unique penetration value. For example, 80/100 penetration grade indicates that the penetration value is between 80 and 100. The penetration test is conducted under specific load, duration, and temperature conditions, and the results are reported in millimeters (mm).
2) Ductility Test (IS 1208:1978):- The ductility test is used to gauge bitumen's strength. It is carried out to determine bitumen's stretching capacity. A crucial component of road building is ductility. Road cracks may occur if bitumen's stretching capacity is reduced because bituminous material is weaker. The sample is tested at a specific speed and temperature, and the ductility test result is expressed in centimeters. The ductility test is conducted in accordance with IS 1208.
3) Softening Point Test (IS 1205:1978):- The purpose of the softening point test is to determine the bitumen's softening temperature. It is completed by according to IS 1205. The ring and ball device is used to perform the softening point test. When the sample can no longer hold the weight of the ball and comes into contact with the steel plate, the softening point is recorded.
4) Specific Gravity Test (IS 1202:1978):- Specific gravity test of bitumen may define as the ratio of mass of specific volume of bituminous material at specific temperature which is equal to volume of water at same temperature. It is done by using density bottle and by following IS 1202.

F. Material Used for Sample Preparation

The following samples were created: 0%, 2%, 4%, 6%, 8%, and 10% engine oil; 0%, 2%, 5%, 8%, and 10% CRMB powder; 0%, 2%, 5%, 7%, and 9% LDPE waste. With VG 10 or 80/100 bitumen grade, HDPE waste and a mixture of 2% LDPE + 3% HDPE + 4% engine oil, 3% HDPE + 4% engine oil + 5% CRMB powder, 4% engine oil + 5% CRMB powder + 2% LDPE, and 5% CRMB powder + 2% LDPE + 3% HDPE were tested separately to compare the results.

Figure 3.4:-Shredded Pieces of Waste LDPE

G. Sample Preparation

In order to conduct several experiments, a wet technique was used. In order to melt the bitumen, it was first heated on a hot plate. A few minutes later, it was heated to 160°C on an induction plate. After the bitumen began to boil, shredded waste material was added and stirred for half an hour. After all of the mixing was finished, bitumen was added to a separate mold so that various testing could be conducted. The mold was then allowed to cool for half an hour before being placed in a water bath chamber set at 25°C for an hour. Various tests, including those for bitumen penetration, specific gravity, softening point, and ductility, were then conducted after an hour.

IV. RESULT ANALYSIS

A. General

The results of several tests that were performed on bitumen using various waste compositions, such as LDPE, CRMB, and waste engine oil gas, are analyzed in this chapter to determine the best value for bitumen replacement.

1) Testing of Bitumen with Waste LDPE

a) Penetration Test Result of Bituminous Mix with Waste LDPE

Penetration test carried out by following proper guideline of IS code IS 1203 with different sample of bitumen with 0%, 3%, 6%, and 9% LDPE.

Table 4.1 Penetration Test Result of Bitumen with Waste LDPE

Samples with Different Compositions	Test Result
0%	80
3%	45
6%	60
9%	85
12%	70

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Figure 4.1:-Penetrometer

Figure 4.2:-Sample for Penetration Test

B. Testing of Bitumen with Mixed Composition of Waste HDPE, LDPE, Engine Oil and CRMB Powder

1) Penetration test result of bitumen with waste HDPE, LDPE, Engine oil and CRMB powder.

Penetration test carried out by following proper guideline of IS code IS 1203 by making different sample of bitumen by making four samples mixed composition of different waste content with VG10 bitumen. Samples were made with 2% LDPE + 3% HDPE + 4% Engine oil, 3% HDPE + 4% Engine oil + 5% CRMB powder, 4% Engine oil + 5% CRMB powder + 2% LDPE and 5% CRMB powder + 2% LDPE + 3% HDPE.

