

## **Study of Bituminous Concrete Mix of Grade-Two for Stability and Flow Analysis using Additives of Waste Materials**

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### **ABSTRACT**

*Typically, a bituminous mixture consists of coarse aggregate, fine aggregate, filler, and binder. A type of bituminous mixture called "Hot Mix Asphalt" (HMA) is made by mixing, placing, and compacting all of these components at high temperatures. Bituminous Concrete (BC) is a type of Dense Graded mix (DGM) used as a surface and wearing course in flexible pavements. It is essential for the wearing course to provide a smooth and dense riding surface while enduring traffic-induced wear and tear. The growth of transportation infrastructure plays a vital role in national development, and with flexible pavements widely used in India, efforts must be made to increase the longevity of bituminous pavements. Flexible pavements often face challenges such as cracking and rutting due to repeated traffic loads, which need to be addressed to enhance their performance.*

*This project focuses on evaluating the suitability of waste plastic bottles, discarded tyre rubber, and coconut fibers as reinforcing materials in Bituminous Concrete Grade 2 mixes. The Marshall method of mix design was utilized to determine the optimum bitumen content for the mixes, and their performance was analyzed accordingly. The optimum binder content was found to be 6% using 60/70 penetration grade bitumen. The study involved stability and flow analysis of Bituminous Concrete Grade 2 mixtures with different percentages of bitumen replacement by waste materials such as waste plastic bottles, discarded tyre rubber, and coconut fibers. Experimental results showed that replacing the optimum binder content with 10% waste plastic, 6% crumb tyre rubber, and 1% coconut fibers increased the stability of the mix by 10.67%, 10.37%, and 10.08%, respectively. Additionally, the flow criteria specified by the Ministry of Road Transport and Highways (MORT&H) for BC Grade 2 were satisfied by all the additives. Among the three additives used in the study, replacing the optimum binder content with 10% waste plastic yielded the highest Marshall stability value.*

**Keywords:-** bitumen, pavements, temperatures, fibers, filler, binder, etc.

### **INTRODUCTION**

Roadways are a crucial component of infrastructure, playing a vital role in our daily lives. Among the various elements of a highway, the pavement holds significant importance. The overall performance of a highway system heavily relies on the performance of its pavement. In India,

bituminous pavement is commonly used for highways. However, due to the increasing traffic intensity, issues such as rutting and cracking are common on Indian roads. Flexible pavements, especially in varying seasonal temperatures, tend to become soft in summer and brittle in winter. Bituminous

pavements account for approximately 90% of India's road network, constructed and maintained using naturally available road aggregates and bitumen, a petroleum product that is mixed at high temperatures to produce hot mix asphalt.

Research has shown that the properties of bitumen can be enhanced by incorporating modifiers. This study focuses on improving the properties of VG30 grade bitumen by incorporating modifiers. The modified bitumen demonstrates improved Marshall Stability values compared to the selected raw bitumen. Constructing highways involves substantial investments, and precise engineering design can save significant costs while ensuring reliable performance of the highway. In flexible pavement engineering, two critical aspects are considered: pavement design and mix design. The mix design for different layers of the pavement has a significant impact on the performance, cost, and sustainability of bituminous surfaces.

A well-designed bituminous mix is expected to possess the following qualities:

Adequate strength, Durability, Resistance to fatigue and permanent deformation, Environmentally friendly characteristics, Cost-effectiveness

Mix designers strive to achieve these requirements through comprehensive testing on various mix proportions, ultimately selecting the optimal mix that meets the desired criteria.

### **FLEXIBLE PAVEMENT**

Flexible pavements are designed to bear loads by distributing them gradually through multiple layers, rather than relying on flexural action. These pavements consist of carefully chosen materials that distribute the load from the surface to the underlying layers. The design of the pavement ensures that each layer can handle the load without exceeding its capacity. Figure 1 illustrates a typical cross-section of a flexible pavement, while

Figure 2 demonstrates how the load is distributed to the subgrade. The different layers of a flexible pavement serve specific functions, which are described below.

