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# Enhancing Flexible Pavement Performance through the Incorporation of Waste Engine Oil, Crumb Rubber, and Polyethylene in Bituminous Mixes

Swati Pathak[1], Harish Sharma[2], Hemanshu Verma[3], Shalom Akhai[4], Syed Mohd. Arif[5,a)], Avishreshtha Singh[6]

[1,5]*Department of Civil Engineering, Chandigarh Engineering College, Chandigarh Group of Colleges-Jhanjeri, Mohali– 140307, Punjab, India.*
[2]*Department of Civil Engineering, Sant Baba Bhag Singh University, Khiala, Jalandhar–144030, Punjab, India.*
[3]*Department of Civil Engineering, Faculty of Science & Technology, The ICFAI University, Atal Siksha Kunj, Kalujhanda, Baddi– 173205, Himachal Pradesh, India*
[4]*Department of Mechanical Engineering, Maharishi Markandeshwar Engineering College, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala– 133207, Haryana, India.*
[6]*Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands.*

[a)] Corresponding author: syed.aarif3@gmail.com

**Abstract.**This current investigation was conducted to improve performance of traditional pavement by reusing/utilizing industrial waste materials in bituminous concrete mixtures for flexible pavements, thereby promoting waste management practices. The optimum mix was found to be at 3% L.D.P.E. with 4% W.E.O., &5% crumb rubber, and having bitumen percentage content of 4.5%. A higher content of waste incorporationwas found to enhance brittleness and deformation. This study assessed the optimalmixes or optimal mix ratios for their dissemination, brittleness, ductility, and specific gravity characteristics. Best/optimal results were identifiedwhile using ratios of 3% L.D.P.E., 4% W.E.O., &5.0% C.R. with 4.5% bitumen. This ratio was found to result leading to a max. stability of 730.5 kg & 17.25 of flow rate. Thesefindingssuggest that industrial waste can be successfully blended with bituminous construction mixes thereby improving pavement performance and supporting waste management at parallel. Thus reusing industrial waste materials in bituminous construction mixes in optimal ratios can lead to better pavement performance in comparison to traditional pavement but for that the exact ratios must first be calculated for obtaining desired characteristics.

**Keywords**: Waste Engine Oil, Crumb Rubber, Polyethylene, Marshal Stability test.



## INTRODUCTION

Waste engine oil (W.E.O.), waste rubber from discarded tires, and low-density polyethylene are examples of the types of industrial waste that are produced in abundance and are difficult to dispose so may cause threat to environment [1]. So as these waste/disposed tires are harmful to the environment and cause landfills to get clogged, while engine oil is a vehicle pollutant that poses a significant danger if burnt or not disposed properly [2]. The construction industry has the potential to recycle and make use of crumb rubber (C.R.) from old tires and low-density polyethylene (L.D.P.E.) [3]. In civil engineering construction sector, these materials may be utilised and thus could cut down on waste, save costs, and improve performance of structures, thus these waste materials are blended into bituminous construction mixes for flexible pavements [4]. According to the findings of past studies, crumb rubber, waste motor oil, and plastic debris all contribute to an improvement in the stability, durability, and resistance to deformation of bituminous mixtures but when used collectively, they must be studied first before using, so as to get desired properties [5]. Using W.E.O., C.R., and L.D.P.E. additives, this study determines the ideal optimum ratios to be blended in bituminous construction mix for flexible pavements with improved characteristics. Thus t goal of this research is in direction towards maximizing the utilization of waste materials and the performance of the pavement [6].

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## MATERIALS AND METHODS

Due of its compatibility with bitumen, Waste Engine Oil (W.E.O), a viscous automotive fluid, was used as an ingredient for bituminous mixtures (Table 1) [7]. Its adhesive and cohesive characteristics make bitumen a popular semi-solid hydrocarbon substance for flexible pavement construction [8]. Crumb Rubber (C.R) from shredding scrap tires improves pavement performance and promotes sustainable waste management [9]. Low-Density Polyethylene (L.D.P.E.), a thermoplastic material used in packaging and consumer products, is also a potential additive for bituminous mixes due to its low density, flexibility, and chemical resistance. Aggregates, consisting of coarse and fine stone particles, provide strength and resistance to degradation. W.E.O, a high-risk pollutant, is compatible with bitumen, making it a viable additive for bituminous mixes [10].

