International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8 Issue-9, July 2019

Effect of Addition of Plastic in Bituminous Mixes Prepared with Modified Bitumen

Shivani Guleria, Ajay Kumar Duggal

Abstract: The present study deal with the utilization of PET waste in Bituminous Concrete prepared with modified bitumen. The detailed analysis will be carried out to assess the physical and strength characteristic of prepared BC mix as per the Indian Standards. Modified bitumen used is CRMB -55 which is a binder obtained from the recycling of rubber tyre. Modified bitumen is temperature susceptible and also increases the fatigue life of pavement under the heavy traffic load. The study involved in the evaluation of more than one modification in bituminous mixes such as CRMB -55 is itself modified binder while modification has been done in the aggregate blend by addition of plastic. However, a combination has not yet been tried. The Marshall Stability test was performed to assess strength characteristics. The Marshall Stability values increase with the amount of PET and maximum stability was obtained at 6% by weight of the binder. The considerable increment was observed in Stability value with PET 6% dosage as 18.99%.

Index Terms: Plastic Waste, Marshall Stability Method, Poly-ethylene Terepthalate (PET), CRMB-55.

I. INTRODUCTION

Bituminous Mixes are commonly used in flexible pavement. Earlier bituminous mixes are susceptible to temperature condition and also works efficiently under normal traffic condition but nowadays there is an increase in temperature and vehicular traffic condition. Today's need is to use modified bitumen which is expected to perform better with an increase in traffic volume, variation in daily and seasonal temperature over that has been experienced in past. (Nabin Rana Magar, 2014) Asim Hassan Ali et al., studied the physical and rheological properties as well as elastic behaviour of modifier bitumen namely CRMB in bitumen pavement. Laboratory testing was done on modifier bitumen as a function of two blending time (30 min and 60 min) and five crumb rubber contents of varying rates as 4%, 8%, 12%, 16% and 20% by weight of bitumen at mixing temperature of 180ºC and the result showed that the increase in blending time did not have significant effect on crumb rubber modifier bitumen binder and elastic recovery could be seen for each crumb rubber, high crumb rubber accounts for increase in elastic recovery and ductility. Crumb rubber is produced from a scrap of recycled tyres. In the recycling process of the tyre, steel and tyre cords are removed and tyre rubber is separated. This process is done either through mechanical means or by cracker mills. The difference in the size of crumb rubber depends on its use and according to their dimensions, it can be screened.

Revised Manuscript Received on July 06, 2019.

Shivani Guleria, Civil Engineering, M. E. Scholar NITTTR, Chandigarh, India.

Ajay Kumar Duggal, Civil Engineering, Associate Professor NITTTR Chandigarh, India

Crumb rubber is used as a top layer of grass in football ground as AstroTurf (Huang et al,2004) Growth in industry, progress and development and day to day life leads to generation and disposal of a large amount of waste material like fly ash, scrap tyres, plastic, etc which pose a great environmental and health problem. Now a day, it is a need of the present era to minimize and control the use of waste plastic materials The main drawback of plastic waste is that it is non-biodegradable and disposal is a major issue. ICPE (Indian Centre for Plastic in Environment) has been promoting road construction using waste plastic known as a waste plastic road. It is found to be performing better compared to conventional bitumen. There is a vast list of literature dealing with such problems. From the previous researches, it is noted that the use of waste plastic in bituminous mixes enhances the property of flexible pavement. Several researchers (Agar et al. (2003), Gawande (2013), Prasad et al(2015), A. Gandhimathi et al. (2017), Aman Khimta et al. (2017), used plastic bags, PET, High-density polythene to improve the property of Bituminous mixes. Waste plastic as filler or additive in the bituminous mix is effectively utilized in the construction of pavement and provided better results in term of strength (G. Sambasiva Rao et al, 2018) In the present study, Pet is used as partial replacement of aggregate which will have a positive impact over the durability of pavement while Modified bitumen will enhance the performance of bituminous mixes in term of strength characteristics. *The study involved in the evaluation of more than one modification in bituminous mixes: a) The binder used was modified and b) modification has been done in the aggregate blend by addition of plastic.*

II. OBJECTIVES OF STUDY

The study shall be conducted to explore the use of waste material in bituminous mixes namely BC. A laboratory investigation and analysis shall be done to check whether it is viable to use economically, environmentally or in terms of suitability.

