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Sustainable Modification of Asphaltic Concrete Using Saw Dust Ash and Sorghum Husk Ash as Filler Materials

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Abstract: *The rising demand for sustainable infrastructure has necessitated the exploration of alternative materials in construction. In asphaltic concrete production, the use of conventional mineral fillers significantly contributes to cost and environmental degradation. This study aimed to investigate the potential of Saw Dust Ash (SDA) and Sorghum Husk Ash (SHA), as partial replacements for conventional fillers in asphaltic concrete, thereby promoting waste recycling and reducing environmental impact. The study involved the laboratory preparation of asphaltic concrete samples with 10%, 20%, 30%, and 40% replacement levels of conventional filler using varying SDA-SHA mix proportions (ranging from 0% to 100%). Material properties of the aggregates and bitumen were tested to ensure compliance with standard specifications. Marshall Stability, Flow, and Marshall Quotient tests were conducted on the asphalt samples to evaluate strength, workability, and stiffness characteristics. Results revealed that the optimal performance was achieved at 30% filler replacement with a 50:50 SDA-SHA mix (Sample 30F), where the highest stability of 19.8 kN, flow value of 3.3 mm, and Marshall Quotient of 6.0 kN/mm were recorded. The stability values increased with higher SDA content up to a point, after which a decline was observed. Flow values generally decreased with increasing SDA, indicating higher stiffness. These results align with findings from previous studies, confirming that moderate incorporation of agricultural ashes can enhance the mechanical performance of asphaltic concrete. In conclusion, the use of SDA and SHA as partial filler replacements in asphaltic concrete is both viable and beneficial. It is recommended that a 30% combined ash replacement (50% SDA + 50% SHA) be adopted for optimal strength and durability. Further field studies are encouraged to assess long-term performance and durability under real traffic and environmental conditions.*

Keywords: *Saw dust Ash (SDA), Sorghum Husk Ash (SHA), Marshall Stability and Flow, Marshall Quotient, Alternative Fillers*

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1. INTRODUCTION

Road infrastructure quality and durability are vital components of any nation's economic development, social cohesion, and overall progress (Abbas et al., 2025). As societies expand and global transportation demands increase, there is a pressing need to ensure that road pavements are constructed using materials that can withstand environmental stressors, traffic loading, and long-term operational use (Kim & Le, 2023). In many parts of the world, particularly in developing nations such as Nigeria, flexible pavement systems made from hot mix asphaltic concrete dominate road construction due to their adaptability, strength, and relative ease of maintenance (Kayode-Ojo and Edeoghon, 2021). The performance of these pavements, however, depends significantly on the materials used in their formulation, especially the filler components, which are essential for improving void filling, cohesion, and stability within the asphalt matrix (Xu et al., 2025).

Fillers, typically materials passing through a 0.075 mm sieve, play a critical role in enhancing the engineering and mechanical properties of asphalt mixtures (Erinjogunola et al., 2025). Conventional fillers such as stone dust, hydrated lime, Portland cement, and fly ash are known to influence the rheological behaviour and mechanical strength of the asphalt binder matrix, impacting essential characteristics such as resistance to rutting, fatigue life, stiffness modulus, moisture susceptibility, and aging resistance (Ajayi et al., 2025). Despite the effectiveness of these traditional fillers, the extraction and processing of these materials place considerable strain on natural resources, leading to environmental degradation and increased construction costs. In the face of these challenges, researchers and policymakers are increasingly advocating for sustainable alternatives derived from waste materials, particularly agricultural and industrial by-products (Akinleye et al., 2020). The use of agro-waste ashes, such as rice husk ash, bamboo leaf ash, corn cob ash, and bagasse ash, has gained significant attention in recent years due to their pozzolanic activity, economic viability, and environmental compatibility. These materials, when appropriately processed, possess the chemical and physical characteristics required to enhance asphalt performance while promoting sustainability in infrastructure development.

Among such agro-waste materials, Saw Dust Ash (SDA) and Sorghum Husk Ash (SHA) present promising alternatives (Dhami et al., 2023). Saw dust, a by-product of wood processing and carpentry activities, is produced in vast quantities in urban and peri-urban areas (Akinleye et al., 2023). When incinerated under controlled conditions, saw dust yields an ash rich in calcium oxide (CaO) and other oxides that contribute to improved binding, reduced thermal susceptibility, and enhanced durability of asphalt mixtures. Similarly, sorghum husk is a readily available agricultural residue in Nigeria, one of the world's leading producers of sorghum. Sorghum husk ash, obtained through controlled combustion, exhibits pozzolanic properties suitable for construction applications, including high silica content which can contribute to additional cementitious reactions within the asphalt matrix (Singh and Patel, 2025).

Despite the availability and potential of Saw Dust Ash (SDA) and Sorghum Husk Ash (SHA), their utilization in combination as fillers in asphaltic concrete remains underexplored. Existing studies predominantly focus on the isolated effects of each ash type when used individually, presenting a significant knowledge gap, particularly in understanding the synergistic effects of these materials when blended in varying proportions (Shi et al., 2025). Moreover, the increasing cost of conventional construction materials and the rapid depletion of natural resources, coupled with the environmental burden posed by unmanaged agro-waste, highlight the urgent need to explore alternative and sustainable material sources. SDA and SHA not only have the potential to improve the structural and mechanical properties of asphalt pavement but also offer a viable pathway for sustainable waste management and resource conservation. The problem is twofold: firstly, the scarcity and rising cost of conventional fillers hinder road construction efforts, especially in low-income economies; secondly, the indiscriminate disposal of agro-industrial wastes such as saw dust and sorghum husk contributes to environmental degradation, including land pollution, air quality deterioration, and the release of hazardous particulates into the ecosystem (Akinleye et al., 2020). Integrating these waste products into asphaltic concrete production addresses both challenges simultaneously, by enhancing pavement performance while promoting circular economy practices and reducing the environmental impact of construction and waste disposal activities.