**TABLE 1:**Industrial waste materials for Bituminous mix [7-10].

| Material | Description | Benefits in Pavement Construction |
|---|---|---|
| **Waste Engine Oil** [7] | Viscous fluid from automotive industry | Compatible with bitumen; reduces asphalt content; enhances properties like stiffness, fatigue resistance, and rutting resistance |
| **Bitumen**[8] | Semi-solid hydrocarbon product | Adhesive and cohesive properties; ideal for flexible pavement construction |
| **Crumb Rubber** [9] | Shredded waste tires | Enhances pavement performance; contributes to sustainable waste management |
| **Low-Density Polyethylene** [10] | Thermoplastic material used in packaging | Low density; flexible; chemical resistance; potential additive for bituminous mixes |
| **Aggregates**[10] | Coarse and fine stone particles | Provides strength and resistance to degradation in pavements pen spark. |

## EXPERIMENTAL INVESTIGATIONS



Bitumen was melted at 160°C on an induction hot plate and industrial waste materials were mixed with it to ensure homogeneity [11]. The mixture was then subjected to cooling at room temperature of 25°C before the testing. The waste materials (WEO, CR, and LDPE) were collected and mixed/combined with bitumen and aggregates to create various mix compositions (Table 2). The mixtures were then thoroughly mixed and allowed to cool before testing. The study showed that the proportion of industrial waste varied between B1 (control) and B5 (5% L.D.P.E. + 7% W.E.O. + 5% C.R.).

**TABLE 2:** The various compositions of waste with bitumen samples (Source: Author).

| Sample | Compositions |
|---|---|
| **B1** | NIL |
| **B2** | 2% L.D.P.E .+ 4% W.E.O. + 5% C.R. |
| **B3** | 3% L.D.P.E + 5% W.E.O. + 5% C.R. |
| **B4** | 4% L.D.P.E. + 6% W.E.O. + 5% C.R. |
| **B5** | 5% L.D.P.E. + 7% W.E.O. + 5% C.R. |

The bitumen mixtures were tested for their properties, including penetration, softening point, ductility, and specific gravity, as per Indian Standard (IS) codes [12]. The Mix of marshal design samples were made with bitumen contents of 4.50% and different waste material compositions. A total of 5 samples were prepared, and their properties were determined using the Marshall Mix Method. The bitumen tests included penetration tests, softening point tests, ductility tests, and specific gravity tests. The Mix of marshal design samples were made with bitumen contents of 4.50% & various waste compositions. The properties of the samples were evaluated using the Marshall testing machine (Table 3).

**TABLE 3:** Marshall mix results (Source: Author).

| Mix Samples | Bitumen Content (%) | Sample ID | Bulk Density (Gm/cc) | Theoretical Sp Gravity (Gt) | Volume of Voids (Vv) (%) | Vb (%) | Voids in Mineral Aggregates (VMA) (%) | Voids Filled with Bitumen (VFB) (%) | Stability Value (kg) | Flow Value (0.25 mm per unit) |
|---|---|---|---|---|---|---|---|---|---|---|
| BC-1 | 4.5 | B1 | 2.362 | 2.365 | 4.098 | 7.84 | 12.12 | 67.05 | 669.5 | 13.42 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BC-2 | 4.5 | B2 | 2.273 | 2.374 | 4.175 | 7.81 | 12.54 | 68.23 | 685.5 | 14.26 |
| BC-3 | 4.5 | B3 | 2.395 | 2.48 | 4.65 | 7.95 | 13.03 | 71.51 | 730.5 | 17.25 |
| BC-4 | 4.5 | B4 | 2.286 | 2.38 | 4.54 | 7.65 | 12.38 | 69.24 | 687.5 | 12.21 |
| BC-5 | 4.5 | B5 | 2.315 | 2.37 | 3.96 | 10.21 | 14.52 | 67.71 | 654.5 | 13.21 |