**a) Bituminous Surface (Wearing Course):** The bituminous surface, also known as the wearing course, is composed of carefully selected aggregates bound together with asphalt cement or other bituminous binders. Its primary functions include preventing water penetration into the base course, providing a smooth and well-bonded surface free from loose particles that could pose risks to aircraft and pedestrians, withstanding the stresses imposed by aircraft loads, and offering a skid-resistant surface without excessive tire wear.

**b) Base Course:** The base course is the primary structural component of the flexible pavement. It distributes the wheel load to the pavement foundation, subbase, and/or subgrade. To prevent subgrade and/or subbase failures, the base course needs to be of sufficient quality and thickness. It also needs to be able to withstand vertical pressures that cause consolidation and surface distortion and volume changes caused by changes in moisture content. The base course comprises select hard and durable aggregates, falling into two main classes: stabilized and granular. Stabilized bases typically consist of crushed or uncrushed aggregate bound with stabilizers like Portland cement or bitumen. The quality of the base course depends on its composition, physical properties, and material compaction.

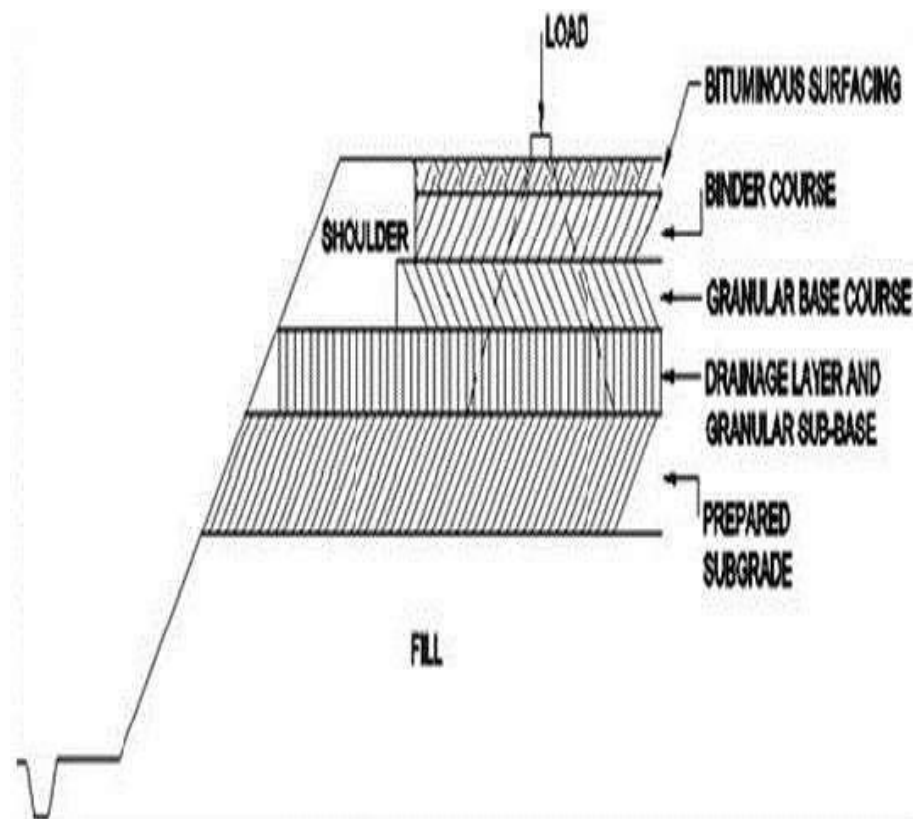
**c) Subbase:** The subbase layer is utilized in areas with severe frost action or weak subgrade soil. It serves a similar purpose as the base course by distributing imposed loads. Subbase materials have less stringent requirements compared to the

base course, as they experience lower load stresses. Subbase materials can be either stabilized or properly compacted granular materials.

