Pavement Performance Studies on Roads Surfaced Using Bituminous Mix with Plastic Coated Aggregates

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Abstract

The real time field performance evaluation of flexible pavements constructed using mix with waste plastic coated aggregates as surfacing layer has been carried out and the results compared with that of the control section. Laboratory studies conducted on semi Dense Bituminous Concrete (SDBC), Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) show that the Marshall Stability value of bituminous mixes increase by 1.5 to 2 times by using Plastic Coated Aggregates. Also bitumen can be reduced by more than 10% by weight. Periodical performance evaluation conducted on test stretches indicated better functional performance. Better strength parameters and road condition indicates increase in life of pavement and delayed and slow deterioration. Utilization of waste plastic on a massive scale will eliminate the pollution caused due to land filling or incineration.

Key Words: Pavement evaluation –plastic coated aggregates- pavement condition – roughness – skid resistance – texture depth-

1. Introduction

Utilization of waste recycled packaging plastic is of great importance in India, particularly for bitumen conservation and reduction in environmental pollution created by dumping of waste plastic. Disposal of waste material has become a great problem in cities. One of the promising ways is to use waste plastic in bituminous road construction industry. Investigations in India and abroad have revealed that properties of bitumen and bituminous mixes can be improved significantly to meet the requirement of pavement with incorporations of certain additives or blends of additives. It is proved that incorporation of additives will improve the pavement stability by imparting viscoelastic property of mix.

Prof. Justo et al [2002] has established that the penetration and ductility values of the plastic modified bitumen decreased with the increase in proportion of the plastic additive, up to 12% by weight. The softening point of the modified bitumen increased with the addition of plastic additive, up to 8.0% by weight. Punith et al [2004] has reported that the fatigue life of bituminous concrete mixes with plastics modifier is significantly higher than that of plain bituminous concrete mixes. Kajal et al [2007] has found that there was an improvement in strength properties when compared to a conventional mix. Verma et al [2008] had conducted an initial study to test the strength and durability of plastic roads. Plastic carry-bags, disposable cups and PET bottles are collected from garbage dumps as an important ingredient of the construction material. When mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar road. Ravisankar et al [2009] found that under heavy traffic and extreme climate conditions, surfacing with modified bituminous mix may help in achieving better performance and longer life, with reduced vehicle operating costs.

2. Scope of the study

Laboratory studies were conducted to determine the optimum Binder Content for different bituminous mixes such as Semi Dense Bituminous Concrete (SDBC), Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM).

Pavement performance studies were conducted on road sections surfaced using modified bituminous mix having waste plastic coated aggregates and ordinary bituminous mix, operating under identical conditions and the results compared.

3. Methodology

3.1 The process of mixing

The addition of waste plastic to modify the bituminous mix can be either by wet process or dry process. In the wet process, shredded waste plastic is mixed with hot bitumen at a temperature of about 160°C with the help of powerful mechanical stirrers. In this process, mixing of higher percentages of plastic is difficult and a homogenous mix may not be obtained because of the difference in viscosities of molten plastic and bitumen. In the dry process, aggregate is heated uniformly at a temperature of 170°C - 175°C and the shredded plastic is added to the aggregates at this temperature and the aggregates gets coated with a thin film of molten plastic. The dry process gives a blend with better binding property, as larger surface area of the aggregate is available for mixing. Hence dry process is advantageous than wet process. The modified mix used in the study roads are prepared by dry process.

3.2 Laboratory studies

Marshal mix design was done for both ordinary mix and modified mix with plastic coated aggregates. The materials used are the constituent materials of bituminous mixes *viz* bitumen VG 30 (binder), aggregates, cement (filler) and shredded waste plastic carry bags (Polyethylene and polypropylene type). The suitability of the materials were established with respect to MORTH and IS specifications. Shredded plastics of size between 2.36 mm to 4 mm obtained by shredding carry bags were used which was shredded in the plastic shredder shown in Fig 1.

