

Performance Evaluation of Sustainable bituminous-Plastic roads for Indian conditions

Arjita Biswas, Amit Goel, Sandeep Potnis

Abstract : *The amount of plastic waste in India is reaching a gigantic scale. Wastes from household, industries and medical facilities contribute towards this. As the plastic waste is a cause of various environmental and health hazards, its proper management that leads to an effective reuse or disposal is a concern for the Government and civic bodies.*

Waste plastic, when added to hot aggregates, forms a fine coat of plastic over the aggregates and such aggregates, when mixed with the binder is found to give a mix that has higher strength and resistance towards the deteriorative actions of water.

Thus, (the bituminous Roads using waste plastic in the wearing course) also called as plastic roads are now gaining popularity in India. With the Indian Road Congress bringing out a code of specifications on plastic roads (IRC SP: 98 -2013), many agencies are coming forward to implement plastic roads in India as it is a sustainable method and also need of the hour. However, for a large scale implementation, the performance and longevity of these roads need to be evaluated comprehensively.

This paper presents the various properties of bituminous mix with 8% waste plastic when compared with normal bituminous mix with the help of a comparative case study. In Pune, Maharashtra, India ten city roads which were overlaid with normal bituminous mix and ten roads which were overlaid by bitumen mixed with shredded waste plastic were studied for their performance over duration of two years from the time of laying of the overlays. Laboratory experiments and on- field tests were carried out to evaluate their functional and performance characteristics after they were opened to traffic. The results report an improved performance of plastic roads over the conventional ones.

Keywords:. Plastic roads, bituminous roads, MoRTH Specification.

I. INTRODUCTION

Plastic in different forms are found in most of the municipal solid waste and most of which are toxic. It is estimated that approximately 10 thousand tons per day (TPD) of plastics waste is generated in India(Planning commission on “Urban solid waste management in India”, GOI, 2012).

Plastic bags and other type of plastic packing material littering the roads as well as the drains is a common sight in both urban and rural India. Due to its non-biodegradability nature, plastic creates stagnation of water and associated hygiene problems. (Planning commission on “Urban solid waste management in India”, GOI, 2012).

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In order to contain this problem, experiments have been carried out to determine whether this plastic wastes can be reused productively in the construction of roads (Dr. R. Vasudevan,2006).

It was found that the waste plastic, when added to hot aggregate forms a fine coat of plastic over the aggregate That aggregate, when mixed with the binder is found to have higher strength, higher resistance to water and gives better performance over a period of time (Dr. R. Vasudevan,2002). Though approved specifications were not available in the beginning, with the help of research carried by Prof. Vasudevan of TCE, Madurai,Prof. Justo and Prof. Veeraragavan at Bangalore University and research carried out by Scientist at CRRI, New Delhi, several trial roads were constructed using waste plastic(Central Pollution Control Board Review,2006).

In India, deterioration of pavements is very common. Plastic roads can reduce the rate of deterioration as these roads are claimed to be more durable. The present study analyses the durability of roads made using waste plastics so as to evaluate their performance.

II. LITERATURE REVIEW

In the construction of bituminous roads, shredded waste plastic can be melted with aggregates and bitumen which proves to create a better bituminous mix with improved properties. (Rajput & Yadav , 2016).

Experimentations at several institutes on properties of plastic road resulted that the waste plastic, when added to hot aggregate forms a fine coat of plastic over the aggregate. The resulting aggregate, when mixed with the binder is found to have higher strength, higher resistance to water and yields better performance over a period of time (Dr. R. Vasudevan,2002).

R Vasudevan et al 2007, studied different characteristics of waste plastic viz. thermal and physical properties. Waste plastic when mixed with aggregates, i.e plastic coated aggregates (PCA) showed better results for Aggregates impact test, Soundness test, Los Angeles abrasion test. Shiva Prasad K, Manjunath K. R,2012, studied Marshall Stability Properties of BC Mix used In road construction by adding plastic waste bottles.

S.Rajasekaran et al 2013, have studied the different properties of different types of plastic and how Polyethylene Polypropylene polystyrene increase the binding properties of bituminous mix when added with aggregates.



III. PRESENT STUDY

In Pune , Maharashtra, India for the first time ten city roads are overlaid by a plastic coating on trial basis in the month of December 2016. To study and compare the properties of normal bituminous mix specimen with the properties of bituminous mix mixed with waste plastic (8% plastic) , the specimen were tested before laying the roads.

The tests were conducted at Pune Municipal Corporation(PMC) Laboratory :

- a) Marshall Stability Test
- b) Stripping Value Test
- c) Water Absorption Test

a) Marshall Stability Test

Marshall Stability value is the basic study on the stability of the mix through application of load. The standard mixture was prepared in accordance with MoRTH (Ministry of Road Transport and Highways) specifications . The plastics coated aggregates mix was made up of 8% of total quantity of VG-30 bitumen Direct specimens /mixture were taken from Hot Mix Plant, Pune Municipal Corporation,(PMC) Pune and tests were carried out at PMC Lab to find out the Marshall Stability results to evaluate its strength. The mixture was transferred to the mould. It was compacted with 75 blows on either side. The specimen were checked for Marshall Stability in Kg, Marshall Flow Value , Average Density and results were compared with MoRTH specifications.