The present study focused mainly on the following points:

i. To evaluate the stability value, flow value, %air voids, %VMA and %VFB of DBM and BC by Marshall Method of mix design.
ii. To determine the optimum binder content of the control mix prepared with CRMB.
iii. To study the effect of the addition of plastic waste on the properties of bituminous mixes namely BC.
iv. To determine the optimum ratio of blending Plastic waste to Bituminous mixes prepared with CRMB
v. To ascertain improvement if any, in Retained Stability due

to addition.

III. METHODOLOGY

Grading shall be done according to the specification laid down in MORTH Specification for Road and Bridge Works, 5th edition. For BC grading corresponds 30mm to 40mm thickness layer (grading 2).

a) Characterization of material like aggregate, binder, plastic and its requirement.
b) Preparation of samples of Bituminous concrete at different binder content.
c) Determination of Optimum binder content for BC mix prepared with CRMB-55.
d) Preparation of samples for BC using plastic waste (PET) at different percentages like 2%, 4%, 6%, 8% to the control mix at optimum binder content and over the samples Marshall Stability test was conducted.
e) Comparing the Retained stability of samples of BC and BC with the addition of plastic.

A. Characterization Of Material

The material used are namely aggregates, binder, plastic and cement

1) Plastic Waste:

In this study plastic waste used is PET. One of the most common types of plastic is PET which is used for the manufacturing of water bottles, soft beverages, packing material for many food products like cosmetics, detergents and many more. The collection of plastic waste was done from the industrial area Phase-1 Chandigarh which is in shredded form. The specific gravity of plastic waste was found to 0.9 for PET material. PET used in granular form (600µ to 2.36 mm) which is colorless. The aspect ratio used in the study is 2(length/breadth). The composition is shown below:

Fig. 1: Poly-ethylene terephthalate (PET)

Table 1: Grading of PET

Sieve size	Percentage passing (%)
4.75	100
2.36	75
1.18	20
0.6	5
0.3	0

2) Aggregates:

For preparing BC samples, the aggregate of nominal size 19mm, 13.2mm and stone dust was used. The certain test was performed on the material in order to satisfy the physical requirements set by MORTH Specifications for Road and Bridge Work (5th revision) Table 500-6 given in Table 2

Table 2: Physical property of Aggregates

Physical Properties	19 mm	13.2mm	Required value as per MORTH (5th revision)
Specific Gravity	2.62	2.65	2.6-2.8
Elongation Index	12.2	12.8	Maximum 30% (Combined)
Flakiness Index	9.3	8.1	
Impact Value	18.1	20.3	Max 24%
Water Absorption	0.40	0.51	Max 2%

3) Cement:

Cement used in the preparation of BC and DBM samples was Ordinary Portland Cement grade 43. The specific gravity was found to be 3.15.

4) Binder:

Crumb rubber modified bitumen used in the studies of grade CRMB-55. Specifications for Modified Bitumen are provided in IS 15462: 2004 (Table-4) Polymer and Rubber Modified Bitumen Specifications. The certain test was conducted on CRMB whose results are given in Table 3

Table 3 Required properties of Modified Bitumen

Properties	CRMB-55	Required
Penetration at 25ºC	30	<60
Softening Point	59.85 ºC	55ºC
Specific Gravity	1.05	Min 1.02
Flash Point	269	Min 220

Requirements of bituminous mixes for Modified Bitumen

The important guidelines for the required property of Bituminous mixes are provided in MORTH Specifications for Road and Bridge Work (5th revision) Table 500-11. Requirements for the bituminous mixes namely BC are the same in Modified Bitumen and test method for Stability and Marshall flow are according to AASTHO T245. Guidelines for bituminous mixes are shown in Table 4.

