Effect of Using a Combination of 50% Coal Dust 50 % Course Sand as Filler in Bituminous Mix Design

[1]Md Shajahan Ali, [1]Mohammad Zakir Hossain Khan, [2] Md. Rifat Hossain, [2] Md. Ashikur Rahman, [2] Diba Tabassum

[1]Assistant Professor, Department of Civil Engineering, Bangladesh Army University of Engineering and Technology, Bangladesh

[2]Graduate Student, Department of Civil Engineering, Bangladesh Army University of Engineering and Technology, Bangladesh

DOI: https://doi.org/10.51244/IJRSI.2025.120800128

Received: 07 Aug 2025; Accepted: 15 Aug 2025; Published: 13 September 2025

ABSTRACT

Bituminous concrete, also referred to as asphaltic concrete, represents one of the most sophisticated and high-cost types of flexible pavement layers utilized in surface courses. Given its elevated cost and performance demands, bituminous mixtures must be meticulously designed to satisfy standards for structural integrity and durability. The mixture typically includes well-graded coarse aggregates, fine aggregates, and mineral filler, all bound together with bitumen. The mineral filler component, which passes through a 0.075 mm sieve, significantly influences the mechanical performance of the mix. An increase in filler content generally enhances Marshall Stability. According to the Asphalt Institute, 4 to 8% filler is recommended in asphalt concrete [1]. Traditional fillers like cement, limestone, and granite powder are not economically feasible or widely available in Bangladesh.

In this context, a 50:50 combination of coal dust and coarse sand is considered a viable alternative, as both are inexpensive and readily accessible. This study evaluates the effect of this blended filler on the behavior of bituminous mixtures. It compares the performance of mixes containing a coal dust–coarse sand blend with that of mixes using conventional filler types such as fine sand with stone dust in Bangladesh. The evaluation was conducted using the Marshall mix design approach. The Marshall stability values for mixtures containing fine sand with stone dust and the coal dust–coarse sand blend were measured at 2.15 kN, and 1.79 kN respectively, all of which surpass the minimum threshold of stipulated by Marshall Design criteria. These results indicate that a 50% coal dust and 50% coarse sand combination can serve as an effective and economical filler in asphaltic concrete.

Key Words: Bituminous concrete, Filler, Coal Dust, Coarse Sand, Marshall Design

INTRODUCTION

Bituminous pavements refer to road surfaces where bitumen serves as the primary binding component during construction. These surfaces are constructed using a homogeneous blend of coarse aggregates, mineral fillers, and bituminous binder. The overall structural performance and longevity of bituminous roads are strongly dependent on both the type and proportion of filler material incorporated [1]. Fillers contribute to the reinforcement and stiffening of the asphalt binder as they disperse uniformly within the bitumen matrix. Commonly used fillers include substances like Portland cement, hydrated lime, granite fines, crushed stone dust, and fine sand. However, materials such as cement, lime, and granite powder are relatively cost-intensive and are often prioritized for other construction applications. Alternatively, low-cost substitutes like fine sand, fly ash, coal dust, and other residual powders that pass through a 0.075 mm sieve are recognized as appropriate filler alternatives.

Recent investigations have emphasized the feasibility of incorporating industrial and construction byproducts as fillers in asphaltic compositions. Reclaimed materials such as phosphate residues [2], oil shale fly ash from

Jordan [3], baghouse fines [4], recovered lime sludge [5], municipal solid waste incinerator ash [6], and ceramic waste [7] have been evaluated for their effectiveness as fillers. These studies suggest that such waste-based fillers can significantly enhance the mechanical and functional characteristics of bituminous mixes. Accordingly, the present study investigates the performance of bituminous mixtures using a blended filler made of 50% coal dust and 50% coarse sand, offering a cost-efficient and environmentally sustainable alternative to conventional fillers.

When the filler content is insufficient, the resulting asphalt mix may become too stiff and dry, hampering workability. Conversely, an excess of bitumen may lead to an overly soft and unstable mix [8]. Fillers increase interparticle friction and can also undergo chemical interactions with the binder, modifying the rheological properties of the asphalt mastic [9]. The incorporation of mineral fillers generally improves the elastic stiffness modulus of asphalt mixtures; however, excessive filler usage may lower mix strength by increasing the binder demand [10, 11]. Furthermore, the grading of the filler has a significant effect on its contribution to mix stability and durability.

