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Plastic Roads: A Recent Advancement in Waste Management

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***Abstract*--Plastics are the non-biodegradable materials and so a means to degrade our environment. Plastic wastes have proved to be a source of health hazard as it is toxic in nature. Plastic waste is a big nuisance in today's world. So, this plastic waste should be reused to eliminate the threat to the surroundings. One such reuse can be in the construction of flexible pavements. Plastic coated aggregates have proved to offer better resistance to abrasion and wear and tear. Moreover the bond between these plastic coated aggregates and the bitumen is also very strong due to increased contact area between plastic (polymers) and bitumen. Such roads show better performance and have increased life spans.**

Keywords: Plastic waste, aggregates, bitumen

I. INTRODUCTION

Plastic is the most widely used material in the present times. It is light in weight, moisture resistant, flexible and very inexpensive. These qualities increase our propensity towards plastic and hence making its use very common. Today plastic is used in every vital sector of the economy, ranging from agriculture to automobile, electronics, construction, etc. It has revolutionized all spheres of life. But this plastic ultimately becomes a waste. It is a common site both in urban and rural areas to see plastic wastes littering the roads. It forms the major portion of the total municipal solid wastes (MSW). Tons of plastic wastes which include polyethenes, cups, bags, etc. are discarded every year, polluting land, rivers, seas, oceans, etc. plastic is a non-biodegradable material and it has been found that it can remain on earth for about 4500 years without showing any signs of degradation. Its improper disposal can cause serious health hazards in humans. Based on the present usage scenario of plastics, its complete ban will not be justified; hence we have to find the alternatives to reuse the plastics.

It is estimated that approximately 10 thousand tons per day (TPD) of plastics waste is generated i.e. 9% of 1.20 lacs TPD of MSW in India. The plastic waste constitutes two major categories of plastics; (i) Thermoplastics and (ii) Thermoset plastics. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India.[11] The Thermoplastics are recyclable plastics which include; Polyethylene Terephthalate (PET), Low Density Poly Ethylene (LDPE), Poly Vinyl Chloride(PVC), High Density Poly Ethylene (HDPE), Polypropylene(PP), Polystyrene (PS) etc. However, thermoset plastics contains alkyl, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, metalized and multilayer plastics etc. The use of plastic materials such as carry bags, cups, etc. is constantly increasing. Nearly 50 to 60% of the total plastics are consumed for packing. Table 1 provides the data on total plastics waste consumption in India during last decade.

Table 1: Plastic consumption in India. [4, 5]

S.no.	Year	Consumption(tones)
1	1996	61000
2	2001	400000
3	2006	700000
4	2011	13500000

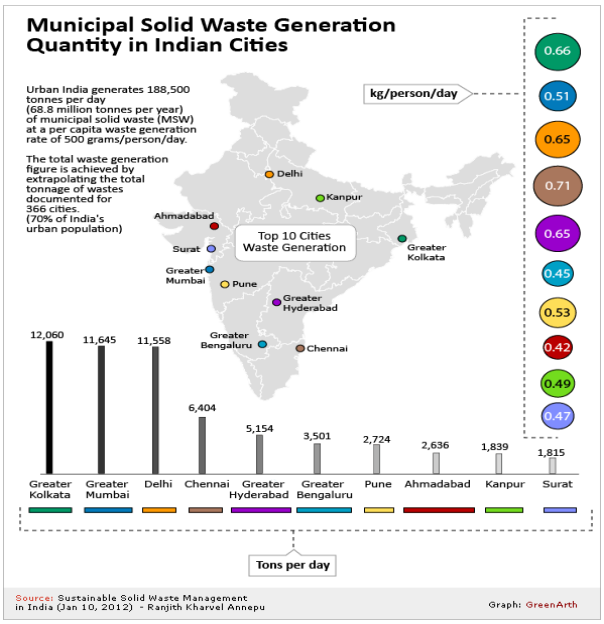

FIG.1: Top 10 cities waste generation in India. [10]

We have to take some practical steps at the ground level in order to control the menace of plastic waste. Studies have shown that plastic waste after proper process can be used in the construction of bituminous pavements. Such pavements show enhanced properties and increased life spans, thus making the road construction economical and solving the environmental problem at the same time.

