International Journal of Recent Research and Review, Vol. XIII, Issue 4, December 2020
ISSN 2277 – 8322

Use of PET (Polyethylene Terephthalate) in Bituminous Mixes

[1]Divyanshu Varshneya, [2] Deepak Mathur,

[1]*M.Tech. Scholar, Transportation Engineering, Kautilya Institute of Technology &Engineering, Jaipur*

[2]*Asssistant Professor, Dept. of Civil Engineering, Kautilya Institute of Technology &Engineering, Jaipur*

[1]divyanshu.varshneya7@gmail.com [2]mathurdeepak1507@gmail.com

Abstract **The use of waste plastic in road construction plays an important role in the development of a good and stable pavement and this makes cost effective. As we know that India is a developing country so by using waste plastic in pavement work economy of the country can be improved. In India for developing of the road network to connect various places by bituminous road should be constructed because initial cost of construction is less. This study is carried out the useof waste plastic in road construction by replacing some amount of bitumen. And the amount of waste plastic is 0%, 2.5%, 5%, 7.5%, 10% in place of bitumen.By analysing the all test on Marshall Mix design, we finally conclude that 7.5 percentage of waste plastic will give us the optimum value.So by using plastic cost can also be minimised. And in our project we have analysed the different properties of bitumen and its mixture with aggregate by different tests and have checked the impact of adding plastic**.

I. Introduction

Waste Management is one of the dominant conceptions recent years. Nowadays, the recycling of various wastes (plastic waste) produced from multiple Industries is a significant problem. [6,7] In last decades, utilization of industrial waste used in road work or paving with great interest in many developing and industrialized countries.[10] Use of waste plastic in pavement design can prove as the partial solution towards minimizing pollution caused by plastic.

If the Road surface is paved with neat bitumen then there are chances of developing cracks in cold weather and bleeding in hot climate, possess low load bearing capacity and can cause severe damages because of heavy axle load due to rapid growth in infrastructure. [8,12]

So by using plastic waste in the bitumen the strength, durability, stability, load bearing capacity can be increased. [2,9] This study shows the use of plastic waste in hot bituminous mix to increase the pavement performance, provide low-cost road sand make the environment eco-friendly.

A. OBJECTIVE

- To study the fundamental properties of plain bitumen and aggregates
- To study the effect of plastic waste on the BC mix.
- To study the stability and strength of the pavement.

- The main motive for these experimental studies to conduct the comparative studies of partial replacement of bitumen with 0%, 2.5%, 5%, 7.5%, 10% as an aggregate in flexible pavement.
- To study the strength characteristics of plastic waste.

B. SCOPE

- The scope of the investigation is to evaluate the performance of flexible pavement by using waste plastic in the bitumen mix.
- Develop a technology, which is economical and environmental friendly.

