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REDUCTION IN CONSUMPTION OF BITUMEN BY USE OF PLASTIC COATED AGGREGATES IN BITUMINOUS MIXES OF FLEXIBLE PAVEMENTS

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KeyWords
Optimum bitumen content, Marshal Stability, Flow value, Air voids, Optimum plastic content , plastic coated aggregates (PCA), dry process.

ABSTRACT

The continuous increase in road traffic in combination with insufficient maintenance due to paucity of funds has resulted in deterioration of road network in India. During last three decades in many countries around the world it has been tested that modification of the bituminous binder with polymer additives enhances the properties and life of asphalt concrete pavements.The present investigation deals with the use of plastic coated aggregate (PCA) in bituminous mix of flexible pavements in order to improve their performance and also to give a way for safe disposal of plastic wastes to provide a solution to threat of environmental pollution as well. There are two processes available for mixing of waste plastic in bituminous mixes namely wet and dry process. In this study the dry process was used for bituminous concrete mixes. Physical properties of conventional and plastic coated aggregates were compared. The comparative study of the bituminous mixes is also presented. The Marshall method of mix design was adopted using 80/100 grade bitumen for conventional aggregates and plastic coated aggregates (PCA). Marshal stability, Flow value, Air voids(Vv), Voids in mineral aggregates (VMA), and Voids filled with bitumen(VFB) were determined and compared with conventional aggregates (without plastic) bituminous concrete mixes. It was found that there was a reduction in consumption of bitumen content of bituminous mix by use of plastic coated aggregates also a considerable improvement in the properties of aggregates and bituminous mix leading to provide longer life and better pavement performance.

1 INTRODUCTION

Rapid increase in traffic load and drastic variations in climatic conditions have compelled the technologists to upgrade the specifications for bituminous mixes to obtain higher mechanical stability for bituminous concrete roads. As the limits of upgrading bituminous concrete mixes with conventional mixes has reached out so there has to be a modification of bituminous mixes. There are mainly two options i.e. firstly to modify the bituminous mix by adding polymers to the bitumen, secondly by coating of shredded thin waste plastic on aggregates and then adding hot bitumen immediately to the plastic coated aggregate (PCA) by dry process. Modification of bituminous mixes has many advantages such as decreased thermal susceptibility and rutting, minimization of low temperature cracking, greater adhesion to the aggregate, increased tire traction etc.

2 LITERATURE REVIEW

Many researchers have shown in past that performance of bituminous concrete mixes used in surfacing of flexible pavements can be improved by adding suitable additives. These additives may be processed waste plastics, mainly polythene, can be used in manufacturing of polymer-modified bitumen. It has been proven that adding of recycled polythene, low density polythene carry bags in bituminous pavement was responsible for its reduced rutting and low temperature cracking of flexible pavement surfacing. (Flynn 1993). Other researchers, Zoorab and Suparma (2000) used plastics which were mainly composed of polythene and low density polythene(LDPE) in bituminous mixes and this resulted in better durability and fatigue life. A increase of 20% in stability and about 30% in Indirect tensile strength (ITS) was observed with mixes modified by using plastic wastes. Shridhar et al (2004) showed that fatigue life of modified bituminous concrete mixes were doubled as compared to conventional one. Rutting characteristics of bituminous concrete mixes had significantly reduced by adding 5 to 10% recycled plastics to binder. Further investigations on Indirect tensile strength (ITS) and fatigue have shown that there is a improvement in modified mixes as compared to conventional one. In mixes containing more than 5% of plastic waste the fatigue was considerably reduced. Kumar et al (2003) by laboratory investigation has revealed that weight loss of modified mix was less as compared to conventional mixes of without plastics. The stability value was increased about 1.65 times by addition of 8% recycled plastics to bituminous concrete mixes. Improvement in stability, tensile strength and moisture resistance of Asphalt mixes was observed by Bose et al (2004) by the addition of 8% waste plastic (by weight of bitumen) Vasudevan et al (2006) showed that coating plastics over hot aggregates in dry process gives better strength to the mixture, than blending it with asphalt in wet process. Ravi Shankar et al (2013) also added shredded waste plastic in bituminous concrete mixture by mixing them directly with the hot aggregates. Out of many different plastic dosages a mix with 6% (by weight of bitumen) plastic content showed better results. In 2013 Rahman et al reported that 10% waste polyethylene modifier can be used from the point of view of stability, stiffness and voids characteristics in the asphalt mixtures for flexible pavement construction in a hotter regions. When waste plastic added in dry process, for preparation of SDBC (Semi dense bituminous concrete) mixes it resulted in improvement of stability by 30% and ITS by 32% (Ravishankar, et al. 2008). Also evaluations on rutting also indicated that the waste plastics modified mixes are less susceptible to rutting than conventional SDBC mixes. by dry process. In this research an attempt is made to study the properties of Bituminous Concrete (BC) mixes Grading-1 Indian Roads Congress (IRC:111-2009) using waste plastics by dry process.

