2012 International Conference on Future Environment and Energy
IPCBEE vol.28(2012) © (2012)IACSIT Press, Singapoore

Use of Waste Plastic and Waste Rubber Tyres in Flexible Highway Pavements

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Abstract. Plastics are user friendly but not eco-friendly as they are non-biodegradable. Generally it is disposed by way of land filling or incineration of materials which are hazardous. The better binding property of plastics in its molten state has helped in finding out a method of safe disposal of waste plastics, by using them in road laying.
Modified Bitumen is one of the important construction materials for flexible pavements. Use of plastic waste (LDPE) and Crumb Rubber i.e. the rubber obtained from the waste tyres of vehicles, in the construction of flexible pavement is gaining importance. It is also worth mentioning that, the modifier raw-material has been sourced from disposed waste plastic and crumb rubber. This not only allows us to collect modifier raw-material at low cost, but also provides a solution towards ecological menace posed by increased use of plastics (non-biodegradable).
In the present study, an attempt has been made to use waste plastic, Low Density Polyethylene (LDPE) and Crumb Rubber, blended using dry process for LDPE and wet process for CRMB. Marshal method of bituminous mix design was carried out for varying percentages of LDPE and Crumb Rubber to determine the different mix design characteristics.

Keywords: low density polyethylene, crumb rubber, Marshall Stability, flexible pavements

1. Introduction

In India, it is estimated that over 33 lakh kilometers of road exists. The road transport carries close to 90% of passenger traffic and 70% of freight transport. Investigations in India and countries abroad have revealed that properties of bitumen and bituminous mixes can be improved to meet requirements of pavement with the incorporation of certain additives or blend of additives. These additives are called "Bitumen Modifiers" and the bitumen premixed with these modifiers is known as modified bitumen. Modified bitumen is expected to give higher life of surfacing (up to 100%) depending upon degree of modification and type of additives and modification process used. Different types of modifiers used are Polymers, Natural Rubber and Crumb Rubber.

1.1. Waste Scenario

The consumption of plastics have increased from 4000 tons/annum (1990) to 4 million tons/annum (2001) and it is expected to rise 8 million tons/annum during the year 2009.

Nearly 50 to 60% of the total plastics are consumed for packing. Once used plastic materials are thrown out. They do not undergo bio-decomposition. Hence, they are either land filled or incinerated. Both are not eco-friendly processes as they pollute the land and the air.

Waste tyres in India are categorized as solid waste or hazardous waste. It is estimated that about 60% of (retreaded) waste tyres are disposed via unknown routes in the urban as well as rural areas. The hazards of waste tyres include- air pollution associated with open burning of tyres (particulates, odour, visual impacts, and other harmful contaminants such as polycyclic aromatic hydrocarbon, dioxin, furans and oxides of

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nitrogen), aesthetic pollution caused by waste tyre stockpiles and illegal waste tyre collecting and other impacts such as alterations in hydrological regimes when gullies and watercourses become waste sites.

2. Literature Review

Banglore Process (2002), study regarding plastic roads presented. A 25 km plastic road was laid in Bangalore. The plastic road showed superior smoothness, uniformity and less rutting as compared to a plastics-free road laid at the same time, which began developing "crocodile cracks" soon after. The process was also approved in 2003 by the CRRI (Central Road Research Institute Delhi). Road life improves through improved tackiness and viscosity of the bituminous mix, thereby binding the stones more firmly together and improving the water-resistance of the mix to rain etc.

Justo et al (2002), at the Centre for Transportation Engineering of Bangalore University on the possible use of the processed plastic bags as an additive in bituminous concrete mixes. The properties of the modified bitumen were compared with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight. Therefore the life of the pavement surfacing course using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.

Mohammad T. Awwad et al (2007), polyethylene as one sort of polymers is used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat the aggregate High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate.

Shankar et al (2009), crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

3. Experimental Program

The Semi Dense Bituminous Concrete (SDBC) mix was prepared using Marshall Method of bituminous mix design. The SDBC was prepared with conventional 60/70 grade bitumen, 60/70 grade bitumen added with varying percentages of LDPE and 60/70 grade bitumen added with varying percentages of Crumb Rubber. The details of the experimental programme are as follows.

