# Experimental Analysis on Performance Assessment of Bituminous Concrete Incorporating Crumb Rubber and Recycled Powder filler

*Shubham Malviya[1], Dr. Shubha Khatri[2]*
*[1]M. Tech Scholar, Civil Engineering Department, SATI Vidisha, MP.*
*[2]Assistant Professor, Civil Engineering Department, SATI Vidisha, MP.*

*Abstract: Nowadays, one of the biggest problems is disposing of rubber waste from different businesses. These compounds contaminate the local atmosphere since they are not biodegradable. Bitumen, cement, sand, soil, and stone aggregate make up the bulk of the materials used in road construction. Finding natural resources is becoming more difficult. Furthermore, the cost of extracting superior natural material is rising. To alleviate this problem and possibly reduce pollution and disposal difficulties, it is recommended that alternative materials be utilized while building highways. The use of crumb rubber for asphalt reinforcement is thought to be an ingenious technique to support sustainable development since it recycles waste materials. Additionally, a separate type of polymer called crumb rubber modifier (CRM) is believed to have the potential to improve hot mix asphalt's performance attributes. The purpose of incorporating crumb rubber modifier (CRM) and recycled powder filler into asphalt mixtures is to improve the properties of bitumen. Thus, the purpose of this study is to evaluate the bituminous mix's performance and how it responds when different waste materials are added. For this study, the properties of CRM binder as a function of percentages were investigated in a laboratory setting. The optimal modification amount has been determined using un-aging and aging parameters for CRM contents—3%, 5%, 7%, by bitumen weight & CRM with SBR 3%, 4%, 5%. The binder was assessed using the ductility, flash and fire point, penetration, and softening point tests. The Marshall Test has been performed on the bituminous mixture. The results demonstrate the potential advantages of using steel crumb rubber in bituminous mix designs, such as increased sustainability and less environmental impact while preserving or even enhancing pavement performance.*

*Keywords: Crumb rubber modifier (CRM), SBR Marshall Test, Powder filler, sustainability, sustainable development, asphalt.*

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## I. INTRODUCTION

The amount of rubbish created by cities worldwide is only growing, despite the slowdown in global economic growth. The World Bank estimates that the yearly production of solid waste in urban areas is 1.3 billion tonnes, and that figure is projected to increase to 2.2 billion tonnes by 2025. Air pollution, social unrest, poverty, and other problems are caused by the majority of trash being disposed of in landfills or, worse, open dumps. Similar to most developing countries, India is facing an increase in waste output and associated problems in disposing of it. Recycling waste materials is one way to solve the issue. India is thought to create one billion motorcar trash tires annually. Furthermore, waste tires are not categorized as solid or hazardous waste. trash tire management is not expressly regulated by any laws or regulations because it is usually considered industrial or trade trash. A tire waste product called crumb rubber is used into bituminous mix designs to enhance the sustainability and performance of asphalt pavement. Using crumb rubber as an inexpensive alternative, this approach aims to reduce bitumen's negative environmental effects. The mix design process typically involves selecting the appropriate proportions of aggregates, bitumen, and crumb rubber, as well as additives if necessary, to achieve desirable engineering attributes including stability, durability, and resistance to deformation. The process's key procedures include aggregate characterization, gradation analysis, volumetric analysis, and performance testing to ensure the final mix meets specific project specifications and performance parameters. By including glass powder, limestone powder, SBR and crumb rubber into bituminous mix designs, we engineers may be able to improve pavement performance and promote ecologically responsible construction practices.

## II. OBJECTIVES

- To evaluate the performance of bitumen modified with an ideal proportion of glass powder, limestone powder, and crumb rubber in a controlled laboratory setting. This entails assessing elements including environmental sustainability, rutting resistance, stability, durability, and moisture susceptibility.
- To compare the outcome with a traditional bituminous mix and assess how the bituminous mix behaves when mixed with glass powder, limestone powder, SBR latex and crumb rubber.
- To evaluate the various physical properties and engineering ramifications of adding waste materials to the binder mixture.
- By adding substitute materials like glass powder, limestone powder, SBR latex and crumb rubber, researchers hope to enhance asphalt mixtures' qualities while lessening their negative effects on the environment and encouraging environmentally friendly pavement building methods.