**d) Frost Protection Layer:** Certain flexible pavements may require a frost protection layer, which serves the same purpose as in both flexible and rigid pavements.

**e) Subgrade:** The subgrade is the compacted soil layer forming the

foundation of the pavement system. Subgrade soils endure lower stresses compared to the surface, base, and subbase courses. Typically, the controlling subgrade stress lies at the top of the subgrade because load stresses decrease with depth. The combined thickness of the subbase, base, and wearing surface must be sufficient to reduce stresses in the subgrade, ensuring they do not cause excessive distortion or displacement of the subgrade soil layer.



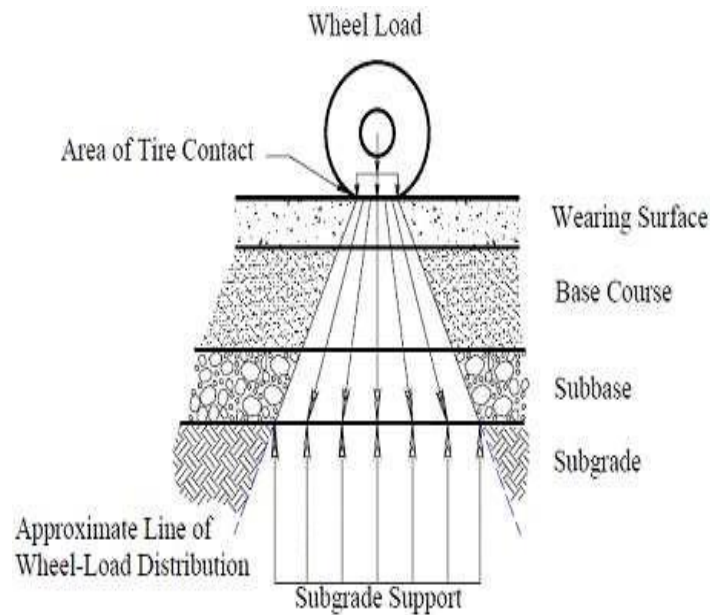
*Fig.1:-Typical flexible pavement structure*

## **BITUMINOUS MIX DESIGN**

### **Objective of Bituminous mix design**

Asphaltic/Bituminous concrete is comprised of a blend of aggregates that are continuously graded, ranging from a maximum size of typically less than 25

mm to fine filler particles smaller than 0.075 mm. An adequate amount of bitumen is incorporated into the mixture to ensure that the compacted mix is impermeable and possesses desirable dissipative and elastic properties.



**Fig.2:-Distribution of load stress in flexible pavement**

The bituminous mix design process aims to determine the optimal proportions of bitumen, filler, fine aggregates, and coarse aggregates in order to create a mix that is both workable and economical while possessing strength and durability. The main objectives of the mix design are as follows:

1. Adequate bitumen content to ensure long-lasting pavement performance.
2. Sufficient strength to withstand shear deformation caused by traffic, particularly at higher temperatures.
3. The compacted bitumen should have adequate air voids to accommodate traffic compaction.
4. Satisfactory workability to enable easy placement of the mix without segregation.
5. Sufficient resistance to prevent premature cracking caused by repeated bending from traffic.
6. Adequate resistance to low temperatures to minimize the risk of shrinkage cracks.
7. By proportioning the various components effectively, the mix design aims to achieve these objectives and

produce a bituminous mix that meets the required performance criteria in terms of durability, strength, workability, and resistance to cracking and deformation.

#### **Requirements of bituminous mixes:**

##### **i) Stability**

Stability in pavement refers to its ability to withstand deformation under the load of traffic. There are two common types of failure associated with stability:

1. **Shoving:** This refers to a transverse rigid deformation that occurs in areas where there is severe acceleration or deceleration of traffic. It results in the formation of ridges across the pavement surface.
2. **Grooving:** Grooving is characterized by longitudinal ridges that form due to the channelization of traffic. It can occur when vehicles consistently follow the same path, causing concentrated wear and deformation.

