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A Study on the Plastic Waste Treatment Methods for Road Construction

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Abstract: Plastic found in different forms is almost 5% amongst municipal solid waste, which can prove to be toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and another type of plastic packing material littering the roads as well as drains. Due to its biodegradability, it creates stagnation of water and associated hygiene problems. In order to contain this problem experiments have been carried out whether this waste plastic can be reused productively in the construction of roads. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Therefore, it is proposed that we may use waste plastic in the construction of Rural Roads.

Keywords: Plastic Waste, Road Construction, Biodegradability.

I. INTRODUCTION

Polymer modified bitumen is currently emerging as one of the most important construction material for flexible bituminous pavements. Usage of plastic waste in the construction of flexible pavement is gradually gaining importance because of the various reasons. The polymer assisted bitumen shows properties for the construction of roads & plastics waste, otherwise is considered as a pollution menace but can find its use in this process and it can help in solving the problem of polluting the environment because most of the plastic wastes are polymers.

Use of disposed of plastic waste (especially plastic bags) is the most vital issue that needs to be coped up. The various studies on the binding property and thermal behavior of the molten plastics promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction.

The use of plastic materials such as carry bags, cups, etc. is increasing rapidly. The consumption of plastics gradually increased from 4000 tons/annum in the year 1990 to 4 million tons/annum in the year 2001 and it is expected to arise to 8 million tons/annum during the year 2009. Nearly 50-60% of the plastics are consumed for the purpose of packaging.

Once the used plastic materials are discarded, they do not undergo biological decomposition. Hence, they are used for land filling or incineration. Both are not at all eco-friendly processes as they pollute both land and air. Any method that can use this plastic waste satisfying the purpose of construction is always welcomed.

II. OBJECTIVES

Basic intention behind this research is to utilize the waste plastic efficiently in a constructive way such that it proves to be useful to the society.

- Plastic Waste Shredding
- Preparing it suitable for the purpose of its use along with Bitumen for construction of Flexible Pavements.

III. PREPARATION OF PLASTIC WASTE MATERIAL

A. Plastic Waste Scenario

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 4 million tons/annum and it is expected to rise 8 million tons/annum during the year 2010. Nearly 50 to 60% of the total plastics are consumed for packing.

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

C. Details of Shredding Machine

a) Agglomerator: For shredding of poly-ethylene "Agglomerator" is used. In this process, a thin plastic waste carries bags cut in small pieces with the help of fix and rotator blades this whole process required 20-25 minutes for shredding.

b) Specification of Agglomerator

- Vessels size 600mm dia. X 900mm ht.
- Rotatory knives-4.
- Fix knives -6.
- Ph induction A.C. motor-30hpmake Crompton greaves ATK 222 Model SE/A2 30 HP.
- Length of blade-200mm.

D. Plastic Waste Blending Materials

➢ **Preparation of Blend**

Polyethylene carry bags are cut into pieces using a shredding machine. They are 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 temperature around 170-1800C. The mixture stirred well using mechanical stirrer for about 20-30 minutes. Polymer-bitumen mixtures of different compositions can be prepared and used for carrying out various tests.

➢ **Characterization of Blend**

At the time of laboratory testing for characterization of bitumen the following Test is adopted:

Separation Test (IRC-SP: 53-1999)

Samples of different composition can be subjected to the separation test. Homogeneity can be obtained approximately up to 1.5% blend. Beyond this composition, the variation of softening point is much higher for the top and bottom layer of the test samples showing that there is a separation of polymer from bitumen on standing.

Classification of Plastic Waste

a) Polyethylene

LDPE (Low Density Poly-Ethylene): Low density poly-ethylene this plastic waste available in the form of carrying bags generally in stores these plastic bags are very thin and also easily available.

HDPE (High Density Poly-Ethylene): Generally High-density poly-ethylene type of plastic waste is available in the form of carrying bags and easily available in the market.

b) Polypropylene: This plastic may be available in the form of carrying bags or solid plastic it depends upon the use and need of the industries. It is available in the form of plastic bottles and mat sheets etc.

