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A Study on Use of Plastic Wastes for Road Construction

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ABSTRACT

Nowadays, disposal of waste plastic has become a major waste management problem in the world. Plastic is a non-biodegradable material and it is found that the material can remain on earth for 4500 years without degradation. Plastic waste is used as modifier of bitumen to improve some of bitumen properties of Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. Use of higher percentage of plastic waste reduces the need of bitumen by 10%. Hence in this present investigation efforts have made to identify the potential application of waste plastic in civil engineering projects. In this present study the aim is to investigate the optimal use of waste plastic in bitumen for road pavement construction. From the above experimental investigation, it is found that the Stability of 80/100 bitumen at 8% of waste plastic coated on aggregates has shown higher value than that of the 60/70 grade bitumen.

KEYWORDS: Bitumen, High Density Polyethylene (HDPE), Low density Polyethylene (LDPE), Marshall Stability method, Waste plastic, Aggregate, Bitumen, plastic-bitumen-aggregate mix, plastic modified bitumen and plastic modified aggregate.

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INTRODUCTION

Nowadays, plastic is everywhere in today's lifestyle. The term "Plastics" includes materials composed of various elements such as carbon, hydrogen and oxygen. Plastics are macromolecules, formed by polymerization and having the ability to be shaped by application of reasonable amount of heat and pressure or another form of forces**.**

Plastic is a very versatile material and is found to be almost 5% in municipal solid waste. The experimental studies at several institutes found that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found (a) to give higher strength, (b) higher resistance to water and (c) better performance over a period of time**.** Plastic waste replaces 10% to 15% of bitumen, and thereby saves approximately Rs.35000 to Rs.45000 per kilometer of a road stretch.

Plastic waste in road construction eliminates the plastic shrinkage, cracking of road surface and reduces the drying shrinkage to some extent. The threat of disposal of plastic will not solve until the practical steps are not initiated at the ground level. The field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems. The use of these materials in road making is based on technical, economic, and ecological criteria.

Thus, use of waste plastic for the construction is efficient where there is lack of funding and facility is available.

EXPERIMENTAL INVESTIGATION

Objective

The main objective of this experimental investigation is to formulate few testing approach for the evaluation of strength offered by plastic waste mixes. Keeping in view of the above point the following specific objectives have been set for study.Laboratory studies will be carried out on polymer modified asphalt mixtures to evaluate engineering properties using marshal stability.

• To study basic properties of aggregates and plain bitumen.

• To study the strength and stability characters of BC (Bitumen Concrete) mix for 60/70 and 80/100 grade bitumen.

• To study the effect of waste plastic on strength and stability characteristics of BC mix.

- Cost efficient pavement material.
- To check the coating property of aggregate with waste plastic materials
- Making environment less harm from plastic waste

EXPERIMENTAL PROGRAM

Materials Used

The basic materials for Bitumen Concrete are required such as:[5]

- Bitumen,
- Aggregates,
- Filler,
- Waste Plastics.

Bitumen

Bitumen is a material which is a byproduct of petroleum refining process. It is a highly viscous at temperature above 100 degrees Celsius and is solid at room temperature.[1]

For the present investigation 60/70 and 80/100 is employed. Bituminous materials or asphalts are extensively used for roadway construction, primarily because of theirexcellent binding characteristics and water prolongs properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementations substances consists high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar doesn't.

Table 1: Properties of bitumen used in present study

Sr. No.	Properties	Grades		Test Methods
		60/70	80/100	
1.	Penetration Tests @27ºC	67	90	IS: 1203-1978
2.	Softening Point(R & B)ºC	51	41	IS: 1205-1978
3.	Ductility @ 27ºC, cm	73.5	75.5	IS: 1208-1979
4.	Specific Gravity of Bitumen	1.017	1.02	IS: 1202-1980

Aggregates

The aggregates shall comply to IRC:111-2009, for dense graded mixes and IRC:14-2004, IRC:SP:78-2008 and IRC:11 0-2005 for open graded mixes respectively. Aggregates are tested for strength, toughness, hardness, shape, and water absorption.

