

Effect of Using a 50:50 Blend of Recycled Concrete (R.C.C) Waste Dust and Brick Masonry Waste Combined as Filler in Bituminous Mix Design

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DOI: <https://doi.org/10.51583/IJLTEMAS.2025.1407000123>

Received: 31 July 2025; Accepted: 04 Aug 2025; Published: 19 August 2025

Abstract: Bituminous concrete, often referred to as asphaltic concrete, is one of the most technically refined and high-cost types of flexible pavement layers employed in surface courses. Due to its premium performance requirements, bituminous mixtures are precisely formulated to meet specific standards for strength, stability, and durability. This composition includes well-graded coarse aggregates, fine aggregates, and a mineral filler, all uniformly coated with a bitumen binder. The mineral filler, which passes through a 0.075 mm sieve, plays a crucial role in enhancing the performance of asphalt mixtures. Research shows that Marshall Stability improves with an increase in filler content, and the Asphalt Institute recommends 4 to 8% filler content in asphalt concrete.

In Bangladesh, traditional fillers like cement, limestone, and granite powder are neither economically viable nor widely available. As an alternative, this study investigates the use of a 50:50 blend of recycled concrete (R.C.C) waste dust and brick masonry waste combined with natural sand as a cost-effective and sustainable filler. The study evaluates the performance characteristics of bituminous mixtures incorporating this blended filler and compares the results with those of mixes using conventional filler materials such as fine sand and stone dust.

The Marshall mix design procedure was utilized to assess the strength and workability of the mixes. The Marshall Stability values obtained for mixtures using fine sand with stone dust and the blended filler (50:50 blend of recycled concrete (R.C.C) waste dust and brick masonry waste) were both of them 2.15 kN respectively, all surpassing the minimum requirement as outlined in the Marshall Design criteria. These findings suggest that the use of recycled R.C.C and brick masonry waste in combination with sand can serve as a promising and economical filler alternative in asphaltic concrete.

Key Words: Bituminous, Marshall Stability, Concrete (R.C.C) Waste Dust, Brick Masonry Waste

I. Introduction

Bituminous roads are constructed using bitumen as the primary binding agent. These pavements consist of a consistent blend of coarse aggregates, mineral filler, and bitumen. The performance, durability, and longevity of bituminous roads are significantly influenced by the type and proportion of filler material used in the mix [1]. Fillers enhance the stiffness of the asphalt binder by being finely distributed throughout the bitumen matrix. Conventional fillers such as cement, lime, granite powder, stone dust, and fine sand are commonly used. However, cement, lime, and granite powder are relatively expensive and often more beneficially applied in other construction sectors. As alternatives, materials like fine sand, fly ash, and various forms of construction and demolition waste particularly those finer than 0.075 mm are gaining attention as effective fillers.

In recent years, research has increasingly explored the reuse of industrial and construction byproducts as filler materials in asphalt mixtures. Recycled substances such as phosphate waste [2], oil shale fly ash from Jordan [3], baghouse fines [4], reclaimed lime waste [5], incinerated municipal solid waste ash [6], and waste ceramic materials [7] have shown promise. These studies confirm that such waste-derived fillers can improve asphalt mix performance. Based on this context, the current study investigates the effects of incorporating a blended filler composed of 50% recycled RCC (reinforced cement concrete) waste dust and 50% brick masonry waste dust with 50% natural sand a locally available, cost-efficient, non-conventional filler combination.

When the filler content is insufficient to absorb the necessary amount of bitumen, the asphalt mixture becomes excessively stiff and dry, reducing its workability. On the contrary, excessive bitumen makes the mixture overly fluid and unstable [8]. Filler particles enhance the internal resistance within the mixture and can chemically interact with the asphalt binder, thereby altering the properties of the mastic [9]. While the addition of mineral fillers can improve the elastic modulus of asphalt concrete, an excessive amount may increase bitumen demand and reduce the overall strength of the mix [10, 11]. The particle size distribution (gradation) of the filler also plays a critical role in determining its performance.

This study seeks to develop a bitumen–aggregate mixture with a controlled internal void structure. If the air void content is too low, the mix will lack sufficient asphalt, resulting in inadequate lubrication, poor compaction, and reduced durability due to a thin bitumen film. On the other hand, excessive voids can reduce the mixture's stability as aggregate interlocking weakens [12, 13]. Fillers also contribute to improving the thermal resistance and long-term performance of asphalt concrete. A well-graded and compatible combination of coarse aggregates, fines, and filler materials is essential for forming a dense, stable structural matrix [14].