IV. METHODOLOGY

Various Mix Design Approaches

There is a number of approaches rather than a unified approach towards bituminous mix design, and each has its specific merits and demerits. Table 1 summarizes some important bituminous design approaches as follows:

- Recipe Method.
- Analytical Method.

- Performance Related Approach.
- Mix Design Method.
- Empirical Mix Design Method.
- Volumetric Method.Bituminous Mix Design is selected on the performance based approaches. There is a time to the time change in the requirement of a good Bituminous Mix Design. Table 1 gives an introduction of how the mix design requirements have changed a lot from past some above-mentioned requirements are conflicting to each other. For, example, more is the bitumen content, more is fatigue life. The increase of bitumen content, the rutting resistance may decrease. In case of deficiency of air voids, the stability fails and bleeding chances will increase. The only method to increase bitumen content keeping sufficient air voids is by maximizing VMA and a suitable gradation us designed.

Table 1: Requirements of Bituminous Mix Design

PAST	PRESNT
Stability Durability Economy	Stiffness Permanent Deformation Fatigue Temperature Susceptibility Low temperature Cracking Moisture Susceptibility Freeze Thaw Permeability Economical Environment Friendly Workability Economy

Coated Bituminous Mix

Waste plastic generation is increasing day to day. The most common polymers are polyethylene, polystyrene and polypropylene sow an adhesive nature in the molten state. The plastic coated aggregate bitumen mix form better materials for the construction of flexible pavements and also shows higher stable values of Marshall Stability Values and suitable Marshall Coefficient. Hence most appropriate and easy method of plastic wastes is its use in flexible pavements. Polymer coated aggregates show a better result than the polymer modified bitumen under many aspects. The binding property and thermal behavior studies promoted a study on the bitumen-plastic waste blend and the properties to find the suitability of the blend for construction of roads. Various procedures that can be carried out for using plastic waste for the construction of roads:

- **Mixing Procedure at Hot Mix Plant**

Step I: Plastics waste like bags, bottles made out of PE and PP cut into a size between 2.36 mm and 4.75mm using shredding machine. Care should be taken that PVC waste should be eliminated before it proceeds into next process.

Step II: The aggregate mix is heated to 1650C and then it is transferred to mixing chamber. Similarly, the bitumen is to be heated up to a maximum of 1600C. This is done so as to obtain a good binding and to prevent weak bonding. During this process monitoring the temperature is very important.

Step III: At the mixing chamber, the shredded plastics waste is added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 seconds. It gives an oily coated look to the aggregate.

Step IV: The plastics waste coated aggregate is mixed with hot bitumen. Then this final resulted mix is used for laying roads. The road laying temperature is between 110oC 120OC. The roller used should be of is 8-ton capacity

- **Mixing by Mini Hot Mix Plant**

Step I: Plastic waste made out of PE, PP, and PS cut into a size between 2.36mm and 4.75mm using shredding machine.

Step II: Similarly, the bitumen is to be heated to a maximum of 1600C to have good binding and to prevent weak bonding. (Monitoring the temperature is very important)

Step III: At the mixing chamber the shredded plastic waste is to be added to the hot aggregate. It gets coated uniformly over the aggregate within 30 Secs, giving an oily look Plastic coated aggregate is obtained.

Step IV: Hot bitumen is then added over the plastic-coated aggregate and the resulting mix is used for road construction. The road laying temperature is from 1100C to 1200C. The roller used is 8-ton capacity.

