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USE OF PLASTIC WASTE IN FLEXIBLE PAVEMENTS

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ABSTRACT

Disposal of waste materials including waste plastic bags has become a serious problem and waste plastics are burnt for apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as will help to improve the environment. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. In my research work I have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen.

KEYWORDS: Plastic Waste, Bitumen, Aggregates, Plastic Roads

1. 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.

According to recent studies, plastics can stay unchanged for as long as 4500 years on earth with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid waste, which is toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and other 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. 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. Waste plastic such as carry bags, disposable cups and laminated pouches like chips, pan masala, aluminum foil and packaging material used for biscuits, chocolates, milk and grocery items can be used for surfacing roads.

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. 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 missing can be done in more better and easier way. According to Dr. R. Vasudevan, Dean ECA and Professor, Department of Chemistry, Thiagarajar College of Engineering, Madurai, 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.

The uses of plastic waste helps in substantially improving the abrasion and slip resistance of flexible pavement and also allows to obtain values of splitting tensile strength satisfied the specified limits while plastic waste content is

beyond 30% by weight of mix. If the consistent mixing time and mixing temperature are not provided for bitumen–modifier mix, modified bitumen cannot exhibit good performance in situ, thus premature failures will occur. Therefore, there are certain recommended mixing time, mixing temperature and modifier content for all the polymers with a trademark. This all should be taken in mind while missing and laying of roads is to be done using plastic waste. Plastic road would be a boon for India. In hot and extremely humid climate durable and eco-friendly plastic roads are of greatest advantages. This will also help in reliving the earth from all type of plastic waste.

- **PROBLEM STATEMENT**

The debate on the use and abuse of plastics vis-à-vis environmental protection can go on, without yielding results until practical steps are initiated at the grassroots level by everyone who is in a position to do something about it. The plastic wastes could be used in road construction and the field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems. The present write-up highlights the developments in using plastics waste to make plastic roads. The rapid rate of urbanization and development has led to increasing plastic waste generation. As plastic is non biodegradable in nature, it remains in environment for several years and disposing plastic wastes at landfill are unsafe since toxic chemicals leach out into the soil, and under-ground water and pollute the water bodies. Due to littering habits, inadequate waste management system / infrastructure, plastic waste disposal continue to be a major problem for the civic authorities, especially in the urban areas. As stated above, plastic disposal is one of the major problems for developing countries like India, at a same time India needs a large network of roads for its smooth economic and social development. Scarcity of bitumen needs a deep thinking to ensure fast road construction.

2. OBJECTIVES

Basic intention is to efficiently utilize the waste plastic in constructive way so that it can be beneficial to society however main objectives of current project work are:

- To coat the aggregates with the waste plastic materials
- To check the properties of bituminous mix specimen
- To check the properties of bituminous mix specimen due to coating of waste plastic materials

To compare the properties of bituminous mix specimen with the properties of coated aggregates

3. PROPOSED METHODOLOGY

Following Tests were conducted to investigate the properties of the aggregate as well as bitumen.

3.1 TESTS FOR AGGREGATE

3.1.1 Sieve Analysis of Aggregates
3.1.2 Specific Gravity & Water Absorption Test [IS: 2386 (Part 3) 1963]
3.1.3 Aggregate Impact Value Test [IS: 2386 (part 4) 1963]
3.1.4 Aggregate Crushing Value [IS: 2386 (Part 4) 1963]
3.1.5 Flakiness & Elongation Index Test [is: 2386 (part 1) 1963]

3.2 TESTS FOR BITUMEN

3.2.1 Penetration Test [Is: 1203-1978]
3.2.2 Softening Point Test [Is: 1205-1978]
3.2.3 Ductility Test [IS: 1208-1978]
3.2.4 Viscosity Test:
3.2.5 Flash Point and Fire Point

4. PREPARATION OF DESIGN MIX

4.1 Plain Bituminous Mix:

Bitumen is a black, oily,viscous material that is a naturally-occurring organic byproduct of decomposed organic materials. Also known as asphalt or tar, bitumen was mixed with other materials throughout prehistory and throughout the world for use as a sealant, adhesive, building mortar, incense, and decorative application on pots, buildings, or human skin. The material was also useful in waterproofing canoes and other water transport.

