International Journal of Engineering Research
Volume No.6, Issue No.2, pp :91-94

ISSN:2319-6890 (online),2347-5013(print)
1 Feb. 2017

Utilization & Specification of Plastic Waste in Bituminous Roads

Somesh Jethwani, Shubham Ashish Jha , Dheeraj Sangtiani
Medi-caps Inst. of Science & Tech. ,B.E. Civil Engg.
somesh.jethwani02@gmail.com , shubhamjha1795@gmail.com , dheerajsangtiani15@gmail.com

Abstract :Plastic is used in abundance by population in day-to-day to life. This engenders significant non-biodegradable waste. Since, plastic bags, wrappers, and other lamination plastic takes around 30 years to decompose completely, it is crying need to decompose such pestilent material with ever increasing population and waste. Moreover, burning plastic produces PCBs which are dioxins and lethal to environment and living. Dioxins are persistent organic pollutants which remain in the environment for a long time due to their strong chemical structure. Reusing plastic waste can be an affordable way out. Using plastic waste in road construction not only solves the decomposing of waste but rather improves binding strength and quality of roads. Roads with plastic increase durability by two folds and show resistance to water retention. This paper intends to create awareness and introduce various aspects for better utilization of plastic for betterment of road construction.
Keywords:Shredded plastic, flexible pavement, aggregates, polyethylene terephthalate (PET), flexible pavement, bitumen

1. INTRODUCTION

Plastic's properties make it a protean material [1]. With the increase in the variety of ways it can be used, led to its industrial revolution which further accounted for growth of all vital sectors of economy ranging from packaging, construction, agriculture, communication etc. But this necessary evil does not decompose easily and various researchers have estimated that it can be on our planet for about 4500 years without degradation. Furthermore inadequate disposable of plastic or incineration can be an invitation for various hazardous health problems like breast cancer, reproductive problems, genital abnormalities and various hygiene problems [2]. Its use in road construction not only helps disposal process but generates better quality roads. Plastic like PP, PS, PE used in disposal glasses, PET Bottles, covers of various appliances and handbags are most appropriate to be used in road construction as they have a same softening point as that of bitumen, that is, 160C [3]. Plastic materials are first segregated and washed and then shredded into small pieces. After that Bituminous mixes were processed with 60/70 bitumen and plastic coated aggregates with cement as a filler material [4]. It is important to maintain required temperature and time for optimum results. Such roads show 100% increase in their strength, better resistance to water stagnation, reduced potholes, rutting and raveling on roads by increasing binding strength property and Marshall Stability value. Such eco-friendly roads serve dual profit to developing countries like India by the curing problem of disposal of plastic and by providing better quality roads.

2. GENERATION OF PLASTIC WASTE

As per a report by Central Pollution Control Board (CPCB) Indian population produces 15,342 tons of plastic every day. Out of this 9,205 tons was reports to be recycled, rest is littered [5]. CPCB along with CIEPT, Ahmadabad carried out a study on "Quantification of Plastic waste generation in 60 Major cities (2010-12)" in the country. The results showed the generation of 3501 tons per day of plastic waste in these cities. Around 3.10% to 12.47% of Municipal solid waste (MSW) was plastic [6].
For a road of 1 Km which is 3.75m wide, 1 ton of plastic waste is used. A country with a second largest road network of over 5 million kilometres and still constructing new roads can save the environment and generate high-quality roads if the use of plastic waste in road construction is taken seriously under consideration.

2.1 PLASTIC AND ITS TYPES

Any synthetic or semi-synthetic organic polymer is called plastic. Though plastics may just about any organic polymer, almost all industrial plastic is made from petrochemicals. The name "plastic" refers to the property of plasticity, which is the ability to deform without breaking [7].

Plastic can be broadly classified as:

2.1.1 Thermosetting polymers

These polymers are also known as thermo sets, which solidify into a permanent shape. They are amorphous and have infinite molecular weight.

