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UTILISATION OF PLASTIC WASTE IN FLEXIBLE PAVEMENT DESIGN

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ABSTRACT

Bottle, containers and packing strips etc. is increasing day by day. As a result amount of waste plastic also increases. This leads to various environmental problems. Therefore it is necessary to utilize waste effectively with technical development in each field. Many by-products are being produced using the plastic wastes. Preservation of road infrastructure requires a systematic approach for the good performance of roads keeping in mind the future condition and maintenance scenarios. Now-a-days pavements are subjected to various kinds of loading which affects the pavement performance condition that causes various distresses. These distresses include rutting, fatigue cracking, and temperature cracking. Looking forward to the environmental condition, complete ban on plastic cannot be made. Thus, using of plastic as an innovative technology not only strengthened the road construction but also increase the road life. This report includes the results of the various laboratory tests conducted on bitumen, aggregate and bitumen-aggregate plastic mix. Use of this mix for road construction helps to use plastics waste. Once the plastic waste is separated from municipal solid waste, the organic matter can be converted to use.

Keywords: Pavement, Plastic Coated Aggregate, Plastic Modified Bitumen,Plastic Road,Waste Plastics

I. INTRODUCTION

Plastic is everywhere in today's lifestyle. The main problem is what to do with the plastic waste. Use of plastic waste which is non-biodegradable is rapidly growing and researchers have found that the material can remain on earth for 4500 years unchanged and without degradation. 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. Several studies carried out by Health Departments have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc. Looking forward the scenario of present life style a complete ban on the use of plastic can't be put. Although the waste plastic taking the face of devil for the present and future generation, we can't avoid

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use of plastic but we can reuse it.This threat of disposal of plastic will not solve itself and certain practical steps have to be initiated at the ground level. On the other hand the road traffic is increasing with time hence there arises a need to increase the load bearing capacities of roads which can be made possible by utilising the waste plastic in flexible pavement design.

1.1. Necessity of the Study

The threat of disposal of plastic will not solve until the practical steps are not initiated at the ground level. It is possible to improve the performance of bituminous mixed used in the surface course of roads. Studies reported in the use of recycled plastic, mainly polyethylene, in the manufacture of blend indicated reduced permanent deformation in the form of rutting and reduced cracking and crazing of the pavement surface. The field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems.

Use of polyethylene in road construction is not new. Some aggregates are highly hydrophilic (water loving), like bitumen polyethylene is hydrophobic (water hating) in nature. So the addition of hydrophobic polymers by dry or wet mixing process to asphalt mix lead to improvement of strength, water repellent property of the mix. Polymer modification can be considered as one of the solution to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement. Creating a modified bituminous mixture by using recycled polymers (e.g., polyethylene) which enhances properties of Hot Mix Asphalt mixtures would not only produce a more durable pavement, but also provide a beneficial way of disposal of a large amount of recycled plastics by following ways:

- Stronger road 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 a ravelling.
- No leaching of plastics.
- No effect of radiation like UV.
- The load withstanding property increases. It helps to satisfy today's need of increased road transport.

1.2. Literature Review

The concept of using plastic in flexible pavement has been done since several years ago in India. Plastic has played a very vital role in increasing the strength of bitumen as well as aggregate. Prof. C.E.G.Justo (2015) states that addition of plastic in bitumen improves the stability, strength, life and other desirable properties of bitumen.[1] Similarly, Dr. R.Vasudevan (2013) states that the polymer bitumen blend is a better binder compared to plain bitumen.[2]Dr.Khandekar S.D. *et al.* (2015)stated that the concept of utilization of waste plastic in the construction of pavement has shown better resistance to water which reduces the stripping of bitumen from aggregate and also made investigations over the use of waste plastic in road construction as an effective way to reutilize the plastic waste.[3]