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FIG. 2: Waste plastics.

II. LITERATURE REVIEW

The plastic wastes have been utilized in the construction of pavements in India since a decade now. It is seen that the use of plastics enhances the rheological properties of bitumen and hence that of the pavement. Considerable research has been carried out to determine the suitability of plastic wastes in the construction of bituminous pavements. Dr. R. Vasudevan has stated in his works that the use of plastic in bitumen improves the binding properties of bitumen. [1] Prof. C.E.G Justo states that addition of 8% percent by weight of processed plastic is desirable in saving 0.4% bitumen by weight of mix as it improves the stability, strength, life and other desirable properties of bitumen. [2] Dense bituminous macadam with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36 – 5 mm aggregates, reduced the mix density by 16% and showed 250% increase in Marshall Stability. Zoorab and Suparma stated that the use of recycled plastics in plain bituminous concrete mixes increases its durability and fatigue life. [6] D. N Little further worked on the effect of plastics on bitumen and found the resistance to deformation of asphaltic concrete modified with low density polyethylene (LDPE) was reasonably improved. [8] Studies have showed that the use of recycled polyethylene in bituminous pavement mixes reduces the permanent deformation in the form of rutting and the low temperature cracking of pavement surfacing. [9] Bindu et al. studied the effects of shredded plastic in stabilizing the stone mastic asphalt (SMA) mixture in flexible pavements. [3]

III. PLASTIC AGGREGATE BITUMEN INTERACTION MODEL

The plastic waste in the shredded form is sprayed and spread over hot aggregates in such a way that these aggregates get coated with a thin layer of molten plastic. The coated plastic remains in softened state for a temperature range of 140ºC to 160ºC. The hot bitumen (160ºC) is added and spread over these aggregates. At this temperature both the coated aggregates and bitumen remains in liquid state and are capable of diffusing easily at the interface. This process is further helped by the increase in the contact area. The observations may be explained as follows. Plastic is basically the polymer having long chain hydrocarbons and bitumen is a complex mixture of ashphaltenes and maltenes which are also long chain hydrocarbon. The plastic layer has already bonded with aggregates. When bitumen was mixed with plastic coated aggregate a portion of bitumen diffuses through the plastic layer and binds with aggregate thus forming the internal three dimensional linked network between plastic (polymer molecules) and bitumen making the bond strong.[7] Hence, the pavement so constructed can withstand extreme weather condition, has extra strength, high cohesiveness and resistance to fatigue, stripping and deformation, thus increasing its lifespan.

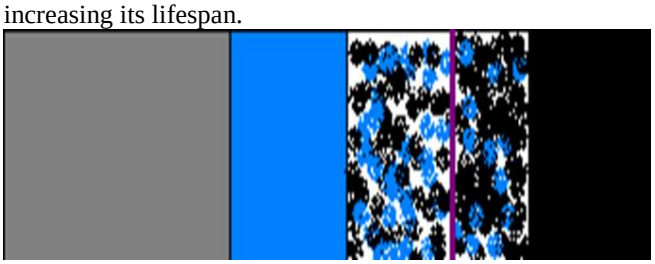

FIG.3: Plastic aggregate bitumen interaction model for the Plastics waste coated aggregate bitumen mix. [11]

IV. RESEARCH METHODOLOGY

A. Materials used and the tests conducted

The materials used for carrying out the present research are:

1. Aggregates
2. Bitumen
3. Plastic waste

The various laboratory tests were carried out on these materials and the results were computed.