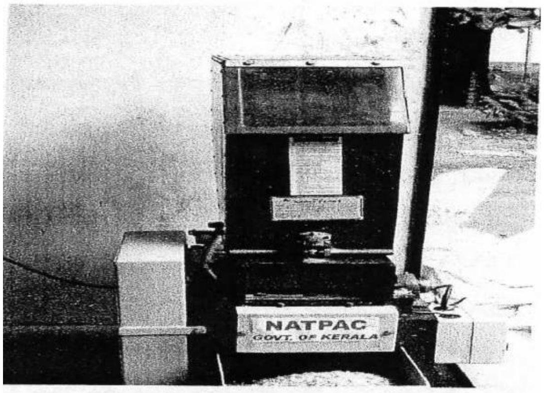

Figure 1 Plastic shredder

Binder content was reduced from optimum value and replaced with equivalent percentage of shredded plastic carry bags. The variations in Marshall stability and flow, voids content, Bulk density and Voids filled with bitumen with the change in binder and plastic content was compared to get the optimum plastic content. This was done for Bituminous concrete (BC), Semi Dense Bituminous concrete (SDBC) and Dense Bituminous Macadam (DBM).

3.3 Pavement evaluation

Periodic pavement evaluation studies were carried out two times a year for the functional and structural performance of the study roads as given below:

Roughness: - This was measured using Bump Integrator which directly displays the unevenness in cm. The obtained values were converted to the International Roughness Index (IRI) and compared with standards prescribed in IRC SP 16-2004.

- Detailed condition surveys were conducted to measure the cracks, raveling, potholes, rutting, edge break, corrugation etc.
- Skid Resistance which is indicative of the micro texture was measured using portable skid Resistance Pendulum and compared with the standards set by BS: 812-1967
- Texture Depth Studies using Sand Patch Method as per BS 598 part 105 (1990) was conducted to get an account of the macro texture. Coarser texture results in quick

drainage of water and less pavement slipperiness.

- Benkleman Beam Deflection studies were conducted to measure the deflection as per IRC 81, 1997.

In the study, the performance data has been compared with that of the control section under identical conditions and traffic and hence validation of the data is not attempted at this stage.

4. Study area

Test stretches were laid and pavement evaluation has been done for 3 roads given below in Table 1.

Table 1.Details of study roads

Name	Length (m)	Carriage way width (m)	Year of resurfacing	Traffic CVPD
Road 1 Gandhipuram Road, Trivandrum	500	4.00 to 5.50	2004	<150
Road 2 Muncipal Town Hall Road, Vadakara	500	3.75 to 5.00	2008	<150
Road 3 Stadium to Puthiyara Road, Kozhikkode	600	4.5 to 5.5	2009	2844

Road 1 – Gandhipuram Road

This road was resurfaced using modified mix, (25 mm PMC) with plastic coated aggregate by Kerala Highway Research Institute (KHRI) in the year 2003 for a length of 500 m. A control stretch of 500 m with identical conditions which is surfaced with ordinary mix is also selected for comparison. The evaluation was done for 2 years after 4 years of construction.

Road 2 – Muncipal Town Hall, Our College Road, Vadakara Muncipality

This is a 400 m long stretch which is surfaced with PCA (20 mm PMC) and 100 m with ordinary mix. This was done in March 2008 with the technical support of the authors. The evaluation was started after 6 months from the time of surfacing.

Road 3 – Stadium- Puthiyara road in Kozhikkode Corporation

This is an urban street linking stadium to mini bye-pass with a total length of 600 m. The stretch carries a heavy traffic of 2844 CVPD. This was surfaced with modified mix having PCA in March 2009, with the technical support of the authors. Field investigations of the road before resurfacing were done to compare the results with subsequent evaluation.

5. Results and discussions

5.1 Laboratory studies

The findings of the laboratory studies are given in Table 2.

Table 2. Marshall test results

Mix	Optimum Binder Content %		% stripping		Stability KN		Flow mm		VFB %	
	A	B	A	B	A	B	A	B	A	B
BC	5	4.5	2	0	15.39	22.68	3.25	3.58	65.9	76.05
SDBC	5	4.6	2	0	14.17	19.45	3.7	3.8	74.1	78.19
DBM	4.6	4	2	0	18.94	22.75	2.5	3.48	73.5	82.73

Note : A – Mix with ordinary aggregate
B – Mix with plastic coated aggregate

5.2 Field studies

5.2.1 Road 1

4 sets of data were collected for the test section and control section and the same is summarized in Table 3.

5.2.2 Road 2

The inventory and condition survey of the road before the surfacing was taken. This showed 60% distress, consisting of raveling, edge drop and potholes. The first data set for evaluation of the pavement which is reported in this paper was taken after 6 months of surfacing. 4 sets of data was collected which is summarized in Table 4.

