Innovations

# Utilizing Plastic Waste in Bituminous Concrete for Flexible Pavement Construction

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***Abstract:***

*The global issue of excessive plastic waste accumulation presents a significant environmental challenge. In recent years, researchers and engineers have been actively exploring innovative approaches to address this problem. This study specifically focuses on the utilization of plastic waste as an effective additive in bituminous concrete for construction purposes. The objective is to not only reduce plastic waste but also enhance the performance of asphalt pavements. The research involved conducting laboratory experiments to examine the impact of incorporating plastic waste into bituminous mixtures. Various physical properties, including stability, Marshall stability, and flow value, were assessed. To achieve this, different types of plastic waste such as carry bags and bin linings were cut into small pieces, coated over hot aggregate, mixed with hot bitumen, and prepared for construction. The resulting mixture of polymer-coated aggregate and bitumen demonstrated increased Marshall stability values and reduced air voids.*

***Keywords:*** *bitumen, coarse aggregate, fine aggregate, stone dust, waste plastic (LDPE) etc.*

## 1. Introduction

In recent years, the world has faced a growing concern over the detrimental impact of plastic waste on the environment. As a result, there has been an increasing emphasis on finding innovative solutions to tackle this global issue and promote sustainable practices. One such solution gaining significant attention is the incorporation of plastic waste in bituminous road construction, offering a promising way to address both the environmental challenges of plastic waste and the need for durable and sustainable infrastructure. The use of plastic waste in road construction involves incorporating shredded or melted plastic, derived from various sources such as single-use plastics, packaging materials, and industrial waste, into the bituminous mixtures. The plastic waste serves as a partial replacement for traditional aggregates, such as stone, sand, and gravel, in the asphalt mix. This approach not only offers a sustainable way to manage plastic waste but also brings several key benefits to the road construction industry.

## 2. Material And Mix Design

### 2.1 Material and it's Physical Properties

Multiple materials are utilized in the construction of flexible pavement, including bitumen, coarse and fine aggregates, stone dust, and shredded plastic waste. For this study, VG30 grade bitumen was sourced from the Nagar Palika of Vidisha, Madhya Pradesh. The coarse and fine aggregates were obtained from a nearby supplier. As for the plastic waste, it was collected from our households and subsequently shredded using scissors. The test findings and acceptable ranges for the aggregates' physical characteristics are shown in Table 1.
The bitumen VG30's physical characteristics are shown in table 2.

**Table 1: Physical properties of aggregate**

| Sr. No | Test | Test result | Specifications Requirement | Standard |
|---|---|---|---|---|
| **1** | **Aggregate impact value** | 18.2% | Max 30% | IS: 2386 (part- IV)-1963 |
| **2** | **Crushing value** | 22.0% | Max 30% | IS: 2386 (part- IV)-1963 |
| **3** | **Specific gravity** | 2.79 | 2.5 to 3.0 | IS: 2386 (part- III)-1963 |
| **4** | **Water absorption** | 0.2% | Max 2% | IS: 2386 (part- III)-1963 |
| **5** | **Combined elongation index and flakiness index** | 16% | Max 35% | IS: 2386 (part- I)-1963 |

**Table 2 Physical Properties of Bitumen**

| Sr. No. | Test | Test result | Specification Requirement | Standards |
|---|---|---|---|---|
| **1** | **Penetration** | 64.0 mm | 60-70 mm | IS: 1203-1978 |

| | | | | |
|---|---|---|---|---|
| **2** | **Softening point** | 55.0 °C | 40-60 °C | IS: 1205-1978 |
| **3** | **Specific gravity** | 1.02 | 0.96-1.02 | IS: 1202-1978 |
| **4** | **Flash point** | 240°C | Min 220°C | IS: 1209-1978 |
| **5** | **Fire point** | 270°C | Min 247°C | IS: 1209-1978 |

**2.2 Experimentation with OBC Determination and Marshall Sample Preparation**

• In an iron pan, the required amounts of fine aggregate, coarse aggregate, and mineral filler (stone dust) were heated to 160 degrees Celsius.

- Before combining, the bitumen was heated to 120 °C, the temperature at which it melts.

- The bitumen content was then added to the aggregates, ranging from 4.5% to 6% with a 0.50% range.