A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) Environment friendly (v) economical and so on.

4.1.1 Selection of Mix Constituents

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

Binder

Generally binders are selected based on some simple tests and other site-specific requirements. These tests could be different depending of the type of binder viz. penetration grade, cutback, emulsion, modified binder etc. For most of these tests, the test conditions are pre-fixed in the specifications. Temperature is an important parameter which affects the modulus as well as the aging of binder. Superpave specifications [Superpave 1997, 2001] suggest that these acceptability tests are to be carried out at the prevalent field temperatures, not in a laboratory specified temperature. This is an important consideration because, binder from two different sources may show same physical properties at a particular temperature, but their performances may vary drastically at other temperatures. In Superpave specifications, therefore, only the acceptable test values are recommended, and not the test temperatures. The temperature values are found out from the most prevalent maximum and minimum temperatures at the field at a given probability level. Rolling Thin Film Oven Test (RTFO), Pressurized Aging Vessel (PAV), Dynamic Shear Rheometer, Rotational Viscometer, Bending Beam Rheometer, Direct Tension Tester are some of the tests recommended in Superpave binder selection [Superpave 1997, 2001].

Aggregate

Number of tests is recommended in the specifications to judge the properties of the aggregates, e.g. strength, hardness, toughness, durability, angularity, shape factors, clay content, adhesion to binder etc. Angularity ensures adequate shear strength due to aggregate interlocking, and limiting flakiness ensures that aggregates will not break during compaction and handling.

Theoretically, it is difficult [Senov 1987, Aberg 1996] to predict the aggregate volumetric parameters, even the resultant void ratio, when the gradation curve is known. The Fuller's experimental study for minimum void distribution [Fuller and Thompson 1907] still forms the basis of these exercises. Strategic Highway Research Program (SHRP), USA formed a 14 member Expert Task Group for evolution of appropriate aggregate gradation to be used for Superpave. The group, after several rounds of discussions decided to use 0.45 power Fuller's gradation as the reference gradation, with certain restricted zones and control points. The restricted zone and control points are incorporated in order to ensure certain proportion of fines for (i) proper interlocking of aggregates (ii) to avoid the fall in shear strength of mix due to excess of fines and (iii) to maintain requisite Voids in Mineral Aggregates (VMA).

Various Mix Design Approaches:

There is no unified approach towards bituminous mix design, rather there are a number of approaches, and each has some merits are demerits. Table-1 summarizes [RILEM 17 1998] some of the important bituminous mix design approaches are as follows:

- Mix design method
- Recipe method
- Empirical mix design method
- Analytical method
- Volumetric method
- Performance related approach
- Performance based
- Approach

The recent emphasis on bituminous mix design is on performance related and performance based approaches. The requirement of a good mix design has changed from time to time. Table-1 gives some idea of how the mix design requirements have changed from past to present.

Table 1: Requirements of Bituminous Mix Design

Past	Present
Stability Durability Economy	Stiffness Permanent deformation Fatigue Temperature susceptibility Low temperature cracking Moisture susceptibility Freeze-thaw Permeability Economical Environment friendly Workability Economy

Some of the above requirements are sometimes mutually conflicting. For, example, the higher is the bitumen content; the better is the fatigue life, provided all the other parameters are kept unchanged. But with the increase of bitumen

content, the resistance to rutting may decrease. Increase in bitumen content not accompanied by adequate amount of air voids will result in the fall of stability of the mix, the chances of bleeding will increase. The only way to increase bitumen content keeping sufficient air voids (VA) is by maximizing VMA and suitably gradation can be designed. Heavy duty bituminous pavements are composed of bituminous binder course and wearing course, for example, Dense Bituminous Macadam (DBM) and BC [MORT&H 2001], as per Indian specification. Same grades of bitumen are generally used for construction of these layers. Generally same grades of bitumen are used for construction of these layers. Stiffer grade of bitumen has higher value of stiffness, and it causes lesser stains to the pavement layers and also it is expected to show lesser rutting. On the other hand, higher fatigue life as observed for bituminous mixes with softer grade of bitumen [Das 1998], indicates greater longevity of the pavement against fracture. It can be shown computationally [Das and Pandey 2000, Das 2004] that if a pavement is constructed with softer grade of bitumen at the lower layer, and harder grade at the top layer, the pavement is expected to last longer, than a pavement constructed with same grades for both the layers – this technique is known as rich-bottom pavement construction [Harvey et. al. 1997, Monismith 2001] in other countries.