Table 3.Road-1 Summary of Pavement Evaluation Data

Tests	Stretch with PCA				Stretch with ordinary mix			
	Data 1	Data2	Data 3	Data 4	Data 1	Data 2	Data 3	Data 4
IRI in (m/km)	5.2082	5.214	5.2202	5.2142	5.4012	5.4162	5.4212	5.426
Texture Depth in (mm)	0.704	0.674	0.714	0.721	0.834	0.899	0.845	1.052
Skid Resistance (Number, SN)	74	..	68	60	77	..	71	66
Distress (% Area)	3	4.3	4.8	5.2	34.3	38.65	42.56	50.5

Table 4 .Road 2 – Summary of Pavement Evaluation Data

Tests	Stretch with PCA				Stretch with ordinary mix			
	1	2	3	4	1	2	3	4
Characteris-tic deflection (mm)	0.8	0.61	0.57	0.37	0.66	0.73	0.76	0.88
IRI m/km	5.2	5.86	6.81	6.62	4.29	5.52	6.48	6.5
Skid NO. SN	73	72	70	72	72	70	77	68
Texture depth mm	0.9	0.94	0.859	0.83	0.75	0.86	0.81	0.78
% distress area	0	0	0	0	0	0	0.82	0.90

No distress was observed in the stretch with modified mix during the study period. But for the control stretch, the 3rd and 4th set of data showed 0.82% and 0.90% distress.

5.2.3 Road 3

Detailed inventory and condition survey of this road was done before the surfacing. The surface defects included raveling, potholes, edge drop and bleeding. The total area of distress before bleeding was 6.93 percent. One year after the resurfacing the total percentage area of distress on the stretch with modified mix was 0.31% while that on the control stretch was 3.85% with numerous potholes. Two sets of data is reported, the 1st set collected after 6 months from resurfacing.

The progression of distress, unevenness, skid resistance, texture depth and deflection for the 3 study stretches are shown in figure 2 to 6. Data collected at 6 months interval is represented here. The values which are showing deviation from the known trend are considered as data error and are omitted from the plot. The plots of the performance evaluation values for the stretch with modified mix and control stretch having identical conditions and surfaced with normal mix shows that mix with PCA is more stable, for all the properties.

