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Utilization of Waste Plastic in Bituminous Mixes for Road Construction

BY

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INTRODUCTION

Bitumen is a useful binder for road construction. Different grades of bitumen like 30/40, 60/70 and 80/ 100 are available on the basis of their penetration values. The steady increase in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature demand improved road characteristics. Any improvement in the property of the binder is the needed.

Today the availability of the waste plastics is enormous, as the plastic materials have become part and parcel of daily life. They either get mixed with Municipal Solid Waste and/or thrown over land area. If not recycled, their present disposal is either by land filling or by incineration. Both the processes have certain impact on the environment. Under this circumstance, an alternate use for the waste plastics is also the needed.

Thinner polythene carry bags are most abundantly disposed of wastes, which do not attract the attending rag pickers for collection for onward recycling, for lesser value. Again, these polythene/polypropylene bags are easily compatible with Bitumen at specified conditions. The waste polymer bitumen blend can be prepared and a study of the properties can throw more light on their use for road laying.

Waste Plastics - as Binder and Modifier:

Waste plastics (polythene carry bags, etc.) on heating soften at around 130°C. thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C. Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

Need for the Study:

1) Disposal of waste plastic is a major problem
2) It is non-biodegradable
3) Burning of these waste plastic bags causes environmental pollution.
4) It mainly consists of low-density polyethylene
5) To find its utility in bituminous mixes for road construction
6) Laboratory performance studies were conducted on bituminous mixes. Laboratory studies proved that wastePlastic enhances the property of the mix
7) Improvement in properties of bituminous mix provides the solution for disposal in an useful way

DEFINITION

Waste Plastics - as Binder and Modifier:

Waste plastics (polythene carry bags, etc.) on heating soften at around 130°C. Thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C. Moreover the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction

Different type of waste plastic (polymer) and its origin:

Type of waste plastic (polymer) origin
Low density polyethylene (LDPE): bags, sacks, bin lining and squeezable
Detergent bottles etc

High density polyethylene (HDPE): bottles of pharmaceuticals, disinfectants,
Milk, fruit juices, bottle caps etc

Polypropylene (PP): bottle cap and closures, film wrapping for
Biscuits, microwave trays for ready-made
Meals etc.

Polystyrene (PS): yoghurt pots, clear egg packs, bottle caps.

Foamed Polystyrene: food trays, egg boxes, disposable cups,
Protective packaging etc

Polyvinyl Chloride (PVC): mineral water bottles, credit cards, toys,

Pipes and gutters; electrical fittings, furniture, Folders and pens;
Medical disposables; etc

CHARACTERIZATION OF WASTE PLASTICS:
Thermal Study
Thermal behavior of the polymers namely PE, PP and PS is shows in Table 1.

Table 1. Thermal Behavior of Polymers Polymer

Polymer	Solubility Water EPT*		Softening Temp in Deg. C	Products reported	Decomposition Temp Deg. C	Ignition Temp Deg .C
PE	Nil	Nil	100-120	No gas	270-350	>700
PP	Nil	Nil	140-160	No gas	270-300	>700
PS	Nil	Nil	110-140	No gas	300-350	>700

* 5% acetic acid

Binding Property:
The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc... Were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths.

Table 2. Binding Property

Percentage of plastics coating over aggregate	Compression Strength (Tonnes)	Bending Strength (Kg)
10	250	325
20	270	335
25	290	350
30	320	390

The increase in the values of the compression strength and bending strength shows that the plastics can be used as a binder

Concept of Utilization of Waste Plastic in Bituminous Mixes for Road Construction:

This Concept of Utilization of Waste Plastic in Bituminous Mixes for Road Construction has been done since 2000 in India, They can return to the earth as beneficial additives in bitumen roads. One such technologies are reviewed below, two for waste-polymer-modified bitumen roads.

BANGALORE'S KK PROCESS:-

At the initiative of M/s K.K. Poly Flex Pvt. Ltd., a study on the possible use of the processed plastic waste bags with the bituminous mixes was carried out at the R.V. College of Engineering Bangalore. A group of students of B.E. degree course in Chemical Engineering of this college under the guidance of the concerned teaching staff carried out their final year project work for studying the possibility of using of the processed plastic bags with bitumen and bituminous mixes. As some encouraging results were reported in this study, M/s K.K. Poly Flex Pvt. Ltd. later approached the Centre for Transportation Engineering of Bangalore University with the request to carry out further research studies on the effects of using the processed plastic bags with bituminous mixes for road construction works.

in practice, such a "plastic road" laid in Bangalore (at the busy Rajarajeshwari Junction) in March 2001 as a technology demonstration for the Chief Minister, showed superior smoothness and uniformity and less rutting as compared to plastics-free road laid at the same time, which has begun to develop "crocodile cracks". As a result, by now 25 km of "plastic roads" have been laid in Bangalore, unfortunately without another same-day plastics-free normal road. All these 25 km are performing well. The process was also approved in 2003 by the CRRI=Central Road Research Institute Delhi, and has Thereafter been included in the Goyt of Karnataka's PWD Schedule of Rates. Road life improves through improved tackiness and viscosity of the bituminous mix, thereby binding the stones more firmly together and improving the water-resistance of the mix to rain etc. For the same reason, the temperature of the mix both at the plant and at the point of lying needs to be 20°Chigher than normal.