3 MATERIALS, PROPERTIES AND PROCEDURE

The materials used for preparation of the bituminous mix were

A- Aggregates- Aggregate was obtained from local areas. Aggregate gradation that satisfies the requirements of IRC 111-2009 for grading-1 was selected.From Figure-1 below, it can be observed that the selected aggregate gradation is with in the specified range for hot asphalt mix design. Aggregate gradation that satisfies the requirements of IRC 111-2009 for grading-1 was selected and tested. Details are given in table below.

Table-1 Aggregate Grading and bitumen content

Specification	Bituminous Concrete(BC)	
Grading	Grad-1	
Nominal maximum aggregate size in mm	19 mm	
Layer thickness	50 mm	
IS Sieve size in mm	Cumulative % by weight of total aggregate passing	
	Gradation specified	Gradation adopted
26.5	100	100
19.0	90-100	95
13.2	59-79	-
9.5	52-72	70
4.75	35-55	50
2.36	28-44	35
1.18	20-34	-
0.6	15-27	-
0.3	10-20	12
0.15	5-13	-
0.075	2-8	5
Bitumen content	5.2% by weight of aggregate minimum.	

The grading curve and test results are shown below in and Fig- 1and table-2

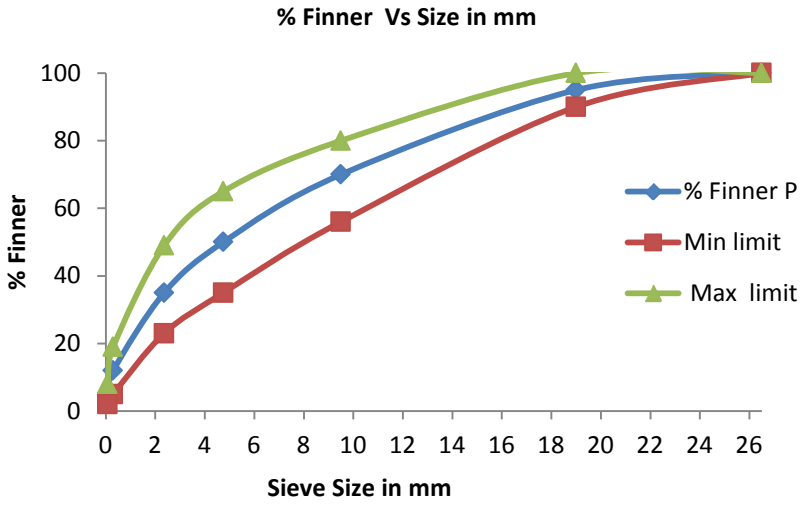


Figure-1 Gradation Curve for the aggregates

Table-2 Physical Properties of Aggregates

Conventional (0% Plastic) and Plastic coated Aggregate(PCA)

