Investigation on the Use of E-Waste and Waste Plastic in Road Construction

Shrikant Dombe[1], Anand B. Tapase[2(✉)], Y. M. Ghugal[3(✉)], B. A. Konnur[1], and Patil Akshay[1]

[1] Department of Civil Engineering, Government College of Engineering, Karad, Karad, Maharashtra, India
shrikantdombe@gmail.com, bakonnur@gmail.com, patil.akshayl595@gmail.com

[2] Department of Civil Engineering, Rayat Shikshan Sanstha's Karmaveer Bhaurao Patil College of Engineering, Satara, Maharashtra, India
tapaseanand@gmail.com

[3] Applied Mechanics Department, Government College of Engineering, Karad, Karad, Maharashtra, India
yuwraj.ghugal@gcekarad.ac.in

Abstract. The amount of e-waste and waste plastic caused by technological and industrial development is increasing day by day. One of the low-cost and most effective way to exclude such waste and protect the environment is recycling, wherein its advantageous use in the road construction sector by replacing conventional exhausting materials can be a good eco-friendly alternative. In the initial stage, an attempt to state the potential use of various waste material reported by the number of researchers is done from an extensive literature review. Furthermore, to check cost effectiveness along with sustainable construction method, the experimental investigation on studying the effect of partial replacement of filler and bitumen by e-waste and waste plastic in the bituminous mixes respectively is done by using Marshall Stability testing machine. To check the suitability of e-waste and waste plastic in road construction, the results obtained from the Marshall Stability testing machine for the number of trials were interpreted in respect to its stability, flow value, % V.M.A., % air voids, bulk density, etc. It was observed that partial replacement of conventional material with e-waste is possible which not only the increase in strength but also gives a cost-effective solution towards the e-waste disposal. Advantageous use of plastic is well documented in the available literature and is again confirmed from the present work.

Keywords: E-waste · Partial replacement · Cost-effectiveness

1 Introduction

The rising amount of commercial vehicles, overloading of trucks further than double its capacity, change in daily and cyclic temperature and environmental factors have been responsible for decreasing the life of the pavement. As per the Research Scheme R-55 of MORTH, the use of E-Waste and Plastic waste in bituminous road construction of

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Central Road Research Institute (CRRI) indicates that the wearing course of e-waste and plastic waste bituminous mixes have longer lives. Indian Road Congress (IRC) has formulated IRC codes for the use of waste plastic and e-waste in road construction. From the literature, it is observed that the properties of pavements with the bituminous mixes can be improved to meet the requirements of pavement with the incorporation of certain modifiers. To achieve this improvement, it is necessary to add polymers to bituminous mixes. Waste plastic is added to enhance the property of the bituminous mixes resulting in improvement of the quality of roads. In India, huge investments are being made to enlarge the existing road infrastructure and also to develop new highways for superior connectivity as well as to serve the economic activity in the country. The time has come to consider these infrastructures as a national asset and to establish a reliable plan to maintain and manage these assets. In India, due to innovation and advancement in new techniques, the electronic equipment's are assembly more attention across the world, due to which modern and most upgraded version is available in the market and the older becomes scrap. The use of these materials as a substitute to conventional material for the construction industry which may not only help in decreasing the manufacturing cost of a particular item but also helps in saving the environment from pollution and other harmful effects which causes problems, reduce landfill cost and also helps in saving our natural resources. The factors like economic growth increased income and the mobility motive has encouraged the people to opt for private vehicles. Also, the inadequate availability, substandard quality, and service of the city's public transportation have further accentuated the trend of using private vehicles in the state. Though there have been considerable improvements in the service of public transport facilities in most of the cities with a growing economy, there still remains a considerable gap between demand and supply of transport facilities.

