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USE OF PLASTIC WASTES IN FLEXIBLE PAVEMENT CONSTRUCTION

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Abstract - *The road connectivity of India is the 2nd largest network of the world. The road transport systems gives many benefits to people, communities and the local economy. Nowadays due to increase in population, urbanization, development activites and living standard quantum of plastics wastes occurs in our environment. Parallel, shortage of natural and conventional constructional materials exists. These pollutants are non-biodegradable, toxic, and unfriendly to the environment, making plastics a major source of worry for the ecosystem and future generations. Waste disposal, particularly waste plastics, has become a major issue, with waste plastics being burned for apparent disposal, causing contamination. The use of waste plastics in bituminous mixes has shown that they improve the mix's characteristics while also addressing disposal issues. Using a shredding machine, clean plastic trash is chopped into a size that passes through a 2-3mm sieve. When the aggregate mix is heated, the plastic coats the aggregate efficiently. The resultant mixture of plastic garbage and hot bitumen is used for road construction. The use of state-of-the-art technology would not only increase road construction but also prolong road life and help to improve the environment. In the hot and humid climate of India, plastic roads would benefit, where temperatures frequently surpass 50 °C and heavy rainfall causes havoc, leaving the majority of roads with big potholes. The processes of manufacturing and use of sustainable materials up to their disposal or reuse/recycling may be accomplished to protect the environment, do not cause an ecological imbalance nor do they have any effect on human health. In my research, I conducted a comprehensive investigation of the technique for utilizing plastic trash in bituminous mixes and provided the results of different aggregate and bitumen tests.*

KEYWORDS: *Plastic Waste, Bitumen, Aggregates, Plastic Roads, Flexible Pavement.*

1. INTRODUCTION

Plastic is a material which contains one or more organic high-molecular weight polymers, is solid in its ultimate state and may sometimes be shaped by its flux during production or processing into finished items. The plastics are durable and slowly decline; the chemical joints that make plastic so robust are also resistant to the natural processes of disintegration. Recent study suggests that plastics may persist on Earth for up to 4500 years. As the global population expands, the demand for food and other needs increases and the amount of garbage that is generated by each household every day. Plastic, in different forms, makes up almost 5% of municipal solid trash, which is by nature dangerous. Empty plastic bags and other kinds of materials of plastic packaging that overrun roadways and drains are a common occurrence, both in urban and rural areas. It creates water stagnation and associated sanitary problems due to its biodegradability. 'To tackle this problem, experiments have been carried out to determine if this waste plastic can be used successfully. The use of plastic wastes enhances the abrasion and diaphragm strength of the flexible pavement and allows splitting tensile strength values to be achieved that are within the necessary limit even if the plastic waste content by weight of the mix exceeds 30 percent. If the bitumen– modifier mix is not provided consistent mixing time and temperature, modified bitumen will not work properly in situ, which will lead to early failures. All polymers with a trademark thus have a proposed mixing time, temperature and modification content. All of this should be kept in mind while constructing and building roadways out of plastic trash. For India, a plastic road would be a godsend. Plastic roads are the most advantageous in hot and humid climates since they are both durable and environmentally beneficial. This will also aid in the removal of all types of plastic trash from the environment. In this case, an alternative application for plastic trash will need to be developed. In recent years, Severals deficiencies in Waste Management System in India.

- No storage of waste at source.
- Partial segregation of recyclable waste.
- Lack of primary collection of waste at the doorstep.
- Irregular street sweeping.
- Inappropriate system of secondary storage of waste
- Irregular transport of waste in open vehicles.
- No treatment of waste.
- Inappropriate disposal of waste at open dumping grounds.
- No separate collection of bio-degradable and non-bio-degradable wastes.

