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Potential use of Waste Plastic in Flexible Road Pavements

Atul Uniyal[1], Assistant Professor, WIT Dehradun, India
Kulvendra Singh[2], Assistant Professor, Dr. K.N.M.E.C Modinagar, India
Vimal Uniyal[3], Assistant Professor, WIT Dehradun, India

Abstract- Solid waste management is the thrust area. Of this various waste materials, plastic waste, tyre waste and municipal solid waste are of great concern. On the other side road traffic as well as traffic intensity is increasing. The load bearing capacity of the road should be increased. The present study is helping to take care of both these aspects. In this study developed techniques to use plastic wastes for construction purpose of roads and flexible pavement has reviewed. Plastic wastes consisting of carry bags, cups and thermocoles that can be used as a coating over an aggregate and these coated aggregates can be used for road construction. On going through this process, a single lane road having parameters 1km length and 3.375m width can consume 10.00000 carry bags and the strength is increased by 100% without any pot hole formation. Secondly the waste tyres are powered and the powder is blended with bitumen and this blend is used along with plastic coated aggregates. The mix polymer coated aggregates and tyre modified bitumen have shown higher strength better binding property, stability, density and more resistant to water. Use of this mix for road construction helps to use both plastic waste and tyre waste.

Keywords- aggregates, bitumen, plastic, polymer, plastic-waste, roads

I. INTRODUCTION

Plastic waste scenario in the world, of the various waste materials, plastic and municipal solid waste is great concern. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, electronics, electrical, building construction, communication sectors has been virtually revolutionized by the applications of plastics. Plastic is a non-biodegradable material and researchers found that the material can remain on earth for 4500 years without degradation. Several studies have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc. Plastics, are versatile packing materials and commonly used by man but they become problem to the environment. India consumption of plastics will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastics in the world. Around 55% is being used for packing. They are mostly dropped and left to litter the environment, after the contents have been consumed. The littered plastics, a non biodegradable material, get mixed with domestic waste and make the disposal of municipal solid waste difficult. The municipal solid waste is either incinerated or land filled. Both disposal methods are not the best ways to dispose the waste and it causes both land and air pollution. Moreover, if municipal solid waste contains PVC waste, when burnt, it produces toxic gases like dioxins. Disposal of plastic wastes in an eco-friendly way is the main thrust area of today's research works. The author has developed innovative technique to use the waste plastics for the construction of asphalt pavement. This process is eco friendly and can promote value addition to the waste plastic. (Plastindia)

The threat of disposal of plastic will not solve until the practical steps are not initiated at the ground level. We cannot ban use of plastic but we can reuse the plastic waste. The use of plastic (be consistent in the use of polymer or plastic, since the focus is on plastic waste) coated aggregate for asphalt pavement allows the reuse of plastics waste. It is possible to improve the performance of bituminous mixed used in the surfacing course of roads. In conventional roads making process bitumen is used as binder. Such bitumen can be modified with waste plastic pieces and bitumen mix is made, which can be used as a top layer coat of flexible pavements. Studies reported in the used of re-cycled plastic, mainly polyethylene, in the manufacture of blended indicated reduced permanent deformation in the form of rutting and reduced low–temperature cracking of the pavement surfacing. 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. Once the plastic waste is separated from municipal waste, the organic matter can be converted into manure and used.

II. MATERIAL USED

The material used for making the mix is aggregate, bitumen and plastic. Investigation of plastic waste materials aggregates and bitumen requires various field test and lab tests.

a) Aggregates (Aggregate of 20mm, 10 mm, Stone Dust etc)

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

b) Bitumen (80/100 grade)

Bitumen is used as binders in pavements constructions. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. In India mostly 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 195kg per 10m^2 areas and 10 to 12kg per 10m^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 12kg per 10m^2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000litres 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.

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 the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics.

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 hardness, density, ionizing radiation, organic solvents, oxidation and resistance to heat. Thermoplastics can be re-melted and reused, and thermo-set 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.

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.

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. Agglomerater and Scrap Grinder. In Agglomerater, 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.

IV. 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˚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:

- ***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.

- ***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.

V. PREPARATION OF PLASTIC-WASTE COATED AGGREGATE

The aggregate are heated to around 170˚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˚C) shown in Fig 1.

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

Fig. 1: Plastic waste coated aggregate

VI. TEST CONDUCTED ON MATERIAL

a) Aggregates

The various test conducted on aggregates are impact value, abrasion value, crushing value, water absorption, soundness and specific gravity test. ***Impact value***, to determine the toughness, ***Los angles*** for abrasion value, ***crushing value*** for strength, ***Flakiness and elongation index*** for flakiness or elongation (shape), ***soundness*** for deformation or weathering action, ***specific gravity*** and ***water absorption test*** of road stone materials, performed in laboratory or site in standard manner with proper equipments.

According to standard experimental procedure it has been observed *impact value, abrasion value, crushing value, specific gravity and water absorption are 10%, 20%, 21%, 2.8 and 2.1%* respectively.

b) Bitumen

The various test conducted on bitumen are penetration, softening point, ductility, flash and fire point and Marshal Stability test. ***Penetration test*** conducted to determine the penetration value or hardness of bitumen, ***softening point*** by ring and ball apparatus for softening point, ***flash and fire point*** for

lowest temperature to flash and fire and ***ductile test*** for its ductility.

The values of penetration test, softening point test, ductility test, flash and fire point has been observed as 32mm, 52˚C, 61cm, 290˚C and 310˚C respectively.

