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USE OF WASTE PLASTIC IN ROAD CONSTRUCTION

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ABSTRACT: The plastic waste quantity in municipal solid waste is increasing due to increase in population and changes in life style. Thus disposal of waste plastic is a hazardous and become a serious problem globally due to their non-biodegradability. Plastic roads are found to perform better than ordinary roads and therefore use of plastic road construction has gained importance these days. Disposal of waste plastic bags has become a serious problem and waste plastics are burnt for disposal which causes environmental pollution. Utilization of waste plastic bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Therefore it is necessary to utilize the wastes effectively with technical development in each field. Many by-products are being produced using the plastic wastes. Our present work is helping to take care of these aspects. Waste like plastic bottles, polymers, cups, etc. can be re-used by powdering or blending it with crusher and can be coated over aggregate and bitumen by any heating process. Once the plastic waste is separated from municipal solid waste, the organic matter can be converted into manure and used. This paper describes the various aspects of utilization of plastic waste in construction of roads.

I. INTRODUCTION

Plastics, a versatile material and a friend to common man become a problem to the environment after its use. Today, in India nearly 4 million tonnes of plastics are used and it is hoped to reach 12 million tonnes by 2010. Their visibility has been perceived as a serious problem and made plastics a target in the management of solid waste. Plastics are non-biodegradable. They also have very long lifetime and the burning of plastics waste under uncontrolled conditions could also lead to generation of many hazardous air pollutants (HAPs) depending upon the type of polymers and additives used. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment, degradation of plastics takes place to a certain extent.

Polymer modified bitumen is emerging as one of the important construction of flexible pavements. The polymer modified bitumen show better properties for road construction and plastics waste can find its use in this process and this can help solving problem of pollution. The studies on the thermal behaviour and binding property of molten plastics promoted a study on the preparation of plastic waste-bitumen blend and its properties to find the suitability of the blend for road construction.

An alternate method to use higher percentage of plastic waste in flexible pavement is by using plastic coated aggregate (PCA). This method is known widely as dry process. The aggregate coated with plastic was used as the raw material. The bitumen was not blended with plastic waste.

Characteristics of Plastic Waste

A. Thermal Study

A study of the thermal behavior of the polymers namely polyethylene, polypropylene, polystyrene, shows that those polymers get softened easily without any evolution of gas around 130-1400C, this has been scientifically verified.
At around 3500C they get decomposed releasing gases like methane, ethane etc and at 7000C they undergo combustion, producing gases like CO and CO2.

B. Binding Property

The molten plastic waste inhibits good binding property. Following experiments were carried out to study the binding property.

- The aggregate was heated to around 1700C and the shredded plastic waste was added. Plastics got softened and coated over the aggregate. The mix of aggregate and plastic was compacted and cooled. The block was very hard and showed compressive strength not less than 130 MPa and binding strength of 500 kg/cm2. This shows that the binding strength of the polymer is good.
- The polymer coated aggregate was socked in water for 72 hours. There was no stripping at all. This shows that the coated plastic material sticks well with the surface of the aggregate.

Types of Plastic

Type of plastic	Characteristics	Applications
Thermosets	Thermosets are hard and have a very tight-meshed, branched molecular structure. Curing proceeds during shaping, after which it is no longer possible to shape the material by heating. Further shaping may then only be performed by machining	Electrical switches, Epoxy
Elastomers	While Elastomers have a cross linked structure, they have a looser mesh than Thermosets, giving rise to a degree of elasticity. Once shaped, heating also cannot reshape Elastomers	Vulcanised rubber for automobile tyres
Thermoplastics	Thermoplastics have a	Polyethyle

	linear or branched molecular structure, which determines their strength and thermal behavior; they are flexible at ordinary temperatures. At approx. 120 - 180°C, thermoplastics become a pasty/liquid mass. The service temperature range for thermoplastics is considerably lower than that for thermosets. The thermoplastics	ne (PE), polyvinyl chloride (PVC) and polystyrene (PS) are used in packaging applications

