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Experimental Study on Partial Replacement of Bitumen by Low Density Plastic Waste

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Abstract: ***Development of a country depends on the connectivity of various places with adequate road network. Roads are the major channel of transportation for carrying goods and passengers. They play a significant role in improving the socio-economic standards of a region. Roads constitute the most important mode of communication in areas where railways have not developed much and form the basic infrastructure for the development and economic growth of the country. In India, Flexible pavement is widely used in most of the road networks. It is important that steps have to be taken to increase the life of the bituminous pavements. Flexible pavement is often subjected to problems like rutting, cracking, and other failures due to repeated traffic loads. In this project, we aim to replace certain amount of bitumen with waste plastic to improve the properties of bituminous pavement.***

Keywords: Flexible pavement, bitumen, Plastic waste,Bituminous mix

1. Introduction

Bituminous mixes are most commonly used all over the world in flexible pavement construction. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together, laid down in layers and then compacted. Today's asphaltic concrete pavements are expected to perform better as they are experiencing increased volume of traffic, increased loads and increased variations in daily or seasonal temperature over what has been experienced in the past. It is important to improve properties of bituminous mixes by adding suitable additives like plastic waste. Research has indicated that the addition of polymers to asphalt binders helps to increase the interfacial cohesiveness of the bond between the aggregate and the binder which can enhance many properties of the asphalt pavements to help meet these increased demands. Plastic waste is one of the major problems in India, it's non-bio-degradable nature makes it hazardous for living beings so it is better to use the properties of plastic in bituminous mix which tends to reduction of plastic waste in nature.

2. Materials Used

2.1 Bitumen

Bitumen is a mix of common lipids that are incredibly gooey, sticky, dissolvable in carbon-di-sulphide and is made from exceptionally combined polycyclic hydrocarbons. Actually, Happening or rough bitumen is a sticky, tar like kind of oil which is so thick and considerable that it must be warmed or debilitated before it will stream. At room temperature, it is much like chilly molasses. Refined bitumen is the remaining part gained by incomplete refining of crude oil. It is the heaviest bit and the one with the most surprising limit, rising at 525°C.

In this project, we had used bitumen with grade VG 30. VG-30 is primarily used to construct extra heavy duty Bitumen pavements that need to endure substantial traffic loads. It can be used in lieu of 60/70 Penetration grade.

Table 1

Properties	*Limits as per IS 73-1992*	*Test Results*
Softening point, ºC	40-60 ºC	**46 ºC**
Ductility at 27º C, cm	>75 cm	**87 cm**
Penetration value, mm	80-100 mm	**83 mm**
Specific Gravity	-	**1.02**

2.2 Aggregate (Filler)

Aggregate is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world. The aggregate serves as reinforcement to add strength to the overall composite material.

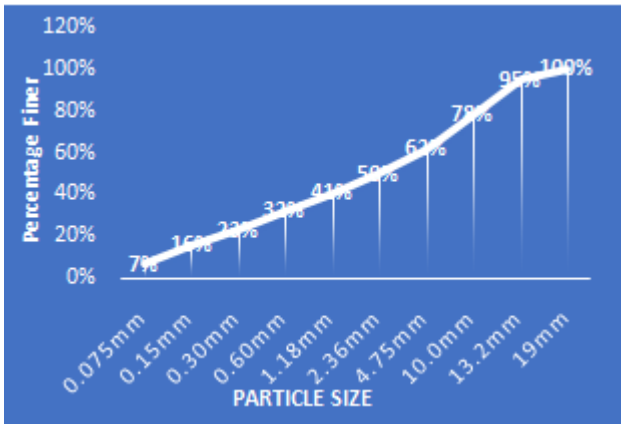
In this project, we have used Aggregates of Grading II with sieve specification 13.2mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, 0.15mm, 0.075mm.

Table 2: Specific Grading of Aggregate

Sieve Size (mm)	Cumulative Percentage Passing by wt.	Retain Percentage Taken	Passing wt. (gm)	Retain wt. (gm)
	Grade II			
19	**100**	-	1200	0
13.2	**79-100**	5%	1140	60
10	**70-88**	17%	936	204
4.75	**53-71**	16%	744	192
2.36	**42-58**	12%	600	144
1.18	**34-48**	9%	492	108
0.60	**26-38**	9%	384	108
0.30	**18-28**	9%	276	108
0.150	**12-20**	7%	192	84
0.075	**4-10**	9%	84	108
PAN	-	5%	-	60
Total	-	-	-	**1176 gm**
Now we add 24gm (2%) cement in the mixture.				

