GUIDELINES FOR THE USE OF WASTE PLASTIC IN HOT BITUMINOUS MIXES (DRY PROCESS) IN WEARING COURSES



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1. INTRODUCTION

1.1 In view of the Prime Ministers Swaach Bharat Mission the H-2 Committee was asked to revise the guidelines for waste plastic in bituminous mixes for incorporation of this technology in National Highways and entrusted this task to Dr. Sunil Bose. Accordingly, Dr. Sunil Bose prepared the initial draft along with Dr. Sridhar Raju and submitted to H-2 Committee in 23rd November, 2019. Thereafter, H-2 Committee deliberated on this draft and suggested a number of modifications which were accordingly considered in a series of meetings.

Member details etc. to be added by IRC.

- **1.2** Safe disposal of plastic waste is a serious environmental problem. Being a nonbiodegradable 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.
- **1.3** Prevalent recycling rate of waste plastic in India.

Current impetus of the GOI under Swachh Bharat mission for promoting reduce, recycle and reuse of plastics as per directives of the Honourable Prime Minister it has become mandatory to recycle waste plastic. Rigid plastic waste is r3ecycled to greater extent since it fetches value across the supply chain. Despite the best efforts of GOI and NGOs, considerable fraction of plastic waste ends up as litter on land and water bodies. This plastic waste is almost always in the form of thin and light weight end-of-life plastic packaging films. The use of such waste plastic in roads would be an excellent way to reuse end-of-life plastics while also improving the quality of roads.

1.4 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 resulting studies after publication of the earlier 2013 edition of this code indicated that it may also be used for National Highways as well as State Highways with use of waste plastic thus contributes to construction of green roads.

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.

Thermoplastic	Thermosetting
Polyethylene Teryphthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy
Poly Vinyl Acetate (PVA)	Melamine
Poly Vinyl Chloride (PVC)	Polyester
Polystyrene (PS)	Polyurethane
Low Density Polyethylene (LDPE)	Urea - Formaldehyde
High Density Polyethylene (HDPE)	Alkyd

Table. 1 Typical Thermoplastic and Thermosetting resins

1.4 Polymers can also be classified according to their chemical sources. According to sources of plastic, there are four 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 confirming to Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), PET and Polyurethane shall only be used in pavement construction. PVC, PET and Polyurethane not to be used. However all types of waste plastics cannot be used for road construction.

Waste Plastic	Origin
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.,
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal 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

Table 2. Waste Plastic & its Source

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 in appropriate physical form like shredding or in the form of pellets in hot aggregates to ensure efficient and accurate addition of plastic without affecting its functionality. But in the wet process, processed waste plastic in the form of powder is added in the hot bitumen.

2. SCOPE

The scope of the code is to provide guidelines for

- i. Specifications of waste plastic to be used for making open and dense graded wearing course as per the dry process
- ii. Implementation of the dry process for making bituminous mixes
- iii. Transportation and storage of bituminous mixes using waste plastic
- iv. Laying of roads with bituminous mixes using waste plastic
- v. Quality testing of roads made from bituminous mixes containing waste plastic

3. ADVANTAGES AND LIMITATION OF USING WASTE PLASTIC AS MODIFIER AND BINDER

Laboratory as well as field performance studies/investigations carried out in India (Annex1) based on the previous edition confirmed the following advantages in using waste plastic in bituminous mixes. The findings indicated that waste plastic may also be used for National Highways and State Highways and ODR's. The results confirmed the following

laboratory findings:

- a) Higher resistance to deformation.
- b) Higher resistance to water induced damages.
- c) Increased durability and improved fatigue life.
- d) Improved Stability and strength.
- e) Disposal of waste plastic and thereby environment friendly.

In order to ensure the advantages the waste plastic should meet the specification mentioned in the next section.

The material shall consist of only low density polyethylene (LDPE) or high density polyethylene (HDPE), PU (available in limited quantity as waste) and PET.

In addition the following need to be ensured in order to achieve the desired specifications:

- 1. Black coloured plastic waste is a result of repeated recycling and should not be used.
- 2. PVC shall not be used since they release lethal levels of dioxines.
- 3. The Thermo Gravimetric Analysis (TGA) analysis 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. 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 (2013). Guidelines for selection for grade of viscosity graded paving bitumen shall be in accordance with the IRC 111-2009 for dense mixes and IRC 110-2005.

