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Study of plastic waste mixed bituminous concrete using dry process for road construction

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Abstract

Waste plastic is accumulation all over the world causing serious environmental problems. This paper aims to study the Plastic Waste Mixed Bituminous Concrete Using Dry Process for Road Construction. The study evaluates the addition of shredded waste plastic in the bituminous concrete which results in significant increase in the stability value and Marshall Properties of mix. The study reveals that the use of waste plastic in bituminous concrete is safe and sustainable for road construction.

Key words: Plastic Waste, Waste reuse, Road construction

1 Introduction

Road network of any country is backbone of its economy. Construction of road involve huge amount of money. One can achieve the desired durability and Considerable saving may be done during the construction of roads if proper engineering design is done. The desired properties to be considered during design of bituminous mix are sufficient stability, durability, Flexibility, Skid resistance, Workability, Air voids and Economy. Increase in population, rapid urbanization, development activities and change in life style has resulted in increase of quantum of plastic waste in India. This huge amount of generated plastic had become a serious problem for our environment. the disposal of plastic wastes is a great problem. These are non-biodegradable product due to which these materials pose environmental pollution and problems like breast cancer, reproductive problems in humans and animals, genital abnormalities and even in human sperm count and quality [1]. One of the solutions to this problem is to convert the waste plastic into some useful product. Indian government has already taken an initiative to implement 4R policy i.e reuse, reduce, recycle and recover in the form of “Swach Bharat Abhiyan”.

The generation of waste plastic has caused many effects on the environment, resulting in huge landfill mountainous structure which is harmful to the human health as well as to all living organisms. Therefore, the recycling and reusing of plastic wastes is found to be more advantageous. The natural bitumen extraction has resulted in more usage of non-renewable sources which are not sustainable in environment. The plastic usage in roads can replace some percentage of natural bitumen that is extracted or distilled from petroleum sources. The rutting, cracking, formation of potholes and disintegration of surface layers of flexible pavements roads due to temperature and seasonal variations, stresses due to heavy traffic loads usually occurs. Hence the utilization of waste plastic in the roads can minimize the above effects and therefore it is more important to make the roads more durable and stronger. The present study investigates the use of plastic waste using dry process in bituminous concrete for road construction. The objectives of study are:

- To study the marshal properties of bituminous mix using plastic waste and fly ash as filler.
- To find the utility of waste plastic material in bitumen mixes for road construction.
- To study and propose durable course by exploring the utilization of plastic waste and fly ash which are available abundantly.
- To provide an eco-friendly road way.

2 Literature Review

Amol S. Bhale (2011) stated that in recent years, applications of plastic wastes have been considered in road construction with great interest in many developing countries. It was concluded that on heating at 100-160°C, plastics such as polyethylene, polypropylene and polystyrene, soften and exhibit good binding properties. Blending of the softened plastic with bitumen results in a mixed that is amenable for road laying. In future this will also result in having strong, durable and eco-friendly roads which will relieve the earth from all type of plastic-waste. [1]

R.Sathishkumar et.al, (2013) investigated and revealed that properties of bitumen can be improved with the incorporation of modifiers. The bitumen treated with these modifiers is known as Modified Bitumen. In this study, bitumen of grade VG 30 is selected and improved its properties by the addition of modifiers such as Low Density Poly Ethylene (LDPE) waste and Pulverised Tyre Waste (PTW). Results showed that Penetration value of modified bitumen decreases by 6.8% for PTW and 13.6% for LDPE waste. Softening point value increases by 8.16% for PTW and 14.28% for LDPE waste. Ductility value has decreased by 39.6% for PTW and increased by 18.86% for LDPE waste. In Marshall test, the stability value has increased by 30% for PTW and 28.46% for LDPE waste. Addition of the modifier reduced the flow value by 34.69% for PTW and 39.59% for LDPE waste, which shows that the flow property has increased. Thus results of this study concluded that addition of PTW and LDPE waste has improved the properties of penetration, ductility and softening temperature of the modified bitumen. As the stiffness of the material is improved, it is capable of taking high load and increase the resistance and durability of the pavements. [2]