Description of tests	Percentage of Plastic/ additive by weight of OBC					Specifications IRC:111-2009
	0%	5% (PCA)	7%(PCA)	9%(PCA)	11% (PCA)	
Aggregate Crushing strength value	18.57%	14.01%	12.52%	10.38%	11.4%	Max 30 %
Impact value	16.88%	14.87%	12.16%	10.42%	11.5%	Max 24%
Specific gravity value	2.65	2.70	2.72	2.78	2.82	2.5-3.0
Los Angeles Abrasion value	15.74%	14.18%	12%	9.3%	10.2%	Max 30%
Flakiness Index value	14.46%	13.46%	12.48%	12.48%	12.48%	Max 35 %
Elongation index value	10.5%	11.5%	11.5%	11.5%	11.5%	Max 35 %
Water absorption value	0.64%	Nil	Nil	Nil	Nil	Max 2%
Soundness value	8%	Nil	Nil	Nil	Nil	Max 12 %
Stripping value	5%	Nil	Nil	Nil	Nil	Max 5%

B- Bitumen

The bitumen used in the experiment was 80/100 grade and was tested in the laboratory for basic tests, penetration, ductility, softening point, specific gravity and viscosity Results are shown in table-3 below.

Table-3 Properties of penetration grade bitumen

Properties Tested	Test Method	Results	Remarks
Penetration(100 gram, 5 seconds at 25°C) ($1/10^{th}$ of mm)	IS 1203-1978	90	Satisfactory
Softening point, °C(Ring and Ball Apparatus)	IS 1205-1978	55.8	Satisfactory
Ductility at 27°C(5cm/ minute pull) cm	IS 1208-1978	88	Satisfactory
Specific gravity at 27°C	IS 1202-1978	1.02	Satisfactory
Viscosity in seconds	IS 1206-1978	51	Satisfactory
Flash Point	IS 1209-1981	270°C	Satisfactory
Fire Point	IS 1209-1981	282°C	Satisfactory
Grade of binder	80/100		

C-Mineral Filler

Filler shall consists of finally divided mineral such as rock dust or hydrated lime or cement. The use of hydrated lime is encouraged because of its very good anti-stripping and anti-oxidant properties. The gradation of filler is shown in table below.

Table-4 Grading requirement of Mineral filler

IS sieve size in mm	Cumulative % by weight of total aggregate passing
0.6	100
0.3	95-100
0.075	85-100

D-Modifiers (Plastic waste)

The processed waste plastic bags(LDPE) from the garbage of local area in the shredded form was used as additive. The shredded waste plastic was cut into pieces of uniform size passing through 2.36 mm IS sieve and retained on 600 μ IS sieve. Thickness between 10 μ to 30 μ.

Table-5 Properties of Waste Plastic

Property	Values
Size (Range)	2.36 mm - 600 μ

Density (gm/cc)	0.95
Melting Temperature in °C	130- 160

3.1- Marshall Mix design

In the present research the aggregate mix was heated to 140- 175°C and the shredded plastic waste was added to the aggregate in specified percentage. The waste plastic initially coats the heated aggregates. In next stage heated bitumen at specified temperature was added to the aggregates and the plastic coated aggregate was mixed with hot bitumen for 15 seconds and in result modified bituminous concrete mix was obtained. Addition of bitumen was made by weight of mix and plastic were added in different percentages to the mix by weight of bitumen.

3.2 Design of Bituminous Concrete mix

In this study the addition of bitumen was made by weight of mix and plastic were added in different percentages (5%, 7%, 9%, 11%, 13% and 15%) to the mix by weight of bitumen. The Marshall samples were prepared of both conventional and plastic modified bituminous mixes and the prescribed tests were performed. When the Marshall specimen are kept in water bath at 60 ±1°C for 24 ± 1 hours called conditioned specimen and the specimen kept thermostatically controlled water bath maintained at 60 ±1°C for 30 to 40 minutes are called unconditioned specimen. Plots of bitumen content against volumetric properties were drawn for all mixes. OBC for each mix was calculated by taking the average of bitumen content values corresponding to maximum stability, maximum density and 4% air voids.