## III. REVIEW OF LITERATURE

Moreno et al. (2012) analyzed the behavior of asphalt mixtures modified with the addition of crumb rubber via the dry method in terms of their sensitivity to humidity and resistance to plastic deformation, finding that the most influential factor on the mixtures' behaviors was the percentage of crumb rubber, while the digestion time (i.e., the time between mixing and compaction) was barely significant. In particular, the best results were obtained with percentages varying between 0.5% and 1.0% of crumb rubber (compared to the weight of the mixture) and a digestion time of 45 min.

Harpalsinh Raol et al (2014) Plastic waste, consisting of carry bags, cups, thermocoles, etc. can be used as a coating over aggregate and this coated stone can be used for road construction. Secondly the waste tires are powdered and the powder is blended with bitumen and this blend is used along with plastic coated aggregate. The mix polymer coated aggregate and tyre modified bitumen have shown higher strength. Use of this mix for road construction helps to use both plastics waste and tyre waste.The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Moreover, the polymer coated aggregate helps to use Crumb rubber modified bitumen resulting in better result. Moreover, the polymer coated aggregate helps to use Crumb rubber modified bitumen resulting in better result.

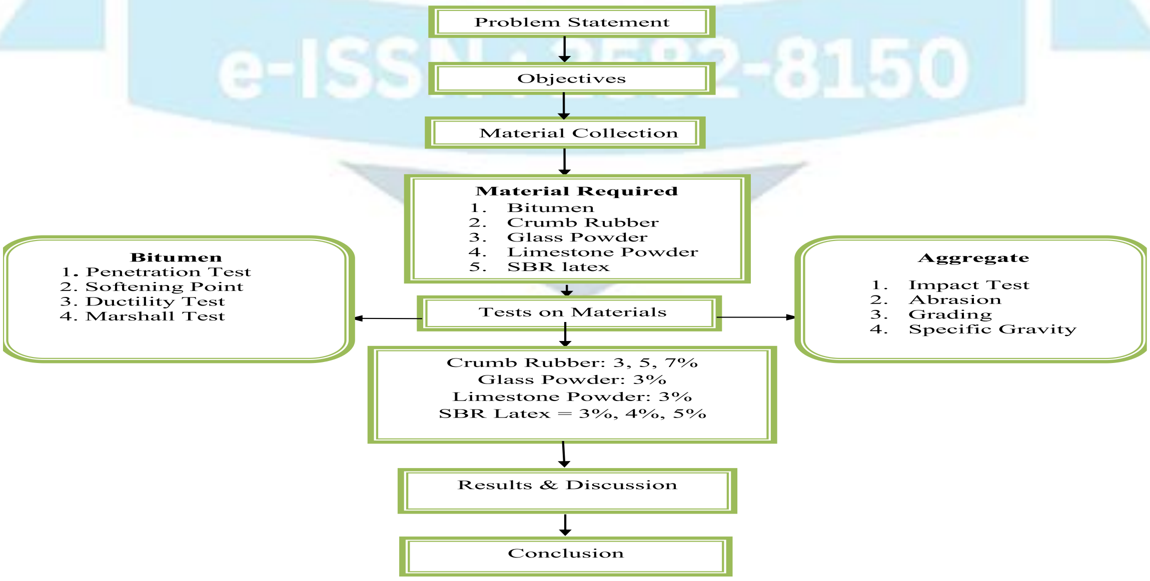
AR Prasad et al (2015) This waste plastic and rubber can be used to partially replace the conventional material which is bitumen to improve desired mechanical characteristics for particular road mix. In the present study, a comparison is carried out between use of waste plastic like PET bottles and crumb rubber (3%, 4.5%,6%,7.5%,9% by weight of bitumen) in bitumen concrete mixes to analyse which has better ability to modify bitumen so as to use it for road construction. In the result it has been observed that 6 % waste gives best results in terms of marshall stability.

