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UTILIZATION OF WASTE PLASTIC MATERIALS IN ROAD CONSTRUCTION

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Abstract: -

Plastics are user friendly but not eco-friendly as they are non-biodegradable. Generally, it is disposed by way of land filling or incineration of materials which is extremely risky. This waste plastic can be partially mixed with material use for road construction. In conventional road making process bitumen is used as binder. Such bitumen can be modified with waste plastic pieces. This waste plastic modified bitumen mix shows better binding property, stability, density and more resistant to water. Worldwide use of waste material in road construction is being increasingly encouraged so as to reduce environmental impact. The use of this innovative technology will strengthen the road construction and increase the road life as well as will help to utilization of waste plastic material. Plastic roads would be a blessing for hot and extremely humid climate, where temperatures normally cross 50°C and abundant rains create damage, leaving most of the roads with big potholes. The main aim of this study is to focus on using the available waste/recycled plastic materials and waste rubber tires present in abundant that can be used economically and conveniently. Using this technique for road construction proves ecofriendly, economical and use of plastic will also give strength in the sub-base course of the pavement.

Keywords: - *biodegradable, conventional, environmental, material, normally.*

1. INTRODUCTION

In today's lifestyle we see plastic in every spot. Plastic is used daily for packaging, protecting, serving, and even disposing of all kinds of consumer goods. India consumption of plastics will grow more than 15 million tons by 2015 and is set to be the third largest consumer of plastics in the world. Today the availability of the waste plastics is so much, as the plastic materials have become part and need of daily life. Only 60% of waste plastic recycled in India. If not recycled, their present disposal is either by land filling or by incineration but both the processes have certain impact on the environment. Finding proper solution for the disposed of plastics waste is the need of the hour on the other side, the road traffic is increasing, hence there is need to increase the load bearing capacities of the roads. Plastic waste like plastic bags, waste disposable cups, waste tires, and laminated pouches like chips, aluminum foil and packaging material used for biscuits, chocolates, milk etc are used. By this process a road of 1 Km length and 3.375M width of single lane can consumes 10,00,000 carry bags and the road strength is increased by 100% and there found no any pot hole. It is claimed that the durability of the roads laid out with plastic–bitumen last up to 10 years which is much more as compared with normal 'highway quality' road lasts four to five years. Use of disposed plastic bags in road construction appears to be the sustainable option in urban areas to protect environment and alleviate problem of clogging drainage system. A detailed description of the process and guidelines for laying roads with plastic blended bituminous materials was also reported by the National Rural Roads Development Agency in India. The roads had an enhanced durability. It was also reported that roads with plastic blended bitumen had an extended life of at least one or two years more as Compared to 3-4 years under normal ideal conditions. Several studies have proven the health hazard caused by improper disposal of plastic waste. The health hazard includes reproductive problems in human and animal, genital abnormalities etc., Looking forward the scenario of present life style a complete ban on polyethylene cannot be put, although the waste plastic taking the face of devil for the present and future generation. We cannot ban on plastic but we can reuse the plastic waste. It is hoped that in near future there will be strong, durable and eco-friendly roads which will relieve the earth from all type of plastic-waste. Therefore, keeping in mind the utility of plastic wastes in the road construction the present study has been carried out, which will not only helpful in improving the stability of mixes but it will also help in reducing the ill effects of the environment caused by dumping of these wastes.