Table 4.21 Penetration Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Sample with Different Compositions	Test Result
0%	80
2 % LDPE + 3 % HDPE + 4% Engine Oil	80
3 % HDPE + 4% Engine Oil + 5 % CRMB Powder	89
4% Engine Oil + 5 % CRMB Powder + 2 % LDPE	85
5 % CRMB Powder + 2 % LDPE + 3 % HDPE	82

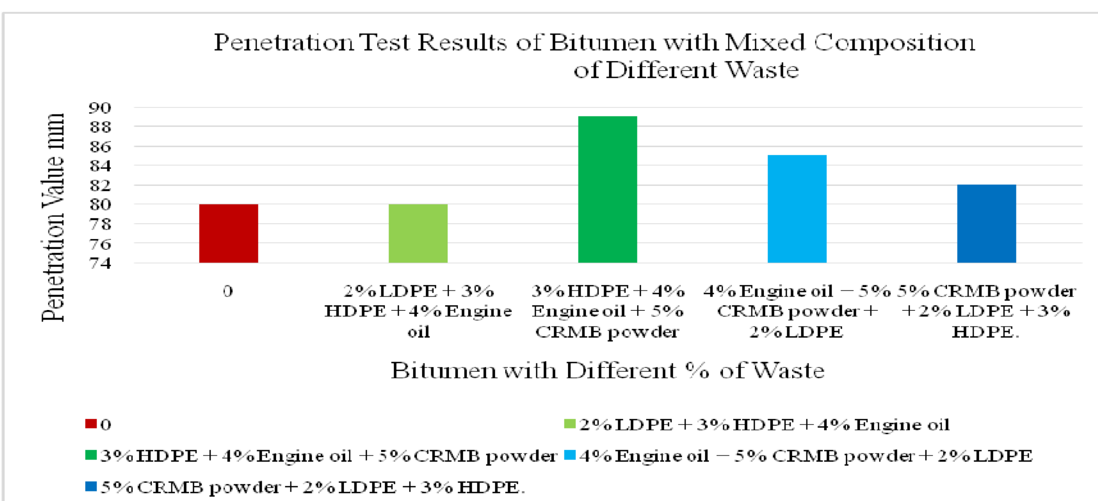

Figure 4.25:- Penetration Test Results Graph of Bitumen with Mixed Composition of Different Waste

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The Penetration test which was conducted by using penetrometer shows that, samples having 3% HDPE + 4% Engine oil + 5% CRMB powder is having maximum penetration value.

2) Softening Point Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Softening point test was conducted with different samples with mixed composition of different waste content with VG10 bitumen. Samples were made with 2% LDPE + 3% HDPE + 4% Engine oil, 3% HDPE + 4% Engine oil + 5% CRMB powder, 4% Engine oil + 5% CRMB powder + 2% LDPE and 5% CRMB powder + 2% LDPE + 3% HDPE

Table 4.22 Softening Point Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder.

Sample with Different Compositions	Test Result
0%	46^0 C
2 % LDPE + 3 % HDPE + 4% Engine Oil	47^0 C
3 % HDPE + 4% Engine Oil + 5 % CRMB Powder	42^0 C
4% Engine Oil + 5 % CRMB Powder + 2 % LDPE	45^0 C
5 % CRMB Powder + 2 % LDPE + 3 % HDPE	48^0 C