Table 1 Detail of Sample Constitution and Percent Constituents

Sample Constitution	Sample Preparation	% Constituent by Weight of Bitumen
60/70 Grade bitumen	Wet Process	
Bitumen + LDPE	Dry process	LDPE: 3%
		LDPE: 6%
		LDPE: 9%
Bitumen + Crumb Rubber	Wet process	Crumb Rubber: 8%
		Crumb Rubber: 10%
		Crumb Rubber: 12%

3.1. Ministry of Road Transport and Highways Specifications for SDBC

Ministry of Road, Transport and Highways (MORT&H) has provided specifications for road and bridge works. The specifications for SDBC are as follows:

Table 2 Specifications for SDBC

S. No.	Parameter	Specified Limits

1	Minimum stability (Kg at 60^{o}C)	820
2	Minimum flow (mm)	2
3	Maximum flow (mm)	4
4	Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
5	Percent air voids	3-5
6	Per cent voids filled with bitumen (VFB)	65-78

4. Results and Discussions

The SDBC was prepared by Marshall method using the 60/70 grade bitumen and the various mix design characteristics of the Marshal stability value, Flow value, Bulk Density , Air Voids (Vv) , Voids in mineral aggregate (VMA) , Voids filled with bitumen(VFB) were found out. The results are shown in table 2.

Table 3. Results of SDBC Mix Design using 60/70 Grade Bitumen

S. No	Bitumen %	Marshal stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	4.50	845	2.86	2.234	4.93	14.97	67.23
2	4.75	865	3.10	2.236	4.44	15.05	70.12
3	5	945	3.26	2.245	3.64	14.85	74.58
4	5.25	880	3.71	2.235	3.24	14.98	77.1
5	5.50	850	3.98	2.23	3.04	15.29	77.96

The results show that with 5% bitumen content higher value of Marshall Stability value and greater density was achieved. All other parameters were also well within the specifications of MORT&H. Hence with 5% bitumen content of 60/70 grade bitumen varying percentages of LDPE and Crumb Rubber was added and SDBC mix was prepared. The results of SDBC mix with varying percentage of LDPE are shown in the following table:

Table 4. Results of SDBC Mix for Varying Percentages of LDPE

S.No	LDPE %	Bitumen %	Marshal Stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	3%	5.0	1050	3.10	2.24	3.86	15.04	74.12
2	6%	5.0	1120	3.88	2.25	3.43	14.66	76.23
3	9%	5.0	1185	3.91	2.25	3.21	14.48	77.18

From the above results it is observed that Marshall Stability Values and Bulk Density increased with the percentage increase in the modifier (LDPE). Hence by addition of LDPE the strength characteristic of the mix was enhanced vis- a- vis when it was not mixed with 60/70 grade bitumen.

Table 4 shows the results of SDBC Mix for Varying Percentages of Crumb Rubber. The Crumb Rubber was added to 60/70 grade bitumen in varying percentage of 8%, 10% and 12%. The SDBC mix was prepared with 5 % bitumen and the varying percentages of Crumb Rubber. The bitumen when mixed with Crumb Rubber is termed as Crumb Rubber Modified Bitumen (CRMB).

Table 4. Results of SDBC Mix for Varying Percentages of Crumb Rubber

S. No	Crumb Rubber %	Bitumen %	Marshal stability (Kg)	Flow value (mm)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	8%	5	1065	3.10	2.23	3.87	14.99	74.12
2	10%	5	1190	3.62	2.24	3.86	15.03	74.35
3	12%	5	1180	3.76	2.26	3.98	15.24	73.25

From the above results it is observed that the Marshal Stability Value are increased from 8% to 10% Crumb Rubber and then it is decreased i.e 10% of Crumb Rubber of the weight of bitumen is the optimum dose for getting enhanced strength characteristics of SDBC mix. The bulk density also shows increasing trend from 8% to 12. The values of other parameters are also within the required specification limits.

5. Conclusions

The study on the use of LDPE and CRMB reveals that the Marshal Stability value, which is the strength parameter of SDBC has shown increasing trend and the maximum values have increased by about 25 % by addition of LDPE and CRMB. The density of the mix has also increased in both the cases of LDPE and CRMB when compared with 60/70 grade bitumen.

This will provide more stable and durable mix for the flexible pavements. The serviceability and resistance to moisture will also be better when compared to the conventional method of construction. The values of other parameters i.e. Vv, VMA and VFB in both the cases LDPE and CRMB have found out to be within required specifications. This study not only constructively utilizes the waste plastic and tyres in road construction industry but it has also effectively enhanced the important parameters which will ultimately have better and long living roads.

Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with heavy distresses. This adversely affects the life of the pavements. The polymer modified bitumen show better properties for road construction and plastics waste which otherwise are considered to be a pollution menace. It can find its use in this process and this can help in solving the problem of pollution because most of the plastic waste is polymers.

In the modified process (dry process) plastics-waste is coated over aggregate. This helps to have better binding of bitumen with the plastic-waste coated aggregate due to increased bonding and increased area of contact between polymer and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. The road can withstand heavy traffic and show better service life. This study will have a positive impact on the environment as it will reduce the volume of plastic waste to be disposed off by incineration and land filling. It will not only add value to plastic waste but will develop a technology, which is eco-friendly.

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