A NOVEL APPROACH TO IMPROVE ROAD QUALITY
BY UTILIZING PLASTIC WASTE IN ROAD CONSTRUCTION

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ABSTRACT

Every year, around 500 billion plastic bags are used worldwide. Over one million bags are being haphazardly disposed every minute and they are damaging our environment. Yet, precious little has been done to recycle, re-use and disposal of non biodegradable plastic waste. Plastic bags are difficult and costly to recycle and therefore mostly end up on landfill sites where they take around 300 years to photo degrade. As a result, several state governments including Delhi had put a ban on the use of plastic bags. But if we are concerned about energy and its conservation, plastic bags is the best option for packaging. We can manage plastic waste, consisting of carry bags, cups and other packing containers by using it for road construction after their disposal. Use of plastic bags waste in road construction is a potential field for the use and scientifically disposal of these industrial waste polymers into roads instead of banning their use or resorting to non-environment friendly methods like burning, landfills etc. The main focus of this paper is to review and discuss plastic as packaging material and the feasibility and hurdles of incorporating postconsumer plastic waste in urban and rural areas. Already developed technologies on utilization of waste plastic for construction of roads in four metros (Bangaluru, Delhi, Bombay and Calcutta) are the basis of implementing these technologies in urban and rural areas. Plastic modified bituminous road surfacing will be first of its kind in Haryana state. Laboratory test results show the improvement in engineering properties like Marshall stability, retained stability and indirect tensile strength of modified bituminous mixes as compared to unmodified bituminous mixes irrespective to the three different approach adopted as elaborated in the on-going text. The findings elaborated in this paper can also serve as the base for the use of other wastes from the industry in road technology on which the research is already in progress.

Key Words: Modified bitumen, Post consumer plastic waste, Construction, Road construction, Landfills

INTRODUCTION

The availability of the waste plastics is increasing day by day, as the plastic materials have become part and parcel of daily life. Every year, around 500 billion plastic bags are used worldwide¹. So many that over one million bags are being every minute and they are damaging the environment. India’s plastics consumption is one of the highest in the world. Yet, precious little has been done to recycle, re-use and dispose of plastic waste. Plastic bags are difficult and costly to recycle and mostly end up on land sites where they take around 300 years to photo degrade. This is the reason state government is trying to put a ban on the use of plastic bags. If we are concern about energy and its conservation. Plastic bags are the best option for packaging. There are number of reasons to choose plastic as packing material. These are:

1. Plastic bags consume far less energy for its manufacturing process than a paper bag.
(Energy to produce plastic bags is 594 BTUs while for the same quantity of paper bag is 2511 BTUs).

2. Plastic bags are generally thin and light in weight and have low shipping requirements. Seven trucks of paper bags to deliver and the same quantity of plastic bags requires only one truck of same capacity. It not only reduces road traffic and pollution but also reduces fuel consumption.

3. Use of plastic bags saves the forests (i.e. renewable but exhaustible energy resources).

4. It is more eco-friendly because it causes 70% less air and water pollution than paper bags during manufacturing. Hence saves energy.

5. It takes 91% less energy to recycle a pound of plastic than it takes to recycle the same quantity of paper.

6. Foamed polystyrene containers take only 70% of the energy to make paperboard containers.

7. Burning of municipal solid waste (MSW) or garbage is an important source of generating energy. The heat thus generated is used to produce steam and electricity, and is called ‘Waste to Energy’ (WTE) facilities. Comparative table of the heat energy that can be obtained by burning various MSW in special combustion chambers: (Table 1)

It shows that plastics have high fuel value because of its organic nature.

Without plastics, the energy used to produce packaging material would double. A study conducted in 1992 elaborated that by using plastic packaging rather than alternative such as glass, paper or metal, American manufactures saved 336 trillion BTU. This difference is equivalent to 58 million barrels of oil, 325 billion cubic feet of natural gas or 32 billion pounds of Coal.

Now, the question arises Why plastic waste becomes nuisance? The answer is its improper management by the authorities and this single reason is not enough to put a ban on plastic material specially packaging bags.

