INCREASED STABILITY OF DENSE GRADED BITUMINOUS MIX USING WASTE PLASTIC

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Abstract: Plastic is the most widely used non-biodegradable 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. 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.

Key Words: Plastic Waste, Bituminous roads, Polymer modified bitumen

I. INTRIDUCTION

Bituminous roads are the most common types of roads in India and abroad. There are a wide variety of bituminous pavement construction techniques in use. Bituminous constructions are also adopted for base and binder courses of pavements on heavy traffic roads. Also stage development is possible in the case of bituminous roads, depending on traffic demands.

The immensely growing network of roads demands never ending source of resources. But the sources of bitumen are depleting day by day. Moreover, the traffic on the roads is increasing tremendously with regard to axle load as well as number of commercial vehicles. The vast expense, wide ranges of climate and different physical characteristics give a continental character to India, which generates quite a number of demands for a pavement engineer to fulfill. These loads cause the pavement to deform developing compressive stresses in the top layers. The tensile stresses are developed in the bottom layers causing the pavements to develop rutting, cracks and other defects. So, the suitable alternatives of bitumen are the need of the hour. . This research aims at modifying the binder as well as to recycle the plastic wastes in order to achieve a cleaner environment.

The use of plastic coated aggregates in road construction has been proposed to improve the pavement properties manifolds. The results have shown that the properties like resistance to rutting, water absorption, stress etc. increases tremendously.

II. MATERIALS USED AND METHODOLOGY

Tests were conducted to investigate the properties of the plastic coated aggregates as well as polymer modified bitumen and then the stability of the plastic coated aggregate bituminous mix was evaluated and comparisons were done between the ordinary mix and the plastic coated aggregate PCA bituminous mix.

2.1 MATERIALS USED:

1. Aggregates
2. Bitumen
3. Plastic waste

2.1.1 AGGREGRATES

Aggregates form an important constituent of pavement structure. 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 aggregates like hardness, crushing, strength, durability are of considerable significance to the highway engineers.

The following tests were conducted on the aggregates:

Table 1: Results of the tests conducted on aggregates

S No	Test	Property determined	Results
01	Los Angeles test	Abrasion	27.63%
02	Crushing test	Crushing strength	19.2%
03	Impact test	Toughness	12%
04	Shape test	Flakiness index	16%
05	Shape test	Elongation index	14.8%

2.1.2 BITUMEN

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 table below shows the results of the tests conducted on bitumen.

Table 2: Results of the tests conducted on bitumen

S No.	TEST	RESULT
01	Penetration Test	82 mm
02	Softening point test	54ºC
03	Ductility test	74 mm
04	Flash point test	192.33ºC
05	Fire point test	201.33ºC

2.1.3 PLASTIC WASTES

The use of plastic materials such as carry bags, cups, etc. is constantly increasing. The consumption of plastics has increased from 4000 tons/annum to 8 million tons/annum and it is expected to rise 15 million tonnes/annum during the year 2020. Nearly 50 to 60% of the total plastics are consumed for packing. The plastic wastes are shredded in the shredding machine and then sprayed in different percentages over the hot aggregates.

Fig 1: Collection of waste plastic

2.1.3.1Waste plastic shredding:

Shredding is the process of cutting the plastic into small sizes between 2mm to 5mm with the help of the plastic shredding machine viz. Agglomerater and Scrap Grinder

Fig 2: Shredded plastic waste

Fig 3: Shredded plastic waste being sprayed over hot aggregates

The shredded plastic is sieved and the plastic pieces passing through 4.75mm sieve and retaining at 2.36mm sieve gets collected. These plastic pieces are added slowly to the hot bitumen of temperature around 170-180˚C. The mixture stirred well using mechanical stirrer for about 20-30 minutes. Increase in the percentage of plastic enhances the properties of aggregates.

2.2TESTS ON PLASTIC COATED AGGREGATES

The following tests were conducted on the plastic coated aggregates:

1. Aggregate impact test
2. Los Angeles abrasion test
3. Water absorption test

The results of these tests with different percentages of plastic are given below in Table 3.

Table 3: 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	Water Absorption
01	0	12%	27.63%	5%
02	2	11.86%	26.71%	3%
03	4	11.63%	26.24%	2%
04	6	11.41%	25.85%	1.1%
05	8	10.79%	25.79%	Traces
06	10	10.55%	25.55%	Negligible

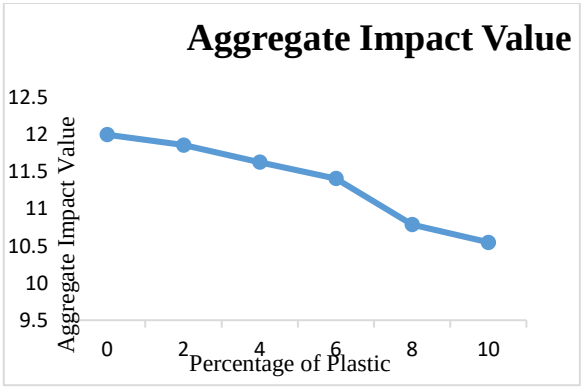

Fig 4 : Variation of aggregate impact value (percentage) with increase in percentage of plastic.