2 Necessity of Work

Roads in India are largely designed based on soil (sub-grade) strength in terms of California Bearing Ratio and the effect of overloading on the pavement is not considered. The increase in traffic volume and the load intensity cause distress to pavements. In such situations, it becomes imperative to strengthen the pavements by providing overlays, etc. To rehabilitate distress roads, the conventional method of laying overlays is not only time consuming but it also obstructs the flow of traffic for a longer period. The non-availability & increasing cost of conventional granular materials make it necessary to think for better alternatives. So, it is a necessity to find an alternative method to improve the strength properties of layers in flexible pavement meeting the additional requirements put forward due to ever-increasing traffic & other related factors.

3 Aims and Objectives

1. To study the use of electronic waste in the bituminous top layer of flexible pavement along with partial replacement of bitumen with plastic by wet mix process.

2. To find a suitable alternative over conventional materials with cost reduction & improvement in strength & other parameters in flexible pavements.
3. To use waste material in flexible pavement without increasing the cost per unit and without sacrificing durability.

4 Materials and Methods

4.1 Bitumen

Bitumen is defined as "A viscous liquid, or a solid, consisting basically of hydrocarbons and their derivatives, which is soluble in trichloroethylene and is substantially nonvolatile and softens gradually when heated. Bitumen is obtained as the last residue in the fractional distillation of crude petroleum.

4.2 Grades of Bitumen Used for Pavement Purpose

Three grades of bitumen confirming to IS 73:1992 are manufactured in India.

a. Bitumen 80/100: This grade is most extensively used in road construction all over India.
b. Bitumen 60/70: 60/70 grades are harder in assessment to 80/100 and are presently used in the construction of National Highways & State Highways.
c. Bitumen 30/40: Bitumen 30/40 is used in particular applications like airport runway construction as this grade is harder than 60/70 grade.

Sr. no.	Tests conducted	Test results	Specifications	IS codes
1	Specific Gravity	1.02	0.97–1.02	IS-1202
2	Flashpoint, °C	270	220 °C	IS-1209
3	Penetration test	65	50-90	IS-1203
4	Softening point test, °C	49	Min 55 °C	IS-1205
5	Ductility test	51	Min 40	IS-1208

4.3 Aggregate

Aggregates are natural materials and are the most significant constituents of road construction. Aggregates are also used as foundation material under road construction. The most universal natural aggregates of mineral origin are sand, gravel, and crushed rock. Unbound aggregates are used for base or sub-base course. Aggregate contributes up to 90–95% of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. There are three kinds of rocks namely-igneous, sedimentary, and metamorphic. It may found that many of the properties of aggregates

namely-specific gravity, hardness, strength, physical stability depend mostly on the quality of parent rock.

Physical Requirements for Coarse Aggregates for Bituminous Concrete Table 500-16.

Property	Test	Specifications	Method of test
Cleanliness (Dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part 1
Particle shape	Combined Flakiness and Elongation Indices	Max 35%	IS:2386 Part 1
Strength	Los Angeles abrasion value/Aggregate Impact value	Max 30% Max 24%	IS:2386 Part 4
Durability	Soundness either: Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part 5
Polishing	Polished Stone Value	Min 55	BS:812-114
Water absorption	Water absorption	Max 2%	IS:2386 Part 3
Stripping	Coating and stripping of Bitumen-Aggregate Mixtures	Min retained coating 95%	IS:6241
Water sensitivity	Retained Tensile Strength	Min 80%	AASHTO 283

4.4 E-Waste

There is no clear definition for electronic waste (e-waste) at this time, but if you can plug it into an electrical outlet or it contains circuit boards or chips, it is most likely e-waste. This term applies to customer and business electronic equipment that is near or at the end of its useful life. Electric and electronic waste (e-waste) is currently the largest growing waste stream. It is harmful, composite and luxurious to treat in an environmentally sound manner and there is a general lack of legislation or enforcement surrounding it. Today, most e-waste is being surplus in the general waste stream. These products can contain heavy metals like cadmium, lead, copper, and chromium that can contaminate the environment.

