Role of Waste Plastic and Waste Rubber on Dense Bituminous Macadam Layer of Flexible Pavement

Sk Sohel Islam, Ayana Ghosh, Riddha Chaudhauri

Abstract— In India major part of roads are flexible in nature which deteriorate rapidly during their design life owing to high traffic intensity, overloading of commercial vehicle, improper drainage system etc. resulting in early initiation of distress condition. These governing factors emphasizes on the necessity of roads with better stability and engineering design. In a country like India with its adverse climatic condition roads made of conventional bitumen fail to impart the required stability hence modification of bitumen as binder is the need of the hour. Ceratain admixtures can be used to partially replace the conventional bitumen to improve desired mechanical characteristics for particular road mix in dense bitumen macadam layer. So replacing the virgin polymer by such recycled polymers in bituminous blends is a promising alternative environmentally favorable, offering a sustainable life-cycle for some petroleum-derivative polymers. This investigation deals with two major groups of recycled polymers namely crumb tire rubber and waste thermoplastic polymers. Another important agriculture waste RHA, produced abundantly in different parts of world and has a pozzolanic characteristic is used in this investigation as alternative filler material by replacing the conventional one.

Index Terms— Dense Bituminous Macadam, Marshall Test, Modified bitumen, Rice Husk Ash, Stability, Waste plastic, Waste rubber

1 INTRODUCTION

IN India it is estimated that over 42 lakh kilometers of road exists [12] which carries close to 90% of passenger traffic and 70% of freight transport. Major part of such roads are flexible in nature, deteriorated rapidly during their design life in some parts of India due to different causes e.g. high traffic intensity, overloading of commercial vehicle, improper drainage system etc. resulting early development of distress condition in the form of cracks, rutting, raveling etc. As the quality of bitumen is one of the governing parameter that imparts bond among the aggregates and may be liable for forming the distresses in the pavement structure. So to arrest same, properties of bitumen and bituminous mixes can be improved by incorporating certain additive or blend of additives. There are numerous laboratory investigations that have shown various beneficial effects of adding polymers to bitumen and using polymer modified binders (PMB) in asphalt mixtures. On the other hand, economic growth and changing consumption and production pattern are resulting into rapid increase in generation of waste materials such as plastic wastes, rice husk ash (RHA), waste tyres of truck and buses etc. Due to lack of integrated solid waste management, most of the wastes is neither collected nor disposed off in appropriate way, posing as a toxic threat to environment. Such waste products are causing littering and chocking of sewerage system also. So the reutilization of postconsumer or postindustrial polymeric materials, and their return to industry, could be a suitable way of solving environmental concerns, offering low-cost recycled resources of polymer. Major sources of polymeric substances may be the high quality carry bags, PET bottles and milk pouches, scrap tires of vehicles available in urban area. The key constituents of these materials are different grades of thermoplastic polyethylene. In this work an attempt has been made to use the waste materials as bitumen modifier to improve the properties of the bitumen mix. Experimental results are indicated that using the waste materials in bitumen is not only a cost effective mix but also it is a very good solution in terms of improving bitumen pavement mix properties. Another very important question comes in this regard is about the reliability and sustainability of such solutions.

2 LITERATURE REVIEW

The concept of utilization of the waste materials in bituminous pavement construction industry emerged in India since 2000. So the literature review reports varied levels of performance of recycled wastes on bituminous mixes. Mohammad et al. (2007) investigated that polyethylene as one sort of polymers to enhance asphalt mixture properties and suggested as the best type of polyethylene by achieving the incremental stability of the mix. The benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic was developed by Bindu et al. (2010).

A study by Chen et al.(2002) indicated that incorporation of polymers into asphalt binders mitigated the major causes of asphalt pavement failures

Rice husk ash is another waste used in investigation as filler material in hot mix asphalt instead of limestone and got better Marshall Stability value (Sargin et al. 2013)

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3 RESEARCH SIGNIFICANCE

The purpose of this study is to investigate the utility of waste plastic, waste rubber as bitumen modifier due to their polymeric characteristics. RHA has been used as filler due to its pozzalonic property in the construction of Bituminous Macadam layer. So the modification in the properties of bituminous mix by utilizing such wastes, provide a cost effective and durable roadway pavement by improving aggregate-bitumen bond and by reducing stripping. Further to avoid its negative impacts on environment and public health by disposing of the said wastes in appropriate manner.

