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Investigation on Utility of Plastic Waste as an Additive for Bituminous Concrete Using Wet Process of Mixing

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***Abstract* - Plastic waste has become a major environmental issue of concern due to its exponential growth due to rapid urbanization. The present study investigates utility of plastic waste as an additive for bituminous concrete using wet process of mixing. In the present study LDPE and HDPE type of plastic waste are used to modify the bitumen. The results show that addition of 6 percent of bitumen improves the Marshall properties of the mix. Use of plastic to modify the bitumen not only makes the road surface more durable but also it is an eco-friendly way of proper disposal of plastic waste.**
***Keywords*: Utility of Plastic Waste, Bituminous Concrete, Wet Process of Mixing**

I. INTRODUCTION

Plastic is a non-biodegradable material increasing exponentially due to tremendous growth in population, urbanization and changed life style with its widespread applications. Researchers found that the material can remain on earth for 4500 years without degradation [1]. Several studies have proven the health hazard caused by improper disposal of plastic waste. In this scenario, the conventional waste disposal methods are found to be inadequate. Researchers and scientist are trying to work on reduction, recycling, reusing and energy recovery from solid wastes. Study revealed that, out of total plastic waste in India, around 94% waste comprises of thermoplastic content, which is recyclable such as PET, LDPE, HDPE, PVC etc. and remaining 6% belongs to the family of thermoset and other categories of plastics such as SMC, FRP, multi-layered, thermocol etc.

In the current era of economic development with such a hefty population, it is required to have a dense network of road for the smooth transportation of goods & passengers. India, despite having one of the largest railway network moves mostly on roads. Be it passenger or freight all move on roads. Nearly 65% of freight and 85% of passenger traffic use roads for their movement [3].In India flexible pavements are generally preferred due various advantages such as low cost, availability of material, speed of construction, ease in construction, low maintenance and ease in upgradation. It should be noted that major portion of highway in India is flexible. Recent research suggests that these plastic materials can be used in road construction as a binding material. Polyethylene is extensively used plastic material, and it has been found to be one of the most effective polymer additives in road construction. Use of plastic along with the bitumen in construction of roads not only increases its ductility and smoothness but also makes it economically sound and environment friendly [4].From an environmental and economic point of view, the use of recycled instead of virgin materials could have several advantages such as help easing landfill pressures and reducing demands of extraction from natural quarries. Furthermore, this would be an alternative solution for environmental pollution by utilizing waste materials as secondary materials in road construction projects [5].Waste plastic bitumen road is found to be more stronger, durable, withstand heavy loads, absorption of radiations, resistive to cracking and rutting. Generally two processes are adopted first is Wet process which is basically the polymer enriched/modified bitumen process and secondly the Dry process that is basically poly coated aggregate process [3].

II. LITERATURE REVIEW

Amit P. Gawande (2013) had used the plastic waste in the construction of bituminous road construction by replacing conventional type of aggregate with plastic coated aggregate and also mixed in bitumen. The dry process was used for the aggregate while the wet process was used for the bitumen. The dry process 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. This technique adds a cumulative benefit to National Economy also gives contribution to environmental benefits, employment generation and agricultural efficiency [1].

Mayura M. Yeole *et. al,* (2014) has highlights the developments in using plastics waste to make plastic roads. In the flexible pavement construction where bitumen binders are used, it is of significant importance that the binders form ductile thin films around the aggregates. This serves as a satisfactory binder in improving the physical interlocking of the aggregates. The objective behind the experiment was to measure the ductility of given sample of homogeneous mixture i.e. bitumen and waste plastic and to determine the suitability of mix. The bitumen was prepared using waste plastic for varying percentage by wet process and allowed to test with the help of ductility apparatus. Percentage of waste plastic added in bitumen, the ductility value of modified bitumen is decreases. If the ductility value is less than specified value then road surfaces may get cracked and due to this life of pavement will be reduced, Hence 9 % of the plastic waste must be added to the bitumen for the better performance of the roads using wet process [4].

