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# Utilization of Waste Plastic in Semi Dense Bituminous Concrete (SDBC) Mix Design

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**Abstract:** *Plastics wastes are increase in developing countries with increase in population. So there is a need to utilize these non-biodegradable wastes in alternate way to make them environment friendly. The work reported through this paper is an experimental work conducted on mix design of semi dense bituminous concrete (SDBC) using conventional aggregate and waste plastic coated aggregate. Job mix formula for SDBC is evolved in accordance with MoRT&H (Ministry of Road, Transport and Highways) specification. Waste plastic is added in the mix design as 5%, 10% and 15% of the bitumen content. Effect of waste plastic in the mix design of SDBC mix was studied through Marshall Stability test. Inclusion of waste plastic in the bituminous mix could reduce optimum bitumen content from 5.42% to 5.24%.*

***Keywords:*** *Waste Plastic, Marshall Stability Test, Semi Dense Bituminous Concrete, Optimum Bitumen Content*

## 1. Introduction

As the traffic is increasing with alarming rates in developing countries so this is the common problem for all the developing countries to save natural resources used in road construction. These natural resources can be saved by using advance construction techniques or improving the road construction material. Aggregates are usually used in the huge quantity for road construction. Aggregates required for flexible pavement having good strength because they are in direct contact of wheel. The properties of aggregates can be improved up to some extent by using appropriate improving material. Waste plastic is the new highly improving material used now the days for improving the properties of bituminous mixes used for flexible pavement. The waste plastic can be used in bituminous mixes by two methods i.e. Polymer Modified Bitumen and Dry Process [1]. In polymer modified bitumen method waste plastic is mixed with bitumen where as in dry process method waste plastic is coated over aggregates before using them in bituminous mixes. The properties of bituminous mixes are affected by type and dose of waste plastic used [2]. Semi Dense Bituminous Concrete (SDBC) is used as a profile corrective course in flexible pavement. Its high density, resistance to deformation and high degree of adhesion between aggregates and binder make it long life under heavy traffic. Excellent grading of materials makes the mixture highly impervious to water. The SDBC surface can be opened quickly for traffic because it is compacted to a high density during construction.

## 2. Review of Literature

There are a number of studies has been carried out on waste plastic used for construction of flexible pavement. The following provides direction of research in the area:

Vasudevan [1] discussed that polyethylene, polypropylene and polystyrene has better adhesion property in their molten state with aggregate, which reduces porosity and absorption of moisture.

Sabina *et al.* [2] studied that coating of plastic waste/polymer on aggregate improves physical properties of aggregate. Further inter-molecular bonding between bitumen and waste plastic/polymer coated aggregate enhanced strength and thus show significant improvements in quality of bituminous concrete mixes.

The research carried by Bindu *et al.* [3] on performance tests including Marshall Stability, Tensile Strength, Triaxial tests and Compressive Strength tests on Stone Mastic Asphalt mixture using waste plastic by varying percentage 6% to 12% by weight of bitumen with an increment of 1%. There is an increase in the stability, split tensile strength and compressive strength of about 64%, 18% and 75% respectively compared to the conventional SMA at 10% plastic content.

Rasel *et al.* [4] describes the properties of bitumen mixes with PVC up to 20% with an increment of 2.5% of optimum bitumen content. The results shows that dense graded bituminous mixes with PVC up to 10% of bitumen content can be used for bituminous pavement construction in warmer region from the standpoint of stability, stiffness and voids characteristics.

Vasudevan *et al.* [5] studied that softening point of various plastic varies between 110°C to 140°C depending upon the composition of material without

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producing any toxic gases. Plastic Coated Aggregate bituminous mixes improve binding property and poor wetting property. The load bearing capacity of the road is increased without any pothole formation.

Rani *et al.* [6] find that there is an increase in Marshall Stability value, reduction in optimum bitumen content using plastic coated aggregate with improvement in rutting. Rajasekaran *et al.* [7] studied that Polyethylene, Polypropylene and Polystyrene increase load bearing capacity of plastic coated aggregate without produce any toxic gases during heating. Modarres *et al.* [8] studied the fatigue properties of asphalt mixes at 5 and 20°C temperature using Polyethylene Terephthalate (PET) with dry process. The range of PET between 2-10% by weight of bitumen content. Based on the results of resilient modulus test, the stiffness of PET modified mix was acceptable and warranted permissible deformation characteristics of these mixes at heavy loading conditions. Shankar *et al.* [9] investigate that stability value increase up to 12% at 6% waste plastic content using dry process as compared to neat mix.