Table 4: Guidelines required for bituminous mixes

Properties	Required Values
Marshall Stability Value, kN	Min 12
Flow (mm)	2.5-4.0
Air Void (%)	3.0-5.0
Minimum Voids in Mineral Aggregates (VMA)%	Min 13
Voids filled with bitumen (VFB)%	65-75
Marshall Quotient	2.5-5

B. Preparation of Samples for Bc At Different Binder Content

Grading was done for an aggregate of maximum nominal size 19mm, 13.2mm, stone dust, and also cement. Grading is shown below in the tabular form.

Table 5: Grading of Aggregates for Control Mix

IS Sieve Size (mm)	%Passing Agg.-1	%Passing Agg.-2	%Passing Stone Dust	Grading Cement	Grading of Mix
19	100	100	100	100	100.00
13.2	84.90	100	100	100	95.47
9.5	50.1	100	100	100	85.03
4.75	3.4	77.2	98.4	100	64.65
2.36	0.7	19	79.8	100	41.48
1.18	0	12.4	65.4	100	33.57
0.600	0	9.5	52.2	100	27.30
0.300	0	7.7	40.6	99	21.95
0.150	0	4.1	23.2	98.5	13.72
0.075	0	0.5	16.6	98	10.04

The ratio of different sized aggregates was calculated by using hit and trial method in MS Excel complying with Grading 2 for BC pavement layer as given in MORTH Specifications for Road and Bridge Work (5th revision), Table 500-17. The ratio for blending aggregates was determined as 30:25:42:3 and corresponding grading of the blend is shown in above Table 5. For the required grading of BC ratio was decided, with this ratio quantity of different aggregates was finalized. The quantity of aggregate to be used in the preparation of sample was calculated and then five different percentage of binder content were selected and accordingly their quantity was calculated for finding the optimum binder content.

Table 6: Percentage and Quantity of Bitumen in Control mix

Percentage of CRMB (%)	Weight of CRMB (g)
5.44	69
5.59	71
5.74	73
5.89	75
6.03	77

Fig.2: Samples were prepared at different binder content

For the required grading of BC ratio was decided, with this The Marshall Stability test was performed on BC samples. At each binder content, three samples were prepared and their average values were calculated as shown in Table 6

Table 7: Marshall Test Results for Control Mix

Binder Content	5.44%	5.59%	5.74%	5.89%	6.03%
Specific Gravity of CRMB	1.05	1.05	1.05	1.05	1.05
Density (g/cc)	2.343	2.346	2.341	2.335	2.328
Specific Gravity of Aggregate Blend	2.656	2.656	2.656	2.656	2.656
Volume of Binder, Vb (%)	12.13	12.48	12.79	13.09	13.36
Volume of Aggregate, Va (%)	83.60	83.57	83.26	82.92	82.55
Voids in Mineral Aggregate, VMA (%)	16.40	16.43	16.74	17.08	17.45
Voids filled with binder, VFB (%)	75.62	75.95	76.40	76.63	76.56
Air Voids (%)	4.27	3.95	3.97	3.99	4.09
Stability (kN)	20.12	21.50	21.14	20.67	19.90
Flow Value (mm)	3.90	4.20	4.10	4.10	3.95

C. Determination of Optimum Binder Content for Bc Mix Prepared with Crmb-55.

i. The maximum value of stability is observed as 21.57 kN at 5.59 % binder content. This indicates that 5.59% is the optimum binder content. While density, void with mineral aggregate, flow value, air voids all are the governing parameter for selecting the optimum binder content but stability is one of the important parameters. In the above relationship, the stability value first starts increasing then after 5.59% binder content stability values start decreasing. There are increases in Stability maivalue as compared to the control mix with the addition of Plastic content

ii. The maximum value of density is observed as 2.346 g/cc at 5.59 % binder content. This indicates that in density relation with binder content is also giving the same optimum binder as selected in stability.

iii. It is observed that VMA value slightly increases to 16.43 at 5.60%

binder content, then further increases in VMA value with increase in Binder content