2.1.2 Thermoplastics

These plastics can be remolded again. Thermoplastics are usually amorphous, while other has a partially crystalline structure. They have a molecular weight between 20,000 to 500,000 amu.

2.1.3 Examples of plastic:

a) polyethylene terephthalate - PET or PETE
b) high-density polyethylene – HDPE
c) polyvinyl chloride – PVC
d) polypropylene – PP
e) polystyrene – PS
f) low-density polyethylene – LDPE [9]

2.1.4 SPECIFICATIONS

1. PLASTIC

Allowable types of plastic waste for road construction:

1) Films plastic mostly used for the formation of Carry Bags & Cups. Required thickness up to 60micron.

 ISSN:2319-6890 (online),2347-5013(print)
1 Feb. 2017

2) Hard foams are also allowable without any limit i.e. any thickness.
3) Soft Foams are also allowed with a thickness of any limit.
4) Laminated Plastics are also used in this with a limitation up to 60 microns (Aluminium coated also).

NOTE: Poly Vinyl Chloride (PVC) sheets or Flux sheets should not be used in any case.

Also, waste plastic should be free from dust and shredded, preferably 2-3 mm particle size. While CRRI specified that the shredded waste plastic should pass through 3 mm sieve. For better spread and coating of aggregates, optimum waste plastic size should be 2-3 mm.

2. AGGREGATES

Aggregates can be either artificial or natural. Aggregates can be further classified as coarse aggregates like crushed rocks, gravels, and fine aggregate. Blast furnace's by-product called blast furnace slag is widely used as road construction material.
Coarse aggregate used for road construction should be hydrophobic to the bituminous surface. Other than this it should be hard, tough and durable. Gravels should not have fineness modulus of less than 5.75 and should be well graded (6.4mm to 38mm). Sand should be well graded and free from organic matter, silt and clay.
The amount of aggregate used in two coats of surface dressing is as follows:-
First coat: 0.15-meter cube per 10-meter square area of 12mm nominal size.
Second coat: 0.15-meter cube per 10-meter square area of 10mm nominal size [8].

3. BITUMEN

PMC states that bitumen content in the mix should be 4% (by weight) of the total mix. Bitumen grades can be industrial (which includes waterproofing) or pave grade (grading used for pavement structures). In India, 60/70 and 180/200 of bitumen are usually used. Often, choice of the grade depends on environment conditions of the area.
For first coat: 17 to 195 kg of bitumen per 10 meters square of the area is needed.
For second coat: 10 to 12 kg of bitumen per 10-meter square area is needed [8].

3. PREPARATION OF PLASTIC-WASTE COATED AGGREGATE

The plastic waste is shredded between 2.36mm and 4.75mm and added over to hot aggregate which was heated around 170C. This gives uniform distribution of plastic over aggregates as plastic gets soften and form a coat around aggregate. The resultant coated aggregate is mixed with bitumen 60/70 or 180/200 grade [10].

3.1 PLASTIC AGGREGATE BITUMEN INTERACTION MODEL

As shredded plastic is added over the hot bitumen it forms a thin coating of plastic around aggregate. This coating remains in the softening state in 140C to 160C. At this temperature, bitumen is added and both plastic and the bitumen are in a liquid state which enables easy diffusion. With both being in the liquid state increases the surface area which helps in the interaction process. Both bitumen and plastic are long chain hydrocarbons. Bitumen is a complex mixture of maltenes and asphaltenes. As soon as bitumen was added to aggregate a quantity of bitumen diffuses through plastic layer causing its bonding with aggregate. The aggregate was already bonded with plastic. This result in a 3-D bonding between polymers of plastic, bitumen, and aggregate. This bond is considerably strong and is very difficult to break [11].

