Guidelines on use of Plastic Waste in Road Construction (Provisional)

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Works Directorate

Research Design and Standards Organization, Lucknow - 226011.

अनुसंधान अभिकल्प एवं मानक संगठन लखनऊ— 226011.
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Guidelines on use of waste plastic in hot bituminous mixes (dry process) in wearing courses

1.0 Introduction:

1.1 Safe disposal of waste plastic is a serious environmental problem. Being a non-biodegradable material it does not decay over time and even if dumped in landfills, finds its way back in the environment through air and water erosion, can choke the drains and drainage channels, can be eaten by unsuspecting grazing animals causing them illness and death, can contaminate the construction fill, etc. The best way of disposal of waste plastic is its recycling to the maximum extent and many developed countries have recycled waste plastics to manufacture various products, including some used in heavy construction, e.g. railway sleepers.

1.2 Studies have revealed that waste plastics have great potential for use in bituminous construction as its addition in small doses, about 5-10%, by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous mix, leading to improved longevity and pavement performance. The use of waste plastic thus contributes to construction of green roads.

1.3 Depending on their physical properties, they may be classified as thermoplastic and thermosetting materials. Thermoplastic materials can be formed into desired shapes under heat and pressure and become solids on cooling. On subjected to the same conditions of heat and pressure, they can be remolded. Thermosetting materials which once shaped cannot be softened/remolded by the application of heat. The examples of some typical Thermoplastic and Thermosetting materials are tabulated in Table 1. **Thermosetting materials are not used in pavement construction.**

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Typical Thermoplastic and Thermosetting Resins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastic</td>
<td>Thermosetting</td>
</tr>
<tr>
<td>Polyethylene Terephthalate (PET)</td>
<td>Bakelite</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>Epoxy</td>
</tr>
<tr>
<td>Poly Vinyl Acetate (PVA)</td>
<td>Melamine</td>
</tr>
<tr>
<td>Poly Vinyl Chloride (PVC)</td>
<td>Polyester</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>Urea- Formaldehyde</td>
</tr>
<tr>
<td>Low Density Polyethylene (LDPE)</td>
<td>Alkyd</td>
</tr>
<tr>
<td>High Density Polyethylene (HDPE)</td>
<td></td>
</tr>
</tbody>
</table>
1.4 Plastics can also be classified according to their chemical sources. According to sources of plastic, there are six general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibers. Table 2 gives the source of waste plastic generation. Only plastic conforming to Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), PET and Polyurethane shall only be used in pavement construction.

<table>
<thead>
<tr>
<th>Waste Plastic</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Density Polyethylene (LDPE)</td>
<td>Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.</td>
</tr>
<tr>
<td>High Density Polyethylene (HDPE)</td>
<td>Carry bags, bottle caps, house hold articles etc.</td>
</tr>
<tr>
<td>Polyethylene Teryphthalate (PET)</td>
<td>Drinking water bottles etc.</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>Bottle caps and closures, wrappers of detergent, biscuit, wafer packets, microwave trays for readymade meal etc.,</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>Yoghurt pots, clear egg packs, bottle caps.</td>
</tr>
<tr>
<td>Foamed Polystyrene</td>
<td>food trays, egg boxes, disposable cups, protective packaging etc.</td>
</tr>
<tr>
<td>Polyvinyl Chloride (PVC)</td>
<td>Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc.</td>
</tr>
</tbody>
</table>

1.5 There are two processes namely dry process and wet process for manufacturing bituminous mixes using waste plastic. In the dry process, processed waste plastic is added after shredding in hot aggregates where as in the wet process, processed waste plastic in the form of powder is added in the hot bitumen.

2.0 Background

The H-2 Committee in its meeting held on 15th June, 2012 decided to formulate guidelines for waste plastic Bitumen and entrusted this task to Dr. Sunil Bose. Accordingly, Dr. Sunil Bose prepared the initial draft and submitted to H-2 Committee in March, 2013.

Thereafter, H-2 Committee deliberated on this draft in a series of meetings. The H-2 Committee finally, approved the draft document in its meeting held on 17th June 2013.
The Highways Specifications & Standards Committee (HSS) approved the draft document in its meeting held on 9th July, 2013. The Council in its 200th meeting held at New Delhi on 11th and 12th August, 2013 approved the draft "Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses" after taking on board the comments offered by the members.

This guideline (IRC:SP:98-2013) deals with the specifications and use of waste plastic in wearing course using dry process, their advantages, application, manufacturing, transportation, storages, and quality testing requirements.

3.0 Advantages and limitation of using waste plastic as modifier and binder:
Laboratory as well as field performance studies/investigations carried out in India (in Tamilnadu, Karnataka and Delhi) identifies following advantages in using waste plastic in bituminous mixes.

- Higher resistance to deformation.
- Higher resistance to water induced damages.
- Increased durability and improved fatigue life.
- Improved stability and strength.
- Disposal of waste plastic and thereby environment friendly.

