Used of Plastic Waste Bituminous Road

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ABSTRACT: Plastic waste is one such resource, a major component of solid waste which is abundantly available and disposed of without proper treatment. There has been an exponential growth in municipal plastic waste disposal especially in urban areas which deteriorates the beauty of the landscape. Plastic was found to be an effective binder for bitumen mixes used in flexible pavements. This efficient method helps the pavements to resist higher temperature by minimizing the formation of cracks and reducing rainwater infiltration which otherwise leads to the development of potholes. These pavements have shown improved crushing and abrasion values and reduced water seepage. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50 and torrential rains create havoc, leaving most of the roads with big potholes. Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as abinder) and mineral aggregate which is mixed together & laid down in layers thencompacted. Now a day, the steady increment in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature putus in a demanding situation to think of some alternatives for the improvisation of the pavement characteristics and quality by applying some necessary modifications whichshall satisfy both the strength as well as economic aspects. Also considering the environmental approach, due to excessive use of plastic in the day to day business, the pollution to the environment is enormous. Since the plastic are not biodegradable, theneed of the current hour is to use the waste plastic in some beneficial purposes.

I. INTRODUCTION

1.1 General Introduction: Bituminous binders are widely used by paving industry. A pavement has different layers. The main constituents of bituminous concrete (BC) are aggregate and bitumen. Generally, all the hard surfaced pavement types are categorized into 2 groups, i.e.flexible and rigid.

Flexible Pavement: If the surface course of a pavement is bitumen then it is called "flexible" since thetotal pavement structure can bend or deflect due to traffic loads

Rigid Pavement: If the surface course of a pavement is PCC then it is called "rigid" since the total pavement structure can't bend or deflect due to traffic loads. Such pavements are much stiffer than the flexible pavements due to the high modulus of elasticity of the Plain Cement Concrete material. Importantly, we can use reinforcing steel in the rigid pavements, to decrease or eliminate the joints.

1.2 Mix Design:

1.2.1 Overview: Construction of highway involves a huge outlay of investment. An accurate engineering design can save considerable investment; as well a reliable performance of highway can be achieved.

1.2.2 Objective of mix design: The bituminous mix design aims to estimate the proportions of bitumen, fiber material, fine aggregates, coarse aggregate & Plastic to produce a mix which should have-

- Sufficient workability so that there is no segregation under load
- Enough strength to survive heavy wheel loads & type pressures
- Sufficient durability
- Should be economical

1.2.3 Type of mix:

- Hot mix asphalt concrete
- Warm mix asphalt concrete
- Cold mix asphalt concrete
- Cut-black asphalt concrete

- Mastic asphalt concrete or sheet asphalt

1.3 Polymer modification of BC

1.3.1 Need of the hour: The steady increase of wheel loads, tire pressure, change in climatic conditions & daily wear and tear severely affect the performance of bituminous mix pavements. Hence any improvement in the property of the pavement is highly essential considering the present scenario.

1.3.2 Waste plastic is a concern: Plastics are durable & non-biodegradable; the chemical bonds make plastic very durable & resistant to normal natural processes of degradation. Since 1950s, around 1 billion tons of plastic have been discarded, and they may persist for hundreds or even, thousands of years. The plastic gets mixed with water, doesn't disintegrate, and takes the form of small pallets which causes the death of fishes and many other aquatic animals who mistake them as food materials.

Today the availability of the plastic wastes is enormous, as the plastic materials have become the part and parcel, of our daily life. Either they get mixed with the Municipal Solid Waste or thrown over a land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration. Both the processes have significant impacts on the environment. If they are incinerated, they pollute the air and if they are dumped into some place, they cause soil & water pollution. Under these circumstances, an alternate use for these plastic wastes is required.

1.3.3 Role of plastic or polymer in pavement

Modification of BC, with the synthetic polymer binder can be considered as a solution to overcome the problems, arising because of the rapid increase in wheel loads and change in climatic conditions. Polymer modification can be considered as one of the solution to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement.Asphalt, when blended or mixed with the polymer, forms a multiphase system, containing abundant asphalt which are not absorbed by the polymer. This increases the viscosity of the mix by the formation of a more internal complex structure.

1.4 Co-processing of plastic waste management

1.4.1 Plastic waste management

1) Conventional Technology Recycling

- Recycling
- Incineration
- Land filling

2) New Technology

- Plasma Pyrolysis Technology
- Liquid Fuel
- Polymer Blended Bitumen Roads
- Co-processing in Cement Kiln

1.4.2 Process:

1. Wet 2. Dry

I). Wet Process

1. Waste plastics by direct mixing with hot bitumen at 160.
2. The Mechanical agitator is needed
3. The Addition of stabilizer and proper cooling
4. Since the wet process require a lot of investment and bigger plants.
5. Not commonly used.

ii) Dry Process

Mixing the appropriate quantity of dry shredded waste plastic with hot aggregate prior to production of bituminous mixes at hot mix plant by varying percentage of plastic by weight of the mix.

