Development of Improved Dense Graded Bituminous Macadam with Low Density polyethylene and High Density Polyethylene with Zykotherm Intermixing

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Abstract: The utilisation of leftover polythene in flexible road constructions is discussed in this paper. In flexible pavements, recovered polymer debris such as carry bags from supermarkets and water bottles, coldrink bottles (LDPE) and plastic bottle caps (HDPE) have been utilised as additives. We'll also use a fixed amount of Zykotherm in this experiment (ZycoTherm is an odourless ingredient that boosts moisture tolerance while decreasing blending and compaction temperatures by up to 65°F). The aforementioned components were chosen for two reasons: to use economically and environmentally undesirable trash and to build a superior material mixture to withstand higher traffic loads, temperature effects, and pressure, which results in fractures in the pavement surface. The polymer debris will be processed and reduced into a size that would flow through a 2-3mm filter in the research study utilizing a shredding machine.

In this investigation, a Dense Bituminous Macadam (DBM) mixture is being presented to be prepared utilizing pure bitumen as a control sample and bitumen blended with LDPE 2 percent and 4 percent & HDPE 2 percent, 3 percent, 4 percent, 5 percent by weight, with a specific amount of Zykotherm of 1.5 percent by weight. On control and modified DBM mixes, the Marshall Stability Test, Penetration Test, and Softening Point Test were performed.

Keywords: Sustainability, Waste Management, Pavement, Polymer

I. INTRODUCTION

Waste management is an approach required to manage waste from the start of collection to the disposal. The present work is focused on using plastic waste for production of admixture which can be used in road construction. One of the important fractions for municipal solid waste material is plastic. All over the world it is considered to be the most important concern with respect to environmental impact [1].

Waste polymer has the prospect to be used in small amounts in bituminous road building because it improves the reliability, resilience, fatigue resistance, and other useful characteristics of bituminous mixtures (about 5-10 percent by weight of bitumen), resulting in increased pavement durability and functionality [2]. Utilizing plastic wastes in bituminous mixtures enhances endurance and leads in greater resistivity towards distortion and water caused harm, according to laboratory and field performance tests [3], thereby leading to increase satisfaction level and accidents minimization. By including waste plastic into the bituminous mix, less bitumen is consumed, which lowers the costs. Waste polymer is also used in road building, which helps to extend the life of the road [2].

Residual high density polyethylene (HDPE) and low density polyethylene (LDPE) as types of plastics are utilized in this study to examine the opportunities for enhancing asphalt mixture characteristics and to assess the design criteria of asphalt mixtures utilizing these two modifiers at optimal binder concentration [4]. The volume of trash LDPE and HDPE is growing by the day, owing to the vast accessibility of these two wastes. After some minimal sifting, almost all of the solid trash is combined with Municipal Solid Debris and dumped over a landmass known as a landfill. Because plastic, polyethylene, LDPE, HDPE and PVC are non-biodegradable, they stay at the location for an unknown period of time, producing a significant rise in trash in the landfill and, as a result, a rise in the prices of open dumping. Because the current disposal methods are either land burying or incineration, waste plastic is expected to be disposed of in a manner that will have a negative influence on the environment [5].

To combat this pattern, much initiative has been taken towards processing garbage and converting it into goods that may be reused. Leftover LDPE and HDPE come from the local store, home waste, and residential and industrial applications. When heated to about 130°C to 200°C, waste LDPE and HDPE melts. Furthermore, molten polyethylene and PVC have a binding ability. As a result, molten polymer may be utilized as binders, and they can be combined with other binders, such as bitumen, to improve their binding ability [5]. These two substances might be useful modifiers for bitumen, which is utilized in road building. Several studies have discovered that using a binder made by altering existing bitumen with additions like sulphur and organic polymer may improve the strength of paving mixtures. Temperature susceptibility and viscosity properties are also improved by the transformed plastics. In the building of roads, upgraded bitumen comprising 10% waste polyethylene could be utilized, especially in warm climates. Modifications of 80/100 paving grade bitumen may be done with low-density polyethylene carry bags obtained from residential solid garbage [6].

