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

(First Revision)

INDIAN ROADS CONGRESS
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3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

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

1. INTRODUCTION

1.1 Safe disposal of waste plastic is a serious environmental concern. Being a non-biodegradable material, waste plastic does not decay with time and even if dumped in land-fills, finds its way back into the environment. Indiscriminate disposal of waste plastic causes choking of drains and drainage channels and contamination of construction fill. India generates about 26,000 tonnes per day (9.4 million tonnes per annum) of plastic waste [1]. Approximately about 60% of the plastic is recycled and more than 9,400 tonnes of waste plastic is used for landfills or ends up polluting water streams.

1.2 Taking cognizance of the fact that disposal of waste plastic is a serious environmental concern and also of the need for recycling of waste plastic material in different ways including its use in pavement construction, the Indian Roads Congress published IRC:SP:98 "Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses" in the year 2013 [2]. While there are two processes; dry and wet, for addition of waste plastic to bituminous mixes, IRC:SP:98 covers only the dry process in which processed waste plastic is added in appropriate physical form (shredded), to hot aggregates. On the other hand, in the wet process, waste plastic, in powder or other suitable form, is blended with bitumen to produce modified bitumen.

1.3 A number of laboratory investigations were conducted by different research groups in different countries including India [3-18] on bituminous mixes prepared by adding waste plastic in dry process. The mixes were prepared using different types of waste plastic materials added in dry process either individually or in combination and with different proportions of waste plastic. The mixes were evaluated for one or more of the following mechanical and performance characteristics of the mixes:- Marshall stability, flow and Marshall quotient, fatigue and rutting characteristics and moisture damage resistance. The beneficial effect of adding waste plastic to the mixes has been reported by the research groups.

1.4 Different agencies such as National Rural Roads Development Agency, Ministry of Housing and Urban Affairs, Central Pollution Control Board [19-24], discussed in their reports about the practice of using waste plastic in dry process in bituminous mixes and prepared guidelines for the implementation of the technology which are based partly or completely on the guidelines contained in IRC:SP:98-2013 [2]. Similarly, a number of field pavements, having wearing courses containing waste plastic added in dry process, are reported [25-26] to have better overall performance compared to pavement sections having similar mixes without waste plastic. The available experience about construction of surface mixes using waste plastic and the performance of such roads indicate that there is potential for more wide spread use of waste plastic (in dry process) in different categories of highways including state highways and national highways. **Annex-A** gives a list of projects implemented in India in which waste plastic was added to bituminous mixes in dry process. The Flexible Pavement, Airfield & Runways Committee (H-2) also took note of the emphasis being placed currently on environmental sustainability and the possibility of a significant increase in the use of waste plastics for road construction in low as well as high traffic volume roads.

1.5 In view of the above, the H-2 Committee of IRC felt the need to revise IRC:SP:98 guidelines for more wide-spread use of waste plastic in bituminous mixes for different categories of roads. The results of different laboratory investigations conducted by the Central Road Research Institute and other academic institutions, the inputs available about the performance of different bituminous pavement sections constructed using bituminous mixes in which the waste plastic material was added to the hot aggregates in dry process and the more detailed technical inputs available about the suitability or otherwise of different types of waste plastic material, were utilized for drafting this first version of the guidelines. The task of revising the document was entrusted to Dr. Sunil Bose who, along with Dr. Sridhar Raju, prepared the initial draft. The draft was deliberated in various meetings of H-2 Committee and was finalized in its meeting held on 23.11.2019.

The composition of H-2 Committee is given below:

Reddy, Prof. (Dr.) K. Sudhakar	.....	Convenor
Nirmal, Sanjay Kumar	.....	Co-Convenor
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Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

The draft document was placed before the Highways Specifications and Standards Committee (HSS) in its meeting held on 06.12.2019. The HSS Committee decided that Co-Convenor, H-2 Committee will modify the document suitably based on written comments and verbal comments offered during the meeting and submit the final document to IRC for placing in the Council meeting. The Executive Committee (EC) in its meeting held on 19.12.2019 approved the draft document for placing before the Council. The 219th Council in its meeting held on 19.12.2019 at Patna, Bihar considered and approved revision of IRC:SP:98 "Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses" for printing subject to revision based on written comments received and comments offered during the meeting. Thereafter, meeting was convened by the Convenor, H-2 Committee alongwith the members of the drafting group on 16.07.2020 to incorporate compliance of the comments in the document. The Convenor, H-2 Committee sent the final modified document and the same was published.

