RESEARCH ARTICLE

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Incorporation of Waste Plastic in Bituminous Mixes for DBM Layer

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ABSTRACT

Proper Management of Plastic waste is necessary for improving aesthetics of the environment. This study is focused on finding the effective use of plastic waste in bituminous mixes. Different proportions of shredded plastic are mixed at a percentage of 3%, 6%, 9% and 12% in bitumen binder and coated on aggregates in a percentage of with fly ash as a filler material using dry and wet process. Marshal stability Analysis is done for DBM mix having bitumen content lying between 4.5-6% at an increasing rate of 0.25% in order to find its compatibility in the field. A comparison has been made between the plastic-coated aggregates and conventional aggregates. This experimental study shows optimum plastic content of 6% and 9% using wet process and dry process respectively with 2 % of fly ash as filler instead of using conventional cement gives better results than the traditional bituminous mix. It is also determined that maximum 9% of bitumen can be replaced by plastic giving 40% higher stability value than the conventional bituminous mixes. Subsequently, the use of plastic waste and fly ash in road construction will be economical and create a sound environment.

Keywords: Controlled mix, stabilized mix, polystyrene, polyethylene, fly ash, Marshall stability analysis.

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INTRODUCTION

The road network of India is second largest in the world with a total road length of 58.98 lakhs out of which 63.24 percent is paved as per the report given by Ministry of Road Transport in 2017(MoRT&H, 2016). This rapid growing road network and traffic have resulted in the modification of the bitumen mixes for better performance. The availability of binders is vast but results in increasing the cost of the project. Waste plastic is one such material which can be recycled and gives satisfactory results as a binder. The plastics that can be used are polyethene, polypropylene, polyamide, polyoxymethylene, polytetrafluoroethylene and polyethylene terephthalate. Polymer modification can be considered as one of the solutions to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement [1]. In India, the total annual plastic waste generation is about 3.3 million tonnes per year as per the report given by Central Pollution Control Board (CPCB) in 2018-2019(https://cpcb.nic.in/).

In a study it was shown thatby replacing the bitumen by 10% with plastic waste, there is an increase in the values of properties without the need of any anti-stripping agent. Also, it will help in avoiding the disposal of waste plastic by land filling and incineration and develop a method which is eco- friendly [2,3]. Aggregates coated with plastic

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waste are mixed with bitumen are bound to give higher value of strength, durability and better water proofing properties [4,5]. Studies shows that modification of bituminous mixes can be achieved by using two methods. Plastic waste can be either directly added into the bitumen mix which is known as wet process or can be first coated on aggregates and then mixed with hot bitumen known as dry process [6,7]. Plastic coated aggregates have improved soundness, less porosity and less moisture absorption. This not only strengthen the road but also increases its life. The use of polyethylene when added to the bitumen binder gives best results below 10% most at 5% during Marshall stability analysis [8,9]. Also, waste plastic addition of 5-10% by weight of bitumen helps in better performance, increasing the life of the pavement, consumes large quantities of waste plastics and gives a better infrastructure [10]. One of the studies shows polymer bitumen blend is a better binder compared to plain bitumen resulting higher Marshall Stability and decreasing the possibilities of potholes formation [11]. Various researches conducted on using fly ash as filler replacing stone dust and cement in bituminous mix design pointed that fly ash at 2% filler content provides the highest stability among the other filler [12].

In order to access the performance of the plastic in bituminous mix two different process of mixing was adopted. A comparative study has been done to figure out the differences in the properties of bituminous mix with varying binder contents and waste plastic (PET) contents mixed using flyash as a filler for both dry and wet process. Laboratory study on hot mix asphalt was carried out to study the properties Marshal mix design using both wet and dry process and conclusions were made based on the comparison done.

METHODOLOGY AND MATERIALS PROPERTIES

Material Properties

Plastic in the form of PS and PE : Plastic In the form of polystyrene and polyethylene discarded waste products were procured from the social gatherings and local residential areas used for modifying binder in equal proportion. The plastic was shredded into small pieces of size 2mm to 4 mm to ensure even coating on the aggregates and properly mixed with the binder [3,10]. Shredded plastic was replaced with binder and coated on aggregates in order of 3%, 6%, 9% and 12%.