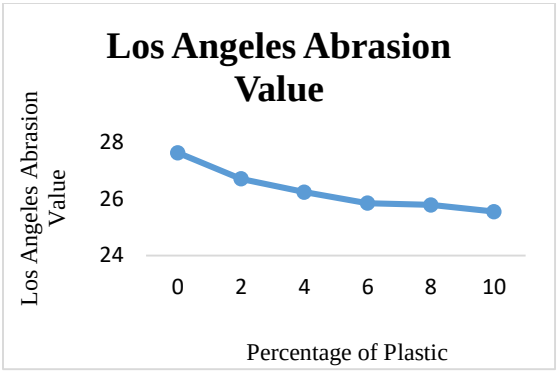

Fig 5 : Variation of Los Angeles abrasion value (percentage) with increase in percentage of plastic.

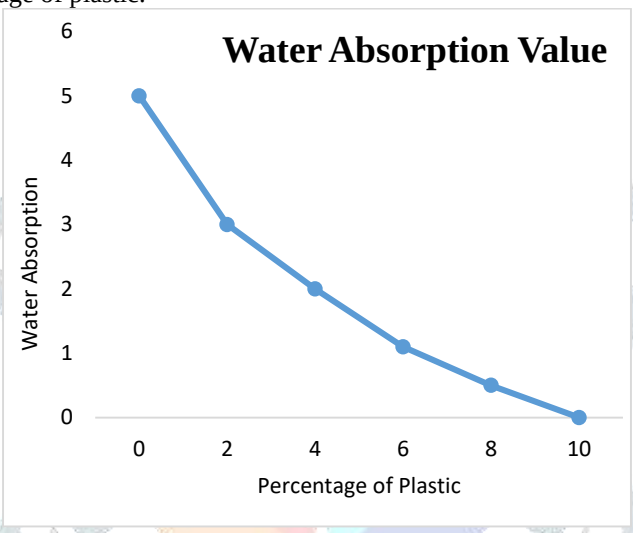

Fig 6 : Variation in Water Absorption value with increase in percentage of plastic.

2.3 TESTS ON POLYMER MODIFIED BITUMEN

Polymer-bitumen mixtures of different compositions can be prepared and the following tests are conducted:

1. Penetration Test
2. Ductility Test
3. Softening Point Test

Fig 7: Bitumen being mixed with plastic coated aggregates.

The results of these tests with different percentages of plastic are given below in Table 4.

Table 4: Results of the tests conducted on plastic modified bitumen with different percentages of plastic

S. No	Percentage of bitumen	Percentage of plastic	Penetration (mm)	Ductility (mm)	Softening point (°C)
01	100	0	82	74	54
02	98	2	69	69	59
03	96	4	63	65	68
04	94	6	57	60	72
05	92	8	55	58	74
06	90	10	48	55	77

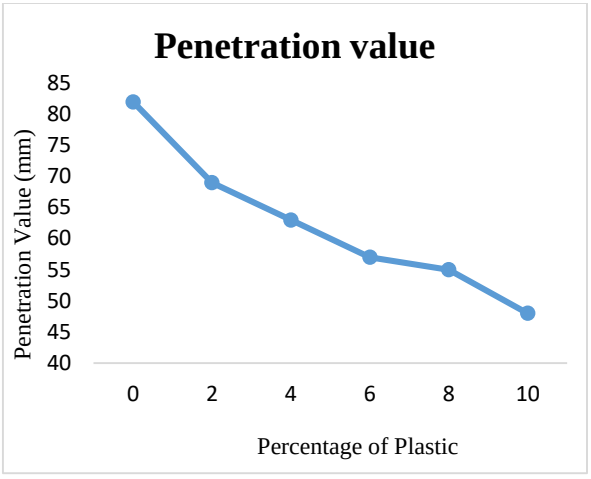

Fig 8: Variation of penetration value of bitumen with the increase in percentage of plastic.