The trash disposal is a major issue since plastics are non-bio-degradable, have a long life and cause environmental contamination; the old method of plastic waste management is still being used in this country. Physical management of plastic trash and recyclables is just one thing that cannot meet the need of sustainability and integrated solutions on its own: Land filling, incineration and recycling not only prove unscientific but also worsen the environmental load.'' The social cost multiplies instead of reduction. At this juncture India needs an innovative technology which has manifold impacts.

1.1 Objective

Hoped the nation, like India, would develop robust, resilient and environmentally sound highways in the near future that will relieve the planet from all kinds of plastic trash. The basic goal is to use waste plastics constructively to help society, however the major aims of present project activity include —

- Coating the aggregates with waste materials Plastics.
- To verify the characteristics of the specimen of bituminous mix.
- To control the characteristics of the bituminous mixing specimen by covering materials made from plastic waste
- Compare the characteristics of the bituminous mixing sample with the aggregate properties.

The deterioration of India's road network is due to increased vehicle traffic and poor maintenance due to lack of money. Many ways have been proven to enhance this procedure, such as getting enough funds for appropriate maintenance, efficient and methods, including land filling, incineration, and recycling, have been tested in India for the safer disposal of plastic trash. Better road design, using high-quality materials and using efficient and modern construction procedures.

2. LITREATURE REVIEW

White and Whitney (1992) said that waste generated during the extraction, manufacturing and consuming process represents another cycle of production and consumption, often referred to as the waste economy. Percentages of plastics are used for single-use disposable applications, such as packaging, agricultural films and consumer products, for long-term infrastructure, including pipes, wire coatings and structural materials, of 20 to 25percent and for long-term consumer applications, such as electronic goods, furniture, vehicles, etc. Post-consumer European Union (EU) trash production amounted to 24,6 million tons in 2007. It was also stated that in 2007, the global output of polymers, comprising thermo, thermo, plastic, adhesives, and coatings, was estimated at 260 million metric tons (MMT), per year.

Environmental Science (Solid waste Pollution) (2010) has mentioned that the resistance against enforcing restrictions on the use of plastic carry bags and others can be attributed to different arguments namely technical (in terms with the growth of the plastic industry, the product has become an integral part of society and that any ban on it was not consistent with technological progress), convenience (self-explanatory and revolves around the increased use of plastic products in daily life), economics (even if other alternatives were to be tried out, the costs would outweigh the benefits, thereby malcing plastics the more affordable alternative), employment (which is now subject to debate with sharply varying figures being cited by the plastic industry and government authorities) and environment (managers of environment argue that there is no fool proof deposit mechanism) respectively.

Further, the guidelines deal with the specification and use of waste plastic in wearing course using dry process, their advantages, application, manufacturing, transportation, storages, and quality testing requirements . In a study presented in the 28th International Baltic Road Conference entitled, Durability of Polymer Modified Binders in Asphalt Pavements, polymer modification was found to improve regular asphalt roads significantly. Improvements such as higher road strain recovery, lower stiffness at low temperatures, and high resistance to rutting and cracking were determined by the study's authors, leading them to conclude that polymer modified binders demonstrate better rheological properties than unmodified pen bitumen, even after several years in asphalt pavements.

3. MATERIALS SELECTION & METHODOLOGY

The materials used are as follows

- Aggregates
- Bitumen as Binder
- Mineral Filler
- Plastic waste material such as LDPE

3.1 Aggregates

Aggregates were selected with adequate strength, hardness, toughness, specific gravity and shape and the standard aggregate and plastic coated (PCA) aggregate test was carried out. The aggregate gradation that meets IRC 111-2009 classification criteria has been chosen, with a specific gravity between 2.6 and 2.9.

3.2 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.

3.3 Mineral Fillers

Filler consists of mineral ultimately separated such as rock dust or hydrated lime or cement. The usage of hydrated lime has extremely excellent anti-stripping and anti-oxidant effects. The hot mix of asphalt is added to improve the density and the strength of the mixture. The filler gradation is given in the table below.