Aggregates : Aggregates of sizes 20 mm, 10 mm, 6 mm were obtained locally and various physical tests such as Impact test, Los Angeles Abrasion test, Water Absorption test, Specific gravity test, Soundness test and Stripping tests were performed to evaluate the properties of the conventional and modified aggregates (Table 1). All the results were within the permissible values as per the MoRT&H specifications as shown in Table 1. This shows the improved quality of aggregates which results in better performance of the road. In order to get the desired gradation, percentages of aggregates used was determined using Rothfutch Method which is a graphical approach used for determining the blending of aggregates as per the MoRT&H specifications. The gradation used for preparing the samples was:

20mm-22%, 10mm- 32%, 6mm-16%, stone dust-30%.

Fly ash as a filler : 2% of fly ash was used as a filler in the mixes prepared for DBM (grading -II) samples.

Table 1: Properties of Aggregates used

Properties	Values obtained					Max values
Plastic added (%)	0	3	6	9	12	
Los Angeles Abrasion Test (%)	19.8	18.6	17.4	14.6	15.3	30
Impact Value (%)	18.8	18.3	17.6	15.4	16.2	24
Aggregate Crushing Value (%)	18.3	17.7	15.4	14.4	15.1	30
Flakiness Index (%)	18.4	17.2	16.9	16.9	16.9	35
Elongation Index (%)	13.5	13.2	13.2	13.3	13.3	35
Specific gravity	2.57	2.60	2.65	2.68	2.72	2-3
Water Absorption test (%)	0.72	0	0	0	0	2
Soundness Test (%)	9	0	0	0	0	12
Stripping value (%)	3	0	0	0	0	5

The specific gravity of fly ash is 2.29. it contains about 56.4% of Silica.

Binder : VG-30 was used for preparing samples. Physical properties were determined by doing conventional tests shown in Table- II

Methodology

Table-2: Properties of Binder

Properties	Values Obtained					Permissible Values
Plastic added (%)	0	3	6	9	12	
Penetration test (at 25 °C, 1/10th of mm)	64	62.5	61	59	57.5	50-70
Ductility Test (27 °C, cm)	85	79	76	69	68	>75
Softening Point test (°C)	56	51	49	52	60	46-54

Marshall Specimen Preparation : The Marshall test were conducted for Dense Bituminous macadam (Grade II) of thickness 63mm. All the three mixes including Controlled mix, Stabilized mix with plastic modified binder and Stabilized mix with plastic coated aggregates were tested and volumetric analysis was done under Indian Standard conditions. For preparing conventional Marshall specimen to obtain Optimum binder content, the test was conducted on a compacted cylindrical specimen of bituminous mix of diameter 101.6 mm and thickness of 63.5 mm. Approximately 1200 gm of blended aggregates were taken and oven dried at a temperature of 160 °C for proper mixing of bitumen. Both binder and aggregate were mixed thoroughly for 15- 20 minutes at a temperature of 155 °C -160 °C and filled into the pre-heated mould. Impact loading was applied with the help of hammer in which 75 blows were given on each face. After cooling and keeping in water bath the sample was tested for Marshall stability and flow values in Marshall Testing Machine. The Stability of the bituminous mix is the maximum load carried by the specimen at a standard temp of 60°C under specified test conditions. It shows the resistance to deformation. The flow value is given as the total deformation of the bituminous mix specimen at the maximum load, expressed in mm unit and shows the extent of deformation [13].

For determining the Optimum binder content (OBC) of the controlled mix, the samples were prepared with a varying percentage of binder ranging from 3-12% with an increase of 3%. The average of binder content for maximum stability, maximum bulk density and 4% air voids will give the value for optimum binder content.

For the preparation of stabilised bituminous mix using dry process, four different samples were prepared with optimum bitumen content of 5.25% by weight of the total mix in the same way after coating the aggregates with plastic in varying proportions of 3,6,9 and 12 % by weight of binder content. The aggregates are heated for each specimen at a temperature of 160°C and shredded PS and PE were added in pre-determined percentage and mixed thoroughly. After coating, plastic coated aggregates will be added into hot bitumen along with fly ash and stone dust to obtained bituminous mix for the desired course.

