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Utilization of Plastic Waste in Construction of Roads

Engineering

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ABSTRACT

The plastic waste quantity in municipal solid waste is increasing due to increase in population and changes in life style. Thus disposal of waste plastic is a hazardous and become a serious problem globally due to their non-biodegradability. Plastic roads are found to perform better than ordinary roads and therefore use of plastic road construction has gained importance these days. Disposal of waste plastic bags has become a serious problem and waste plastics are burnt for disposal which causes environmental pollution. Utilization of waste plastic bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Waste like plastic bottles, polymers, cups, etc. can be re-used by powdering or blending it with crusher and can be coated over aggregate and bitumen by any heating process. This paper describes the various aspects of utilization of plastic waste in construction of roads.

INTRODUCTION

Most of the paved roads in our country have granular sub base and base; bituminous base and wearing courses. The past practice of providing thin wearing coat of 20 mm premix carpet with seal coat was to allow deformation in granular layers to take place once road is opened to traffic. After the layers get compacted then thick bituminous wearing course was provided. Plastic is a very versatile material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers found that the material can remain on earth for 4500 years without degradation. Several studies have proven the health hazard caused by improper disposal of plastic waste [1]. Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Disposal of a variety of plastic & rubber wastes in an eco-friendly way is the thrust area of today's research [2]. Looking forward the scenario of present life style a complete ban on the use of waste plastic cannot be put, although the waste plastic taking the face of a devil for the present and the future generation. But the use of waste plastics in road construction is gaining importance these days because plastic roads perform better than ordinary ones and the plastic waste considered to be a pollution menace, can find its use. The use of waste plastic for coating the aggregates of the bituminous mix found to improve its performance characteristics. Recycled polythene carry bags were shredded into small sizes and is coated on aggregates of the mix at specified temperature. Bituminous mixes were prepared with 60/70 bitumen and plastic coated aggregates/ordinary aggregates with cement as a filler material [3]. The uses of plastic waste helps in substantially improving the abrasion and slip resistance of flexible pavement and also allows to obtain values of splitting tensile strength satisfied the specified limits while plastic waste content is beyond 30% by weight of mix. If the consistent mixing time and mixing temperature are not provided for bitumen– modifier mix, modified bitumen cannot exhibit good performance in situ, thus premature failures will occur. Therefore, there are certain recommended mixing time, mixing temperature and modifier content for all the polymers with a trademark. This all should be taken in mind while mixing and lying of roads is to be done using plastic waste. Plastic road would be a boon for India. In hot and extremely humid climate durable and eco-friendly plastic roads are of greatest advantages. This will also help in reliving the earth from all type of plastic waste [4].

GENERATION OF PLASTIC WASTE IN INDIA

A material that contains one or more organic polymers of large molecular weight, solid in its finish state and at some state while manufacturing or processing into finished articles, can be shaped by its flow is termed as plastics. The plastic constitutes two major category of plastics; (i) Thermoplastics and (ii) Thermoset plastics. The thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total postconsumer plastics waste generated. Table 1 shows the consumption of plastic waste in india.

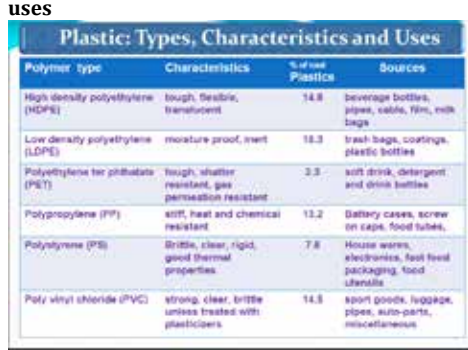
TABLE – 1
CONSUMPTION OF PLASTIC WASTE

Sr. No.	Year	Consumption(Tones)
1	1996	61000
2	2001	400000
3	2006	700000
4	2011	1350000
5	2013	1740000

Figure 1 shows the different sources of plastic waste in india. Figure 2 shows different types of plastics with their characteristics and uses in India.