The quantity and characteristics of the filler significantly affect the mixture's workability and structural behavior [15]. Fillers with high surface areas may absorb more asphalt, which influences the binder-filler interaction and can lead to variations in the performance of the asphalt mix [16, 17]. Characteristics such as grain size distribution, particle shape, texture, void ratio, and chemical composition differ among fillers and therefore impact asphalt mixture behavior differently [18].

II. Literature Review

In Bangladesh, fine sand and stone dust are traditionally used as filler materials in bituminous mixes. This study aims to evaluate the performance of bituminous mixtures incorporating an alternative, low-cost filler blend consisting of 50% recycled RCC waste dust and 50% brick masonry waste. Through a series of laboratory tests, the physical and mechanical properties of asphalt mixtures using this non-traditional filler were analyzed and compared with those using conventional fillers. The results demonstrate that a filler combination of RCC and brick dust with sand presents a promising and economical option for sustainable asphalt pavement construction.

The literature review on the use of recycled construction and demolition (C&D) waste in bituminous mix design highlights several key points. Pavement conditions in South Asia, including Bangladesh, reveal challenges due to climate, traffic, and maintenance deficiencies, with substantial road deterioration [19]. The increasing use of recycled materials, such as demolished Reinforced Cement Concrete (RCC) and brick masonry waste, is explored for enhancing sustainability in road construction. Research suggests that these materials, when processed properly, can improve bituminous mix properties such as stability, durability, and environmental impact [20]. Recycled aggregates from C&D waste can replace conventional fillers like stone dust, contributing to waste reduction, resource conservation, and cost savings [21]. Various waste materials, including rubber from tires, fly ash, and glass powder, have also been investigated for their positive impact on bitumen's properties, improving crack resistance and pavement longevity [22]. The research underscores the potential of waste fillers in reducing landfill pressures, minimizing raw material consumption, and enhancing the durability of road infrastructure [23]. These findings advocate for the incorporation of C&D waste to foster a circular economy in construction.

III. Methodology

Flow Diagram

For the successful completion of the paper, a comprehensive literature review is essential, demonstrating broad coverage of relevant materials to support the research questions. Defining the methods and materials used was crucial to ensure clarity and prevent loss of information. The prediction of results should be checked against actual data to determine whether the research has achieved its intended goal. Addressing existing gaps, challenges, and experiences would help guide future development and modifications in the field. Finally, a conclusion should be provided to summarize and terminate the study and the flow diagram was shown in Figure: 1.

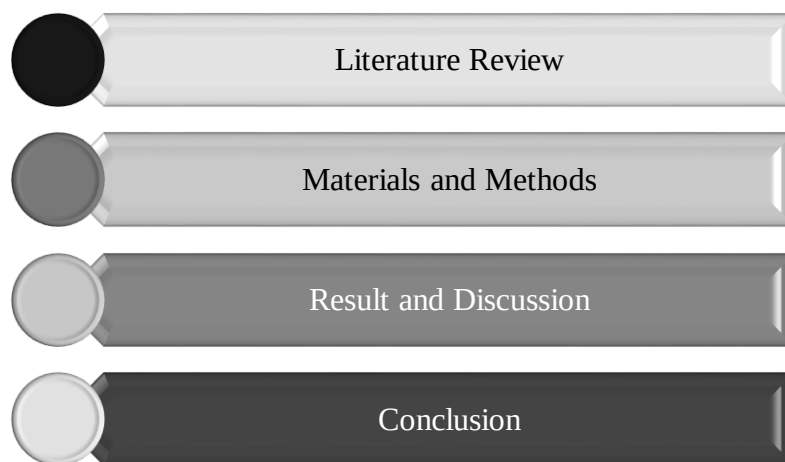


Figure: 1 Flow diagram of the research works was illustrated

Materials

The study utilized various materials including black stone chips in Figure: 2, Domar sand in Figure: 3, grade 60/70 bitumen in Figure: 4, and fillers Figure: 5 like brick masonry and RCC waste. The materials were tested using international standards such as ASTM and AASHTO. Coarse and fine aggregates were assessed for specific gravity, sieve analysis, and other properties. Bitumen quality was evaluated through penetration, softening point, and ductility tests. The Marshall Mix Design method was employed for specimen preparation, stability testing, and determining the optimum bitumen content. The tests followed ASTM D1559 and AASHTO T245 standards [24].