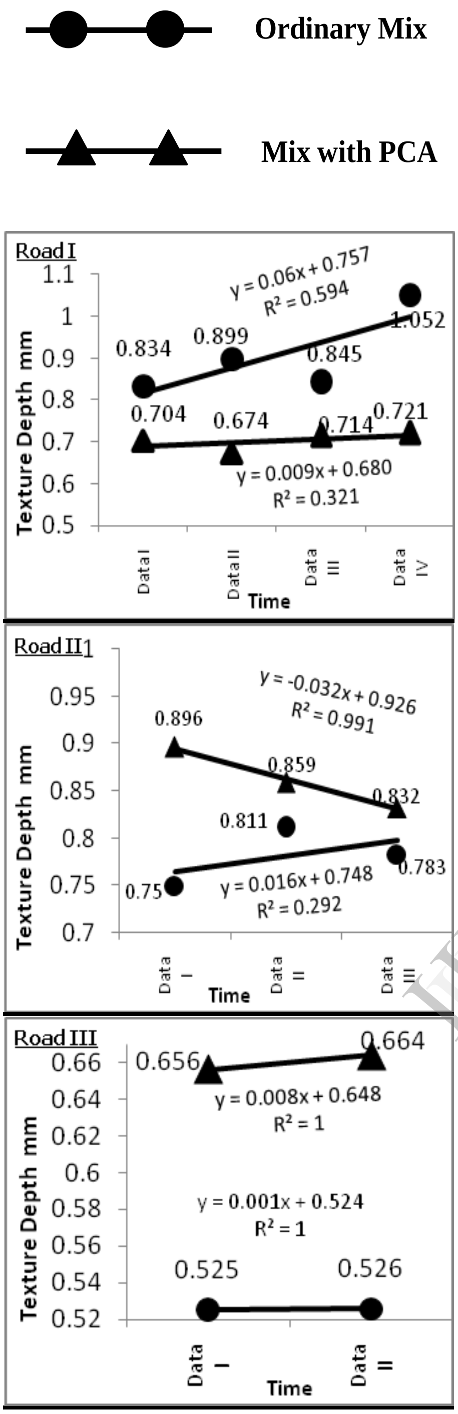

Figure 2.PROGRESSION OF TEXTURE DEPTH

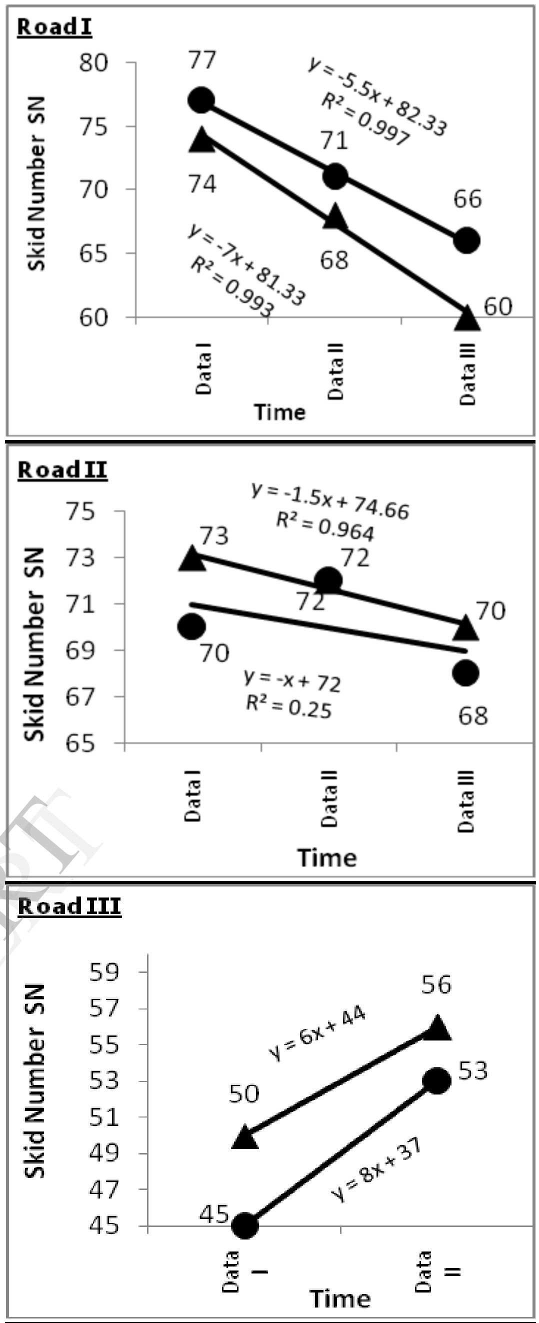

Figure 3.PROGRESSION OF SKID RESISTANCE (SN)

In case of Road I and II, the skid resistance value decreases with time in both cases. In the case of Road III, the skid resistance value increases initially, but will be stabilized only after a period of time which is dependent on the construction quality also.

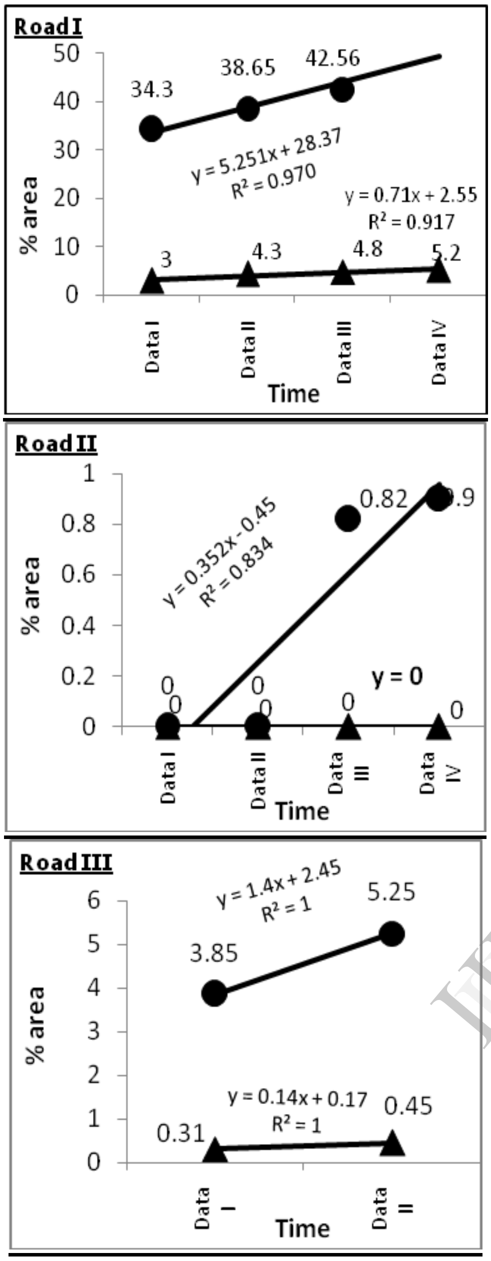

Figure 4.PROGRESSION OF DISTRESS

From figure 4, it is seen that the study value of distress in the case of the stretch is nearly 10 times that of the test stretch, for all the measurements showing the advantage of the modified mix.