This research aims to formulate an aggregate-bitumen composite with a carefully controlled air void structure. A low void content may lead to insufficient binder coating and thin asphalt films, reducing both durability and compaction ease, whereas excessive voids may result in a lack of structural interlock and instability [12, 13]. Fillers also aid in enhancing temperature resistance and the long-term service life of asphalt mixtures. Strong cohesion between coarse aggregates, fine particles, and fillers is essential for forming a stable load-bearing structure [14].

Both the quantity and nature of filler materials affect the workability, strength, and performance of the bituminous mix [15]. Due to their high surface area, fillers absorb more binder and influence its viscoelastic properties, which in turn affect the overall pavement response [16, 17]. Properties such as particle gradation, angularity, surface roughness, void content, and mineral composition have a profound effect on the behavior of the asphalt composite [18].

In Bangladesh, typical filler compositions consist of a mixture of fine sand and crushed stone dust. This study assesses the feasibility of using a 50:50 blend of coal dust and coarse sand as an alternative filler. Coal dust is an abundantly available byproduct of industrial processes, and sand is widely accessible. The physical and mechanical properties of the bituminous mixes with this blended filler were analyzed through laboratory testing. Results were compared with those obtained using traditional fillers. The findings highlight that a coal dust- coarse sand blend has considerable potential as a viable, low-cost filler material for bituminous pavements, supporting sustainable and economical infrastructure development.

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 is 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 will 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 is shown in Figure: 1.

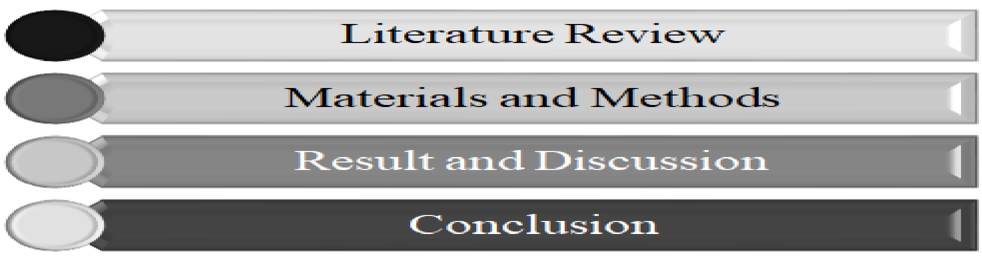

Figure: 1 Flow diagram is shown

INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

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 like coarse in Figure:5 sand and coal dust-coarse sand. 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 [19].

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

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

METHODS

The Marshall Mix Design method is used for evaluating Hot Mix Asphalt (HMA) by testing the strength, workability, and rigidity of bituminous mixtures under traffic conditions. The method involves 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 involves preparing samples with varying bitumen contents, compacting them, and conducting stability and flow tests. The test results for aggregates, fillers, and bitumen are presented, showing properties such as specific gravity, absorption capacity, and resistance to degradation. The study also includes 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. The results provide 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

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

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 60^0 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/m^3)			
% BC by Weight	Fresh filler	50% coal dust and 50% sand combination	Standard Values (RHD, Bangladesh)
4	1745.08	1847.85	2000-2500
4.5	2142.8	2139.32	
5	2254.54	2348.54	
5.5	2242.38	2288.96	
6	1548.54	2154.58	
Marshall Stability (kN)			
% BC by Weight	Fresh filler	Brick waste	Standard Values (RHD, Bangladesh)
4	1.13	1.24	--
4.5	1.89	1.79	
5	2.15	1.67	
5.5	1.78	1.25	
6	1.25	0.94	
Flow (mm)			
% BC by Weight	Fresh filler	50% coal dust and 50% sand combination	Standard Values (RHD, Bangladesh)
4	1.75	3.11	2-4
4.5	1.9	3.28	
5	2.12	3.48	
5.5	2.76	3.63	
6	3.15	4.13	
Percent VMA			
% BC by Weight	Fresh filler	50% coal dust and 50% sand combination	Standard Values (RHD, Bangladesh)
4	22.58	21.67	15-20

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

4.5	20.25	20.88	
5	18.38	20.53	
5.5	18.63	21.46	
6	23.09	22.23	
Percent VFB			
% BC by Weight	Fresh filler	50% coal dust and 50% sand combination	Standard Values (RHD, Bangladesh)
4	19.89	38.89	50-80
4.5	46	46.09	
5	60.37	52.6	
5.5	65.65	55	
6	68.55	57.66	
Percent Air Void			
% BC by Weight	Fresh filler	50% coal dust and 50% sand combination	Standard Values (RHD, Bangladesh)
4	28.11	13.24	--
4.5	20.54	11.25	
5	16.48	9.72	
5.5	12.58	9.12	
6	10.41	9.41	

RESULT AND DISCUSSION

The Marshall Mix Design method is a widely used technique for designing and evaluating Hot Mix Asphalt (HMA). The method assesses the strength, workability, and resistance of bituminous mixtures under traffic conditions by examining several key properties, including unit weight, Marshall stability, flow, volumetric properties, and air voids. The data provided above includes the results of tests conducted using different fillers, such as fresh filler and a 50% coal dust and 50% coarse sand combination, comparing them with standard values established by the Roads and Highways Department (RHD) in Bangladesh.