4- RESULTS AND DISCUSSIONS

In this research the properties of Bituminous Concrete (BC) mixes Grading-1 Indian Roads Congress (IRC:111-2009) using waste plastics by dry process was evaluated and comparison was made with conventional mix (0% plastic) properties.

4.1 Determination of Optimum Bitumen Content (OBC)

A number of 15 samples each of approximately 1200 gm in weight were prepared using five different bitumen contents (from 4 - 6% with 0.5 % incremental) in order to obtain the optimum bitumen content (OBC). Curves were plotted between % bitumen versus parameters like Stability value, Bulk Density, Air voids content and Flow value. The optimum bitumen content (OBC) was calculated by taking the average of the following three values.

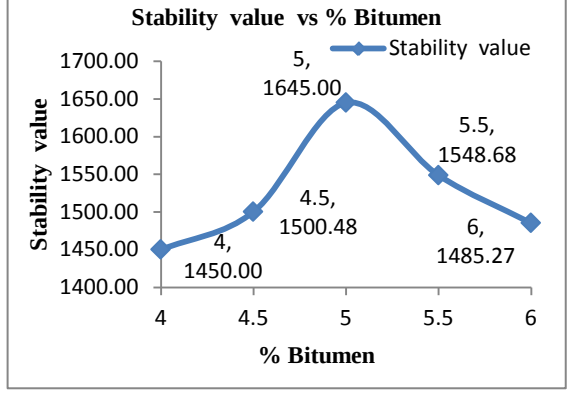


Figure-2 - % Bitumen Vs. Stability value

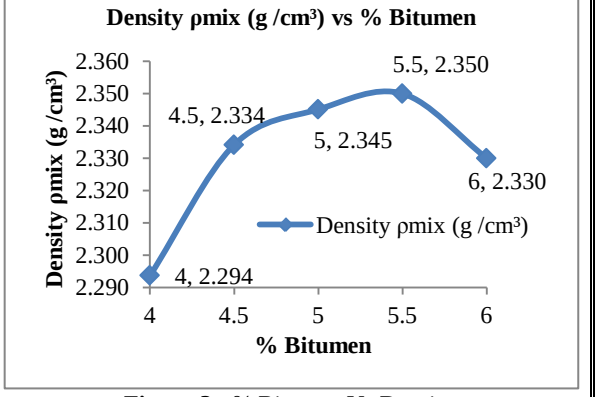


Figure-3 - % Bitumen Vs.Density

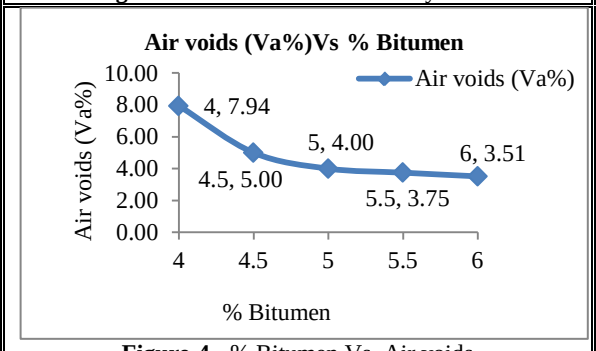


Figure-4 - % Bitumen Vs. Air voids

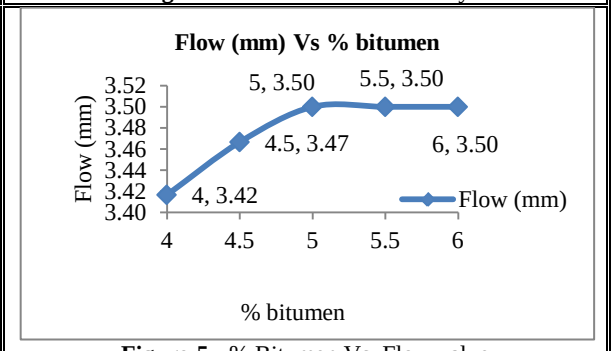


Figure-5 - % Bitumen Vs. Flow value

- Bitumen content at highest stability value = 5 %
- Bitumen content at highest value of bulk density = 5.5%