Afroz Sultana.SK et.al, (2012) studied Utilization of Waste Plastic as a Strength Modifier in Surface Course of Flexible and Rigid Pavements. The study investigates the potential use of waste plastic as a modifier for asphalt concrete and cement concrete pavement. Plastic waste,

consisting of carry bags, cups etc can be used as a coating over aggregate and this coated stone can be used for road construction. Different ratios of plastic such as Polypropylene (PP), Low Density Polyethylene (LDPE), and High Density Polyethylene (HDPE) by weight of asphalt were blended with 80/100 paving grade asphalt. By using plastic as a coating over aggregates, the properties of aggregates are improved. Based on the stability values, the optimum percentage of plastic is 8%, 6% for plastic coated aggregate samples and polymer modified bitumen samples respectively for PP type of plastic, and 8% is optimum for LDPE type of plastic for both plastic coated aggregate and polymer modified samples. This shows that weak aggregates can be used in construction by using plastic as a binder material. By adding plastic to the unmodified bitumen, the rheological properties have been improved. There is an increase in the softening point and decrease in penetration and ductility values [3].
Akanksha Yadav (2016), has stated that the use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects. The aggregate is heated about temperature160oC. After the heating of aggregate, the hot aggregate is transfer into the mixing chamber. At the mixing chamber, the shredded plastics waste is to be added. It gets coated uniformly over the aggregate within 30 to 60 seconds, giving an oily look. The bitumen is added in hot plastic coated aggregate at 160oC. It is observed that Marshall Stability value increases with polyethylene content up to 6% and thereafter decreases and also the Marshall Flow value decreases upon addition of polythene i.e the resistance to deformations under heavy wheel loads increases [4].
Vatsal Patel et.al, (2014) highlighted the urgent need for re-examining and formulating new guidelines and specifications with regard to the design and construction of roads in India using plastic wastes. The cost of road construction is also decreased and the maintenance cost is almost nil. The roads are found to be stronger with increased Marshall Stability value, better resistance towards rain water and water stagnation so no stripping and no potholes, increase binding and better bonding of the mix thus reduction in pores in aggregate and hence less rutting raveling [5].

3 Material and Mix Design

Various materials used in the construction of flexible pavements 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 flyash were collected from local crusher. The plastic waste was segregated from the municipal waste and shredded at the local plastic waste recycling plant at MIDC, Amravati.

Table 1: Physical Properties of Coarse Aggregates

Sr.no	Test	No. of test Performed	Test Result	Specification Requirement	Standards
1	Aggregate impact value	3	22.40%	Max 30%	IS : 2386 (Part IV) - 1963
2	Abrasion value	3	28.10%	Max 40%	IS : 2386 (Part IV) – 1963
3	Crushing value	3	24.30%	Max 30%	IS : 2386 (Part IV) – 1963
4	Combined Elongation index	3	17.20%	Max 30%	IS : 2386 (Part

	and Flakiness index				I) – 1963
5	Specific gravity	6	20 mm: 2.830 10 mm: 2.792	-	IS : 2386 (Part IV) – 1963
6	Water Absorption	3	0.1%	Max 2%	IS: 2386 (Part III)-1963

Table 2: Physical Properties of Bitumen

Sr.no	Test	Test Result	Specification Requirement	Standards
1	Penetration test	68	65-90	IS : 1203-1978
2	Softening point test	53	40-60	IS : 1205-1978
3	Specific Gravity	1.01	Min 0.99	IS: 1206 (Part I) -1978
4	Ductility test	87	Min 75	IS : 1208-1978

Marshall Mix Design was conducted to optimize the mix design and quantity of waste plastic. Dry process was used to prepare Marshall Samples. In this process the aggregates were heated to 170°C. The shredded plastic waste retaining on 2.36 mm sieve is added in proportion by weight to the hot aggregate. The quantity of waste plastic LDPE and HDPE was added varying from 0% to 12%. This plastic gets coated over the aggregate uniformly. Immediately the hot Bitumen at 160°C is added with the mixture and compacted with 75 blows on both face to get Marshall Samples. The average values for Bulk Specific Gravity, stability, flow, AV, VMA and VFB were calculated and graphs were plotted. According to Das, A. and Chakroborty P. the following properties were calculated based on volumetric analysis [6].