## 3. Experimental Objectives

The objectives of experimental study:

- To observe physical properties of aggregates used in bituminous mix design.
- To study physical properties of bitumen used in bituminous mix design.
- To determine the Optimum Bitumen Content for SDBC mixes for conventional and waste plastic coated aggregate by Marshall Stability Method.

## 4. Material Used

The research work in this paper has been carried out on Semi Dense Bituminous Concrete (SDBC) with grading-1 for Haryana region.

### 4.1 Bitumen

Bitumen used in present study has been collected from Panipat Refinery. The tests performed on bitumen before using in bituminous mix are as given in Table 1.

***Table 1:*** *Properties of Bitumen*

| Test Performed | Test Method | Results |
|---|---|---|
| Penetration (100 gm, 5 seconds at 25° C, 1/10$^{th}$ of mm) | IS:1203-1978 | 67 |
| Softening point °C | IS:1205-1978 | 54 |
| Ductility @27° C, cm | IS:1208-1978 | 72 |
| Flash point, °C | IS:1209-1981 | 260 |
| Fire point, °C | IS:1209-1981 | 285 |
| Specific Gravity of bitumen at 27 °C | IS:1202-1978 | 1.020 |

### 4.2 Aggregates

The aggregates used in present study have been chosen from Yamunanagar quarry. The properties of aggregates are given below in Table 2.

***Table 2:*** *Physical Property of Aggregates*

| Test Performed | Results | MoRT&H Specifications Table 500-15 (IV Revision) | Test Methods/ Indian Standard used |
|---|---|---|---|
| Impact value (%) | 21.80 | 27% Maximum | IS: 2386 (Part-4) |
| Los Angeles Abrasion Value (%) | 24.40 | 35% Maximum | IS: 2386 (Part-4) |
| Water Absorption (%) | 0.76 | 2% Maximum | IS: 2386 (Part-3) |
| Specific Gravity | 2.635 | - | I : 2386 (Part-3) |

### 4.3 Stone Dust

Proportioning of material used in the bituminous mix largely depends upon the quality of fine aggregates. Stone dust having specific gravity 2.674 (IS: 2386 Part-3) used in the present study collected from the Yamunanagar quarry.

### 4.4 Mineral Filler

Voids contents in bituminous mixes are affected by filler used. The filler material used in present study was cement having specific gravity of 3.140 (IS: 2720 Part-3).

### 4.5 Modifiers

The waste plastic bottles collected from market used as a modifier and shredded in the range 2.36mm to 4.75mm for proper coating over aggregates.

## 5. Job Mix Design

Proportioning of material affects the properties of bituminous mixes used for pavements. The specification of materials followed in present study as per MoRT&H. In present study SDBC Grade – 1 is used. Aggregates (nominal size 13mm and 6mm) and stone dust were sieved through desired sieves. For stiffness of bitumen-fines matrix 2% cement was taken as mineral filler. Analytically different proportion of aggregates and stone dust was mixed to obtain the desired gradation of SDBC mix as per MoRT&H specification as shown in Table 3 and Figure 1.

***Table 3:*** *Proportioning of Aggregate for SDBC [10]*

| Sieve size (mm) | Cumulative % by weight of total aggregate passing | | | | | |
|---|---|---|---|---|---|---|
| | Aggregate designation | | | MORT&H specified grading ( Table 500.15 Grading -1) | | Observed grading of Bituminous mix (A: B: C: 50:15:35) |
| | 13mm A | 6mm B | Stone Dust C | Range | Mean | |
| 19 | 100.0 | 100.0 | 100.0 | 100 | 100 | 100.0 |
| 13.2 | 100.0 | 100.0 | 100.0 | 90-100 | 95 | 100.0 |
| 9.5 | 71.2 | 88.68 | 100.0 | 70-90 | 80 | 83.9 |
| 4.75 | 2.3 | 24.27 | 99.8 | 35-51 | 43 | 39.7 |
| 2.36 | 0.0 | 0.65 | 80.3 | 24-39 | 31.5 | 28.2 |
| 1.18 | 0.0 | 0.37 | 64.0 | 15-30 | 22.5 | 22.5 |
| 0.3 | 0.0 | 0.37 | 35.6 | 9-19 | 14 | 12.5 |
| 0.075 | 0.0 | 0.37 | 11.7 | 3-8 | 5.5 | 4.2 |

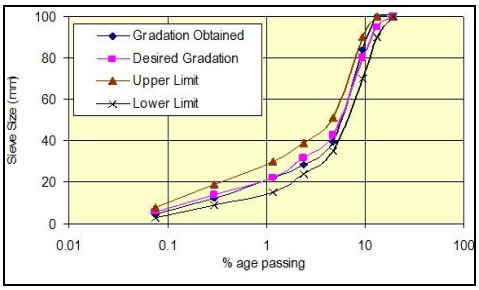


***Figure 1:*** *Gradation of Semi Dense Bituminous Concrete Mix*

## 6. Methodology Used

There are two methods for utilization of waste plastic in bituminous mixes. Mixing of waste plastic with bitumen known as wet process where as coating of waste plastic over coarse aggregates known as dry process. In present study dry process has been adopted as per flow chart of Figure 2 [1].