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Sharma H. K. (2015) reported less ageing of plastic bitumen blends in comparison with the neat bitumen was observed during thin film oven test, which is one of the superior performing characteristics that control the premature failure of a pavement due to cracking. There is considerable improvement in the indirect tensile strength and significant reduction in rutting characteristic of the mixes prepared with modifiers as compared to conventional one. They reported that waste plastics replaced about 10% by weight of bitumen. Stripping test conducted after mixing operation proved that adhesion of the stone-plastic waste–bitumen aggregate was good. Plastic waste could be successfully mixed with stone and bitumen at high speed asphalt plant and the condition of the tar road when properly laid was good. They reported that though plastics modified bitumen improves the quality of the roads, the process of using the plastics for the blending decides the strength of the bonding. Coating plastics waste over aggregate gives better strength than blending it with bitumen. Dry process is definitely better process than wet process. They also reported that polymer will not leach out after laying the road using plastic waste coated aggregate bitumen mix.[4]

Nemade S. *et al.* (2013) studied the feasibility of the use of shredded waste plastics in semi-dense bituminous concrete with 60/70 penetration grade bitumen employing dry process of mixing. On heating the softened plastics, provide a thin coating on the aggregate. Marshall Stability and flow values, over a 50 samples with varying percentage bitumen by weight of mix and percentage plastics by weight of binder were evaluated. There was a 10% saving in the bitumen content which leads to a saving in national economy and also an eco-friendly method for the disposal of waste plastics. The stability value of the mix was increased by about 30%. There is also less ageing of bitumen and no bleeding. The plastic coated aggregates showed no stripping even after 96 hours of water immersion and hence avoid the use of anti-stripping agents in bituminous mixes. Water absorption was found to be less as compared to uncoated aggregates indicating its higher degree of water susceptibility.[5]

Many researchers have studied the use of waste plastic in flexible pavement design by conducting various tests. In this research paper, various tests such as viscosity test and loss on heating test on bitumen are also included. Various important tests on bituminous mixes are also conducted such as crushing strength and indirect tensile strength.

1.3. Objectives of Study

After identification of problem and setting the objective of research, following specific objectives are framed to study the utilisation of plastic waste in design of flexible pavement:

1. To determine the relevant index and engineering properties of bitumen and aggregates
2. To cast various trial mixes with varying percentages of plastic waste in bitumen and coating over aggregates
3. To compare the trail mixes with conventional bitumen and aggregates
4. To select the optimum percentage of plastic waste to be blended with commonly used bitumen to produce maximum compressive strength
5. Prepare test samples with the percentage value obtained in step 4 and test these samples for various pavement properties

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6. To comment on the suitability and limitations of plastic waste for partial blending material with conventional bitumen construction of flexible pavement.

II. RESEARCH METHODOLOGY

The research methodology for present study has adopted various tests to investigate the results on aggregate, bitumen and plastic substituted bitumen and aggregate-bitumen-plastic mix. The waste plastic has been collected from the neighbourhood college area and used for testing. The various tests conducted on bitumen and plastic substituted bitumen were as follows:

Table 2.1. Tests on Bitumen

Sr.no.	Test	Apparatus used	Reference
1	Penetration test	Standard Penetrometer	IS : 1203-1978
2	Ductility Test	Ductility Apparatus	IS : 1208-1978
3	Softening Point	Ring Ball Apparatus	IS : 1205-1978
4	Flash And Fire Point	Pensky-Martens Apparatus	IS : 1209-1978
5	Viscosity Test	Orifice Viscometer	IS : 1206(Part I)-1978
6	Loss On Heating	Oven	IS : 1212-1978

For checking whether the plastic coating can be used to enhance the strength of aggregates, following tests were conducted on aggregates and plastic coated aggregates:

Table 2.2. Tests on Aggregates

Sr.no.	Test	Apparatus used	Reference
1	Aggregate Impact Value	Impact Testing Machine	IS : 2386(Part IV)-1963
2	Abrasion Value	Los Angeles Abrasion Testing Machine	IS : 2386(Part IV)-1963
3	Crushing Value	Crushing Value Apparatus	IS : 2386(Part IV)-1963