TABLE -1: Gradation of mineral filler

IS sieve size in mm	Cumulative % by weight of total aggregate passing
0.6	100
0.3	93-100
0.075	85-100

3.4 Modifiers Plastics Wastes

The processed waste plastic bags (LDPE) from the garbage of local area in the shredded form were 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 -2: Properties of modifiers of plastic

Property	Values
Size (Range)	2.36 mm - 600µ
Density (gm/cc)	0.97
Melting Temp. in °C	125- 165

Thermal gravimetric study showed that the temperature range of 130 - 180°C does not change gas. In addition, the soft polymers have a binding effect.

In order to evaluate the properties and performance of waste plastics, the required testing of aggregates and bitumen is done. The tests are as follows:

A. Tests on Aggregates:

The aggregate was coated with waste plastic material by heating the aggregate up to 165 °C. The shredded plastic was sprayed over the heated aggregate. "The plastics gets placed and coated over the aggregates.'' The following tests are conducted to know the characteristics of the Plastic Coated Aggregates (PCA):

I. **Crushing test:** Strength of aggregates is determined with the help of this test. APPARATUS USED: Steel cylinder of dia. 15.2cm with a base plate and a plunger, compression testing machine, tamping rod and sieves.

Procedure:

- Dry Aggregates passes through 12.5mm IS sieve and retained on 10mm sieve.
- Fill that aggregates in cylinder in three equal layers
- Each layer is tamped by 25 times by tamping road.
- Load is applied through plunger at the rate of 5 tons per minute.
- After that sieving is done for crushed aggregates through 2.36 mm IS sieve.
- And value is calculated as —

ACV = (W2 / W1) x 100

Where,

W1= Total weight of aggregates

W2= Weight of aggregates passing through 2.36mm IS sieve

Satisfactory value of ACV is up to 35%.

II. **Soundness Test:** To study the resistance against weathering action soundness test of aggregates is performed through accelerated weathering test.

Procedure:

- Aggregates are to be soaked in MgSO4 or Na2SO4 solution for 1 day.
- Heat the aggregates at 105°C – 110°C and make one cycle of immersion and drying
- Repeated this procedure up to 10 cycle and noted the average loss of aggregates in weight.
- Should not exceed 12% Na2SO4 for18% MgSO4.

III. **Specific Gravity Test:** It is defined as mass of solid to that mass of an equal volume of distilled water at a specified temperature. It's measure of quality of strength materials and the value of specific aggregates lies between 2.6 to 2.9 through pycnometer method.

IV. **Impact Test:** Used to evaluate the toughness of aggregate or resistance of aggregate under the cyclic loading condition.

APPARATUS USED: Jet impact testing machine consists of metal base and a cylindrical steel cup having internal dia 10.2 cm and depth 5 cm , a metal hammer of weight 13.5 – 14.0 kg.

Procedure:

- Dry Aggregates passes through 12.5mm IS sieve and retained on 10mm sieve.
- Fill that aggregates in cylinder in three equal layers
- Each layers is tamped by 25 times by tamping road.
- Sample is transferred to Jet impact testing machine and hammer falls freely 15 times blow from the height of 38cm in each blow.
- Crushed aggregates is sieved through 2.36mm IS sieve and sample is weighted.
- Aggregates impact value (AIV) is calculated as —

AIV = (W2 / W1) x 100, not exceed 35%.

Where,

W1= Total weight of aggregates

W2= Weight of aggregates passing through 2.36mm IS sieve

Fig 3.1: Aggregate Impact Test

V. **Abrasion Test:** Used to carry out hardness property of aggregates. Abrasion include rubbing between aggregates and steel whereas attrition include rubbing between aggregates to aggregates.

Different types of abrasion tests are

- Los Angeles Abrasion Test
- Dorry Abrasion Test
- Dovel Abrasion Test

While in this experiment we use Los Angeles Abrasion Test.

VI. **Water Absorption Test:** Obtained percent water absorbed in term of weight of aggregates with the help of oven dried method.