The stability of a pavement is influenced by the inter-particle friction, primarily between the aggregates, as well as the cohesive properties provided by the bitumen. To maintain stability, it is essential to have an adequate amount of binder that can coat all the particles

effectively and provide sufficient liquid friction. However, excessive binder content and particle segregation can lead to a decrease in stability. Therefore, finding the right balance between binder content and particle distribution is crucial for ensuring optimal stability in the pavement.

**ii) Durability:** Durability refers to the ability of the pavement mix to withstand weathering and abrasive actions over time. Weathering can lead to the hardening of the bitumen due to the loss of volatiles. Abrasion occurs as a result of wheel loads, causing tensile strains on the pavement. Common examples of durability failure include pot-holes, localized pavement deterioration, and stripping, which involves the loss of binder from the aggregates, exposing them. To minimize disintegration, a higher binder content is beneficial as it enhances the mix's air and waterproofing properties and improves the resistance of the bitumen film to hardening.

**iii) Flexibility:** Flexibility measures the bending strength required to withstand traffic loads and prevent surface cracking. Cracks, such as hairline cracks or alligator cracks, can form on the surface due to shrinkage and the brittleness of the binder. Shrinkage cracks occur due to volume changes in the aging binder, while brittleness is caused by repeated bending under traffic loads. A higher bitumen content promotes better flexibility and reduces the likelihood of fractures.

**iv) Skid resistance:** Skid resistance refers to the ability of the finished pavement to resist skidding. It depends on the surface texture and bitumen content. Skid resistance is particularly important for high-speed traffic. Generally, an open-graded coarse surface texture is preferred to enhance skid resistance.

**v) Workability:** Workability relates to how easily the mix can be laid, compacted, and shaped to meet the desired condition. The aggregate gradation, shape, texture,

amount of bitumen, and type all play a role. Angular, flaky, and elongated aggregates can affect workability, while rounded aggregates tend to improve it.

**vi) Desirable properties:** Based on the above considerations, the desirable properties of a bituminous mix can be summarized as follows:

- Sufficient stability to withstand traffic demands
- Adequate bitumen content for proper binding and waterproofing
- Appropriate voids to accommodate compaction under traffic
- Satisfactory flexibility to endure traffic loads, especially during cold seasons
- Sufficient workability for ease of construction
- Economical mix design that balances cost and performance.

## **ASPHALT CONCRETE (BITUMINIOUS MIXTURE)**

Asphalt concrete is a composite material widely used in construction projects like road surfaces, airports, and parking lots. It consists of asphalt, serving as a binder, mixed with mineral aggregates. The mixture is then laid in layers and compacted. There are several methods for mixing asphalt and aggregates:

**Hot Mix Asphalt Concrete (HMAC or HMA):** This type of asphalt concrete involves heating the asphalt binder to reduce its viscosity and drying the aggregates to remove moisture before mixing. Typically, the aggregate is heated to around 300 °F (approximately 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt. The asphalt cement is heated to 200 °F (95 °C). As soon as the asphalt is hot enough, paving and compaction are done. In many countries, paving is limited to the summer months because the compacted base cools the asphalt too quickly during winter, affecting optimal air content. On



intensively used surfaces like interstates, racetracks, and airports, HMAC is frequently employed.

**Warm Mix Asphalt Concrete (WMA):** WMA is created by adding additives like zeolites, waxes, asphalt emulsions, or even water to the asphalt binder before mixing. This allows for lower mixing and laying temperatures, reducing fossil fuel consumption and resulting in lower carbon dioxide emissions, aerosols, and vapors. WMA not only improves working conditions but also enables faster availability of the surface for use, which is crucial for construction sites with tight schedules. These additives can also enhance compaction and facilitate cold weather paving or longer hauls when used in hot mixed asphalt.