Unit Weight (Kg/m³)

For fresh filler, the unit weight ranges from 1745.08 kg/m³ at 4% BC by weight to 1548.54 kg/m³ at 6% BC in Table 1. In contrast, the mix containing 50% coal dust and 50% sand combination shows a similar trend, but the values are slightly higher than those with fresh filler, with the highest unit weight being 2348.54 kg/m³ at 5% BC by weight.

The standard unit weight for bituminous mixes, as prescribed by RHD, Bangladesh, falls between 2000-2500 kg/m³. From the data, it is evident that the unit weight of both the fresh filler and the coal dust-sand mix generally falls below the standard values, especially at higher bitumen content levels (above 5% BC). This discrepancy suggests that the mixes may have insufficient compaction or lack a sufficient amount of fine materials (such as sand and filler) to meet the standard requirements for heavier traffic loads.

Marshall Stability (kN)

For fresh filler, stability increases from 1.13 kN at 4% BC to a peak value of 2.15 kN at 5% BC, after which it drops to 1.25 kN at 6% BC in Table 1. This pattern reflects the general trend that bitumen content initially increases the mix's strength, but beyond an optimal point, excessive bitumen may reduce stability due to insufficient aggregate interlocking.

The stability of mixes containing 50% coal dust and 50% sand is generally lower than that of mixes with fresh filler, particularly at higher bitumen contents. At 4% BC, the stability is 1.24 kN, and it decreases gradually as the bitumen content increases, reaching 0.94 kN at 6% BC. This reduction in stability could be attributed to the lower quality and binding properties of coal dust compared to fresh filler, as coal dust might not contribute effectively to aggregate bonding.

Flow (mm)

For fresh filler, flow increases from 1.75 mm at 4% BC to 3.15 mm at 6% BC, indicating that higher bitumen content makes the mix more flexible. The flow for the 50% coal dust and 50% sand mix shows a similar trend, but the values are consistently higher, especially at 6% BC, where the flow reaches 4.13 mm in Table 1. This suggests that mixes with coal dust and sand are more flexible and deform more under load compared to those with fresh filler, which could affect their long-term durability under heavy traffic.

The standard flow values according to RHD, Bangladesh, range from 2 to 4 mm. Both types of mixes fall within this range, although the mixes containing coal dust and sand have flow values closer to the higher end of the standard range, indicating a higher likelihood of deformation under load.

Percent VMA (Voids in Mineral Aggregate)

For the fresh filler, VMA ranges from 22.58% at 4% BC to 23.09% at 6% BC. For the 50% coal dust and 50% sand combination, the VMA starts at 21.67% at 4% BC and gradually decreases to 22.23% at 6% BC in Table 1. The standard VMA values set by RHD, Bangladesh, range between 15-20%. Both the fresh filler and coal dust-sand mixes exceed this range, which might indicate an excess of voids, affecting the mix's durability.

Percent VFB (Voids Filled with Bitumen)

fresh filler, VFB increases from 19.89% at 4% BC to 68.55% at 6% BC, showing a trend toward better bitumen filling as bitumen content increases. For the coal dust-sand mix, VFB is significantly higher across all bitumen contents, ranging from 38.89% at 4% BC to 57.66% at 6% BC in Table 1. The RHD standard for VFB is between 50-80%, and both mixes generally meet the standard, except for the mix with fresh filler at 4% BC.

Percent Air Void

For the fresh filler, air voids decrease from 28.11% at 4% BC to 10.41% at 6% BC. The coal dust-sand combination shows a similar trend, with air voids decreasing from 13.24% at 4% BC to 9.41% at 6% BC in Table 1. The lower air voids in the coal dust-sand mix could indicate a more compact mix with better performance under traffic loads.

CONCLUSION

The results presented above show that the bitumen content, type of filler, and aggregate properties significantly influence the performance of the asphalt mix. The mixes containing coal dust and sand generally exhibit higher flow and lower stability compared to the fresh filler, which indicates that coal dust may not be as effective in contributing to the overall strength of the mix. However, both types of mixes generally meet the RHD standard requirements for VMA and VFB, ensuring that they are workable and durable for use in transportation infrastructure.