II. BASIC PROCESSES:

- Segregation
- Cleaning process
- Shredding process
- Collection process

III. LABORATORY STUDIES

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

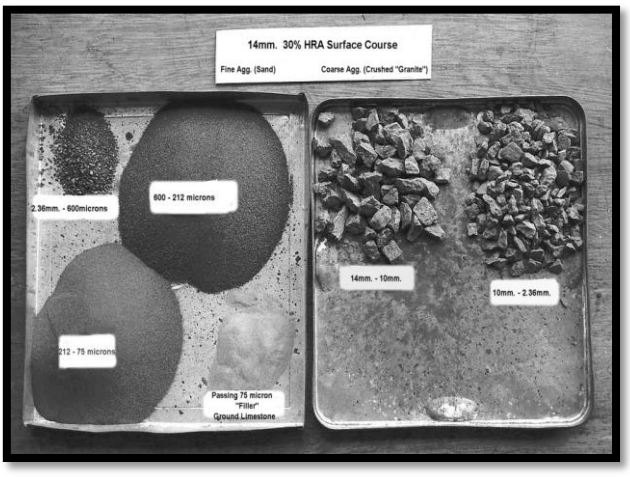


Fig: Aggregates

Gradation of aggregates for bituminous concrete mix

Sieve size (MM)	Design gradation	Specified Gradation
19.0	100	100
13.2	87	79-100
9.5	78	70-88
4.75	58	53-71
2.36	51	42-58
1.18	41	34-48
0.60	31	26-38
0.30	24	18-28
0.15	14	12-20
0.075	7	4-10

B. Bitumen

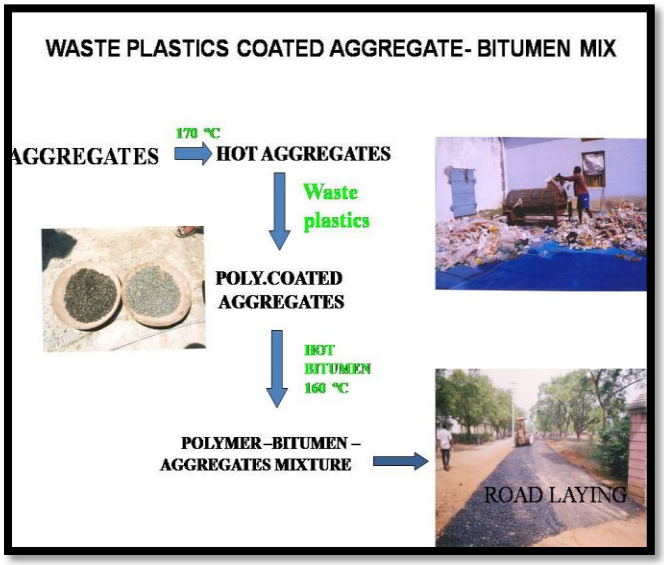
Bitumen is used as binders in pavements constructions. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as "Mixtures of hydrocarbons of natural or pyrogenous origin, 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 m2 areas and 10 to 12 kg per 10 m2 area in case of renewal of black top surfacing. For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg per 10 m2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000 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.

Fig: Bitumen

C. Waste Plastics:

Plastic is a material consisting of any of a wide range of synthetic or semi-synthetic organics that are malleable and can be molded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural. Plasticity is the general property of all materials that are able to irreversibly deform without breaking, but this occurs to such a degree with this class of moldable polymers that their name is an emphasis on this ability. Due to their relatively low cost, ease of manufacture, versatility, and imperviousness to water, plastics are used in an enormous and expanding range of products, from paper clips to spaceships. They have already displaced many traditional materials, such as wood, stone, horn and bone, leather, paper, metal, glass, and ceramic, in most of their former uses. In developed countries, about a third of plastic is used in packaging and another third in buildings such as piping used in plumbing or vinyl siding. Other uses include automobiles (up to 20% plastic), furniture, and toys. In the developing world, the ratios may be different - for example, reportedly 42% of India's consumption is used in packaging. Plastics have many uses in the medical field as well, to include polymer implants, however the field of plastic surgery is not named for use of plastic material, but rather the more generic meaning of the word plasticity in regards to the reshaping of flesh. The world's first fully synthetic plastic was Bakelite, invented in New York in 1907 by Leo Baekeland who coined the term 'plastics'. Many chemists contributed to the materials science of plastics, including Nobel laureate Hermann Staudinger who has been called "the father of polymer chemistry" and Herman Mark, known as "the father of polymer physics". The success and dominance of plastics starting in the early 20th century led to environmental concerns regarding its slow decomposition rate after being discarded as trash due to its composition of very large molecules. Toward the end of the century, one approach to this problem was met with wide efforts toward recycling.