However following need to be ensured in order to achieve the advantages of laid down specifications;

- The material shall consist of only low density polyethylene (LDPE) or high density polyethylene (HDPE), PU (available in limited quantity as waste) and PET.
- Black coloured plastic waste is a result of repeated recycling and should not be used.
- **PVC shall not be used since they release lethal levels of dioxines.**
- The Thermo Gravimetric Analysis (TGA) of thermoplastics has revealed gas evolution and thermal degradation may occur beyond 180°C. Thus misuse or wrong implementation of this technology may result in release of harmful gases, premature degradation, if the temperatures are not maintained during construction.

4.0 Materials:

4.1 Bitumen:
The bitumen for bituminous mixes for wearing course with waste plastic shall comply with the Indian Standard Specifications for viscosity graded paving bitumen IS 73. Guidelines for selection for grade of viscosity graded paving bitumen shall be in accordance with the IRC: 111-2009.

4.2 Aggregates:
4.3 **Filler:**
The filler for dense graded mixes shall comply with IRC: 111-2009.

4.4 **Waste Plastic:**
- The waste plastic shall conform to the size passing 2.36 mm sieve and retained on 600 micron sieve.
- Dust and other impurities shall not be more than 1 percent. The process is indicated in **Annexure-1**. An easy method to determine the quantity of impurity is to determine the ash content at 600°C.
- To ascertain the ability of plastic to mix with the binder, the melt-flow value shall be tested as per ASTM D 1238-2010, for which the range shall be as follows:
  - For LDPE: 0.14-58 gm/10 min
  - For HDPE: 0.02-9.0 gm/10 min

5.0 **Design of Mix:**
The requirements for waste plastic modified design and open graded mixes are as follow:

5.1 **Dense Graded Mixes:**
The properties for dense graded mixes are indicated below:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum stability (kN at 60°C)</td>
<td>12.0</td>
</tr>
<tr>
<td>Minimum flow (mm)</td>
<td>2</td>
</tr>
<tr>
<td>Maximum flow (mm)</td>
<td>4</td>
</tr>
<tr>
<td>Marshall Quotient (kN/mm)</td>
<td>2.5-5</td>
</tr>
<tr>
<td>Compaction level (Number of blows)</td>
<td>75 blows on each of the two faces of the specimen</td>
</tr>
<tr>
<td>Per cent air voids</td>
<td>3-5</td>
</tr>
<tr>
<td>Retained Stability (%)</td>
<td>98</td>
</tr>
<tr>
<td>ITS (min) MPa</td>
<td>0.9</td>
</tr>
<tr>
<td>VMA</td>
<td>16</td>
</tr>
<tr>
<td>VFB</td>
<td>65-75</td>
</tr>
<tr>
<td>Quantity of Waste Plastic % by weight of bitumen</td>
<td>6 to 8 depending on low rainfall or high rainfall areas</td>
</tr>
</tbody>
</table>

5.2 **Open Graded Mixes:**
Waste Plastic @ 6 to 8 percent of the weight of the bitumen can be used for Open-Grade Premix Surfacing and Mix Seal surfacing mix. Quantity of bitumen can be reduced correspondingly.
6.0 MANUFACTURING OF BITUMINOUS MIX USING WASTE PLASTIC:

The scope of the guidelines IRC: SP: 98-2013 is restricted to dry process only for the following reasons;

- Plastic is coated over stones - improving surface property of aggregates.
- Coating is easy & temperature required is same as road laying temp.
- Use waste should be 6-8 percent by weight of bitumen depending on the climatic conditions of high and low rainfall areas.
- Flexible films of all types of plastics can be used.
- Doubles the binding property of aggregates.
- No new equipment is required.
- Bitumen bonding is stronger than normal.
- The coated aggregates show increased stability of the mixes.
- Better performance after construction based on the experience gained for medium level city traffic.
- No evolution of any toxic gases as maximum temperature is 180°C.

6.1 Dry Process
In order to ensure that the quality of the finished waste plastic product is consistent the following process must be adhered to before considering its use in bituminous construction:

a) Collection of waste plastic
b) Cleaning and shredding of waste plastic
c) Shredding Machine
d) Mixing of shredded waste plastic, aggregate and bitumen in central mixing plant

7.0 CONSTRUCTION
Construction operation shall be in accordance with the IRC: 111-2009, IRC: 14-2004, IRC: 11 0-2005 and IRC: SP: 78-2008 for dense graded and open graded mixes respectively.

8.0 CONTROLS
Controls shall be in accordance with the IRC: 111-2009, IRC: 14-2004 and IRC: 110-2005 and IRC: SP: 78-2008 for dense graded and open graded mixes respectively. Besides, plastic shall be tested for impurity and melt flow value. Three sample be tested for each day work or when there is change in the source of plastic.

9.0 Method of Road Laying.

Dry process is recommended for isolated works. It is recommended that the percentage of shredded waste plastic will be 8% by CRRI, while the same is specified as 10% by Dr. Vasudevan (Dr. R. Vasudevan of Thiagarajar College of Engineering, (TCE), Madurai). However, we can adopt 8% as the optimum plastic
content for blending the bitumen in the construction of plastic roads. The details of the process are given below. Bitumen of grades 60/70 or 80/100 can be used as binder as in case of conventional method.