Shirish N. Nemade *et.al*, (2013) uses the polymer waste with or without crumb rubber to modify the properties of bitumen. The wastes like crumb rubber, HDPE waste, LDPE, PP Waste and mixture of crumb rubber- HDPE waste were taken into consideration. When these plastics are added into bitumen, various differentiating results have obtained. The addition of this waste is determined by means of weight % of bitumen. It is called out by two processes, viz, dry and wet process. Dry process is used for aggregate while wet process is used for bitumen. The waste obtained and mixed in different forms i.e. polymer waste was in shredded form and HDPE waste in strand form and crumb rubber was in powder form. From the obtained results they conclude that it not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income [6].

Dhirar Taha Mohammed *et.al*, **(**2014**)** used polyethylene terephthalate (PET) as asphalt modifier in asphalt. The research paper has focused on the ability of improving the performance of asphalt mixtures using Polyethylene Terephthalate (PET) obtained from plastic waste in Mosul landfills. Five different percentages of PET are added using wet process. Marshall Test, moisture susceptibility and durability test are conducted on unmodified and modified asphalt mixtures. The results showed that the optimum polymer content of PET is 4%. the addition of this percentage of polymer lead to an improvement in the durability, resistance of asphalt mixture to moisture damage & increase of the Marshall stability by 36.09 % while the flow values reduced slightly [7].

Dixit Sandhya *et.al,* (2013) quoted that in the wet process; shredded waste plastic is mixed with hot bitumen at a temperature 160^0C. With the help of powerful mechanical stirrers. The stabilizers are also added to the bitumen during heating. The mix is then laid on the road. In this process, mixing of higher percentages of is however, difficult because of the difference in viscosities of molten plastic waste and bitumen [8].

Bindu *et al.* (2010) investigates the benefits of stabilizing the stone mastic asphalt (SMA) mixture in flexible pavement with shredded waste plastic. Conventional (without plastic) and the stabilized SMA mixtures were subjected to performance tests including Marshall Stability, tensile strength and compressive strength tests. Triaxial tests were also conducted with varying percentage bitumen by weight of mineral aggregate (6% to 8%) and by varying percentage plastic by weight of mix (6% to 12% with an increment of 1%). Plastic content of 10% by weight of bitumen is recommended for the improvement of the performance of Stone Mastic Asphalt mixtures [9].

III. MATERIALS AND METHODS

Various materials used in the present study are bitumen, aggregate (fine and coarse), filler, and shredded plastic waste. The bitumen used for present study is of 60/70 penetration grade and is obtained from BPCL, Nagpur and PWD, Amravati. Coarse aggregates, fine aggregates and fly ash were collected from local producer of crushed aggregates. The plastic waste was segregated from the municipal waste and shredded at the local plastic waste recycling plant at MIDC, Amravati.

The experiment was conducted into two parts. The first part consists of calculating the optimum value of the bitumen and second part consists of optimizing the quantity of plastic waste used to replace the bitumen. Wet process was used to modify the bitumen and Marshall Samples were prepared using the same bitumen. In this process the coarse aggregates and fine aggregate and fly ash were heated to 170°C. The bitumen was heated to 160^0C and shredded plastic waste retaining on 2.36 mm sieve is added in proportion by weight to the hot bitumen and mixed thoroughly using mechanical stirrer to obtain homogenous mix. The waste plastic LDPE, PVC and HDPE were added varying from 0%, 2%, 4%, 6%, 8%, 10% and 12% by the weight of bitumen. This modified bitumen was added to the homogenous mix of aggregate, bitumen and plastic waste. After proper mixing the mix was placed in the compaction mould and compacted with 75 blows on both face to get Marshall Samples. The stability and flow were obtained by testing the sample on the digital Marshall frame and the average values for Bulk specific Gravity, AV, VMA and VFB were calculated and graphs were plotted. The values obtained stability values are corrected after applying the correction for thickness of the sample. According to Das, A. and Chakroborty P. the following properties were calculated based on volumetric analysis [10]

A. Bulk Specific Gravity of sample (Gb)

The bulk density of the sample is determined by weighing the sample (Wa) and by taking its submerged weight (Ww). The specific gravity of the specimen is given by

$$\mathrm{Gb} = \frac{\mathrm{Wa}}{\mathrm{Wa} - \mathrm{Ww}}$$

where,
Gb = Bulk Specific Gravity of sample
Wa = Weight of sample in air (g)
Ww = Weight of sample in water (g)

