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Use of Plastic Waste Along with Bitumen in Construction of Flexible Pavements

Rajneesh Kumar
Lucknow Institute of Technology

Maaz Allah Khan
Dr Shakuntala Misra National Rehabilitation University, Lucknow

Abstract:- **The most common sources of waste products are from the growth of various industries and increase in population. The type of waste which is most hazardous to the nature is the Plastic Waste. The main concern about the plastic waste is its non-biodegradability. According to recent researches plastic waste when mixed with bitumen gives it desired mechanical properties. Bitumen is primarily used in the construction of flexible pavements and when it is mixed with plastic waste it improves the water resistivity, capacity and stability of the mix. Laboratory test have proved that it can be used as a binder material in the bitumen mix for construction of flexible pavements. Plastic waste percentage in bitumen has to be checked. Marshal stability test is the most commonly used method to relate with field conditions. The samples used are made up with bitumen concrete commonly called Asphalt in which plastic content and bitumen are kept at various percentages in each of the sample. The tests have shown positive results and gives a scope of further practical implementations. The basic objective of the test is to find out the optimum percentage of plastic waste which can overrule the bitumen content in the mix for the design of flexible pavements. The basic intention behind this study is to replace bitumen by a conventional and non-biodegradable material which is the plastic waste.**

Keywords: Flexible Pavements, Plastic Waste, Bitumen

INTRODUCTION

Disposal of various types of waste in different place from various sources has been a matter of concern from a long time. These materials cause different types of pollution to the environment. The plastic material is non-biodegradable making them inexhaustible in nature and start to collect at an exponential rate. The cost of extraction of good quality material has increased due to the effect of existence of these materials in our environment. Exponential increase in the population and the expansion of industries has resulted into the considerable disposal of the plastic wastes. The plastics that can be used are polyethene, polypropylene, polyamide, polyoxymethylene, polytetrafluoroethylene and polyethylene terephthalate. Thermoplastics have got properties by the help of which it expands and softens when heated and regains its normal shape at the room temperature. Thermoplastics can easily be moulded or shaped into various products such as milk jugs, floor coverings, credit cards and carpet fibers. These types of plastics are known as phenolic, melamine, unsaturated polymers, epoxy resin, silicone and polyurethane. Recent studies tell that plastics remain unchanged for more than 4500 years depending upon the rise in food demands and essentials. Also, the increasing population results into more waste generated from the households daily. According to surveys plastic constitutes 5% in municipal wastes which is toxic. Plastic bags are the most commonly found sources of plastic wastes, we come to see littering of plastics result into the choking of drains etc. this results into stagnation of water and results to ill hygiene of the locality.The only way to overcome these problems is to reuse the plastic effectively. During recent researches it has been inferred that waste plastic when mixed up with hot aggregate will form a fine plastic coat over it and when mixed up with the binder gives it a higher strength, high water resistance and enhanced performance over a period of time. Waste materials usually constitutes of plastic bags, laminated pouches, disposable cups etc. The use of plastic with bitumen in construction of flexible pavements not only increases its smoothness and life but helps in reducing the cost of project and also contributes into an ecofriendly environment. The plastic roads are found to give better results and performance compared to the conventional bitumen roads. The use of bitumen was reduced to 10% on introduction of plastic waste as filler materials. It also enhances the strength and performance of the roads. Plastic filling increases the melting point of the bitumen. The plastic waste mixing improves the abrasion and slip resistance of flexible pavements allows us to calculate splitting tensile strength when the plastic mixed is beyond 30% of the weight of the mix. There are specified mixing time, mixing temperature and modifier content for all polymers, in case of not following the specifications it may lead to premature failures. Plastic roads can prove to be a next step to developing India. This will also facilitate in overcoming the plastic disposal problems in the World.

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.
Main objectives of this project work are:

- To coat the aggregates with waste plastic materials.
- Check the properties of various bitumen mixes.
- Check the properties of bitumen mix after the coating the waste plastic materials.
- Compare the bituminous mixes with plastic waste coating and conventional ones.

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PROPOSED METHODOLOGY

The properties of aggregate and bitumen are investigated by following tests:

A. Test for aggregate

- Sieve Analysis of Aggregates
- Specific Gravity & Water Absorption Test [IS: 2386]
- Aggregate Impact Value Test [IS:2386(Part4)1963]
- Aggregate Crushing Value Test [IS:2386 (part 4) 1963]
- Flakiness & Elongation Index [is:2386 (Part1) 1963]

B. Test for Bitumen

- Penetration Test [IS 1203-1978]
- Softening Point Test [IS :1205-1978]
- Ductility Test[IS:105-1978]
- Viscosity Test
- Flash Point and Fire Point

C. Preparation of Design Mix

1) Plain Bituminous Mix

Bitumen is a black, oily, viscous material which is an organic byproduct of decomposed organic material and is naturally originated. Also known as asphalt or tar, bitumen was usually mixed with various materials throughout prehistory and all over the world for use as a sealant, adhesive, building mortar, incense, and decorative application on pots, buildings, or human skin. The material was widely used in waterproofing canoes and other ways of water transport.