Sara Bressia et al (2017) The present paper aims at proposing a mix design approach specifically tailored for rubberized asphalt (dry process) that takes into account the behaviour of the crumb rubber during the compaction and post-compaction processes. An analytical approach to quantify the recovered deformation of the crumb rubber in the post compaction phase has been developed in order to adjust the number of gyrations proposed by SUPERPAVE method when crumb rubber is used. The final goal is to define an appropriate compaction that allows meeting the requirements of voids content for the asphalt mixture considered. The energy stored by the rubber during the process has been calculated. Moreover, a mathematical relationship has been defined for computing the maximum allowable amount of rubber that it is possible to add to the mixture once the target voids content has been established. Finally, based on the results obtained, a full-steps protocol has been proposed in order to fabricate and compact CR mixtures in the laboratory.

Shaurya Sharma et al (2019) The main aim of this study was to determine an alternative for bitumen which will satisfy the physical and binding properties of bitumen in terms of strength, endurance, and flexibility. The asphalt market is looking for alternative sustainable binders that can (fractionally) replace the bitumen in terms of environmental sustainability and which may also augment the availability of binders. In this research study, crumb rubber has been consumed in bituminous mixes and its optimum content percentage is found, the crumb rubber is used in powdered form and that amount has been replaced from the quantity of bitumen. Standard Marshal Mix design and Penetration test and Ductility test were performed. The various percentages of crumb rubber (from 2% to 10% by the weight of bitumen) were used to prepare the samples, with optimum value of bitumen content (5%). It was observed that crumb rubber at 6% (by weight of bitumen) and at 5% Optimum Bitumen Content came out to be optimum percentage of crumb rubber. The test results shows that stability of the modified bitumen mix was increased as compared to the plain bitumen mix. The physical properties of modified bitumen were also improved, with the help of penetration test it was observed that the modified bitumen was harder consistency and was less flexible as per ductility test.

Adeola Alogba et al (2020) This study investigates the use of non-biodegradable wastes namely plastic water bottles and recycled glass in the construction of flexible pavements which, conventionally, uses bitumen as the binder and cement or stone dust as the filler. Consequently, the binder and filler were modified using varying percentages of pulverized plastic and recycled glass powder respectively. The modified binder showed improvement in properties when compared to the unmodified bitumen. The asphalt produced thereafter using the modified materials indicated a stability of 3.33kg obtained at an optimum value of 6% plastic replacement which is higher than the 2.017kg obtained without modifying the bitumen.

## IV. METHODOLOGY



## V. MATERIALS USED

Aggregate: - Granular mineral particles make up aggregates; the ideal aggregate should be robust, resilient, long-lasting, and able to crush into large particles with few flaky ones. The aggregate must be strong enough to support and transfer the applied loads in addition to meeting gradation standards.

Bitumen: - The term "bitumen" describes a class of solid or semi-solid hydrocarbons that occur naturally. It is also referred to as tar or asphalt and is frequently found in crude oil. Road building, roofing, waterproofing, and some industrial processes are just a few of the uses for bitumen. It is a useful material in infrastructure and construction projects because of its well-known adhesives and waterproofing qualities.

Crumb Rubber: -A granular substance called crumb rubber is created from recycled rubber, usually from used tires. Granules of varying sizes are produced by shredding the tires into tiny bits. The majority of the recycled tires' steel wires and reinforcement fibers or fluffs are eliminated during the process. Either the ambient process or the cryogenic method is used for the fine grinding. To satisfy the needs of a specific application or organization, the crumb rubber is frequently sieved and categorized according to gradation.
The tearing and shredding action of the rubber particles in the cracker mills gives the crumb rubber particles that are produced by ambient processing an uneven shape and a rough texture.