II. LITERATURE REVIEW

- **G. Vijaya Raju et.al. 2017 [1]** design of Flexible Pavement by using waste Plastic in Bitumen in which bitumen content is used as 4%, 4.5%, 5%, 5.5%, 6% and bitumen content is replaced by 5%, 10%, 15% and 20% of waste plastic. Use of shredded plastic waste materials act as a strong "binding agent" for bitumen making the asphalt last long and this combination of waste plastic along with bitumen induces high strength and increase durability of roads.
- **R.Manju et.al. 2017 [2]** use of Plastic waste in bituminous pavement. The use of plastic waste in bituminous mix enhances the strength of pavement. In this plastic is shredded and then mixed with aggregates at high temperature, after this bitumen is added to this mix. In this the use of bitumen content is reduced by 10% by using plastic waste. The waste plastics used are poly-ethylene, poly-styrene, and poly-propylene. The waste plastic is cut into small pieces and coated on the aggregate and mixed with hot bitumen and the resulting mixture is used for pavement construction. This will not only strengthen the pavement but also increases the durability.
- **Agrawal et. al. 2017 [3]** investigated the use of Plastic Waste in Flexible Pavement Design. The use of plastic waste material is an innovative technology to strengthen the road construction and increase the road life. This experiment includes the result of various tests conducted on Bitumen, aggregate and Bitumen-aggregate plastic mix.
- **Brajesh Mishra et.al. 2015[4]** a study on use of Waste Plastic Materials in Flexible Pavements. There are two processes available for mixing of waste plastics in bituminous mix namely dry process and wet process in this study dry process was used for mixes. The Marshall Method of Mix design is used in which 80/100 grade bitumen is used. In this experimental study bitumen contents are taken 4 to 6% by increment of 0.5% by weight of aggregates and the plastic waste was taken as 6%, 8%, 10%, 12%, 14%, and 16% which was replaced to the bitumen content.
- **Moghaddam and Karim 2012 [5]** indicated that it would be advantageous to use waste material in the asphalt pavement to find an alternative solution to improve the asphalt pavement's service life and also minimize environmental pollution. The study concludes that polyethylene terephthalate (PET) blends have a higher stability value, flow, fatigue life compared to blends without PET.
- **Punith and Veeraragavan 2012 [6]** studied the actions of asphalt concrete mixtures with recovered polyethylene as an additive. In their investigation, dynamic creep tests (unconfined), indirect tensile tests, resilient modulus tests, and Hamburg wheel track tests were carried out on mixtures of PE (2.5, 5.0, 7.5, and 10% by weight of asphalt) with (80/100) asphalt paving grade and found that the value of rutting potential and temperature could be minimized by the incorporation of PE in the asphalt mixture.

III. MATERIALS

The following materials are used in constructing the road surface courses are:

1. Aggregates
2. Bitumen

Along with these materials the plastic waste (Polyethylene) is used which considerable reduced the amount of bitumen content.[2-4]

To make the impervious compacted mix, bitumen is added in adequate quantity and will have acceptable elastic properties [1-3].

The aggregates are classified as Coarse Aggregate (particles which are retained on 4.75 mm sieve), Fine Aggregate (particles which are passing through 4.75 mm sieve and retained on 75µ sieve) and Fillers (passing through .075 mm sieve) [2-4].

IV. Mixing of plastic

Dry process:-The stone aggregates are heated at 170^0c temp. and mixed with hot bitumen (160^0 C) and then the mix is used for road construction [4-8]. When the shredded plastic is coated with aggregate.it improves the quality concerning voids, moisture absorption, and soundness. The coating of the plastic waste decreases the porosity and helps to improve the quality of the aggregate and performance in the flexible pavement.[6,10]

Wet process: - In this process the bitumen is heated at temperature of 170°c and then the polymer wastes (plastic waste such as polyethylene and bottles) are mixed with heated bitumen [8-11]. After this the mixed bitumen is stirred properly by strong mechanical stirrer and continuous rotation, then the plastic waste is blended with bitumen and after this the blended bitumen mix is cool up to 120°c and mixed with aggregates and laid on the land surface[5,6]. This is the method in which the limitations of dry process can be overcome, if the heat losses and temperatures are controlled effectively then tis process is effective in the sense of minimizing the production time and productivity can be improved. In our project wet process is used [8-11].

Test Results on Aggregates and Bitumen:-

Table No. 1 Test on Aggregates

S. No	TESTS	RESULTS
1.	Aggregate Impact Value	20.5%
2.	Aggregate Crushing Value	26%
3.	Cleanliness Test	2
4.	Flakiness and Elongation Index	29%
5.	Stripping Test	97%
6.	Water Absorption	0.46%

Table No. 2 Penetration Test Results on Bitumen

PET Content (%)	Penetration (1/10 mm)
0 (Pure Bitumen)	69
2.5	60
5	40
7.5	21
10	19

Table No. 3 Ductility Test Results on Bitumen

PET Content (%)	Ductility (cm)
0 (Pure Bitumen)	100
2.5	31
5	28
7.5	18
10	15

Table No. 4 Softening Point Test Results on Bitumen

PET Content (%)	Softening Point (°C)
0 (Pure Bitumen)	51
2.5	52
5	61
7.5	69
10	71