- Bitumen content at 4% air voids value = 5%

Optimum Bitumen Content (OBC) = $\frac{5+5.5+5}{3}$

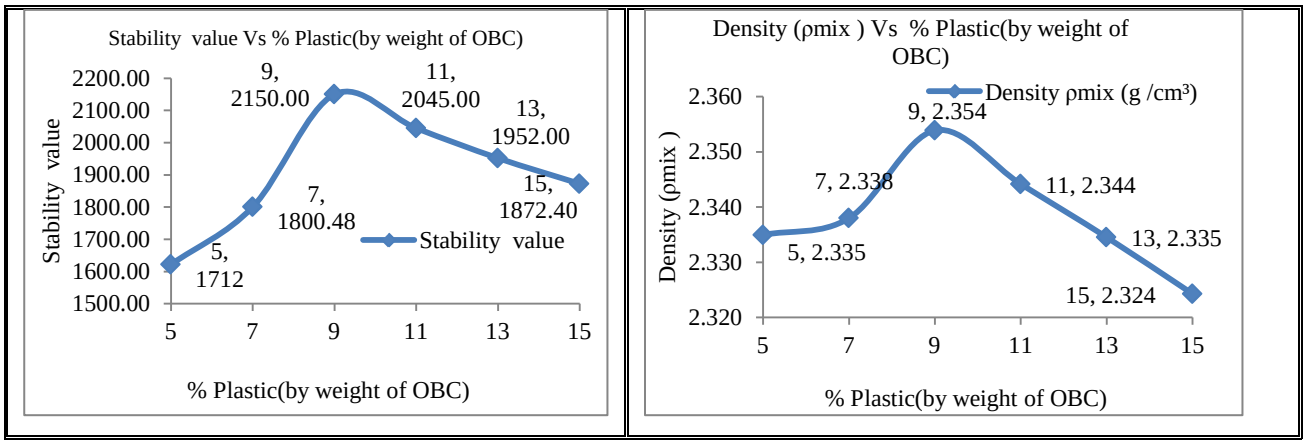
= 5.17 %

Table - 6 Properties of Bituminous Concrete mix using waste plastic additive by weight of Optimum bitumen content(OBC)

Sn	Property of bituminous mix evaluated from tests	Waste plastic expressed as % by weight of Optimum Bitumen Content (OBC) i.e. 5.17%						
		0%	5%	7%	9%	11%	13%	15%
1	Marshall Stability (Kg)	1625	1712.00	1800.48	2150	2045	1952	1872.40
2	Flow value , mm	3.50	3.20	3.50	4.0	4.25	4.0	3.50
3	Marshall Quotient, Kg/ mm	464	535	528	537	481	488	535
4	Theoretical max density (Gt) (g/cm³)	2.45	2.44	2.43	2.44	2.43	2.41	2.41
5	Bulk density(Gb) (g/cm³)	2.36	2.335	2.338	2.354	2.344	2.335	2.324
6	Volume of air voids(Va)%	3.67	4.48	3.68	3.59	3.54	3.11	3.43

4.2 Determination of Optimum Plastic Content (by weight of OBC)

Determination of Optimum plastic content(OPC) was obtained by taking the average of Plastic content at highest stability, Plastic content at highest value of bulk density and Plastic content value at Va % air voids within allowed range(4%). It is obtained by plotting these curves of the Marshal Test results. Curves were plotted below. The optimum plastic content (OPC) was calculated by taking the average of the following three values.