B. Theoretical specific gravity of the mix (Gt)

Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

$$\mathrm{Gt} = \frac{\mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{Pf} + \mathrm{Pb}}{\frac{\mathrm{P1}}{\mathrm{G1}} + \frac{\mathrm{P2}}{\mathrm{G2}} + \frac{\mathrm{P3}}{\mathrm{G3}} + \frac{\mathrm{Pf}}{\mathrm{Gf}} + \frac{\mathrm{Pb}}{\mathrm{Gb}}}$$

where,
P1 is the Percentage by weight of 20mm coarse aggregate in the total mix
P2 is the Percentage by weight of 10mm coarse aggregate in the total mix
P3 is the Percentage by weight of Stone Dust in the total mix
Pf is the Percentage by weight of filler in the total mix
Pb is the Percentage by weight of bitumen in the total mix
G1 is the specific gravity of 20mm coarse aggregate
G2 is the specific gravity of 10mm coarse aggregate
G3 is the specific gravity of Stone Dust
Gf is the specific gravity of Filler
Gb is the specific gravity of bitumen

C. Bulk Specific Gravity of Aggregate (Gsb)

$$\mathrm{Gsb} = \frac{\mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \mathrm{Pf}}{\frac{\mathrm{P1}}{\mathrm{G1}} + \frac{\mathrm{P2}}{\mathrm{G2}} + \frac{\mathrm{P3}}{\mathrm{G3}} + \frac{\mathrm{Pf}}{\mathrm{Gf}}}$$

where,
P1 is the Percentage by weight of 20mm coarse aggregate in the total mix
P2 is the Percentage by weight of 10mm coarse aggregate in the total mix
P3 is the Percentage by weight of Stone Dust in the total mix
Pf is the Percentage by weight of filler in the total mix
G1 is the specific gravity of 20mm coarse aggregate
G2 is the specific gravity of 10mm coarse aggregate
G3 is the specific gravity of Stone Dust
Gf is the specific gravity of filler

D. Air voids percent (AV)

It is the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture. The amount of air voids in a mixture is extremely important and closely related to stability, durability and permeability. The following equation represents the percentage of air voids in the specimen.

$$\mathrm{AV} = \frac{(\mathrm{Gt} - \mathrm{Gb})100}{\mathrm{Gt}}$$

E. Voids in the Mineral Aggregate (VMA)

VMA is the volume of inter granular void space between the aggregate particles of a compacted paving mixture. It includes the air voids and the volume of the asphalt not absorbed into the aggregate .VMA describes the portion of space in a compacted asphalt pavement or specimen which is not occupied by the aggregate. VMA is expressed as a percentage of the total volume of the mix Voids Filled with Binder (VFB).

$$\mathrm{VMA} = \left[1 - \frac{\mathrm{Ps\ x\ Gmb}}{\mathrm{Gsb}}\right] 100$$

where,
Ps = Aggregate content, %
Gsb = Bulk specific gravity of total aggregate
Gmb = Bulk specific gravity of mixed aggregate

F. Voids Filled with Bitumen (VFB)

VFB is the voids in the mineral aggregate frame work filled with bitumen binder. This represents the volume of the effective bitumen content. It can also be described as the percent of the volume of the VMA that is filled with bitumen. VFB is inversely related to air voids and hence as air voids decreases, the VFB increases.

$$\mathrm{VFB} = 100\,\frac{(\mathrm{VMA} - \mathrm{AV})}{\mathrm{VMA}}$$

where, AV is air voids in the mix and
VMA is the voids in the mineral aggregate.

IV. RESULTS AND DISCUSSION

The optimum binder content for the mix was found to be 6% since the maximum stability was found at 6 % of binder content. The obtained value was further used for the subsequent study. During the experiment PVC type of plastic waste was also used but while mixing the shredded PVC plastic with hot bitumen some gases were coming out of the mix and hence PVC plastic was not used for further experiment. The details of volumetric and mechanical properties are tabulated in the table and figures below.