**Improper management of plastic waste**

The disposal of plastic waste, especially Municipal Solid Waste containing plastics is carried out mainly by Land filling and Incineration methods.

**Land filling** : It is a process in which the waste materials are buried in a specific area, away from the city. This process is purely temporary. This may result in

1. Affecting water recharge,
2. Reducing soil microbial activity,
3. Clogging the drainage and
4. Water line clogging

Such clogging may result in the production of gases like methane, which affects Green House effect. Above all, land availability for filling is also a problem.

**Incineration** : It is normally carried out above 700 degree C. Incineration of polymers like PE, PP, PS produces gases like CO, CO₂ etc. and these gases cause global warming, air pollution, monsoon failure etc. If PVC is mixed with the waste, it may result in the production of HCl, Cl₂ and sometimes in Dioxin, the poisonous and carcinogenic gas. Incineration could also aggravate pollution problem, if strict standards are not enforced. This process also needs scientific monitoring.

**Table 1 : Heat energy obtained by boring various MSW**

<table>
<thead>
<tr>
<th>Type of MSW</th>
<th>Heat Energy btu/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed MSW</td>
<td>4,800</td>
</tr>
<tr>
<td>Mixed paper</td>
<td>6,800</td>
</tr>
<tr>
<td>Mixed Plastics</td>
<td>14,100</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>17,800</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>19,850</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>19,900</td>
</tr>
</tbody>
</table>

On the other hand, the steady increase in high traffic intensity in terms of commercial vehicles, the increase in over loading of trucks and the significant variation in daily and seasonal temperature demand improved road characteristics. The improvement of some kind in the property of the binder is the need of the hour.

**Effective utilization of waste plastic in bituminous mixes for road construction and maintenance**

The waste plastics can be good modifier for the bitumen used for the road construction. Like the virgin polymers (PE, PP, and PS), waste plastic also shows adhesion property in its molten state,
besides improving hardness (softening point of bitumen, viscosity, etc) and strength and rut resistance of bituminous mixes. Thus, the use of innovative technology not only improves the road quality but also their durability in terms of road life as well as save the environment deterioration.

**AIMS AND OBJECTIVES**
The main objective of adding waste plastic (polymer) to binders for asphalt mixes is to improve resistance to deformation by increasing the binder and mix stiffness and by enhancing their elastic behavior, rut, fatigue and fretting resistances. These can be incorporated as an individual or mixed plastic waste into the conventional bitumen to yield waste plastic modified bitumen (WPMB) or directly in bituminous concrete mixture (WPMB-MIX) resulting in durable and high strength modified bitumen mixture as compared to the conventional mixture without additive.

**METHODOLOGY**
Three different possible processes to incorporate waste plastic into bituminous mixes are:

**Dry Process**
A generic dry process technology was developed in the late 1980’s to early 1990’s to produce dense graded hot mixtures. This concept uses both coarse and fine Crum rubber to match aggregate grading and to achieve improved binder modification. The Crum rubber may need a pre-reaction or pre treatment with catalysts to achieve optimum particle swelling. In this system rubber content does not exceeded 2% by weight of total mixture for surface courses. Experimental pavement sections have been used in Florida, New-York, Oregon and Ontario. Similarly waste plastic is added to hot aggregates to get Plastic Coated Aggregates (PCA). Optimum quantity of Bitumen is then added to produce WPMB-MIX. A particle size 1mm to 3mm of waste plastic in shredded or powder form is preferable for commercial production of mix and field trials have successfully been completed in India in several Metro cities including Bangaluru and Delhi.

**Wet process**
Waste Plastic along with other additives is melted and stirred in hot bitumen around 150 degree C using a high shear mixer to produce WPMB which is then added to hot aggregates to produce Modified Bituminous Mixes. The process has been patented by Central Road Research Institute, Delhi and the process is yet to be commercialized. The field trials are also required to validate the process.