RECOMMENDATIONS

1. It is obtained to use fresh filler in asphalt mixes, as it provides better stability, optimal air voids, and improved VFB compared to coal dust. This leads to enhanced durability and long-term performance of the pavement.

2. Coal dust should not be considered a suitable replacement for fresh filler in asphalt mixes due to its poor performance in key parameters. Its use may increase susceptibility to deformation and reduce the structural integrity of the pavement over time. Further studies could explore ways to improve its suitability if necessary.

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.

REFERENCES

1. Kadeyali: Principles and practice of Highway Engineering.3rdedition (1997).
2. Katamine NM: Phosphate waste in mixtures to improve their deformation. J Transport Eng 2000; 126:382–9.
3. Asi Ibrahim, Assa’ad Abdullah: Effect of Jordanian oil shale fly ash on asphalt mixes. J Mater CivEng 2005; 17:553–9.
4. Lin Deng-Fong, Lin Jyh-Dong, Chen Shun-Hsing: The application of baghouse fines in Taiwan. Resour Conserv Recycle 2006; 46:281–301.
5. Sung Do Hwang, Hee Mun Park, Suk keun Rhee: A study on engineering characteristics of asphalt concrete using filler with recycled waste lime. Waste Manage 2008; 28:191–9.
6. Xue Yongjie, Hou Haobo, Zhu Shujing, Zha Jin: Utilization of municipal solid waste incineration ash in stone mastic asphalt mixture: pavement performance and environmental impact. Constr Build Mater 2009; 23:989–96.
7. Huang Baoshan, Dong Qiao, Burdette Edwin G: Laboratory evaluation of incorporating waste ceramic materials into Portland cement and asphaltic concrete. Constr Build Mater 2009; 23:3451–6.
8. Kalkattawi, H.R: Effect of Filler on the Engineering Properties of Asphalt Mixes, M.S. Thesis, King Abdul Aziz University, Jeddah, Saudi Arabia. (1993)
9. Anderson, D. A.: Guidelines for use of dust in hot mix asphalt concrete mixtures.”Proc. Association of Asphalt Paving Technologists, 56, Association of Technologists, St. Paul, MN, 492–516, 1987 Asphalt Paving
10. Elliot, R.P., Ford, M.C., Ghanim, M., and Tu, Y.F. :Effect of aggregate gradation variation on asphalt concrete mix properties, Transportation Research Record, 1317, National Research Council, Washington, D.C., 1991
11. Kandhal, P.S., Lynn, C.Y., and Parker, F.: Characterization tests for mineral fillers related to performance of asphalt paving mixtures, NCAT Rep. No. 98-2, 1998
12. Bahia, H.U., Zhai, H., Bonnetti, K.,and Kose, S.: Non-linear visco-elastic and fatigue properties of asphalt binders, Journal of Association of Asphalt Paving Technology, 68, 1-34,1999
13. Geber, R. and Gomze, L.A.: Characterization of mineral materials as asphalt fillers, Material Science Forum,659, 471-476, 2010

14. Vavrik, W.R., Pine, W.J., Carpenter, S.H., and Bailey, R.: Bailey method for gradation selection in hot-mix asphalt mixture design, Transportation Research Board, National Research Council, Washington, D.C., USA., 2002
15. Zulkati, A., Diew, W. Y. and Delai, D.S. :Effects of Fillers on properties of Asphalt-Concrete Mixture, Journal of Transportation Engineering, ASCE, Vol. 138, No. 7, 902-910.,2012
16. Taylor, R.: Surface interactions between bitumen and mineral fillers and their effects on the rheology of bitumen-filler mastics. Ph.D. thesis, Univ. of Nottingham, UK., 2007
17. Lesueur, D.: The colloidal structure of bitumen: consequences on the rheology and on the mechanisms of bitumen modification. Adv.Colloid Interface Sci., 145(1–2), 42–82., 2009
18. Bahia, H. U., Faheem, A., Hintz, C., Al-Qadi, I., Reinke, G., and Dukatz, E.: Test methods and specification criteria for mineral filler used in HMA."NCHRP Research Results Digest, 357, Transportation Research Board, Washington, DC., 2011
19. American Society for Testing and Materials (ASTM): Road and Paving Materials; Vehicle Pavement System, Annual Book of ASTM Standards, Section 4, Volume 04.03,2003.