Literature Reviews

A Use of Re-Cycled Plastics as Additives in Bituminous Mixes

Performance of bituminous mixtures used for surfacing in flexible pavements, can be improved by incorporating suitable additives to mixture. These additives include commercial materials, by products and even processed waste materials. Re-cycled plastics, mainly polyethylene, can be used in the manufacture of polymer-modified asphalt cement or bitumen. Re-cycled polyethylene from grocery bags in bituminous pavements, results reduced rutting and low - temperature cracking of the pavement surfacing (Flynn 1993). Zoorab and Suparma (2000) incorporated plastics, which predominantly composed of polypropylene and Low-Density Polyethylene, in bituminous mixture and this resulted in better durability and fatigue life. By adding waste plastics as modifier, the stability of bituminous concrete mixture has increased by 20%. Similar comparisons have shown that, there is also a considerable increase in indirect tensile strength by about 30% with mixes modified using waste plastics. The fatigue life of modified BC mixes was twice that of the conventional bituminous mix (Shridhar, et al. 2004). Addition of 5 to 10% recycled plastics and about 0.5% resin to binder had shown significant reductions in rutting characteristics of bituminous concrete mixes. Further investigations on fatigue and ITS (Indirect tensile strength) have shown that there is improvement in modified mixes as compared to conventional mixes. There was also significant reduction in the fatigue life of mixes containing more than 5% of plastic waste. Another lab evaluation has revealed that the weight loss of modified formulations was less than that of specimen's prepared using neat bitumen (Kumar, et al. 2003). By adding 8% of recycled plastics to bituminous concrete mixes, stability was increased by about 1.65 times that of neat bituminous mixes. The fatigue life of plastics modified bituminous concrete mixes increased by factors 1.7, 1.6 and 1.5 at 25ºC, 30ºC and 35ºC temperature at 40% and 50% stress levels. This showed that the addition of plastic modifier in shredded form to bitumen by about 8% by weight of bitumen increased the fatigue life of the bituminous concrete mix substantially (Punith and Veeraragavan, 2003). Bose et al (2004) observed improvement in stability, tensile strength and moisture resistance for asphalt mixtures by the addition of 8% (by weight of asphalt) waste plastics. Vasudevan et al (2006) reported that coating plastics over hot aggregates (dry process) gives better strength to the mixture, then blending it with asphalt (wet process). Ravi Shankar et al (2013) also incorporated shredded waste plastic in BC mixture by mixing them directly with the hot aggregates. Out of different plastic dosages tried, mixes with 6% (by weight of bitumen) plastic content sowed better results. Rahman et al (2013) observed that the asphalt mixtures with waste polyethylene modifier up to 10% and waste PVC modifier up to 7.5% can be used for flexible pavement construction in a warmer region from the standpoint of stability, stiffness and voids characteristics.

A. Recent applications

A 25 km plastic modified bituminous concrete road was laid in Bangalore. This plastic road showed superior smoothness, uniform behavior and less rutting as compared to a plastics-free road which was laid at same time, which began developing "crocodile cracks" very soon after. The process has also been approved, in 2003 by the CRRI (Central Road Research Institute Delhi). Justo et al (2002), at the Centre for Transportation Engineering, of Bangalore University used processed plastic bags as an additive in asphalt concrete mixes. The properties of this modified bitumen were compared to that of ordinary bitumen. It was noted that penetration and ductility values, of modified bitumen was decreasing with the increase in proportion of the plastic additive, up to 12 % by weight. Mohammad T. Awwad et al., (2007) the objective include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat

the aggregate High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate. Shankar et al., (2009) crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

II. Data on plastic consumption and generation of plastic waste

A material that contains one or more organic polymers of large molecular weight, solid in its finish state and at some state while manufacturing or processing into finished articles, can be shaped by its flow is termed as plastics.

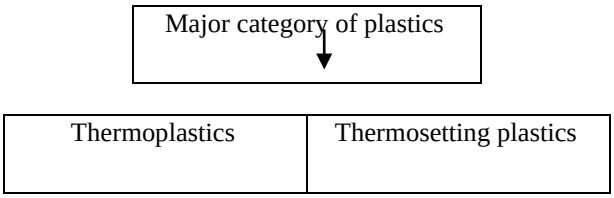

Fig. 1 shows major category of plastic

The thermoplastics, constitutes 80% and thermosetting constitutes approximately 20% of total postconsumer plastics waste generated. The following graph describes