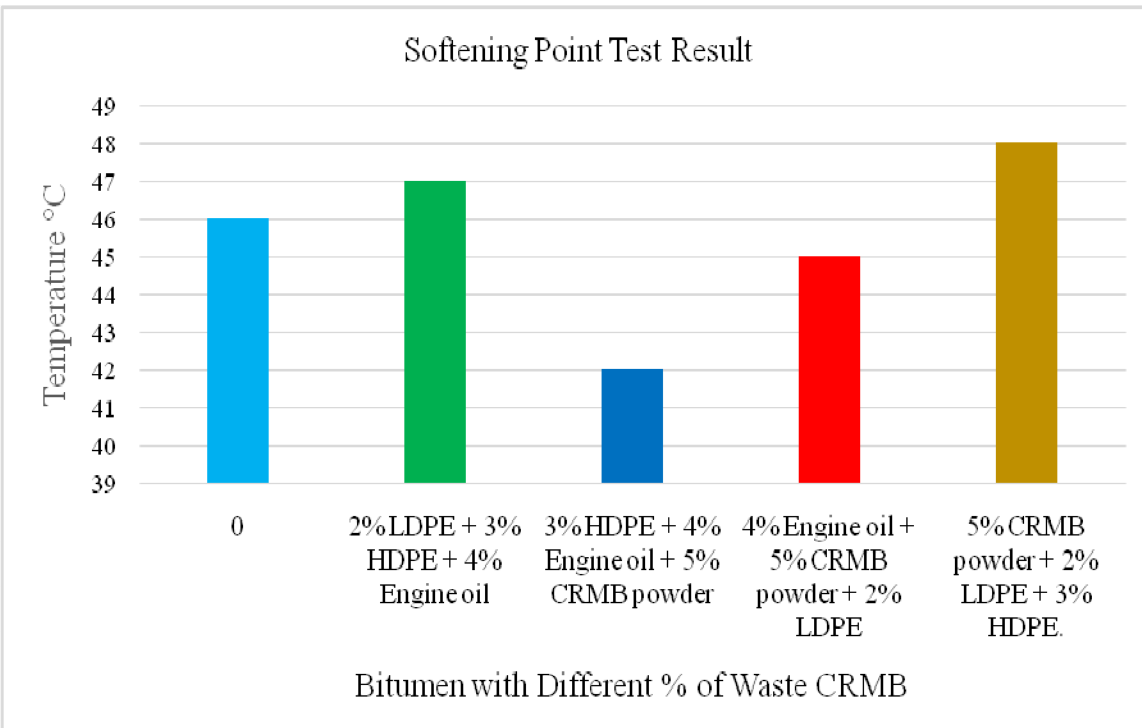

Figure:-4.26 Softening Point Test Result Graph

In softening point test result, the test was conducted with four different sample made with different composition and On the basis of result, sample having 5% CRMB powder + 2% LDPE + 3% HDPE shoes maximum softening point value.

3) Ductility Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Ductility test was done with proper guideline of IS 1208, by making different samples with mixed composition of different waste content with VG10 bitumen. Samples were made with 2% LDPE + 3% HDPE + 4% Engine oil, 3% HDPE + 4% Engine oil + 5% CRMB powder, 4% Engine oil + 5% CRMB powder + 2% LDPE and 5% CRMB powder + 2% LDPE + 3% HDPE.

Table 4.23 Ductility Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Sample with Different Compositions	Test Result
0%	75 cm
2 % LDPE + 3 % HDPE + 4% Engine Oil	72 cm
3 % HDPE + 4% Engine Oil + 5 % CRMB Powder	87 cm
4% Engine Oil + 5 % CRMB Powder + 2 % LDPE	82 cm
5 % CRMB Powder + 2 % LDPE + 3 % HDPE	79 cm