The optimum percentage of plastic substitution is found out from bitumen testing. Various bituminous mixes were prepared by using pure bitumen and plastic substituted bitumen. These mix samples were tested for following tests:

Table 2.3. Tests on Bituminous Mixes

Sr.no.	Test	Apparatus used	Reference
1	Marshall Stability Test	Marshall Test Apparatus	IRC SP 53-1999 and ASTM D 1559-1979
2	Compressive Strength Test	Universal Testing Machine	ASTM D 1074-09
3	Indirect Tensile Strength Test	Universal Testing Machine	ASTM D 6931

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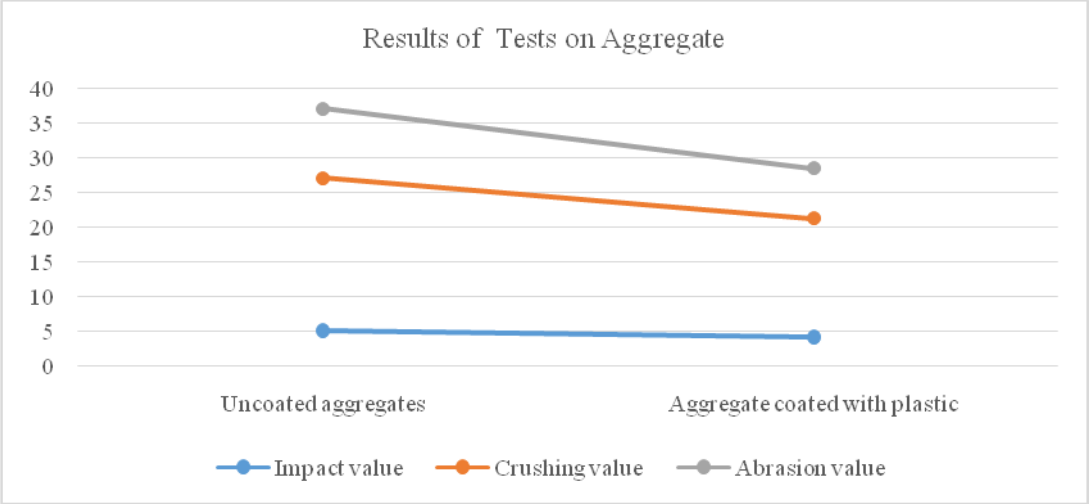
III. RESULTS AND DISCUSSIONS

3.1. Laboratory tests on Aggregates

The results of various tests conducted over aggregates are as follows:

Table 3.1. Results of Tests on Aggregates

Sr.No.	Test	Specification	Results	Standards
1	Crushing Value	Pure Aggregate	22%	30% (max)
		Aggregate With Plastic Coating	17.18%	
2	Impact Value	Pure Aggregate	5%	30% (max)
		Aggregate With Plastic Coating	4%	
3	Abrasion Value	Pure Aggregate	10%	30% (max)
		Aggregate With Plastic Coating	7.2%	



Comment: The strength of aggregates get increased after coating with plastic which is beneficial in pavement.

3.2. Laboratory tests on Bitumen

The results of various tests conducted on bitumen are as follows:

Table 3.2. Results of tests on Bitumen

Sr.no.	Specification	Results						
		Penetra-tion (mm)	Ductility (cm)	Soft. Pt. (^{0}c)	Flash pt. (^{0}c)	Fire pt. (^{0}c)	Viscosity (sec)	Loss on heating (%)
1	Pure bitumen	86	83	45	250	290	292	0.31
2	6% replacement	80	60	48	260	300	182	0.2
3	8% replacement	75	54	56	268	312	168	0.16