Table 3

Test	Test Method	Requirements	Achieved
Impact Value	IS: 2386 (Part-4)	24% Max	20.55 %
Water absorption	IS:2386 (Part-3)	3% Max	1.2 %
Specific gravity Course aggregate Fine aggregate	 IS:2386 (Part-3)	 2.6% Min 2.6% Min	 2.96% 2.85%
Shape test Flakiness & Elongation index (combined)	IS: 2386 (Part-1)	30% Max	29.62 %



Percentage Finer VS Particle Size Graph

2.3 Low Density Plastic Waste (LDPE)

Plastic is material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be moulded into solid objects. Plastics are typically organic polymers of high molecular mass and often contain other substances. They are usually synthetic, most commonly derived from petrochemicals. In this Project, we had used low density plastic which is a thermoplastic made from the monomer ethylene. It is the first grade of polyethylene. It is defined by a density range of 0.910–0.940 g/cm^3. 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. Itis widely used for manufacturing various containers, dispensing bottles, wash bottles, tubing, plastic bags for computer components, and various moulded laboratory equipment. It's most common use is in plastic bags.

Advantages of LDPE

- Low Cost
- Low Water Absorption
- Low specific Gravity
- Moisture resistance
- Good chemical resistance
- Readily Processed by all Thermoplastic methods
- Good impact strength

3. Objective

- Selection of the materials required for desired bituminous mix (i.e. Bitumen, Aggregate (Filler) & Plastic waste) and perform different tests on them to get suitable properties.
- To find bitumen thickness of road required on a certain area of study by pavement design method.
- To find optimum bitumen content in bituminous mix with the help of Marshall stability test on mix of bitumen and aggregate (filler).
- To specify percentage replacement of Low density plastic waste in bituminous mix according to optimum bitumen content calculated before.
- To perform Marshall stability test again at different percentage of Low density plastic (i.e. 1.5%, 2%, 2.5%) replaced in bituminous mix and comparison of different values with simple bituminous mix.

4. Methodology

In this project, we perform several tests on bitumen to get physical properties of bitumen used (Given in table1) that are-

1) Softening point test
2) Ductility test
3) Penetration test

Then we grade the aggregate (filler) according to MORTH (Table2) and then perform several tests to get a workable values of their properties(Table3) –

1) Impact value test
2) Water absorption test
3) Specific gravity test
4) Shape test (Flakiness and Elongation)

Next a simple bituminous mix is prepared and then with different percentage of plastic (1.5, 2 & 2.5) and then all

specimens are placed in Marshall apparatus to compare different properties of mix.

Figure: Tests on Bitumen

Figure: Tests on Aggregate (filler)

4.1Marshall Stability Test

In next step, we had prepared a bituminous mix by mixing bitumen and aggregate at a certain bitumen contents. The main purpose of this test is to find the optimum bitumen content from these different bitumen contents. Bituminous concrete mix is commonly designed by Marshall Method.This test is extensively used in routine test program for the paving jobs.

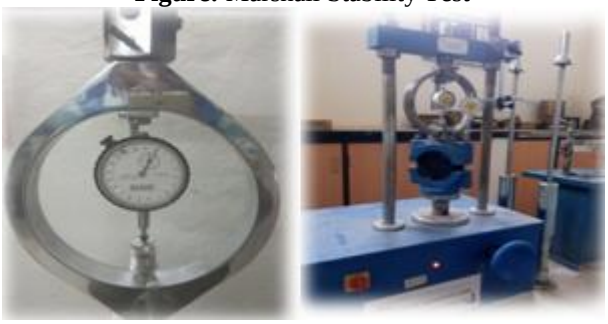
The stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 60^0C. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test (flow value may also be measured by deformation units of 0.1 mm).

This test attempts to get the optimum binder content for the aggregate mix type and traffic intensity. This is the test which helps us to draw Marshall Stability vs. bitumen percentage.

5. Procedure

1) Heat the weighed aggregates and the bitumen separately up to 170^0C and 163^0C respectively.
2) Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
3) Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
4) Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
5) A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or 1 bitumen content.
6) Before testing of the mould, keep the mould in the water bath having a temperature of 60^0C for half an hour.
7) Check the stability of the mould on the Marshall stability apparatus.