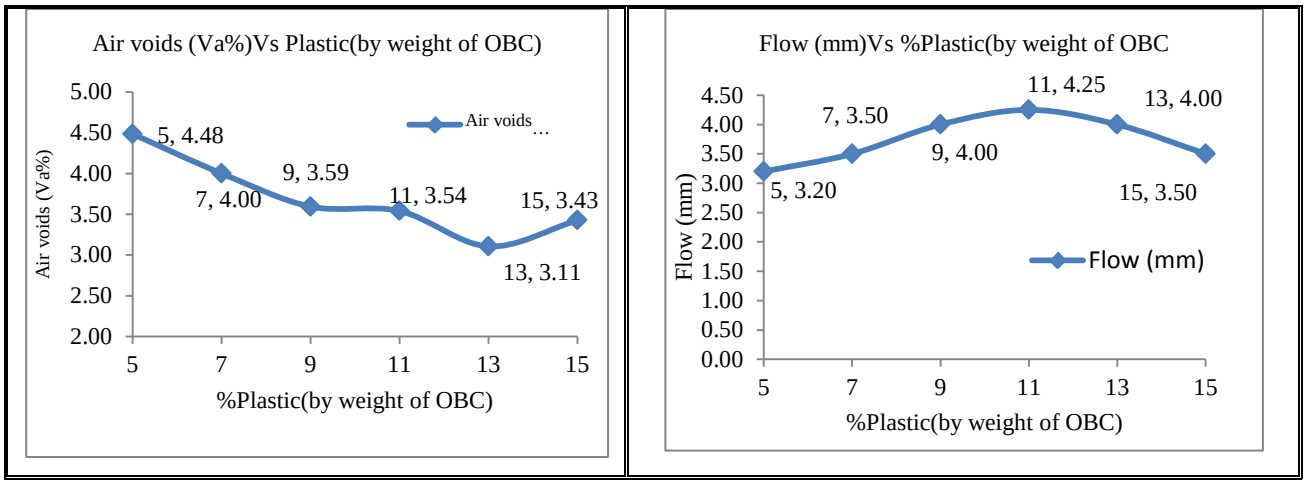


Figure-6 - % Plastic Vs. Stability , Density, Air voids& Flow values values

- Plastic content at highest stability value = 9 %
- Plastic content at highest value of bulk density = 9%
- Plastic content value at Va % air voids with in allowed range = 5.5%

Optimum Plastic Content (OPC) = $\frac{9+9+7}{3}$

= 8.33%

Table - 7 Comparison of WPB modified asphalt mix and conventional mix properties

Property	Conventional asphalt mix	(8.33%) Plastic modified asphalt mix (By weight of OBC)	Variation %	Specifications As per	
				IRC:111-2009	IRC:SP:98 -2013
Optimum Bitumen content	5.17%	5.17%	-	Min. 5.2%	
Stability (kg)	1625	2020	+ 24.30	Min 900	Min 1200
Flow (mm)	3.50	3.90	+ 2.09	2.5 - 4.0	2.0 - 4.0
Stiffness (kg/mm)	464	482.05	+ 20.01	250 - 500	250 - 500
Void in Mineral aggregate (VMA)%	15.56	16.10	+ 3.4	15.0	16.0
Air voids (Va)%	3.67	3.75	+2.1	3 - 5	3 - 5
VFB%(Void filled with bi-tumen)	76.41	76.70	+0.37	65 - 75	65 - 75
Bulk density (gm/cm³)	2.36	2.34	- 0.84	-	-

It is clearly shown that asphalt mix modified with (8.33 % OPC by weight of OBC) have higher stability value. Higher Stability value of modified asphalt mix indicates that it can withstand with heavier traffic loads as compared to conventional asphalt mix. Stiffness compared to the conventional asphalt mix is more but it is with in the specified range , other properties of modified mix are still within the allowed range of the specifications. Slight increase of flow and VMA% in modified asphalt mix is exhibited. Bulk density of modified mix is slightly reduced this is due to low specific gravity of waste plastic. Other properties are with in the specified range for the two asphalt mixes.