**Cold Mix Asphalt Concrete:** Cold mix asphalt concrete is produced by emulsifying the asphalt in water, typically with the addition of soap, before mixing it with the aggregates. In its emulsified state, the asphalt is less viscous, making the mixture easy to work with and compact. The emulsion breaks down as water evaporates, ideally resulting in cold HMAC properties. Cold mix asphalt is commonly used as a patching material and on low-traffic service roads.

**Cut-Back Asphalt Concrete:** The binder is dissolved in kerosene or similar lighter petroleum fraction before being combined with the aggregates to form cut-back asphalt concrete. The dissolved asphalt has lower viscosity, making the mix easy to work with and compact. After the mix is laid, the lighter fraction evaporates. Asphalt emulsion has mostly displaced cut-back asphalt due to worries about pollution from volatile organic compounds in the lighter component.

**Mastic Asphalt Concrete or Sheet Asphalt:** Mastic asphalt concrete involves heating hard-grade blown bitumen until it becomes a viscous liquid, after which the aggregate mix is added. The bitumen-aggregate mixture is then cooked for

several hours. The mastic asphalt mixer is brought to the job site once it is ready, and skilled employees either use a machine or by hand spread the mastic asphalt onto the road. Mastic asphalt concrete is typically laid at a thickness of 3/4 to 3/16 inches (20-30 mm) for footpath and road applications, and around 3/8 of an inch (10 mm) for flooring or roof applications. Additives like polymers and antistripping agents may be included to enhance the final product's properties.

**Natural Asphalt Concrete:** Bituminous rock, which is present in some areas and has been absorbed by porous sedimentary rock close to the surface from upwelling bitumen, can be used to create natural asphalt concrete.

#### **BITUMINOUS MIXES FOR FLEXIBLE PAVEMENT LAYERS**

Bituminous mixes are composite materials composed of a binder, filler/fines, and aggregates. These mixes are used in asphalt pavements, where the bituminous binder connects the filler/fines and aggregates. In India, the MORTH Specifications provide mix specifications for base courses, binder courses, and wearing courses. The key properties of bituminous paving mixtures include stability, flow, durability, flexibility, and skid resistance for wearing surfaces. Traditional mix design methods aim to determine the optimal binder content that will ensure satisfactory performance, particularly in terms of stability and flow values. The selection of components and their proportions depends on the specific pavement section where the mix will be used. The design of bitumen-aggregate mixes for different layers involves the following steps:

- Choosing the type and gradation of mineral aggregates.
- Selecting the type and grade of binder.
- Determining the amount of binder needed to meet project-specific

requirements for mix properties.

The properties of bituminous mixes can be enhanced to improve durability, cost-effectiveness, and sustainability by incorporating polymers, plastics, and various additives. Different materials like crumb rubber, waste plastics, rice husk ash, mineral fillers, fly ash, and various types of polymers can be utilized to modify the physical properties of bitumen and enhance the stability of bituminous mixes.

### **BITUMINOUS CONCRETE MIX**

Bituminous Concrete is utilized for wearing and profile corrective courses in pavement construction. The process involves applying one or multiple layers of bituminous concrete onto a prepared bituminous bound surface.

A single layer typically ranges in thickness from 25mm to 100mm. When designing a Bituminous Concrete mix, there is flexibility in adjusting the gradation to achieve an optimal mix without compromising pavement durability. Adequate compaction of bituminous mixes is essential for ensuring the performance of flexible pavement. The Marshall Mix design method is commonly used for determining the appropriate mix design for Bituminous Concrete.

### **Material Specifications for Bituminous Concrete (BC) Mix**

#### **i) Bitumen**

The bitumen used for the BC mix should be a paving bitumen of penetration Grade that meets the specifications outlined in the Indian Standard Specifications for "Paving Bitumen" IS: 73. The penetration grade of the bitumen should comply with the values specified in the table provided by MOSRT&H Specifications for Road and Bridge Works (Fourth Revision) Re-print March 2007 for Bituminous Concrete.

