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EFFECT OF VARIABLE PERCENTAGE OF LOW-DENSITY PLASTIC WASTE ON DENSE BITUMINOUS CONCRETE MIX

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Abstract: The increasing accumulation of non-biodegradable plastic waste, particularly Low-Density Polyethylene (LDPE), has emerged as a serious environmental challenge worldwide. In this study, an effort has been made to utilize waste LDPE as a modifier in bituminous mixtures to improve pavement performance while addressing the issue of plastic waste disposal. The primary objective of this research was to evaluate the influence of LDPE addition on the Marshall Stability, flow value, bulk density, air voids, and volumetric characteristics of Dense Bituminous Mix (DBM) prepared using 60/70 grade bitumen. Experimental investigations were carried out by incorporating LDPE at different percentages (2%, 4%, 6%, and 8%) by weight of bitumen. The Marshall Mix Design method was adopted in accordance with MORTH specifications. The results revealed that the addition of LDPE significantly enhanced the performance of the bituminous mix up to an optimum level. The maximum Marshall Stability value of 1450 kg was achieved at 6% LDPE, compared to 1255 kg for the conventional mix. Flow values increased moderately, indicating improved flexibility and resistance to cracking. Bulk density also improved due to better coating and compactness, while air voids and binder content reduced, resulting in a denser and more durable mix. The study confirmed that the optimum binder content (OBC) was reduced from 5.5% to 5.0% when LDPE was added, demonstrating economic benefits and efficient material utilization. All test results were within the acceptable limits prescribed by MORTH, confirming the suitability of LDPE-modified DBM for flexible pavement construction. The incorporation of waste plastics not only enhances the mechanical properties of asphalt mixtures but also contributes to sustainable infrastructure development by reducing plastic waste accumulation and bitumen consumption. Hence, the study concludes that LDPE-modified bituminous mixtures offer a viable, eco-friendly, and cost-effective solution for modern pavement construction. This approach promotes circular economy principles by transforming waste materials into valuable engineering resources, thereby supporting national and global sustainability goals.

Keywords: Low-Density Polyethylene (LDPE), Optimum binder content (OBC), Marshall Stability, flow value, bulk density, air voids, volumetric characteristics of Dense Bituminous Mix (DBM).

1. Introduction

Plastics and polythene do not decompose

naturally and they are environmentally unacceptable, and so alternative methods need to be implemented, to recycle these materials. There are numerous modifiers that may be utilized to develop the characteristics of road surfaces; however, the majority of the materials are raw or natural materials. Natural materials are complicated to locate and are too costly when utilized as modifier to the ingredients. Consequently, with the application of waste plastic bottles as a modifier in the construction of roads can significantly helps in plummeting material wastage and upgrading in the characteristics of roads. Recycling of waste materials can provides a much-needed reason of removing an expensive and environmentally intolerable solid waste dumping trouble for above products. at the present time, allowing for the risks related with land filling of waste resource sand the dumping difficulty, researchers are discovering ways of mixing used materials into asphalt pavements that have brought about action throughout the world.

Augmented traffic intensity and rise in high pressures caused from heavy vehicles are with the factors that origins cracking resulting in premature collapse of pavements. A multiplicity of solutions have been tried to decrease the propensity of asphalt concrete mixtures to cracking. In this time, there is a speedy augmentation in using additives in asphalt concrete mixtures to develop its properties. LDPE has been utilized by numerous researchers to amend asphalt cement and to develop the properties of bituminous mixes as an asphalt modifier with the purpose of get better presentation and enlarge the life span of asphalt pavement mixtures. Asphalt is a sticky substance which can be obtained from crude petroleum and can be used in paving roads. Asphalt is usually taken as to comprise asphaltines, resins, and oils. This can be mainly collection of hydrocarbon molecules (hydrogen and carbon); it in addition comprises of parts that are oxygen, nitrogen, and sulfur. Asphalt has an extremely dissimilar molecular structure depending on the crude resource. Asphalts are thermoplastic materials so steadily dissolves when heated. Asphalts were normally exemplified by their firmness, consistency, or capability to flow at different temperatures. This research investigates the feasibility of utilizing domestic polyethylene obtained through low-density polythene carry bags as chemical additive in flexible pavement.