- This was blended evenly and thoroughly until a homogeneous mixture was produced.
- The mixture was then placed in the standard Marshall mould, and 75 blows were applied to each face to produce Marshall Samples.

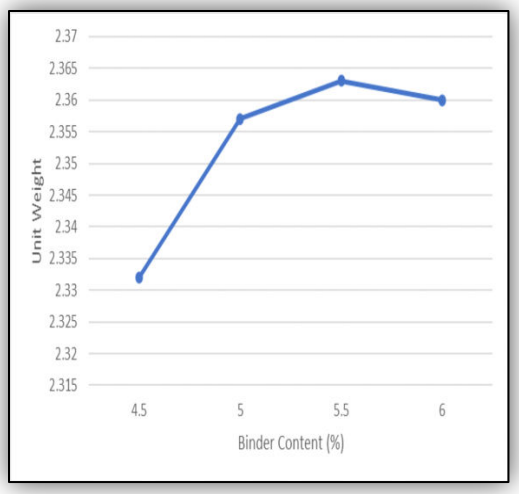
- The specimen's weight and average size were calculated.

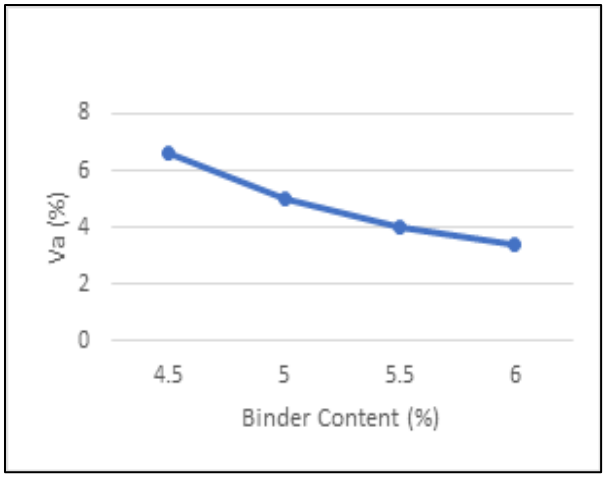
• The VMA (Voids in Mineral Aggregates), VFB (Voids Filled with Bitumen), and Va (Voids in Air) percentages were calculated for each test specimen. These values were then averaged across multiple specimens.

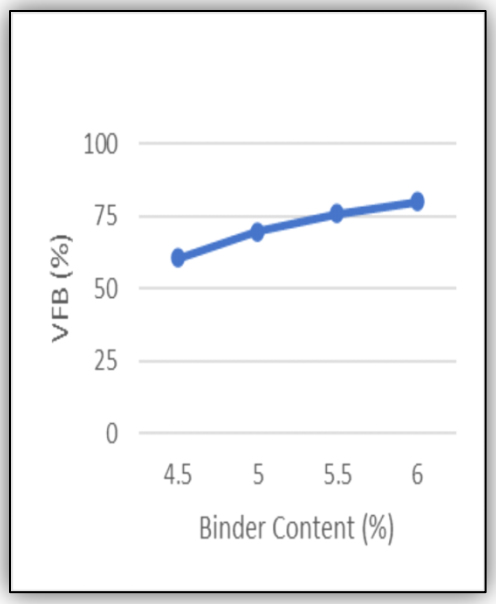
• The X-axis represented the bitumen content, while the Y-axis displayed the plotted values for stability, flow, Va, unit weight, VMA, and VFB. The achieved stability value and flow value can be found in Table 3. Following the same method, a different set of samples were created with bitumen content replaced.

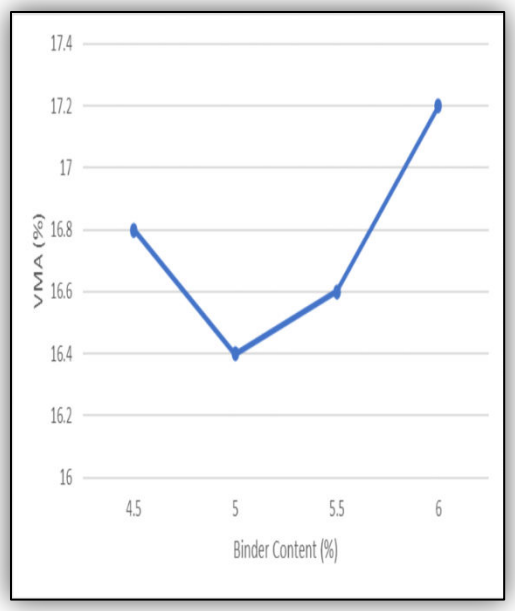
**Table 3 Marshall test results for stability and flow**