Figure 2: Collected Coarse Aggregate (Black Stone Chips)



Figure 3: Collected Fine Aggregate (Domar Sand)



Figure 4: Collected Bitumen (Grade 60/70)



Figure 5: Collected Regular Filler from Sand Dust

IV. Methods

The Marshall Mix Design method was used for evaluating Hot Mix Asphalt (HMA) by testing the strength, workability, and rigidity of bituminous mixtures under traffic conditions. The method involved various tests, including Marshall Stability, flow value, optimum bitumen content, and bitumen film thickness, using materials like coarse aggregates, fine aggregates, fillers, and bitumen. The process involved preparing samples with varying bitumen contents, compacting them, and conducting stability and flow tests. The test resulted for aggregates, fillers, and bitumen were presented, showing properties such as specific gravity, absorption capacity, and resistance to degradation. The study also included a detailed data table comparing the properties of mixes with fresh filler, RCC waste, brick waste, and combined fillers, along with standard values for Marshall Stability, flow, VMA, VFB, and air voids with 30 nos specimens, testing temperatures 60°C, mixing durations 30mins, and compaction by drop hammer 5k. The results provided insights into the quality of the mix and its suitability for transportation purposes. Figure: 6 to 13 were illustrated as parts of the test.



Figure 6: Weighting of CA, FA and Fillers according to their amount required with respect to Bitumen Percentages.



Figure 7: Heating of Bitumen till its melting point.



Figure 8: Mixing of CA, FA and Filler respectively and heating them on Electric Stove



Figure 9: Marshall Compaction Machine



Figure 10: Adding the bituminous mix into the compaction machine and compacting to make a specimen



Figure 11: Putting Specimen for Water Bath



Figure 12: Taking SSD Weight after 30 minutes of water bath at 60°C



Figure 13: Putting the Specimen inside Marshall Testing Machine to obtain values

Table 1: Obtained Data Table for Marshall Mix Design

Unit Weight (Kg/m³)			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	1745.08	2135.25	2000-2500
4.5	2142.8	2150.54	
5	2254.54	2156.54	
5.5	2242.38	2164.58	
6	1548.54	2159.88	
Significance level for Unit Weight = 0.0007			

Marshall Stability (kN)			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	1.13	1.93	--
4.5	1.89	2.15	
5	2.15	2.05	
5.5	1.78	1.21	
6	1.25	0.87	
Significance level for Marshall Stability = 0.005			
Flow (mm)			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	1.75	1.75	4-Feb
4.5	1.9	1.9	
5	2.12	2.12	
5.5	2.76	2.85	
6	3.15	3.15	
Significance level for Flow = 0.001			
Percent VMA			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	22.58	20.28	15-20
4.5	20.25	20.17	
5	18.38	20.17	
5.5	18.63	20.28	
6	23.09	20.52	
Significance level for Percent VMA = 0.0009			
Percent VFB			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	19.89	42.76	50-80
4.5	46	48.15	
5	60.37	53.45	
5.5	65.65	59.09	
6	68.55	62.59	
Percent Air Void			
% BC by Weight	Fresh filler	RCC and Brick combined	Standard Values (RHD, Bangladesh)
4	28.11	12.58	--

4.5	20.54	10.46	
5	16.48	9.21	
5.5	12.58	8.29	
6	10.41	7.79	
Significance level for Percent VMA = 0.0023			

V. Result and Discussion

The provided data presents various properties of bituminous mixes designed using the Marshall Mix Design method, which was used to evaluate the performance of Hot Mix Asphalt (HMA). These properties included unit weight, Marshall stability, flow, volumetric properties such as VMA (Voids in Mineral Aggregate) and VFB (Voids Filled with Bitumen), and air voids. Two types of fillers were compared: fresh filler and RCC (Reinforced Cement Concrete) and Brick combined filler. The results were analyzed and compared to standard values provided by the Roads and Highways Department (RHD) of Bangladesh.

Significance Levels

The significance levels for Unit Weight (0.0007), Marshall Stability (0.005), Flow (0.001), Percent VMA (0.0009), and Percent VFB (0.0023) indicate that the differences in these properties between fillers are statistically significant, emphasizing their impact on mix performance.

Unit Weight (Kg/m³)

For fresh filler, the unit weight ranged from 1745.08 kg/m³ at 4% BC to 2254.54 kg/m³ at 5% BC, and decreased to 1548.54 kg/m³ at 6% BC. In comparison, the unit weight for the RCC and Brick combined filler was generally higher, ranging from 2135.25 kg/m³ at 4% BC to 2159.88 kg/m³ at 6% BC in Table: 1. Both mixes started with a unit weight lower than the RHD standard values of 2000-2500 kg/m³, particularly at lower bitumen contents. This suggested that both mixes may not achieve the ideal density, potentially leading to reduced stability and performance.