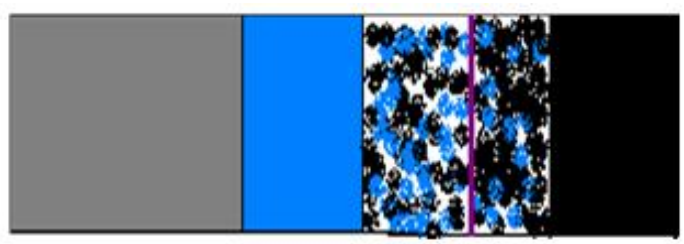

Fig.1: Plastic Bitumen Interaction Model

4. BASIC PROCESS & METHODOLOGY

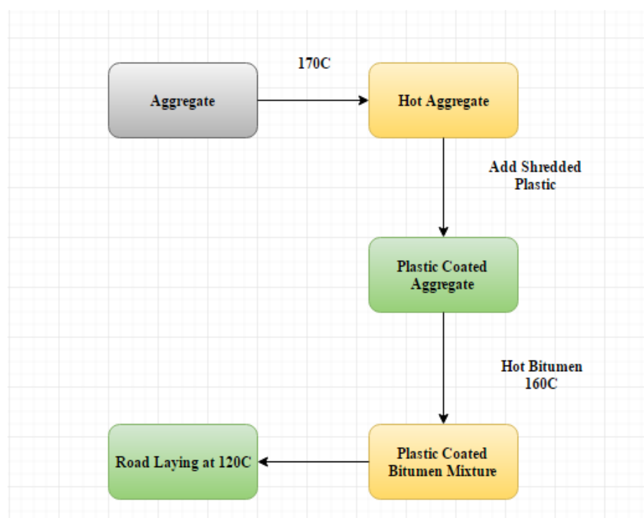

Fig. 2: Dry Process

All plastic waste is collected from streets and industries. These plastics are then properly segregated, eliminating PVC. Further, these are washed to remove impurities. Plastic once
Washed are then kept to dry and shredded by shredding machine which converts them in small pieces of 3-4 mm. The aggregate is heated at 170C and then plastic is added to it.
Plastic melts and forms an oily coat over aggregates. Simultaneously bitumen is heated at 160C and then mixed with plastic coated aggregates. Road laying is done at 120C.

ISSN:2319-6890 (online),2347-5013(print)
1 Feb. 2017

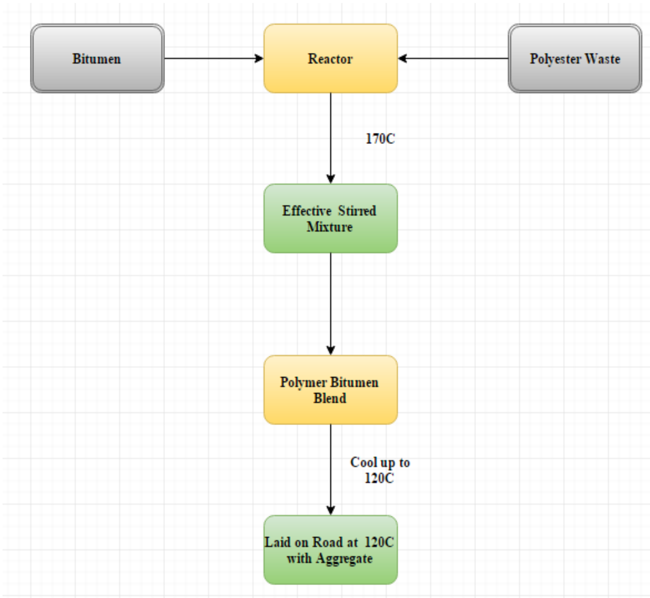

Fig. 3: Wet Process

In the wet process, we mix shredded plastic and bitumen before our final modified road. Flow chart shows the wet process of modification of bitumen. Plastics are swelled and degraded from polymerization and devulcanization by absorbing more volatile compounds from bitumen. This chemical process produces effective binding between plastic and bitumen.

Various factors affecting rate of reaction are-

a) The temperature during mix (more the temperature; faster is the reaction).
b) Size and characteristics of plastic used (rougher and smaller the plastic; faster is the reaction).
c) The time period of reaction (Longer time; faster reaction). The quality of mix immensely affects the quality of the road. A poor mix will result in chipping of Plastic from the road after some time.