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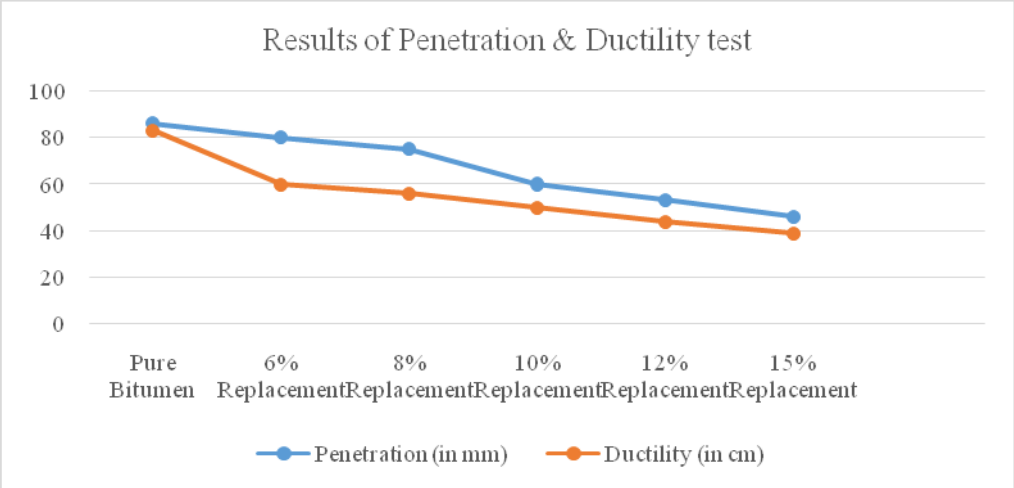
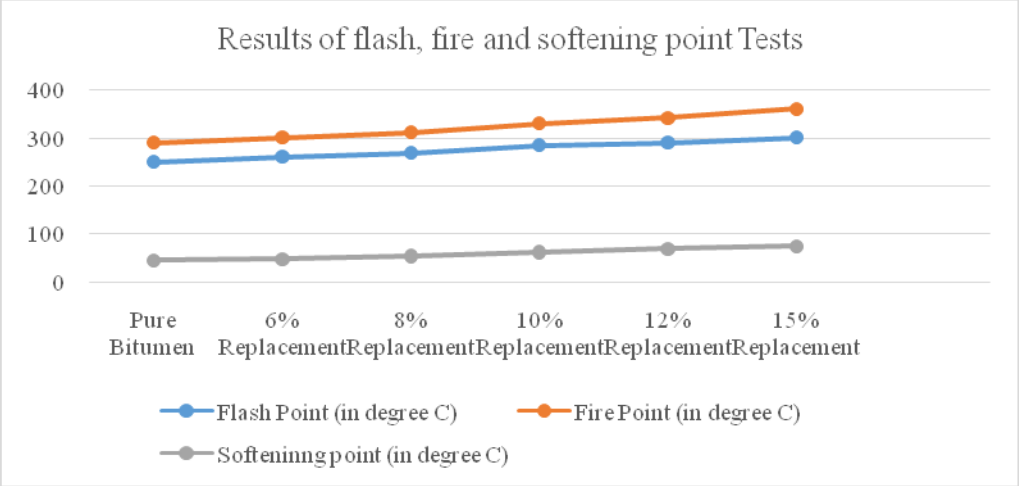
4	10% replacement	60	50	62	285	330	154	0.21
5	12% replacement	53	44	69	290	342	135	0.24
6	15% replacement	46	39	74	300	360	121	0.29
	standards	60 (min)	50 (min)	40 (min)	220 (min)	290 (min)	50 (min)	1% (max)



Comment: After replacement of plastic with bitumen, there is decrease in penetration & ductility value which indicates that the bitumen is getting harder with more plastic replacement.



Comment: With increase in plastic percentage, there is an increase in flash, fire and softening point which indicates more susceptibility of bitumen in tropical regions.