VII. **Shaped Test:** Shaped is determined by percentage of flaky and elongated particles and by its angularity number.

- Flakiness Index: Percentage by weight of aggregate particles whose least dimension is less than 0.6 of their mean dimension.
- Elongation Index: Percentage by weight of aggregate particles whose greatest dimension is greater than 1.8 of their mean dimension.

B. Tests on Bitumen:

By mixing the plastic with bitumen the brittleness losses and elastic nature enhances. The plastic wastes are melted and mixed with bitumen in appropriate ratio.
Dry process and wet process are the two processes used for bitumen mix in flexible pavement.

I. **Penetration Test:** Hardness of bitumen is obtained by penetration test. It is measure by standard vertical blunt point needle and expressed as 1/10th mm. Grade of bitumen is decided with the help of penetration test.

If the grade of bitumen is 80/100 it means the penetration value is 8-10 mm for that bitumen.

Procedure:

- Take a sample of bitumen as per required.
- Applied 100g load vertically on bitumen for 5 seconds at 27°C with the help of Blunt point needle.
- Read the penetration value of needle.

II. **Ductility Test:** Bitumen should be sufficiently ductile and stretched without failure and it's measure of adhesiveness and elasticity of bitumen . It is measure in term of Distance in cm with the help of briquette apparatus of standard size of 10 x 10 mm at 27 °C. Minimum ductility value as per ISI is 75 cm.

III. **Softening Point Test:** Softening point is a temperature at which substance attains a particular degree of softening at a specified condition. RING AND BALL assembly apparatus is used.

Procedure:

- A Steel ball is placed over a sample of bitumen
- Then liquid is heated at the rate of 5°C per minute
- Temperature at which steel ball passes through bitumen layer and touched bottom layer is softening point.

Softening point of various bitumen genrally lies between 35-70°C.

IV. **Viscosity Test:** It's measure of resistance of flow and simply inverse of fluidity Viscosity of liquid bitumen is measure by efflux visconnectors .Time taken in seconds by 50ml of bitumen to flow from container through a specified orifice at standard condition is viscosity.

V. **Specific gravity Test:** It's measure with the help of picnometer method and its value for pure bitumen is ranging from 0.97 to 1.02 at 27°C temperature.

4. RESULT AND CONCLUSION

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. Results of various tests performed on conventional and plastic coated aggregates (PCA) are shown in table 3 below.

TABLE -3: Physical Properties of Aggregates

Description of tests	Percentage of Plastic by weight		
	0%	6% (PCA)	Specification IRC:111-2009
Aggregate Crushing strength value	16.5%	12%	Max 30 %
Impact value	15.86%	11.5%	Max 24%
Specific gravity value	2.68	2.72	2.5-3.0
Los Angeles Abrasion value	15.68%	10.8%	Max 30%
Flakiness Index value	13.58%	13%	Max 35 %
Elongation index value	10.5%	15.8%	Max 35 %
Water absorption value	0.63%	0.61%	Max 2%
Soundness value	11%	7%	Max 12 %
Stripping value	4.8%	Nil	Max 5%