#### **ii) Coarse Aggregates**

The coarse aggregates used in the BC mix should consist of crushed rock, crushed gravel, or other hard materials that are retained on the 2.36 mm sieve. These aggregates must be clean, hard, and durable, with a cubical shape, and free from dust, soft or friable matter, as well as any organic or deleterious substances. If the selected aggregates from the Contractor's source do not have good affinity for bitumen, the bitumen shall be treated with an approved anti-stripping agent, as recommended by the manufacturer, at no additional cost. Before approving the source, the aggregates must be tested for stripping. The physical requirements for the aggregates should meet the specifications. (Reference: MOSRT&H Specifications for Road and Bridge Works - Fourth Revision - for Bituminous Concrete).

#### **iii) Fine Aggregates**

The crushed or naturally existing mineral material that passes through the 2.36 mm sieve and is retained on the 75-micron screen makes up the fine aggregates for the BC mix. The fine aggregates must be free of dust, soft or friable materials, any organic matter, and other harmful compounds. They should also be dry, hard, durable, and rigid.

#### **iv) Filler**

The filler used in the BC mix is a finely divided mineral matter such as rock dust, hydrated lime, or cement. If the aggregates fail to meet the requirements of the water sensitivity test, then 2 percent of hydrated lime, based on the total weight of the aggregate, shall be added without any additional cost. The filler should be graded within the limits.

### **AGGREGATE GRADING AND BINDER CONTENT**

In accordance with IS:2386 Part 1 (Wet grading method), the combined grading of the coarse and fine aggregates, along with

the added filler, should meet the requirements.

### **MIXTURE DESIGN**

In addition to meeting the grading and quality requirements for each ingredient as mentioned previously, the mixture must also comply with the specified requirements outlined in the given guidelines.

### **BINDER CONTENT**

To fulfill the specified requirements outlined and considering the traffic volume specified in the Contract, the binder content will be optimized. The determination of the optimal binder content will follow the Marshall method, as detailed in the Asphalt Institute Manual MS-2. In cases approved by an Engineer, this method will involve replacing the aggregates retained on the 26.5mm sieve and the aggregates retained on the 22.4mm sieve.

### **ADDITIVES IN THE BITUMINOUS MIXES**

**Utilization of Plastic Waste:** Bitumen, a valuable binder for road construction, is available in various grades based on penetration values such as 30/40, 60/70, and 80/100. With the continuous increase in high traffic intensity and the varying temperature demands throughout the year, there is a need for enhancing road characteristics. Improvements in binder properties are essential in this regard. Currently, plastic waste is abundantly available as a result of its integration into daily life. If not recycled, plastic waste often ends up mixed with Municipal Solid Waste or discarded in land areas. Disposing of plastic waste through landfilling or incineration has negative environmental impacts. Therefore, an alternative use for waste plastics is necessary. When heated, waste plastics (e.g., polythene carry bags) soften around 130°C and exhibit no gas evolution in the

temperature range of 130-180°C, as indicated by thermogravimetric analysis. Furthermore, the softened plastics possess binding properties. So, bitumen and molten plastic materials can be combined to improve bitumen's binding capabilities or employed as binders independently. This approach can serve as a promising modifier for bitumen used in road construction.

### **Significance of the Study:**

1. Proper disposal of waste plastic is a major challenge.
2. Waste plastic is non-biodegradable.
3. Incinerating waste plastic bags causes environmental pollution.
4. Waste plastic mainly comprises low-density polyethylene.
5. Exploring the utility of waste plastic in bituminous mixes for road construction.
6. Laboratory performance studies were conducted on bituminous mixes, demonstrating that waste plastic improves the properties of the mixes.
7. Improvement in bituminous mix properties provides a beneficial solution for waste plastic disposal.