Table 2: Properties of Aggregates used in present study

Sr. No.	Aggregate tests	Test Results Obtained	Requirements a per Table 500—4 of MoRT&H (IV Revision) Specifications
1.	Crushing Value (%)	24.8	-
2.	Impact Value (%)	20.8	Max. 24%
3.	Los Angeles Abrasion Value (%)	32	Max. 30%
4.	Combined Index (%)	29	Max. 30%
5.	Water Absorption (%)	0.25	Max. 2%
6.	Specific gravity of coarse Aggregates	2.72	2.5-3.0
7.	Specific gravity of Fine Aggregates	2.76	
8.	Specific gravity of Filler	2.5	

Filler

The filler for dense graded mixes shall comply with IRC:111-2009.

Plastics

The waste plastics are collected from many sources like industries, commercial sector, agricultural sector, and

Municipal sector. After the cleaning of plastic, the waste plastic shall conform to the size passing 2.36 mm sieve and retained on 600-micronsieve. To ascertain the ability of plastic to mix with the binder, the melt-flow value shall be tested asper ASTM D 1238-2010, for which the range shall be as follows:

For LDPE: 0.14-58 gm/10 min

For HDPE: 0.02-9.0 gm/10 min

Adequate road aggregate has been used and different types of plastics have been used as specified below with the desirable properties.[4]

Polyethylene Terapthalate (PET) is the type of plastic labeled with the #1 code on or near the bottom of bottles and containers and is commonly used to package soft drinks, water etc. Waste bottle plastic of water cans is made up of either High Density Polyethylene (HDPE) or Low Density Polyethylene (LDPE).

Table 3: Properties of plastic used in present study

Properties	Results Obtained
Specific Gravity	1.03
Melting Point (ºC)	250-260
Sieve Analysis	Passing 4.75 mm sieve retained on 2.36 mm sieve

RESULTS AND DISCUSSION

Marshal test moulds were prepared for different percentages of plain bitumen by varying the bitumen percentage from 3.5% – 6.5% by increment of 0.5%. The specimens were kept for 24hrs and then were de molded. Marshall Stability test was conducted and parameters like flow value, bulk

density, percentage air voids, voids filled with bitumen (VFB) and voids filled with mineral aggregates (VMA) were calculated. The optimum bitumen content, maximum bulk density and 4% volume of voids for bitumen grade 60/70 and 80/100 were calculated using the above properties. Also maximum stability was evaluated.

Marshall Stability method was also conducted by adding waste bottle plastic of varying percentage from 0-10% for the know binder content of 60/70 and 80/100 grade bitumen. The maximum stability attained for a particular percentage of plastic is noted down.

Table 4: Properties of bituminous mix after adding waste plastic for 60/70 grade bitumen

Waste Plastic %	Gt	Gb	Vv	VMA	VFB	Vb	Stability Value, kg	Flow Value in 0.25mm
0	2.58	2.284	7.701	19.477	60.462	11.776	1231	5.7
2	2.57	2.285	7.563	19.326	60.865	11.763	1272	6
4	2.54	2.278	5.343	17.201	68.937	11.858	1291	6
6	2.52	2.356	5.558	17.273	67.823	11.715	1300	6
8	2.48	2.284	4.067	15.786	74.238	11.719	1552	6
10	2.46	2.327	3.776	15.446	75.549	11.668	1525	6
12	2.43	2.320	2.658	14.283	81.387	11.624	1558	5.7

Table 5: Properties of bituminous mix after adding waste plastic for 80/100 grade bitumen

Waste Plastic %	Gt	Gb	Vv	VMA	VFB	Vb	Stability Value, kg	Flow Value in 0.25mm
0	2.60	2.333	11.978	23.612	49.269	11.633	1529	5
2	2.56	2.330	9.139	20.892	56.255	11.753	1508	5
4	2.53	2.344	7.636	19.436	60.711	11.800	1609	4.7
6	2.51	2.325	6.492	18.295	64.518	11.803	1672	4.3
8	2.49	2.394	4.652	16.580	71.942	11.928	1963	4.7
10	2.46	2.326	5.842	17.505	66.627	11.663	1736	4.7
12	2.40	2.315	2.140	13.925	84.631	11.785	1573	4.3