1.1 Flexible Pavement

Bitumen can be defined as constructive binder used in the construction of different types of road surfaces. The steady enhance in elevated traffic intensity in terms of business automobiles, the increase in over loading of trucks and the noteworthy inconsistency in every day and continuing temperature requires enhanced road characteristics Several grades of bitumen like 30/40, 60/70, and 80/100 had been accessible on the basis of the designated values of penetration. Any expansion in the characteristics of the binder is the necessity of the present time. Bitumen is the excess product or residue of the distillation of crude oil. They are used mainly for performing waterproofing in the construction industry and for binding the ingredients as binder in the road engineering. Bitumen is a thermoplastic substance and has vital limitations due to their temperature sensitivity. It also helps to develop the strength of the road material. Use of the anti stripping material depends on the category of bitumen and the surrounding environmental conditions. The bituminous binder functions as a waterproof, thermoplastic adhesive. In other words, bitumen can work as the adhesive to grip the mineral aggregates jointly to act as a single layer. In the majority general form, bituminous binder can be considered as simply the remainder from petroleum refining. To attain the essential properties for paving purposes, binder should be produced from a cautiously selected crude oil mix, and processed to a suitable grade. In the manufacturing of flexible pavements, bitumen is having an important responsibility of binding the aggregate mutually by making a coated layer over the aggregate. Bitumen facilitates to get better strength of the road and its water resistance is very poor.

2. Materials

2.1 Bitumen

Bitumen is available in a variety of types and grades. The grades of bitumen used for pavement construction work of roads and air-fields are called paving grades and those used for water proofing of structures, industrial floors, etc. are called industrial grades. The paving bitumen available in India is classified into two categories- A type (from Assam petroleum) and S-type (from other sources). The common tests to assess the grade of paving bitumen are penetration test, ductility test and the softening point test flash and fire point tests and the specific gravity tests are also needed. In this work, we have used S-type, 60/70 grade bitumen.

2.2 Modified Bitumen

Several considerable properties of bitumen and bituminous mixes can be enhanced to meet up the essential requirements of pavement with the inclusions of definite additives or a mix of additives. Modified Bitumen is expected to give 50 to 100 per cent higher life of surfacing depending upon degree of modifications and type of additives used. Modification of bitumen by the addition of polymers can lead to significant changes in the mechanical properties of the bitumen. These additives were nominated as Bitumen Modifiers and the bitumen modified with these additives is known as Modified Bitumen. To utilize the non- biodegradable material which is otherwise a threat to the environment, in highway bituminous mixes considerably enhancing the firmness or strength, fatigue life and other enviable properties of bituminous concrete mix, even under undesirable water-logging conditions. Consequently, the life of the asphalt road surfacing course using the customized bitumen is also predictable to augment considerably in contrast to the use of ordinary bitumen. Growing axle loads, variation in climatic conditions and traffic enlargement has posed dispute to paving manufacturing industries to explore the requirements made on the bitumen pavement manufacturing. In this view,asearlyasin1980's amendment to base bitumen has been done by accumulation of certain modifiers like polymers, natural or crumb rubber, plastics and others, to develop the presentation of bitumen mechanically by physical adjustment. Also, chemical modifications have been challenged in the form of polyethylene, poly-phosphoric acid, etc. The use of improved bitumen can provides a number of reasons. It can marks a precise expansion in the bitumen, such as everlasting deformation such as rutting or cracking at low temperature. Advantages of modifying binders by adding supplementary additives, includes enhancement in several properties such as consistency, temperature susceptibility, stiffness and cohesion, flexibility, resilience and toughness, binder aggregate adhesion and resistance to in-service aging.

2.3 Polymer Modified Bitumen

Now, in recent days Polymer modified bitumen has been raising as one of the vital manufacturing materials for flexible road-works or pavements. Consumption of plastic waste in the making of flexible pavement is gaining consideration because of several reasons such as polymer modified bitumen, which shows superior properties for road construction & plastics waste. LDPE has been considered to be a pollution nuisance, investigating its use in this procedure can assist solving the trouble of pollution because the majority of the plastic waste is polymers. A range of studies had been conducted to improve the quality of bitumen used in bituminous road building. Use of disposed plastic waste such as plastic bags, is the necessity of the present days. One of the effects of such researches is to make use of polymer-modified bitumen. Now, today the accessibility of the waste plastics is huge, as the plastic materials are now becoming significant part of regular daily life. They might get combined with public solid waste and or thrown over useful land. All of these procedures were not environmentally acceptable. In this situation, a second utilization for the waste plastics was now needed in the current days. Their current removal can be done by land filling or by burning.