4 MATERIALS USED AND THEIR PROPERTIES

Present study involves the use of materials like aggregate, bitumen, RHA, waste plastic and waste rubber, where RHA acted as a filler material and waste plastic and waste rubber used as bitumen modifier.

4.1 Aggregate

Aggregates take the major role of pavement structure. It has to bear stresses occurring due to the wheel loads on thepavement and on the surface course. They also have to resist wear due to abrasive action on traffic. The mineral aggregate used in this study were obtained from Pakur (Jharkhand) quarry. Representative samples have been tested in the laboratory and results are presented in Table-1.

TABLE 1
PHYSICAL PROPERTIES OF AGGREGATE

Test	Result
Impact value	21.51%
Flakiness Index	14.9%
Elongation Index	14.3%
Abrasion Value	22.4%
Specific gravity	2.8
Water absorption	0.12

4.2 Rice Husk Ash

RHA is a major by-product of the rice milling industry. About 20 – 22% rice husk is generated from paddy and about 25% of this total husk become ash when burn. It has a good pozzolanic property and non-plastic in nature. In this study RHA was collected from local rice mill of Burdwan, a district of West Bengal

TABLE 2
PHYSICAL PROPERTIES OF RHA

Properties	Value
Specific Gravity	1.95
Max. Dry Density (gm/cm^3)	0.93
Bulk Density (Kg/m^3)	86-114
Atterberg Limits	Non-Plastic
Soaked C.B.R (%)	13.72
Unsoaked C.B.R (%)	19.5

4.3 Bitumen

It is a semi-solid hydrocarbon product and highly viscous at temperature above 100 degrees celsius and is solid at room temperature. In this study, 60/70 pen grade bitumen has been selected.The physical properties of the same are given in table 3 along with their permissible limits as per IS specifications.

TABLE 3
PHYSICAL PROPERTIES OF BITUMEN

Type of test	Test Value	Permissible Limit
Penetration Value at 25^{0}c (1/10 mm)	67	60-70
Ductility Value at 25^{0}c (cm)	>100	>75
Softening Point (^{0}C)	52	40-55
Specific gravity (kg/m^3)	1.03	>0.99

4.4 Waste Rubber

Sources of waste rubber are the various commercial vehicles like trucks, busses, and trailers.In this study,waste tyre of buseswas used as rubber waste. Collectedrubber waste has beenpowdered bythe grinding machine andsubjected to mechanical sieve analysis to get the desired particle size passes from 150 mm sieves and retained in 75 mm size

5 EXPERIMENTAL PROGRAMME

The mix design for Dense Bituminous Macadam with Grading-I have been selected for this investigation by using the Marshall method. In this study, total tests were performed in two phases. In **first phase**, Marshall Properties were evaluated by using two different fillers e.g. cement and RHA and compared the evaluated properties against optimum bitumen content (OBC) with the MORTH specifications for selecting the best suitable filler. In **second phase,** modification of binder material was made by adding varying percentage of waste plastic and waste rubber and OBC was obtained for respective perentages of combined mix.

6 RESULTS AND DISCUSSIONS

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The Experimental results of mix design on dense bituminous macadam (DBM) by using different wastes are presented in this section.

In **First phase**, specimens were prepared by two different filler (Cement and RHA) @ 2% by wt. of aggregatewith varying bitumen contents @ 0.25% increment over a range of 4.5% to 5.25% and tested and OBC was determined. Evaluated results are given from fig 1- fig-6 and comparision is made in table 4

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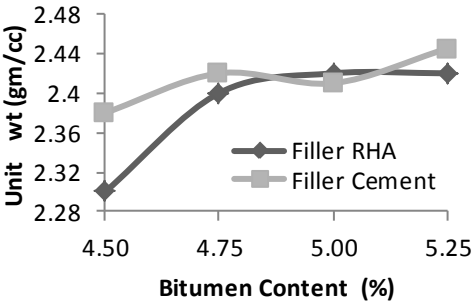