Table No:1: Marshall Test Results of Normal DBM Mix for ten Roads laid in Dec 2016

Sample No	Stability in Kg	Marshall Flow Value	Average Density	Specified Limits as per MORTH for DBM (For Stability)	Specified Limits as per MORTH for DBM (For Flow value)
1	1185	3.9	2.38	900	2-4
2	1141	3.7			
3	1078	3.5			
4	1098	3.6			
5	1020	3.4			
6	1080	3.7			
7	1100	3.6			
8	1058	3.4			
9	1090	3.6			
10	1100	3.6			

Table No :2 Marshall Test Results of Mix (DBM Mix with 8% waste plastic mix) for ten Roads laid in Dec 2016

Sample No	Stability in Kg	Marshall Flow Value	Average Density	Specified Limits as per MORTH for DBM (For Stability)	Specified Limits as per MORTH for DBM (For Flow value)
1	1141	3.8	2.38	900	2-4
2	1098	3.8			
3	1163	3.8			
4	1098	3.6			
5	1020	3.4			

6	1080	3.7			
7	1100	3.6			
8	1110	3.7			
9	1090	3.6			
10	1080	3.6			



Fig No : 1 Marshall Stability Test

b) Stripping Value Test

Stripping value is the determination of binding strength of the aggregate and the bitumen. It is tested by immersing bitumen coated aggregate in water for 24hrs at 400C. When bitumen coated aggregate was immersed in water, the water penetrates into the pore and voids of the stone resulting in the peeling of the bitumen. This in turn results in the loosening of the aggregate and forming potholes(Goel & Sachdev, 2016). 200gm of normal aggregates and Plastic coated aggregates PCA- bitumen mix was taken and cooled to room temperature and weighed. The mixture was immersed in water bath maintained at 40° C for 24hrs. After 24hrs the stripping was observed for both the cases and the percentage of stripping was noted and the results are tabulated in Table below:

Table No 3 : Stripping Value Results

	Normal aggregates					Plastic coated aggregates(8% plastic)				
	2hr	12hr	24hr	72hr	96hr	2hr	12hr	24hr	72hr	96hr
stripping g	0	0	0	2	2	0	0	0	0	0



Figure No: 2 Stripping Value

c) Water Absorption Test

Water is the main cause of deterioration of flexible pavements. Water absorption test was carried out to verify whether the aggregates coated with waste plastic are more resistant to water which ultimately makes the roads more durable (METHODS OF TEST FOR AGGREGATES FOR CONCRETE, 2002).

Water Absorption Test (AASHTO T 96 (2001): A known quantity of plastics coated aggregate was taken. It was then immersed in water for 24hrs. Then the aggregate was dried using dry clothes and the weight was determined. The water absorbed by the aggregate was determined from the weight difference.

The test was repeated with plain aggregate for comparison of results. Table-4.



Table No : 4 Water absorption Test (Normal Mix)

Initial Weight of the sample Aggregates + 5% Bitumen(200g +10gm)	Final Weight of the sample After immersion in water for 24 hours at room temperature	Percentage of water Absorption
203.43 gm	203.63 gm	0.098%

Table No : 5 Water absorption Test (Plastic Mix)

Initial Weight of the sample Aggregates + 5% Bitumen(200g +10gm)	Final Weight of the sample After immersion in water for 24 hours at room temperature	Percentage of water Absorption
207.30 gm	207.35gm	0.024%

Water absorption test results showed that aggregates mixed with bitumen and waste plastic are more water resistant.

IV. PERFORMANCE STUDY

Core Cutting Test

To evaluate actual performance of roads, it was decided to conduct core cutting tests. These tests were conducted on normal roads and plastic roads built in the month of December 2016. Roads selected were such that they were laid on same time, they had almost same traffic density. Experiments were conducted on Core Samples (Appendix No :1). After collecting the core samples, three tests were conducted on them. They are as follows.

A) Bitumen Extraction Test

Bitumen extraction test was done to find out the binder content in the road samples.

The core samples were separated in Dense Graded Macadam and Bituminous Concrete. Separate results for DBM and BC are shown below.

Table No6: Bitumen Extraction results of DBM

Name of the Test	Dense Graded Macadam (DBM) Core Samples		Specifications as per MORTH	
	Normal Bituminous	Modified Bituminous with Plastic	Min.	Max.
Bitumen Extraction Test	3.70%	4.92%	4.50%	---

Table No 7:Bitumen Extraction results of BC

Name of the Test	Bituminous Concrete (BC) Core Samples		Specifications as per MORTH	
	Normal Bituminous	Modified Bituminous with Plastic	Min.	Max.
Bitumen Extraction Test	5.43%	6.40%	5.40%	---

Table No: 9 Dry Sieve analysis results of DBM

B) Core Density Test

The amount of compaction effects the quality of flexible pavement. Core density test signifies the bonding between the materials

Table No: 8 Core Density results

Name of the test	Normal Bituminous Core Samples	Modified Bituminous with Plastic Core Samples		
	Dense Modified Macadam (DBM)	Bituminous Concrete (BC)	Dense Modified Macadam (DBM)	Bituminous Concrete (BC)
Core Density Test	2.36	2.47	2.34	2.34

C) Dry Sieve Analysis

Table No. 9 and 10. show the readings of sieve analysis of DBM of both normal mix and plastic mix.