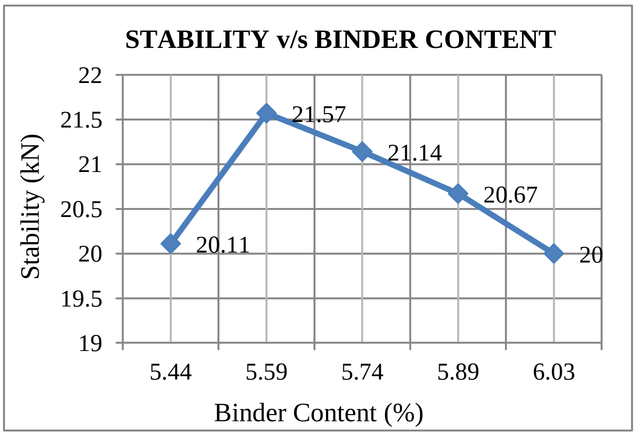


Fig. 3: Relationship between stability and Binder content.

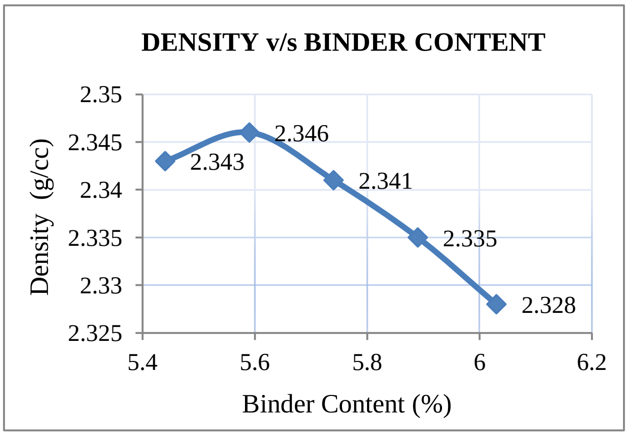


Fig. 4: Relationship between Density and Binder Content.

D. Quantity of Pet (Poly-Ethylene Terephthalate) In Bc

For finding the optimum dosage of plastic waste, samples were made at four different percentages i.e. 2%, 4%, 6% and 8% by weight of aggregate.

Table 7 Percentage and quantity of PET used

Percentage of PET (%)	Weight in grams (g)
2	24
4	48
6	72
8	96

Preparation of samples being done on varying percentage of PET i.e. 2%, 4%, 6% and 8% % by weight of binder at optimum binder content i.e. 5.59% and also at one binder content above and below optimum. Samples are prepared based on required grading and the ratio for control mix is modified based on percentage of plastic waste as 2%, 4%, 6% and 8% of PET will replace 24g, 48g, 72g and 96g of aggregates respectively. Samples are prepared on three different binder content (5.44%, 5.59% and 5.74%).

BC samples were prepared with PET 2%, 4%, 6% and 8% and Marshall Stability test was performed. Three samples at each binder content were prepared and their average values are as given in table 9

Table 9: Marshall Stability test result for a varying percentage of PET

S. No	Properties	PET Content			
		2%	4%	6%	8%
1	Density of Sample (g/cc)	2.336	2.312	2.290	2.283
2	Volume of Binder, Vb (%)	12.43	12.30	12.22	12.15
3	Volume of aggregate,Va (%)	84.49	84.60	84.37	84.85
4	Voids in Mineral Aggregate, VMA (%)	15.50	15.73	15.63	15.15
5	Voids filled with binder, VFB (%)	80.19	78.19	78.18	80.19
6	Air Voids (%)	3.07	3.43	3.45	3.00
7	Stability (kN)	22.44	23.59	24.89	23.00
8	Flow value (mm)	4.10	3.40	4.06	4.30

Determination of optimum plastic content

i. As the quantity of PET is increasing the stability value are also increasing. Here control mix is showing the least value of stability i.e. 21.5KN at 5.60% binder content. The maximum stability is obtained in the mix with PET 6% i.e. 24.89KN at 5.59% binder content.