Figure: Marshall Stability Test



This test provides certain data about different properties like stability, flow, unit weight etc. with respect to different bitumen contents by several graphs (discussed in results). With the help of these graphs we can find the optimum bitumen content for simple bituminous mix. After we get

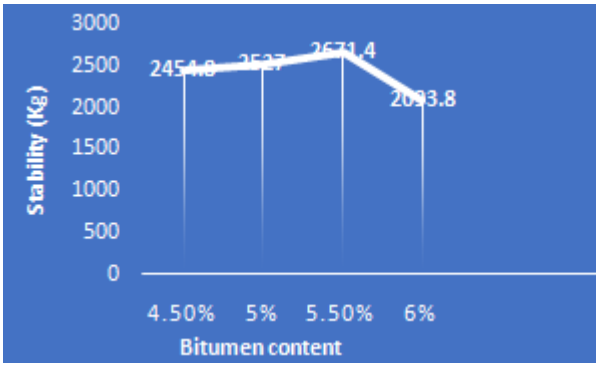
optimum bitumen content by Marshall method, we will design a pavement thickness with the help of CBR method of pavement design (As per IRC 37 2012 Guidelines). Then we replace certain percentages of bitumen from bituminous mix with low density plastic and Marshall stability test will be again carried out and at last we compare properties of different percentage replaced bituminous mix to get a workable bituminous mix.

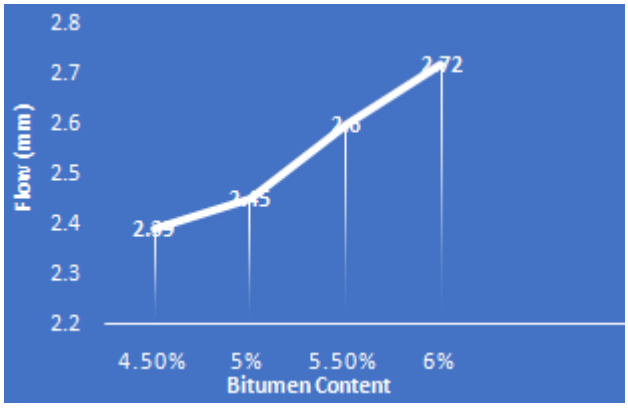
6. Results and Observations

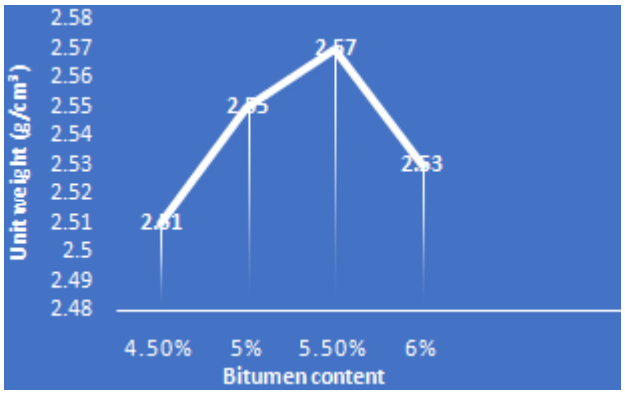
Table 4

Bitumen Content (%)	Unit weight (g/cm³)	Stability (kg)	Flow (mm)
4.5%	2.51	2454.8	2.39
5.0%	2.55	2527.0	2.45
5.5%	2.57	2671.4	2.60
6.0%	2.53	2093.8	2.72