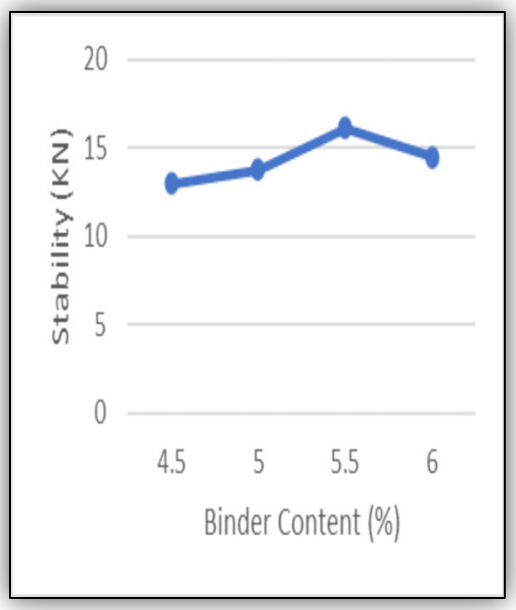
| **Binder content (%)** | **Gm** | **Va (%)** | **VMA (%)** | **VFB (%)** | **Stability value in KN** | **Flow value in mm** |
|---|---|---|---|---|---|---|
| **4.5** | **2.332** | **6.6** | **16.8** | **60.6** | **13.0** | **3.73** |
| **5.0** | **2.357** | **5.0** | **16.4** | **69.8** | **13.78** | **4.68** |
| **5.5** | **2.363** | **4.0** | **16.6** | **76.0** | **16.13** | **5.52** |
| **6.0** | **2.360** | **3.4** | **17.2** | **80.0** | **14.52** | **4.32** |

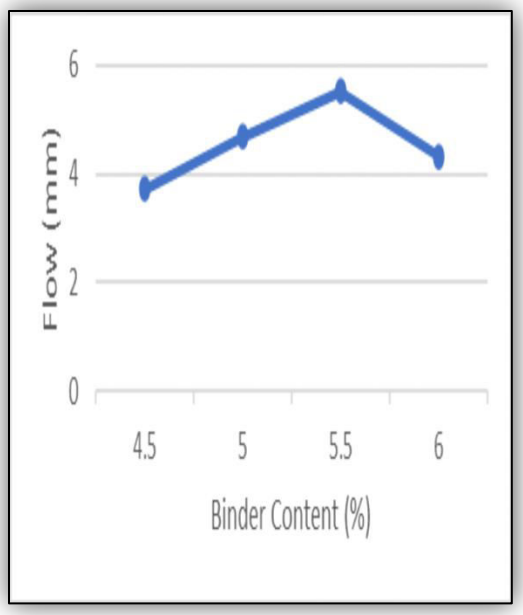

2.37
2.365
2.36
2.355
2.35
2.345
2.34
2.335
2.33
2.325
2.32
2.315
Unit Weight
4.5
5
5.5
6
Binder Content (%)


8
6
4
2
0
Va (%)
4.5
5
5.5
6
Binder Content (%)



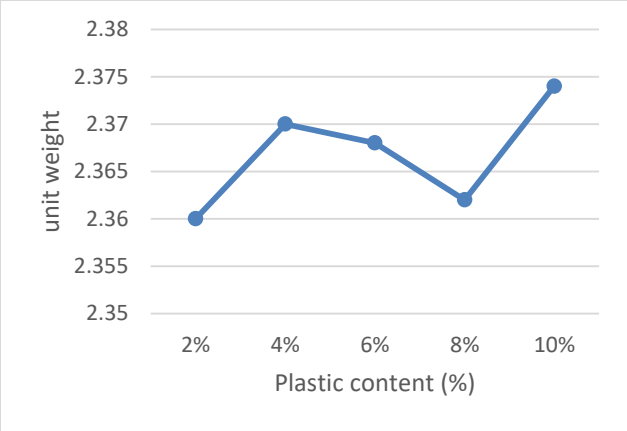

Upon examining the curves depicting the relationship between bitumen content (%) and stability (maximum value), unit weight (maximum value), and air voids (equivalent to 4% air voids), it was noted that the peak values for these parameters were all 5.5%Consequently, the optimal bitumen content (OBC) was determined to be 5.5% based on the average value of the aforementioned three parameters.