(i) Various types of waste plastic are collected, analyzed as per their type and sent for storage
(ii) These segregated wastes are then cleaned and dried to remove impurities from them. Then cut into a size of 1.18436 mm using shredding machine (PVC waste should be eliminated).
(iii) The aggregate mix is heated to 165°C (as per the HRS specification) and transferred to mixing chamber.Similarly, the bitumen is to be heated up to maximum of 1600C (HRS Specification) to have good binding and to prevent weakbonding. (Monitoring the temperature is very important).
(iv) At the mixing chamber, the shredded plastics waste is to be added to the hotaggregate. It gets coated homogeneously over the aggregate within 30 to 45 seconds,giving a look of oily coated aggregate.
(v) The plastics waste coated aggregate is mixed with hot bitumen at the temperaturerange between 150oC-165%C. The resulted mix of temperature range 130oC-1400C isused for road construction. The road laying temperature is between 1100C-1200C.Using the roller of 8 ton (min.) capacity.

1.5 Cost Estimation

The Cost of Waste Plastics: Rs.7/Kg.
The Cost of Processing: Rs.5/ Kg.
The Total cost of Waste Plastics: Rs.12/Kg.

- Optimum percentage of plastic in the blend as per the test results is around 8% (% Wt. of bitumen).
- Generally roads in India are constructed in basic width of 3.0 m, 3.75 m. and 4.0 m.
- Consider 1 Km length road of width 3.75 m. it uses bitumen approx. 21300 Kg. For new work and 11925 Kg. for Up-gradation.

The Cost of Bitumen: Rs.8400/ Drum (200 Kg.)
The Cost of Bitumen: Rs.42/Kg.
1. Cost of New Road/Km including BBM, Carpet, and Seal Coat: Rs.18, 95,000/-
   → Bitumen required for work (approx.): 21,300 Kg. /Km
   → Cost of bitumen in new work: Rs.8,95,000/ Km.
   → Waste plastic, co-processed with bitumen for PMB (8% by Wt.): Rs.1,704/ Kg.
   → Cost of waste plastic used: Rs.20,450/Kg.
   → Cost of Bitumen saved (1704Kg. equivalent to plastic used): Rs.71550
   → Total savings per Km.: Rs.51,100

% of plastic coating over aggregate	Compressive Strength (Mpa)	Bending strength (Mpa)
10%	250	325
20%	270	335
30%	290	350
40%	320	390

2.Cost of Road (Up gradation)/km including Carpet and Seal Coat: Rs.10, 80,000.
   → Bitumen Required for work (approx.): 11925 Kg. /Km.
   → Cost of bitumen in repairs (Up gradation) per Km.: Rs.5,01,000/-
   → Waste plastic, co processed with bitumen for PMB (8% by WL): 954 Kg.
   → Cost of waste plastic used: Rs.11450
3. Cost of Bitumen saved (954Kg. equivalent to plastic used): Rs.40, 0500

   → Total savings per Km.: Rs.28,600

- Optimum amount of waste plastic used in dry process: 10% (by Wt. of aggregates).
- The Amount of aggregates used in road construction (1 Km length x 3.75 m width): 3750 sqm x12.5 Kg per sqm (Avg.)=46875 Kg.

→ Therefore Amount of waste plastic used in the road (10% by Wt.): 4687.5 Kg.

4. Total Amount of waste plastic used in road construction using both the processes together (i.e. Combination of wet process & dry process): 1 704 + 4687.5 = 6391.5 Kg.

5.Total Cost of waste plastic used in road using mix process: Rs.76,700

6. Extra cost for construction of road (Cost of waste plastic used in road construction.

→Total savings using modified bitumen): 76,700-51,100 = Rs.25,600/Km.

Table 1.1 Showing compressive & Bending strength.

According to the finding as a percentage of plastic coating over aggregate increases the corresponding compressive and bending strength increases.

II. LITERATURE REVIEW

I. **Fransis Hveem, 1942;** who was a project engineer of California Department of Highways, has developed the Hveemstabilometer in 1927. He did not have any previous experience on judging, the required mix from its colour, hence he decided to measure various mixture parameters to find the optimum quantity of bitumen **[Vallerga and Lovering 1985].** He had used the surface area calculation concept, (which was already in use, at that time for the cement concrete mix design), to estimate the quantity of bitumen actually required.