2. SCOPE

2.1 The scope of the document is to provide guidelines for

(a) Selection of waste plastic material to be used for making open and dense graded wearing courses as per the dry process

(b) Practical implementation of the dry process for producing bituminous mixes

(c) Quality testing of roads made from bituminous mixes containing waste plastic and

(d) Safety measures to be taken for processing the materials

2.2 These guidelines cover the process of dry addition of selected waste plastic material in different hot bituminous mixes used in the surface layers such as open-graded pre-mix carpet covered by IRC:14-2004 [27], mix seal surfacing/close-graded premix surfacing for which specifications are given by IRC:SP:78-2008 [28] and dense graded bituminous mixes specified by IRC:111-2009 [29], for different categories of roads i.e. other district roads, major district roads, state highways, national highways and urban roads and excluding expressways and long-life pavements.

3. MATERIALS

3.1 Bitumen

The bitumen used for different wearing course bituminous mixes shall comply with the Indian Standard Specifications for viscosity graded paving bitumen IS:73-2013 [30]. The guidelines for

selection of grade of viscosity shall be in accordance with the Indian Roads Congress guidelines [27-29].

3.2 Aggregates

The aggregates shall comply with provisions of the Indian Roads Congress guidelines relevant for the surface mix considered [27-29].

3.3 Filler

The filler for dense graded mixes shall comply with IRC:111-2009 [29].

3.4 Waste Plastic

3.4.1 Depending on their physical properties, plastics may be classified as thermosetting and thermoplastic materials. The thermosetting plastic materials, such as Bakelite, Epoxy, Melamine, Polyester, Polyurethane, Urea-Formaldehyde, Urea-Formaldehyde, Alkyd etc., once shaped, cannot be softened or remolded by the application of heat. Hence, thermosetting waste plastic materials shall not be used for dry process addition (considered in these guidelines) in bituminous mixes. Thermoplastic materials can be repeatedly softened by heating and hardened by cooling. **Table 1** gives the list of some thermoplastic waste materials, their typical waste sources and whether they are recommended in these guidelines for addition in bituminous mixes in dry process. Besides their proven beneficial effects, when added to bituminous mixes in dry process, the waste plastic materials considered for addition to bituminous mixes should not emit toxic gases and should melt at or below typical mixing temperatures. As can be seen from **Table 1**, only Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) waste plastic materials are recommended in these guidelines for use in pavement construction by dry process.

Table 1 Typical Thermoplastic Waste Plastic Materials

Thermoplastic Type	Origin	Recommended for use in Bituminous mixes in Dry Process?
Low Density Polyethylene (LDPE)	Carry bags, Sacks, Milk pouches, bin lining, cosmetic and detergent bottles	YES
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.,	YES
Polyethylene Terephthalate (PET)	Drinking Water Bottles etc.,	NO
Polypropylene (PP)	Bottle Caps and Closures, Wrappers of detergent, biscuit wrappers, microwave trays for readymade meal etc.,	NO
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps, foamed polystyrene, food trays, egg boxes, disposable cups, protective packaging, etc.,	NO

Thermoplastic Type	Origin	Recommended for use in Bituminous mixes in Dry Process?
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutter; electrical fittings, furniture, folders and pens, medical disposable, etc.,	NO

3.4.2 Black coloured waste plastic is a result of repeated recycling and shall not be used. Particular care should be taken to ensure that the waste plastic does not contain Polyvinyl Chloride (PVC) since it releases lethal levels of dioxins at high temperatures. Thermoplastic materials are likely to emit gases and may undergo thermal degradation at temperatures higher than 180°C. Thus, it is essential to ensure that the waste plastic is not heated to more than 180°C temperature under any circumstance.

3.4.3 Dust and other impurities, measured in terms of ash content as per Annex C of IS:14535-1998 [31], shall not be more than 1.0 percent (by weight of plastic).

3.4.4 For satisfactory coating of the aggregates and mixing with hot bitumen, the melting point temperature of the plastic material, measured as per ASTM D 7138-16 [32], shall be less than 170°C.

3.4.5 The waste plastic shall be shredded to have plastic shred sizes ranging between 2.36 mm and 600 microns with a maximum length of 2.36 mm and a maximum width of 2.00 mm.