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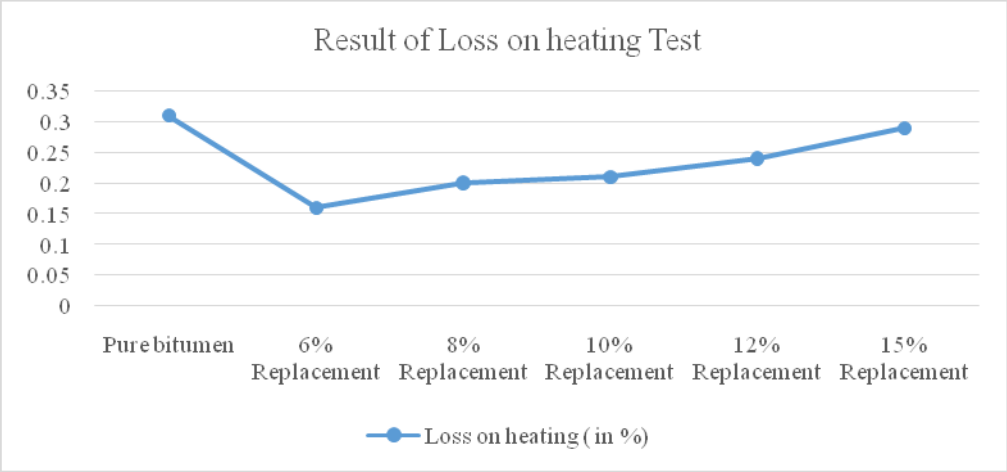
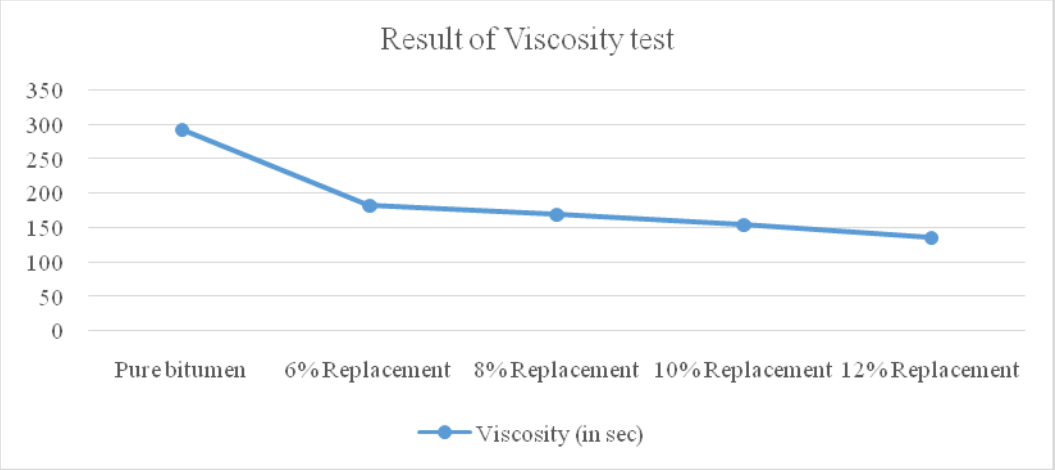


Comment: Addition of plastic shows slight decrease in loss on heating.



Comment: Reduction of viscosity is useful to lower the mixing and compaction temperature of asphalt.

3.3. Laboratory tests on bituminous mixes

The results of various tests conducted on bituminous mixes are as follows:

Table 3.3. Result of Tests on Bituminous Mixes

Sr.No.	Test	Specification	Results	Standards
1	Marshal Stability Test (Stability)	Pure Bitumen	600 kg	Minimum 340 kg
		10% Replacement	980 kg	
2	Marshal Stability Test (flow value)	Pure Bitumen	8.5 mm	Min 8 mm Max 17 mm
		10% Replacement	11 mm	
3	Compressive strength of bitumen	Pure Bitumen	860 kg	Minimum 700 kg
		10% Replacement	1740 kg	
4	Indirect tensile strength of bitumen	Pure Bitumen	370 kg	Minimum 330 kg
		10% Replacement	700 kg	