Table No. 5 Specific Gravity test Results on Bitumen

PET Content (%)	Specific Gravity
0 (Pure Bitumen)	1.036
2.5	1.031
5	1.028
7.5	1.024
10	1.018

Table No. 6 Flash and Fire Point Test Results on Bitumen

PET Content (%)	Flash Point (°C)	Fire Point (°C)
0 (Pure Bitumen)	290	340
2.5	295	340
5	325	350
7.5	335	350
10	295	310

I. MARSHALL MIX DESIGN

Grading of aggregate should be done before mix design. For this purpose sieve analysis of aggregates have been done having size 19mm,13.2 mm,4.75 mm, 2.36 mm, 1.18 mm, 300um, 75 microns, and stone dust. Grading requirement of BC for this study should satisfy the MORTH.The aggregate gradation should be in the desired limits and within the desired limit as per MORTH table 500-7 for bitumen content of Grade 2.

Table No. 7 Material Requirement for One Sample as per Gradation

Sieve size (mm)	20 mm (30%)	10 mm (30%)	Stone Dust (40%)	Obtained Gradation	Desired Gradation
19	30	30	40	100	100
13.2	27.88	27.15	40	95.03	79-100
9.5	7.4	24.65	40	72.05	70-88
4.75	1.07	17.31	36.23	54.61	53-71
2.36	0	14.07	29.68	43.75	42-58
1.18	0	11.53	23.92	35.45	34-48
0.6	0	10.44	17.62	28.06	26-38
0.3	0	6.87	12.22	19.09	18-28
0.15	0	4.61	8.7	13.31	12-20
0.075	0	2.14	3.04	5.18	4-10

Table No. 8 Unit Weight results for mixes with pure and PET modified Bituminous Concrete

Binder Content (%)	Unit Weight (kg/m^3)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	2290.23	2249.72	2209.54	2209.04	2219.04
5.5	2299.45	2290.31	2220.49	2229.71	2228.97
6	2309.67	2319.64	2259.71	2259.82	2249
6.5	2339.38	2330.18	2290.84	2279.67	2249.56
7	2359.64	2359.12	2309.32	2290.84	2258.93

Table No. 9 Marshall Stability values for mixes with pure and PET modified Bituminous Concrete

Binder Content (%)	Marshall Stability (kg)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	479	658	871	806	501
5.5	462	749	945	807	733
6	671	852	823	1060	882
6.5	894	939	1046	1098	1055
7	826	665	1002	865	992

Table No. 11 Marshall Flow values for mixes with pure and PET modified Bituminous Concrete

Binder Content (%)	Flow Value (1/10 mm)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	10.6	12	14	14.6	14.6
5.5	12	16	19	21.6	11
6	11	17.6	15	19	14.3
6.5	15.6	18.6	18.6	21.6	15
7	11.6	16.9	14.5	22.6	16.6

Table No. 12 Voids (V_a) Results for mixes with Pure and PET modified Bitumen

Binder Content (%)	Air Void (%)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	6.63	8.64	11	10.26	10.94
5.5	5.45	6.25	9.86	9.08	10.18
6	4.25	4.23	7.86	7.1	8.64
6.5	2.6	3.02	5.86	5.49	7.89
7	0.94	1.36	4.25	4.28	6.71

Table 13 Void Mineral Aggregate (VMA) Results for mixes with Pure and PET modified Bitumen

Binder Content (%)	VMA (%)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	17.14	18.59	20.03	20.01	19.68
5.5	17.21	17.57	20.1	19.74	19.73
6	17.29	16.93	19.08	19.08	19.43
6.5	16.65	17.01	18.79	18.79	19.86
7	16.39	16.39	18.87	18.87	19.93

Table 14 Void Filled with Aggregate (VFA) Results for mixes with Pure and PET modified Bitumen