Fig. 1. Bitumen Content Vs Unit Wt

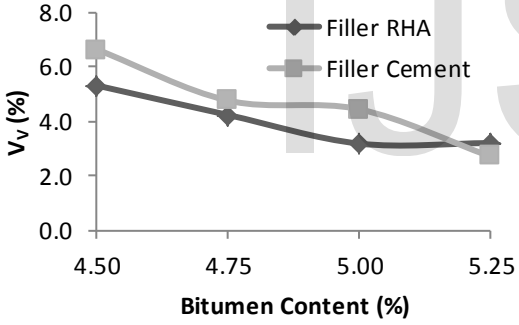


Fig. 2. Bitumen Content Vs Air Void

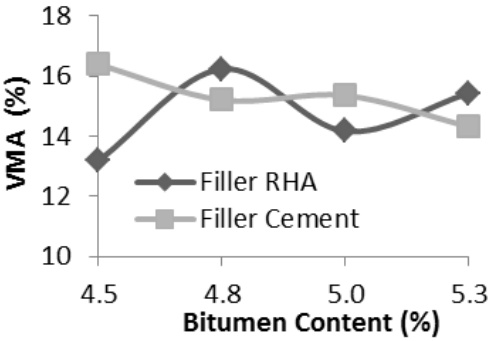
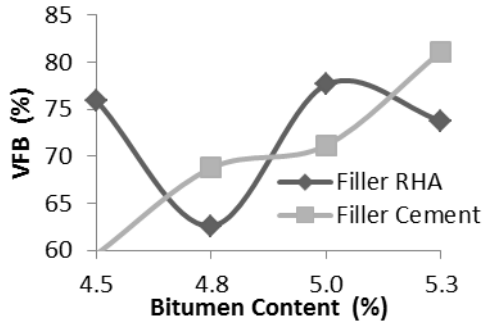
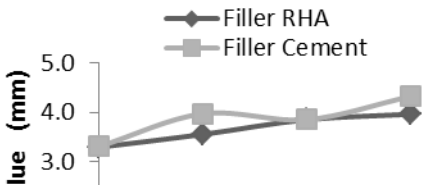


Fig. 3. Bitumen Content Vs VMA





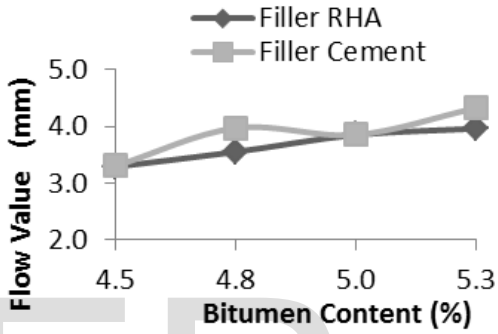


Fig. 5. Bitumen Content Vs Flow Value

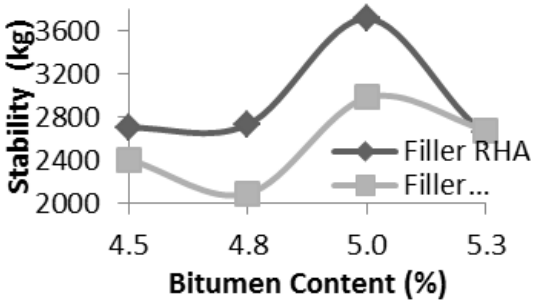


Fig. 6. Bitumen Content Vs Stability

TABLE 4

MARSHALL PROPERTIES OF DBM USING CEMENT AND RHA AS FILLER AGAINST OBC

Filler	Optimum Bitumen Content(%)	Vv(%)	VMA(%)	VFB (%)	Stability (KN)	Flow (mm)
Cement	5.08	4.15	15.36	73	21.35	2.97
RHA	4.91	3.4	14.55	75	36	3.8

In comparison between Marshall parameters obtained by using filler as cement and RHA, it is seen that OBC of DBM is 4.91% when added RHA as filler and it is 3.4% less than that of the conventional one. . Incremental stability value is also observed for RHA mixed DBM compared to that of the cement mixed DBM by reducing the percent air voids. However all the evaluated parametres of RHA mixed DBMsatisfied the standard specifications recommended by MORT&H.

In **second Phase**, Marshall Properties were determined by mixing various % of waste plastic and waste Rubber separately as well as in combination with the optimum bitumen content and tested results have been furnished in the table 5.