Figure 1waste plastic sources

Figure 2 Different types of plastics with characteristics and uses



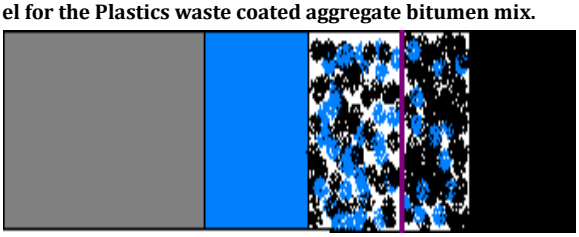
BASIC PROCESS

Waste plastic is ground and made into powder; 3 to 4 % plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life. Shredded plastic waste acts as a strong "binding agent" for tar making the asphalt last long. By mixing plastic with bitumen, the ability of the bitumen to withstand high temperature increases. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when temperature reaches 45.5°C but when plastic is mixed, it remains stable even at 55°C. The vigorous tests at the laboratory level proved that the bituminous concrete mixes prepared using the treated bitumen binder fulfilled all the specified Marshall mix design criteria for surface course of road pavement. There was a substantial increase in Marshall Stability value of the BC mix, of the order of two to three times higher value in comparison with the untreated or ordinary bitumen. Another important observation was that the bituminous mixes prepared using the treated binder could withstand adverse soaking conditions under water for longer duration [11].

PLASTIC AGGREGATE BITUMEN INTERACTION MODEL

The shredded plastics on spraying over the hot aggregate melted and spread over the aggregate giving a thin coating at the surface. When the aggregate temperature is around 140^0 C to 160^oC the coated plastics remains in the softened state. Over this, hot bitumen (160^oC) is added. The added bitumen spreads over the aggregate. At this temperature both the coated plastics and bitumen are in the liquid state, capable of easy diffusion at the inter phase. This process is further helped by the increase in the contact area (increased surface area). These observations may be explained as follows. Waste polymers namely PE, PP and PS are hydrocarbons with long chains. The bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydro carbon. When bitumen was mixed with plastic coated aggregate a portion of bitumen diffuses through the plastic layer and binds with aggregate. The plastic layer has already bonded strongly with aggregate. During this process three dimensional internal cross linked net work structure results between polymer molecules and bitumen constitutes. Therefore the bond becomes stronger and the removal of bonded bitumen becomes difficult [5].

Figure 3 shows plastic aggregate bitumen interaction model for the Plastics waste coated aggregate bitumen mix.



MIX DESIGN APPROACHES

There is no unified approach towards bituminous mix design, rather there are a number of approaches, and each has some merits and demerits. Table-1 summarizes [RILEM 17 1998] some of the important bituminous mix design approaches are as follows: [4].

- Mix design method
- Recipe method
- Empirical mix design method
- Analytical method
- Volumetric method
- Performance related approach
- Performance based approach

MIXING PROCEDURE AT HOT MIX PLANT

Step I: Plastics waste like bags, bottles made out of PE and PP cut into a size between 2.36 mm and 4.75mm using shredding machine. Care should be taken that PVC waste should be eliminated before it proceeds into next process.

Step II: The aggregate mix is heated to 165^0C and then it is transferred to mixing chamber.

Similarly the bitumen is to be heated up to a maximum of 160^0C. This is done so as to obtain a good binding and to prevent weak bonding. During this process monitoring the temperature is very important.

Step III: At the mixing chamber, the shredded plastics waste is added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 seconds. It gives an oily coated look to the aggregate.

Step IV: The plastics waste coated aggregate is mixed with hot bitumen. Then this final resulted mix is used for laying roads. The road laying temperature is between 110^oC 120^0C. The roller used should be of is 8-ton capacity.

PREPARATION OF PLASTIC-WASTE COATED AGGREGATE

The aggregate is heated to around 170^0C; the plastic waste is shredded to the size varying between 2.36mm and 4.75mm. This shredded plastic-waste is added over hot aggregate with constant mixing to give a uniform distribution. The plastic got softened and coated over the aggregate. The hot plastic waste coated aggregate is mixed with the hot bitumen 60/70 or 80/100 grade (160^0C) [8].

CASE STUDY FOR CHARACTERIZATION OF PCA BITUMEN MIX

1. Stripping Test (IS: 6241-1971): The plastic waste coated aggregate bitumen mix prepared by the above process was immersed in water. Even after 96 hours there was no stripping. This shows that the plastic waste coated aggregate-bitumen mix has good resistance towards water.
2. Marshall Stability Test: It is observed that the Marshall Stability values obtained for were generally much higher than the Marshall Stability value obtained for pure bitumen.
3. Field study: Using this dry process technique, road length of more than 1200 km were laid at different places in Tamil Nadu both by the department of Rural Development Agency and by Highways at Cochin, Mumbai, and Pondicherry the corporation laid test roads using this technology. The roads are exposed to heavy traffic, monsoonal change, heavy rain, hot summer etc. The roads are functioning well without potholes, ravelling and rutting. Expert's opinions are also in agreement.
4. Water absorption test: A known quantity of aggregate was taken dried at 110^0C and cooled. The weight of aggregate was determined. It was then immersed in water for 24 hrs. Then the aggregate was dried using dry clothes and the weight was determined. The water absorbed by the aggregate was determined from weight difference. 500gms of the aggregate was taken and heated to around 170^0C. It was then coated with plastic at that temperature. The plastic coated aggregate was cooled to room temperature. It was immersed in water for 24 hrs. Then it was removed dried and the weight of the aggregate was determined. It is observed that the absorption of water had decreased with the increase in the percentage coating of plastic over the aggregate. This shows that the coating of plastic reduces the voids. Hence, coating of plastic over aggregate helps to improve the quality of the aggregate.