Construction methods

Bituminous hot mixes made from waste polymer for road building can be made in a 'dry' or a 'wet' technique. The dry method is thought to be easy, cost-effective, and environmentally safe, whereas the wet process necessitates more capital and apparatus, and hence is not often utilized (Mishra and Gupta, 2018) [7]

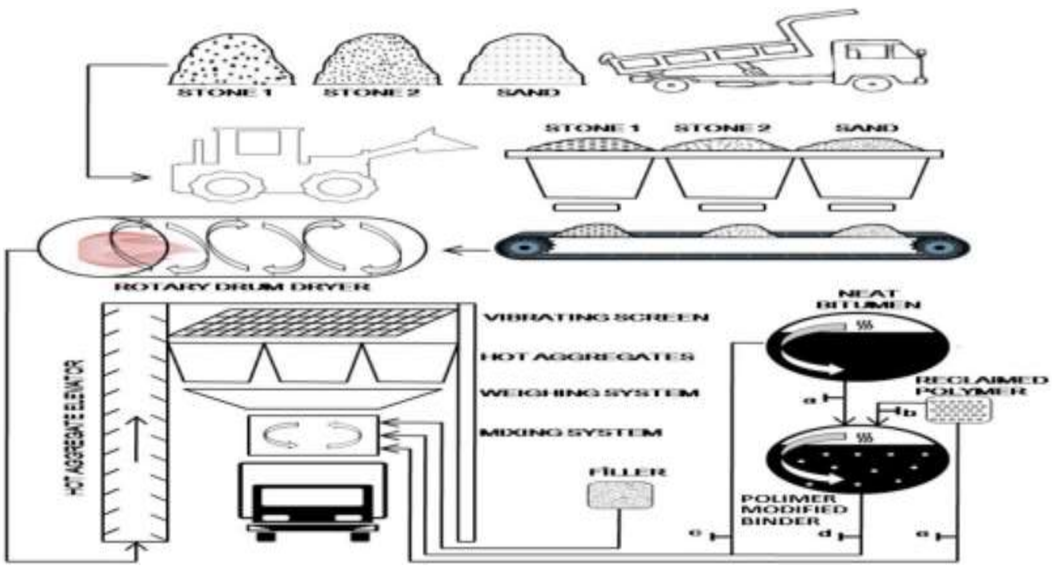

Fig 1. Sketch of the wet and dry processes in an asphalt plant

1. **Dry process**

   The shredded discarded polymer is mixed with the heated aggregate during the dry process (in figure 3, when lines a, b and d are opened, keeping c and e closed). According to the Indian Road Congress (2013) and the National Rural Roads Development Agency (2019), the fragmented waste polymer dimension must ideally be 2-3 mm for improved dispersion and coatings on the aggregate. The percentage of dust and other contaminants in the product must not surpass 1%. After that, the fragmented waste polymer is mixed together with the heated aggregates. To produce a covering around the aggregates, the shredded waste polymer softens and melts [7]. The bitumen is also preheated to 160°C before being combined with the plastic-coated aggregates and utilized for road building.

1. **Wet process**

   The treated waste polymer is mixed to the heated bitumen as a powdered form in the wet method (in Figure 3, when lines c and e are opened, and a, b and d are closed). Prior to actually combining them with the aggregates, the granular waste polymer is blended straight with bitumen. The range of temperature for this technique is 155oC to 165oC, and it must be assured that there is an equal mixture of polymer and bitumen [7].

II. LITERATURE REVIEW

Razali M.N et al. [8] The potential of polyacrylic wig waste (PAWW) as a roadway microsurfacing additive is investigated in this work (RMS). The aim is to combine PAWW with bitumen to make polymer modified bitumen (PMB). Unaltered bitumen with PAWW also called as modacrylic fiber, which includes variable proportions of Polyacrylic (PA) wig within every sample, is the best quality grade of bitumen obtainable from the industry with the grade 80-100 mm penetration grade.