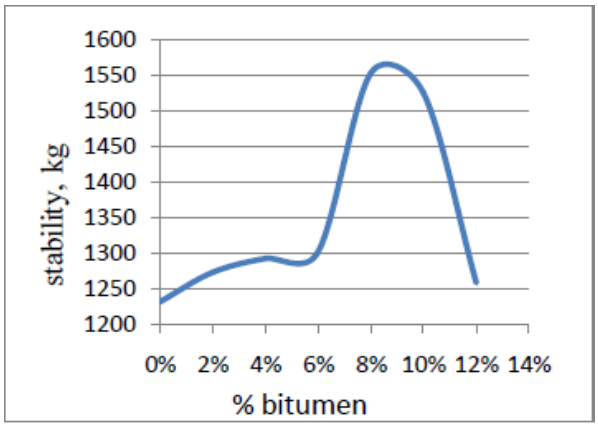

Figure1. For 60/70 grade Bitumen

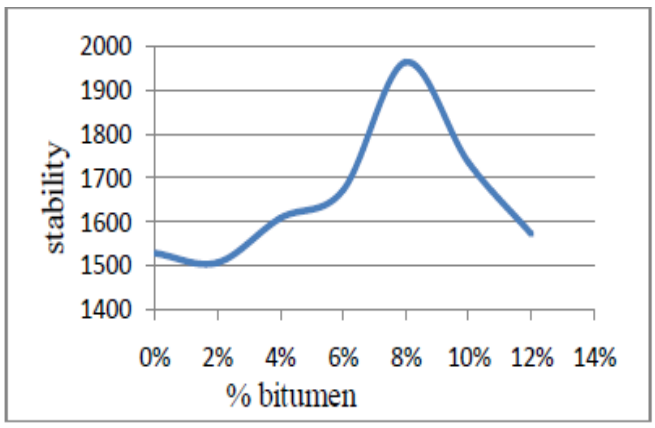

Figure2. For 80/100 grade Bitumen

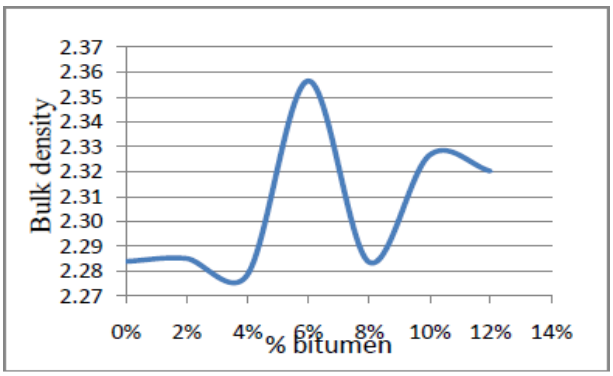

Figure3.For 60/70 grade Bitumen

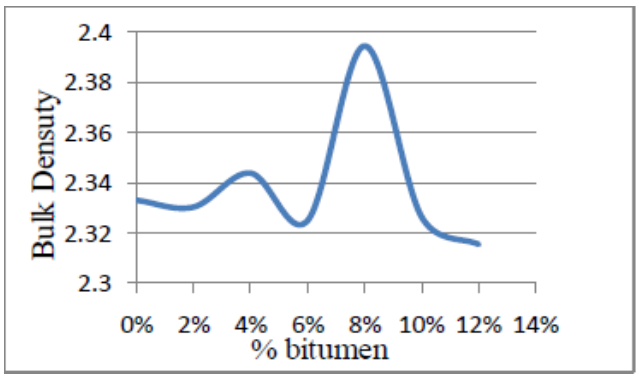

Figure4. For 80/100 grade Bitumen

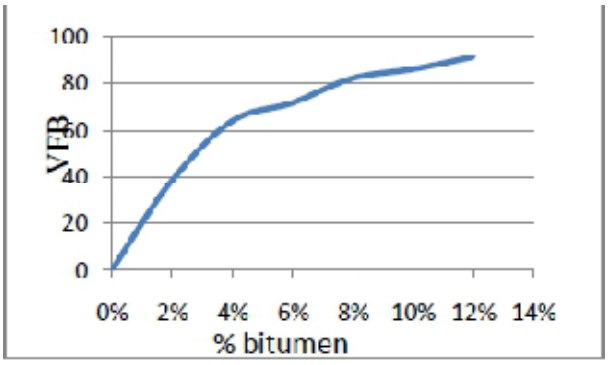

Figure5. For 60/70 grade Bitumen

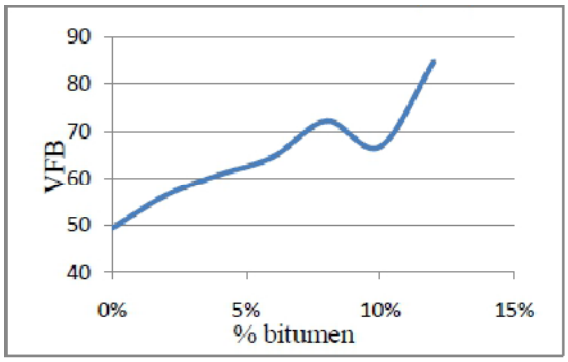

Figure6. For 80/100 grade Bitumen

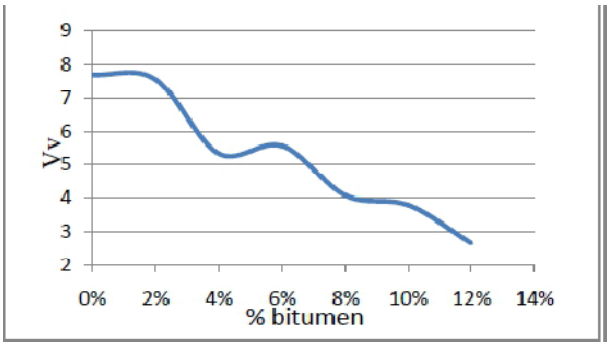

Figure7. For 60/70 grade Bitumen

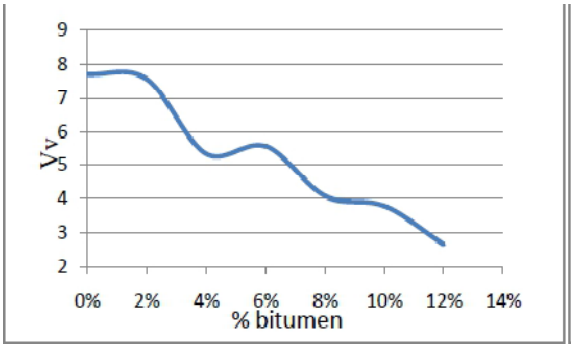

Figure8. For 80/100 grade Bitumen

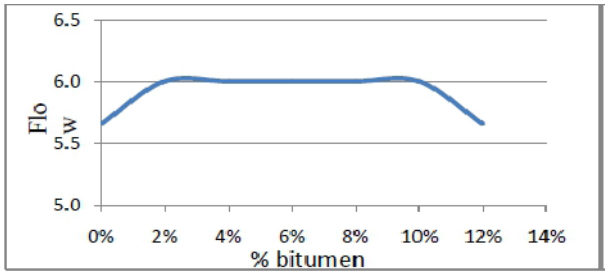

Figure9. For 60/70 grade Bitumen

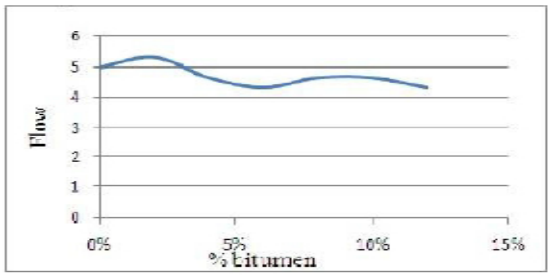

Figure10. For 80/100 grade Bitumen