4.2 Aggregates

The aggregates shall comply with IRC 111-2009, for dense graded mixes, IRC 14-2004, IRC SP:78-2008 and IRC 110-2005 for open graded mixes respectively.

4.3 **Filler**

The filler for dense graded mixes shall comply with IRC 111-2009.

4.4 Waste Plastic

Waste plastic shall conform to the specifications stated in Annex-2 and may be purchased only from suppliers who can provide guarantee for its performance in making bituminous mix.

- The waste plastic shall confirm 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 Annex 2. 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 as under shall be tested as per ASTM D 1238-2010

For LDPE: 0.14-58 gm. /10 min For HDPE: 0.02-9.0 gm. /10 min

5. DESIGN OF MIX

There are two types of designs of mixes namely, dense graded mix and open graded mixes. The requirements for designs of mixes to be used with waste plastics are as follows:

5.1 Dense graded wearing course mixes.

The properties for dense graded mixes are indicated in Table 3. For NH and other heavily trafficked highways, the use of waste plastic can be considered as a bitumen extender and not as bitumen replacement and hence the durability of the roads will increase. The plastic added roads will become brittle if the bitumen is reduced and hence the optimum bitumen shall not be reduced with use of waste plastic. Laboratory studies carried out at CRRI have shown that the use of waste plastic will help in moisture and rut resistant mixture but to increase fatigue life the optimum bitumen content of BC mixtures with and without waste plastic had to be the same. The waste plastic mixture has to be prepared at a temperature of 170 deg C to get better coating on the aggregates otherwise the plastic requires more bitumen to coat so round itself.

 TABLE 3. Requirements for waste plastic modified dense graded bituminous pavement

 layers

Minimum stability (kN at 60°C)	12.0			
Minimum flow (mm)	2			
Maximum flow (mm)	4			
Marshall Quotient (kN/mm)	2.5-5			
Compaction level (Number of	75 blows on each of the two faces of			
blows)	the specimen			
Per cent air voids	3 – 5			
Retained Stability (%)	ained Stability (%) 90			
Or				
Retained ITS (min) MPa	90			
VMA	15			
VFB	65-75			
Quantity of Waste Plastic % by	6 to 8 depending on low rainfall or high			
weight of bitumen	rainfall areas			

5.2 Open graded Mixes

Waste Plastic @ 6 % to 8 % of the weight of the bitumen can be used for Open-Grade Premix Surfacing and Mix Seal surfacing mix.

6. MANUFACTURING OF BITUMINOUS MIX USING WASTE PLASTIC

The scope of the present guidelines is restricted to dry process only for the following reasons;

- Waste plastic is coated over aggregates to improve their surface property and provide increased bonding with bitumen.
- Coating is easy & temperature required is same as road laying temp.
- Use waste should be 6-8% by weight of bitumen depending on the climatic conditions of high and low rainfall areas.

- Specifications of waste plastic must be as per section 4.4 and Annex-2. The quantity of waste plastic to be added must be as per Section 5.
- Waste plastic is to be added to the aggregate in the same equipment that is used to manufacture bituminous mixes.
- Suitable waste plastic feeding protocols and/or accessories may be used to dose appropriate amounts as mentioned in section 5.
- Better performance after construction based on the experience gained for medium level city traffic has given enough indication for excellent for its improved performance on National Highways.
- 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 (Annex1) 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
- Mixing of shredded waste plastic, aggregate and Bitumen in Central mixing Plant.
 For low volume roads the practice of manually adding waste plastic may be continued.
 However for National Highways for large scale use in the long run in future the following modifications are suggested:
 - i. To ensure that the quality of the waste plastic is consistent, section 4.4 and Annex -2 should be strictly adhered to. Specifications for the quantity of waste plastic to be used in bituminous mixes as given in section 5 must be strictly adhered to.
 - ii. Dry mixing:
 - a. The aggregate mix is heated to 150-175°C in a central mixing plant. The requisite percentage of waste plastic as specified in section 5 is added in the drum of a drum mix plant with an appropriate dosing system such as for example, using compressed air to pneumatically convey the waste plastic through a pipe at an appropriate location inside the drum mix plant so that the waste

plastic is not subjected to very high heat near the flame of the burner. The waste plastic must coat the heated aggregates before going to the next stage where bitumen is added to the aggregates.