**Semi wet process**
As waste plastic is miscible in bituminous phase in hot melt condition and get separated from bituminous phase on cooling WPMB to ambient temperature. But, some of the plastics in the mixed waste stream do not melt completely and remains disperse in spite of adding additives. Partially Modified Bitumen containing waste plastic particles is then used to coat the hot aggregates to produce Waste Plastic Modified Bituminous Mixes. The undissolved plastic acts as a cushion aggregate in modified mixes at ambient temperature to service temperature as during recycling process plastics are toughened with colorants dyes and other fillers, chemical and inert additives, as a result improving their softening, melting and glass transition temperatures. This process is preferred over wet process to have the dual benefit of plastic waste i.e. as a modifier to bitumen and as a cushion aggregate for better inter locking of aggregates. This process is also under validation.

**Design of bituminous mixes for dry process**
The processed plastic is used as an additive with heated bitumen and mixed thoroughly with a blender to obtain modified bitumen, but the plastic could not be blended in the bitumen due to its low specific gravity and non-uniform size. Hence waste plastics are added to heated aggregates and mixed before adding bitumen. This may be called as modified bituminous mix. Waste plastics are added in different proportions (0-12 % by weight of Bitumen) at optimum binder content of the conventional mix and found that 8% of waste plastics by weight of bitumen are found to be optimum to improve the volumetric properties of bituminous mix. Further studies on BC mixes are carried out using the waste plastics and different proportions of conventional 60/70 grade bitumen. The optimum quantity of waste plastic is 8 per cent by weight of bitumen (0.4% by weight of
RESULTS AND DISCUSSION

Dry process

Marshall stability test: The Marshall Mix design is conducted on mixes with and without waste plastics to arrive at the optimum binder content. The samples are prepared using conventional 60/70 grade bitumen and the volumetric studies were conducted on the mixes. It is observed that the mix with waste plastics had lesser density as compared to conventional bituminous mix; this is because of the low specific gravity of waste plastics.

The Marshall stability of the mix with addition of 8% plastics is 1.5 times higher than the mix without plastics in one of the case study. (Fig. 1)

Retained stability

The samples are prepared at optimum binder content to study the Marshall criteria and also to evaluate the ability of the BC mix to withstand adverse soaking condition under water, Marshall stability tests are conducted after soaking the specimen in water at 60°C for 24 hours. The Marshall stability (Kg) percentage retained stability obtained for mixes with and without waste plastics shows that mixes with addition of plastics are least affected by water as these retained more than 95% Marshall Stability(strength) against 85% for conventional bituminous mix. (Fig. 2)

Indirect tensile strength

The indirect tensile strength of bituminous mixes with waste plastics is found to be 1.54 times higher than without waste plastics at 25°C (Fig. 3).

Fatigue life of the mix

Beams are prepared to study the fatigue behavior under repetitive loadings and it is observed that the fatigue life is doubled under laboratory condition at 25°C by adding 8% waste plastics by weight of bitumen and fatigue life of the mix are found to be more than 2 times higher as compared to bituminous without waste plastics.
Rutting depth

Rutting resistance is also studied using Hamburg Wheel Tracking Device (HWTD). HWTD was originally designed in Hamburg, Germany, and is widely used for the evaluation of rutting of bituminous mixes. Usually a steel wheel rolls across the surface of Hot-Mix Asphalt (HMA) specimens that are submerged in water at 40°C. A standard test applies a maximum number of 20,000 passes. Failure is defined as rut depth of 20 mm. (Fig. 4).

Fig. 4 : Bulk density

![Graph showing bulk density]

The dry process can be used for hot mix asphalt paving in dense graded, open graded, or gap graded mixtures. It cannot be used in other asphalt paving applications, such as cold mix and chip seals or surface treatments.

Economics of plastic waste management

Major benefits

Major benefits achieved in Bangaluru and other southern states using plastic roads include:

- Processed plastic cost six rupees a kg while bitumen costs Rs 14 per kg in 2002. There is no resultant pollution, as plastics are not burnt but only melt. Road strength is twice as strong as normal roads. It has resistance towards water stagnation. No potholes are formed. No extra machinery is required. In Delhi, in 2007-08, processed Plastic (shredded or powder form) cost 28 rupees a kg while bitumen costs Rs 34 a kg for laying 3.5 Km. six lanes road stretch.