Bulk Specific Gravity of sample (Gb)

The bulk density of the sample is determined by weighing the sample in air and in water. The specific gravity of the specimen is given by

$$Gb = \frac{Wa}{Wa - Ww} \tag{1}$$

Theoretical specific gravity of the mix (Gt)

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

$$Gt = \frac{P1 + P2 + P3 + Pf + Pb}{\frac{P1}{G1} + \frac{P2}{G2} + \frac{P3}{G3} + \frac{Pf}{Gf} + \frac{Pb}{Gb}} \tag{2}$$

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.

$$AV = \frac{(Gt - Gb)100}{Gt} \tag{3}$$

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).

$$VMA = \left[1 - \frac{Ps \times Gmb}{Gsb}\right] 100 \quad (4)$$

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.

$$VFB = 100 \frac{(VMA - AV)}{VMA} \quad (5)$$

4 Results and Discussion

The optimum binder content for the mix was found to be 6% which was further used for the subsequent study. The details of volumetric and mechanical properties are tabulated in the table below.

Table 3: Results for optimum Binder content

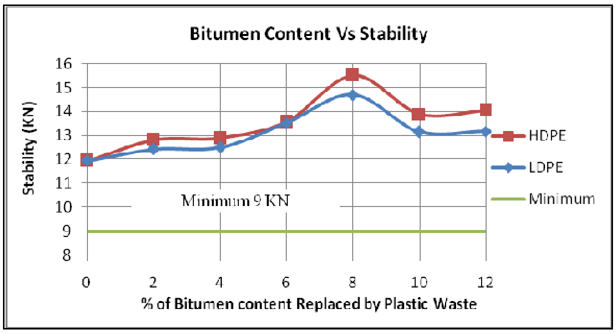
Bitumen content %	**Bulk Specific Gravity Gb (gm/cm³)**	**Theoretical Specific Gravity Gt (gm/cm³)**	**Void Analysis**			**Marshall Stability (KN)**		**Flow (mm)**
			AV	**VMA**	**VFB**	**Measured**	**Corrected**	
5	2.195	2.389	8.131	23.046	64.818	10.52	9.40	2.32
5.5	2.204	2.361	6.673	23.146	71.334	12.14	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	0.05	3.72

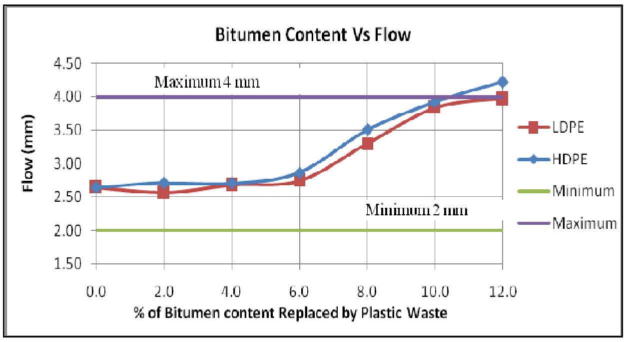
The volumetric and mechanic properties of the mix were obtained after adding various types of plastic and the results were tabulated in the table below.

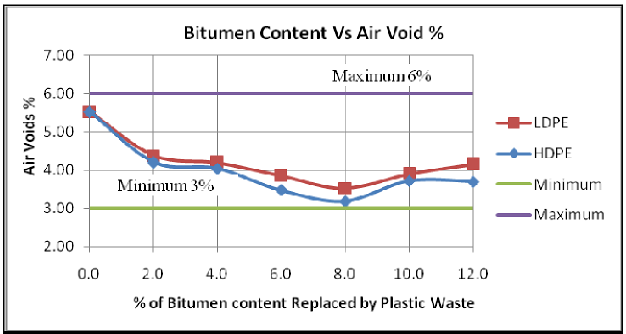
Table 4: Results for optimum Binder content for samples with Plastic waste