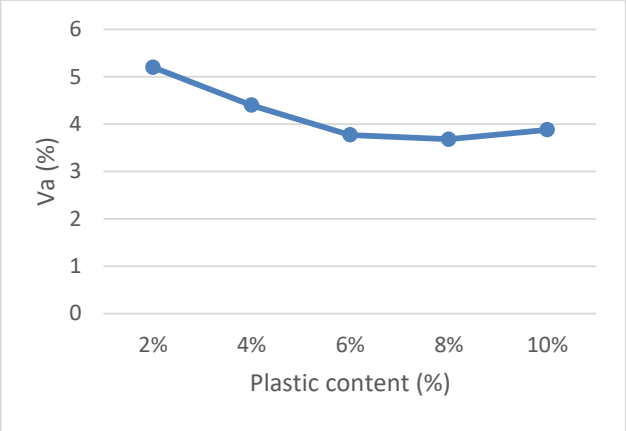
**2.3 Below is a Representation of the Flow value and Stability value of Bituminous concrete specimen achieved by the Marshall test with the addition of Plastic waste.**

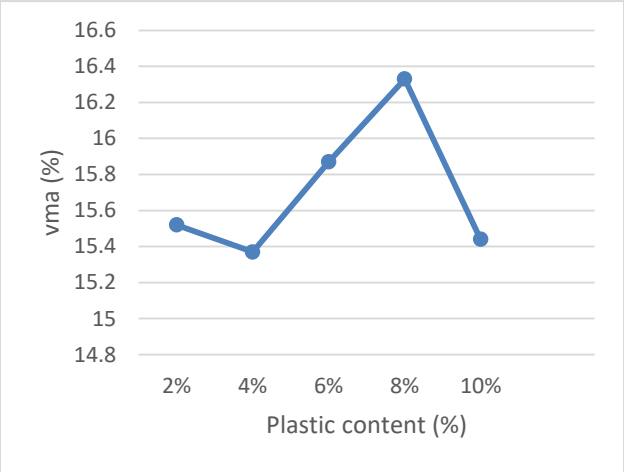
- The aggregates were heated to 170°C using a dry technique to create Marshall samples.
- Plastic waste in various weight ratios, 2%,4%,6%,8% and 10%, has been added to the heated aggregate.
- the hot bitumen at 160°C is added in the plastic coated aggregate mixture
- then hot bitumen at 160°C is added in the plastic coated aggregate mixture
- The mixture was then placed in the standard Marshall mould, and 75 blows were applied to each face to produce Marshall Samples.

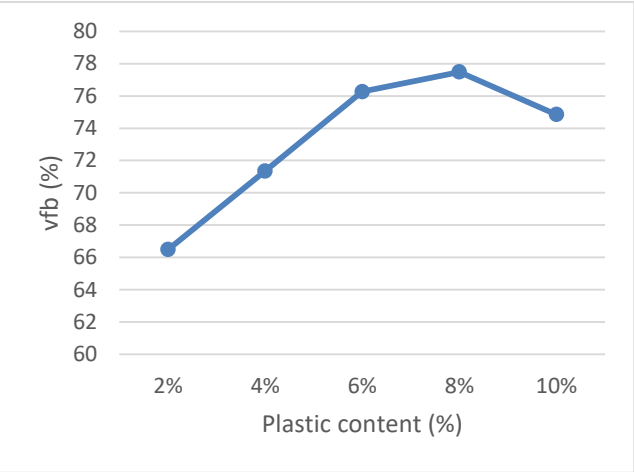
**Table 4Marshal test results for Stability and Flow value with additional plastic waste**