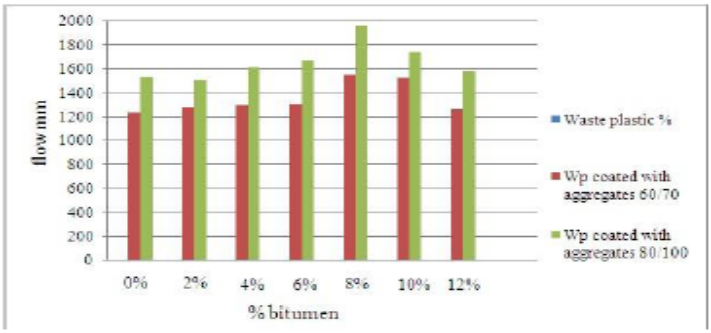

Figure11. Comparison of stability values of 60/70 and 80/100

DISCUSSIONS

From the above investigation it is observed that Optimum bitumen content obtained for bituminous concrete grade I mix for 60/70 grade bitumen was 5% and 80/100 grade bitumen was 5.1% as per the specification of MORT&H standards. The stability obtained for the respective OBC was 12.606 Kn and 17.334 Kn. Waste shredded plastic bottle were added in the increasing percentage of 0% - 12% to bituminous concrete mix and an Addition of 2% to 12% waste shredded plastic bottles by the weight of bitumen to BC mix has resulted in following:[3]

(a) Stability of 80/100 bitumen at 8% of waste plastic coated on aggregates has shown higher value than that of the 60/70 grade bitumen.