IV. LABOTATORY TEST RESULTS AND ANALYSIS

a)Bitumen:

60/70 grade bitumen was used in this experiments .the physical properties of bitumen was tabulated below.

Physical properties of bitumen

Sl no	Test description	Test method	Result
1	Penetration (100gm 5 sec at 25°C)	Is-1203-1978	64
2	Ductility(27°C (cm))	Is-1208-1978	78
3	Specific gravity	Is-1208-1978	1.00
4	Softening point(°c) ring ball method)	Is-1203-1978	50
5	Flash point (°c) Fire point (°c)	Is-1203-1978	240 270

b) Waste Plastics:

Waste plastics in the shredded form obtained from M/S K. K. Poly flex Pvt. Ltd. were used in the present study. The specific gravity was found to be 1.03. As the material obtained was heterogeneous, it was difficult to study its thermal behavior. Thermal behavior studies like melting

and degradation helps in optimizing the blending parameters. Therefore to study its thermal behavior. Shredded waste plastics were passed through extruder to convert this material into homogenous solid wire form of approximately 2 mm diameter. Melting behavior: was studied using differential scanning calorimeter (DSC) and degradation behavior of the material was studied using a thermo-gravimetric analyzer (TGA). Approximately 12-14 mg sample are heated at the rate of 10°C/min to carryout theses tests.

About 13.85 mg sample was used for conducting the DSC test. DSC thermo-gram indicated a sharp endoderm in the temperature range of 75 - 138°C with a peak position at 130,4°C confirming that the waste plastics used in the present study consisted of polyethylene. Shoulder in the temperature range of 150 to 170° C with a mild peak position at b162.5°C was also observed as shown in Fig 3.1. This may be due to the impurities present in the waste plastics. The oxidative · degradation of waste plastics was at around 200°C. About 12.65 mg of sample was used for TGA test. From the TGA curve it was observed that there was no weight loss up to 200° C Approximately 6 per cent of weight loss was observed in the temperature range of 200-400°C due to oxidative degradation. From these can it can be concluded that these waste plastics can be safely used up to 200°C in bituminous mixes.

c). Properties of BC mix to determine OBC

Property	Binder content by weight of aggregate(%)			
	4.5	5.0	5.5	60
Marshall stability	1258	1383	1480	1280
Bulk density (gm/cc)	2.327	2.363	2.377	2.367
Flow value (MM)	2.6	3.5	4.2	4.6
Air voids (%)	6.8	4.6	3.4	3.2
Voids filled with bitumen, (%)	58.7	70.7	78.4	80.9
Voids in minerals aggregates(%)	16.8	15.7	15.6	16.4
Optimum bitumen content(%)	5.4			

d) Design of bituminous mix using waste plastic
Marshall mix design was conducted by using binder content with 4.5,5.0.,5.5,6.0 percentage by weight of aggregate and 8perctage of waste plastic (by the binder).Marshall samples were prepared and tested for its volumetric properties and the results are tabulated below

Properties of BC mix with 10 percent of waste plastics

Property	Binder content by weight of aggregate (%)			
	4.5	5.0	5.5	60
Marshall stability	1633	1663	1694	1633
Bulk density (gm/cc)	2.324	2.338	2.354	2.350
Flow value (MM)	3.6	3.7	4.2	4.3
Air voids (%)	6.9	5.6	4.4	3.8
Voids filled with bitumen, (%)	59.7	66.7	73.4	70.9
Voids in minerals aggregates(%)	16.7	16.7	15.6	16.9
Optimum bitumen content(%)	5.4			

The mix design procedure was repeated with addition of waste plastic to find if there could be any reduction in OBC when compared to conventional mix. From the results it was found that the OBC was 5.4 % by weight of aggregates.