- How much plastic? how many roads?

Each 5-member family’s uses about 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 average 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).

Cost parameters

The details given in Table 1, Table 2, Table 3 and Table 4.

<table>
<thead>
<tr>
<th>Item/Technology</th>
<th>Cost</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen (60/70)</td>
<td>Rs.34,071/-per tonne</td>
<td>–</td>
</tr>
<tr>
<td>Waste plastic modifier</td>
<td>Rs.2400 per 80 Kg.</td>
<td>8 % of 1 tonne=80 Kg.</td>
</tr>
<tr>
<td>Total cost of binder</td>
<td>Rs.36,471/-per tonne</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 1 : The data was collected in June 2008

Table 2 : The cost component

<table>
<thead>
<tr>
<th>Item/Technology</th>
<th>Cost</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMB-40</td>
<td>Rs.42625/tonne</td>
<td>–</td>
</tr>
<tr>
<td>CRMB-60</td>
<td>Rs. 37168/tonnes</td>
<td>–</td>
</tr>
</tbody>
</table>

Waste minimization and infrastructure improvement

India spends Rs 35,000 crores a year on road...
Table 3: The cost comparison of bituminous binder’s w.r.t. P.M.B., CRMB and waste plastic technology is as given below

<table>
<thead>
<tr>
<th></th>
<th>PMB</th>
<th>Binder cost for waste plastic technology</th>
<th>Cost saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Rs.42,625/tonne</td>
<td>Rs.36471/tonne</td>
<td>Rs.6154/tonne</td>
</tr>
<tr>
<td>CRMB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Rs.37,168/tonne</td>
<td>Rs.36471/tonne</td>
<td>Rs.697/tonne</td>
</tr>
</tbody>
</table>

Table 4: The comparison between plastic road overlay containing plastic and without plastic (conventional bituminous road)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Properties</th>
<th>Plastic road</th>
<th>Conventional bituminous road</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Marshall stability value</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>2.</td>
<td>Binding property</td>
<td>Better</td>
<td>Good</td>
</tr>
<tr>
<td>3.</td>
<td>Softening point</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>4.</td>
<td>Penetration value</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>5.</td>
<td>Tensile strength</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>6.</td>
<td>Rutting</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>7.</td>
<td>Stripping(pot holes)</td>
<td>Low(No)</td>
<td>High(Yes)</td>
</tr>
<tr>
<td>8.</td>
<td>Seepage of water</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>9.</td>
<td>Durability of the road</td>
<td>Better</td>
<td>Good</td>
</tr>
<tr>
<td>10.</td>
<td>Cost of pavement</td>
<td>Less</td>
<td>Normal</td>
</tr>
<tr>
<td>11.</td>
<td>Maintenance cost</td>
<td>Almost Nil</td>
<td>More</td>
</tr>
</tbody>
</table>

construction and repairs, 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. 8% plastics waste by weight of bitumen in bituminous mixes a saving of 0.4% of bitumen by weight in roads. Negligible extra is required cost for far better infrastructure.

CONCLUSION
1. No toxic gas is produced as the maximum temperature to coat the aggregates is 150-160 degree C in technology related to dry process of plastic waste utilization.
2. Disposal of waste plastic will no longer be a problem.
3. Binding properties of polymer also improve the strength of bituminous mixes.
4. The use of waste plastics on the road has helped to provide better place for burying the plastic waste without causing disposal problem. At the same time, a better road is also constructed.
5. It also helps to avoid the general disposal technique of waste plastics namely land-filling and the incineration, which are certainly a burden on ecology.
6. The addition of waste plastic modifier in bituminous road construction (Dry process) also increases the volume of total mix as the
waste plastic modifier is added as an extra item to the whole mix, thus contributing much more strength and service life to the roads. Comparison between the properties of plastic roads and ordinary (conventional bituminous) roads is given in the Table 4.

REFERENCES
4. Packaging without plastics, ecological and economic consequences from a packaging material market without plastics, The society for research into the packaging market (Germany), (1992).