Examples of electronic waste include, but not limited to:

a. TVs, computer monitors, printers, scanners, keyboards, mice, cables, circuit boards, lamps, clocks, flashlight, calculators, phones, answering machines, digital/video cameras, radios, VCRs, DVD players, MP3, and CD players
b. Kitchen equipment (toasters, coffee makers, microwave ovens)
c. Laboratory equipment (hot plates, microscopes, calorimeters)
d. Broken computer monitors, television tubes (CRTs)

4.5 Plastic

Safe disposal of waste plastic is a serious environmental problem. Being a non-biodegradable material it does not decay over time and even if dumped in landfills, finds its way back in the environment through air and water erosion can obstruct the drains and drainage channels. Bottles, containers and packing strips, etc. is increasing day by day. As a result of the amount of waste plastic also increases. This leads to various environmental problems. Many of the wastes produced today will remain in the environment for many years leading to various environmental concerns. Therefore it is necessary to utilize the wastes effectively with technical development in each field. Many by-products are being produced using plastic wastes. Our present work is helping to take care of these aspects. Plastic waste, consisting of carrying bags, cups and other utilized plastic can be used as a coating over aggregate and this coated stone can be used for road construction. The mix polymer coated aggregate and tire modified bitumen have shown higher strength. The use of this mix for road construction helps to use plastics waste. Once the plastic waste is separated from municipal solid waste, the organic matter can be converted into manure and used. Our paper will discuss in detail the process and its successful applications.

Plastic is a very adaptable material. Due to the industrial revolution, and its large scale production plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packing, automobile, electronics, electrical, building construction, and communication sector has been virtually revolutionized by the application of plastics. Plastic is a non-biodegradable material and researchers are found that the material can remain on earth for 4500 years without degradation. We cannot ban the use of plastic but we can reuse plastic waste.

Plastics and their origin

Waste plastic	Origin
Low-density polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles, etc.
High-density polyethylene (HDPE)	Carry bags, bottle caps, household articles, etc.
Polystyrene Terephthalate (PET)	Bottle caps and closures, film wrappers of detergent, biscuit, wafer packets, microwave trays for a ready-made meal, etc.
Polypropylene (PP)	Yogurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging, etc.
Polystyrene (PS)	Food trays, egg boxes, disposable cups, protective packaging, etc.

Tapase Anand et al., "Utilization of E-Waste and Polymer Modified Bitumen in Flexible Pavement"

The escalation in various types of productions together with population growth has resulted in a massive increase in the production of various types of the waste material world over creating a problem of its disposal in an eco-friendly way. To deal with the problem here an attempt is made to study the use of e-waste as an alternative to conventional material like aggregate in a DBM layer of flexible pavement along with

partial replacement of bitumen with plastic by the wet mix process. A number of laboratory tests were conducted using the Marshall Stability testing machine to check the suitability of e-waste and plastic as an alternative to conventional materials like aggregates and bitumen respectively. The results obtained in laboratory investigation indicate not only the increase in strength but also a considerable reduction in cost is seen. From the experimental work, it is clear that the properties of laboratories designed bituminous mix for DBM are much more superior to those of the control mixes entirely composed of mineral aggregates and can be effectively used in practical applications.

Tapase Anand, et al., "Consumption of Electronic Waste in Quality Enhancement of Road"

The work consists of an experimental approach towards waste management and finding an alternative to conventional materials in flexible pavements. Most of the electronic waste is recyclable or repairable, but a number of worthless electronic pieces causes higher transportation cost for their processing which may be higher than its scrap value. So, such electronic waste is disposed of very casually, which may cause serious health and pollution problems. Also, the disposal of electronic waste is difficult because of non-degradable plastic contents and metals like lithium, copper, and aluminum, which may lead to adverse effects on the environment. To deal with the problem, here an attempt is made to study the use of electronic waste as an alternative to conventional material like aggregate in a DBM layer of flexible pavement. A number of laboratory tests were carried out by replacing aggregates partially by shredded electronic waste. The outcomes from the laboratory investigation prove the suitability of electronic waste in road construction with substantial cost saving. So, disposal of hazardous electronic waste in the pavement can prove to be one of the alternatives to make the earth greener and pavements more durable.