Melted waste plastic provides a rougher surface texture for aggregate particles in modified asphalt mix that would enhance asphalt mix engineering properties due to improved adhesion between bitumen and plastic coated aggregates(PCA). Improved stability would positively influence the fatigue and rutting resistance of the modified asphalt mix leading to more durable asphalt pavement.

5- ECONOMY OF THE PROCESS

Based on the experimental evidences and the amount of raw materials used for 20 mm thick Bituminous Premix carpet (top layer of the bituminous road) with type-A seal coat. One Kilometer long road having width 3.75 meter (3750 Sqm.) the following calculation has been arrived –

Table - 8 Economy of Process

Material needed	Quantity of bitumen with conventional aggregate	Quantity of bitumen with Plastics coated aggregate (PCA)
80/100 Bitumen	9150Kg	8388 Kg
Plastic waste	Nil	762 Kg
Cost	Rs 549000	(Bitumen)Rs 503280+ (Plastic) Rs 7620 = Rs 510900
Cost Reduced (per KM) for Single lane road having width 3.75 Meter	Nil	Rs 38100

Cost of Bitumen Approx: Rs 60 per Kg and Waste Plastic : Rs. 10 per Kg (Cost of waste plastic Rs 6 per Kg and Cost of processing Rs 4 per Kg)

Savings of bitumen = 762 Kg

Use of Plastics waste – 762 Kg

Cost Reduced (per KM) for single lane road having width 3.75 Meter = Rs 38100

There is no maintenance cost for a minimum period of five years. Hence the process is cheap and eco- friendly.

5.1- REDUCTION IN CONSUMPTION OF BITUMEN

Optimum plastic content(OPC) = 8.33% of Optimum bitumen content(OBC)

= 8.33x 5.17/100

=0.43% of weight of Mix

Therefore reduction in consumption of bitumen in the mix comes out to 0.43% by weight of the Mix.

Conclusion

Based on the study and experimental data for waste plastic modified bituminous concrete mix compared with conventional bituminous concrete mix, the following conclusions can be drawn-

The results showed that waste plastic can be conveniently used as a modifier for bituminous concrete mix as it gets coated over the aggregates of the mixture and reduces porosity, absorption of moisture and improves binding property of the mix. The Optimum Bitumen Content (OBC) was found to be 5.17% by weight of aggregates and the Optimum Plastic Content (OPC) to be added as a modifier of bituminous concrete mix was found to be 8.33% weight of Optimum Bitumen Content (OBC) of bituminous concrete mix. Bituminous concrete mix modified with waste plastic coated aggregates showed higher (approximately 24%) Marshall stability and higher flow value as compared to conventional bituminous concrete mix. Marshall stability value increases with plastic content up to 9% and thereafter decreases. Thus the use of higher percentage of waste plastic/ polythene is not preferable. The stiffness of the modified mix was increased but it was with in specified norms. The volumetric and Marshall properties of conventional and modified bituminous concrete mixes were almost satisfying both MORTH and IRC:111-2009 specifications. This shows that plastic waste blended bituminous concrete mix is better one and is more suitable for flexible pavement construction.

Plastic waste modified mix is strip resistant even when subjected to worst moisture condition.Physical properties like Aggregate Impact Value, Los Angles Abrasion Value , Water Absorption Value and soundness etc. of plastic coated aggregates (PCA) were improved appreciably as compared to conventional aggregates (without plastic coating) due to thin plastic coating over aggregates. Plastic waste modified mix consumes less bitumen (OPC= 8.33% by weight of OBC) so it is economical. Hence cost of construction of plastic roads will be less and no maintenance cost for a minimum period of five years. The process is cheap and eco-friendly. One can also effectively use the relatively weak stone aggregates by making them comparatively stronger by providing suitable plastic coating over it by Dry Method.

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