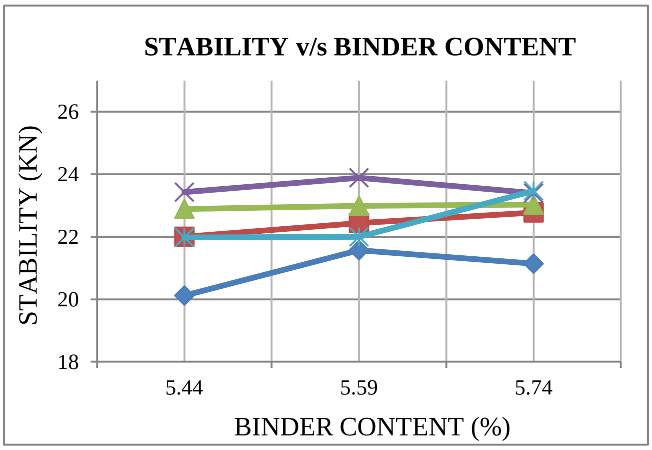


Fig. 5: Variation of Stability with Binder Content with varying PET Content.

ii. The Density for all four mixes with varying percentage of PET in 2%, 4%, 6%, and 8% shows the same pattern i.e. with the increase in binder content density decreases. The maximum density of mix with 2% PET i.e. 2.342 g/cc, PET 4% i.e. 2.322g/cc, PET 6% i.e. 2.300g/cc, PET 8% i.e. 2.280g/cc. While comparing the mixes the maximum density at 5.60% binder content is achieved by control mix i.e. 2.346g/cc and lowest density is achieved by PET 6% i.e. 2.290g/cc.

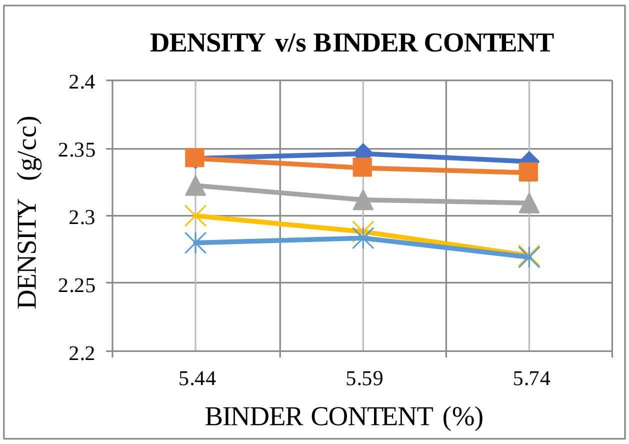


Fig. 6: Variation of Density with Binder Content with varying PET Content.

iii. The mix with 6% is showing the least value of flow i.e. 3.5 mm. The maximum flow value is obtained at PET 4% i.e. 4.06mm which is slightly less than the control mix i.e. 4.2 mm.

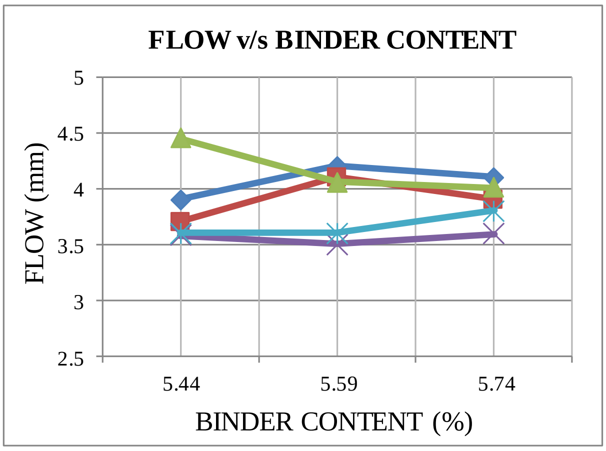


Fig. 7: Variation of Flow with Binder Content with varying PET Content.

iv. It is observed that in the Control mix with an increase in Binder content air voids decreases. But with the addition of PET to mix the air void is increasing with the increase in binder content. Min air voids at 5.60% binder content is for PET 8% i.e. 3% and maximum air void is for PET 6% i.e.3.