3.4.6 Besides satisfying different requirements mentioned in this clause (3.4), consideration shall also be given to the guidelines given in **Annex-B**.

4. DESIGN OF MIXES

4.1 The use of waste plastic in dry process is recommended in these guidelines for certain surface (thick or thin) bituminous courses used for different categories of roads. Some of these surface mixes are designed for determining their design binder contents while for the other mixes, which are recipe mixes, Indian Roads Congress provides guidelines for selection of aggregate and binder types and the quantities of different materials to be used.

4.2 The quantity of waste plastic material to be added to the aggregates, for all types of mixes considered in these guidelines, is 8.0 % by weight of bitumen.

4.3 Dense Graded Wearing Course Mixes

The dense graded surface course mixes, designed as per the procedure given by MS-2 of Asphalt Institute [33] for preparation and analysis of specimens and tested as per ASTM D 6927 [34] using 102 mm (4 inches) diameter specimens, shall satisfy the requirements given in **Table 2**. The waste plastic mixture has to be prepared at a temperature of 170°C to get better coating on the aggregates; otherwise, the plastic requires more bitumen to coat around itself. The optimum (design) bitumen content of dense bituminous wearing mixes, prepared by addition of selected proportion (8 % by weight of bitumen) of waste plastic in dry process, shall be arrived

at by designing the mixes to satisfy the mix specifications given in **Table 2**. No further reduction shall be made in the bitumen content arrived at as per mix design.

Table 2 Specifications for Waste Plastic Modified (Dry Process) Dense Graded Bituminous Mixes

Test Condition/Mix Parameter	Specification
Compaction level (Number of blows)	75 blows on each of the two faces of the specimen
Marshall Stability (kN at 60°C), Minimum	12
Marshall Flow (mm)	2 to 4
Marshall Quotient (Stability/flow, kN/mm)	2.5 to 5
Air Voids (%)	3 to 5
Voids in Mineral Aggregates (VMA, %), Minimum	15
Voids Filled with Bitumen (VFB, %)	65 – 75
Retained Marshall Stability (%), Minimum **OR** Retained Indirect Tensile Strength (Tensile Strength Ratio, %)	90 90
Quantity of Waste Plastic (% by weight of bitumen)	8

4.4 Close and Open Graded Thin Surface Mixes

The selection of aggregate gradation and binder type and binder quantity for open-graded premix carpet [27] and mix seal surfacing/close-graded premix surfacing [28] will be as per relevant Indian Roads Congress guidelines. No further reduction shall be made in the bitumen content selected for these two mixes as per the relevant Indian Roads Congress guidelines.

5. PRODUCTION OF WASTE PLASTIC BITUMINOUS MIXES

5.1 In order to ensure that the quality of the finished waste plastic product is consistent, the guidelines given in **Annex-B** for collection, segregation, cleaning and processing (shredding) of waste plastic, mixing of shredded waste plastic with aggregates and addition of bitumen in central mixing plants and mini hot mix plants, must be adhered to. The conventional equipment and machinery used for manufacture of conventional bituminous mixes can be used for producing the mixes in which waste plastic is added in dry process. Suitable waste plastic feeding protocols and/or accessories may be used to dose appropriate quantities of waste plastic.

6. CONSTRUCTION OPERATIONS

6.1 The construction operations shall be carried out in accordance with relevant provisions of Indian Roads Congress guidelines [27-29] and as per relevant clauses of Ministry of Road Transport and Highways [35].

6.2 The following additional precautions will be required for using waste plastic in bituminous mixes in dry process.

(a) Safety masks must be provided to all workers in the Hot Mix Plant and at the laying site.

(b) Waste plastic bituminous mix should be rejected if found to have oversized plastic.

(c) Care should be taken to ensure that the waste plastic should consist of only the two identified types of waste plastic materials (LDPE and HDPE).

(d) Waste plastic, when heated to high temperatures, causes air pollution and micro-plastics through run-off water contaminating soil and water bodies and the environmental effects. Hence care should be taken to handle the material in a judicious manner and to ensure strict control of the temperatures of mixing and heating.

7. CONTROLS

7.1 The frequency of testing and acceptance criteria shall be in accordance with relevant provisions of Indian Roads Congress guidelines [27-29] and as per relevant clauses of Ministry of Road Transport and Highways [35]. Each new source of waste plastic material shall be tested for purity (clause 3.4.3) and melting point temperature (clause 3.4.4).