4.1 Initial Process: [12]

a) Segregation

Plastic waste is usually collected from rag pickers or waste disposal plants. Plastic up to 60 microns (PS, PP, PE) are separated. PVC should not be used in any case.

b) Cleaning process

Plastic collected is cleaned and dried.

c) Shredding process

Plastics are then passed through a shredding machine. Appropriate particles between 2mm to 3mm are collected.

5. MIX DESIGN APPROACHES

There are a number of different approaches with their merits and demerits. The suitable process should be adopted. Most important bituminous mix design approaches are as follows [13]:

a. Mix design method
b. Recipe method
c. Empirical mix design method
d. Analytical method
e. Volumetric method
f. Performance related approach

5.1 Mixing Procedure at Hot Mix Plant

a) Polymer waste constituting plastic bottles, bags etc should be collected. It is important to avoid PVC and hard plastics. Plastic segregated is shredded into 2 to 4mm particles.
b) Aggregates are heated at 170C and bitumen is heated at 160C separately. This is done to have a most effective mix.
c) Plastic coats around bitumen in 30 to 45 seconds. This coating gives oily look to aggregate.
d) In mixing chamber bitumen and coated aggregate are mixed. This final mix is used for laying roads. Road laying temperature is strictly kept between 110C to 120^0C. 8 ton capacity roller is used [14]

6. IMPORTANT TESTS TO BE CONSIDERED

a) **Stripping Test (IS: 6241-971)**

Plastic coated aggregates along with bitumen were kept in water for 72 hours. The blend showed no signs of stripping. This proves that it has good resistance towards the water.

b) **Marshall Stability Test**

Specimen of plastic coated aggregate along with bitumen prepared as per IRC showed the greater value of Marshall Stability which was even in the range of tolerance. Hence blend showed more suitability for flexible pavement.

c) **Field study**

1200 km were laid at different places in Tamil Nadu, Cochin, Mumbai, and Pondicherry by the department of Rural Development Agency and by Highways at corporation laid test roads using this technology. These roads face climatic conditions and traffic conditions. These roads give promising results and increased strength with no raveling and potholes.

d) **Water absorption test**

Water absorption revealed that with an increase in plastic coating reduced amount water absorbed. This indicates that plastic coating reduces air voids. Hence, a coating of plastic over aggregate helps to improve the quality of the aggregate [15].

Table 1: Comparison between plastic & ordinary roads

S.No.	Properties	Plastic Road	Ordinary Road
1	Binding Property	Better	Less
2	Softening Point	Less	More
3	Penetration Value	More	Less
4	Tensile Strength	High	Low
5	Rutting	Less	More
6	Stripping	No	More
7	Seepage Of Water	No	Yes
8	Durability	More	Less
9	Cost	Less	Normal
10	Maintenance	Almost Nil	More
11	Marshall Stability Value	More	Less

7. SALIENT FEATURES

a) Plastic waste increases binding strength of the mix, leading to longer life of asphalt.

b) Marshall Stability was substantially increased.

c) It was observed that roads with plastic waste can withstand adverse soaking conditions and can remain under water undamaged for longer durations.

d) The strength of such road increases by a factor of 100%.

e) No potholes are formed and the road is unaffected by rain.

f) Load withstanding properties are also increased.

g) 1 ton of bitumen is saved per Km of the road. This makes such roads cost efficient.

h) The durability of the roads is increased.

i) Maintenance cost of the road comes to zero.

j) Such roads provide better grip to tyres, thus preventing sliding skidding and sliding of vehicles.

k) Rutting and raveling of roads are decreased.

l) There is no need of addition of any complex machinery as machinery available for road construction can be used for the process.

m) Landfilling and incineration can be avoided. This makes the process eco-friendly