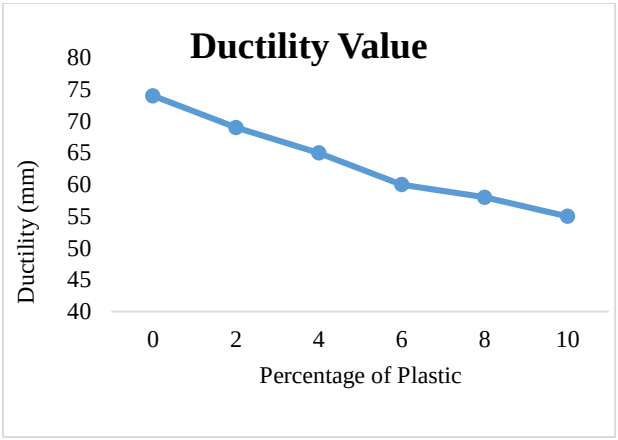

Fig 9: Variation of ductility of bitumen with the increase in percentage of plastic

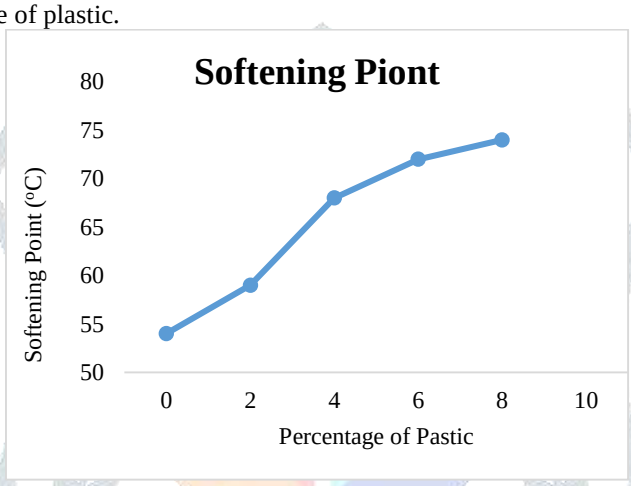

Fig 10: Variation of softening point of bitumen with increase in percentage of plastic.

3. PLASTIC COATED AGGREGATES AND BITUMEN MIX

After the shredded plastic is spread over the hot aggregates, the plastic melts and coats the aggregates. These plastic coated aggregates are added to hot bitumen at a temperature of about 180°C. The bitumen, which is a hydrocarbon forms long chains with the plastic polymers like PE, PP etc. The coated plastic remains in softened state for a temperature range of 140°C to 190°C. The hot bitumen (180°C) is added and spread over these aggregates. At this temperature both the plastic coating 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.

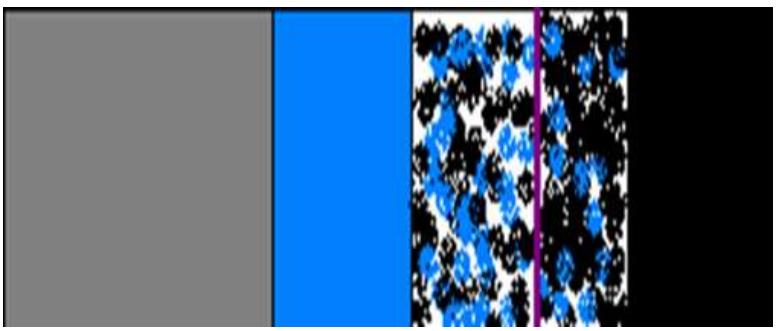

Fig 11: Plastic aggregate bitumen interaction model for the Plastics waste coated aggregate bitumen mix. [11]

3.1 TEST CONDUCTED ON BITUMIBOUS MIX

The plastic coated aggregates and bitumen are mixed to form a compacted specimen and the optimum plastic content is determined by Marshall Stability Test. This test was conducted to check the stability and the flow values which are tabulated below in table 5.

Table 5: Marshall Stability value for plastic coated aggregate – bitumen mix

S. No	Percentage of plastic	Marshall Stability Value (KN)	Flow Value (mm)
01	0	11.8	3
02	2	12.6	3.3
03	4	13.4	3.5
04	6	16	3.7
05	8	16.9	4.0
06	10	17.6	4.2
07	12	17.9	4.8
08	14	18.4	5.3
09	16	16.1	5.9
10	18	14.3	6.4