### **Classification of Plastic Waste:**

Plastics can be classified in various ways, primarily based on their physical properties. They may also be classified according to their chemical sources. The different types can be grouped into four general categories: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers, and Fibers. However, based on their physical properties, plastics can be further classified as thermoplastic and thermosetting materials. Thermoplastic materials can be molded into desired shapes under heat and pressure and solidify upon cooling. They can be remolded if subjected to the same heat and pressure conditions. On the other hand, thermosetting materials, once shaped,



cannot be softened or remolded through heat application.

### **Benefits of Utilizing Waste Plastic as a Modifier**

- It effectively binds the coarse aggregate without the need for elevated temperatures.
- It integrates seamlessly into existing road laying practices without any significant modifications.
- The material, in the form of shredded waste, is readily available locally and is currently considered as waste.

### **COCONUT FIBRES**

Coconut fiber, also known as coir fiber, is a natural fiber obtained from the husk of the coconut fruit. Due to its color, it is frequently referred to as the "Golden Fiber." The individual cells of coconut fiber are narrow, hollow, and have thick walls composed of cellulose. Initially, these fibers are pale, but they become hardened and yellowed as lignin deposits on their surface. Brown coir fibers, containing higher amounts of lignin than cellulose, are stronger but less flexible. Each coconut fiber thread is less than 1.3 mm long and has a diameter of 10 to 20 micrometers. This fiber exhibits relative water resistance and is the only natural fiber resistant to damage from saltwater.

Utilizing coconut coir waste can contribute to reducing environmental pollution. Incorporating it as a construction material to enhance composite properties incurs minimal costs compared to the overall composite expenses. Disposing of coconut waste, particularly coconut water, has led to various problems such as environmental pollution, insect infestations, foul odors, disease risks, methane emissions, reduced landfill lifespan, and increased street cleaning costs. Integrating natural fibers into asphalt mixtures introduces a novel technology for road construction that is sustainable, durable, and employs

environmentally friendly materials. With the escalating traffic volume and heavy vehicle loads in major cities, where highways serve as the primary means of transportation, it becomes increasingly crucial for pavements to meet high durability and safety requirements while providing convenience and comfort to users in a sustainable manner. Additionally, considering the cost-benefit aspect strongly influences the choice of asphalt coatings, opting for a highly durable alternative reduces road maintenance and operation costs over time.

The discarded coconut husk yields distinctively featured fibers, as depicted in Plate 1.2, which can be employed in formulating environmentally valuable composites. Although coconut fiber has the lowest percentage of cellulose (36-43%) compared to other plant fibers, it contains approximately twice the amount of lignin (41-45%) found in jute and sisal fibers. This higher lignin content contributes to enhanced resistance and hardness, setting it apart from other fibers.

### **CRUMB TYRE RUBBER**

Crumb rubber, also known as waste tire rubber, is a mixture comprising synthetic rubber, natural rubber, carbon black, antioxidants, fillers, and oils of the extender type that are soluble in hot paving grade. Rubberized asphalt is produced by incorporating crumb rubber obtained from ground tires into asphalt binder under specific time and temperature conditions. This can be done through either a dry process method, which involves adding granulated or crumb rubber modifier (CRM) from discarded tires as a substitute for a portion of the aggregate in the asphalt concrete mixture (not as a part of the asphalt binder), or wet processes, where the asphalt binder is modified with CRM from scrap tires before it is combined to form the asphalt concrete mixture.

The utilization of crumb rubber (CR) for bitumen modification is a popular practice to address the environmental challenge posed by discarded tires and to create superior hot bituminous mixes, particularly through the implementation of the wet process.

In the present era, the accumulation and growing disposal of waste tyres have emerged as a significant environmental concern, leading to pollution. These tyres, extensively used in vehicles, are often not properly discarded after their useful lifespan. Various methods and additives are currently employed for modifying bitumen, including styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA), and crumb rubber modifier (CRM).

