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Use of Plastic Waste Material in Flexible Pavements

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ABSTRACT: Use of plastic along with the bitumen in construction of roads not only increases its life and smoothness but also makes it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties Roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. Further it has been found that such roads were not subjected to stripping when come in contact with water. In this paper the use of higher percentage of plastic waste reduces the need of bitumen by 10%. It also increases the strength and performance of the road. Plastic increases the melting point of bitumen and hence mixing can be done in more better and easier way. Plastic waste replaces 10% to 15% of bitumen, and thereby saves approximately Rs. 35000 to Rs. 45000 per kilometer of a road stretch. Inclusion of plastic waste in road construction eliminates the plastic shrinkage cracking of road surface and reduces the drying shrinkage to some extent.

Keywords: Plastic Waste Material, Flexible Pavements, Plastic Roads, stripping

I. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided in to two major categories: thermoses and thermoplastics. A thermoset solidifies or "sets" irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane.

The objective of study is

(i) To coat the aggregates with the waste plastic materials

(ii) To check the properties of bituminous mix specimen

(iii) To check the properties of bituminous mix specimen due to coating of waste plastic materials

II. MATERIALS AND METHODS

A. Test for Aggregate

Sieve Analysis of Aggregates: By passing the sample downward through a series of standard sieves, each of decreasing size openings, the aggregates are separated into several groups, each of which contains aggregates in a particular size range. This test is done to determine the particle size distribution of fine and coarse aggregates.

Aggregate Impact Value Test : The property of the material to resists impact is known as toughness. Due to movement of vehicles on the road the aggregate are subjected to impact resulting in their breaking down into smaller pieces. The aggregate should therefore have sufficient toughness to resists their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load. The Aggregate Impact Tester is equipped with a circular base with two vertical guides. This test accesses the suitability of aggregates in road construction on the basis of impact value.

Aggregate Crushing Value: The 'aggregate crushing value' gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. It is the percentage by weight of the crushed (or finer) material obtained when the test aggregates are subjected to a specified load under standardized conditions, and is a numerical index of the strength of the aggregate used in road construction. Aggregates with lower crushing value indicate a lower crushed fraction under load and would give a longer service life to the road and hence a more economical performance. Weaker aggregates if used would get crushed under traffic loads, would produce smaller pieces not coated with binder and these would be easily displaced or loosened out resulting in loss of the surface / layer. In short the aggregate used in road construction must strong enough to withstand crushing under roller and traffic.

Specific Gravity & Water Absorption Test: The specific gravity of an aggregate is an indirect measure of its strength, the more specific gravity the more is the strength, in general.

Water absorption is expressed as percentage ratio of water absorbed to the weight of the oven dry aggregate. The water absorption of aggregates is needed in deciding the proportion of water in concrete while designing the mix

B. Tests For Bitumen

Penetration Test: Penetration is a measurement of hardness or consistency of bituminous material. It is a vertical distance traversed or penetrated by the point of a standard needle into the bituminous material under specific condition of load, time and temperature. This distance is measured in one tenth of a millimeter. This test is used for evaluating consistency of bituminous materials

Softening Point Test: The softening of point of bitumen is the temperature at which the substance attains a particular degree of softening. As per IS: 334-1982, it is the temperature (in °C) at which a standard ball passes through the sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerin at specified conditions of test.

The binder should have sufficient fluidity before its applications in road uses. The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus.

Ductility Test: The ductility test gives a measure of adhesive property of bitumen and its ability to stretch. In a flexible pavement design, it is necessary that binder should form a thin ductile film around the aggregates so that the physical interlocking of the aggregates is improved. Binder material having insufficient ductility gets cracked when subjected to repeated traffic loads and it provides pervious pavement surface. The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when two ends of a standard briquette specimen are pulled apart at a specified speed and temperature.