The retained stability test were conducted on convention mix and modified mix after soaking the sample obtained was 98 and 88 % for modifier and conventional mixes respectively .this shows that mixes with 8% waste plastic tabulated as shown. The comparative charts representing the volumetric properties of modified and conventional mixes are shown

e). Properties of BC mix with 10 percent of waste plastics

Property	Mix with waste plastic	Conventional mix
Marshall stability	1800	1663
Bulk density (gm/cc)	2.348	2.358
Air voids (%)	3.4	3.3
Voids filled with bitumen, (%)	71	73
Flow (MM)	4	4
Voids in minerals aggregates(%)	16.5	16.7
Retained stability (%)	95	80

V. TESTS ON PLASTIC COATED AGGREGATES (10%)

Abrasion value of plastic coated aggregates = 18.6%
Aggregate Crushing Value = 35%
Aggregate impact value = 7.3%

Advantages of Using Waste Plastic as Additive in BituminousMixAdvantages of Platic Tar Road

- Stronger road with increased Marshall Stability Value.
- Better resistance towards rainwater and water stagnation 18
- No stripping and no potholes.
- Increase binding and better bonding of the mix.
- Reduction in pores in aggregate and hence less rutting and raveling.
- No effect of radiation likes UV.
- The strength of the road is increased by 100%.
- The load is withstanding property increases. It helps

to satisfy today's need for increased road transport.

- For 1km X 3.75m road, 1 ton of plastic (10 lakh carry bags) is used, and 1 ton of bitumen is saved.
- Value addition to the waste plastics (cost per kilogram increased from Rs 4 to Rs12).
- The cost of road construction is also decreased.
- The maintenance cost of the road is almost nil.
- Disposal of waste plastic will no longer be a problem.
- The use of waste plastics on the road has helped to provide the better place for burying the plastic waste without causing disposal problem.
- Employment for unskilled laborers will be generated.

Characteristics of the process are:

- Easy process without any new machinery
- Simple process without any industry involvement
- In situ process
- Use of lesser percentage of bitumen and thus savings on bitumen resource
- Use of plastics waste for a safe and eco-friendly process
- Both Mini Hot Mix Plant and Central Mixing Plant can be used
- Only aggregate is polymer coated and bitumen is not modified
- Use 60/70 and 80/100 bitumen is possible
- No evolution of any toxic gases like dioxin

Disadvantages:

- The burning of plastic waste creates air pollution and also health hazards.
- In the presence of chlorine will definitely release noxious HCL gas.
- It is opined that the first rain will trigger leaching.
- As the plastics will merely form a sticky layer, (mechanical abrasion).
- The components of the road, once it has been laid, are not inert.

ESTIMATION

How Much Plastic? How Many roads?

Each 5-member family's use of 5 gm plastic bags a week, all-India =52,000 tons a year. Assume 50% of this is available for roads.

1.5 tons plastic goes into avg 1 km road.

So resurfacing just 35,000 km of roads a year will absorb all this littered waste. This is just 3.5 % of India's 1 million km surfaced roads. (1.1 million km more roads are unsurfaced).

Waste Minimization and Infrastructure Improvement

India spends Rs 35,000 croresa year on road construction and repair, including Rs 100,000 crores a year just on maintenance.

Roads lasting 2-3 times longer, will save us Rs 33,000 crores a year in repairs, plus reduced vehicle wear and tear.

10% by weight of plastic waste in bitumen = a saving of 0.6% of bitumen by weight in roads. Negligible extra cost for far better infrastructure.

Economic considerations:

It has been found that modification of bitumen with shredded waste plastic marginally increases the cost by about Rs.2500 per ton. However this marginal increase in the cost is compensated by increase in the volume of the total mix, thereby resulting in less overall bitumen content, better performance and environmental conservation with usage of waste plastic. When the life of a road is doubled, then the savings that accrue to the national exchequer are in thousands of crores. Segregating the plastic from the MSW at the municipal yard involves the application of resources, the cost of which runs into crores of rupees. A substantial amount of this can be saved. The Central Government's annual allocation of funds towards roads and highways is approx. 35 thousand crores. Lab tests and real-time tests have revealed that the life expectancy of a plastic polymer road as compared to a normal road is at least 100% more In addition to the savings accrued at the central level, every state Municipal Solid Waste Management would save crores of rupees by eliminating the plastic segregation process at its yards.

VI. CONCLUSION

The generation of waste plastics is increasing day by day. The major polymers 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. Foe example if all the roads in India (3.3 million km) are converted into plastic tar road, all the waste plastic available will be used on the road and the disposal of waste plastics will no longer be a problem.But as the burning of plastic waste creates health hazards and also air pollution, the use if this should be restricted to open areas or in lesser populated areas. Also; the workers involved should be provided with proper safety devices. These processes are socially highly relevant, giving better infrastructure. Let us grow with these newer technologies.

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