II**. Bruce Marshall** developed the Marshall testing machine just before the World War-11. It was adopted in the US Army Corpse of Engineers in 1930's and subsequently modified in 1940s and 50's.

III**. Bahia and Anderson, 1984**; studied the visco-elastic nature of binders and found that, the complex modulus & phase angles of tq2he binders, need to be measured, at temperatures and loading rates which different resemble climate and loading conditions.

IV. **Shukla and Jain (1984)** described that the effect of wax in bitumen can be reduced by adding EVA (Ethyl Vinyl Acetate), aromatic resin and SBS in the waxy bitumen. The addition of 4% EVA or 6% SBS or 8% resin in waxy bitumen effectively reduces the Susceptibility to high temperatures, bleeding at hightemperature and brittleness at low temperature of the mixes.

V. The findings of the studies conducted by the Shell Research and TechnologyCentre in Amsterdam indicated that the rutting rate is greatly reduced as a result ofSRS modification of the binder**. Button and Little (1998)** on the basis of stresscontrolled fatigue testing at 20 and 00C, reported that SBS polymer exhibited superiorfatigue properties as compared to straight AC-5 bitumen.

VI.**Shuler et al. (1987)** found that the tensile strength of SBS modified binderincreased significantly as compared to unmodified asphalt mix at minus 21, 25 and41°C.

VII. **Collins et al. (1991) and Baker (1998)** observed that SBS modified asphalt mixeshave longer lives than unmodified asphalt mixes. The addition of SBS polymer tounmodified bitumen also increases its resistance to low temperature cracking.

VIII.**Denning and Carswell (1981)** reported that asphalt concrete using polyethylenemodified binders were more resistant to permanent deformation at elevatedtemperature.

IX.**Palit et al. (2002)** found improvement in stripping characteristics of the crumbrubber modified mix as compared to unmodified asphalt mix.

X. **Sibal et al. (2000)** evaluated flexural fatigue life of asphalt concrete modified by3% crumb rubber as part of aggregates.

XI**Goodrich (1998)** reported that fatigue life and creep properties of the polymermodified mixes increased significantly as compared to unmodified asphalt mixes.

III. MATERIAL USED

3.1 Basic Materials

The materials used are as follows.

i. Aggregates
ii. Bituminous Binder
iii. Material Filler
iv. Plastic

3.1.1 Aggregate

Aggregate constitutes the granular part in bituminous concrete mixture which Contributes up to 90-95%% of the mixture weight and contributes to most of the load Bearing and strength characteristics of the mixture. Hence, the quality and physical Properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregate should have to be used in pavement are shown below.

1) Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable particles should be limited to utmost 19%.

2) Durability or resistance to weathering should be measured by sulphate soundness testing.

3) The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.

4) It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes.

5) Aggregates are of 2 types. i.e.

a) Coarse Aggregate (CA)

b) Fine Aggregate (FA)

3.1.1.1 Coarse Aggregate (CA)

The aggregate retain on 4.75 mm ARE Sieve is called as coarse aggregate. Coarse aggregate should be screened crushed rock, angular in shape, free from dust particles, clay, vegetation and organic matters. They should have followingproperties

1) The Los Angeles Abrasion value shall not be more than 25 % (ASTM C131).

2) The weighted average weight loss in magnesium sulphate soundness test shallnot be more than 18% (AASTHO T 104).

3) Flakiness index shall not be more than 25% (MS 30).

4) The water absorption should not be more than 2% (MS30)

5) The polished stone value should not be less than 40%.

3.1.1.2 Fine Aggregate (FA)

Fine aggregate should be clean screened quarry dusts. It should be free from clay, loan vegetation or organic matter, FA should have the following properties,

1) The angularity should not be less than 45% (ASTMC 1252).

2) The methylene blue shall not be more than 10 mg/g (Ohio Department of Transportation Standard Test Method).

3) The weighted average weight loss in magnesium sulphate soundness test shall not be more than 20% (AASTHO T 104).

4) The absorption of water, should not be more than 2% (MS30).