Limestone Powder: -A by-product of processing limestone is limestone powder, sometimes referred to as limestone fines or limestone screens. It is produced during mining or quarrying processes when limestone rock is broken up into smaller pieces. The fundamental ingredient of limestone, calcium carbonate, makes up the majority of this fine powder. Limestone dust is frequently used as a filler or as an ingredient in concrete and asphalt mixtures in landscaping and construction.

Glass Powder: - A substance with many uses, glass powder is especially prized for its environmental advantages when made from recycled glass. The consistent particle size, purity, and suitable chemical makeup of high-quality glass powder are its defining characteristics. It improves the longevity and sustainability of the environment by improving the performance of coatings, building materials, and other items.

SBR latex

Styrene-Butadiene Rubber (SBR) latex is a synthetic polymer emulsion widely blended with bitumen to significantly enhance its performance. When added, the latex forms a flexible, elastic, interpenetrating network within the bituminous matrix, transforming its physical and rheological properties.

## VI. EXPERIMENTAL ANALYSIS

The following tests were conducted in order to determine the physical properties of aggregates.

- Specific gravity
- Water absorption
- Aggregate impact test
- Aggregate crushing test
- Shape test
- Los-angeles abrasion test

The following tests were conducted in order to determine the properties of modified bitumen.

- Ductility test
- Flash and fire point
- Penetration test
- Softening point test
- Marshall Test


Figure 1: Live working in Lab

VII. RESULTS & DISCUSSION

Table 1: Sieve Analysis Result

| Sieve Size (mm) | Aggregate Weight(gm) | Weight Percent (Passing) | Passing Percent Limit |
|---|---|---|---|
| 19 | 0 | 100% | 100 |
| 13.2 | 90 | 92.5% | 79-100 |
| 9.5 | 180 | 77.5% | 59-79 |
| 4.75 | 204 | 60.5% | 52-72 |
| 2.36 | 162 | 47% | 35-55 |
| 1.18 | 120 | 37% | 28-44 |
| 0.6 | 108 | 28% | 20-34 |
| 0.3 | 108 | 19% | 15-27 |
| 0.15 | 108 | 10% | 10-20 |
| 0.075 | 72 | 4% | 4-13 |
| Pan | 36 | 2% | 2-8 |

Aggregate tests Result:

Table 2: Aggregate Test Result

| S.No. | Aggregate Test Performed | Result | Specified Limits | References |
|---|---|---|---|---|
| 1 | Specific gravity<br>(i) Coarse Aggregate<br>(ii) Fine Aggregate | <br>2.52<br>2.34 | <br>2.5-3.2<br>2.3-2.9 | IS 2363(Part III) - 1963 |
| 2 | Water absorption | 2.42% | 0.1-5% | IS 2386(Part III) - 1963 |
| 3 | Aggregate impact test | 10.29% | <35% | IS 2386(Part IV) - 1963 |
| 4 | Aggregate crushing value test | 18.91% | <30% | IS 2386(Part IV) - 1963 |
| 5 | Flakiness index | 13.32% | <15% | IS 2386(Part I) - 1963 |
| 6 | Elongation index | 22.76% | <25% | IS 2386(Part I) - 1963 |
| 7 | Los Angeles abrasion test | 18.24% | <35% | IS 2386(Part IV) - 1963 |

Determination of Softening Point Test of Bitumen:

The grade of bitumen on which test are performed is VG-30. Method of test according to IS 1205-1978.