For the preparation of stabilised bituminous mix using wet process, four samples with varying percentage of plastic by weight of binder content were prepared. Shredded plastic was added in a percentage of 3, 6, 9 and 12 into hot bitumen and stirred at a temperature of 200 °C - 220 °C. Simultaneously, hot aggregates along with fly ash as a filler and stone dust were added into the bituminous mix for the desired course.

At least three samples were prepared for each gradation and bitumen content to get the accurate results. All the prepared samples were tested in Marshall testing machine. Specimens were then placed in head assembly and test head was placed in the correct position in the loading machine and the load was applied at a constant rate of 5cm per minute. Maximum load value, corresponding flow values and voids were then recorded for the analysis. The optimum plastic content (OPC) for dry and wet process was determined.

RESULTS AND DISCUSSIONS

This study shows that incorporating higher percentages of plastic i.e., 12% provides a higher value of abrasion, impact and crushing than 9% due to thinner coating of plastic around the aggregates. An increasing trend was seen in the specific gravity with higher percentages of plastic. No water absorption was observed in plastic coated aggregates as the voids were sealed. No loss of aggregate fraction was observed during the soundness test. Plastic coating increased in the adhesion forces between bitumen and aggregates resulting in no stripping of bitumen after immersing for 24 hours [14].

Penetration test, Softening test, Ductility test shows a decrease in trend with the increase in

plastic percentage. Specific gravity of binder increases due to incorporation of plastic in binder.

Marshall stability analysis with varying percentages of PE and PS using dry process was done on 15 samples and result shows that the values vary between 12.45 kN to 15.81 kN as shown in figure 1 while flow value ranges from 3.31 mm to 3.87 mm shown in figure 2 which is within the permissible limit of 2-4 mm as per MoRT&H specifications. The maximum stability was obtained with 6 % plastic using dry process and in case of wet process maximum stability was obtained at 9 %. Figure 1 shows that the stability value for the stabilized mixes was higher than the controlled bituminous mix. This means stabilized mix can withstand higher traffic loads than the conventional mix. In case of Bulk density (figure 3), Air voids (figure 4) and VMA (figure 5), with higher percentage of plastic all the values obtained were within the permissible limits as per MoRT&H specifications.

Marshall stability analysis with varying percentages of PE and PS using wet process was done on 15 samples and the result shows that the values are in the range 14.86kN to 10.82kN shown in figure 1 while the flow values were in the range of 3.7 mm to 3.31 mm as shown in figure 2 which is as per MoRT&H specifications. It is clearly explained from figure 1 that the stability values for the stabilized mixes were more than the controlled mixes. In case of Bulk density, Air voids and Voids in mineral aggregates, with higher percentage of plastic all the values obtained were within the permissible limits as per MoRT&H specifications.

Modifying the bituminous mix using dry process shows better values of stability with the increase

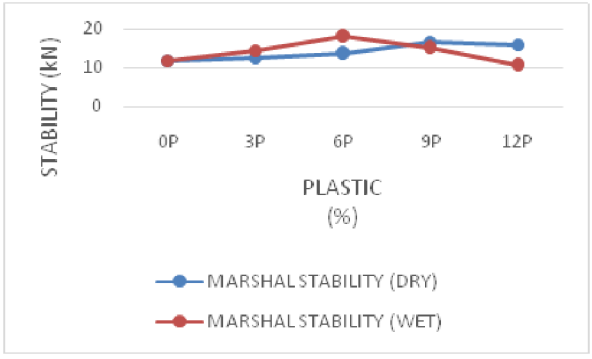

Figure 1: Marshal stability after addition of various percentages of plastic using Dry and Wet process

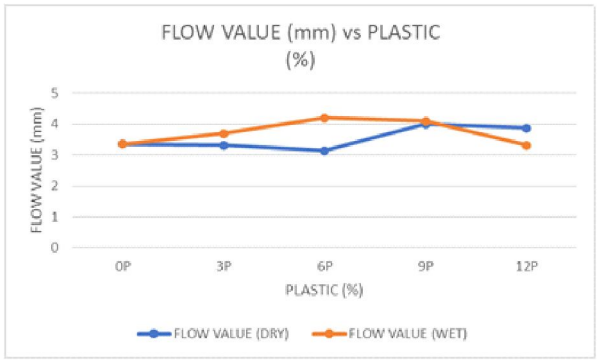

Figure 2: Flow Value Analysis with the addition of various percentages of plastic using Dry and Wet process