DivyaV, GyanenTakhelmayum et al. (2017) [9] The writer introduced an investigational research to assess the dosage of WMA admixtures (from 1 to 5 percent by weight of Sasobit, based on the binder, with a 1 percent weight increase and 0, from 0, 5 percent to 0.2 percent by weight of cyclotermia, relying on the binder, with a 0.05 percent weight increase). The perceived density of compacted mixtures (Gmb), air entrainment (VTM), voids filled with mineral aggregate (VMA), and voids filled with asphalt (VFA) were all investigated as part of the Marshall mix design.

Adebayo Olatunbosun Sojobi et al. [10] This study clarifies the idea of environmentally sustainable road building, which includes eco-design, eco-extraction, eco-manufacturing, eco-building, eco-rehabilitation, eco-maintenance, eco-demolition, and socioeconomic empowerment. It also showed the obstacles to its acceptance as well as the advantages that may be gained by using it. In addition, the impacts of reprocessing PET plastic bottle trash generated in North Central Nigeria in bituminous asphaltic concrete (BAC) utilized in flexible road construction were assessed.

H. Wang et al. [11] The goal of this study is to use crumb rubber from scrap tires as an environmentally acceptable and long-lasting addition for improving the rheological characteristics of asphalt binders for asphalt pavements at both high and low temperatures. In this research, two distinct crumb rubber sources with various gradations – fine and coarse – were employed. Crumb rubber-modified (CRM) binder was made by adding 10, 15, 20, and 25% crumb rubber particles to a Superpave PG 64-22 asphalt binder by weight.

V.S. Punith et al. [12]The goal of this study is to modify (80/100)-grade asphalt using recovered polyethylene (PE) derived from low-density polyethylene (LDPE) carry bags, a locally accessible low-cost waste material recovered from landfills. At varied asphalt compositions, test specimens were compressed utilizing a gyratory testing machine. PE-modified asphalt mixes exhibited enhanced resistance to moisture-induced degradation based on tensile strength ratio and maintained stability test outcomes.

III. Methodology:

In the present work, the task necessitates the acquisition of samples, their examination, the execution of a wide range of tests, and the drawing of conclusions from the results. The work may be separated into its component parts-

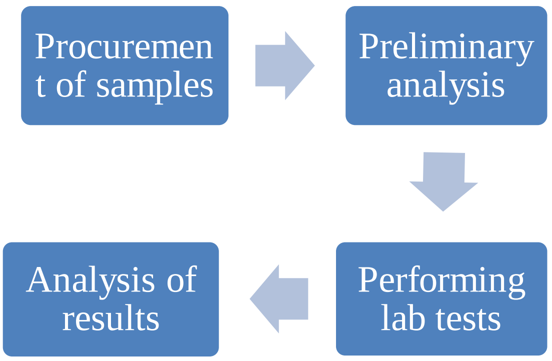

Fig 2. Methodology adopted

1. Material Collection

Constituents of a mix

A mixture of asphalt consists of a mixture of total values that has most extreme dimension which is usually less than 25 mm, controlled with a thin charge of less than 0.075 mm. A sufficient amount of bitumen is added to the mixture such that the compacted mixture is substantially impermeable and has satisfactory dissipative and polyvalent properties. The configuration of the bituminous mix is designed to determine the amount of bitumen, filler, total fine and coarse quantities to provide a useful, strong, strong and effective mixture.

The basic materials used are as follows:

- Aggregates
- Zycotherm (Admixture)
- LDPE (polythene)
- Bituminous Binder
- HDPE (polythene)

2. Experimental Investigation

The Marshall Technique was used to perform the experiments (ASTM: D-1559). Marshall tests for stability and flow are performed on three samples for each specimen of bituminous mixture without zycotherm and polymer, as well as with Zycotherm and plastic in combinations. All of the specimens had the same amount of bitumen (4.5%).