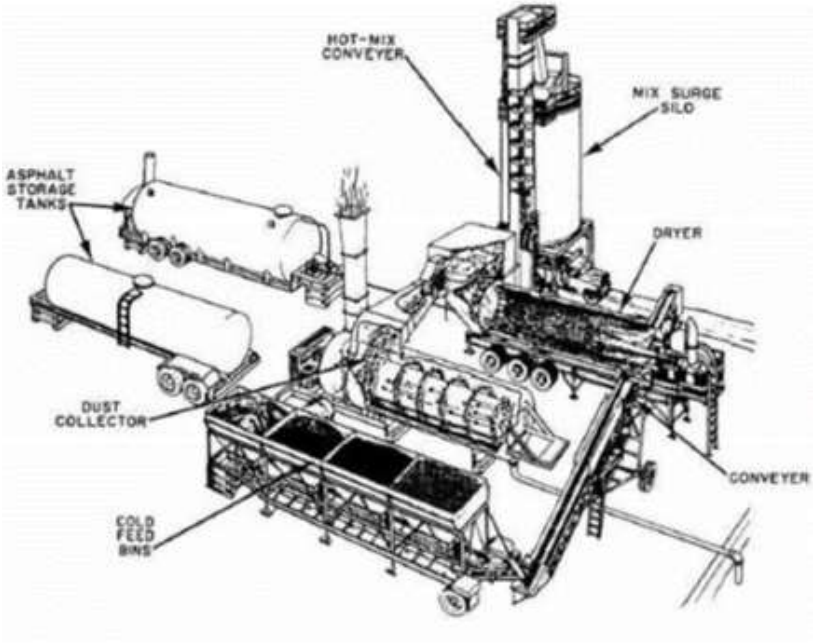

Figure 1: Hot Mix Plant

- **Mixing by Central Mixing Plant (CMP)**

The dry process is also carried out using central mixing plant. The shredded plastic is mixed with the aggregate in the conveyor belt. This is transferred to the hot cylinder. There aggregate is coated firstly with plastic and later on with the bitumen. The mixer so prepared is then loaded into the dipper lorry and transported for road laying. CMP gives a better control of temperature and better mixing of this material thus helping to have a uniform coating.

V. DATA COLLECTION AND ITS ANALYSIS

Investigation of plastic waste materials aggregates and bitumen requires various field test and lab tests. This section tells us about the physical requirement of aggregates and bitumen, the properties of plastic and preparation plastic waste materials for shredding on aggregates.

A. **Aggregates**

The aggregates are bound together either by cement or by bituminous materials. Sometimes, the rock dust itself when mixed with water forms a slurry which behaves as a binding medium.

The aggregates may be classified into:

1. Natural Aggregates: Further classified into:
   - Coarse aggregates consisting of crushed rock aggregates.
   - Gravels and fine aggregates or sand.

2. Artificial Aggregates

Stone aggregate used for road work should be hard, tough, durable and hydrophobic for the bituminous surface. Gravel should be well graded (6.4mm to 38mm) and should have a fineness modulus of not less than 5.75. Sand should be sharp, well graded, clean of all silts, clay and organic matter.

The quantity of aggregates used in the first coat of surface dressing should be 0.15 m^3 per 10 m^2 area of 12mm nominal size. On the other hand, the quantity of aggregate used in the second coat of surface dressing should be 0.15 m^3 per 10 m^2 areas and of 10mm nominal size.

Table 2: Physical Requirements of Coarse Aggregates

Sr. No	Test	Permissible Values
1.	Abrasion Test a. Using Los Angeles machine (max) b. Aggregates impact test (max)	 35% 30%
2.	Stripping test (max)	25%
3.	Water absorption (expect in the case of slag) max	1%
4.	Soundness test: Loss with Sodium Sulphate 5 cycles (in case of slag only) max	12%
5.	Weight unit or Bulk density (in slag only)	1120 per m3

Aggregate: Aggregate of 20mm, 10 mm, Stone Dust and Lime as Filler.

B. Bitumen

Bitumen is most commonly used a binder in pavements constructions. According to the definition given by the American Society of Testing Materials bitumen has been defined as "Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide."

When petroleum crude is refined in a refinery, they are separated by fractional distillation in the order of decreasing volatility. On distillation of the residual bituminous residue, straight-run bitumen is obtained. This bitumen is known as penetration grade bitumen or steam refined petroleum bitumen. In most parts of India 80/100 and 180/200 grade bitumen is used. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed. The grade of basic bitumen is altered either by controlled refining or by mixing with diesel oil or other oils.

For single dressings on WBM base course, the quantity of bitumen needed ranges from 17 to 195 kg per 10 m^2 areas and 10 to 12 kg per 10 m^2 area in case of renewal of black top surfacing. For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg per 10 m^2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000 liters are used to transport bulk bitumen. As per PMC, the bitumen content in a mix should be 4% of weight by total mix for B.M.