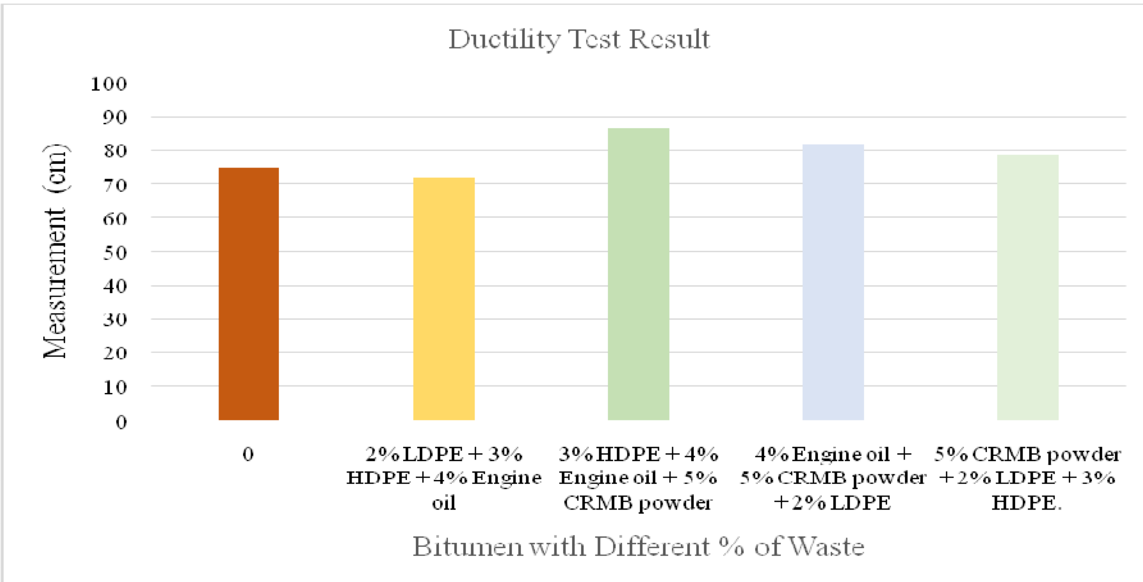

Figure 4.27:- Ductility Test Graph of Bitumen with Mixed Composition

In ductility test result, the test was conducted with four different sample made with different composition and On the basis of result, sample having 3% HDPE + 4% Engine oil + 5% CRMB powder shoes maximum ductility value.

4) Specific Gravity Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder.

Specific gravity test result was conducted by two different specific gravity bottles of different size for different samples with mixed composition of different waste content with VG10 bitumen. Samples were made with 2% LDPE + 3% HDPE + 4% Engine oil, 3% HDPE + 4% Engine oil + 5% CRMB powder, 4% Engine oil + 5% CRMB powder + 2% LDPE and 5% CRMB powder + 2% LDPE + 3% HDPE.

Table 4.24 Specific Gravity Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Sample with Engine Oil Waste	Weight of Empty Bottle	Weight of Bottle with distilled Water	Weight of Bottle with Half-distilled Bitumen	Weight of Bottle with Bitumen and distilled water	Specific Gravity Calculation
0%	55 gm	114 gm	80 gm	115 gm	1.03
2 % LDPE + 3 % HDPE + 4% Engine Oil	48 gm	98 gm	59 gm	99 gm	1.1

3 % HDPE + 4% Engine Oil + 5 % CRMB Powder	31 gm	85 gm	64 gm	89 gm	1.06
4% Engine Oil + 5 % CRMB Powder + 2 % LDPE	43 gm	94 gm	77 gm	95 gm	1.03
5 % CRMB Powder + 2 % LDPE + 3 % HDPE	57 gm	112 gm	83 gm	111 gm	0.96