Table 3: Softening Point Test Result

| | % of Crumb Rubber (CR) & SBR with respect to weight of bitumen sample. | Mean Temperature |
|---|---|---|
| Temperature at which sample touches the bottom plate | 0 % | 43.5 °c |
| | 3 % | 50.5°c |
| | 5 % | 52.5°c |
| | 7 % | 53.5°c |
| | 3 % (CR) + 3% (SBR) | 55.5°c |
| | 5 % (CR) + 4% (SBR) | $56^0$ c |
| | 7 % (CR) + 5% (SBR) | $54^0$ c |

Flash and fire point of bitumen:

The grade of bitumen on which test are performed is VG-30. Method of testing is then according to IS 1209-1978.

Table 4: Flash and fire point test results of bitumen

| % of Crumb Rubber (CR) & SBR with respect to weight of bitumen sample. | Flash point | Fire point |
|---|---|---|
| 0 % | 246.66°C | 261.66°C |
| 3 % | 266.66°C | 286.66°C |
| 5 % | 283.33°C | 316.66°C |
| 7 % | 291.66°C | 330°C |
| 3 % (CR) + 3% (SBR) | 303.33°C | 336.66°C |
| 5 % (CR) + 4% (SBR) | 305$^{0}$C | 340$^{0}$C |
| 7 % (CR) + 5% (SBR) | 304$^{0}$C | 337°C |

Penetration test of bitumen:

The grade of bitumen on which test are performed is VG-30. Method of testing is then according to IS 1203-1978

Table 5: Penetration test results of bitumen

| Method of test is according to IS- 1203-1978. Grade of bitumen used vg-30. % of Crumb Rubber (CR) & SBR added with respect to the weight of bitumen sample | Penetration 1/10th mm |
|---|---|
| 0 % | 88.67 mm |
| 3 % | 76.33 mm |
| 5 % | 74.33 mm |
| 7 % | 68.66 mm |
| 3 % (CR) + 3% (SBR) | 62 mm |
| 5 % (CR) + 4% (SBR) | 70 mm |
| 7 % (CR) + 5% (SBR) | 68 mm |

Ductility test of bitumen:

The grade of bitumen on which test are performed is VG-30. Method of testing is then according to IS 1208-1978

Table 6: Ductility test results of bitumen

| Method of testing according to IS 1208-1978. Bitumen sample used vg-30. % of Crumb Rubber (CR) & SBR added with respect to the weight of bitumen sample. | Ductility in cm |
|---|---|
| 0 % | 93.33 cm |
| 3 % | 89 cm |
| 5 % | 85.67 cm |
| 7 % | 83.33 cm |
| 3 % (CR) + 3% (SBR) | 83.66 cm |
| 5 % (CR) + 4% (SBR) | 90.33 cm |
| 7 % (CR) + 5% (SBR) | 87 cm |

Marshall stability test of bitumen:

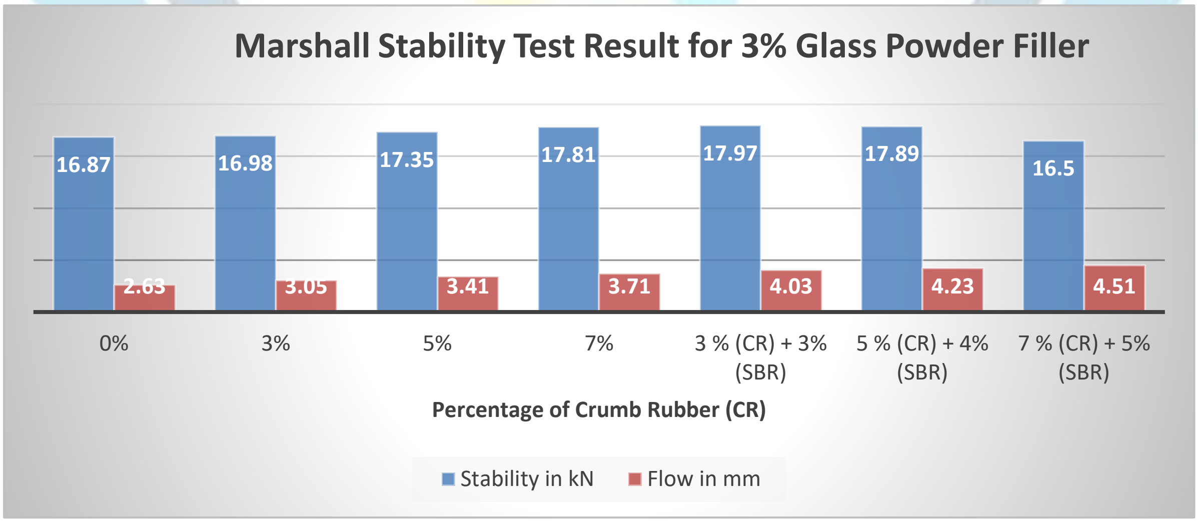
Table 7: Results of 3% Glass Powder filler for Varying Percentage of CR