- b. The temperature of the binder shall conform to the temperature depending on the grade of binder and the type of mix.
- c. The plastics waste coated aggregate is mixed with hot bitumen at a temperature of 150 deg C to 170 deg C for about 15 secs and the resulting mix transported for road construction.
- d. 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.
- iii. Laying of bituminous mix: The road laying temperature is between 130°C to 160°C
 for waste plastic bituminous mix. The roller used can be of any specified capacity.

Alternately the plant may modified with an inbuilt attachment for National Highways as follows:

Working Principal

Waste Plastic has to be transferred to charging hopper and with the help of special screw and metering system, the required quantity of plastic will be charged on hot aggregates in the drum in case of Parallel and counter flow drum mix plant and charging into the mixer or pug mill in case of batch mix plant. The complete system in both the cases should be fully automatic with the exact consumption of waste plastic displayed in the operating system and with the facility of printout. The plastic waste shall contain only the permissible plastic of polyethylene grade and shall not contain harmful volatile matters with vaporizing point lower than mix temperature.

Description

Waste plastic will be metered through either frequency controlled rotary valve or screw and will have digital display in the control panel will be blown and mixed into hot aggregate followed by bitumen insertion in to dryer in case of parallel and counter flow drum mix plant and into the mixer or pug mill with heated aggregates for uniform coating and dry mixing. In case of Batch Mix plants as per IRC Guidelines.

7. CONSTRUCTION

Construction operation shall be in accordance with the IRC 111-2009, IRC 14-2004, IRC 110-2005 and IRC SP: 78-2008 for dense graded and open graded mixes respectively. The construction of dense mixes shall be carried out as Section 5.1 of IRC 111-2009. The mix temperature shall be maintained as indicated in Section 6.2 (ii) and (iii).

8. CONTROLS

Controls shall be in accordance with the IRC 111-2009, IRC 14-2004, 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.

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Sunil Bose, Raju Sridhar, "Utilization of Waste Plastic in Bituminous Concrete Mixes", New Building Materials & Construction World, Vol 9 Issue-8, Feb 2004, pp 8-13. The project has been undertaken by Lucknow Development Authority (LDA), which will construct a road using plastic waste, stretching from Gomti Nagar Police Station to Indian Institute of Management (IIM), Lucknow

Chennai: While the plastic roads may be a new concept in many parts of India, Chennai has been experimenting with it since 2011. Chennai has used nearly 1,600 tonnes of plastic waste to construct 1,035.23 kilometres length of roads in recent years, which include N.S.C Bose road, Halls road, Ethiraj Silai Street and Sardar Patel Street.

Pune: Using bitumen technology on waste plastic, the Pune Municipal Corporation constructed a 150-metre stretch of Bhagwat lane at Navi Peth near Vaikunth Crematorium in 2016. The other trial patches in Pune include Dattawadi Kaka Halwai Lane, Katraj Dairy, Magarpatta City HCMTR Road, Kavde Mala Road, Koregaon Park Lane No 3 and Yeravada Sadal Baba Darga Road from Chandrama Chowk.

Jamshedpur: Jamshedpur Utility and Services Company (JUSCO), which is a subsidiary company of Tata Steel, constructed a 12-15 kms road in the steel city as well as Tata Steel Works using plastic road, including a nearly 1km stretch in Ranchi, 500m stretch each in Dhurwa and Morabadi, 3km of roads in Chas and Jamtara each and 500m stretch in Giridih.

Indore: Dating 2014, the Madhya Pradesh Rural Road Development Authority (MPRRDA) has constructed around 35 km of roads in 17 districts with plastic waste.