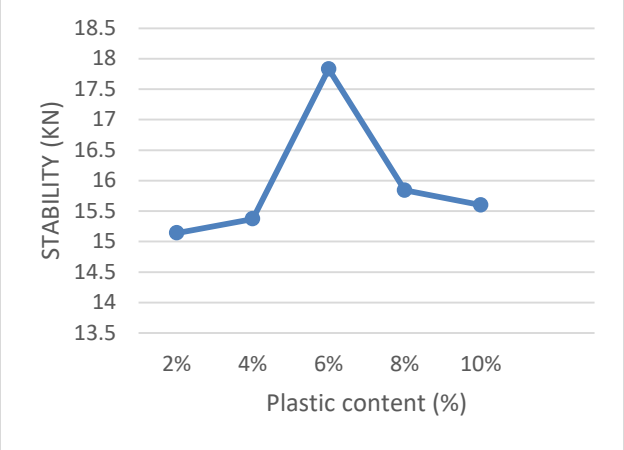
| Plastic content (%) | Gm | Va (%) | VMA (%) | VFB (%) | Stability value in KN | Flow value in mm |
|---|---|---|---|---|---|---|
| 2% | 2.360 | 5.20 | 15.52 | 66.49 | 15.14 | 4.65 |
| 4% | 2.370 | 4.4 | 15.37 | 71.35 | 15.37 | 5.25 |
| 6% | 2.368 | 3.77 | 15.87 | 76.26 | 17.83 | 4.55 |
| 8% | 2.362 | 3.68 | 16.33 | 77.48 | 15.84 | 4.27 |
| 10% | 2.374 | 3.88 | 15.44 | 74.85 | 15.6 | 4.03 |

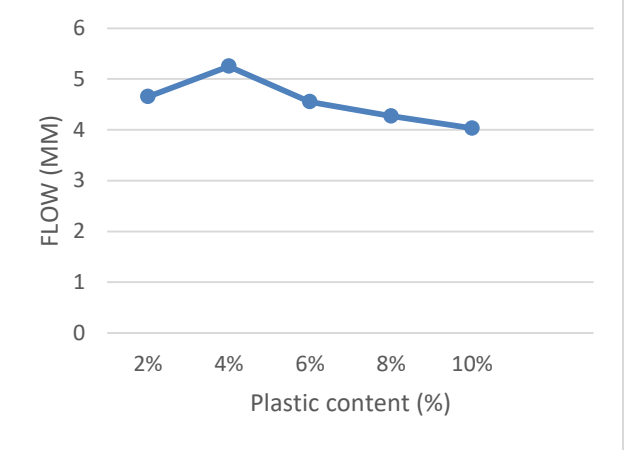

unit weight
2.38
2.375
2.37
2.365
2.36
2.355
2.35
2%
4%
6%
8%
10%
Plastic content (%)


Va (%)
6
5
4
3
2
1
0
2%
4%
6%
8%
10%
Plastic content (%)


vma (%)
16.6
16.4
16.2
16
15.8
15.6
15.4
15.2
15
14.8
2%
4%
6%
8%
10%
Plastic content (%)


vfb (%)
80
78
76
74
72
70
68
66
64
62
60
2%
4%
6%
8%
10%
Plastic content (%)


STABILITY (KN)
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
13.5
2%
4%
6%
8%
10%
Plastic content (%)


FLOW (MM)
6
5
4
3
2
1
0
2%
4%
6%
8%
10%
Plastic content (%)

In the experimental study the maximum stability value is 17.83 KN corresponding to the 6% plastic content. So the optimum plastic content is 6%.

According to Table 5, the qualities improve following the addition of plastic waste.

**Table 5 The Qualities following the addition of Plastic waste were compared**

| Sr. No. | Property | Without plastic | After addition of plastic waste |
|---|---|---|---|
| 1 | Unit weight | 2.363 | 2.368 |
| 2 | Air void | 4.0 % | 3.77 % |
| 3 | VMA | 16.6 % | 15.87 % |
| 4 | VFB | 76.0 % | 76.26 % |
| 5 | Stability | 16.13 KN | 17.83 KN |
| 6 | Flow value | 5.52 mm | 4.55 mm |

## 3. Conclusion

- Adding 6% of LDPE plastic waste increases the Marshall stability value and reduces the flow value.
- There is no formation of potholes. The roads have higher durability and can handle heavy traffic.
- The addition of plastic waste reduces air gaps, reducing bitumen bleeding.
- The volumetric and Marshall properties of the mixture demonstrate favorable trends and have the potential to meet the necessary criteria.
- Bituminous concrete can be made with waste plastic, and this method is secure and environmentally friendly.

## References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