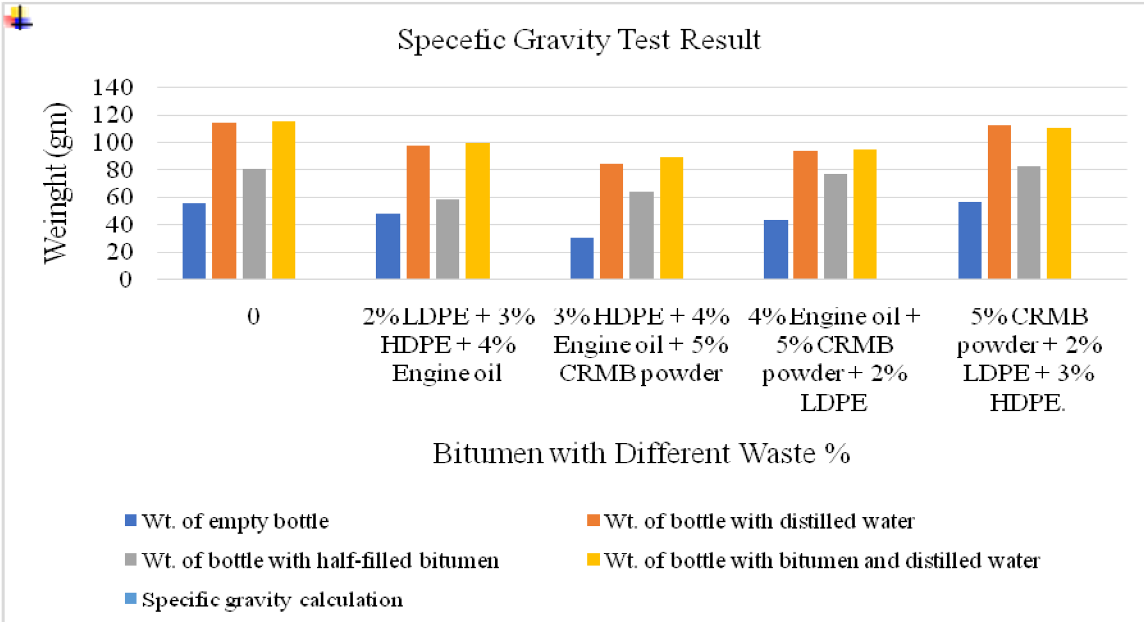

Figure 4.28:- Specific Gravity Test Graph of Bitumen with Mixed Composition

In specific gravity test, test was conducted with different size of bottles and different samples of modified bitumen and result of all samples were almost same.

5) Marshall Stability Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder.

Marshall Stability test result was conducted by making sample of bitumen with different samples with mixed composition of different waste content with VG10 bitumen. Samples were made with 2% LDPE + 3% HDPE + 4% Engine oil, 3% HDPE + 4% Engine oil + 5% CRMB powder, 4% Engine oil + 5% CRMB powder + 2% LDPE and 5% CRMB powder + 2% LDPE + 3% HDPE.

Table 4.25 Marshall Stability Test Result of Bitumen with Waste HDPE, LDPE, Engine Oil and CRMB Powder

Bitumen Content in %	Stability of Conventional mix 0% (KN)	Stability of mix having 2 % LDPE + 3 % HDPE + 4% Engine Oil	Stability of mix having 3 % HDPE + 4% Engine Oil + 5 % CRMB Powder	Stability of mix having 4% Engine Oil + 5 % CRMB Powder + 2 % LDPE	Stability of mix having 5 % CRMB Powder + 2 % LDPE + 3 % HDPE
3	5.4	5.9	6.3	6.7	6.5
4	7.1	7.3	7.1	7.5	6.9
5	6.2	6.4	6.7	6.5	7.1