| % of Crumb Rubber (CR) & SBR added with respect to the | Stability in KN | Flow in mm | VMA (%) | Air Void (%) | VFB |
|---|---|---|---|---|---|

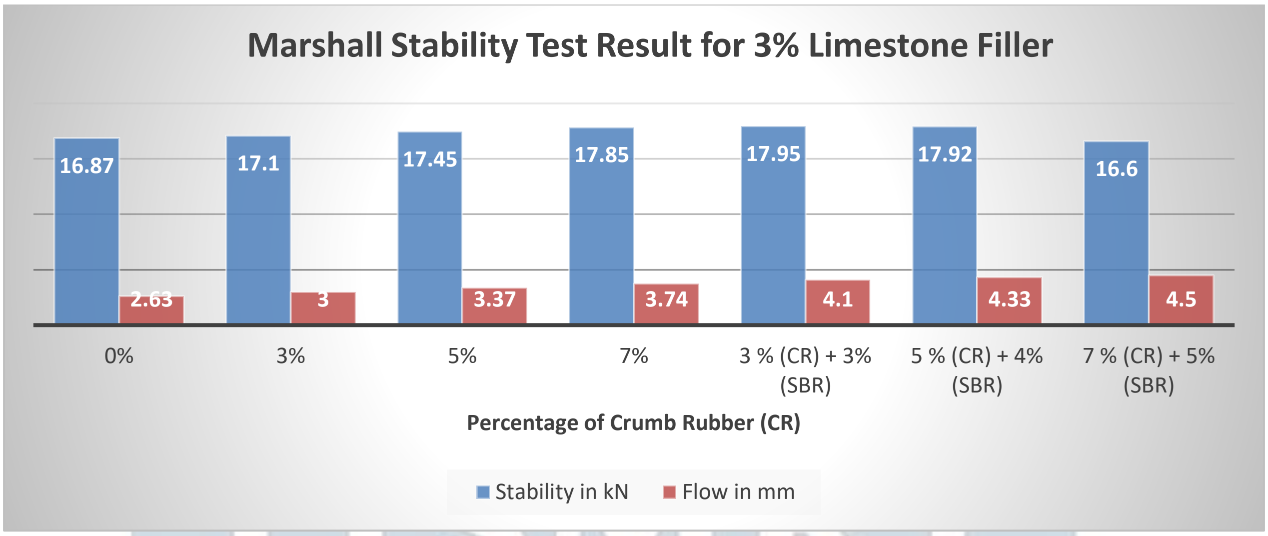
| | | | | | |
|---|---|---|---|---|---|
| weight of bitumen mix sample. | | | | | |
| 0 % | 16.87 | 2.63mm | 15.58 | 2.63 | 67.82 |
| 3 % | 16.98 | 3.05mm | 15.28 | 3.05 | 69.32 |
| 5 % | 17.35 | 3.41mm | 15.77 | 3.41 | 72.48 |
| 7 % | 17.81 | 3.71mm | 16.48 | 3.71 | 74.55 |
| 3 % (CR) + 3% (SBR) | 17.97 | 4.03mm | 16.92 | 4.03 | 76.89 |
| 5 % (CR) + 4% (SBR) | 17.89 | 4.23mm | 17.28 | 4.23 | 78.84 |
| 7 % (CR) + 5% (SBR) | 16.5 | 4.51mm | 17.48 | 4.51 | 78.7 |