Graphs based on Marshall stability test of bituminous mix





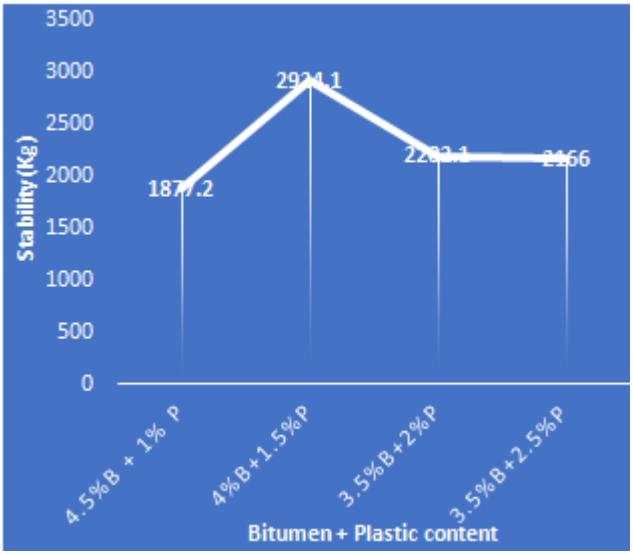


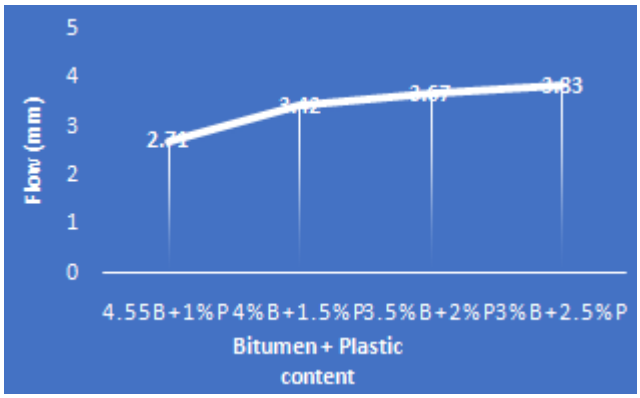
From the previous graphs of Marshall Stability Test, we computed that the Optimum Bitumen content of a simple bituminous mix is 5.5% of total weight of specimen.

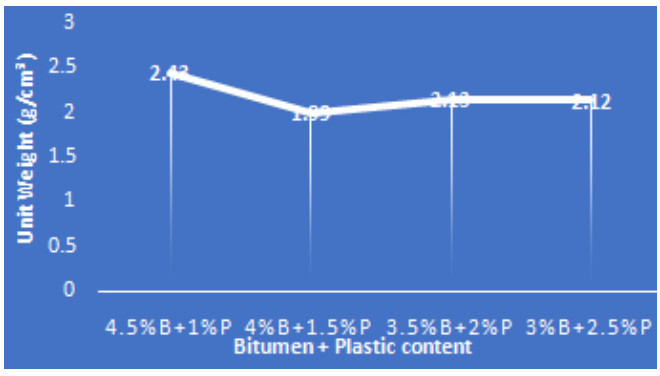
Table 5

Bitumen content + Plastic waste	Unit weight (g/cm³)	Stability (kg)	Flow (mm)
4.5%B + 1%P	2.43	1877.2	2.71
4%B + 1.5%P	1.99	2924.1	3.42
3.5%B + 2%P	2.13	2202.1	3.67
3%B + 2.5%P	2.12	2166.0	3.83

Graphs of bituminous mix with different percentage of Low density plastic based on Marshall stability test







7. Conclusion

As we observed from above Marshall stability curves of simple bituminous mix firstly we get optimum bitumen content as 5.5% then after replacing bitumen from optimum bitumen content with low density plastic waste (i.e. 1%, 1.5%, 2% & 2.5%). We get different Marshall stability values from which we conclude that we can replace up to 1.5% bitumen with LDPE as the stability of this mix is much higher as compare to stability of optimum bitumen content and as we increase the percentage replacement it tends to decrease as compare to optimum bitumen content.

References

[1] Vetturayasudharsanan R. et al (2017)
In this paper, they used the waste materials like lignin and plastic as a replacement material for bitumen in the percentage of 5&10%, 10&15%, 15&20%, 20&25% respectively. It has been found that lignin can act as a binding material for asphalt hence improving the properties of the bitumen. By the mix proportions which is analyzed and determined by series of tests like penetration, ductility, viscosity, softening point, it is found that the mix proportion of 15&20% has efficient results when compared to other proportions used.

[2] Wayal Abhaykumar S. et al (2013)
In this study, we have used polymer and crumbed rubber as a binder with respect to aggregate andbitumen. They give different Marshall stability test values which shows and proves that by adding certain amount of waste in the bitumen, it gains strength and thus becomes more durable and tough. So, if roads are constructed as plastic-rubber tar road,there will be less waste plastic & waste tires available on the road.

[3] Rajkumar P. (2015)
The study has tried to understand the extent of usage of plastic materials and the mode of disposal thereof by the people. It is an empirical study based upon the data collected from the Tiruchirappalli City of Tamil Nadu, India. The data collected for the study are from 515 residents of the city who are selected through multi-stage random sampling method. The study shows that the economic status i.e., income level has a bearing on the usage and disposal of plastic materials. The low-income group stands low in attitude towards disposal and environmental concern. They dispose the plastic wastes in the open area in such a way as to cause environmental degradation.

[4] Mohanty Monika (2013)
It is a study on use of waste polyethylene in bituminous paving mixes. In this study, an attempt has been made to use reclaimed polyethylene which has been obtained from plastic packets used in packaging of a very popular brand of milk named OMFED, in dry form with the aggregates like a fiber in a bituminous mix.

[5] **Sharma S.K**.
A book on Highway Engineering.

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