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UTILISING WASTE POLYETHYLENE IN BITUMINOUS PAVING MIXES: ENHANCING SUSTAINABILITY AND PERFORMANCE

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Abstract

Bituminous mixtures are frequently employed in the construction of flexible pavements all over the world. However, under some conditions, such as excessive traffic, increased loads, temperature fluctuations, and moisture-induced scenarios, their performance can be subpar. To overcome these issues, research has concentrated on the incorporation of additives and the modification of bitumen in bituminous mixes. Polymer additives have showed promise in improving aggregate-binder cohesion and thus the characteristics of asphalt pavements. This study explores the use of reclaimed polyethylene, obtained from packaging materials, as a modifier in bituminous mixes.

The aim of this study is to investigate the effects of locally available reclaimed polyethylene from milk packaging on the engineering properties of bituminous concrete (BC), dense bituminous macadam (DBM), and stone mastic asphalt (SMA) mixes. Optimum binder content (OBC) and optimum polyethylene content (OPC) were determined using the Marshall procedure. The OBCs for SMA, BC, and DBM mixes were found to be 4%, and when replacing some fine aggregate with granulated blast furnace slag and fly ash as filler, the OBCs increased to 5% for SMA and 4% for BC and DBM mixes. The OPCs were determined to be 2% for SMA and DBM mixes, and 1.5% for BC mixes using stone dust as filler. When incorporating slag and fly ash as fillers, the OPCs remained consistent at 1.5% for all mix types.

Mixes were prepared based on the determined OBC and OPC, and various performance tests including drain down test, static indirect tensile strength test, and static creep test were conducted to evaluate the effects of polyethylene as a stabilizer on mix properties. The results indicate that the addition of OMFED polyethylene improves properties such as Marshall stability, drain down characteristics, and indirect tensile strength.

Keywords: *Bituminous concrete (BC), Stone mastic asphalt (SMA), Dense bituminous macadam (DBM), OMFED polyethylene, Marshall properties, Static indirect tensile strength test, Static creep test.*

1. Introduction

1.1 General

Bituminous binders are widely used by paving industry. In general pavements are categorized into 2 groups, i.e. flexible and rigid pavement.

Flexible Pavement

Flexible pavements are those, which on the whole have low flexural strength and are rather flexible in their structural action under loads. These types of pavement layers reflect the deformation of lower layers on-to the surface of the layer.

Rigid Pavement

If the surface course of a pavement is of Plain Cement Concrete then it is called as rigid pavement since the total pavement structure can't bend or deflect due to traffic loads.

Pavement design and the mix design are two major considerations in case of pavement engineering. The present study is only related to the mix design of flexible pavement considerations. The design of asphalt paving mixtures is a multi-step process of selecting binders and aggregate materials and proportioning them to provide an appropriate compromise among several variables that affect mixture behaviour, considering external factors such as traffic loading and climate conditions.

1.3.3 Role of Polyethylene in Bituminous Pavements

Use of polyethylene in road construction is not new. Some aggregates are highly hydrophilic (water loving). Like bitumen polyethylene is hydrophobic (water hating) in nature. So the addition of hydrophobic polymers by dry or wet mixing process to asphalt mix lead to improvement of strength, water repellent property of the mix. Polyethylenes get added to hot bitumen mixture and the mixture is laid on the road surface like a normal tar road. Plastic roads mainly use plastic carry-bags, disposable cups, polyethylene packets and PET bottles that are collected from garbage as important ingredients of the construction material. Polymer modification can be considered as one of the solution to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement. Creating a modified bituminous mixture by using recycled polymers (e.g., polyethylene) which enhances properties of HMA mixtures would not only produce a more durable pavement, but also provide a beneficial way of disposal of a large amount of recycled plastics.

1.4 Objectives of Present Investigation

A comparative study has been made in this investigation between SMA, BC, and DBM mixes with varying binder contents (3.5% - 7%) and polyethylene contents (0.5% - 2.5%).