The Marshal Characteristics of each combination with varied percentages of HDPE (2-5) and 2-4 percent have been established (LDPE). The purpose of this study is to see how introducing polythene (LDPE & HDPE) and a mixture of Zycotherm and polymer waste improves the qualities of hot mix asphalt (HMA).

Experiments which were conducted are mentioned as follows:

(A) For Aggregates

(i) Impact Value Test
(ii) Flakiness Index Test
(iii) Elongation Index Test
(iv) Water Absorption Test

(B) For Bitumen

(i) Specific Gravity Test
(ii) Penetration Test
(iii) Softening Point Test
(iv) Flash Point and Fire Point Test
(v) Ductility Test

(C) For stability

(i) Marshall Stability Value Test

IV. RESULTS ANALYSIS & INFERENCES

1. Stability Test:

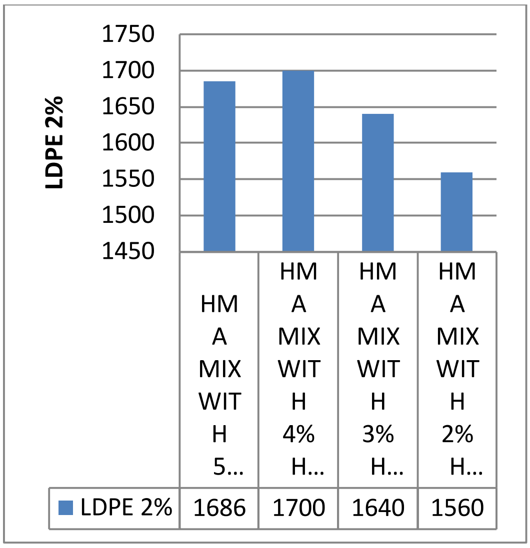

Fig 3. Marshall Stability test with 2% LDPE

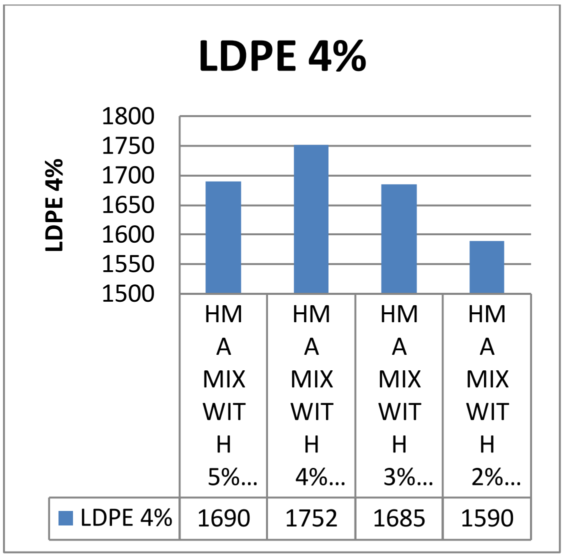

Fig 4. Marshall Stability Test With 4% LDPE

2. Experiments for bitumen

- **Penetration test**

The separation in tenths of millimetres that a standard needle will enter vertically into a specimen under standard conditions of temperature, load, and time is known as infiltration of a bituminous substance. IS: 1203 – 1978, as per the I.S. Code.