Binder Content (%)	VFA (%)				
	Pure Bitumen	2.5% PET	5% PET	7.5% PET	10% PET
5	61.78	53.91	45.46	49.12	44.74
5.5	68.83	64.9	51.34	55.2	48.75
6	75.96	75.56	59.21	63.22	55.92
6.5	85	82.83	68.68	70.69	60.67
7	94.94	92.37	77.12	76.88	66.77

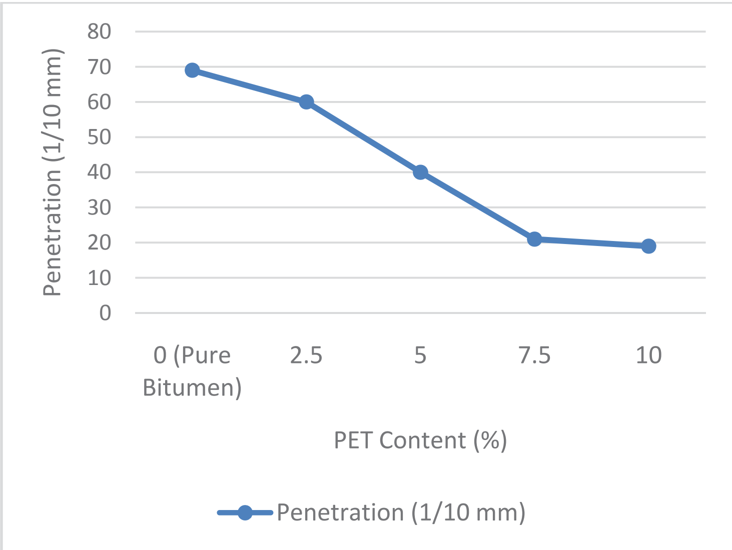

Figure 1 Variation of Penetration value with PET Content

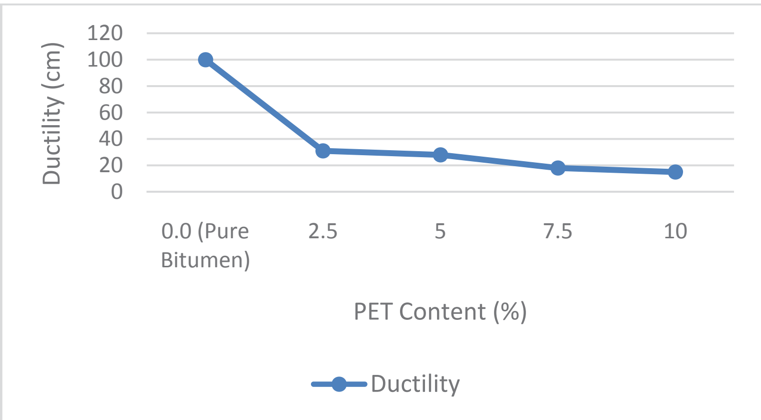

Figure 2 Variation of Ductility value with PET Content