Marshall Stability (kN)

The stability for fresh filler increases from 1.13 kN at 4% BC to 2.15 kN at 5% BC, after which it drops to 1.25 kN at 6% BC in Table: 1. This is typical, as the optimal bitumen content tends to provide the best stability, but excessive bitumen can lead to weaker stability. The RCC and Brick combined mix shows a similar trend but with lower stability values. At 4% BC, the stability is 1.93 kN, and it peaks at 2.15 kN at 4.5% BC before decreasing to 0.87 kN at 6% BC in Table: 1. The lower stability values for the RCC and Brick mix, especially at higher bitumen contents, suggest that the aggregates in this mix may not bond as effectively as in the fresh filler mix, leading to reduced overall strength.

Flow (mm)

For fresh filler, the flow increases from 1.75 mm at 4% BC to 3.15 mm at 6% BC. For the RCC and Brick combined mix, the flow remains consistent at 1.75 mm at 4% BC, then increases to 3.15 mm at 6% BC in Table: 1. While both mixes meet the RHD standard range (2-4 mm) for flow, the brick filler has consistently higher flow values, suggesting that it is more prone to deformation under load. This could reduce its durability and performance, especially under heavy traffic.

Percent VMA (Voids in Mineral Aggregate)

The VMA for fresh filler decreased from 22.58% at 4% BC to 23.09% at 6% BC, while for RCC and Brick combined, it ranges from 20.28% at 4% BC to 20.52% at 6% BC in Table: 1. Both mixes exceed the standard range of 15-20%, particularly the fresh filler mix, suggesting that both mixes might have excessive voids, which could negatively affect the strength and durability of the mix. Excessive voids can lead to water infiltration, weakening the asphalt over time.

Percent VFB (Voids Filled with Bitumen)

For fresh filler, the VFB increases from 19.89% at 4% BC to 68.55% at 6% BC, which was typical as higher bitumen content fills more voids. For the RCC and Brick combined mix, the VFB also increases but remained lower than the fresh filler mix, ranging from 42.76% at 4% BC to 62.59% at 6% BC. The VFB valued for both mixes generally fall below the RHD standard range of 50-80%, especially for the RCC and Brick combined mix, indicating that neither mix is optimally filled with bitumen. This can lead to reduced durability and an increased risk of cracks and deformations under traffic loads.

Percent Air Void

For fresh filler, air voids decreased from 28.11% at 4% BC to 10.41% at 6% BC, indicating that increasing bitumen content leads to better compaction. For the RCC and Brick combined mix, air voids decreased from 39.95% at 4% BC to 25.21% at 6% BC in Table: 1. Although air voids decrease for both mixes, the valued for RCC and Brick combined are higher, indicating that this mix

may be less compact than the fresh filler mix. High air voids can lead to reduced stability and increased susceptibility to moisture damage, which can weaken the pavement over time.

VI. Conclusion

The study leads to the following conclusions:

1. Both fresh filler and RCC and Brick combined mixes show increased properties with higher bitumen content, but neither meets RHD standards for optimal performance.
2. The fresh filler mix provides better stability and VFB but has excessive voids and lower unit weight compared to RHD standards.
3. The RCC and Brick combined mix exhibits lower stability, VFB, and higher air voids, indicating weaker performance.
4. Neither mix achieves the ideal density, which could reduce overall strength and stability.
5. High air voids in both mixes suggest increased susceptibility to moisture damage and reduced durability.
6. Both mixes require further adjustments in composition, particularly aggregate gradation and filler content, to improve long-term performance and meet RHD standards.

VII. Recommendations

The study leads to the following recommendations:

Adjust the aggregate gradation and filler content in both mixes to achieve optimal unit weight, stability, and VFB, ensuring compliance with RHD standards.

Reduce air voids and excessive VMA in the mixes to enhance durability and improve resistance to moisture damage and deformation under traffic loads.

Suggesting directions for further research

The study leads to the following directions for further research:

1. Further research should focus on optimizing the aggregate gradation and filler content in both mixes to enhance stability, VFB, and unit weight, ensuring compliance with RHD standards.
2. Investigating the long-term performance of RCC and Brick combined mixes under varied traffic and environmental conditions could provide insights into their durability and practical application in road construction.

Declaration of Competing Interests: The authors declare that they have no financial or personal conflicts of interest that could have influenced the work reported in this paper.

Author Contributions: MSA: Conceptualization, Supervision, Methodology, Investigation, Writing - Review and Editing, Validation. MZHK.: Formal Analysis, Writing - Review and Editing. MRH.: Formal Analysis, Writing - Review and Editing. MAR.: Formal Analysis, Writing - Review and Editing. DT.: Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Resources, Visualization, Writing - Original Draft.

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