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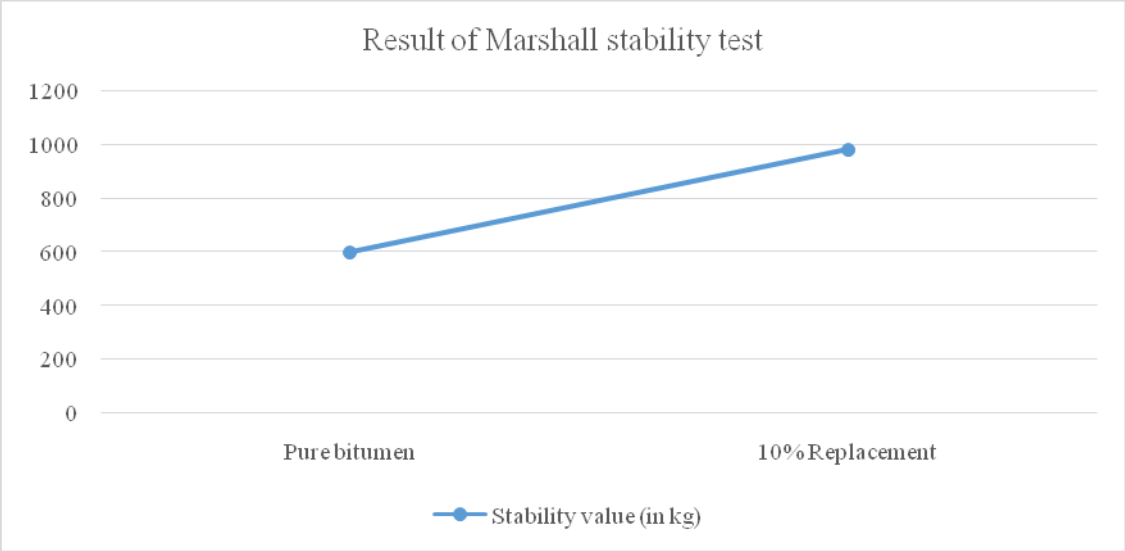
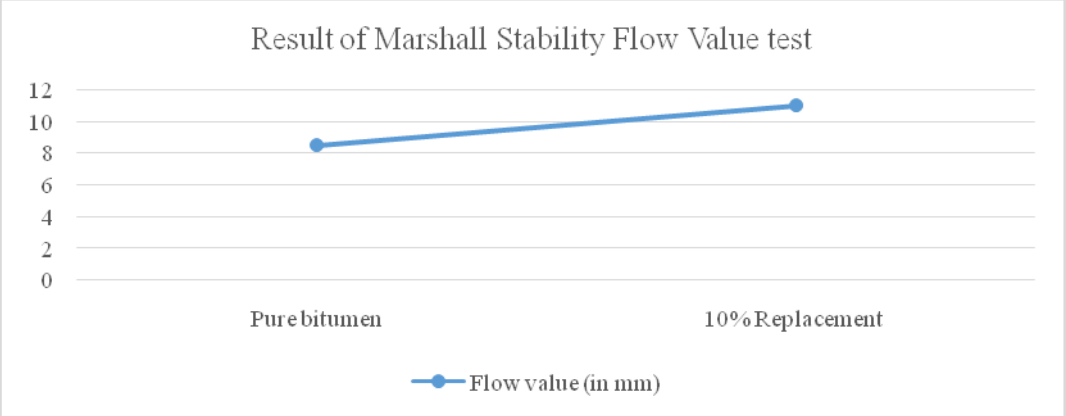
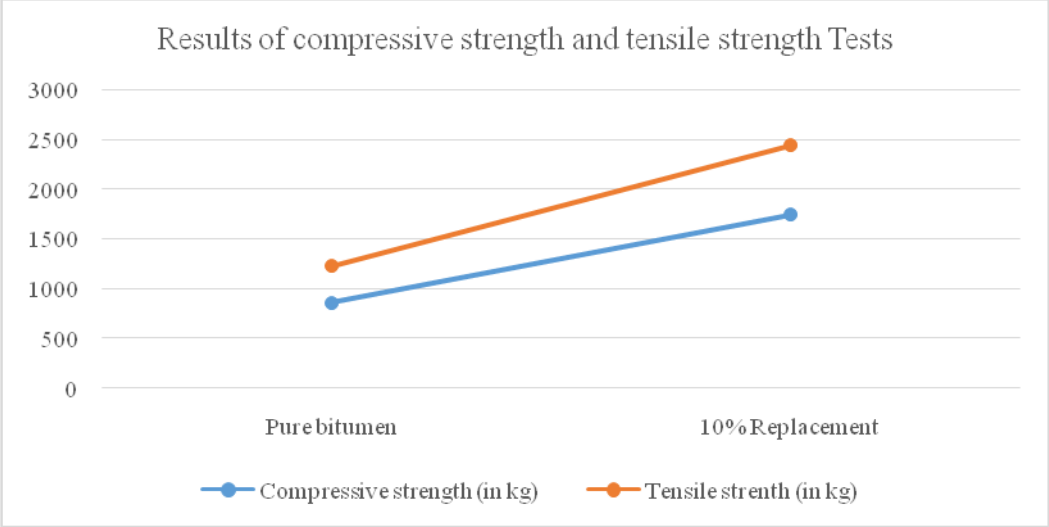