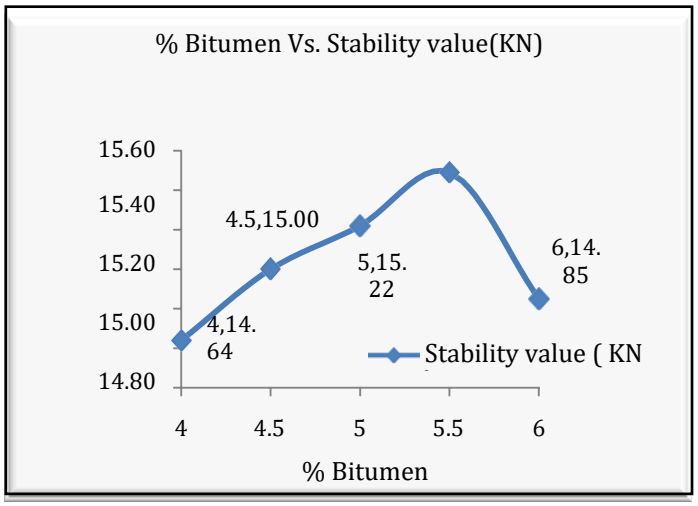

CHART -1: Bitumen Vs Stability

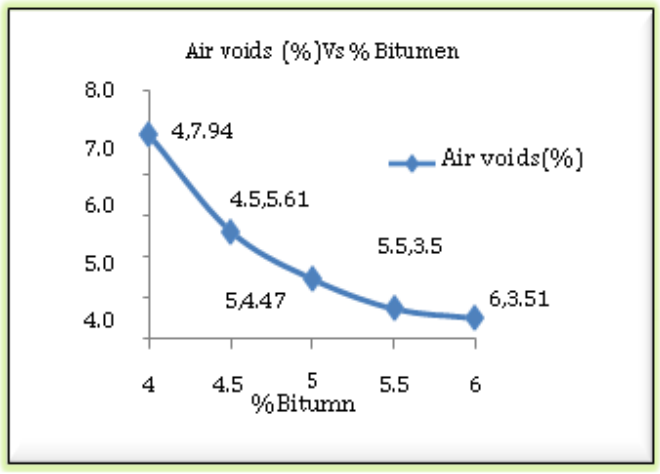

CHART -2: Air voids Vs Bitumen

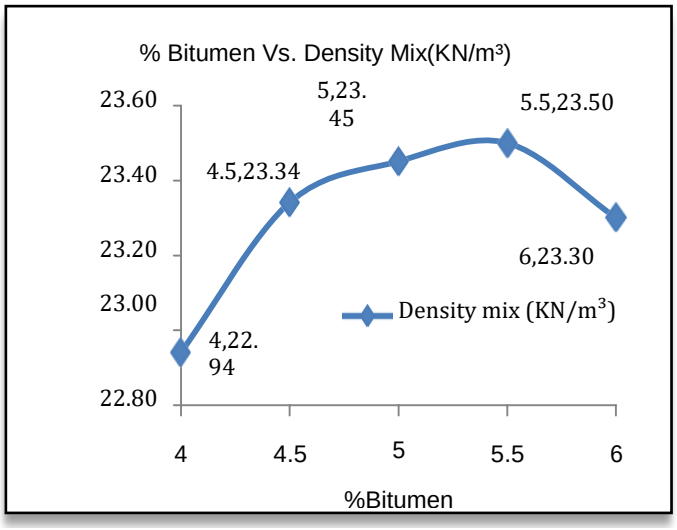

CHART-3: Bitumen Vs Density mix.