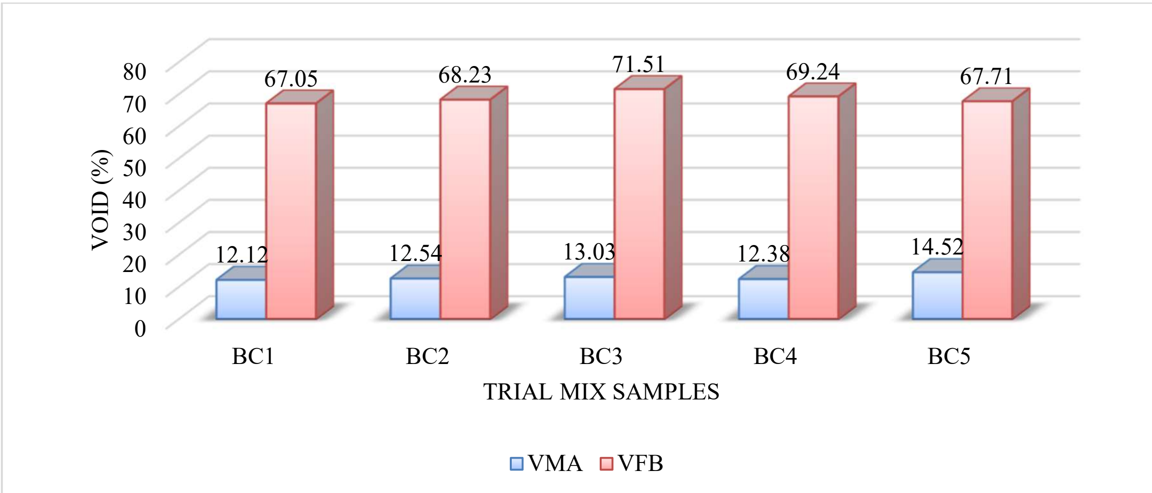


**FIGURE.1:** Comparison between Voids in Mineral Aggregates & Voids Filled with Bitumen of samples(Source: Author).

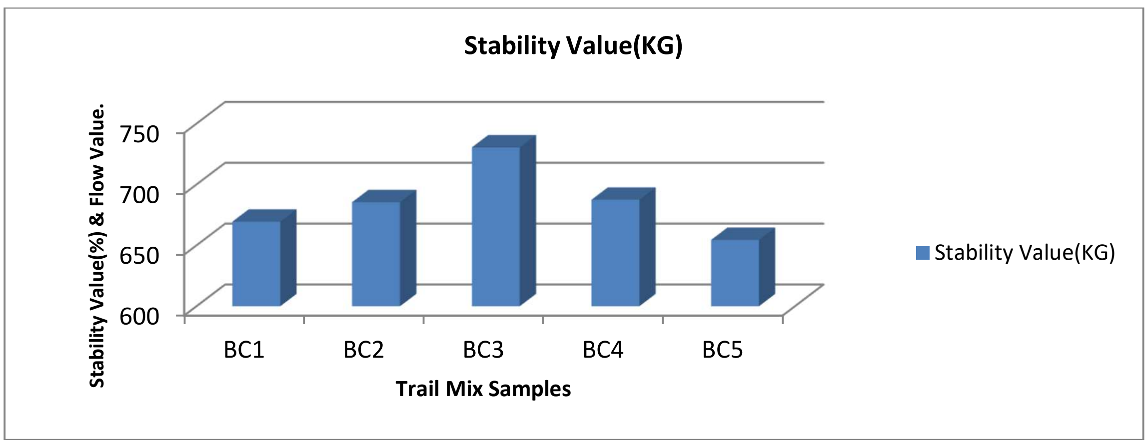


**FIGURE.2:** Stability value of samples in kg.(Source: Author)

The comparison between voids in mineral aggregates and voids filled with bitumen in samples is shown in Fig. 1.The stability value of samples in kg is depicted in Fig. 2. The stability and durability of Compacted Marshall Mix are determined by factors such as bulk density, theoretical specific gravity, void volume, bitumen volume, Mineral Aggregates volume, bitumen-filled volume, load-bearing capacity, and flow value [13]. Bulk density indicates stronger compaction, while theoretical specific gravity estimates void volume [14]. Pavement structural performance depends on load-bearing capacity, while flow reflects the mixture's ability to absorb traffic loads without breaking [15]. Greater waste content may cause instability, while higher bitumen content improves stability and flow [16].Future studies could utilize AI algorithms for long-term performance prediction [17-19]. Also, Taguchi or Response Surface Methodology or similar optimisation techniques can be applied to optimize mix proportions, improve performance and cost [20-25].

## RESULTS AND DISCUSSION

The Marshall Mix results/study reveals that industrial waste (L.D.P.E., W.E.O., C.R.) improves the stability and flexibility of a mixture, making it suitable for flexible pavement building and overcoming waste disposal issues. The best results are achieved at 3% L.D.P.E., 5% W.E.O., and 5% C.R. with 4.5% bitumen. Higher waste content (4-5% L.D.P.E., 6-7% W.E.O.) may cause brittleness or instability, while the 4.5% bitumen percentage marginally increases stability and flow. BC-5, with 5% L.D.P.E., 7% W.E.O., and 5% C.R., is stable and flowy. The study also found that waste materials increase penetration up to a specific limit (B3 content), then abruptly drop. The B3 composition (3% L.D.P.E., 5% W.E.O., and 5% C.R.) met design objectives with a max. stability value of 730.50 kg and 17.25 of flow value.

## CONCLUSION

The experimental results shows that the mix of bituminous for asphalt pavement may include waste materials (industrial) including L.D.P.E., W.E.O., and C.R. The mixture's stability and environmental effect enhance with these elements, making waste management sustainable. The optimal mix—3% L.D.P.E., 5% W.E.O., 5% C.R., and 4.5% bitumen—met design criteria with 730.5 kg max. stability and 17.25 flow. Pavement performance depends on proportioning. Above this level, the mix was brittle and likely deformed. This study improves pavement and trash management. For stability and flexibility, 3% L.D.P.E., 5% W.E.O., 5% C.R., and 4.50% bitumen work well. This mixture fulfilled pavement design standards with 730.50 kg stability and 17.25 flow. Exceeding these prescribed waste proportions weakened stability and might induce brittleness, emphasizing the importance of waste material composition for performance. These waste materials in bituminous mixtures may improve pavement performance, minimize environmental impact, and save virgin resources. Further research might assess these mixes' long-term performance in real-world traffic and the economic benefits of waste material in pavement construction.

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