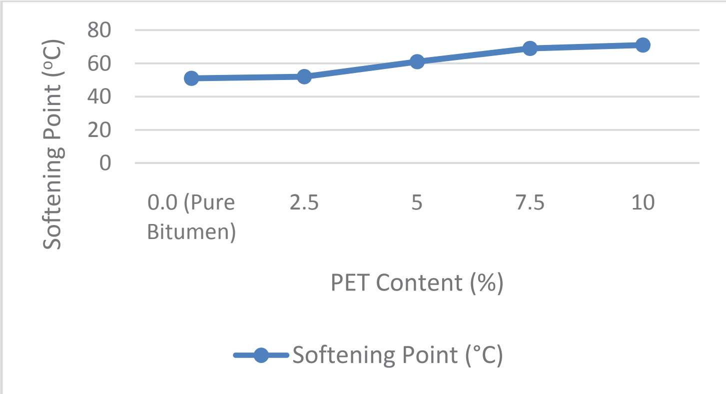

Figure 3 Variation of Softening Point with PET Content

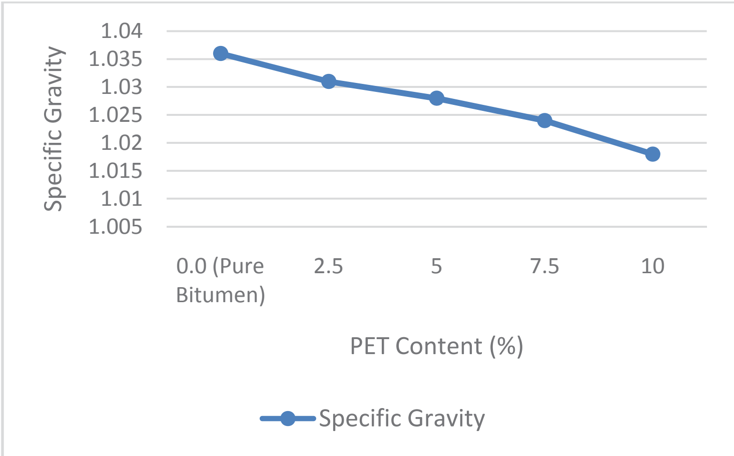

Figure 4 Variation of Specific Gravity with PET Content

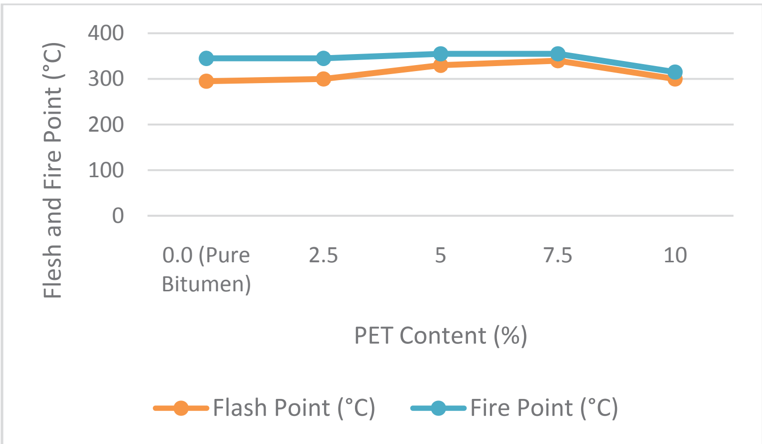

Figure 5 Variations of Flash and Fire Point with PET Content

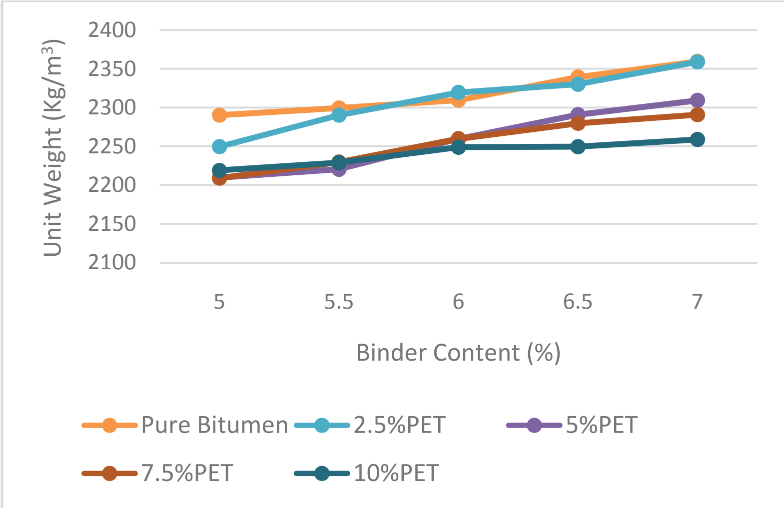

Figure 6 Variations of Unit Weight Point with Pure and modified PET Bituminous Concrete