Following are the material used for this study

Aggregates, Bitumen, Plastic materials (PET, polyethylene terephthalate, HDPE, high-density polyethylene, PVC, polyvinyl chloride, PP, polypropylene, PS, polystyrene)

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. In Agglomerater, thin films of poly-ethylene and poly-propylene carry bags are shredded and in Scrap Grinder a solid plastic material are shredded i.e. plastic bottles, drip lines, electric cable lines etc

Plastic-Waste Coated Aggregate: The aggregate are heated to around 170^0C; the plastic waste 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 get softened and coated over the aggregate. The hot plastic waste coated aggregates are mixed with hot bitumen 60/70 or 80/100 grade (160^0C).

III. RESULTS AND DISCUSSIONS

On the basis of above methodology, various aspects regarding the Polymer coated aggregates are being discussed below:

Aggregate Impact Value

The coating of plastics improves Aggregate Impact Value, thus improving the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers. It helps to improve the quality of flexible pavement. This shows that the toughness of the aggregate to face the impacts. Following are the ranges of the aggregates used in road construction. It was seen that the results obtained were in the limits.

Table 1 : Results of aggregate impact value.

Test	Results (%)			Range (%)
Aggregate Impact Value	Control Specimen	PP8	PP10	< 10
	5.43	4.91	4.26	

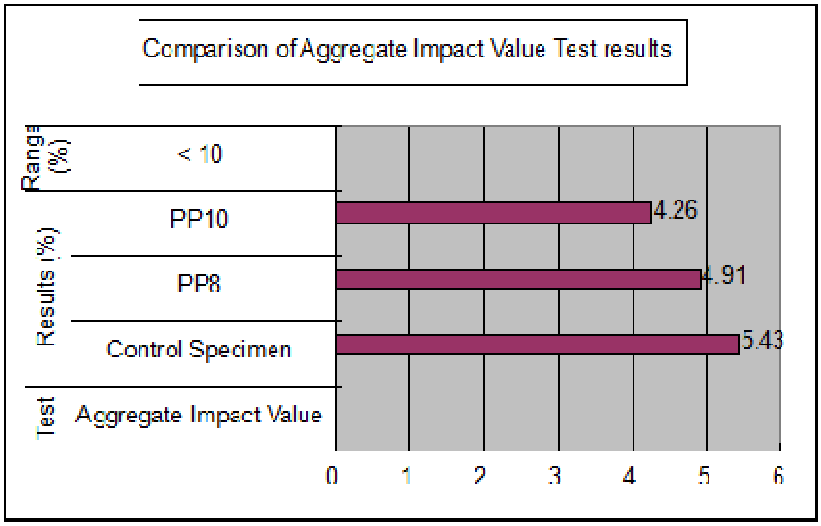

Fig. 1. Comparison of Aggregate Impact Value Test results.

Aggregate Crushing Value: The aggregate with lower crushing value indicate a lower crushed fraction under load and would give a longer service life to the road. Weaker aggregate would get crushed under traffic load. It is clearly seen from Table 2 that plastic coated aggregates shows the lower crushing value and which can be withstand to traffic load more efficiently than the plain aggregates. The results show that the aggregates are within the range according to ISS. However aggregate crushing value have not been specified by the IRC for course aggregates to be used in bituminous pavement construction methods. Hence the aggregate can be used for the road construction.

Table 2: Results of Aggregate Crushing Value Test.

Test	Results (%)			Range (%)
Aggregate Crushing Value	Control Specimen	PP8	PP10	< 30-45
	19.2	13.33	9.82	