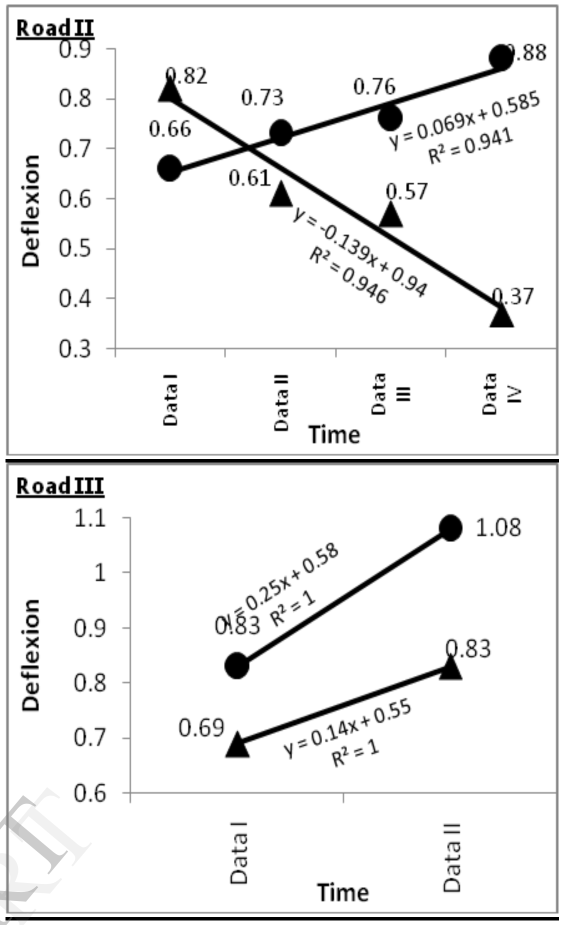

Figure 5.PROGRESSION OF DEFLECTION

Four sets of measurements was taken for Road II and two sets for Road III to observe the deflection, which is a measure of the Structural Strength of the pavement. In Road I, even though the critical deflection value is higher for the stretch with PCA compared to the control stretch, but after 6 month there is steep reduction which is well below the maximum allowable value in the 4th measurement. But in the case of the control section, the deflection shows an increasing trend.

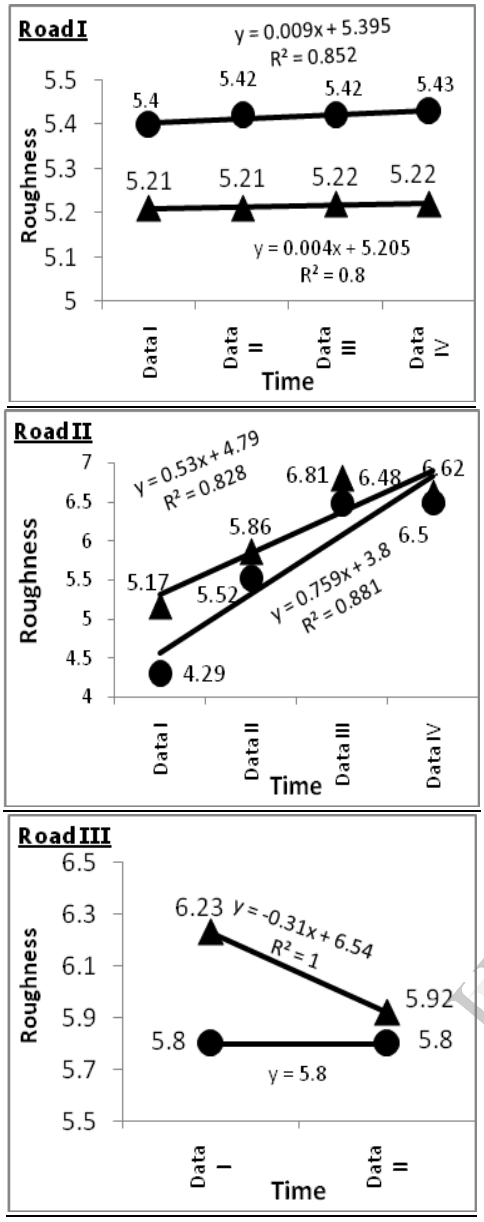

Figure 6.PROGRESSION OF ROUGHNESS

It is seen that even though the roughness value was high initially, for the stretch with modified mix, it equalize after 2 years in the case of Road II and after one year in the case of Road III. Thereafter the roughness value increases in the case of ordinary mix.