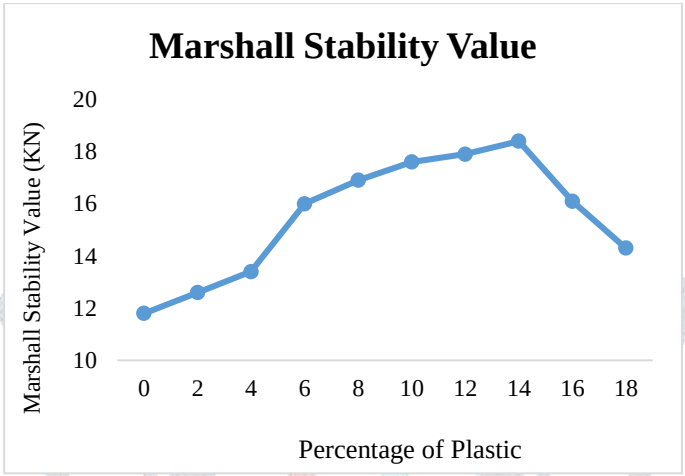

Fig 12: Variation of Marshall stability value of modified bitumen mix with increase in percentage of plastic

The figure12 shows that the stability of the bituminous mix can be increased by the addition of plastic upto 14% after which it starts decreasing.

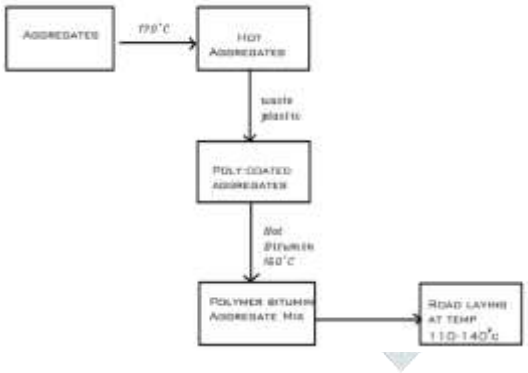

Fig. 13: Flow diagram of bituminous toad construction

4. 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

5. CONCLUSION

The generation of waste plastics is increasing day by day. The plastics show adhesion property in their molten state. By using plastics in the bituminous road, the overall properties of both aggregates as well as the bitumen and that of the road gets enhanced as a whole. This increases the stability and hence the life of our pavements. 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 charts below shows the comparison between the properties of plain aggregates and the aggregates coated with 10% of plastic waste and that of bitumen.

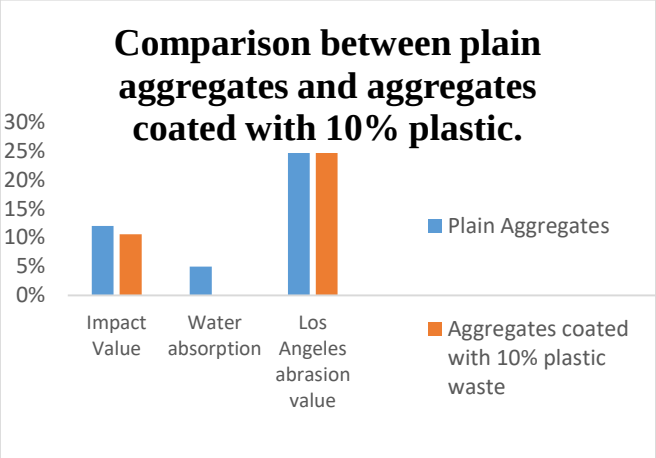

Fig 14: Comparison between plain aggregates and plastic coated aggregates

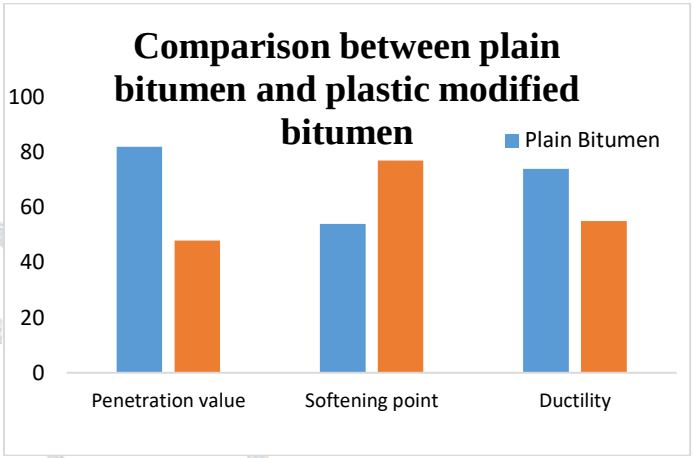

Fig 15: Comparison between plain bitumen and plastic modified bitumen

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 50°C 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.
In short we can conclude that, using plastic waste in mix will help reduction in need of bitumen by around 10%, increase the strength and performance of road, avoid use of anti-stripping agent, avoid disposal of plastic waste by incineration and land filling and ultimately develop a technology, which is ecofriendly. Increased traffic conditions will and are reducing the life span of roads. Plastic roads are means of prevention and ultimately will be the cure. It will save crores of rupees in future and reduce the amount of resources used for construction.

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