1. Aggregates

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Aggregates have to bear stresses occurring due to the wheel loads on the pavement and on the surface course. They also have to resist wear due to abrasive action of traffic. These are used in pavement construction in cement concrete, bituminous concrete and other bituminous constructions and also as granular base course underlying the superior pavement layers. Therefore the properties of the aggregates are of considerable significance to the highway engineer. Some of the desired properties of these aggregates are strength, durability, toughness, hardness, etc.

The various tests conducted on aggregates in the laboratory are Los Angeles test, crushing test, impact test, flakiness and elongation index and the results obtained are tabulated below in Table 2.

Table 2: Results of the tests conducted on aggregates

S No	Test	Property determined	Results
01	Los Angeles test	Abrasion	26.8%
02	Crushing test	Crushing strength	21.2%
03	Impact test	Toughness	11%
04	Shape test	Flakiness index	13%
05	Shape test	Elongation index	12.3%

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2. Bitumen

Bituminous materials used in highway construction are broadly classified into bitumen and tar. Bitumen may further be divided into petroleum asphalt or bitumen and native asphalt. There are different forms in which native asphalts are available. These are those which occur in a pure or nearly pure state in nature. The viscosity of bitumen is sometimes reduced by a volatile diluent; this material is called **cutback.** When bitumen is suspended in a finely divided condition in an aqueous medium and stabilized with an emulsifier, the material is known as emulsion. Tar is the viscous liquid obtained when natural organic materials such as wood and coal are carbonized or destructively distilled in the absence of air.

Bitumen is available in various grades and types. To judge the suitability of these binders various physical tests have been specified by agencies like ASTM, Asphalt Institute, British Standards Institution and the ISI. These tests include penetration tests, ductility tests, softening test, flash and fire point tests, viscosity tests, etc. The results of the tests conducted on our sample are tabulated below in Table 3.

Table 3: Results of the tests conducted on bitumen

S No.	TEST	RESULT
01	Penetration Test	73 mm
02	Softening point test	43ºC
03	Ductility test	63 mm
04	Flash point test	192.33ºC
05	Fire point test	201.33ºC

3. Plastic Waste

The plastic waste such as carry bags, cups, disposables, etc. are shredded in the shredding machine and then sprayed in different percentages over the hot aggregates. The details of the process are given below.

FIG 4: Collection of Waste plastic.

a. Waste plastic shredding:

Shredding is the process of cutting the plastic into small sizes between 2.36mm to 4.75mm with the help of the plastic shredding machine viz. Agglomerater and Scrap Grinder.[12]

b. Details of Shredding Machine:

For shredding of poly-ethylene "Agglomerator" is used. In this process, plastic wastes are cut in small pieces with the help of rotator blades. The process is completed in about half an hour.[12]

FIG 5: Collection of Waste plastic.

The shredded waste plastic was sprayed over the hot aggregate which got coated on aggregate when molted. The extent of coating was varied by using different percentage of plastic. Increase in the percentage of plastic increases the properties of aggregates.

FIG 6: Shredded plastic waste being sprayed over hot aggregates.

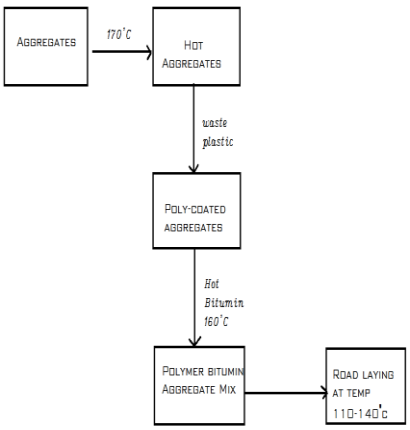

FIG 7: Flow diagram of plastic coated bitumen mix road

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The following tests were carried out on the coated aggregated:

1. Impact test
2. Los Angeles abrasion test

The results of these tests are given below in Table 4.

Table 4: Results of the tests conducted on aggregates coated with different percentages of plastic.

