Gainful utilization of plastic waste in dense bituminous macadam

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Abstract: Globally, as the users are increasing, there is a vital competition in Industries to make their products Cheaper, more durable, attractive and easily transportable. For these qualities most of the Industries are using plastics without considering its hazardous nature to the Environment and human beings. Different Types of plastics such as polyethylene of High and Low density, polypropylene and other polymers are widely used in our daily consumable things such as water bottles, cups, rappers of food, carriage bags, and single used containers. So much use of plastics generates a huge waste worldwide. As this waste is non biodegradable in nature, it is a long lasting headache to avoid its hazardous impacts to ruined human health and degraded Environment. A lot of studies are going on efficient utilization of this waste to convert it into wealth. Highway industry has a big range for different material uses so it can be a smart way to use this waste into the construction of Highways. Studies on properties of plastics gives hint of its long lasting property which can be taken as durability on a positive Note and its presence in oceans from thousands of years shows that even water is impact less on this material which can prove a extraordinary property for Roads. Further on Investigation it was found that optimum percentage of this waste plastics in a particular form can be used for modifying the properties of Bitumen which is known as polymer modified Bitumen. For checking adequacy of required properties of Bitumen that modified bitumen is used in a layer of flexible pavement construction. In this research waste polymer is replaced by bitumen in variation from 2 to 10% at interval of 2% in dense Bituminous Macadam layer of flexible pavement. Marshall Stability test is performed to examine the strength and flow parameter to obtain the optimum doses waste polymer. It has been observed that 4 and 6 % of waste plastic in mix shows better results of Marshall Test as compare to conventional mix.

Keywords: Plastic waste, Marshall Stability, Marshall Flow, DBM, Plastic roads etc

1. INTRODUCTION

IRC Introduces the code IRC: SP: 98:2013\cite{1}, for the proper guidelines for mixing plastic waste in bituminous pavement construction. This same approach is used here with different percentage. We are using plastic waste bottles here which are abundantly available at most of the places. DBM is used as wearing course for flexible pavement so it was quite appropriate to study the impacts on this layer\cite{2-4}. Test results of waste plastic mixes will be helpful in having Idea of optimized percentage of waste plastic in this DBM layer.

Objectives of Study
1. To analyze the effect of waste plastic on Dense Bituminous Macadam.
2. To evaluate the optimum binder content for different proportion of plastic waste in DBM.
3. To find the maximum stability with plastic waste in DBM
4. To reduce the demand of natural resource by using plastic waste.
2. MATERIAL AND METHODOLOGY

2.1. **Material Used**
- a) Aggregate – Collected from Bassi, Agra road, Jaipur
- b) Bitumen – VG-30 grade
- c) Plastic Waste – PET (Waste plastic bottle)

2.2. **Properties of Aggregate**
As per the guidelines aggregates were tested to check their suitability for the pavement construction. The results of different properties are shown in Table 1 with the confirming codes.

2.3. **Properties of Virgin Bitumen**
Before the use of modifier the Bitumen properties are tested and results are shown in Table 2. These results are appropriate according to allowable limit also shown in Table 2. These properties can be found out in lab as shown in Figure 1.

| Properties                        | Confirming IS Code | Aggregate |
|-----------------------------------|--------------------|-----------|
| Crushing Value                    | IS:2386 Part IV    | 14.5%     |
| Aggregate Impact Value (AIV)      | IS:2386 Part IV    | 15.6%     |
| Abrasion Value (LA)               | IS:2386 Part IV    | 16.8%     |
| Specific Gravity                  | IS:2386 Part III   | 2.71      |
| Elongation Index and Flakiness Index (Combined) | IS: 2386 Part I | 26.7%     |
| Water Absorption Value            | IS:2386 Part III   | 0.26%     |

| Property                          | Virgin Bitumen     | Allowable limit |
|-----------------------------------|--------------------|-----------------|
| Specific Gravity                  | 1.02               | 1.12            |
| Penetration                       | 67 mm              | 60-70 mm        |
| Ductility @ 27°C                  | 78                 | Min.40          |
| Softening Point                   | 49°C               | 60°C            |

3. EXPERIMENTAL WORK

3.1. **Job Mix Gradation**
The gradation is done by Trial method according to specification of MORTH. The results of gradation are shown in Table 3. Gradation curve can also be drawn as shown in figure 2.