2.4 LDPE

Low Density polyethylene (LDPE) is a thermoplastic made from petroleum. LDPE is defined by a density range of 0.910–0.940 g/cm³. It is not reactive at room temperatures, except by strong oxidizing agents, and some solvents cause swelling. It can withstand temperatures of 80°C continuously and 95°C for a short time. Made in translucent or opaque variations, it is quite flexible, and tough but breakable.LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces (instantaneous-dipole induced-dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen. The LDPE used in this project is derived from waste plastic (polyethylene bags, etc.).

3.Result and Discussion

Samples of ordinary bitumen were prepared with varying percentage of bitumen (4.5% to 6.0%) and marshal stability test were conducted on each sample. The physical properties of each sample are measured and calculated. The graphs have been plotted to find the optimum binder content which comes out to be 5.5% of bitumen. The results obtained are shown in Table1.

Table 1: Results of Marshal Mix Design for DBM with ordinary bitumen (60/70):

S. No.	Bitumen %	Weight of sample (gm)		Marshal stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air Voids %	VMA %	VFB %
		Air	Water						
1	4.5	1194	685	1125	2.39	2.340	5.28	14.29	59.71
2	5.0	1196	692	1225	2.52	2.375	4.65	15.05	67.29
3	5.5	1187	690	1255	2.62	2.382	3.86	15.14	74.12
4	6.0	1186	681	1228	2.78	2.345	3.42	15.25	82.56

3.1 Results of DBM with LDPE :

The results and analysis for ordinary bitumen mix shows that optimum binder content for the mix is 5.5% of the total weight of the aggregate. By using this optimum binder content i.e. 5.5% various samples of varying LDPE percentages (2%, 4%, 6%,8%) were prepared and subsequent test have been performed to find properties of modified dense bitumen mix. The table (2) shows various properties of LDPE modified DBM.

Table 2: Properties of DBM with LDPE Modified bitumen with optimum binder content (5.5%)

S. No.	LDPE %	Weight of sample (gm)		Marshal stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air Voids %	VMA %	VFB %
		Air	Water						
1	2%	1195	690	1295	2.42	2.363	3.95	13.36	70.31
2	4%	1188	688	1343	2.54	2.374	3.84	14.58	73.59
3	6%	1186	687	1381	2.61	2.377	3.77	15.24	74.35
4	8%	1197	691	1407	2.74	2.362	3.70	16.09	76.21

The results show that increase in percentage of LDPE in mix increases marshal stability value, bulk density and voids filled with bitumen (VFB) but decreases air voids. It has been observed that modified mix shows better marshal stability value at 8% LDPE but VFB exceeds the limiting value, so the optimum dose of LDPE is selected as 6%. Now the test were performed to find the optimum binder content with 6% LDPE modified mix. The test results are shown in table 3 followed by various graphs to find Out optimum binder content.

Table 3: Properties of DBM with 6% LDPE modified bitumen and varying percentage of bitumen binder

S. No.	Bitumen %	Weight of sample (gm)		Marshal stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air Voids %	VMA %	VFB %
		Air	Water						

1	4.5	1193	692	1355	2.60	2.378	4.55	14.43	67.36
2	5	1189	690	1395	2.65	2.386	4.43	14.92	70.13
3	5.5	1188	693	1450	2.80	2.401	4.20	15.27	73.29
4	6	1195	694	1415	2.88	2.382	4.02	15.40	76.47

Following graphs have been plotted to find the optimum binder content

1. Binder content vs Marshal stability (fig. 3.1)
2. Binder content vs flow value (fig. 3.2)
3. Binder content vs Bulk Density (fig. 3.3)
4. Binder content vs Air voids (fig. 3.4)
5. Binder content vs Voids filled with bitumen (fig. 3.5)

It is observed from graphs, that maximum marshal value is obtained with 5% modified bitumen compared 5.5% ordinary bitumen in DBM. It is therefore inferred that 6% LDPE admixtures vs bitumen content, without adversely affecting Marshal Stability Value.