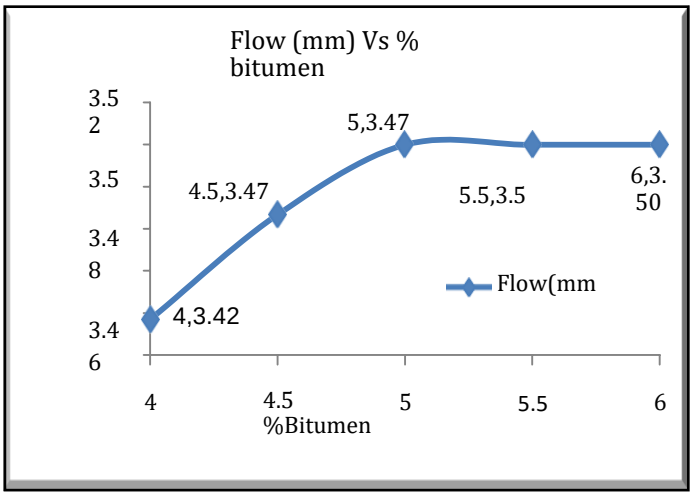

CHART-4: Flow Vs Bitumen

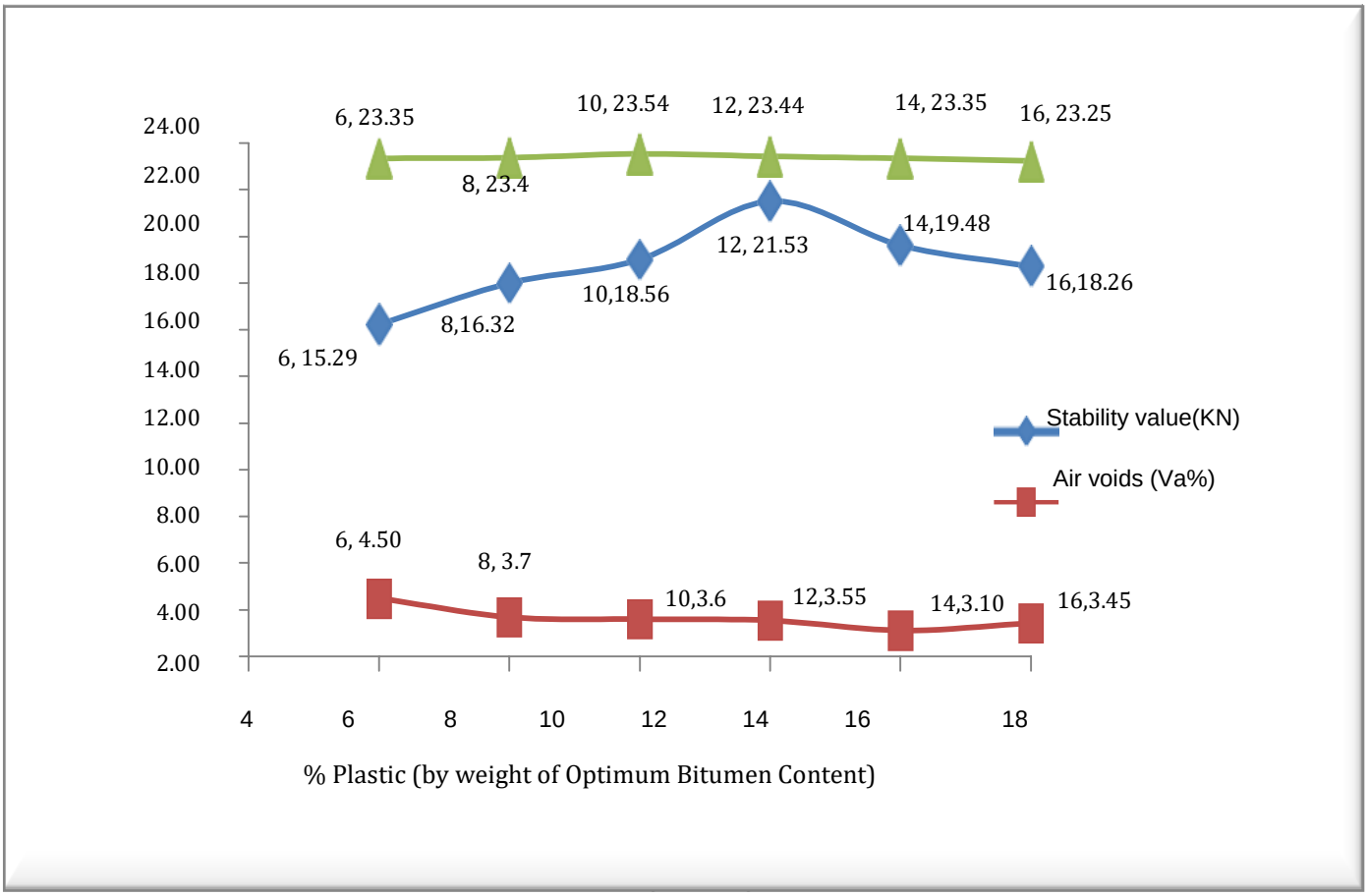

TABLE -4: Properties of penetration grade bitumen

Properties Tested	Test Method	Results	Remarks
Penetration(100 gram, 5 seconds at 25°C) (1/10th of mm)	IS 1203-1978	93	Satisfactory
Softening point, °C(Ring and Ball Apparatus)	IS 1205-1978	56.8	Satisfactory
Ductility at 27°C(5cm/ minute pull) cm	IS 1208-1978	95.3	Satisfactory
Specific gravity at 27°C	IS 1202-1978	1.02	Satisfactory
Viscosity in seconds	IS 1206-1978	50	Satisfactory
Flash Point	IS 1209-1981	203°C	Satisfactory
Fire Point	IS 1209-1981	212°C	Satisfactory
Grade of binder	80/100		

TABLE -5: Comparisons of Waste Plastics Modified Asphalt Mix and Conventional Mix

S/N.	Properties of Bituminous Mixes Evaluated From Test	Waste Plastics Expressed as % Weight of Optimum Bitumen Content (OBC)						
		0%	6%	8%	10%	12%	14%	16%
1	Marshall Stability (KN)	15.29	16.32	18.56	19.00	21.53	19.48	18.26
2	Flow Values (mm)	3.25	3.45	3.56	4.27	4.00	4.36	3.50
3	Marshall Quotient (KN/mm)	4.00	5.07	5.12	4.56	5.06	5.00	5.34
4	Theoretical Density (KN/m3)	24.8	24.4	23.4	24.4	24.1	24.2	24.1

5	Bulk Density (KN/m3)	23.6	23.35	23.4	23.54	23.44	23.35	23.25
6	Volume of Air Voids (Va %)	3.75	4.5	3.7	3.6	3.55	3.12	3.45

TABLE -6: Comparisons of Waste Plastics Modified Asphalt Mix and Conventional Mix

Properties	**Conventional Mixes**	**(9.73%) OPC Modified Asphalt Mix (By Weight of OBC)**	**Limit As Per IRC:SP:98-2013**
Bulk Density (KN/m3)	23.6	23.4	-
OBC %	5.43	5.43	5.2 Min.
Marshall Stability Value (KN)	15.34	18.50	Min. 12