**Table 3. Gradation for DBM Grade I Layer**

| Mix Proportion | IS Sieve Size (mm) | % Passing | Trail Mix | Combined |
|----------------|--------------------|-----------|-----------|----------|
|                | 40                 | 20        | 10        | 6        | Dust & Filler | 40 | 20 | 10 | 6 | Dust & Filler | Sample |
| 45             | 100                | 100       | 100       | 100      | 100%       | 10 | 20 | 20 | 30 | 20 | 100% |
| 37.5           | 100                | 100       | 100       | 100      | 100%       | 10 | 20 | 20 | 30 | 20 | 100% |
| 26.5           | 21                 | 100       | 100       | 100      | 2.1        | 20 | 20 | 20 | 30 | 20 | 92.1 |
| 13.2           | 3                  | 34        | 89        | 100      | 0.3        | 6.8 | 17.8 | 30 | 20 | 74.9 |
| 4.75           | 0.8                | 9         | 13.2      | 73       | 100        | 0.08 | 1.8 | 2.64 | 21 | 9 | 20 | 46.4 |
| 2.36           | 0.3                | 4         | 5.2       | 21       | 100        | 0.8 | 0.80 | 1.04 | 6.3 | 20 | 28.1 |
| 0.3            | 0.3                | 0.24      | 2.8       | 64       | 0          | 0.0 | 0.48 | 0.8 | 4 | 12.8 | 14.1 |
| 0.075          | 0.6                | 1.6       | 6.8       | 0        | 0          | 0.0 | 0.12 | 0.4 | 8 | 1.36 | 2.0 |

**Figure 2.** Gradation for DBM Grade I Layer

3.2 *Marshall Stability Test*

Stability value is observed to estimate strength of the prepared sample of bituminous mix under the certain loading. This certain loading is created in MARSHALL Stability testing machine by a loading Mechanism. The MARSHALL specimens were prepared following standard procedure as some of these are shown in figure 3 and figure 4. The Flow value was also determined with the help of deformation noted by deflectometer. This Stability Analysis is also a needed tool for the Optimum Binder content.
3.3 Waste Plastic Mixing Details
Waste plastic is used in different proportion with virgin bitumen to inspect strength and flexibility. Past studies show that 10% is maximum content of waste plastic to utilize in asphalt mix. So for this study waste bitumen is replaced by waste plastic in 2, 4, 6, 8 and 10% as shown in Table 4 to evaluate optimum waste plastic content.

| Designation & Details for Different Mixes |
|------------------------------------------|
| Designation | M0 | M2 | M4 | M6 | M8 | M10 |
| Bitumen (%) | 100 | 98 | 96 | 94 | 92 | 90 |
| Plastic Waste (%) | 0 | 2 | 4 | 6 | 8 | 10 |

4. RESULTS AND DISCUSSION

4.1. Marshall Stability-Flow Test
Marshall Test is a way to observe the optimum binder content for the specific bituminous mix. This test is performed by changing different trial percentage of bitumen and different graphs of density, Air voids with changing percentage of Bitumen is extracted. From the help of this different percentage we get the optimum Binder content as shown in figure 5. As per MORTH specifications this trial percentage cannot be less than 4%. Here we are varying the Binder content from 4% to 6.5% for getting the optimized value for the DBM layer. Graphical representation of stability is shown in figure 6. Graphs for Marshall Quotient and flow value for various DBM mixes are shown in figure 7 and figure 8 respectively.
Table 5. Outcomes of Marshall Stability-Flow Test of Different DBM mixes

| DESIGN MIX | VFB | Density | OBC(%) | Marshall Flow(mm) | Max. Stability (Kg) | Marshall Quotient (kN/mm) |
|------------|-----|---------|--------|-------------------|---------------------|--------------------------|
| M0         | 68% | 2.442   | 5.6    | 2.7               | 1510                | 5.59                     |
| M2         | 70% | 2.458   | 5.2    | 2.9               | 1610                | 5.55                     |
| M4         | 72% | 2.432   | 5.4    | 3.2               | 1680                | 5.25                     |
| M6         | 69% | 2.425   | 5.45   | 3.45              | 1710                | 4.96                     |
| M8         | 66% | 2.514   | 5.5    | 3.7               | 1665                | 4.50                     |
| M10        | 67% | 2.344   | 5.55   | 3.8               | 1480                | 3.89                     |

Figure 5. Graphical representation of OBC for various DBM mixes

Figure 6. Graphical representation of Maximum Marshall Stability for various DBM mixes
5. CONCLUSION

It has been found that mixing waste plastic in bitumen lessen the demand of bitumen around the 6% and enhance serviceability of pavement. Using plastic waste in pavement reduces the cost bitumen used as binder. At high temperature zones plastic modified bitumen can be utilize as it has higher melting value than conventional bitumen[5][6]. Waste plastic reduces penetration and ductility, a higher softening point which directly indicates reduction of rutting and cold crack in flexible pavement[7][8].

Marshall Stability for various mixes at 0%, 2%, 4%, 6%, 8% and 10% as per the Table 4 replacing waste polymer by virgin bitumen in DBM mix are 1510, 1610, 1680, 1710, 1665 and 1480 kg. As per the Table 5, Stability is increase till 6% of replacement after than stability is in decreasing order. From outcomes of Marshall Flow values it can be concluded that deformation is increased with increment of plastic. Greater flow value represents high flexibility in pavement which is in allowable range[9-11]. It has also observed that requirement of binder content is reduced with percent of replacement. Waste polymer reduces the construction cost as it reduces the requirement of natural material which makes
project economical[12]. Utilization of waste polymer in dense bituminous macadam increases the strength and flow at certain amount of doses which reduces the waste and makes environment eco-friendly.

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