The objectives of this investigation are to observe the followings;

- Study of Marshall properties of mixes using both
    1. Stone dust as filler and,
    2. Slag as fine aggregate and fly ash as filler.
- The effect of polyethylene as admixture on the strength of bituminous mix with different filler and replacing some percentage of fine aggregate by slag.
- The performance of bituminous mix under water with and without polyethylene admixture with different filler and replacing some percentage of fine aggregate by slag.
- To study resistance to permanent deformation of mixes with and without polyethylene.
- Evaluation of SMA, BC, and DBM mixes using different test like Drain down test, Static Indirect tensile Strength test, Static Creep test etc.

3.Raw Materials

3.1 Constituents of a Mix

Bituminous mix consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to producea mix which is workable, strong, durable and economical.

The basic materials used are as follows:

- Aggregates
- Fly Ash
- Slag
- Bituminous Binder
- Polyethylene

3.2 Material Used in Present Study

3.2.1 Aggregates

For preparation of Bituminous mixes (SMA, DBM, BC) aggregates as per MORTH grading as given in Table 3.1, Table 3.2 and Table 3.3 respectively, a particular type of binder and polyethylene in required quantities were mixes as per Marshall Procedure. The specific gravity and physical properties of aggregate are given in Table-3.4 and Table-3.5.

Table 3.1: Gradation of aggregates for SMA

Sieve Size (mm)	Percentage Passing
19	100
13.2	94
9.5	62
4.75	28
2.36	24
1.18	21
0.6	18
0.3	16
0.075	10

Table 3.2: Gradation of Aggregates for BC

Sieve Size (mm)	Percentage Passing
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-38
0.3	18-28
0.15	12-20
0.075	4-10

5. Analysis of Results and Discussion

5.3 Effect of Polyethylene Concentration on Marshall Properties of SMA, BC and DBM Mixes With Stone Dust as Filler

Here result in variation of Marshall properties with different binder content where polyethylene content is taken as 0%, 0.5%, 1%, 1.5%, 2% and 2.5% for SMA and DBM and 0%, 0.5%, 1%, 1.5%, 2% for BC are explained below.

5.3.1 Marshall Stability

It is observed from graphs that with increase in bitumen concentration the Marshall stability value increases up to certain bitumen content and there after it decreases. That particular bitumen content is called as optimum binder content (OBC). In present study OBC for conventional SMA, BC, and DBM mixes are found as 6%, 4.5%, and 4.5% and similarly OBC are found as 4% for modified SMA, BC and DBM mixes with polyethylene at different concentration.

From the graphs it can be observed that with addition of polyethylene stability value also increases up to certain limits and further addition decreases the stability.

This may be due to excess amount of polyethylene which is not able to mix in asphalt properly. That polyethylene concentration in mix is called optimum polyethylene content (OPC) which is found as 2% for SMA and DBM and 1.5% for BC mixes.

Table 5.1 Optimum Binder Contents

Types of Mix	Optimum Polyethylene Content (%)	Optimum Binder Content (%)
SMA Without Polyethylene	0%	6%
SMA With Polyethylene	2%	4%
DBM Without Polyethylene	0%	4.5%
DBM With Polyethylene	2%	4%
BC Without Polyethylene	0%	4.5%
BC With Polyethylene	1.5%	4%

Table 5.2 Comparisons of Stabilities at OBC

Types of Mix With Stone Dust	Stability(Kn)
SMA Without Polyethylene	12.765
SMA With Polyethylene	14.965
DBM Without Polyethylene	12.76
DBM With Polyethylene	17.444
BC Without Polyethylene	10.875
BC With Polyethylene	17.587

5.4 Effect of Polyethylene Concentration on Marshall Properties of SMA, BC and DBM Mixes With Slag As a Partof Fine Aggregates and Fly Ash as Filler

Here the test result in variation of Marshall properties with different binder content where polyethylene content is taken as 0%, 0.5%, 1%, 1.5%, and 2% for SMA , BC, and DBM mixes are explained below by replacing two gradation (0.3mm-0.15mm and 0.15mm - 0.075mm) of fine aggregates by granulated blast furnace slag and using fly ash as filler.