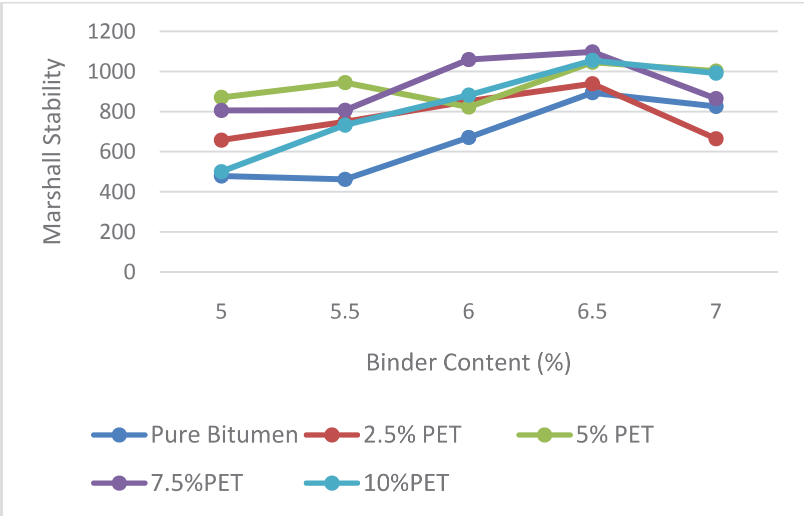

Figure 7 Variations of Marshall Stability with Pure and modified PET Bituminous Concrete