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Sieve size (mm)	% Finer Dense Bituminous Macadam (DBM) Core Samples (%)		Specifications as per MORTH Table 500-10 of 5th Revision	
	Normal Bituminous core sample	Modified Bituminous with Plastic core sample	Min.	Max.
37.5	100	100	-	100
26.5	100	100	90	100
19	83.78	96.02	71	95
13.2	61.33	93.98	56	80
4.75	20.37	50.6	38	54
2.36	10.71	25.06	28	42
0.3	2.81	5.3	7	21
0.075	1.25	2.41	2	8

Table No: 10 Dry Sieve analysis results of BC

Sieve size (mm)	% Finer Dense Bituminous Macadam (DBM) Core Samples (%)		Specifications as per MORTH Table 500-10 of 5th Revision	
	Normal Bituminous core sample	Modified Bituminous with Plastic core sample	Min.	Max.
19	98.93	100	-	100
13.2	97	84.27	90	100
9.5	90.25	80.03	70	88
4.75	67.52	59.76	53	71
2.36	44.69	30.56	42	58
1.18	24.87	14.67	34	48
0.6	18.01	10.74	26	38
0.3	10.08	5.6	18	28

V. PAVEMENT CONDITION

To analyze the pavement conditions and deterioration rates, a study on normal road and plastic road was conducted every month after their construction. Bleeding, raveling and rutting distresses were found in both types of roads. It was observed that normal road showed early distresses than plastic roads. Appendix 1 contains the images of the core cutting procedures. Appendix 2 represents the images of normal road and plastic road taken every month since January 2017. The comparison of these images reveals that normal road started showing distresses in the month of February, just after 2 months of its construction. In case of plastic road, it can be observed that removal of bitumen layer from upper surface started in the month of April, 4 months after the construction.

VI. CONCLUSIONS

Study revealed superior quality of plastic roads over normal roads. Physical evaluation of both the roads has proven that the plastic roads are performing well as compared to normal roads.

1. Various experiments such as Marshall stability, Water absorption and Stripping test were conducted on the sample roads. Core Cutting tests were conducted to evaluate actual performance of roads. The results showed satisfactory results in both types of roads, normal bituminous roads as well as plastic roads with respect to MoRTH specification. However plastic roads showed better performance.
2. Bitumen Extraction test results were better in plastic roads which can further prove that plastic roads may perform better in a long run. Deterioration of roads was early in normal roads as compared to plastics roads. Therefore, the study found waste plastic as a productive material for road construction. Application of plastic in such projects will not only reduce bio-environmental hazards associated with plastics, it will also increase the durability of roads.

APPENDIX

Appendix 1 and 2 are given at the end.



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Prof. Arjita Biswas, She is a research scholar and has an experience of 14 years in academics and 3 years at MMRDA, Mumbai as Deputy Engineer. She is currently serving at National Institute of Construction Management & Research (NICMAR) , Pune as an Assistant Professor. She has presented many papers in conference and published many papers in national and international journal.



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Appendix No :1 Following is the core cutting procedure:









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Appendix No:2 : Road images since January 2017 at Pune, MH, India.

Month	Normal Bituminous Road	Modified Bituminous Road with Plastic
January	 <p data-bbox="400 667 740 696">Road near Vaikunth Crematory</p>	 <p data-bbox="1007 667 1347 696">Road near Vaikunth Crematory</p>
February	 <p data-bbox="475 1171 667 1200">Tathawade udyan</p>	 <p data-bbox="1082 1171 1273 1200">Tathawade udyan</p>
March	 <p data-bbox="475 1697 667 1727">Tathawade udyan</p>	 <p data-bbox="1082 1697 1273 1727">Tathawade udyan</p>

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April	 <p>Road near Vaikunth Crematory</p>	 <p>Road near Vaikunth Crematory</p>
May	 <p>Tathawade udyan</p>	 <p>Tathawade udyan</p>
June	 <p>Tathawade Udyan</p>	 <p>Tathawade Udyan</p>

July	 <p data-bbox="400 577 740 607">Road near Vaikunth Crematory</p>	 <p data-bbox="1010 577 1350 607">Road near Vaikunth Crematory</p>
Aug	 <p data-bbox="472 920 668 949">Tathawade Udyan</p>	 <p data-bbox="1078 931 1278 960">Tathawade Udyan</p>
Nov	 <p data-bbox="464 1328 676 1357">Thathawade Udyan</p>	 <p data-bbox="1074 1328 1286 1357">Thathawade Udyan</p>