(b) The stability value of the mix in unsoaked condition has high values than compared to the soaked specimens. Stability value decreases as the soaking time of the specimen increases.

(c) Specimen with 3days soaking results in least stability than that of 1day and 2day soaking periods.

For Plain 60/70 Bitumen

a) The waste plastic which is added to aggregate mix by heating upto 260-2800C. then the bitumen is added to form the grade I bituminous concrete and optimum bitumen content of 5% has shown the following results:

• The maximum stability was 1552 Kg at 8% waste plastic by the weight of bitumen, 6mmflow at 8% waste plastic and 74.238 VFB at 8% waste plastic

- Bulk density □b was found to be maximum of2.356 gm/cc at 6% waste plastic and then reduces to 2.284 gm/cc at 8% waste plastic.
- Voids in the total mix Vv varies from 4% to 10% by varying the waste plastic content from2% - 12% and at 8% waste plastic Vv was found to be 4.067%.

b) By blending shredded waste plastic to the bitumen by heating and then adding the required aggregate to form BC mix grade I resulted in improper mix and stability obtained is less than thatof the optimum binder content [OBC]. This is due to following:

• Improper blending of plastic in bitumen. This is because the melting point of poly ethyleneteraphthalate [PET] is 260-2800ºC

• Since the melting temperature of plastic is too high it is difficult to melt plastic in bitumen to get a proper blend.

• Bitumen should be heated up to the temperature of 260-2800C in order to obtain the proper blend. If this is done there will be a chance of bitumen to catch fire and also there will bea loss in weight of bitumen.

For Plain 80/100 Bitumen

a) The waste plastic which is added to aggregate mix by heating upto 260-2800C. Then the bitumenis added to form the grade I bituminous concrete and optimum bitumen content of 5% has shown the following results:

• The maximum stability was 1963 Kg at 8% waste plastic by the weight of bitumen, 4.7mmflow at 8% waste plastic and 71.942 VFB at 8% waste plastic

• Bulk density □b was found to be maximum of 2.394 gm/cc at 8% waste plastic and then reduces to 2.315 gm/cc at 12% waste plastic.

• Voids in the total mix Vv varies from 8% to 10% by varying the waste plastic content from2% - 12% and at 8% waste plastic Vv was found to be 4.652%.

b) By blending shredded waste plastic to the bitumen by heating and then adding the required aggregate to form BC mix grade I resulted in improper mix and stability obtained is less than that of the optimum binder content [OBC]. This is due to following:

• Improper blending of plastic in bitumen. This is because the melting point of poly ethyleneteraphthalate [PET] is 260-2800ºC.[2]

• Since the melting temperature of plastic is too high it is difficult to melt plastic in bitumen to get a proper blend.

Bitumen should be heated up to the temperature of 260-2800C in order to obtain the proper blend.

If this is done there will be a chance of bitumen to catch fire and also there will bea loss in weight of bitumen. All the parameters like stability, flow, bulk density, voids and VFB shows that, the addition of waste plastic in mix has no much change in fluidity and rigidity parameters as compared to that of plain bituminous mix.

CONCLUSION

In the present study, the importance was to add the shredded waste plastic bottles to bituminous concrete (BC) mix and to evaluate the various mix properties like Marshall Stability,

flow, bulk density, voids in the mix and VFB. Also the effect of soaking conditions of the mix was investigated.

- Indirect tensile strength was investigated for OBC and 8% plastic coated on aggregates which had yielded the highest marshal stability.
- The optimum plastic content for 60/70 and 80/100 grade bitumen was 8%.
- For both 60/70 and 80/100 grade bitumen with plastic content 8%, the maximum stability was achieved in 80/100 grade bitumen.
- Wet process i.e. blending of plastic and bitumen cannot be carried out due to the plastic which is used has a very high melting point.
- There is an increase in stability up to 15% and 10% after adding waste plastic to the mix in 60/70 and 80/100 grade bitumen respectively.
- There is a decrease in stability value in water sensitivity test results. Unsoaked specimens show high stability value but soaked specimens showed a decreasing stability value.

Hence there is an increase in stability with the addition of PET plastic in asphalt mix by incorporating dry process this can be used in highway construction for better stability for the appropriate traffic

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