S. Rajasekaran et al., "Reuse of Waste Plastic Coated Aggregates- Bitumen Mix Composite for Road Application-Green Method"

Normally Waste plastic is made up of PP, PE and P. Softening point of plastic up to 130 °C and they do not produce any toxic gases during the softening condition. The nature of softened plastic is to form a coating like material over the material. Spray of plastic over the hot aggregate at 160 °C to form the film-like structure on the aggregate. It formed PCA, which is a better raw material for the construction of the bitumen road. Moisture absorption test, Soundness test, Aggregate impact test, Los Angeles abrasion test conducted in this paper. Mix the plastic coated aggregates in 80/100 pen bitumen at 160 °C after the completion of test Mix. The researcher took Marshall Stability tests for bitumen. The mixture of polyethylene coated aggregate and bitumen mix shows the improvement in binding property of aggregate and less wetting property. The control mix with plastic sample shows greater Marshall Stability value is up to 18–20 KN also increases the load-bearing capacity up to 100%.

Tapase Anand et al., "Performance Evaluation of Polymer Modified Bitumen in Flexible Pavement"

The growth in various types of industries together with population growth has resulted in an enormous increase in the production of various types of waste materials world over creating a problem of its disposal in an eco-friendly way. To deal with the problem, a study on the use of plastic waste as a partial replacement to bitumen in the flexible pavement is considered in the present work. The work consists of an experimental approach towards waste management and finding an alternative to conventional materials in flexible pavements. To simulate with the field conditions the Marshall Stability method is considered to carry out experimental work. The objective of work is to investigate the effect of plastic waste in flexible pavement and to suggest the optimum percentage of bitumen that can be replaced by plastic waste for the improvement of roads. The number of laboratory tests has been carried out by replacing bitumen with plastic waste. The results obtained in laboratory investigation indicate a major gain in strength with substantial savings in cost.

M.S. Ranadive et al., "Performance Evaluation of E-Waste In Flexible Pavement – An Experimental Approach"

The objective of this study is to investigate the effect of e-waste and fly ash, as a filler replacement, on the strength parameters of the bituminous concrete road. It is observed that there is a definite increase in Marshall Stability and flows value with an increase in the percentage of e-waste by replacing up to 10 percent aggregates. The use of fly ash as a filler cannot increase the strength but helps to attain it nearly equal to that of the control mix. Here is an attempt is made to use waste products like fly-ash and e-waste in flexible road construction which affect the environment and are difficult to process. The study concludes that e-waste and fly ash could be used as filler material in bituminous mixes.

Silvia Angelone et al., "Green pavements: reuse of plastic waste in asphalt mixtures"

The important objective of this research is to find an eco-friendly approach for effect of recycling various percentages of urban and rural plastic waste by adding them in asphalt mixture by the dry process, for a comparative laboratory study. Marshall Stability, Indirect tensile strength Marshall Quotient, fracture energy, permanent deformation, creep compliance and resilient modulus, this all factors is conducted for the laboratory study. Polyethylene from silo bags and Polypropylene from waste bags bottles are used as the waste plastic material for the modified bitumen mixture. The proportion of plastic dosage in bitumen is 2%, 4%, 6% weight of the mixture. After conducting all the above tests, researchers concluded that the addition of plastic in flexible pavement improves the properties of flexible pavement.

Zahra Niloofar Kalantar et al.," A review of using waste and virgin polymer in the pavement"

Researchers describe the adding of virgin polymer in bitumen for improving properties of bitumen. More additions of the virgin polymer have the same result as compare to waste polymer according to historical study. This paper review of the virgin also wastes polymer in the pavement with help of study on the history of use of polymer in asphalt, benefits of using polymer in asphalt, use of polymer waste into the virgin polymer. A benefit of using polymer in asphalt section describes the major

improvement in Optimum stability of bitumen, Improvement in resistance of bitumen temperature, Improvement in engineering properties. The results of the Virgin polymer as compare to waste polymer are the same. So the economic and environmental point of view the use of waste polymer is the best modifier as compare to virgin polymer I.e. waste polymer solves the waste-disposal problem also improves in performance of the pavement. Researchers give more information related to polymer characteristics and bitumen characteristics. After all review, researchers concluded that the use of virgin polymer in asphalt pavement is better for improving in the certain characteristics of asphalt pavement. From an economic view and environmental view, the use of waste polymer in asphalt pavement is better.