Comment: Addition of plastic shows increase in stability value which is useful to sustain large load.



Comment: Replacement of plastic shows increase in flow value i.e. less resistance to deformation but change is very little which is in specified limit.



Comment: Addition of plastic shows increase in compressive and tensile strength.

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3.4. Cost Analysis

According to market cost of plastic waste (collection, segregation and processing) = Rs. 5 per kg.

Cost of bitumen per drum (200 kg) = Rs. 8000

Cost of bitumen per kg = Rs. 40

Cost of bitumen per ton = Rs. 40000

Generally roads in India are constructed in basic width of 7m.

Consider 1km length road.

To lay 1 km of roads about 15 tonnes of bitumen is required.

Cost of bitumen required per km = Rs. 6,00,000

Assuming optimum percentage of plastic as per the test results is around 10% (by % wt of bitumen)

Total quantity of bitumen required = 13.5 tonnes

Total quantity of plastic waste required = 1.5 tonnes

Cost of bitumen for 13.5 tonnes = Rs. 5,40,000

Cost of plastic waste = Rs. 7500

Total cost of bitumen & plastic = Rs. 5,47,500

Total saving = Rs. 6,00,000 – Rs. 5,47,500

= Rs. 52,500 per km

IV. CONCLUSION

4.1. Advantages

The various advantages of using plastic waste in flexible pavement design are as follows:

- It shows better binding property.
- It shows higher softening point, flash and fire pointwhich means it can withstand high temperature and suitability in tropical region.
- It shows lower penetration and ductility value which means it can withstand higher load.
- It shows higher Marshall Stability value and higher compressive and tensile strength which means increased strength of road.
- The cost of construction is less as compared to bitumen road.
- It is better way of disposal of waste plastics. About ten lakhs to one ton carry bags can be used in one kilometre road.
- The polymer coating also reduces the voids. This has resulted in reduced rutting and there is no chance of formation of pot hole.
- The road can withstand heavy traffic & show better durability.

4.2. Limitations

The main limitation of using waste plastic in flexible pavement design is as follows:

- The burning of plastic waste creates air pollution and also health hazards.

4.3. Conclusion

From this research paper, we conclude that,

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- Based on Literature, Plastic is a very hazardous material which causes adverse effects on environment. So, it is today's need to find eco–friendly methods in disposal of plastic.
- Plastic can be utilized as a partial blending material in design of flexible pavement. It can be used as a partial replacement in bitumen as well as coating over aggregate.
- According to various tests conducted, plastic as a 10% replacement in bitumen can give better result in flexible pavement design.
- As per prevailing Market rates, due to 10% replacement in Bitumen, about Rs. 52,500 per km road constructiongets saved.

V. ACKNOWLEDGEMENT

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