6. FINDINGS

The results obtained from the laboratory studies showed that use of plastic coated aggregates increased the stability which is indicative of the strength by 1.5 times for BC & SDBC. The optimum binder content got reduced from 5% to 4.5% in the case of BC and from 5% to 4.6% in the case of SDBC. For DBM, the stability increased 1.2 times and the optimum binder content got reduced from 4.6% to 4%. There is also reduction in voids in all types of mixes. Aggregates coated with waste plastic showed zero stripping after 72 hours of soaking where as ordinary bituminous mix showed 2% stripping.

Field performance evaluation has established the following:

- Distress initiation and progression is delayed in roads laid with modified mix containing waste plastic coated aggregates. Especially Pothole initiation and progression are delayed in modified stretches when compared to the control sections, indicating resistance towards water soaking, thereby avoiding the use of anti stripping agents.
- Massive consumption of waste plastics can be effectively made; thereby reducing the pollution caused by burning or land filling.
- Easy, cost effective and does not involve any additional machinery.
- The process can be carried out in situ.
- Social benefit is predominant since it generates wealth from waste and as an income to rag pickers or self-help groups.

7. CONCLUSION

The use of waste plastic for road construction can save the environment, increase the service life of roads, reduce the consumption of petroleum products and serve the society with additional income for those associated with it. But the technology can be adopted easily and successfully only with the co-operation and involvement of the general public and local bodies. The segregation of the waste plastic should be done at the source itself and then transfer it to the self-help groups without throwing it away to pollute the earth.

When compared with the control section, the stretches resurfaced using plastic coated aggregates have shown improved functional performance in terms of better surface condition, delayed pothole and crack initiation and progression, desirable skid resistance and surface texture.

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9. REFERENCES

(1) Nabil Mustafa, "Plastics Waste Management", *Canadian Plastics Institute*, Marcel Dekker, Inc, Toronto, Ontario, Canada, 1993.

[2] Prof. Dr. Justo, C.E.G. and Dr. Veeraragavan, A, "Utilisation of Waste Plastic Bags in Bituminous Mix for Improved Performance of Roads", *Centre for transportation engineering, Banglore university,* [Unpublished], 2002.

(3) Vasudevan.R, Rajasekaran.S, and Saravanavel.S, "Utilization of Plastics Waste in Construction of Flexible Pavement", *Proceedings of the National Seminar on Integrated Development of Rural and Arterial Road Network for Socio-Economic Growth*, 2003, P-II-243

(4) V.S. Punith & Dr. A. Veeraragavan, "Fatigue Characteristics of Recycled Plastics Modified Bituminous Concrete Mixes", *Journal of Indian Roads Congress,* 2004, pp. 11-29.

(5) Vasudevan.R, Saravanavel.S, Rajasekaran.S, and Thirunakkarasu.D, "Utilisation of Waste Plastics in Construction of Flexible Pavement", *Indian Highways*, 2006, pp. 5-20.

(6) Kajal, Pundher, N.K.S. Sangita, and Chandra.A, "Use of waste plastics and copper slag for low cost bituminous roads", *Journal of Scientific and Industrial Research, Vol-66,*2007, pp. 938-994.

(7) Verma.S.S, "Roads from Plastic Waste", *The Indian Concrete Journal,* 2008, pp. 43-47.

(8) Ravi Shankar.A.U., Durgaprasad Salian and Koushik.K, "Utilization of Waste Plastic in Semi Dense Bituminous Concrete by Dry Mixing", *Highway Research Journal, Indian Roads Congress, Vol-2, No.2*, 2009, pp. 23-35.

(9) Sreedevi B.G, Salini P.N, "Performance Studies on Use of Plastic Modified Bituminous Mixes for Road Construction", *Proceedings of the 22nd Kerala Science Congress,* 2010, pp. 422.

(10) Indian Roads Congress, IRC:81-1997, Guidelines for Strengthening of Flexible Road Pavements Using Benkleman Beam Deflection Technique.

(11) "Use of Waste Plastic for Road Construction", *NATPAC Report,* 2011-2012.