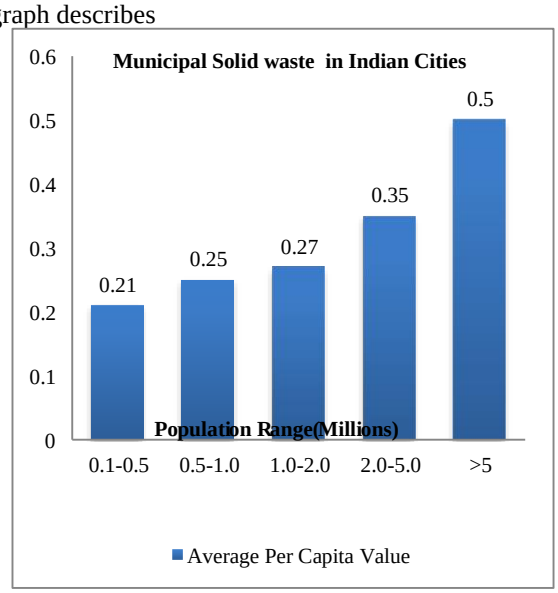

Fig. 2 The average municipal solid waste production from 0.21 to 0.50 Kg per capita per day in India.

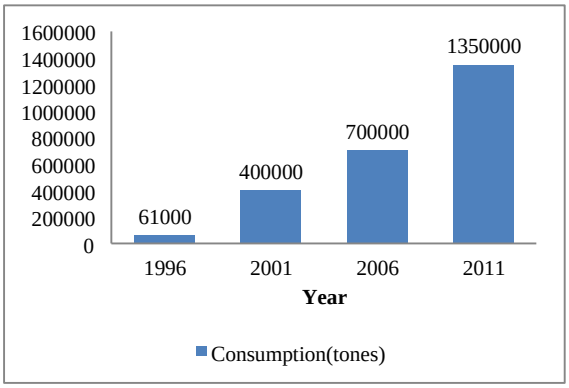

Fig. 3 Provides the data on total plastics waste consumption in India during last decade

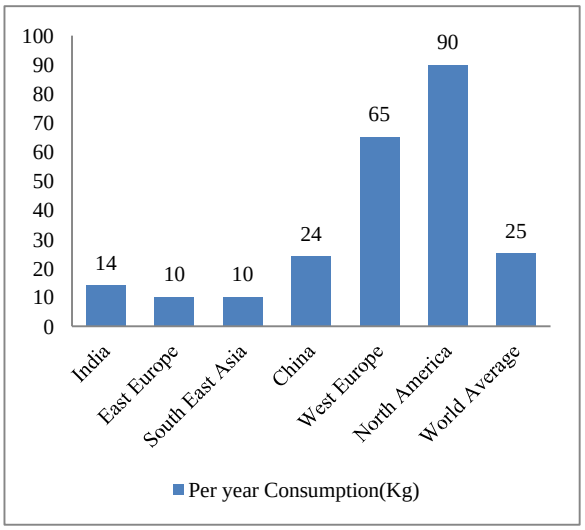

Fig. 4 The comparison of per capita plastic consumption in India with rest of the word

III. Basic Raw Material The materials used are as follows:

A. Aggregates
B. Bituminous Binder
C. Mineral Filler
D. Waste materials

A. Aggregate

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregates should have to be used in pavement are shown below

- Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Lumps and crumbly particles should be limited to utmost 1%.
- Durability or resistance to weathering should be measured by sulphate soundness testing.
- The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.
- It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes
- Aggregates are of 2 types.

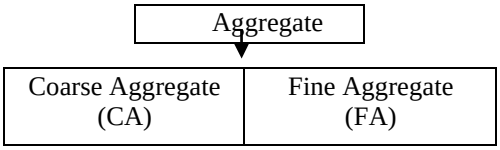

Fig. 5 types of aggregate

1) ***Coarse Aggregate (CA):*** The aggregates retained on 4.75 mm Sieve is called as coarse aggregates. Coarse aggregate should be screened crushed rock, angular in shape, free from dust particles, clay, vegetations and organic matters. They should have following properties

- The Los Angeles Abrasion value shall not be more than 25 % (ASTM C131).
- The weighted average weight loss in magnesium sulphate soundness test shall not be more than 18% (AASTHO T 104).
- Flakiness index shall not be more than 25% (MS 30).
- The water absorption should not be more than 2% (MS30)
- The polished stone value should not be less than 40%.