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Annex-A
(Para 1.4)

LIST OF SOME PROJECTS IN WHICH WASTE PLASTIC MATERIAL WAS USED IN DRY PROCESS IN SURFACE BITUMINOUS MIXES

The technology of addition of waste plastic in dry process to surface bituminous mixes has been successfully implemented in India in a number of road projects, most of which are low volume commercial traffic village and urban roads. A list of some of the roads/projects in which waste plastic was utilized is given below.

- In Tamil Nadu, waste plastic was utilized in surface mixes of different stretches of roads whose total length is more than 1000 km. This was implemented under "1000 km Plastic Road" scheme. The pavements are reported to perform satisfactorily.
- The performance of the road stretches constructed using waste plastic in Bangalore (Karnataka) was also found to be satisfactory. More than 2000 km length of road was constructed using waste plastic (dry process) bituminous wearing course.
- In Delhi, in a number of test sections, whose total length is about 50 km, waste plastic was used and most of them are performing well.
- National Rural Infrastructure Development Agency (NRIDA) has constructed over 13,139 km of roads using waste plastics. The performance of these roads has been rated as excellent by the quality monitors.
- The R-85 research project sponsored by the Ministry of Road Transport and Highways on the use of waste plastics in SDBC mixes laid on the test track on NH-207, has reported excellent performance of waste plastic in bituminous mixes.
- Lucknow Development Authority (LDA) has undertaken the rehabilitation of the road from Gomti Nagar Police Station to Indian Institute of Management (IIM), Lucknow in which waste plastic is proposed to be used in surface bituminous mix.
- Nearly 1,600 tonnes of waste plastic was used in the city of Chennai to construct 1,035 km length of roads in recent years, which include N.S.C Bose road, Halls road, Ethiraj Silai Street and Sardar Patel Street.
- Using the technology of use of waste plastic in bituminous mixes, the Pune Municipal Corporation constructed a 150-metre stretch of Bhagwat lane at Navi Peth near Vaikunth Crematorium in 2016. The other trial stretches 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 Utility and Services Company (JUSCO), which is a subsidiary company of Tata Steel, constructed a 12-15 km road in the steel city as well as in Tata Steel Works using plastic road, including a 1 km stretch in Ranchi, 500 m stretch each in Dhurwa and Morabadi, 3 km length of roads in Chas and Jamtara each and 500 m stretch in Giridih.
- Madhya Pradesh Rural Road Development Authority (MPRRDA) constructed about 35 km of roads in 17 districts with waste plastic.

Annex-B
(Para 3.4.6)

WASTE PLASTIC TYPES SUITABLE FOR USE IN BITUMINOUS SURFACES MIXES (IN DRY PROCESS) AND THEIR PROCESSING FOR PREPARATION OF MIXES

Different aspects related to the types of waste plastic to be considered for use in bituminous wearing course mixes, their processing, preparation of mixes using waste plastic and construction of surface (wearing) courses using mixes containing waste plastic are covered in this Annex.

B.1 Selection of Waste Plastic type for use in Bituminous Mix

In addition to the specifications and requirements laid down in Clause 3.4 of these guidelines, the following shall be considered for selecting the type of waste plastic to be used in the surface course mixes in dry process.

B.1.1 Carcinogenic material shall not be used.

B.1.2 Waste plastic usually consists of a typical mix of rigid waste plastic and flexible waste plastic. 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 producing bituminous mixes by dry process

B.1.3 Only flexible packaging waste material shall be used for preparing bituminous mixes by dry process for surface mixes. 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. Common examples of flexible packaging products are given below.

- 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 for packaging food items, clothes, personal care and daily-use products, chips-biscuit packings etc.
- Flexible carry bags, shopping bags, non-woven bags, trash bags. Black bags/ films should not be used.
- Courier bags, bubble wrap films, air-bubble pouches, gift wrap films, big bag liners, agricultural mulch films.
- Stretch film for wrapping pallets/boxes, shrink-wrap films for wrapping boxes.

B.1.4 Special care should be taken to remove PVC from the flexible waste plastic since heating of PVC in central and batch mixing plants can cause the release of acid vapours (that can corrode the equipment) and also other toxic chemicals (that are hazardous). Segregation and removal of PVC from waste plastic can be achieved by the following means:

- Visual segregation: Items such as bubble wrap films, flexi-posters, container labels, mobile covers, insulation tapes, stationery items such as files, folders, diary covers, etc., confectionary twist wrap, photo album covering films, playing cards, laptop bags, wallet, louvers, membership cards etc. are generally 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. The plastic material which sinks should not be selected for use in roads. Films that float in water may be accepted.