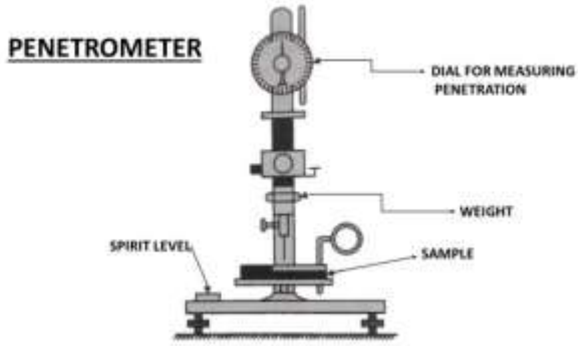

Fig 5. Penetrometer test

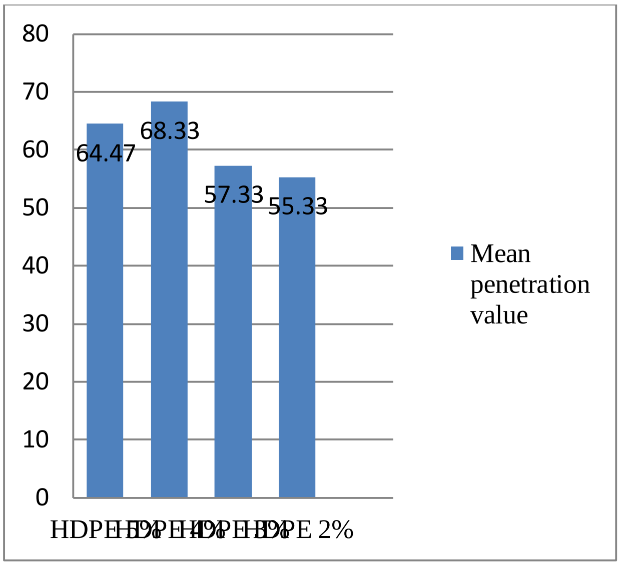

Fig 6. Penetration Test With 2%LDPE

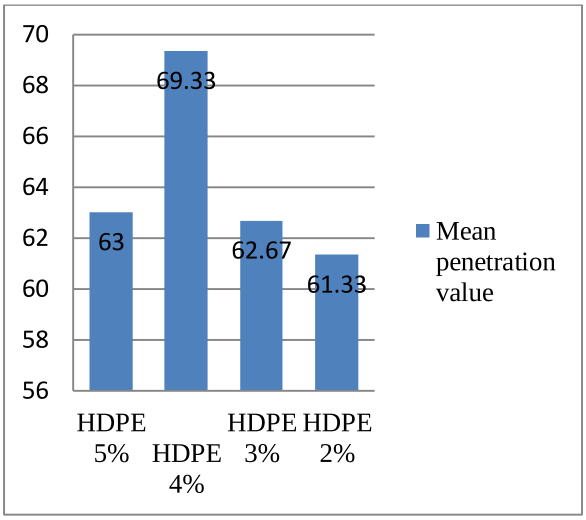

Fig 7. Penetration Test With 4% LDPE

- **Softening point test**

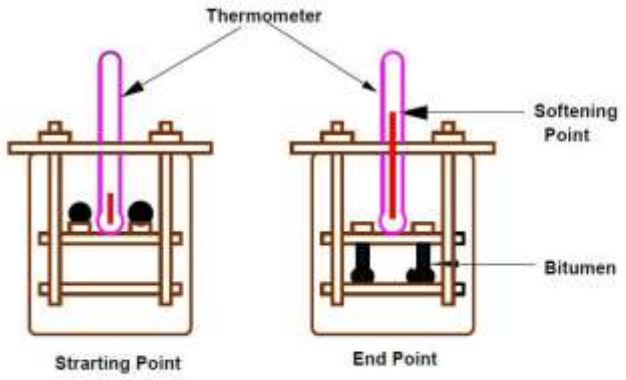

Fig 8. Softening Point Test

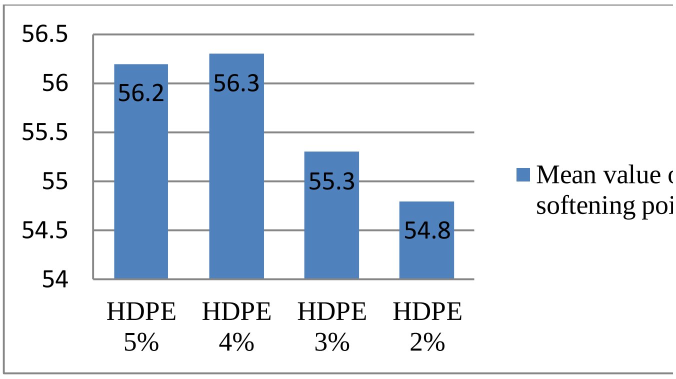

Fig 9. Softening Point LDPE 2%

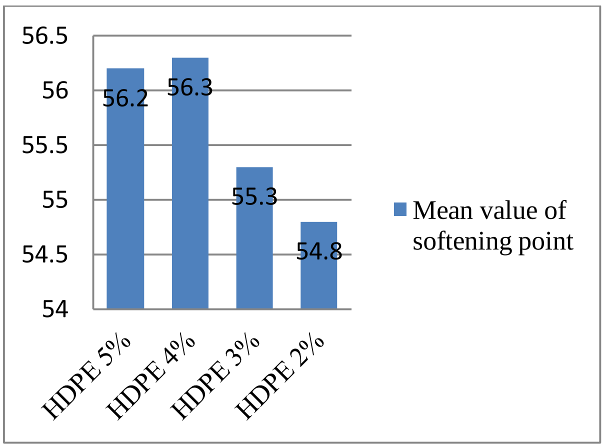

Fig 10. Softening Point LDPE 4%

- **Specific gravity**

For sample 1 = 2.39

For sample 2 = 2.41

For sample 3 = 2.42

For sample 4 = 2.61

3. Experiments for aggregates

- **Impact value test**

The ratio of the weight of fines formed to the total sample weight in each test shall be expressed as a percentage, the result being recorded to the first decimal place:

Aggregate impact value: (B/A) X 100 = 35%

Where A= Weight in g of saturated surface – dry sample

B= weight in g of fraction passing through 2.36 mm IS sieve

- **Flakiness index test**

Flakiness Index = [W_2/ W_1] x 100 = 16.4%

Where, W_2= Weight passed from 0.6 x d_{mean} size = 395.4g

W_1= Total weight of aggregates = 2411g

- **Elongation test index**

Elongation Index= [W_2 / W_1] x 100= 14.08 %

Where W_2= Weight of aggregates passing through 1.8 x d_{mean} size = 356.8g

W_1= Total weight of aggregates = 2411g

- **Water absorption test**

Formula used is Water absorption = [(A – B)/B] x 100%. = .208%

A= weight of the aggregate after proper cleaning= 2409g

B= weight of the aggregate after removal from oven and cooling= 2404g

6.1 Conclusion:

In this research project, we designed a method of use of waste polythene in the construction sector, where

LPDE polythene has been used in the past. However with the help of this research, we can conclude that HPDE polythene can also be used in the construction sector because HPDE has high tensile strength, ductility, and adhesion as compared to LDPE. However, in this investigation, we found that by using HPDE polythene and a set amount of zycotherm, we were able to improve the characteristic of HPDE sample as well as its binding properties.