The paving bitumen available in India is classified into two categories:

- Paving bitumen from Assam petroleum denoted as A-type and designated as grades A35, A90, etc.
- Paving bitumen from other sources denoted as S-type and designated as grades S35, S90, etc.

Types of Bitumen used in India:

- **Road Tar**: This bituminous material is obtained by the destructive distillation of organic matters such as wood, coal shale etc. In the process of destructive distillation, the carbonation results in the production of crude tar which is further refined by the distillation process.
- **Cut-back bitumen**: The asphaltic bitumen is very often mixed with comparatively volatile solvents to improve the workability of the material. The solvent gets evaporated leaving behind the particles together. This cutback bitumen is classified into slow, medium and rapid curing depending upon the type of solvent used.
- **Emulsions:** An emulsion is a mixture of normally two immiscible liquids. Asphalt gets broken up into minute globules in water in the presence of the emulsifiers. It improves the workability of bitumen or asphalt. As a result of emulsification, asphalt is available at normal temperature in the liquid form.

Bitumen: 60/70, 80/100 Grade Bitumen.

C. Plastic Material

Plastics are usually classified by their chemical structure of the polymer's backbone and side chains. Some important groups in these classifications are:

- Acrylics.
- Polyesters.
- Polyurethanes.
- Halogenated Plastics.
- Silicones.

There are two types of Plastics:

- Thermoplastics: They are the plastics that do not undergo chemical change in their composition when heated and can be moulded again and again. Examples include polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polytetrafluoroethylene (PTFE).
- Thermosetting: In the thermosetting process, a chemical reaction occurs that is irreversible. The vulcanization of rubber is a thermosetting process. Before heating with sulfur, the polyisoprene is a tacky, slightly runny material, but after vulcanization, the product is rigid and non-tacky.

VI. RESULTS AND DISCUSSIONS

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

A. 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. Its range should be less than 10%.

B. Aggregate Crushing Value

The aggregate with lower crushing value indicates 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- that plastic-coated aggregate shows the lower crushing value and which can withstand to traffic load more efficiently than the plain aggregates. The results show that the aggregates are within the range according to ISS. Its range should be less than 30-35%.

C. 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 compared 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 is increased increasing its strength. Its range should be within 2.5-3.0%.

D. Stripping Value

Stripping value gives the effects of moisture upon the adhesion of the bituminous film to the surface particles of the aggregate. The plastic coating to aggregates gives the nil value of stripping. It indicates that the aggregates are more suitable for bituminous road construction than plain aggregates. The results obtained from the control specimen are within the range of the IRC standards whereas coating of the aggregate reduces the affinity of the aggregate towards the water. Its range should be less than 25%.

E. Water Absorption

The aggregate is chosen also on the basis of the moisture absorption capacity. The aggregate, when coated with plastics, improved its quality with respect to moisture absorption. The coating of plastic decreases the moisture absorption and helps to improve the quality of the aggregate and its performance in the flexible pavement. The results show that the moisture absorption of the aggregate is within the range of IRC specifications which reduced to nil due to coating. Its range should be less than 10%.

F. Los Angeles Abrasion Value

The repeated movement of the vehicle will produce some wear and tear over the surface of the pavement. This test gives that wear and tear in percentage. Under this study, the percentage of wear and tear values of plastic coated aggregate is found to be in decreasing order with respect to the percentage of plastics. When the Los Angeles abrasion value of plain aggregate value is compared with the plastic-coated aggregates the values are less for coated aggregates. The results obtained are within the range hence can be used for the construction. Its range should be less than 35%.

G. Results of Tests on Aggregates

Table 3: 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

H. Results of Tests on Bitumen

Table 4: 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	48.25^0 C	$45\text{-}60^0$C
Flash Point Test	280^0C	>650-175^0C
Fire Point Test	302^0C	

VII. CONCLUSION

The plastic coating on aggregates is used for the better performance of roads. 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.

1. 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.

2. 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. The low aggregate crushing value indicates strong aggregates, as the crushed fraction is low.

3. 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.

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

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

6. 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.

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