MATERIAL COST COMPARISION FOR 1KM ROAD

Reusing plastic waste to pave roads is an experiment that has been successfully conducted in many places, such as Kalamassery in Kerala and in Kolkata and Bangalore. The first technology approach, developed by Bangalore-based K K Plastic Waste Management Limited, entails using plastic waste along with bitumen – the ingredient conventionally used to make roads [6]. Not only does the road become a receptacle for plastic waste, but it also has a better grip. This dry process helps to use good quantity of plastic waste in road construction. A model calculation is given in Table 2. A model is being worked using Tirunelveli, a town in Tamil Nadu. The plastics waste collected is around 650 tonnes/ annum. The roads available are approximately 400km and their annual requirement of plastic waste to lay plastic road is more than 600 tons. So the total waste generated could be used for road laying. The life of the road is in-

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creased and hence the maintenance expenditure is reduced [9].

TABLE – 2
COST COMPARISON

Size of the road	Bitumen needed	Plastics needed	Bitumen saved	Cost reduced
1kmX 3.75	9 tonnes	1 tonnes	1 tonnes	Rs,15,000

NATURAL AND PLASTIC COATED AGGREGATES

Table 3 shows the properties of natural and plastic coated aggregates used for construction of roads [7].

TABLE – 3
PROPERTIES OF NATURAL AND PLASTIC COATED AGGREGATES

Stone aggregates	% of plastic	Aggregate impact value (IS 2386 (part IV) - 1963) %			Los Angeles Abrasion Test (IS 2386 (part IV) - 1963) %			Aggregate Crushing Value (IS 2386 (part IV) - 1963)%		
Without plastic	0	23.7			22.24			24.5		
		PP	LDPE	HDPE	PP	LDPE	HDPE	PP	LDPE	HDPE
With plastic	1	19.5	17.9	18.2	18.56	16.68	20.44	23.4	20.19	21.56
	2	15.3	14.1	12.42	17.48	14	16.3	18.5	13.55	17.4
	3	10.2	9.7	8.45	16.4	12.2	11.42	15.6	11.74	13.28

SALIENT FEATURES OF ROAD

In India more than 4.25 million Km of road is available. If only some of them are constructed or repaired using this technique, there will be less waste plastic littered on the road. The process is eco friendly. Segregating plastic from the MSW at municipal yard involves application of resources, the cost of which runs into crores of rupees. A substantial amount of this can be saved. Lab tests and real time tests have revealed that the life expectancy of a plastic road, compared to a normal road is at least 100% more. This technique adds a cumulative benefit to National Economy also gives contribution to environmental benefits, employment generation and agricultural efficiency [10]. Figure 3 shows some of the roads in Delhi region made with plastic waste.

i) Stronger road with increased Marshall Stability value.
ii) Better resistance towards rain water and water stagnation so no stripping and no potholes.
iii) Increase binding and better bonding of the mix thus reduction in pores in aggregate and hence less rutting a raveling.
iv) No leaching of plastics. No effect of radiation like UV.
v) The load withstanding property increases. It helps to satisfy today's need of increased road transport.
vi) Value addition to the waste plastics (cost per kg. increases from Rs. 4 to Rs. 12).
vii) The cost of road construction is also decreased and the maintenance cost is almost nil.

As road pavement life is doubled when we use this novel technique for road construction, we have to pay only Rs. 25000/- more, instead of spending Rs. 10,80,000/- for its up gradation in just 2-3 years, thus saving Rs.10,50,000/- per Km.

Figure 4 Roads made with plastic waste

CONCLUSION

The issues highlighted above throw light on the urgent needs for re-examining and formulating new guidelines/specification with regard to design and construction of concrete roads in India. The issues raised become more pertinent in the context of the large scale construction of cement concrete roads at the anvil. Feedback from the various construction agencies and from research and development fraternity can lead to meaningful contribution in solving many issues at stake in the field of design and construction of concrete roads in India. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics.

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