2) ***Fine Aggregate (FA):*** Fine aggregate should be clean screened quarry dusts. It should be free from clay, loam, vegetation or organic matter. FA should have the following properties

- The angularity should not be less than 45% (ASTM C 1252).
- The methylene blue shall not be more than 10 mg/g (Ohio Department of Transportation Standard Test Method).
- The weighted average weight loss in magnesium sulphate soundness test shall not be more than 20% (AASTHO T 104).
- The absorption of water, should not be more than 2% (MS30)

B. Bitumen

Bitumen is a sticky, black and highly viscous liquid or semi-solid, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulfur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also, bitumen is Mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. It is the heaviest fraction of crude oil, the one with highest boiling point (525 ˚C).
Penetration's grade 60/70 and 80/100 are mainly used. The bitumen used should have the following properties.

1) Grade of bitumen used in the pavements should be selected on the basis of climatic conditions and their performance in past.
2) It is recommended that the bitumen should be accepted on certification by the supplier (along with the testing results) and the State project, verification samples. The procedures for acceptance should provide information, on the physical properties of the bitumen in timely manner.
3) The physical properties of bitumen used which are very important for pavements are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirements for each property except specific gravity.

- Penetration at 77° F
- Viscosity at 140° F
- Viscosity at 275° F
- Ductility/Temperature
- Specific Gravity
- Solubility
- Thin Film Oven (TFO)/Rolling TFO; Loss on Heating
- Residue Ductility
- Residue Viscosity

C. Mineral Filler

Mineral filler consists of very fine, inert mineral matter that is added to the hot mix binder, to increase the density and enhance strength of the mixture. These fillers should pass through 75μm IS Sieve. The fillers may be cement or fly ash.

D. Plastic Waste Material

Different plastic waste materials are collected and are used as raw material for preparation of the samples. All packets were collected; they were washed and cleaned by putting them in hot water for 3-4 hours. They were then dried. Specific Gravity of polythene = 0.905

Shredding:

The dried materials were cut into tiny pieces of size 2 mm maximum. This is because when the material is to be added with bitumen and aggregate it is to be ensured that the mixing will be proper. The smaller the size of the polythene, the more is the chance of good mixing.

IV. Processes for manufacturing bitumen mix road using waste plastic

There are two important processes used for manufacturing plastic waste bitumen:

A. Dry Process
B. Wet Process

A. Dry process

Mixing the appropriate quantity of dry shredded waste plastic with hot aggregate prior to production of bituminous mixes at hot mix plant by varying percentage of plastic by weight of mix.

1) Various types of waste plastic are collected, analyzed as per their type and sent for storage.
2) These segregated wastes are then cleaned and dried to remove impurities from them. Then cut into a size of 1.18-4.36 mm using shredding machine, (PVC waste should be eliminated).
3) The aggregate mix is heated to 165 °C (as per the HRS specification) and transferred to mixing chamber. Similarly the bitumen is to be heated up to a maximum of 160 °C (HRS Specification) to have good binding and to prevent weak bonding. (Monitoring the temperature is very important).

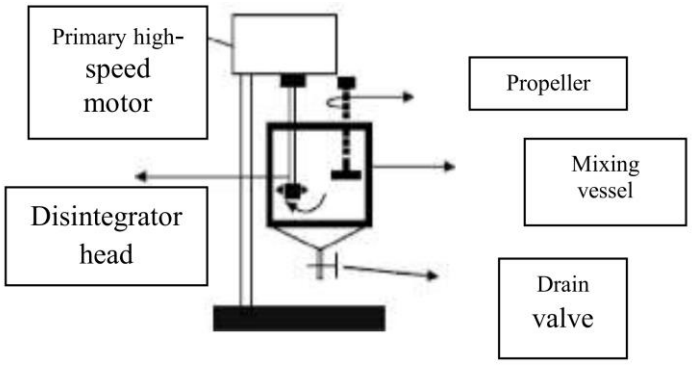

Fig. 6 Polymer-bitumen mixing assembly

4) At the mixing chamber, the shredded plastics waste is to be added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 seconds, giving a look of oily coated aggregate.
5) The plastics waste coated aggregate is mixed with hot bitumen at the temperature range between 150°C-165°C. The resulted mix of temperature range 130°C-140°C is used for road construction. The road laying temperature is between 110 °C-120 °C. Using the roller of 8-ton (min.) capacity.