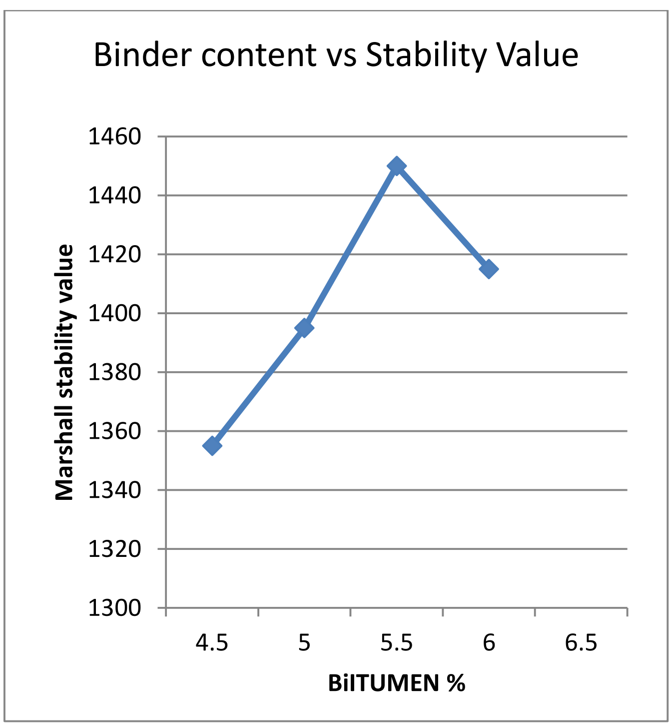

Figure 3.1 Bitumen% Vs Marshal Stability

Value

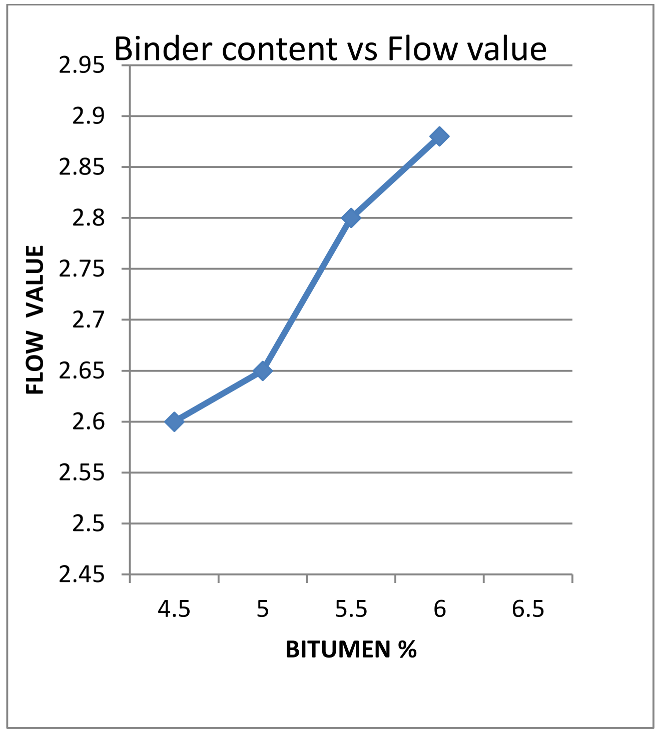

Figure 3.2 Bitumen% Vs Flow value

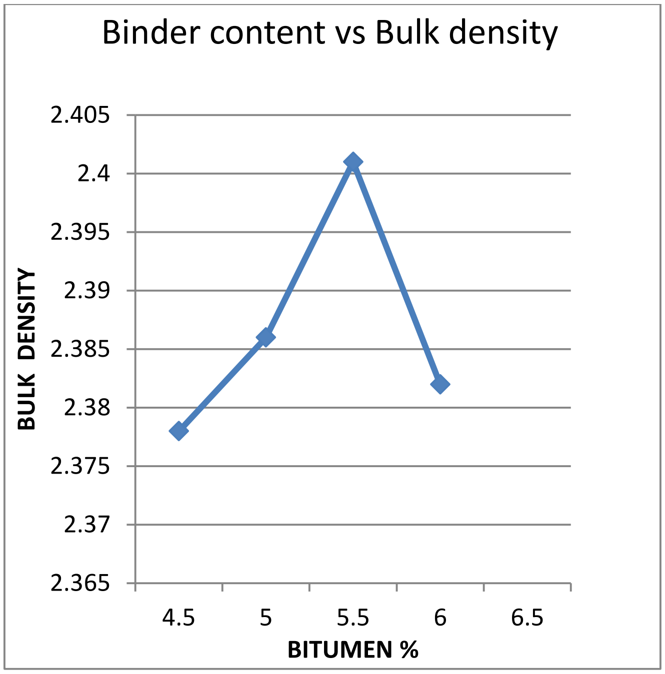

Figure 3.3 Bitumen% Vs Bulk Density

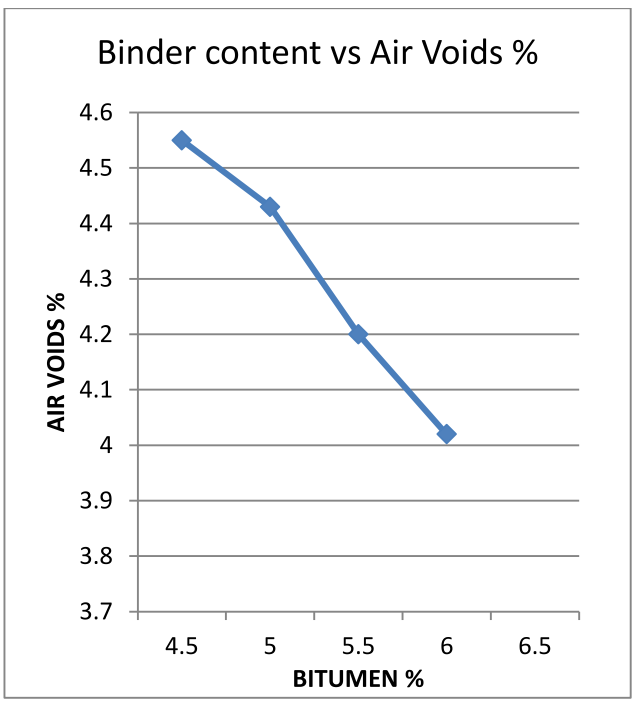

Figure 3.4 Bitumen% Vs Air voids %

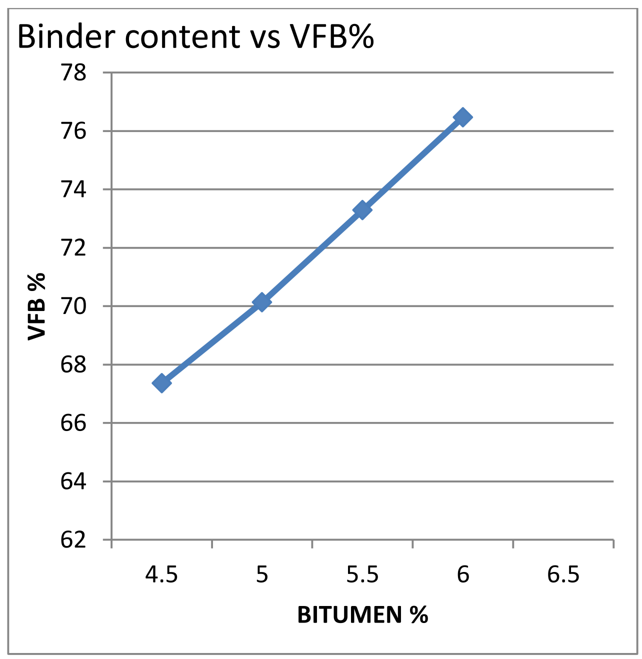

Figure 3.5 Bitumen% Vs Voids filled with bitumen % (VFB)

4. Conclusions

1. The Marshall Stability value of the mix

increased with the addition of LDPE up to 6%, beyond which a slight decline was observed. The highest stability (1450 kg) was obtained at 6% LDPE, representing a 15–16% improvement compared to the conventional mix (1255 kg).

2. The Flow Value also increased gradually from 2.62 mm (control mix) to 2.80 mm (6% LDPE), indicating enhanced flexibility and better deformation resistance.
3. The Bulk Density of the mix improved from 2.382 g/cc (conventional mix) to 2.420 g/cc at 6% LDPE, confirming improved aggregate coating and compaction characteristics.
4. Air Voids increased from 3.86% in the conventional mix to 4.2% in the LDPE-modified mix, suggesting better densification and increased permeability.
5. The VMA values increased slightly from 15.14% to 15.27%, showing moderate aggregate packing, while VFB decreased from 74.12% to 73.29%, reflecting better binder utilization.
6. The Optimum Binder Content (OBC) decreased from 5.5% (unmodified) to 5.0% (LDPE-modified), demonstrating potential material cost savings.
7. The test results for LDPE-modified DBM mixes were found to be within the MORTH-specified limits, confirming that LDPE-modified mixes meet all requirements for use in flexible pavement construction.

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