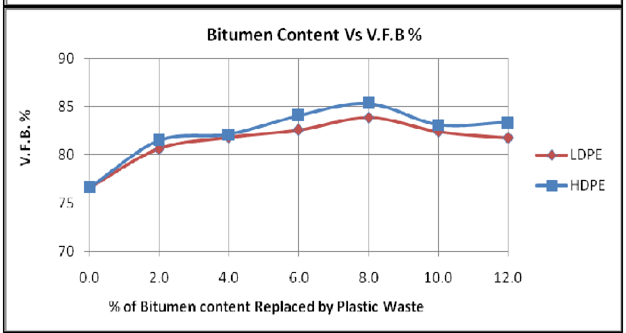
Type of Plastic	Plastic Waste %	Bulk Specific Gravity Gb (gm/cm^3)	Theoretical Specific Gravity Gt (gm/cm^3)	Void Analysis			Marshall Stability (KN)		Flow (mm)
				AV	VMA	VFB	Meas.	Correct.	
	0	2.205	2.334	5.53	23.51	76.61	13.89	11.95	2.64
LDPE	2	2.232	2.334	4.38	22.58	80.64	12.95	12.43	2.57
HDPE	2	2.236	2.334	4.20	22.44	81.49	13.17	12.81	2.71
LDPE	4	2.236	2.334	4.20	22.43	81.85	13.30	12.51	2.68
HDPE	4	2.240	2.334	4.04	22.31	82.15	13.77	12.89	2.71
LDPE	6	2.244	2.334	3.85	22.15	82.61	15.37	13.52	2.74
HDPE	6	2.253	2.334	3.48	21.85	84.08	15.25	13.57	2.87
LDPE	**8**	**2.252**	**2.334**	**3.53**	**21.89**	**83.89**	**16.52**	**14.70**	**3.30**
HDPE	**8**	**2.259**	**2.334**	**3.19**	**21.62**	**85.34**	**16.92**	**15.51**	**3.51**
LDPE	10	2.243	2.334	3.90	22.19	82.44	14.56	13.16	3.83
HDPE	10	2.247	2.334	3.72	22.04	83.15	15.01	13.90	3.92
LDPE	12	2.237	2.334	4.15	22.39	81.77	14.37	13.17	3.97
HDPE	12	2.248	2.334	3.70	22.03	83.39	15.34	14.06	4.22

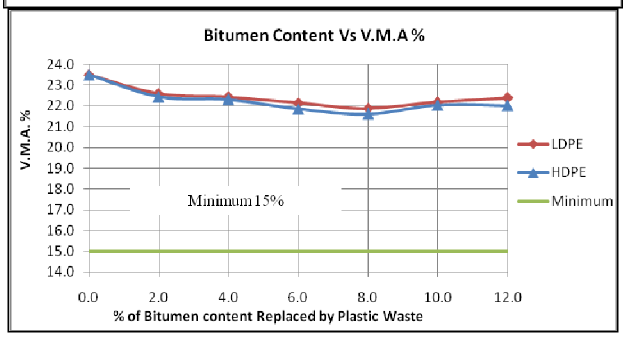
The maximum stability was found to be 14.70 KN and 15.51 KN for the 8% of LDPE and HDPE plastic waste content respectively. The addition of waste plastic at 8% increased the stability value which results in the improvement of toughness of the mix. Subsequently the flow value of the mix has increased which results in the increase in the workability of the mix. The excessive air void may result in the cracking due to insufficient bitumen binders, whereas low air void may produce more plastic flow and result in bitumen bleeding. The air voids for the 8% of the LDPE and HDPE plastic waste content was found to be within the specified limit of minimum 3% to maximum 6%. Also the other properties like VMA and VFB were found to be well within the limits.











5 Conclusion

- Addition of 8% of the LDPE and HDPE plastic waste improves the stability value of the mix which results is the increase in the toughness of the mix.
- Due to addition of plastic waste the flow value increases resulting the improvement in the workability.

- Addition of plastic waste results in decrease in the air voids which reduces the bleeding of bitumen.
- The volumetric and marshall properties of the mix show the acceptable trends and could satisfy the specified limits.
- The use of waste plastic in bituminous concrete is safe and sustainable for road construction

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