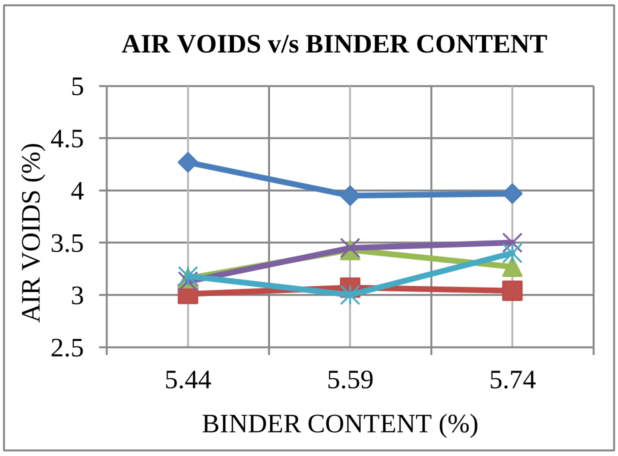
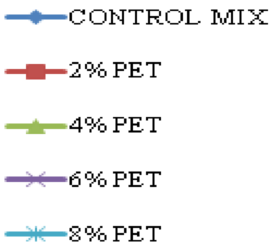


Fig. 8: Variation of Air voids with Binder Content with varying PET Content.

In the above figure different colour are shown to indicate Control Mix, 2%PET, 4% PET, 6% PET and 8%PET.



E. Test for Retained Stability of Bc Samples

For finding the retained stability, samples were prepared at optimum binder content and BC at optimum plastic content. After keeping the samples in a water bath at 60ºC for 24 hours their Marshall stability values were noted. A comparison is made between the stability retained after putting the samples in water for 24 hours.

Table 4.21: Retained Stability

Binder Type	S1(kN)	S2(kN)	Retained Stability
CRMB – 55 (control mix)	21.57	18.22	84.46
CRMB – 55 with addition of plastic at optimum content 6%	23.89	21.55	90.20

S1 = Marshall Stability for specimen immersed in a water bath for 40 minutes.
S2 = Marshall Stability for specimen immersed in a water bath for 24 hours.
Retained Stability = (S2 ÷ S1) × 100

IV. CONCLUSION

Following conclusions are obtained after a thorough study of the results:

i. The Density for all four mixes with varying percentage of PET in 2%, 4%, 6%, and 8% shows the same pattern i.e. with the increase in binder content density decreases. In the case of BC density at optimum binder content at 5.60% for the control mix is 2.346 g/cc and then decreases to 2.298 g/cc for PET 6%. This is expected as PET is lighter material.

ii. Stability is found to be enhanced with the addition of PET (up to 8% dosage) as compared to the control mix.

iii. The addition of PET at a different percentage of binder content shows the better result in each case but optimum results in term of better Stability was obtained at 6% dosages and then at 8% PET there is a decrease in Stability value with respect to PET at 6 %. In BC sample, there was an increase in value up to 6% dosage i.e. 24.89 kN and then decreases to 23.00 kN at 8% dosages

iv. The various properties of mixes like air voids, VMA, VFB, Flow value show good results and are nearly within permissible limit with 6% PET in BC.

v. The Retained Stability for CRMB-55 together with

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

optimum plastic content i.e. 6% show better results after putting the sample in water for 24 hours than the conventional CRMB-55. The percentage increase in stability retained was 84.46 to 90.20 for BC. Hence, the use of PET along with CRMB not only provides better resistance toward rainwater but also provide a reduction in cracks and potholes.

vi. The use of PET in bituminous mixes prepared with CRMB is economical, durable and shows better results than control mix. Both PET and CRMB may reduce the cost of the project as CRMB is easily available and prepared using waste recycle tyres while PET will reduce the volume of plastic waste which is disposed of by incineration or land filling. This approach results both in an environmentally friendly way of reutilizing the waste.