The Bruhat Bangalore Mahanagara Palikir (BBMP) has used plastic on about 600 km of roads, including many thoroughfares and arterial roads. It uses the plastic blend in at least 25% of the road-laying works, including the present project to upgrade about 45 roads in the city. The plastic model was successful on major roads in Bangalore, including Shankar Mutt Road, K H Road, M G Road (towards Trinity Circle), J C Nagar Road, Miller's Road and Cunningham Road. The rise in bitumen costs over the past few years has also made the plastic model more cost-efficient. To top it, plastic is not recycled but buried with the roads, forever.

materials used:-

AGGREGATE:-

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

bitumen:-

* 60/70,80/100grade bitumen

*waste plastic:-

Waste plastic in the shredded form

processing details:-

i. collection of waste plastic
ii. cleaning and shredding of waste plastic
iii. mixing of shredded waste plastic, aggregate and bitumen in central mixing plant
iv. laying of bituminous mix

a. collection of waste PLASTIC:-

Waste plastic is collected from roads, garbage trucks, dumpsites or compost plants, or from school collection programs, or bypurchase from rag-pickers or waste-buyers at Rs 5-6 per kg

Rag-pickers

b. cleaning and shredding of waste plastic:-

Waste plastic litter in the form of thin-film carry-bags, use-and-throw cups, PET bottles, etc. these are sorted, de-dusted, washed if necessary.

Fig. cleaning process

Plastic waste which is cleaned is cut into a size between 1.18mm using shredding machine as shown below

Fig. shredding machine

c. mixing of shredded waste plastic, AGGREGATE and bitumin in central mixing plant:-

The aggregate mix is heated to 1650c (as per the HRS specification) in central mixing plant. Similarly the bitumen is to beheated up to a maximum of 160ºc.

The 8% of waste plastic to the weight of bitumen are added in the conveyor belt or special mechanical device is developed

which will spray the plastics inside the chamber to coat the plastics effectively.

Central mixing plant helps to have better control of temperature and better mixing of this material thus helping to have auniform coating and heated bitumen is also sprayed.

Fig. central mixing plant

d. Laying of bitumenous mix:-

The plastics waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The roadlaying temperature is between 1100c to 1200c. The roller used is 8-ton capacity.

METHODOLOGIES:-

I. Mix Design by Marshall Method
a) Optimum Waste Plastic Content
b) Comparison of Two Mixes
c) Volumetric properties of BC Mixes

II.Performance Studies of Waste Plastic Bituminous Mixes:-

i. Indirect Tensile Strength
ii. Rutting Tes

I. Mix Design by Marshall Method:-

Marshall test:-

Laboratory studies were carried out at the Centre for Transportation Engineering of Bangalore University on the possible use of the processed plastic bags as an additive in bituminous concrete mixes. The material used in this study was supplied by/s KK Poly Flex (P) Ltd., Bangalore. The processed plastic was used as an additive with heated bitumen in different proportions (ranging from zero to 12 % by weight of bitumen) and mixed well by hand, to obtain the modified bitumen.

The properties of the modified bitumen were compared with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight.
The softening point of the modified bitumen increased with the addition of plastic additive, up to 8.0 % by weight.

Auto Marshall Compactor

Auto Marshall tester

Optimum Waste Plastic Content:

Ø varying percentages of waste plastic by weight of bitumen was added into the heated aggregates

Ø Marshall Specimen with varying waste plastic content was tested for bulk density and stability

Ø Maximum value of stability was considered as criteria for optimum waste plastic content

Studies were carried out on Bituminous mixes using 60/70 grade bitumen having average Marshall Stability Value (MSV) of1300 kg at optimum bitumen content of 5.0 % by weight of the mix. Further studies on mixes were carried out using the modified binder obtained by the addition of varying proportions of processed plastic bags (percentage by weight of bitumen)with the conventional 80 /100 grade bitumen. The optimum modified binder content fulfilling the Marshall Mix design criteria was found to be 5.0 % by weight of the mix, consisting of 8.0 % by weight of processed plastic added to the bitumen. The average MSV of the mix using the modified binder was found to be as high as 1750 kg at this optimum binder content, resulting in about three fold increase in stability of the BC mix, which contains 4.6 % bitumen plus 8 % processed plastic by weight of bitumen, i.e., 0.4 % processed plastic by weight of the mix.

order to evaluate the ability of the mix prepared with the above-modified bitumen to withstand adverse soaking condition under water, Marshall Stability tests were conducted after soaking in water at 60 Co for 24 hours. The average MSV of thebe mix with modified binder (using 8 % processed plastic by weight of bitumen, as above) was found to increase by about2.6 times of the mix with ordinary bitumen. Further laboratory studies carried out on the BC mixes using this modified binder also indicated note worthy increase in fatigue life under repeated application of loads.