Amit Gawande et al., "An overview on waste plastic utilization in asphalting of roads"

This paper describes the use of plastic in bitumen to improve desired mechanical characteristics for the flexible road. This paper review important techniques for using waste plastic in construction flexible pavements and bituminous road. Researchers collect more data on plastic consumption and the generation of plastic waste. Also, this paper describes the properties and characteristics of bitumen and plastic. This paper gives detail information about the wet and dry process. The final conclusion of that paper is modified bitumen is better for the upper layer of flexible pavement, and modified bitumen shows more resistant to water, stability, load carrying capacity and better binding property.

Sui Yuanyuan et al., "Application and Performance of Polyethylene Modifying Additive in Asphalt Mixture"

This paper deals with the mixing or adding method of polyethylene modifying additive in different from asphalt modifier. The method of research is mixing the Polyethylene as modifying additive in the mineral aggregate for some minutes and then adds the asphalt mixing in polyethylene and aggregate. This method is different from the regular asphalt modifier. This paper mainly described the improvement in asphalt mixture when it is mixed with polyethylene modifying additive on higher temperature stability, resistance at low temperature cracking and water resistance is obviously, analyze the mechanism that additive affect asphalt mixture performance and evaluate polyethylene modifying additive on the basis of technical, economic and environmental aspects. Also, researchers explained about High-temperature Stability and Low-temperature Performance, Water Stability is weak in bitumen. The conclusion of this research paper is improving the quality of bitumen. (i.e. maximum temperature stability and low-temperature performance, water stability) by mixing polyethylene modifying additive.

5 Wet Mix Process

Waste plastic is mixed with bitumen in 4.5% to 6% as partial replacement to bitumen. Aggregates were partially replaced by the electronic waste in a shredded form with 7.5%, 10%, 12.5%, and 15% by volume of the mold. Plastic increases the melting point of bitumen and makes the road retain its flexibility during winters resulting in its

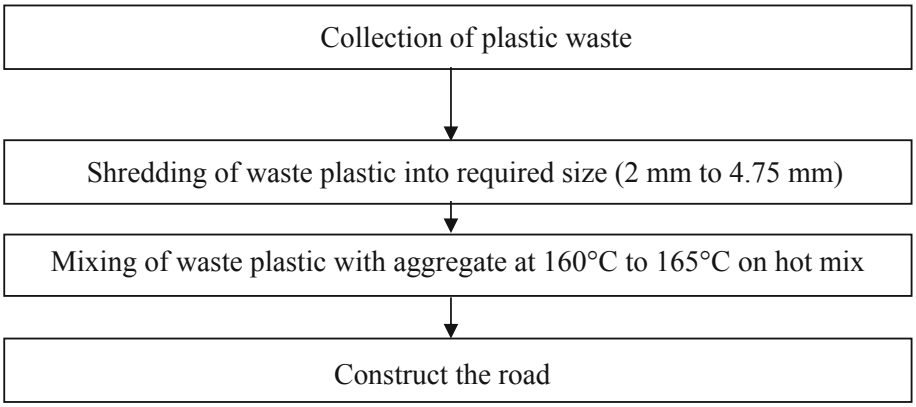
long life. Use of shredded plastic waste in road act's as a strong binding agent for making it durable. The plastic waste is melted and mixed with bitumen in a particular ratio. Normally, blending takes place when the temperature reaches 45.5 °C, but when plastic is mixed, it remains stable even at 55 °C. The vigorous tests at the laboratory level proved that the mixes prepared using the treated bitumen binder fulfilled all specified Marshall Mix Design criteria for the surface course of road pavement. There was a substantial increase in the Marshall Stability value of mix, of the order of "two to three times" higher value in comparison to ordinary, untreated bitumen.