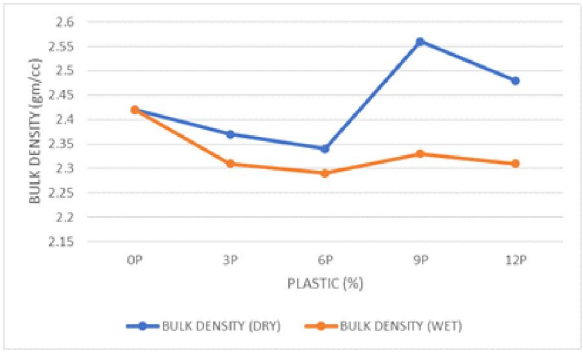

Figure 3: Bulk density Analysis with the addition of various percentages of plastic using Dry and Wet process

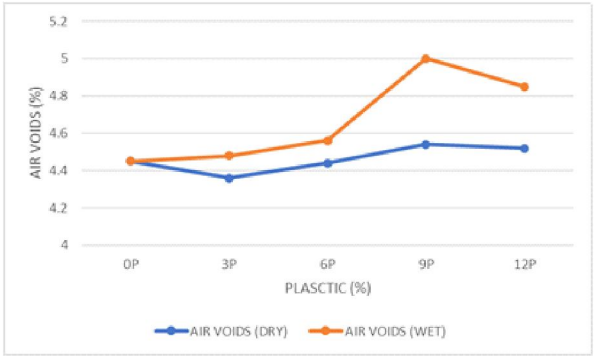

Figure 4: Voids Analysis with the addition of various percentages of plastic using Dry and Wet process

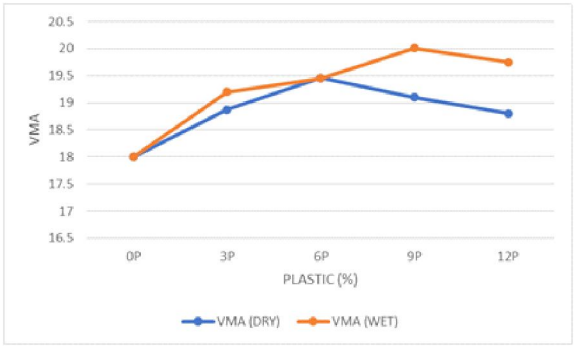

Figure 5: Voids Analysis with the addition of various percentages of plastic using Dry and Wet process

of plastic incorporation into it than using wet process in which the value of stability starts decreasing after a specific percentage of plastic added to it as shown in figure 1. Flow values obtained in case of mixes prepared using wet process were higher than the mixes prepared using dry process as shown in figure 2. Higher flow value means higher flexibility of the pavement, which means the deformation in case of mixes prepared using wet process is higher. Air voids percentage escalated with the increase in plastic content in case of plastic mixed bitumen samples more than the plastic coated aggregates samples as shown in figure 4. Lesser air voids show lower porosity and lesser permeability of the specimens prepared using dry process and the values are within the specified limits. Increase in plastic content increases the voids in mineral aggregates than the conventional mixes as shown in figure 5 which may be due to the manual mixing of two different types of waste plastic in the form of PE and PS. Also, higher VMA are seen in samples prepared using wet process than the samples prepared using dry process which shows higher impermeable and durable nature of the test specimens prepared using dry process.

CONCLUSION

This study proves that the use of plastic improves the quality of the pavement increasing its service life and fly ash as a filler is effective replacement for cement. Two different processes used for the mixing of the samples were used for comparative study and the following inferences were made:

- The optimum binder content for the controlled mix was found to be 5.25% and the optimum plastic content in case of wet process is 6% at which the maximum stability of 18.22kN and in case of dry process is 9% at which the maximum value of stability of 16.6kN was obtained.
- It is observed that plastic coated aggregates are better in terms of their crushing value, lesser abrasion value and lesser water absorption, which results in the better performance in dense bituminous macadam than conventional aggregates.
- In case of dry process, there is better performance of pavement due to zero stripping and no formation of potholes in rainy season.
- Using dry process for the mixing of the bituminous mixes results in higher consumption of plastic waste, reduces the content of binder, increases the strength, improves the binding resulting in better economical solution and waste management reducing the carbon footprint.

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