Table 8: Results of 3% Limestone filler for Varying Percentage of CR

| % of Crumb Rubber (CR) & SBR added with respect to the weight of bitumen mix sample. | Stability in kN | Flow in mm | VMA (%) | Air Void (%) | VFB |
|---|---|---|---|---|---|
| 0 % | 16.87 | 2.63 | 15.58 | 2.63 | 67.82 |
| 3 % | 17.1 | 3 | 15.38 | 3.1 | 69.58 |
| 5 % | 17.45 | 3.37 | 15.87 | 3.46 | 72.08 |
| 7 % | 17.85 | 3.74 | 16.38 | 3.85 | 74.65 |
| 3 % (CR) + 3% (SBR) | 17.95 | 4.1 | 16.82 | 4.15 | 76.99 |
| 5 % (CR) + 4% (SBR) | 17.92 | 4.33 | 17.18 | 4.28 | 79.02 |
| 7 % (CR) + 5% (SBR) | 16.6 | 4.5 | 17.38 | 4.61 | 79.12 |




Graph 1: Marshall Stability Test for Glass Powder Filler




Graph 2: Marshall Stability Test for Lime stone Filler

VIII. CONCLUSION

The present study investigated the performance of bituminous concrete mixes modified with Crumb Rubber (CR), recycled powder fillers such as limestone powder and glass powder, and Styrene-Butadiene Rubber (SBR) latex. The objective was to evaluate the feasibility of utilizing waste materials in bituminous mixes to enhance pavement performance while promoting sustainable and environmentally responsible road construction practices.

Based on the laboratory investigations and analysis of test results, the following conclusions are drawn:

- The incorporation of crumb rubber significantly influenced the physical and engineering properties of bitumen and bituminous concrete mixes. Modified binders exhibited improved resistance to deformation and enhanced durability compared to conventional bitumen.
- The addition of recycled powder fillers such as limestone powder and glass powder improved the filler-binder interaction, resulting in better aggregate coating, reduced air voids, and improved mix stability.
- The penetration value of modified bitumen decreased with increasing crumb rubber content, indicating increased hardness and improved resistance to rutting under high-temperature conditions.
- Softening point values increased with the addition of crumb rubber and recycled fillers, demonstrating improved temperature susceptibility and greater resistance to permanent deformation.
- Marshall Stability values of modified mixes were found to be higher than those of the conventional mix, indicating enhanced load-carrying capacity and structural strength of the pavement.
- The inclusion of SBR latex further improved the elasticity, flexibility, and adhesive characteristics of the bituminous binder, contributing to better crack resistance and pavement durability.
- The combined use of crumb rubber and recycled powder fillers provided a synergistic effect, improving overall pavement performance while reducing dependence on virgin construction materials.
- Utilization of waste tire rubber and recycled powder fillers offers an environmentally sustainable solution for waste management by diverting significant quantities of waste materials from landfills and reducing environmental pollution.
- From an economic perspective, the use of recycled materials has the potential to reduce material costs while simultaneously improving pavement service life, making the approach both technically and economically viable.
- The study confirms that modified bituminous concrete incorporating crumb rubber, recycled powder fillers, and SBR

latex can be successfully used in flexible pavement construction to achieve enhanced performance, sustainability, and long-term durability.

Overall, the research demonstrates that the incorporation of waste-derived materials in bituminous concrete is an effective strategy for developing high-performance and eco-friendly pavements. The findings support the adoption of crumb rubber and recycled powder fillers as sustainable alternatives in modern highway construction practices.

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