Flow Values (mm)	3.82	3.90	2-4
Marshall Stiffness (KN/mm)	4.01	4.81	2.5-5
Voids in Mineral Aggregates (VMA)%	15.56	16.1	16
Voids Filled With Bitumen (VFB)%	76.26	77.50	65-75
Air Voids (Va)%	3.7	3.6	3-5

CONCLUSIONS

The following conclusions can be drawn:

- The optimum bitumen content (OBC) by weight of aggregates was determined to be 5.43%. Optimum plastic content (OPC) applied as a bituminous concrete mix modifier has been shown to weigh 9,73 percent of the bituminous concrete mix's optimum bitumen content (OBC).
- The modified bituminous concrete mix with plastic-coated waste aggregates exhibited a greater (about 21%) Marshall stability and higher flow value compared to standard bituminous concrete mixtures.
- Marshall The stability value rises to 12% with plastic content and thereafter declines. Higher utilization of plastic/polythene waste is thus not desirable.
- This indicates that the mixture of bituminous concrete mixed plastic waste is better and better suited to flexible pavement construction.
- The modified mixture of plastic waste is strip resistant even in the worst moisture condition.
- The adjusted mix of plastic waste uses less bitumen (OPC = 9.73 percent by weight of the OBC) and is thus cost efficient. ''Consequently, the cost of building plastic roads will be cheaper."
- Results have shown that waste As a modifier for bituminous concrete mixes plastic may easily be employed because it is covered over the particles and decreases porosity, moisture absorption and enhances the binding property of the mixture.

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