TABLE I BITUMEN VALUE CALCULATION

Bitumen content %	Bulk Specific Gravity Gb (gm/cm^3)	Theoretical Specific Gravity Gt (gm/cm^3)	Void Analysis			Marshall Stability (kN)		Flow(mm)
			AV (%)	VMA (%)	VFB (%)	Measured	Corrected	
5	2.195	2.389	8.131	23.046	64.818	10.52	9.40	2.32
5.5	2.204	2.361	6.673	23.146	71.334	12.14	10.69	2.54
6	2.205	2.334	5.527	23.508	76.605	13.89	11.95	2.64
6.5	2.200	2.307	4.639	24.076	80.897	12.11	10.70	3.22
7	2.198	2.281	3.638	24.552	85.285	11.56	10.05	3.72

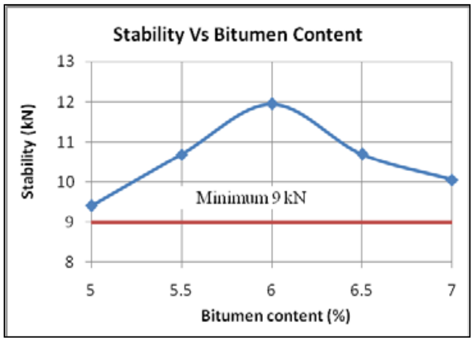

Fig. 1 Bitumen Content Vs Stability

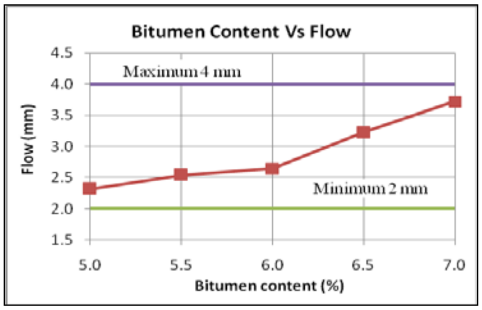

Fig. 2 Bitumen Content Vs flow

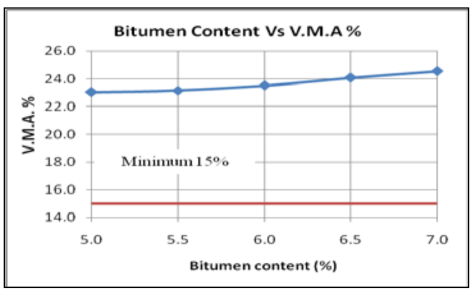

Fig. 3 Stability Vs V.M.A %

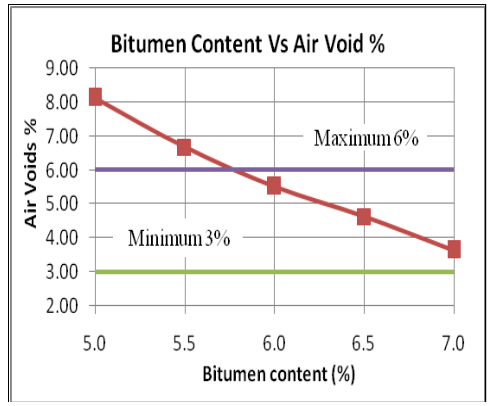

Fig. 4 Bitumen Content Vs Air Void %

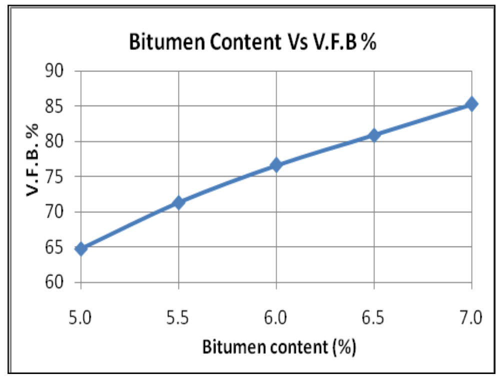

Fig. 5 Bitumen Content Vs V.F.B %

The volumetric and mechanic properties of the mix were obtained after adding LDPE and HDPE types of plastic at 2%, 4%, 6%, 8%, 10% and 12% by the weight of bitumen and the results are tabulated in the table and figures below.