The utilization of commercial polymers like SBS and SBR in road and pavement construction can significantly escalate the construction expenses due to their high cost. However, the implementation of alternative materials like CRMB (Crumb Rubber Modified Bitumen) can offer environmental benefits while improving the properties and durability of bitumen. Additionally, it has the potential to be a cost-effective solution. Recent research on the application of rubberised bitumen binders has highlighted numerous advantages, including enhanced resistance to rutting, improved resilience, reduced surface cracks, fatigue and reflection cracking, decreased temperature susceptibility, improved durability, and reduced maintenance costs for road pavements.

## **DISCUSSION OF RESULTS**

### **Effect of Plastic waste on the Stability Flow analysis of BC Grade 2 Mix**

The variation of stability and flow of BC mix with different percentages of waste plastic content in the optimum binder content (OBC) is presented. The data

reveals that the stability value of the mix increases up to 10% plastic waste content in the OBC, after which it starts to decrease with further additions of plastic waste. Additionally, the flow criteria of 2-4 mm was satisfied by incorporating 10% plastic waste in the bitumen. Based on the stability and flow analysis conducted using the Marshall method, it can be concluded that the addition of 10% plastic waste in bitumen can enhance the mix stability by approximately 10.67%.

### **Effect of Crumb Tyre Rubber on the Stability Flow analysis of BC Grade 2 Mix**

The variation of stability and flow of BC mix with different percentages of crumb tyre rubber in the optimum binder content (OBC) is presented. The data indicates that the stability value of the mix increases up to 6% crumb tyre rubber content in the OBC, after which it starts to decrease with further additions of crumb tyre rubber. Furthermore, the flow criteria of 2-4 mm was met by incorporating 6% crumb tyre rubber in the bitumen. Based on the stability and flow analysis conducted using the Marshall method, it can be concluded that the addition of 6% crumb tyre rubber in bitumen can enhance the mix stability by approximately 10.37%.

### **Effect of Coconut fibres on the Stability Flow analysis of BC Grade 2 Mix**

The variation of stability and flow of BC mix with different percentages of coconut fibre in the optimum binder content (OBC) is presented. The data reveals that the stability value of the mix increases up to 1% coconut fibre content in the OBC, after which it starts to decrease with further additions of coconut fibre. Additionally, the flow criteria of 2-4 mm was satisfied by incorporating 1% coconut fibre in the bitumen. Based on the stability and flow analysis conducted using the Marshall method, it can be concluded that the addition of 1% coconut fibre in bitumen

can enhance the mix stability by approximately 10.08%.

## CONCLUSION

Based on the results and discussions of the experimental investigation conducted on Bituminous concrete mix, the following conclusions can be drawn:

1. The addition of different waste materials in the optimum binder content (OBC) by weight of bitumen improves the stability of the mix and satisfies the flow criteria specified by MORTH.
  2. The optimum binder content for BC Grade 2 is determined to be 6%.
  3. The incorporation of various waste materials in the OBC leads to an increase in the Marshall Stability value of the mix. However, the magnitude of increase varies depending on the type and percentage of the waste material.
  4. A 10% waste plastic addition to the OBC enhances the Marshall Stability value of BC Grade 2 by 10.67%. Furthermore, the addition of 10% waste plastic satisfies the flow criteria specified by MORTH.
  5. The inclusion of 6% crumb tyre rubber in the OBC enhances the Marshall Stability value of BC Grade 2 by 10.37%. Moreover, the flow criteria specified by MORTH is met with the addition of 6% crumb tyre rubber.
  6. The incorporation of 1% coconut fibre in the OBC increases the Marshall Stability value of BC Grade 2 by 10.08%. Additionally, the flow criteria specified by MORTH is fulfilled by adding 1% coconut fibre.
  7. Among the three materials used, the addition of 10% waste plastic in the OBC results in the highest Marshall Stability value.
- These conclusions indicate the effectiveness of incorporating waste materials, such as waste plastic, crumb

tyre rubber, and coconut fibre, in improving the stability and flow characteristics of Bituminous concrete mixes.

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