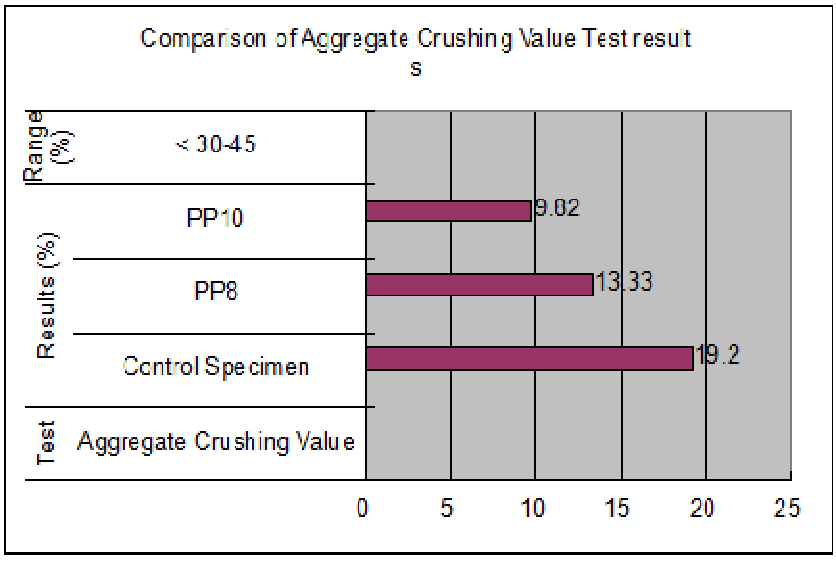

Fig. 2. Comparison of Aggregate Crushing Value Test results.

Specific Gravity: The specific gravity of an aggregate is an indirect measure of its strength. The more specific gravity the more is the strength. The value of specific gravity of plain aggregate is less as compare to that of plastic coated aggregate. Since aggregates having low specific gravity are generally weaker than those with higher specific gravity values, the results say that the specific gravity of the aggregates are increased increasing its strength.

Table 3: Results of Specific Gravity Test.

Test	**Results (%)**			**Range (%)**
Specific Gravity	Control Specimen	PP8	PP10	2.5-3.0
	2.45	2.7	2.85	

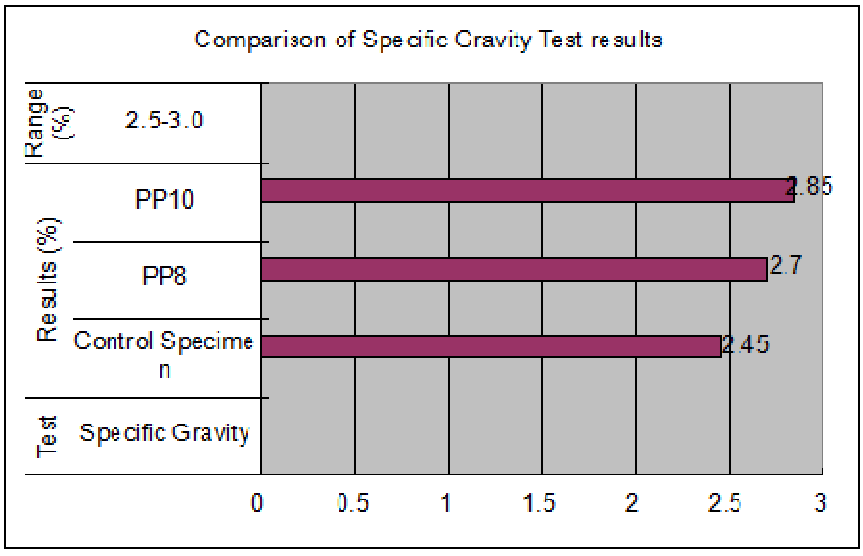

Fig. 3. Comparison of Specific Gravity Test results.

Results of tests on aggregates:

Table 4: Observation Table for Aggregates Test Results.

Percentage of Plastic	Moisture Absorption (%)	Aggregate Impact Value (%)	Aggregate Crushing Value (%)	Los Angeles Abrasion Value (%)	Specific Gravity	Stripping Value (%)
Control Specimen	1.7	5.43	19.2	13.42	2.45	8
PP8	Nil	4.91	13.33	10.74	2.7	Nil
PP10	Nil	4.26	9.82	9.41	2.85	Nil

Results of Tests on Bitumen:

Table 5: Observations for tests on bitumen.