8. CONCLUSION

The durability of the roads is much more than general ‘highway quality’ roads. Approximately two times. Plastic in tar prevents water seepage, thus plastic roads can withstand water stagnation more effectively. Roads with plastics are having very low maintenance than conventional roads. Though plastic roads may initially cost a little higher than conventional roads, low maintenance, and increased durability compensates well. Roads with plastic not only dispose of plastic waste but increase the quality of roads. Marshall Stability number is increased and water resistant properties of the roads are improved to a notable level. Such roads have nil maintenance and can be constructed without the addition of any heavy machines. Thus, such roads should be adopted in developing countries like India where rutting, raveling and potholes are serious causes of accidents. The presence of chlorine in the plastic can release harmful gasses during laying process. It is important to take precautions during laying process. If the proper process is not adopted, plastic may stat to leach out after some time.

9. REFERENCES

i. *Van Soest, Jeroen JG, and Johannes FG Vliegenthart. "Crystallinity in starch plastics: consequences for material properties." Trends in biotechnology 15, no. 6 (1997): 208-213.*

ii. *Renneker, Richard, and Max Cutler. "Psychological problems of adjustment to cancer of the breast." Journal of the American Medical Association 148, no. 10 (1952): 833-838.*

iii. *Huff, Bobby J. "Process of producing a rubberized asphalt composition suitable for use in road and highway construction and repair and product." U.S. Patent 4,166,049, issued August 28, 1979.*

iv. *Gawande, Amit, G. Zamare, V. C. Renge, Saurabh Tayde, and G. Bharsakale. "An overview on waste plastic utilization in asphalting of roads." Journal of Engineering Research and Studies 3, no. 2 (2012): 1-5.*

v. *Kale, Swapnil Kisanrao, Amit G. Deshmukh, Mahendra S. Dudhare, and Vikram B. Patil. "Microbial degradation of plastic: a review." Journal of Biochemical Technology 6, no. 2 (2015): 952-961.*

vi. *Nguyen, Hoa Huu, Sonia Heaven, and Charles Banks. "Energy potential from the anaerobic digestion of food waste in municipal solid waste stream of urban areas in Vietnam." International Journal of Energy and Environmental Engineering 5, no. 4 (2014): 365-374.*

vii. *Ramamurty, U., S. Jana, Yoshihito Kawamura, and K. Chattopadhyay. "Hardness and plastic deformation in a bulk metallic glass." Acta Materialia 53, no. 3 (2005): 705-717.*

viii. *Bense, Pierre, and Jean-Francois Patte. "Method and device for producing a surface coating on a surface such as a road." U.S. Patent 5,069,578, issued December 3, 1991.*

ix. *Arvanitoyannis, Ioannis, Costas G. Biliaderis, Hiromasa Ogawa, and Norioki Kawasaki. "Biodegradable films made from low-density polyethylene (LDPE), rice starch and potato starch for food packaging applications: Part 1." Carbohydrate Polymers 36, no. 2 (1998): 89-104.*

x. *Saikia, Nabajyoti, and Jorge de Brito. "Use of plastic waste as aggregate in cement mortar and concrete preparation: A review." Construction and Building Materials 34 (2012): 385-401.*

xi. *Huang, Yue, Roger N. Bird, and Oliver Heidrich. "A review of the use of recycled solid waste materials in asphalt pavements." Resources, Conservation and Recycling 52, no. 1 (2007): 58-73.*

xii. *Valiev, Ruslan Zafarovich, Rinat K. Islamgaliev, and Igor V. Alexandrov. "Bulk nanostructured materials from severe plastic deformation." Progress in materials science 45, no. 2 (2000): 103-189.*

xiii. *Abdulshafi, A. A., and Kamran Majidzadeh. "J-integral and cyclic plasticity approach to fatigue and fracture of asphaltic mixtures." Transportation Research Record 1034 (1985).*

xiv. *Hasanbeigi, Ali. "International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry." (2013).*

xv. *Van Steenkiste, T. H., J. R. Smith, and R. E. Teets. "Aluminum coatings via kinetic spray with relatively large powder particles." Surface and Coatings Technology 154, no. 2 (2002): 237-252.*