S.No	%age of plastic	Aggregate Impact value	Los Angeles abrasion value
01	0	11%	26.8%
02	2	10.92%	25.93%
03	4	10.84%	25.69%
04	6	10.76%	25.57%
05	8	10.52%	25.51%
06	10	10.33%	25.36%

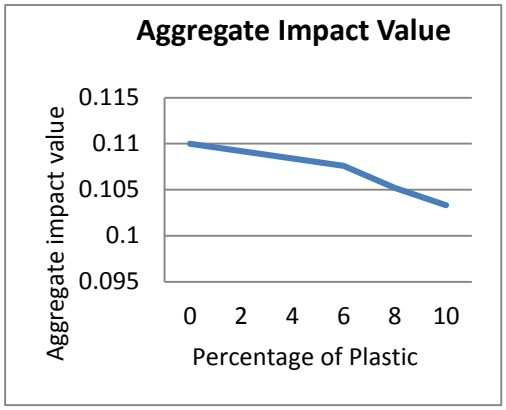

FIG 8: Variation of aggregate impact value with increase in percentage of plastic.

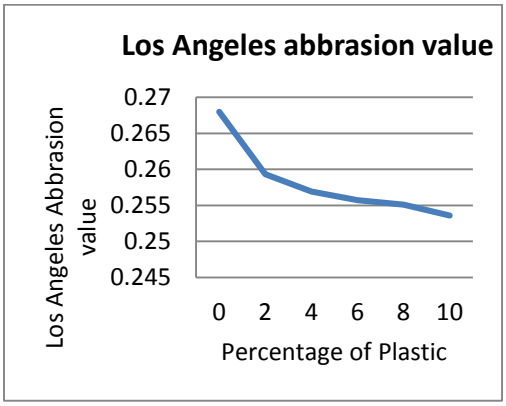

FIG 9: Variation in Los Angeles abrasion value with increase in percentage of plastic.

The following tests were conducted on the polymer modified bitumen:

1. Softening point test
2. Penetration test
3. Ductility test

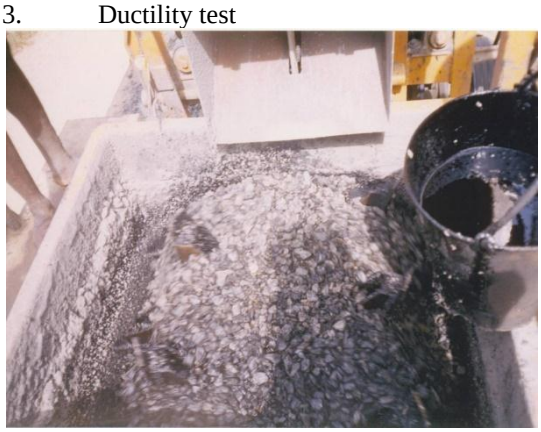

FIG 10: Bitumen being mixed with plastic coated aggregates.

The results of these tests are tabulated below in Table 5.

Table 5: Results of the tests conducted on bitumen modified with different percentages of plastic.

S.No	%age of bitumen	%age of plastic	Softening point (°C)	Penetration (mm)	Ductility (mm)
01	100	0	43	73	63
02	98	2	48	58	58
03	96	4	57	55	54
04	94	6	61	53	50
05	92	8	63	50	47
06	90	10	66	46	44

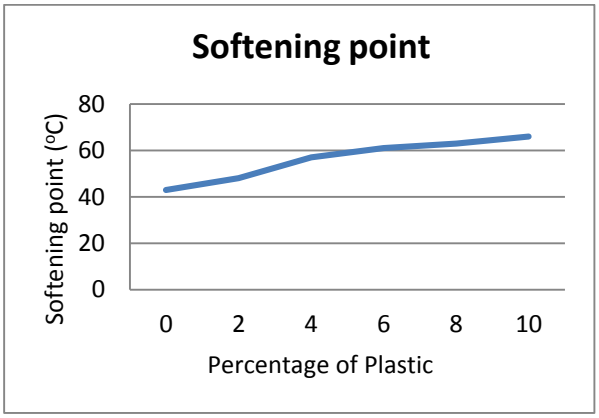

FIG 11: Variation of softening point of bitumen with increase in percentage of plastic.