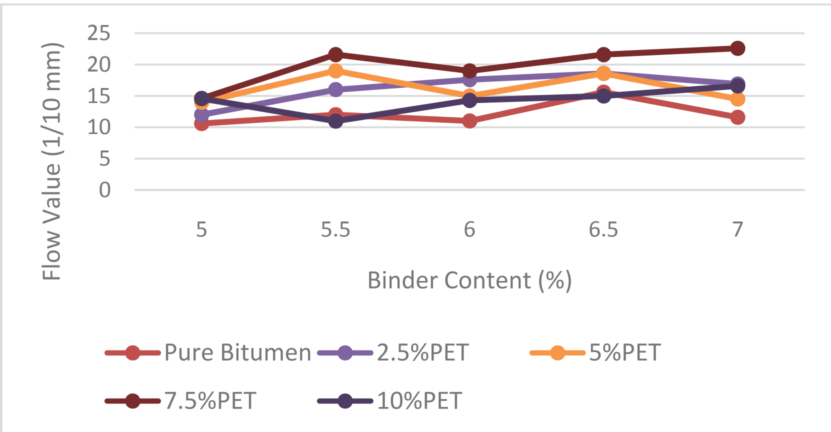

Figure 8 Variations of Flow Value with Pure and modified PET Bituminous Concrete

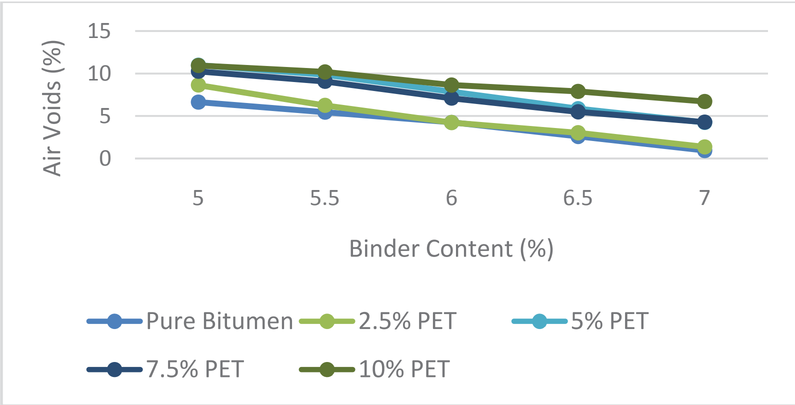

Figure 9 Variations of Air Voids with Pure and modified PET Bituminous Concrete

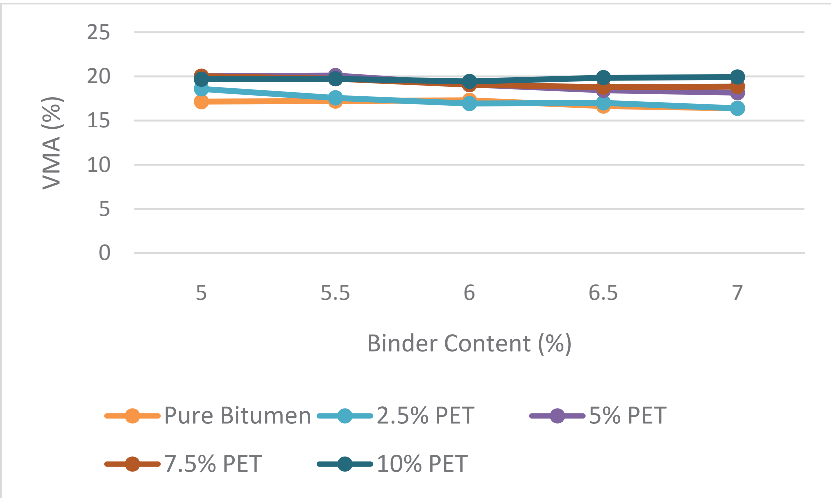

Figure 10 Variations of Voids in Mineral Aggregate with Pure and modified PET Bituminous Concrete

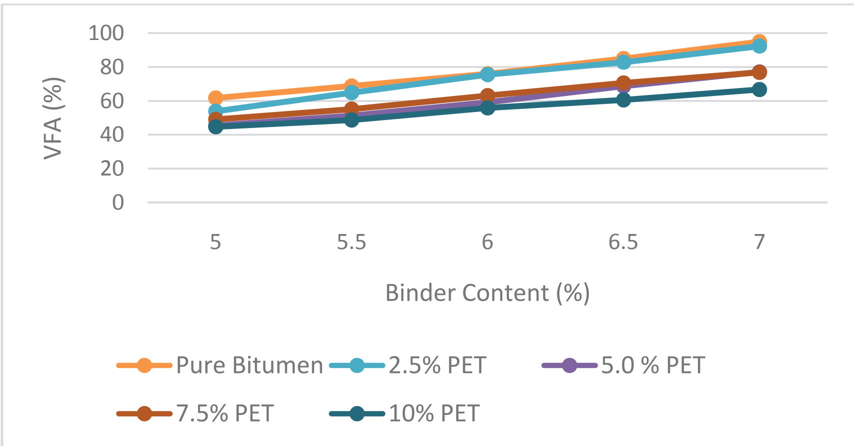

Figure 11 Variations of Voids filled with Aggregate with Pure and modified PET Bituminous Concrete

II. CONCLUSIONS

- The penetration of the modified PET binder decreases with an increase in the PET content of the bitumen. It is observed that the addition of 7.5 per cent of PET in bitumen results in a decrease of more than 70 per cent in penetration relative to pure bitumen.
- The ductility of the modified PET binder decreases dramatically with the increase in the inclusion of PET in bitumen. The experimental investigation reveals that the ductility value decreased by more than 83 per cent in the case of 7.5 per cent PET in bitumen compared to that of pure bitumen.
- The softening point increases with the rise in bitumen PET content. Softening rises by around 36 per cent compared to virgin bitumen in the case of 7.5 per cent waste plastic material.
- Specific gravity of modified binders are almost identical to pure bitumen binders.
- The stability of the compacted mixtures increases dramatically with an improvement in the PET content of bitumen up to 7.5 per cent and a decrease in the stability at PET content of 10 per cent. The optimum PET content can therefore be taken as 7.5 per cent.
- It is noticed from the stability test of Marshall Specimens that the Marshall Stability improves by around 19 percent at 7.5 percent PET versus 5.5 percent binder content. This means that by adding 7.5 percent PET without altering any other mix ingredient, high strength bituminous mixes can be made.
- With an increase in PET content of up to 7.5 percent in the mix, the flow values obtained in the Marshall tests indicate an increasing trend. It has been found that the impact of PET on density, air void (Va), mineral aggregate void (VMA) and asphalt-filled void (VFA) is not important.
- From close observations of the curves of Marshall Characteristic (viz. Stability Vs Binder content, Flow Vs Binder Content, Unit Weight Vs Binder Content, %V_a Vs Binder Content percent, %VMA Vs Binder Content and %VFB Vs Binder Content) for modified binder, the patterns and shapes are very similar to those of pure bitumen mixes. This means that the optimal amount of modified binder could be calculated according to the same Marshall Mix Specification and criteria.
- PET's unit cost is around 30 percent lower than that of pure bitumen. Therefore, for road building and maintenance work, the use of PET (7.5% bitumen by weight) with bitumen may be economically viable.