Test	Result	Ranges
Ductility Test	77.50 cm	Min 40
Penetration value	63 mm	60-70 mm
Viscosity value	50.1 sec	-
Softening Point	48.25^0C	45-600C
Flash Point Test	280^0C	$>65^0$-175^0C
Fire Point Test	302^0C	

Comparison of Tests Results:

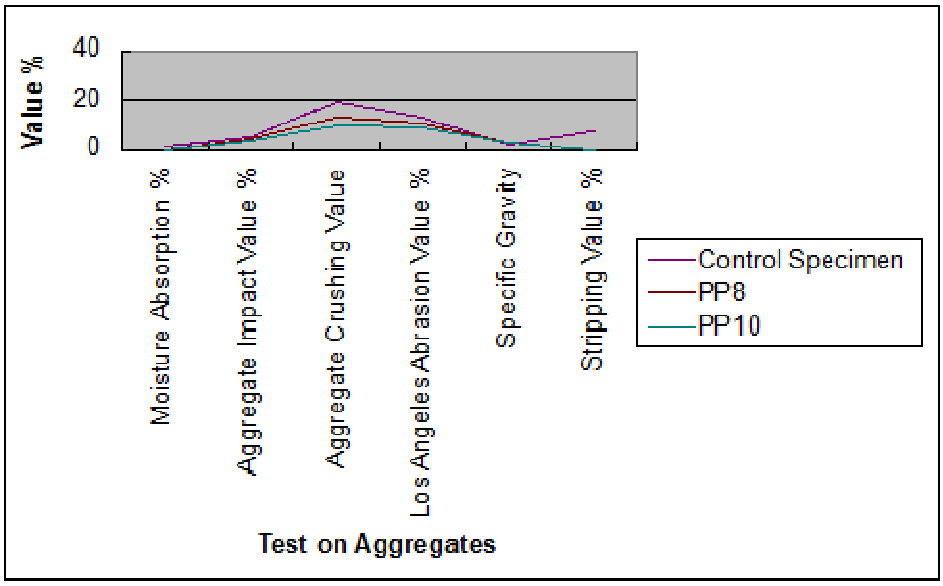

Fig. 4. Comparison of Aggregate Test results.

The above figure shows the comparison of test results. It is evident from the figure that the use of polymer gives better results as compared to plain bitumen.

Also higher percentage of polymer content gives lower values of impact, crushing, abrasion. The percentage of moisture content and the stripping value is nil in plastic coated aggregate.

Table 6 : Comparison between ordinary bitumen roads & waste plastic bitumen road Polymer Road.

Properties	**Ordinary Road**	**Polymer Road**
Binding property	Good	Better
Softening point	More	Less
Penetration value	Less	More
Tensile strength	Less	High
Stripping (pot holes)	More	No
Seepage of water	Yes	No
Durability of roads	Good	Better
Cost of pavement	Normal	Less
Maintenance cost	More	Almost nil
Environment friendly	No	Yes

IV. CONCLUSIONS

The use of innovative technology not only strengthens the road construction but also increased the road life as well as will help to improve environment and will also create source of income.

Plastic coating on aggregates is used for its better performance. This helps to have a better binding of bitumen with plastic wasted coated aggregate due to increased bonding and increased area of contact between polymers and bitumen.

The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air.

This has resulted in reducing rutting, raveling and there is no pothole formation. The roads can withstand heavy traffic and show better durability.

Following are some points which are drawn from the study:

(i) Aggregate Impact value of control specimen was 5.43%. It reduced to 4.91% for PP8 and 4.26% for PP10. Reduction in value was 10% for PP8 and 22% for PP10. This shows that the toughness of the aggregate was increased to face the impacts.

(ii) Crushing Value was reduced from 19.2% to 13.33% and 9.82% for PP8 and PP10 respectively. Value reduced by 30% for PP8 and 48% for PP10. Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low.

(iii) Specific Gravity of the aggregate increases from 2.45 for control specimen to 2.7 for PP8 and 2.85 for PP10 due to plastic coating.

(iv) Stripping Value was reduced from 8% for control specimen to nil for PP8 and PP10. This shows that coated aggregate are more suitable for bituminous construction than plain aggregates.

(v) Water Absorption is also reduced to nil for PP8 and PP10 from 1.7% for control specimen.

(vi) Los Angeles Abrasion Value of the control specimen was found to be 13.42%. Coating of polymer over aggregate for PP8 increased abrasion value by 19.97% and 29.88%for PP10. This indicates the hardness of the aggregate.

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 eco friendly.

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 millions of dollars in future and reduce the amount of resources used for construction.

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