3.2 Bitumen

Figure 3.2- Bitumen

Asphalt binder 60/70 and 80/100 are used in this research. The bitumen used should have following properties,

a) Grade of bitumen used in the pavements should be selected on the basis of climatic conditions and their performance in past.

b) It is recommended that the bitumen should be accepted on certification by the supplier (along with the testing results) and the State project, verification samples. The procedures for acceptance should provide information, on the physical properties of the bitumen in timely manner.

c) The physical properties of bitumen used which are very important for pavements are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirements for each property except specific gravity.

a) Penetration at 77° F
b) Viscosity at 140° F
c) Viscosity at 275° F
d) Ductility/Temperature
e) Specific Gravity
f) Solubility
g) Thin Film Oven (TFO)/Rolling TFO; Loss on Heating
h) Residue Ductility
i) Residue Viscosity

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3.3 Mineral Filler: Mineral filler consists of, very fine, inert material matter that is added to the hot mix asphalt, to increase the density and enhance strength of the mixture. These fillers should pass through 75um IS Sieve. The fillers may be cement or fly ash.

3.4 Materials used

3.4.1 Aggregates: The grades of aggregates and their quantities to be used for preparing Marshall Samples were used according to the chart given in the MORTH specification.

SIEVE SIZE	% RETAINED
26.5 mm	-----
19 mm	5
9.5 mm	25
4.75 mm	20
2.36 mm	15
300 µ	23
75 µ	7
Filler (fly ash)	5

Table 3.1; Gradation of Aggregate: So the aggregates of different grades were sieved through different IS Sieves and they were kept in different containers with proper marking.

Specific Gravity of Coarse aggregate =2.7

Specific Gravity of Fine aggregate =2.6

3.4.2 Bitumen: The bitumen used in preparing Marshall samples was of 80/100 penetration grade.

Specific Gravity bitumen = 1.02

3.4.3 Filler: The filler material used was fly ash.

Specific gravity of fly ash= 2.2

3.4.4 Plastic: The plastic from roadside waste was used as raw material for preparation of the samples. These packets were collected; they were washed and cleaned by putting them in hot water for 3-4 hours, they were then dried.

Specific Gravity of Plastic =0.905

Figure 3.3; Plastic

Shredding: The dried Plastic packets were cut into tiny pieces of size 2 mm maximum. This is because when the plastic is to be added with bitumen and aggregate it is to be ensured that the mixing will be proper. The smaller the size of the plastic, the more is the chancesof good mixing.

IV. METHODOLOGY

Technology/ Material	Sub-category	IRC guideline
Waste plastic	Type	• LDPE, HDPE, PU, PET permissible. • Black coloured plastic waste, PVC must not be used.
	Properties	• Size 2.36 mm. • Dust and other impurities should not be more than 1%. • The melt-flow value of plastic-binder mix shall be tested as per ASTM D 1238-2010 (permissible value for LDPE: 0.14-58 gm/10 min; HDPE: 0.02-9.0 gm/10 min).
Bitumen		• The Indian Standard Specification for viscosity graded paving bitumen (VGPB) IS 73. • IRC: 111-2009 (for grade of VGPB).
Aggregates		• IRC: 111-2009 (for dense graded mixes). • IRC:14-2004, IRC: SP: 78-2008 and IRC: 110-2005 (open graded mixes).
Filler		• IRC: 111-2009 (dense graded mixes).
Technology		Plastic must not be heated beyond 180°C as it may cause release of harmful gases.
During of mix	Dense graded mixes	**See table 5**
	Open graded mixes	Waste plastic at 6-8% of weight of bitumen can be used
Manufacturing of bitumen plastic mix	Dry process	1. Collection of waste plastic 2. Cleaning and Shredding of waste plastic 3. Shredding machine 4. Mixing of shredded waste plastic, aggregate and bitumen in central mixing plant.
Construction	Dense graded mixes	IRC: 111-2009, IRC: 14-2004, IRC: 110-2005
	Open graded mixes	IRC: SP: 78-2008
Control	Dense graded mixes	IRC: 111-2009, IRC: 14-2004, IRC: 110-2005
	Open graded mixes	IRC: SP: 78-2008
	Waste Plastic	• Shall be examined for impurity and melt flow value • Three sample be tested for each day work or when there is change in the source of plastic

4.1 1 A summary of IRC Guidelines Regarding the use of plastic in Roads/Other constructs

The Indian Road Congress is the highest body of highway engineers in the country. The society was set-up by the recommendations of the government of India. The organization over the years has been contributing to enhancement of the roads and bridges in India. IRC had in the H-2 committee meeting of members on the 15th of June 2012 had decided to formulate guidelines for utilizing waste plastic with bitumen in road construction. The guidelines formulated by the committee were approved by the Council of IRC in August 2013. Key items of the IRC published guidelines are mentioned in the above table.

Evidence has demonstrated that dry process is better than wet process and former is recommended in the guidelines for laying roads by Indian Road Congress, Central Pollution Control Board and National Rural Roads Development Agency, Ministry of Rural Development, GOI.