B.1.5 As mentioned in clause 3.4 of these guidelines, only LDPE and HDPE based waste plastic products shall be used for preparing bituminous mixes in dry process.

B.2 Processing of Waste Plastic

B.2.1 The general guidelines laid down in Central Pollution Control Board (CPCB) Plastic Waste Management Rules -2016 [21] and Plastic Waste Management (amendment) rules-2018 [23] shall be followed by the agencies involved in the generation, collection and recycling of waste plastic.

B.2.2 For lists of agencies/institutions/transaction advisors/PROs empanelled by various authorities/departments including Ministry of Urban Development, Central Pollution Control Board, NHAI and some additional identified private vendors actively involved in plastic waste management competent enough to supply processed waste plastic material and/or provide necessary technical support, may be identified.

B.2.3 The waste plastic selected for use in the bituminous mix may be shredded for feeding it 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 processing time of the bituminous mix plants.

B.2.4 The collection and processing of waste plastic has the following main steps:

- ***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.
- ***Cleaning and shredding of waste plastic:*** The waste plastic material is sorted, de-dusted and washed, if necessary.
- ***Segregation of waste plastic:*** It is essential to separate the waste plastic from the solid waste by different mechanical techniques detailed in the report of Ministry of Housing and Urban Affairs [1] such as air classifier method (Zig Zag separator used for separation of light films or contaminating paper/foil, or for separating fine dust from reclaimed material such as plastic flake or other granular materials), air tabling technique (which is a density concentration technique in which particles of mixed sizes, shapes, and densities are separated from each other due to the differential settling in an upward airflow with controllable velocity and under the influence of a vibrating action), ballistic separator, dry and wet gravity separation (sink-Float tank test in which different types of plastics are separated based on their density), froth floatation (often used to clean mixed plastics and for highly contaminated films), electrostatic separation (in which negatively charged particles gravitate towards the positively charged plate and vice-versa) and other sensor based separation technologies.

The LDPE and HDPE recommended for use in these guidelines can easily be segregated from other forms of waste plastics through visual identification of the plastic products made using LDPE and HDPE. **Table 1** gives a list of typical commercial products made out of different types of plastic. Sink-float test, which makes use of the differences in the densities of different plastics for segregation, can be used to segregate different types of plastics. For example, if the shreds of a mixture of waste plastic are placed in a container having water, LDPE (densities 0.91 to 0.95) and HDPE (densities 0.93 to 0.97) having densities less than 1.0 will float and the shreds of heavier plastics such as Polyethylene Terephthalate (PET) (density 1.27 to 1.60), Polyvinyl Chloride (PVC) (density 1.15 to 1.70) and Polystyrene (PS) (density 1.04 to 1.5) whose average densities are more than 1.0 are expected to sink.

- ***Shredding of waste plastic:*** The waste plastic, which is cleaned, is cut into small shreds of size ranging between 2.36 mm and 600 microns with a maximum length of 2.36 mm maximum width of 2.00 mm using a suitable shredding machine.

B.3 Mixing of Shredded Waste Plastic, Aggregate and Bitumen in Central and Mini Hot Mixing Plants

B.3.1 The aggregates are heated to 140-175°C temperature in the central mixing plant. The requisite quantity of waste plastic material in shredded form, estimated as proportion (by weight) of bitumen, is introduced slowly into the drum of a drum mix plant. In the case of central mixing plants, waste plastic is injected into the drum through a pipe under pneumatic pressure (compressed air) at a position which is at two-third the length of the drum or through an opening over the pug mill in the case of a batch mix plant. The duration of exposure of waste plastic to hot aggregates shall be 25 to 30 seconds. In this stage, the waste plastic coats the heated aggregates. In the next stage, bitumen is added to the aggregates with the temperature of the binder conforming to the mixing temperature selected depending on the grade of binder and the type of mix. The aggregates coated with waste plastic are mixed with hot bitumen for 15 seconds and the resulting mix is transported for road construction.

B.4 Laying of the Bituminous Mix

B.4.1 The laying temperature for the waste plastic bituminous mix shall be between 110°C to 120°C. The roller used can be of any capacity.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

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