TABLE 5

MARSHALL PROPERTIES OF DBM WITH ADDITION OF 1 % BOTH WASTE RUBBER & WASTE PLASTIC

sample No.	Bitumen Content	Waste plastic +waste rubber		Stability Value (kg)	Flow Value (mm)	Unit wt. (gm/c.c)	V_v	VMA (%)	VFB (%)
1	4.30%	1%	1%	2235	2.8	2.38	4.69	14.45	67.57
2	4.50%	1%	1%	2670	3.1	2.40	3.88	13.73	71.70
3	4.70%	1%	1%	2910	3.5	2.41	3.48	143.37	73.94
4	4.90%	1%	1%	2850	3.9	2.39	4.29	14.09	69.58
	5.1	1	1	2320	4.2	2.42	3.08	13.01	76.29

TABLE 6

DIFFERENT MARSHALL VALUE CORRESPONDING TO OPTIMUM BITUMEN CONTENT:

Optimum Bitumen Content(%)	Vv (%)	VMA (%)	VFB (%)	Stability (KN)	Flow (mm)	Marshall Quotient
4.80	3.80	13.70	71.20	28.90	3.72	7.76

TABLE 7

MARSHALL PROPERTIES OF DBM WITH ADDITION OF 2 % BOTH WASTE RUBBER & WASTE PLASTIC

sample No.	Bitumen Content	Waste plastic + waste rubber		Stability Value (kg)	Flow Value (mm)	Unit wt. (gm/c.c)	V_v	VMA (%)	VFB (%)
1	4.30%	2%	2%	3935	3.10	2.39	4.97	15.91	68.77
2	4.50%	2%	2%	4880	3.30	2.41	3.86	14.80	73.95
3	4.70%	2%	2%	5760	3.80	2.42	3.23	14.38	77.52
4	4.90%	2%	2%	5330	4.20	2.39	4.25	15.27	72.19

TABLE 8

DIFFERENT MARSHALL VALUE CORRESPONDING TO OPTIMUM BITUMEN CONTENT:

Optimum Bitumen Content(%)	Vv (%)	VMA (%)	VFB (%)	Stability (KN)	Flow (mm)	Marshall Quotient
4.61	3.49	14.40	75	54	3.6	15

TABLE 9

MARSHALL PROPERTIES OF DBM WITH ADDITION OF 3 % BOTH WASTE RUBBER & WASTE PLASTIC

sample No.	Bitumen Content	Waste plastic + waste rubber		Stability Value (kg)	Flow Value (mm)	Unit wt. (gm/c.c)	V_v	VMA (%)	VFB (%)
1	4.30%	3%	3%	3210	3.30	2.39	4.80	14.28	68.65
2	4.50%	3%	3%	3960	3.45	2.40	4.10	13.51	73.46
3	4.70%	3%	3%	4890	3.60	2.40	3.48	13.36	74.96
4	4.90%	3%	3%	4800	4.30	2.42	3.10	12.8	76.2

TABLE 10

DIFFERENT MARSHALL VALUE CORRESPONDING TO OPTIMUM BITUMEN CONTENT:

Optimum Bitumen Content(%)	Vv (%)	VMA (%)	VFB (%)	Stability (KN)	Flow (mm)	Marshall Quotient
4.74	3.28	13.60	75.10	49	4.05	13

From the above Tables it can be reported that by using combination of 2% waste plastic and 2% waste rubber modified bituminous mix,gives the lowest optimum bitumen content ie.

4.61%. Corresponding to this OBC other Marshall properties are well acceptable as per MORT&H Specifications.

4 CONCLUSION

From the present investigation it is concluded that the specimen prepared by using 2% waste plastic and 2% waste rubber as modifying agent, optimum bitumen content becomes minimum and stability becomes maximum. These results also indicated that the waste modified bituminous mix is much stronger (61%) than that of conventional mix. Marshal Quotient (MQ) increased by 52% compared to that of conventional mix. Thus it meant that asphalt concrete having higher MQ values indicated a high stiffness mix with a greater ability to spread the applied load and the pavement being more resistance to pavement deformation. So from the present study it may be concluded that a high stable road service may be provided in cost effective way by using waste material and on the other hand solid waste disposal problem can be solved.

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