6 Bitumen Tests

Bitumen is an important parameter for flexible pavement; the binding property of bitumen is played an important role in flexible pavement. Plastic waste is mixed in bitumen by the wet mix process. Modified bitumen is the partial replacement of bitumen by waste plastic. Replacement quantity of waste plastic is 6.5% of bitumen weight as per IRC: SP: 53-2010. In the wet mix process, Temperature parameter is important for all process.

6.1 Wet Process

Plastic has a high melting point also increases the melting point of the modified bitumen and makes the road retain its flexibility during winters resulting in its long life. Use of shredded plastic waste which is passing through 4.75 mm sieve and mix with bitumen at 160 °C to 165 °C. Addition of 6.5% waste plastic in bitumen as per IRC: SP: 98-2013.



6.2 Advantages of Wet Process

This Process is applied for recycling of any type, size, shape of waste material (Plastics, Rubber, etc.).

6.3 Disadvantages of Wet Process

Required more time- high energy for blending, a special type of equipment is required. Extra time required for cooling.

7 Mix Design

The gradations adopted for the mix are taken as specified by MORTH 2001. Here mix design is made for Bituminous top layer of flexible pavement, in which aggregates size of 20 mm, 12.5 mm, 6 mm, and grit are used. After blending operation, for grade-I, it is observed that the percentage of aggregates mentioned above is 25%, 25%, 20%, and 30% respectively.

Following steps are carried out while preparing mix design:

1. Sieve analysis
2. Mix gradation according to MORTH 2001
3. Mix design blending
4. Recommendations for mix design from the overall process

Table 500-17: Composition of bituminous concrete pavement layer

Grading	I
Nominal aggregate size	19 mm
Layer thickness	50 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing
45	–
37.5	–
26.5	100
19	90–100
13.2	59–79
9.5	52–72
4.75	35–55
2.36	28–44
1.18	20–34
0.6	15–27
0.3	10–20
0.15	5–13
0.075	2–8
Bitumen content % by mass of total mix	Min 5.2
Bitumen grade (Penetration)	65 to 90

8 Marshall Stability Test

This is the most regular method that eventually proved to be the Marshall Stability method developed by Bruce G. Marshall of the Mississippi state highway department. The method is modified and standardized by many organizations, such as ASTM, AASHTO, US Corps of engineers and British Standers Institution. The Ministry's specifications and Indian Road Congress also refer to this method.

The experimental set-up for Marshall Stability test consists of the following:

a. Loading machine (Marshall testing machine)
b. Mould
c. Automatic or manual compaction hammer (4.5 kg)
d. Flowmeter
e. Breaking head
f. Digital water bath
g. Hot plates
h. Ovens
i. Miscellaneous equipment

9 Sample Preparation

Following factors has to be considered while sampling preparation:

1. Steps for sample preparation for control mix with different bitumen content
2. Bitumen replaced by plastic waste
3. Aggregate replaced by e-waste

10 Steps for Sample Preparation for Control Mix with Different Bitumen Content

The specimens for control mixes were prepared. Numbers of samples were prepared by varying bitumen percent from 4.5% to 6% with an increment of 0.5%.

The further process is as given below.

a. Aggregates are oven dried at 105 °C to 110 °C and sieved into specified sizes.
b. About 1200 g aggregates were taken as per mix design proportion is given in Table 1
   And mix thoroughly.
c. Then bitumen is heated up to 160 °C and mixed by weight of aggregate.
d. First, the entire mold was filled and 75 blows were given on either side of the specimen with the manual compactor.

11 Bitumen Replaced by Plastic Waste

For the preparation of sample the steps a. and b. mentioned above are the same. The further process is as discussed below:

c. Before mixing aggregate, the shredded plastic waste was mixed with hot bitumen at 160 °C. The percentage variation in plastic was 4.5%, 5%, 5.5%, 6% of bitumen.
d. Required percent of bitumen was added to the sample and mixed at 160 °C. Molds were filled with bituminous mix and 75 blows were given on either side

This constituted the specimen.