Following are the advantages of dry process

- Use higher percentage of plastics waste.
- Reduce the need of bitumen by around 8%, Increase the strength and performance of the road Avoid the use of anti-stripping agents, Reduce the cost by nearly 26,000 per kilometer of single lane road, Carry the process in situ.
- Avoid industrial involvement and also avoid disposal of plastics waste by incineration and land filling Generates job for public health workers.
- Add value to plastic waste.
- Develop a technology, which is eco-friendly.
- There are some limitations of using waste plastic as modifier and binder in bituminous mixes which are listed below.

1. Only low density polyethylene (LDPE) or high density polyethylene (HDPE) and PET Shall be considered for the construction material mixes.
2. Repeated recycling of plastic results in black colour plastic waste and therefore should not be used.
3. The use of PVC is not recommended since they release lethal levels of dioxins (toxic gases).
4. A gas evolution and thermal degradation of thermoplastics has been indicated beyond 180℃ by the Thermo Gravimetric Analysis (TGA), hence, misuse or wrong implementation of this technology may cause release of harmful gases, premature degradation making it essential to maintain the temperatures during construction.

4.2 General

It involves mainly two processes.

a) Preparation of samples

b) Void analysis

c) Testing

Prior to these experiments, the specific gravity of Plastic used was calculated as perthe guidelines provided in ASTM D792-08.

4.2.1 Determination of specific gravity of Plastic.

The procedure adopted is given below-

1) The weight of the Plastic in air was measured by a balance. Let it be denoted by “a”.

2) An immersion vessel full of water was kept below the balance.

3) A piece of iron wire was attached to the balance such that it is suspended about 25mm above the vessel support.

4) The Plastic was then tied with a sink by the iron wire and allowed to submerge inthe vessel and the weight was measured. Let it be denoted as "b".

5) Then Plastic was removed and the weight of the wire and the sink was measured by submerging them inside water. Let it be denoted as "w”.

The specific gravity is given by: s=a/ (a+w-b)

Where:

a = apparent mass of specimen, without wire or sinker, in air.

b = apparent mass of specimen and of sinker completely immersed and of the wire partially immersed in liquid.

w = apparent mass of totally immersed sinker and of partially immersed wire.

4.3 Void analysis

For analysis of voids, the samples were weighted in the air and also in water, so thatwater replaces the air present in the voids. But by this process some amount of water will be absorbed by the aggregate which give erroneous results. Hence

1st the samples were coated with hot paraffin so that it seals the aggregate-bitumen mix completely and checks the absorption of water into it.

4.4 Marshall testing

The Marshall test was done as procedure outlined in ASTM D6927-06.

4.4.1 Marshall Stability Value

It is defined as the maximum load at which the specimen fails under the applicationof the vertical load. It is the maximum load supported by the test specimen at aloading rate of 50.8 mm/minute (2 inches/minute). Generally, the load was increaseduntil it reached the maximum & then when the load just began to reduce, the loadingwas stopped and the maximum load was recorded by the proving ring.

4.4.2 Marshall Flow Value:

It is defined as the deformation undergone by the specimen at the maximum loadwhere the failure occurs. During the loading, an attached dial gauge measures thespecimen's plastic flow as a result of the loading. The flow value was recorded in0.25 mm (0.01 inch) increments at the same time when the maximum load was recorded.

Test on Aggregate

Table: Result of test on aggregate

State Aggregate	Plastic Content (%)	Aggregate Impact Value	Los Angles Abrasion Value	Specific Gravity	Water Absorption	Stripping Value
Without Plastic	0	10.79%	12.85%	2.5	3.2%	1%
With Plastic	10	9.27%	11.70%	2.66	2%	Nil
	15	8.94%	10.65%	2.7	1.1%	Nil

Test on Bitumen
Table: Result of the test on Bitumen

Test	Result	Range
Ductility test	75.50 cm	Minimum 40 cm
Penetration value	83 mm	80-100 mm
Softening point	48.25	45-60
Flash point test	280	>175°C
Fire point test	302	

V.CONCLUSION

The plastic mixed with bitumen and aggregates is used for the better performance of the roads. The polymercoated on aggregates reduces the voids and moisture absorption. This results in the reduction of ruts and there isno pothole formation. The plastic pavement can withstand heavy traffic and are durable than flexible pavement.The use of plastic mix will reduce the bitumen content by 10% and increases the strength and performance ofthe road. This new technology is eco-friendly. The use of smoke absorbent material (titanium di-oxide) by 10%of polymer content can reduce the vehicular pollution.

1. Plastic will increase the melting point of the bitumen.
2. This innovative technology not only strengthened the road construction but also increased the road life.

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