Case studies in India

- In Tamil Nadu, length of roads around 1000 m in various stretches were constructed using waste plastic as an additive in bituminous mix under the scheme "1000 km Plastic Road", and found that, the performance of all the road stretches are satisfactory.
- The performance of the road stretches constructed using waste plastic in Bangalore (Karnataka) also found to be satisfactory. More than 2000 km have been laid so far.
- In Delhi a number of test sections about 50 km were laid in Delhi and most of them are performing well.
- Around the country several sections have been laid under PMGSY.

Type of waste plastic suitable for bituminous surfacing:

- 1. Waste plastic may be collected by/via aggregators
- 2. Waste plastic will typically have a mix of rigid plastic waste and flexible plastic waste. Rigid plastics are those products that are rigid (firm when held) and whose shape does not easily change during usage. Rigid plastics should not be used for making wearing courses.
- 3. Cacogenic material should not be used.
- 4. Flexible packaging is any package or any part of a package which is thin, pliable while handling and whose shape can be readily changed during usage. Broad categories of flexible packaging are films, bags, pouches, liners and overwraps. Only flexible packaging waste is to be used for building wearing course. Common examples of flexible packaging and recommendation on whether they can be used for building wearing courses are given in Table below. Some examples of flexible packaging products that can be used in making wearing courses are also given pictorially below.

Examples of flexible packaging	Recommendation for use
	in wearing course
Flexible pouches/stand-up pouches/zip-lock pouches/ heat-sealed bags made from multi-layer packaging (MLP) films or single layer/ transparent packaging (SLP) films that are used to package food items, clothes, personal care and daily-use products, .chips-biscuit packings etc.	Recommended
Flexible carry bags, shopping bags, non-woven bags, trash bags	Recommended except for black bags/films.
Courier bags, bubble wrap films, air-bubble pouches, gift wrap films, big bag liners, agricultural mulch films	Recommended
Stretch film for wrapping pallets/boxes, shrink-wrap films for wrapping boxes	Recommended
Flexible labels of bottles, containers	Recommended only if they are not made from PVC
Products such as file covers, folders, diary covers, flexi- posters, mobile covers, electrical insulation tapes, adhesive tapes, confectionary twist wrap, photo album covering films, playing cards	Not recommended since PVC and/or high melting polymers are widely used to manufacture these items
Pharmaceutical strips for drugs/blister packaging	Not recommended since PVC is widely used to manufacture these items



Diverse types of flexible packaging



Food packaging



Carry bags

Non-woven bags



Single layer/transparent film for food packaging

Bubble wrap packaging film



Shrink-wrap films

Zip-lock bags

Bag liners

- 5. PVC must be removed from the flexible plastic waste since it is not allowed for use in making bituminous mix. Heating of PVC in central mix plants can cause release of acid vapours (that can corrode the equipment) and also other toxic chemicals (that are hazardous). Removal of PVC can be achieved by the following means
 - Visual segregation: Items such as bubble wrap films, flexi-posters, container labels, mobile covers, insulation tapes, stationary products such as files, folders, diary covers, etc, confectionary twist wrap, photo album covering films, playing cards, laptop bags, wallet, louvers, membership cards etc are made from PVC and must not be incorporated into the waste plastic that is to be used for road making.
 - Flotation: The single layer/transparent film remaining after PVC removal must be subjected to floatation in water. Plastic which sinks should not be selected for use in roads. Films that float in water may be accepted.
- 6. The waste plastic selected for use in road may also be converted into other forms such as shredded or agglomerates and pellets, which are easier to feed into bituminous mix plants. The size of these forms of plastic shall be determined based on their ability to fully melt and coat the aggregates during the process time of the bituminous mix plants.

Processing details:-

- a. collection of waste plastic
- b. cleaning and shredding/palletization of waste plastic
- c. mixing of shredded/pellets of waste plastic/, aggregate and bitumen in central mixing plant
- d. 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 by purchase from rag-pickers or waste-buyers



Fig 1. Collection of Waste Plastic

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 2. Cleaning process

c) Shredding Machine

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



Fig 3. Shredding machine

d) Mixing of shredded waste plastic, aggregate and Bitumen in Central mixing Plant for National Highways

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 mill 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 secs 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.



Fig 4. Central mixing plant

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 capacity.