**With Mini Hot Mix Plant**
The stone aggregate mix (as per specification) is transferred to the mix cylinder where it is heated to 165°C (as per the IRC specification) and then it is transferred to the mixing puddler (Temperature can be monitored using Infrared thermometer), while transferring the hot aggregate into the puddler, calculated quantity of shredded plastics is sprayed over the hot aggregate within 30 seconds. The sprayed plastic films melts and gets coated over the aggregate, thus forming an oily coating.

Similarly, the bitumen is to be heated to a maximum of 160°C in a separate chamber and kept ready (The temperature should be monitored to have good binding and to prevent weak bonding).

At the mixing puddler, the hot bitumen is added over the plastic coated aggregate and the resulted mix is used for road construction. The road laying temperature is between 110°C to 120°C. The roller used is normal 8-ton capacity.

**For intensive works Central Mixing Plant can also be used.** The operating Techniques for this are given below:

The aggregate materials will be transferred to the cylinder through the conveyer belt.

- The shredded plastics will be sprayed over the aggregate while it is moving in the conveyer belt.
- The spraying is done by manual labors standing up on both side of the conveyer belt of the central mixing plant.
- The addition of plastics should be done quantitatively.

The amount of binder to be added is calculated and monitored:
- In the central mixing plant, at the control room the addition of bitumen is monitored.
- It is easy to know the amount of bitumen sprayed per minute inside the cylinder.

Amount of plastic to be added is @8% of bitumen.

For example if the bitumen quantity per minute is 10Kg, the plastic need to be added is 0.8 Kg. i.e. (A bucket can be used which can hold 0.8 Kg at a time)

Now, as the aggregate moves in the conveyer belt, the shredded plastics, taken in the bucket are sprayed with a speed of 0.8 Kg/min with suitable mechanical device or manually.
In manual method, one person will be adding the shredded plastic on to the conveyer belt. In the mean time another person will keep ready another bucket full of plastics so that the addition of plastics will be continuous. Thus manual labor can also be so chosen that the addition is done continuous. Two or three labors will be on this work of addition of plastics.

As the plastics is added over the aggregate, the mix (aggregate and plastics) moves into the cylinder.

As the stone is heated the plastic films get melted over the heated stone and get coated. Slowly the plastics coated aggregate moves forward where this polymer coated aggregate is mixed with bitumen. The polymer coated aggregate bitumen mix is then transferred to the dipper.

Advantages of Central Mixing Plant:

1. Mixing of the plastics over the aggregate is uniform.
2. The coating is better and the mixing of bitumen is being carried out at places like:
   a. Inside the Cylinder
   b. During loading in the dipper.
   c. During transferring the mix in the paver
   d. During the spreading of the mix by the paver

Hence better distribution takes place in the Central Mixing Plant Process.

9.1 Salient feature of the process.

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

10.0 Economic considerations.

It has been found that modification of bitumen with shredded waste plastic marginally increases the cost by about Rs. 10.26 per sqm. 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.
11.0 Facilitation for using Waste Plastic in Roads Construction:

M/s K. K. Poly Flex Pvt. Ltd., 86/C, Y.V. Annaiah Road, Yelachenahalli, Kanapura road, Banglore- 560078 and M/s Arun Enterprises, Chennai (28, First Reddy Street, Ekkatuthangal, Chennai -600097, Website: www.arunpla.com) is involved in shredding the waste plastic. M/s S.K. Polymer, New Delhi has been given the technical know how by CRRI for modifications to be done in the portable mini mixing plants for mixing pre calibrated quantity of shredded waste plastic for dry processing. The details of the assistance can be obtained from M/s S.K. Polymers, E-146, Pandav Nagar, Patpargunj, Delhi-110091.

References:

1.0 Guidelines for the use of waste plastic in hot bituminous mixes (dry process) In wearing courses (IRC: SP: 98-2013) issued by Indian Road Congress.

2.0 Guidelines for the use of Plastic Waste in Rural Roads Construction issued by National Rural Roads Development Agency, Ministry of Rural Development, Govt. of India.
WASTE PLASTIC COLLECTION & PROCESSING

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 programmes, or by purchase from rag pickers or waste-buyers.

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.

c) **Shredding machine:**
   Plastic waste which is cleaned is cut into a size between 2.36 mm and 600 microns and of maximum size 2.36 mm length and 2.00 mm width using a shredding machine.

d) **Mixing of shredded waste plastic, aggregate and Bitumen in Central mixing Plant:**
   The aggregate mix is heated to 140-175°C in Central mixing plant. The requisite percentage of waste plastic to the weight of bitumen is injected with a pipe under compressed air in the drum of a drum mix plant through a pipe at 2/3 length of the drum or through an opening over the pugmill in the case of a batch mix plant. The waste plastic initially coats the heated aggregates.

   In the next stage bitumen is added to the aggregates, the temperature of the binder shall conform to the temperature depending on the grade of binder and the type of mix. The plastics waste coated aggregate is mixed with hot bitumen for 15 sees and the resulting mix transported for road construction.

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

e) **Laying of bituminous mix:**
   The road laying temperature is between 110°C to 120°C for waste plastic bituminous mix. The roller used can be of any specified capacity.

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