Comparison of Two Mixes:

Volumetric properties OF MIXES:-

Volumetric properties of Mixes

Properties	Modified Mix (Waste plastic) 8 % by wt of bitumen	Conventional Mix
Marshall Stability (kg)	1700	1350
Bulk Density(gm/cc)	2.374	2.350
Air Voids (%)	4.4	3.5
VFB (%)	73	76
Flow (mm)	4	4
VMA (%)	16.5	15.6
Retained Stability (%)	98	88

II.Post testing of Waste Plastic Bituminous Mixes:-

a) Performance Studies of the Mixes

i. Indirect Tensile Strength
ii. Rutting Test

I. Indirect Tensile Strength:-

Use this test method to determine the tensile strength of compacted bituminous mixtures.

As the figure shown below tensile strength of the Waste Plastic Bituminous Mixes is greater then Conventional Mix

Indirect testing machine

II. Rutting Test:-

Wheel tracking is used to assess the resistance to rutting of asphalt materials under conditions which simulate the effect oftraffic.

A loaded wheel tracks a sample under specified conditions of speed and temperature while the development of the rut ismonitored continuously during the test.

The rut resistance can be quantified as the rate of rutting during the test or the rut depth at the conclusion of the test.

Test specimens can be either slabs prepared in the laboratory or 20cm diameter cores cut from the highway.

Ordinary mix waste plastic mix Hamburg wheel track equipment

Beam specimen after rutting test

No traces of stripping even after 20,000 cycles therefore No pothole formation, rutting or raveling has been observed after 5to 6 years after construction.

Graphical representation of rutting test

comparison between ordinary bituminous roads and waste plastic bituminous roads:-

Sl. no	properties	plastic road	ordinary road
1	Marshall Stability Value	more	less
2	Binding property	better	good
3	Softening Point	less	more
4	Penetration Value	more	less
5	tensile strength	high	less
6	rutting	less	more
7	stripping(pot holes)	no	more
8	seepage of water	no	yes
9	durability of the roads	better	good
10	cost of pavement	less	normal
11	Maintenance cost	Almost nil	more
12	Environment friendly	yes	no

advantage of waste plastic bituminous mix:-

1) Stronger road with increased Marshall Stability Value

2) Better resistance towards rain water and water stagnation

3) No stripping and no potholes.

4) Increase binding and better bonding of the mix.

5) Reduction in pores in aggregate and hence less rutting and raveling.

6) No leaching of plastics.

7) No effect of radiation like UV.

8) The strength of the road is increased by 100%.

9) The load withstanding property increases. It helps to satisfy today's need of increased road transport.

10) For 1km X 3.75m road, 1 ton of plastic (10 lakh carry bags) is used and 1 ton of bitumen is saved.

11) Value addition to the waste plastics (cost per kilogram increases from Rs 4 to Rs12).

12) The cost of road construction is also decreased.

13) The maintenance cost of road is almost nil.

14) Disposal of waste plastic will no longer be a problem.

15) The use of waste plastics on the road has helped to provide better place for burying the plastic waste without causing disposal problem

Benefits of waste plastic roads:-
* Environmental benefits
* MSWM (Municipal Solid Waste Management)
* Employment Generation
* Farming Community
* National Economy

Environment benefits:-

Today, plastic waste treatment is largely hazardous to the environment as most of the plastic is burnt resulting is toxic gases being released in the environment.

By effectively managing the collection, separation and processing of plastic waste, the environmental damages can be limitedby eliminating the waste from our streets

REFERENCES:-

1) Ministry of Road Transport and High Ways, Manual for construction and supervision of bituminous works, New
Delhi, November 2001.

2) Sri Ram Institute for Industrial Research, Plastics Processing and Environmental Aspects, New Delhi - 7

3) Vasudevan, R., Utilization of waste plastics for flexible pavement, Indian High Ways (Indian Road Congress),Vol. 34, No.7. (July 2006).

4) Ajman Khan, Gangadhar, Mural Mohan and Vine Ranker, "Effective Utilization of Waste Plastics in Asphalting of Roads". Project Report prepared under the guidance of R. Suresh and H. Kumar, Dept. of Chemical En gg., R.V.College of Engineering, Bangalore, 1999.

5) Utilizations of Waste Plastic Bags in Bituminous Mix for Improved Performance of Roads, Centre for Transportation Engineering, Bangalore University, Bangalore, India [Unpublished] Apr02

6) K. K. Plastic Waste Management Pvt. Ltd.(Subsidiary of KK Polyflex Pvt. Ltd.) No. 1, Chairman Compound,Y.V. Ananias Road, Yelachenahalli, Krishnadevaraya Nagar II Stage Kanakapura Road Bangalore - 560 078