4.2 Coated Bituminous Mix:

The generation of waste plastics is increasing day by day. The major polymers are namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods of easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects.The studies on the thermal behavior and binding property promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction. Following procedure can be adopted for using plastic in road construction:

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.

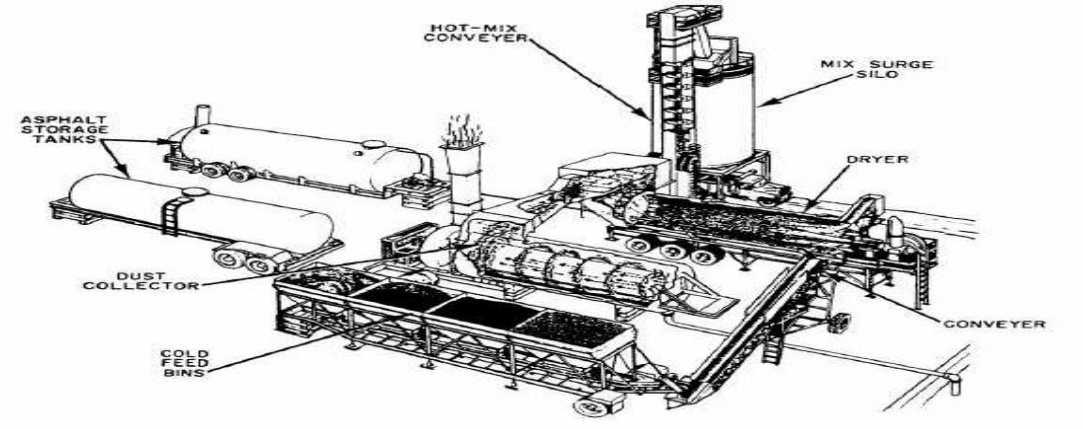


Figure 1: Hot Mix Plant

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

MIXING BY CENTRAL MIXING PLANT (CMP)

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

5. DATA COLLECTION AND ITS ANALYSIS

5.1 General

Investigation of plastic waste materials aggregates and bitumen requires various field test and lab tests as explain in previous chapter. This chapter presents material which is collected from site given below for plastic coated aggregates in detail. The present chapter divided into three main sections. First section presents the physical requirement of aggregates and bitumen. Second section presents the properties of plastic. Third section presents the preparation plastic waste materials for shredding on aggregates.

- **Site Details:**

This site is located in Maske Wasti in Pune district. It is a flexible pavement laid at Rehabilitation of roads in old Sanghavi area under Model Ward Develpoment Program Ward No.91 (Jaymala Nagar and Priyadarshini Nagar). The experimental investigations were done at the Central Lab of Ajwani Infrastructure Pvt. Ltd., Maske Wasti at Rawet.

5.2 AGGREGATES

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

The aggregates may be classified into natural and artificial aggregates. The natural aggregates again are classified as coarse aggregates consisting of crushed rock aggregates or gravels and fine aggregates or sand. The blast furnace slag obtained as by-product from blast furnaces is the one extensively used as road construction material.

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 m^3 per 10 m^2 area of 12mm nominal size. On the other hand, the quantity of aggregate used in 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 m^3

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

5.3 BITUMEN

Bitumen is used as binders in pavements constructions. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per 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." Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter.

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.

The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed. In most parts of India 80/100 and 180/200 grade bitumen is used. Heavier grade cut backs, rapid setting emulsions or heavier grade tars may also be used. 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 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 litres 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.