The ***Marshall Stability*** and ***flow test*** provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) as a result of the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded.

c) Plastic Coated aggregates

The tests conducted on plastic coated aggregates are soundness, impact value, crushing, Los Angeles, moisture absorption and void content.

i) Aggregate Impact Value & ***crushing Value,*** A study on the effect of plastic and rubber coating was extended to study on the aggregate impact value and crushing value. Aggregate was coated with 4, 6, 8, 10% plastics by weight and then was submitted to aggregate crushing Value test and the values were compared with values for non-coated aggregate for impact value and crushing value. For each percent of waste, the tests were conducted twice to get the better results shown in Table 1(a) and Table 1(b).

ii) Los Angel's Abrasion Test, The repeated movement of the vehicle with iron wheeled or rubber tire will produce some wear and tear over the surface of the pavement. The percentage of wear and tear values of the 4, 6, 8and 10% plastic coated aggregate is found to be in decreasing order with respect to the conventional values. This wear and tear percentage of an aggregate is determined with the help of Los Angeles abrasion study shown in Table 1(c).

Table 1(a): aggregate impact value

%age of Plastics(%)	Aggregate Impact value (%)	
	Simple	conventional
4	8.8	11.76
6	7.8	10.17
8	6.33	9.33
10	5.77	9.33

Table 1(b): aggregate crushing value

%age of Plastics(%)	Aggregate Crushing value (%)	
	Simple	Conventional
4	15.3	21
6	15.0	21.2
8	14.7	21.4
10	14.5	21.4

Table 1(c): Los angel's value

%age of Plastics(%)	Los angel's value (%)	
	Simple	Conventional
4	19.46	22
6	19.33	26
8	18.57	28
10	18.22	28

It has been observed from Table 1(a), Table 1(b) and Table 1(c), the coating of plastics & rubbers improves Aggregate Impact Value. Coating of plastics & rubber over the stone aggregate improves the quality of the aggregate. Moreover a poor quality of aggregate can be made useful by coating with polymers & rubbers. This in turn helps to improve the quality of flexible pavement. When the Los Angeles abrasion value of plain aggregate value is compared with the Plastic and rubber coated aggregate the values are less for conventional aggregates as compared to polymer and rubber coated aggregates.

iii) Moisture Absorption and Void Measurement, Hot stone aggregate (1500c) is mixed with hot bitumen (170 0c). The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding Property, Penetration value and visco-elastic property. The aggregate, when coated with plastics and rubber improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic and rubber decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement. It is to be noted here that stones with < 2% porosity only allowed by the specification.

iv) Soundness Test, Soundness test is intended to study the resistance of aggregate to weathering action. The weight loss is attributed to the poor quality of the aggregate. The plastic and rubber coated aggregate, did not show any weight loss, thus conforming the improvement in the quality of the aggregate.

VII. CHARACTERISTICS OF POLYMER AND CRUMBBED RUBBER MODIFIED BITUMEN:

An alternate use of plastic and rubber waste is also under study where plastics and rubber is mixed with bitumen and used for preparing the mix. The waste tires are made into powder by grinding into some special type of grinders. The powder is collected and it is used for modification of bitumen. The bitumen is heated to 120-140 degree Celsius and the powdered crumb rubber and plastic is added to the bitumen by its weight and stirred well with help of mechanical stirrer. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. Here 10% & 20% rubber is taken in proportion by weight. Conventional and modified value of polymer

and crumbed rubber are shown in Table 2 and Table 3 respectively.

Table 2: Polymer and Crumbed rubber Conventional value:

Bitumen (gm)	Ductility (mm)	Softening point °C	Penetration (mm)
37	61	45	75
38	64	43	73
39	65	40	70
40	66	41	70

Table 3: Polymer and Crumbed rubber modified value:

% rubber	Ductility (mm)	Softening point (mm)	Penetration (mm)
4	51	56	56
6	49	59	54
8	48	60	53
10	46	62	50

It has been observed that above values were compared with the conventional value & was found better. Thus by using waste plastics & waste rubbers can increase the durability & life of the road material substantially.

VIII. CONCLUSION

Plastics will increase the melting point of the bitumen. The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income. 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. It is hoped that in near future we will have strong, durable and eco-friendly roads which will relative the earth from all type of plastic waste.

In this process, the aggregate is modified by coating with polymers and producing a new modified raw material for flexible pavement. Coating of polymers on the surface of the aggregate has resulted in many advantages and ultimately helps to improve the quality of flexible pavement as well as aggregates. This technology has helped to use the waste plastics obtained 80% of the waste polymers from domestic and industrial packing materials. This has already been accepted by the Central Pollution Control Board, New Delhi. They have already released a guideline on the technique of the road laying by dry process and its advantage. By this technique, which is in-situ, waste polymer like carry bags, foam, laminated sheets, cups are all used for road laying. Moreover, the use of polymers helps to reduce equivalent quantity of bitumen, thus reducing the cost of the road laying.

In a nut shell this Process thus helps to:

(i) Use higher percentage of plastics waste.
(ii) Reduce the need of bitumen by around 10%.
(iii) Increase the strength and performance of the road.
(iv) Avoid the use of anti stripping agents.
(v) Reduce the cost of the project.
(vi) Carry the process in situ.
(vii) Avoid industrial involvement.
(viii) Avoid disposal of plastics waste by incineration and land filling.
(ix) Generate jobs for rag pickers.
(x) Add value to plastics waste.
(xi) Develop a technology, which is eco-friendly.

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