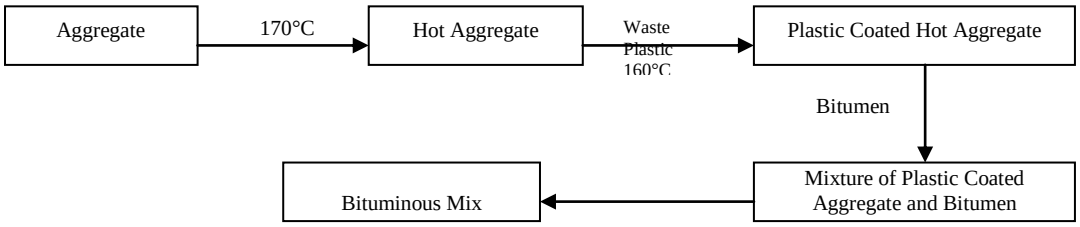


***Figure 2:*** *Dry Process of Mixing Plastic in Bituminous Mixes*

## 7. Mix Design for Semi Dense Bituminous Concrete

Marshall Method of bituminous mix design as per ASTM: D-1559 is used in evolving job mix formula for Semi Dense Bituminous Concrete (SDBC) mix using conventional and waste plastic coated aggregate as per MoRT&H specification.

Marshall Specimens were prepared with different dose of bitumen content ranging from 4.5% – 5.5% (by increment of 0.5%) to obtained the optimum bitumen content for conventional and waste plastic coated aggregates. Quantity of waste plastic used for coating of aggregates was 5%, 10% and 15% of bitumen content. Prepared specimens were kept in Marshall Moulds for 24hrs before extracting them from the moulds. Marshall Stability tests were conducted to study mechanical and volumetric properties of bituminous mixes. The optimum bitumen content and corresponding maximum stability, bulk density, permissible flow value, air voids, VFB and VMA are obtained mentioned in Table 4.

***Table 4:*** *Properties of SDBC mixes for Conventional and Waste Plastic Coated Aggregate*

| Sr. No. | Semi Dense Bituminous Mixes properties | Waste Plastic Expressed as %age by Weight of Bitumen | | | | MoRT&H Specifications |
|---|---|---|---|---|---|---|
| | | 0% | 5% | 10% | 15% | |
| 1 | Marshall stability Value, kN | 14.65 | 16.92 | 19.36 | 15.46 | >8.2 |
| 2 | Flow Value, mm | 3.15 | 3.20 | 3.26 | 3.24 | 2-4 |
| 3 | Marshall Quotient, kN/mm | 4.65 | 5.29 | 5.94 | 4.77 | - |
| 4 | Theoretical Max. Density , gm/cc | 2.486 | 2.476 | 2.468 | 2.464 | - |
| 5 | Bulk Density($G_b$), gm/cc | 2.392 | 2.364 | 2.359 | 2.346 | - |
| 6 | Volume of air voids (Vv) , % | 3.78 | 4.52 | 4.42 | 4.79 | 3-5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Volume of bitumen ($V_b$) % | 12.71 | 12.99 | 12.69 | 12.92 | - |
| 8 | Voids in mineral aggregate (VMA), % | 16.49 | 17.51 | 17.11 | 17.71 | >15 |
| 9 | Voids filled with bitumen (VFB) % | 77.08 | 74.19 | 74.17 | 72.95 | 65-78 |
| 10 | Optimum bitumen content % | 5.42 | 5.35 | 5.24 | 5.35 | Mini. 4.5% |

## 8. Conclusions

On the basis of the results of this investigation following conclusions are drawn:

Optimum bitumen content for the SDBC mix using conventional aggregates was observed as 5.42% whereas 5.24% for waste plastic coated aggregate , resulting in saving of bitumen content. Optimum quantity of waste plastic was observed as 10% of bitumen content of conventional aggregate. The significantly increase in the stability value shows an improvement in the properties of Semi Dense Bituminous Concrete (SDBC) mix because of plastic coating over aggregates. Hence utilization of plastic waste in bituminous pavements is environmental friendly solution in terms of disposal of non-biodegradable waste plastic along with reduction in bitumen content.

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