Important properties of bitumen are:

- Viscosity of bitumen should be adequate at the time of mixing and compaction. It is achieved by heating prior to mixing and by use of cutbacks and emulsion.
- In presence of water bitumen should not strip off from aggregate.
- Bitumen should be durable in all seasons.
- It should not become too soft during summers and develop cracks during winters.
- **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.

5.4 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 the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can also be classified by the chemical process used in their synthesis, such as condensation, polyaddition, and cross-linking.

There are two types of plastics: thermoplastics and thermosetting polymers. Thermoplastics 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 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.

The properties of plastics are defined chiefly by the organic chemistry of the polymer. such as hardness, density, and resistance to heat, organic solvents, oxidation, and ionizing radiation.

5.4.1 Types of Plastics

- PET, polyethylene terephthalate
- HDPE, high-density polyethylene
- PVC, polyvinyl chloride
- LDPE, low-density polyethylene
- PP, polypropylene
- PS, polystyrene

Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Since the 1950s, one billion tons of plastic have been discarded and may persist for hundreds or even thousands of years. Perhaps the biggest environmental threat from plastic comes from nurdles, which are the raw material from which all plastics are made. They are tiny pre-plastic pellets that kill large numbers of fish and birds that mistake them for food. Prior to the ban on the use of CFCs in extrusion of polystyrene (and general use, except in life-critical fire suppression systems; see Montreal Protocol), the production of polystyrene contributed to the depletion of the ozone layer; however, non-CFCs are currently used in the extrusion process.

Thermoplastics can be remelted and reused, and thermoset plastics can be ground up and used as filler, although the purity of the material tends to degrade with each reuse cycle. There are methods by which plastics can be broken back down to a feedstock state.

5.4.2 Classification of Plastic Waste:

a) 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.

b) 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.

5.5 PREPARATION OF PLASTIC WASTE MATERIAL

5.5.1 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.

5.5.2 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.

5.5.3 Details of Shredding Machine:

a) Agglomerator:

For shredding of poly-ethylene "Agglomerator" is used. In this process a thin plastic waste carry 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.

5.5.4 PLASTIC WASTE BLENDING MATERIALS

a) 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 of temperature around 170-180^{0}C. 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.

b) Characterization of blend

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

c) 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.

d) Characterization of Plastic Waste-Bitumen Blend for Flexible Pavement

The utility of the plastic waste blended bitumen-aggregate mix for flexible pavement construction is characterized by studying stripping value and Marshall Stability value of the mix for the blends having a maximum of 1.5% plastic waste.

Preparation of Plastic-Waste Coated Aggregate

The aggregate are heated to around 170^{0}C; 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^{0}C).

Figure 2: Shredding Machine Blade

For shredding of solid plastic waste of poly-propylene 'scrap grinding machine' is used. In this process, a solid plastic waste cut in small pieces with the help of with two rotating and one fixed blades. This whole process gives output in per hour rate. Following are the Specifications of Scrap Grinder

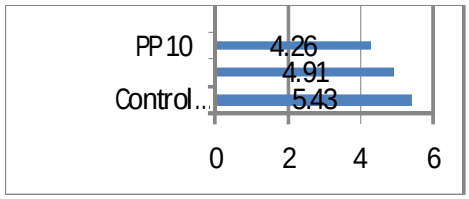
- Output 7.5Kg/hr.
- Length of rotor-200mm
- Length of blade-200mm
- No. of blades rotating-2Nos.
- Fixed blade-1No.
- Motor-3HP,900RPM

6. RESULTS AND DISCUSSIONS

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

6.1 Aggregate Impact Value

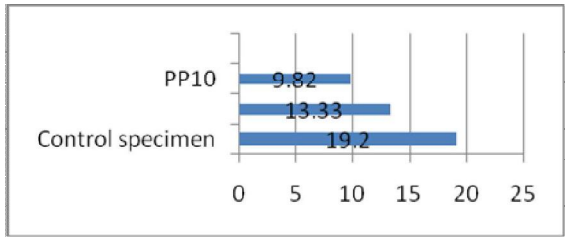
The coating of plastics improves Aggregate Impact Value, thus improving the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers. It helps to improve the quality of flexible pavement. This shows that the toughness of the aggregate to face the impacts. Its range should be less than 10%.