This research is important for highway building because it can help settle non-biodegradable debris and enhance the lifespan of bitumen (flexible) pavements.

The following findings were obtained from the above-mentioned tests:-

- Marshall Tests on bituminous mixes containing 4 4 percent HPDE plastic and 1.5 percent Zycotherm yielded a greater stability value of 1700 kg, corresponding to flow values of 4.1, percentage air voids of 3.0 percent, VMA of 9.48 percent, and VFB of 68.30 percent at 2 percent LPDE, and stability value of LDPE is 1752 kg at 4 percent.
- It has been discovered that adding polymer HDPE to the mixture boosts the resistance of mixture against the moisture susceptibility. In the HMA mix, BC with polyethylene produces the maximum tensile strength ratio.
- According to the findings, zycotherm boosts the adhesive properties of the mixture in a natural manner.
- As the amount of HDPE polymer in the specimen increases, the ductility of specimen improves since it has a high tensile strength.
- This technology is highly important in terms of expenditure reduction in construction since it is very beneficial in cost reducing of bitumen in a mixture.

Future Scope:

Following are some of the current study's drawbacks and potential future scope in this area:

- The scope of this research was confined to HMA design techniques. Therefore , separate processes for various mixtures should be developed.
- The investigation of Marshall Stability and air void content in compacted mixtures is used to determine the functionality of mixtures. Many additional engineering parameters must be addressed while evaluating mixture functionality.

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