B. Wet Process

It is the blending of shredded plastic bags and bitumen prior to the production of modified bituminous mixes. Figure 2 shows process flow in wet process of bitumen modification in wet process, the chemical process that produces binders, are considered to be swelling of the plastic particles from absorbing some of the more volatile compounds from the bitumen, followed by degradation of the plastic from devulcanising and polymerization.

The rate of reaction is affected by the following:

- Temperature of the binder (higher temperatures provide a quicker reaction), the surface characteristics of the plastic used (rougher surface reacts quicker),
- The size of the waste plastic particles (smaller particles swell quicker but lesser)
- The period, blend is kept at the reaction temperature (longer time, greater reaction).
- The main and important process in bitumen modification using wet process is blending of polymers and bitumen. It requires proper blending technique to ensure a required quality of blend. This can be achieved by using blending assembly.

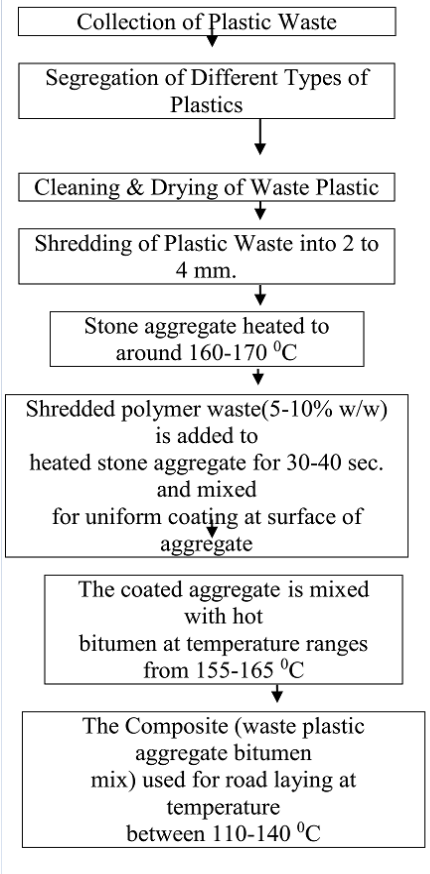

Fig. 7 Schematic flow diagram wet processes

V. Cost Estimation

In wet process, we use waste plastic for modification of bitumen, whereas in dry process, waste plastic is used for coating over aggregates. Waste plastic collection in India is typically a huge network of man power, engaged at various stages. Thus, a separate economy is running there. On the other hand, we travel a lot by roads than any other means of travelling such as railways, airways or waterways, as roadways are the most convenient & economical ways of travelling. But the condition of the roads is decreasing day by day. The cost for up gradation is increasing as the availability of natural recourses are minimizing. Therefore, any techniques for improving quality of roads parallel saving some of natural resources such as bitumen and aggregates are needed. Use of this novel technique for up gradation of roads proved to be useful and economical, saving thousand Corers of rupees. There are tremendous possibilities of road up gradation in terms of quality and cost effectiveness, as condition and quality of roads are declining with next day.

Some of basic information is given below –Cost ofwaste plastics Rs. 7/- per Kg.
- Cost of processing: Rs. 5/- per Kg.
- Total cost of waste plastics: Rs. 12/- per Kg.
- Optimum percentage of plastic in the blend is around 8% (% wt. of bitumen)

Generally, roads in India are constructed in basic width of 3.0 m, 3.75 m. and 4.0 m.
Consider 1 Km length road of width 3.75 m. it uses bitumen approx. 21,300 Kg. (For new work) and 11,925 Kg. (For Up gradation).
- Cost of Bitumen per drum (200 Kg): - 8400/-
- Cost of Bitumen Per Kg.: - 42.00/-
- Cost of Road (New)/Km including BBM, Carpet and Seal Coat: Rs. 18,95,000/-
- Bitumen required for work (approx.): 21,300 Kg. per Km
- Cost of bitumen in new work per Km.: Rs. 8,95,000/-
- Waste plastic, co processed with bitumen for PMB (8% by wt.): 1,704 Kg
- Cost of waste plastic used: Rs. 20,450/-
- Cost of Bitumen saved (1704Kg. equivalent to plastic used): Rs. 71550/-
- Total savings per Km.: Rs. 51,100/-