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

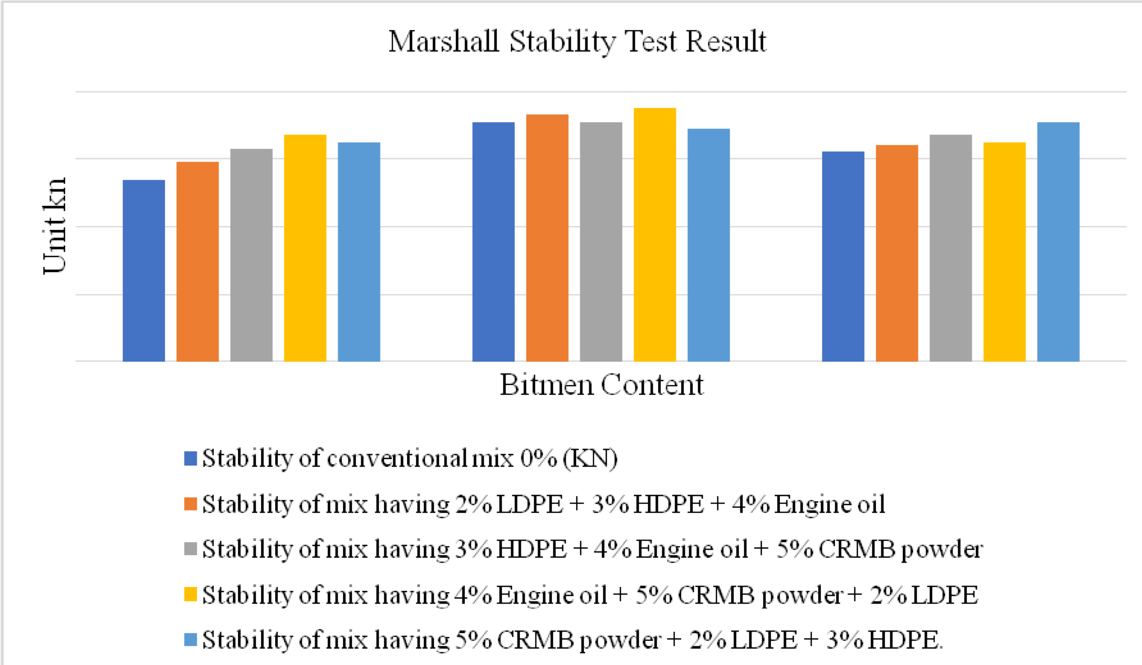

Fig. 4.29 Marshall Stability Test Result Graph of Mixed Composition with Bitumen

Marshall stability test was conducted with four different sample of mixed composition and according to the result, sample having Stability of mix having 4% Engine oil + 5% CRMB powder + 2% LDPE waste is showing maximum stability value.

V. DISCUSSION AND CONCLUSION

A. General

In this study, different waste materials namely LDPE, HDPE, CRMB powder, and waste engine oil-were partially substituted for bitumen in varying proportions, as elaborated in Chapter 3. A series of samples were prepared using VG10 grade (or 80/100 grade) bitumen with varying compositions of these waste additives. The selection of waste materials was guided by their chemical characteristics in accordance with Indian Standard specifications. LDPE was incorporated at 0%, 3%, 6%, and 9%; waste engine oil at 0%, 2%, 4%, 6%, 8%, and 10%; CRMB powder at 0%, 2%, 5%, 8%, and 10%; and HDPE at 0%, 2%, 5%, 7%, and 9%. In addition, composite mixtures were prepared using combinations such as 2% LDPE + 3% HDPE + 4% engine oil; 3% HDPE + 4% engine oil + 5% CRMB powder; 4% engine oil + 5% CRMB powder + 2% LDPE; and 5% CRMB powder + 2% LDPE + 3% HDPE, all blended with VG10 or 80/100 grade bitumen.

B. Discussion and Conclusion

In this study, bitumen was modified using various waste materials including LDPE, HDPE, CRMB powder, and waste engine oil. The results revealed that the addition of LDPE generally reduced the penetration value; however, with a further increase in LDPE content, the penetration value began to rise. In the softening point test, it was observed that increasing the LDPE content led to a decrease in the softening point of the modified bitumen. Similarly, the ductility initially decreased and then began to increase as the proportion of LDPE increased, in comparison to the conventional mix. The specific gravity of all LDPE-modified samples remained nearly constant.

For samples containing waste engine oil, the penetration value initially dropped, but increased again as the content rose, with the maximum effective range being up to 8%. According to the ductility and softening point test results, the optimum performance was noted at 6% engine oil content, suggesting this percentage as suitable for blending with bitumen.

When CRMB powder was used, improvements were seen in penetration, ductility, and softening point values up to 8% content, indicating that this level is optimal for use with VG10 bitumen.

In the case of HDPE-modified bitumen, a decrease in penetration was observed with 2% HDPE, but further increases in content led to rising penetration values up to 7%. The ductility showed a similar trend, with an initial drop followed by a steady increase as HDPE content was raised. The softening point, however, increased with 2% HDPE but started to decline as more HDPE was added.

Regarding the mixed compositions of waste materials, the blend containing 3% HDPE + 4% engine oil + 5% CRMB powder exhibited the highest penetration value. The highest softening point was recorded for the sample containing 5% CRMB powder + 2% LDPE + 3% HDPE. In terms of ductility, the mixture with 3% HDPE + 4% engine oil + 5% CRMB powder demonstrated superior flexibility compared to the other samples. Across all compositions, the specific gravity remained nearly unchanged.

C. Future Scope

Looking ahead, the current study can be expanded by increasing the percentage of waste material used to replace bitumen (either alone or in combination). In addition, more appropriate waste materials may be added in accordance with their physical and chemical analyses. Future research can look at the various loading effects brought on by traffic flow and temperature stressors, which are what cause pavement failure.

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