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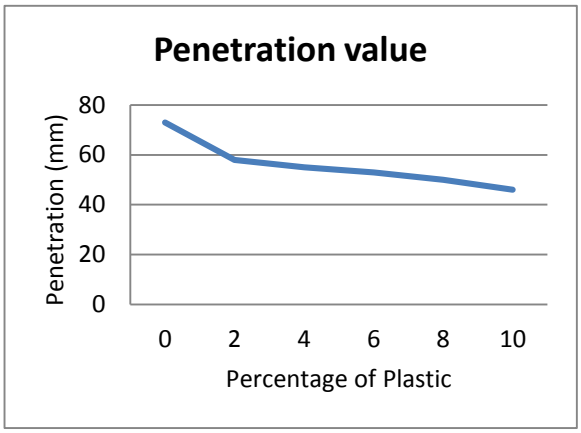

FIG 12: Variation of penetration value of bitumen with the increase in percentage of plastic.

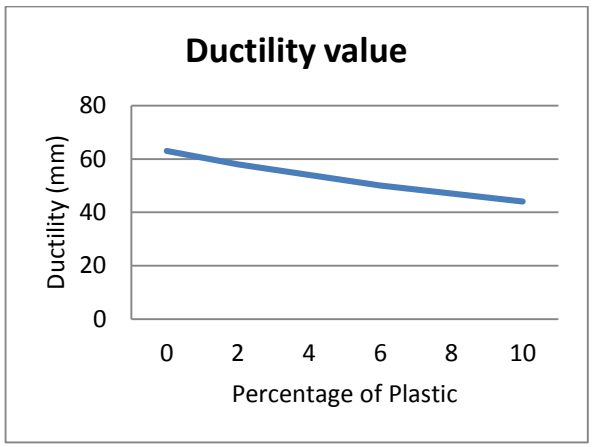

FIG 13: Variation of ductility of bitumen with the increase in percentage of plastic.

It is evident from the above graphs that the aggregates coated with plastics give lower values of impact and abrasion which is good for the aggregates to be used in the road construction as they are subjected to wear and tear from the traffic plying on the roads. Similarly, the qualities of bitumen, i.e. softening point, ductility and penetration is also improved considerably by replacing the bitumen with the plastic wastes, thereby making plastic waste an easy and economic replacement of bitumen in the construction of flexible pavement.

V. TEST REFERENCES

Table 6: Aggregate test references

TEST ON AGGREGATES	REFERENCE CODE
Impact test	IS 2386 (Part IV) -1963
Los Angeles test	IS 2386 (Part IV) -1963
Crushing test	IS 2386 (Part IV) -1963
Shape test	IS 2386 (Part I) -1963

Table 7: Bitumen test references

TEST ON BITUMEN	REFERENCE CODE
Penetration test	IS 1203-1978
Ductility test	IS 1208-1978
Softening point test	IS 1205-1978
Flash and fire point test	IS 1209-1978

VI. CONCLUSION

The generation of waste plastics is increasing day by day. The plastics show adhesion property in their molten state. Plastics will increase the melting point of the bitumen. Hence, the use of waste plastics for pavement is one of the best methods for easy disposal of waste plastics. Moreover, plastic is not recyclable and using them in road construction will help in the disposal of these plastic wastes in an eco-friendly manner.

The use of the innovative technology will not only strengthen the road construction but also make it economical as well as increase the life span of roads. Plastic roads will be most feasible for a country like India, where temperature is around 50ºC and the heavy monsoons too create havoc, leaving the roads with potholes and ruts. It is hoped that in near future we will have strong, durable and eco-friendly roads that will relieve the earth from all type of plastic waste.

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