TABLE II BITUMEN VALUE CALCULATION

Type of Plastic	Plastic Waste %	Bulk Specific Gravity Gb (gm/cm^3)	Theoretical Specific Gravity Gt (gm/cm^3)	Void Analysis			Marshall Stability (kN)		Flow(mm)
				AV (%)	VMA (%)	VFB (%)	Measured	Corrected	
	0	2.205	2.334	5.53	23.51	76.61	13.89	11.95	2.64
LDPE	2	2.224	2.334	4.72	22.86	79.34	13.02	13.02	2.46
HDPE	2	2.22	2.334	4.89	22.99	78.75	13.34	12.85	2.49
LDPE	4	2.241	2.334	3.98	22.26	82.12	14.76	13.73	2.52
HDPE	4	2.232	2.334	4.35	22.56	80.70	14.58	14.00	2.56
LDPE	6	2.25	2.334	3.58	21.93	83.69	15.35	14.73	2.65
HDPE	6	2.241	2.334	3.98	22.26	82.11	16.39	14.59	2.71
LDPE	8	2.235	2.334	4.22	22.45	81.21	15.44	13.94	2.78
HDPE	8	2.235	2.334	4.24	22.47	81.21	15.39	14.10	2.88
LDPE	10	2.219	2.334	4.93	23.02	78.60	14.43	13.03	3.27
HDPE	10	2.213	2.334	5.17	23.22	77.74	14.37	13.17	3.34
LDPE	12	2.201	2.334	5.71	23.65	75.88	13.04	11.78	4.37
HDPE	12	2.195	2.334	5.94	23.85	75.10	13.23	11.95	4.10

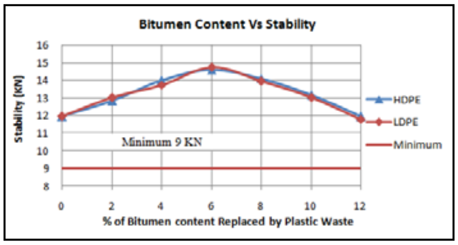

Fig. 6 % of Bitumen replaced by plastic waste Vs Stability

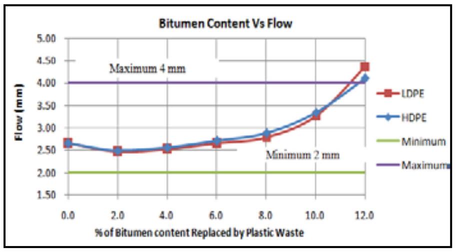

Fig. 7 % of Bitumen replaced by plastic waste Vs Flow

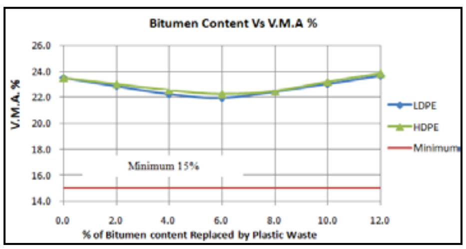

Fig. 8 % of Bitumen replaced by plastic waste Vs Air void %

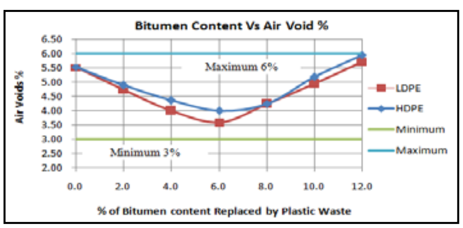

Fig. 9 % of Bitumen replaced by plastic waste Vs V.F.B %

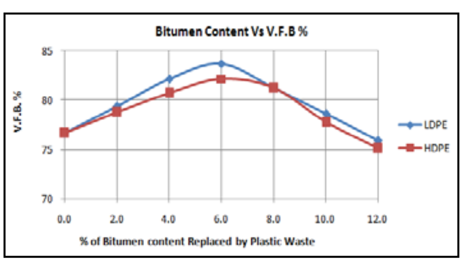

Fig. 10 % of Bitumen replaced by plastic waste Vs V.M.A%

V. CONCLUSION

1. Om the investigation on utility of plastic waste as an additive for bituminous concrete using wet process of mixing it can be concluded that addition of plastic improves the Marshall properties of the mix.
2. The Addition of 6% of the LDPE and HDPE plastic waste improves the stability value of the bituminous mix which results is the increase in the toughness of the mix. The roads can withstand heavy traffic and shows better service life.
3. Due to addition of plastic waste the flow value increases resulting the improvement in the workability.
4. Addition of plastic waste results in decrease in the air voids which reduces the bleeding of bitumen.
5. The volumetric and Marshall properties of the mix show the acceptable trends and could satisfy the specified limits.
6. This study has a positive impact on environment and the use of waste plastic in bituminous concrete is ecofriendly way of using waste plastic for road construction.

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