A well-prepared design of bituminous mix is considered to result in a mix which is satisfactorily

- Strong
- Durable
- Resistive to fatigue and permanent deformation
- Environment friendly
- Economical etc

D. Selection of Mix Constituents

Blinder and aggregates are the two main constituents of bituminous mix. The section discusses some of the issues involved in selection of binder and aggregates.

1) Binder

Selection of binders is based on Simple Tests and other site-specific requirements. The test could depend on the different types of binder viz. penetration grade, emulsion, cutback, modified binder etc... For most of the test, the testing conditions are pre-fixed in the specifications. Temperature is a vital parameter which has a direct influence on the modulus and the aging of the binder. Superpave specifications [Superpave 1997, 2001] suggest that these acceptability test should be carried out at relative field temperature, not in the lab specified temperatures. This consideration is important because binders extracted from various sources may show same physical properties at particular temperatures, but the performance may vary drastically at various temperatures. In Superpave specifications, only the acceptable testing values that are suggested, and not the test temperatures. The standard temperatures are extracted out of most prevalent maximum and minimum temperatures at the field at pre- mentioned probability level. Rolling Thin Film Test (RTFO), Rotational Viscometer, Pressurized Aging Vessel(PAV), Direct Tension Tester, Bending Beam Rheometer, Dynamic Shear Rheometer are the recommended tests in Super pave Binder Selections [Super pave 1997, 2001].

2) Aggregate

To judge the properties of aggregates there are number of tests recommended in the specifications like strength, toughness, angularity, clay content, hardness, durability, shape factors, adhesion to binders etc. Angularity is a property that ensures shear strength due to aggregate interlocking, and limiting flakiness assures that aggregates will not break during Compaction and Handling.

E. Various Mix Design Approaches:

There are number of approaches rather than a unified approach towards bituminous mix design, and each has its specific merits and demerits. Steps summarize 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 are selected on the performance based approaches. There is a time to time change in requirement of a good Bituminous Mix Design.

F. 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:

1) Mixing Procedure at Hot Mix Plant:

1) 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.

2) 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.

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During this process monitoring the temperature is very important.

3) 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.

4) 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

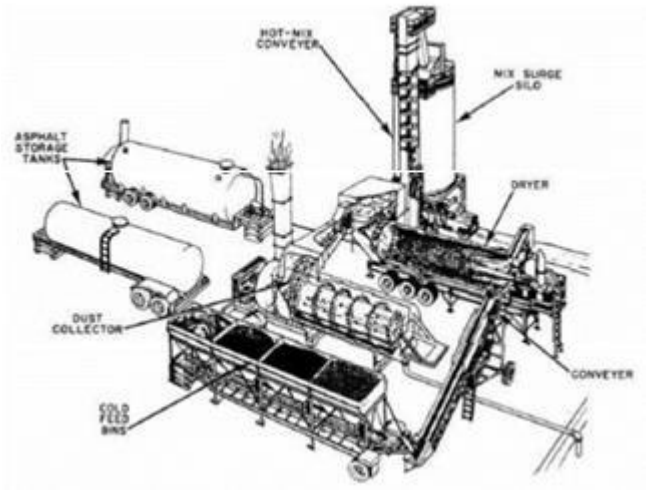
2) Mixing by Mini Hot Mix Plant:

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

2) 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)

3) 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.

4) 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 between 1100C to 1200C. The roller used is 8-ton capacity.



G. 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 into the hot cylinder. There aggregate is coated firstly with plastic and later on with the bitumen. The mixer so prepared is then loaded in 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.

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 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 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 first coat of surface dressing should be 0.15 m3 per 10 m2 area of 12mm nominal size. On the other hand, the quantity of aggregate used in second coat of surface dressing should be 0.15 m3 per 10 m2 areas and of 10mm nominal size.

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

Physical Requirements of Coarse Aggregates

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

B. Bitumen

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Bitumen is most commonly used 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, quantity of bitumen needed ranges from 17 to 195 kg per 10 m2 areas and 10 to 12 kg per 10 m2 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 m2 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 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 polytetra fluoro ethylene (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.

D. Classification of Plastic Waste:

1) Polyethylene:

- LDPE (Low Density Poly-Ethylene): Low density poly-ethylene this plastic waste available in the form of carry 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 carry bags and easily available in the market.

2) Polypropylene:

This plastic may be available in the form of carry bags or solid plastic it's depend upon the use and need of the industries. It is available in the form of plastic bottles and mat sheets etc

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 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- 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. 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

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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. Its range should be within 2.5-3.0%.

D. Stripping Value

Stripping value gives the effects of moisture upon the adhesion of 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 of the control specimen are within the range of the IRC standards whereas coating of the aggregate reduces the affinity of the aggregate towards 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 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*:**

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

Observation Table for Aggregates Test Results

H. Results of 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	48.250 C	45-600C
Flash Point Test	2800C	>650-175C
Fire Point Test	302	>650-175C

CONCLUSION

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. 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.

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