III. FUTURE SCOPE

- Government agencies like City Corporations should come up with at least one comprehensive project of processing waste plastics and constructing roads using the PET modified bituminous mix.
- The models of collection of plastic wastes by the Bangalore City Corporation be followed by City Corporations of India. Private sector may be involved in the collection process.
- Initiatives need to be taken to improve the locally fabricated equipment and machinery for shredding and blending of waste plastics. The private sector should be encouraged and involved Government may provide necessary financial incentives.
- To ensure the use of specified waste plastics in road works with proper specification road agencies along with academic institutions should develop Standard Test Procedures and set up

laboratory facilities to do the specified tests.

- Professional and academic training should be given to different appropriate levels in the implementing chain – Engineers, Technicians, Foreman and up to field level Labourers with regard to the new technology.

IV. REFERENCES

1. **G. Vijaya Raju et.al.** ***2017*** *"Design of Flexible Pavement by using waste Plastic in Bitumen"* Volume 3,Issue 11, April 2017, ISSN: 2349-6002

2. **R. Manju et.al. 2017** *"Use of Plastic waste in bituminous pavement"* Vol. 10 No. 8, pp: 804-811, 2017, ISSN: 0974-4290, ISSN (Online): 2455-9555

3. **Agrawal et. al. 2017 "***Utilization of Plastic Waste in Flexible Pavement Design"* Volume 3, Issue 3, March 2017, ISSN (O):2454-9665, ISSN (P): 2454-0663.

4. **Brajesh Mishra et.al. 2015** "*A Study on Use of Waste Plastic Materials in Flexible Pavements*" Vol. 4, Issue 8, August 2015, ISSN No. (Online): 2319-8753, ISSN (Print): 2347-6710.

5. **Moghaddam T. B. and Karim M. R. (2012)**, "Properties of SMA mixtures containing waste Polyethylene Terephthalate", International *Journal of Chemical and Biological Engineering 6*, pp. 188-191

6. **Punith V. S. and veeraragavan A. (2012**), "Behavior of asphalt concrete mixtures with reclaimed polyethylene as additive", *Journal of materials in civil engineering, Volume 19*, pp. 500–50

7. **Gawande A., Zamare G. et. al. (2012),** "An overview on waste plastic utilization in asphalting of roads", *Journal of Engineering Research and Studies Vol. III/ Issue II.*

8. **Khan I. and Gundaliya P. J. (2012)**, "Utilization of waste polyethylene materials in bituminous concrete mix for improved performance of flexible pavements", *Journal of applied research, volume 1, issue 12*, pp. 85-86

9. **Swami V., Jirge A., et. al. (2012)**, "Use of waste plastic in construction of bituminous road", *International Journal of Engineering Science and Technology, Volume 4*, pp. 2351- 2355

10. **Pareek A., Gupta T. et. al. (2012),** "Performance of polymer modified bitumen for flexible pavements", *International journal of structural and civil engineering research, Volume 1*, pp. 1-10

11. **Ahmadinia E., Zargar M. et. al. (2012),** "Performance evaluation of utilization of waste Polyethylene Terephthalate (PET) in stone mastic asphalt", *Journal of Construction and Building Materials, Volume 36*, pp. 984–989

12. **Attaelmanan M., Feng C. P. et. al. (2011),** "Laboratory evaluation of HMA with high density polyethylene as a modifier", *Journal of Construction and Building Materials, Volume 25,* pp. 2764–2770