Graph 1: Comparison of Aggregate Impact Value Test Results

6.2 Aggregate Crushing Value

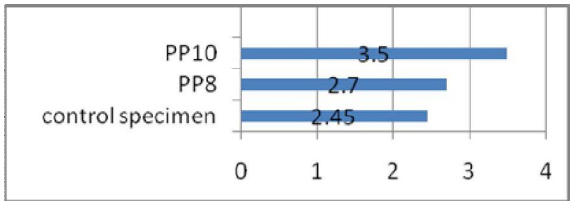
The aggregate with lower crushing value indicate a lower crushed fraction under load and would give a longer service life to the road. Weaker aggregate would get crushed under traffic load. It is clearly seen from Table- that plastic coated aggregates shows the lower crushing value and which can be withstand 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%.



Graph 2: Comparison of Aggregate Crushing Value Test Results

6.3 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. Its range should be within 2.5-3.0%.

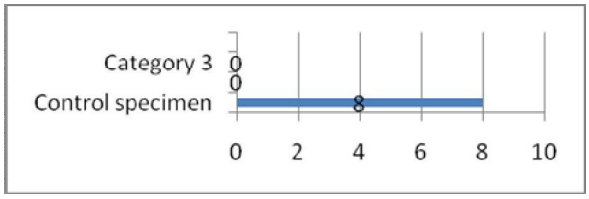


Graph 3: Comparison of Specific Gravity Test Results

6.4 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

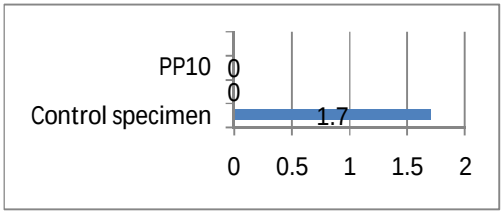
the range of the IRC standards whereas coating of the aggregate reduces the affinity of the aggregate towards water. Its range should be less than 25%.



Graph 4: Comparison of Stripping Value Test Results

6.5 Water Absorption

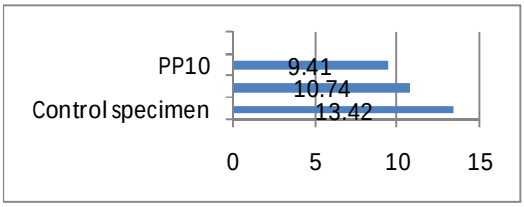
The aggregate is chosen also on the basis of the moisture absorption capacity. The aggregate when coated with plastics improved its quality with respect to moisture absorption. The coating of plastic decreases the moisture absorption and helps to improve the quality of the aggregate and its performance 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%.



Graph 5: Comparison of Water Absorption Test Results

6.6 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%.



Graph 6: Comparison of Los Angeles Test Results

6.7 Results of tests on aggregates:

Based on the tests conducted on the aggregate and bitumen following are the results obtained. The tables are followed by the standard ranges of the respective tests.

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

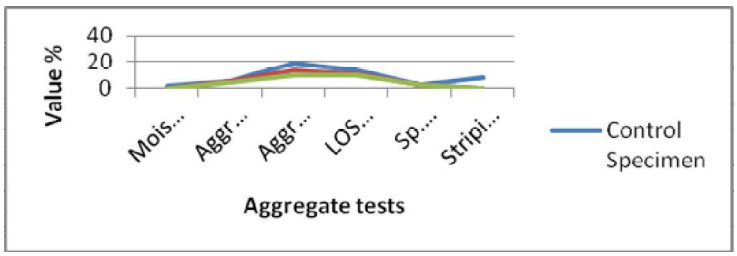
PP10	Nil	4.26	9.82	9.41	2.85	Nil

6.8 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	45-600C
Flash Point Test	280^0C	$>65^0$-175^0C
Fire Point Test	302^0C	

6.9 Comparison of Tests Results



Graph 7: 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.

7. 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.

Following are some points which are drawn from the study:

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 are 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.

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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