REFERENCES

1. Agar E. and Hinislioglu S.(2004), " Use of waste high-density polythene as bitumen modifier in asphalt concrete mix," Indian Journal of Engineering and Material sciences IJMES, Volume 12, October 2005, pp 456-460.
2. Ghandhimati A. and Abinaya S (2017), "An Experimental study on the behaviour of modified bitumen using recycled plant," International Journal of Civil Engineering and Technology (IJCIET), Volume-8, Issue-8, August 2017, pp. 1707-1715.
3. Khmita Aman and Arora Sahil (2017), “Use of waste plastic in Bituminous Concrete,” International Journal of Civil Engineering and Technology (IJCIET), Volume-8, Issue-8, August 2017, pp 30-37
4. Gawande A.P. (2013), “Economics and viability of Plastic road: A Review,” Journal of current chemical and pharmaceutical Science, Volume 3(4), 2013, pp 231-242.
5. Nabin Rana Magar Nabin (2014), “A Study on the Performance of Crumb Rubber Modified Bitumen by Varying the Sizes of Crumb Rubber,” International Journal of Engineering Trends and Technology (IJETT), Volume 14(2),51-56 Aug 2014.
6. Prasad Athira R., Sowmya N. J, “Bituminous Modification with Waste Plastic and Crumb Rubber,” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 12, Issue 3 Ver. II (May - Jun. 2015), pp 108-115.
7. Kumar C. Prasanna, Shashishankar, “Study of Crumb Rubber for the Partial Replacement for Bitumen or as an Alternative Material for Bitumen”, International Conference on Current Trends in Eng., Science and Technology(ICCTEST), 2015.
8. Vora Nishant, Desai Rutvij, Lunagaria .M.H, “Physical Property Comparison of CRMB with Conventional Bitumen Used in Bituminous Concrete,” Indian Journal of Research Vol: 2, Issue: 4, April 2013.
9. Sangita, Sharma D. K., Sharma B. M., "Performance evaluation of waste plastic/polymer modified bituminous concrete mixes", Journal of scientific and industrial research vol. 68, Nov 2009, pp. 975-979.
10. Rokade S, “Use of Waste Plastic and Waste Rubber Tyres in Flexible Highway Pavements”, 2012 International Conference on Future Environment and Energy IPCBEE vol.28(2012)
11. Kapil Soni, Punjabi K.K, “ Improving the performance of Bituminous Concrete Mix by Waste Plastic”, International Journal of Engineering Research and Applications vol. 5, Sept-Oct 2013, pp. 863-868.
12. Tapase K.P and Kadam D.B., “Performance Evaluation of Polymer Modified Bitumen in Flexible pavement,” Journal of Environmental Research and Development Vol. 8 No 3, January-March 2014
13. Bhageerathy K.P., Alex Anu P., Manju V.S, Raji A.K., “Use of Biomedical Plaste Waste in Bituminous Road Construction,” International Journal of Engineering and Advanced Technology (IJEAT) ISSN:2249-8958, Volume -3 Issue-6, August 2014
14. Adane Legesse and Muleta Diriba, “Survey on the usage of Plastic Bags, their disposal and adverse impact on environment: A case study in Jimma City, Southwestern Ethopia,” Journal of Toxicology and Environmental Health Sciences Vol 3(8) pp.234-248, August 2011
15. Jain P.K, Kumar Shanta & Sengupta J.B, “Mitigation of Rutting in bituminous roads by use of waste polymeric packaging materials,” Indian Journal of Engineering & Materials Sciences Vol 18, June 2011, pp 233-238 (Central Road Research Institute, CSIR, New Delhi)
16. Sreedevi B.G., Salini P.N., “Pavement Performance Studies on roads surfaced Using Bituminous Mix with Plastic Coated Aggregates,” International Journal for Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 9, September-2013

AUTHORS PROFILE

Shivani Guleria, ME (CTM) from National Institute of Technical Teachers Training and Research Chandigarh, India

Ajay Kumar Duggal, Associate Professor Dept. of Civil Engineering National Institute of Technical Teachers Training and Research Chandigarh, India M.tech. (Transportation Engg.) from University of Roorkee and B.Tech (Civil Engg.) from REC Kurukshetra.