12 Aggregates Replaced by E-Waste

a. Aggregates are oven dried at 105 °C to 110 °C and sieved into specified sizes.
b. Then the aggregates were partially replaced by e-waste by its volume. The e-waste percentage was varied from 7.5% to 15% with an increment of 2.5%. This quantity was mixed with hot aggregate at 160 °C. Then the hot bitumen was added to it.
c. Molds were filled with a modified mix and 75 blows were given on either side which constituted the specimen.

13 Result

(1) In the wet mix process for modified bitumen testing 6.5% accurate percentage value for replacement of bitumen by waste plastic. Penetration value is decreased by 6.68% after mixing of 6.5% waste plastic in bitumen but softening point of bitumen is increased by 8.60% and other properties of bitumen are same.
(2) In Dry mix process for aggregate testing, 7% waste plastic quantity is accurate as compare to another percentage variation. 7% optimum bitumen content is replaced by plastic waste; it forms the plastic coated aggregate.
(3) Specific gravity of plastic coated aggregate is increased by 2.88% after coating of 7% waste plastic on aggregate also crushing value, impact value, loss abrasion value are decreased by 3% to 4%.
(4) This all result of aggregate test indicates that replacement of bitumen by plastic waste is increasing the properties of aggregate.
(5) Plastic coated aggregate increase the stones improving surface property of aggregates.
(6) Plastic coating form thin layer around the aggregate to fulfill parameter and binding property of aggregate. Plastic coated aggregate is used for good performance of flexible pavement.
(7) Marshall Stability value of bituminous material increased in dry mix process and wet mix process.

(8) In wet mix process 6% plastic content is optimum shows the better result as compare to other content.
(9) In Dry mix process plastic content is 7%, shows high Marshall Stability value. Due to addition of waste plastic, Marshall Value increase as compare to control mix. High Marshall Values shows high strength, high durability, and high load carrying capacity. This all parameter shows increase the properties of flexible pavement.
(10) As compare to wet mix process, dry mix process is suitable method for mixing of waste plastic in bitumen for construction of flexible pavement because wet mix process required more time and energy for blending; new equipment's are required for wet mix process, Dry mix process is simple and feasible.

The project work consists of an experimental approach towards waste management and finding alternative to conventional materials in flexible pavements. The objective of work is to investigate the effect of plastic waste and electronic waste in DBM layer flexible pavement, and to suggest the optimum percentage of bitumen that can be replaced by plastic waste for the improvement of roads. Also, aggregates are also replaced by e-waste. Marshall Stability test setup is used for testing 100 mm diameter specimen, to simulate actual field condition. Different performance parameters of specimen are studied for varying percent of e-waste and bitumen content.

Following are some conclusions drawn during testing of specimen and interpretation of results:

a. The use of bitumen with the addition of processed waste plastic of about 5% by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, with marginal saving in bitumen usage.
b. Using the wet process with varying percentage of 7.5, 10, 12.5, and 15 of aggregate can be replaced by e-waste and 5% plastic to form modified bitumen in DBM layer having 5.5 percent optimum bitumen content.
c. The process is environment friendly.
d. From the experimental work it is clear that the properties of laboratorial designed bituminous mix for DBM are much more superior to those of the control mixes entirely composed of mineral aggregates and can be effectively used in practical applications.

Thus we can conclude in general that it is a simple process, helps to save cost of bitumen, improves performance of roads, solves problem of plastic waste disposal and it is one time investment for shredding machine which can be reused.

14 Suggestions

a. Instead of going through the banning of plastics, it is important that needed education is to be given.
b. Domestic plastic waste need to be separated at the source & collected efficiently.
c. Awareness camps should be conducted.

d. Electronic waste should not be dumped in landfills.
e. Electronic waste should be efficiently collected.

15 Future Scope

a. e-waste disposal in eco-friendly way is a problem and there is a scope to study e-waste as an alternative to aggregates in road construction.
b. Waste plastic carry bags were used in this project which shows adhesion properties in their molten state hence, there is a scope to use different forms of polymers for road construction.
c. Here, as pavement is an alternative for disposal of plastic waste and e-waste, various other engineering structures can also be analyzed for finding an alternative for waste disposal.

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