6. Conclusion

In this study, three types of mixes i.e. SMA, DBM and BC are prepared with VG30 grade bitumen used as a binder. The effect of addition of waste polyethylene in form of locally available artificial milk with brand OMFED packets in the bituminous mixes has been studied by varying concentrations of polyethylene from 0% to 2.5% at an increment of 0.5%.

- Using Marshall Method of mix design the optimum bitumen content (OBC) and optimum polyethylene content (OPC) have been determined for different types of mixes. It has been observed that addition of 2%

polyethylene for SMA and DBM mixes and 1.5% polyethylene for BC mixes results in optimum Marshall Properties where stone dust is used as filler. But when small fraction of fine aggregates are replaced by granulated blast furnace slag and filler is replaced by fly ash, optimum Marshall Properties for all types of mixes result with only 1.5% polyethylene addition. The OBCs in case of modified SMA, BC and DBM mixes by using stone dust as filler are found 4% and OBCs in case of modified (i) SMA, and (ii) BC, and DBM by using fly ash and slag are found to be 5% and 4% respectively.

- Using the same Marshall specimens prepared at their OPCs and OBCs by using both (i) stone dust as filler and (ii) replacing of stone dust by fly ash and fine aggregate by slag, for test under normal and wet conditions it is observed that the retained stability increases with addition of polyethylene in the mixes, and BC with polyethylene results in highest retained stability followed by DBM with polyethylene and then SMA with polyethylene.
- Addition of polyethylene reduces the drain down effect, though these values are not that significant. It may be noted that the drain down of SMA is slightly more than BC without polyethylene. However, for all mixes prepared at their OPC there is no drain down.
- In general, it is observed that the Indirect Tensile Strength (ITS) value decreases with increase in temperature and for a particular binder, when polyethylene gets added to the mixes the value further increases in both cases. The BC mixes with polyethylene result in highest indirect tensile strength values compared to SMA, followed by DBM.
- It is observed that by addition of polyethylene to the mixture, the resistance to moisture susceptibility of mix also increases. BC with polyethylene results in highest tensile strength ratio followed by DBM mixes with polyethylene and SMA mixes with polyethylene for both cases.
- It is observed from the static creep test that deformation of mix generally decreases by addition of polyethylene at all test temperatures used. The BC mixes with polyethylene result minimum deformation compared to others.

From the above observations it is concluded that use of waste polyethylene in form of packets used in milk packaging locally results in improved engineering properties of bituminous mixes. Hence, this investigation explores not only in utilizing most beneficially, the waste non-degradable plastics, but also provides an opportunity in resulting in improved pavement material in surface courses thus making it more durable.

6.1 Future Scope

1. Many properties of SMA, BC and DBM mixes such as Marshall Properties, drain down characteristics, static tensile strength, and static creep characteristics have been studied in this investigation by using only VG 30 penetration grade bitumen and polyethylene. However, some of the properties such as fatigue properties, resistance to rutting, dynamic indirect tensile strength characteristics and dynamic creep behavior needed to be investigated.

2. In present study polyethylene is added to them mix in dry mixing process. Polyethylene can also be used for bitumen modification by wet mixing process and comparisons made.
3. Microstructure of modified bituminous mixture should be observed by using appropriate technique to ascertain the degree of homogeneity.
4. Combination of paving mixes formed with other types of plastic wastes which are largely available, wastes to replace conventional fine aggregates and filler an different types of binders including modified binders, should be tried to explore enough scope of finding suitable materials for paving mixes in the event of present demanding situations.

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