Cost of Road (Up gradation)/km including Carpet and Seal Coat: Rs. 10, 80,000/-
- Bitumen Required for work (approx.): 11925 Kg. per KM.
- Cost of bitumen in repairs (Up gradation) per Km.: Rs. 5,01,000/-
- Waste plastic, co processed with bitumen for PMB (8% by wt.): 954 Kg.
- Cost of waste plastic used: Rs. 11450/-
- Cost of Bitumen saved (954Kg. equivalent to plastic used): Rs.40,050/-
- Total savings per Km.: Rs.28, 600/-
- Optimum amount of waste plastic used in dry process: 10% (by wt. of aggregates)

Amount of aggregates used in road construction (1 Km length x 3.75 m width):
3750 m^2 x 12.5 Kg per m^2 (avg.) = 46875 Kg.
Therefore, Amount of waste plastic used in road (10% by wt.): 4687.5 Kg.
- Total amount of waste plastic used in road construction using both the processes together (i.e., Combination of wet process & dry process):1704 + 4687.5 =6391.5 Kg
- Total cost of waste plastic used in road using mix process: Rs.76,700/-

Extra cost for construction of road (Cost of waste plastic used in road construction – Total savings using modified bitumen): 76,700 – 51,100 = Rs.25,600/- per Km.

VI. Conclusion

A. Wet process

Polymer Modified Bitumen is used due to its better performance. But in the case of higher percentage of polymer bitumen blend, the blend is a more polymer dispersion in bitumen, which gets separated on cooling. This may affect the properties and quality of the blend and also the road lay using such blend.
1) Blending requires a special type of mixing assembly for proper and effective blending.
2) Increase and decrease in specific values of bitumen shows improved performance of bitumen which in turn helps to improve quality and durability of road.
3) When modified bitumen is to be used at site of construction; there should be provision of maintaining proper service temperature and blending to prevent phase separation.

B. Dry process

In the modified process (dry process) plastics-waste is coated over aggregate. This helps to have better binding of bitumen with the plastic-waste coated aggregate due to increased bonding and increased area of contact between polymer and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reduced rutting, raveling, and there is not pothole formation. The road can withstand heavy traffic and show better durability.

1) Coating is easy and the temperature needed is the same as the road laying temperature.
2) Bitumen is bonded with the aggregate by means of plastic which acts as a binder.
3) Coated plastics acts as binder and the added bitumen binds strongly.
4) Waste plastic is collected, shredded and can be used in the hot mix plant to lay the roads.
5) No new technology is involved. The existing Mini hot mix plant or Central Mix plant can be used without any modification.
6) The coated aggregate shows increased strength
7) Dry process can be practiced in all type of climatic conditions. Process can be modified by Varying the percentage of plastic with respect to the environmental conditions namely, Temperature, Rain, Snow, load, etc.,
8) No evolution of any toxic gases like dioxin as the maximum temperature is only 170 ^{0}C.

VII. Salient features of the road

A. Better resistance towards rain water and water stagnation so no stripping and no potholes.
B. Increase binding and better bonding of the mix thus reduction in pores in aggregate and hence less rutting a raveling.
C. No leaching of plastics. No effect of radiation like UV.
D. The load with standing property increases. It helps to satisfy today's need of increased road transport.
E. Value addition to the waste plastics (cost per kg. increases from Rs. 4 to Rs. 12).
F. The cost of road construction is also decreased and the maintenance cost is almost nil. As road pavement life is doubled when we use this novel technique for road construction, we have to pay only Rs. 25000/- more, instead of spending Rs. 10,80,000/- for its up gradation in just 2-3 years, thus saving Rs.10,50,000/- per Km. In India more than 4.25 million Km of road is available. If only some of them are constructed or repaired using this technique, there will be less waste plastic littered on the road. The process is eco-friendly. Segregating plastic from the MSW at municipal yard involves application of resources, the cost of which runs into crores of rupees. A substantial amount of this can be saved. Lab tests and real time tests have revealed that the life expectancy of a plastic road, compared to a normal road is at least 100% more. This technique adds a cumulative benefit to National Economy also gives contribution to environmental benefits, employment generation and agricultural efficiency.

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