2.1 Materials

This study utilized several key materials to produce and test modified asphaltic concrete. Crushed granite, serving as the coarse aggregate, was sourced from a local quarry in Ede, Osun State, and tested for properties such as moisture content, specific gravity, sieve analysis, water absorption, abrasion resistance, crushing, and impact values. Sharp sand, also obtained from a local quarry in Ede, was used as fine aggregate and subjected to specific gravity, water absorption, sieve analysis, and moisture content tests. Quarry dust, sourced from the same location, underwent similar testing procedures. Saw Dust Ash (SDA) was derived from sawdust collected at a sawmill in Allahu-Lateef Area, Ede; it was burned at controlled furnace temperatures and sieved through a 75 µm (No. 200) sieve to serve as a mineral filler. Sorghum Husk Ash (SHA), obtained from nearby villages around Adeleke University, was similarly processed. Both ashes were used as partial replacements for conventional fillers in the asphalt mix. Additionally, 60/70 penetration grade bitumen, sourced from a bitumen plant in Ogun State, was used as the binder and tested for penetration, flash point, ductility, and softening point.

2.2 Tests on Materials

Various standard laboratory tests were conducted on the materials used in this study to determine their suitability for asphaltic concrete production. Aggregate gradation was carried out using mechanical sieve analysis following BS 812 and ASTM C136 standards to assess particle size distribution. Moisture content of the aggregates was determined using the oven-drying method in line with BS 812: Part 109, which accurately measures water content relative to the dry mass.

Specific gravity was determined following BS 1377 and ASTM C127 procedures, involving the use of a pycnometer bottle to calculate the ratio of aggregate mass to volume. The Los Angeles Abrasion test, in accordance with BS 812: Part 113, assessed the aggregates' resistance to wear by measuring mass loss after 500 revolutions in an abrasion machine. The Aggregate Impact Value (AIV) test, conducted according to BS 812: Part 112, evaluated the aggregates' resistance to sudden impact by measuring the percentage of material passing a 2.36 mm sieve after impact. Similarly, the Aggregate Crushing Value (ACV) test followed BS 812: Part 110 to determine the ability of aggregates to resist gradual compressive loads, with results based on the proportion of crushed material passing through a 2.36 mm sieve after testing. These comprehensive tests ensured the mechanical strength, durability, and performance suitability of the aggregates used in the asphaltic concrete mixtures.

2.3 Bitumen

Several standard tests were conducted on bitumen to evaluate its physical properties and suitability for asphaltic concrete. The penetration test, following ASTM D1321, assessed the hardness or softness of bitumen by measuring the depth a standard needle penetrates the sample at 25°C. Bitumen was heated, poured into containers, conditioned in a water bath, and tested using a precision penetrometer. For flash and fire point tests, bitumen was heated and exposed to an ignition source to determine the lowest temperature at which vapors ignite (flash point) and sustain combustion (fire point), ensuring safety during handling. These tests followed standard procedures with precise temperature control. The ductility test, conducted at 27°C per ASTM D113, measured the stretchability of bitumen before it breaks, expressed in centimetres, using a standard briquette mold and a pulling rate of 50 mm/min. Lastly, the softening point test determined the temperature at which bitumen softens under specific conditions. The test used the ring-and-ball apparatus, with distilled water and controlled heating, to assess consistency and temperature resistance, essential for evaluating thermal behavior in pavement applications. These tests collectively confirmed the bitumen's performance and fitness for construction use.

2.4 Modified Asphaltic Concrete

A total of six modified asphalt mixtures were produced using 0%, 2%, 4%, 6%, 8%, and 10% combinations of Sorghum Husk Ash (SHA) and Corn Cob Ash (CCA) as partial replacement for traditional fillers. The bitumen used was 60/70 penetration grade. The performance of these modified mixes was evaluated through Marshall Stability and Flow tests, following ASTM D6927-05, as well as Indirect Tensile Strength tests.

2.4.1 Marshall Stability Test

The **Marshall Stability test**, in line with BS EN 12697-34:2007, was used to assess the load-bearing capacity (stability) and deformation (flow) of asphalt samples at 60°C. Each asphalt mix was compacted into cylindrical specimens, conditioned in a water bath, and then tested using the Marshall apparatus.

i. **Aggregate & bitumen preparation**: Aggregates (1200g per specimen) were heated to 175–190°C, while bitumen was heated to 121–138°C. Mixing occurred at 145–160°C.

ii. **Sample compaction**: Each sample was compacted using 50 blows on both sides at 130–145°C.

iii. **Testing**: Specimens were immersed in a 60°C water bath for 30 minutes before testing. The stability (maximum load in kN) and flow value (deformation in mm) were measured during the test.

2.4.2 Design Mix Summary

The mix design involved varying quarry dust (QD) from 100% to 0% in 10% intervals, while the combined replacement of SHA and SDA (Sorghum Husk Ash and Sugarcane Bagasse Ash) ranged from 0% to 100% in reverse. Within each combined percentage, SHA and SDA were also varied from 0% to 100% and vice versa, in 10% steps as summarised in Table 1.

Tabel 1: Simplified Summary Table of Design Mix

Quarry Dust (%)	SDA (%)	SHA (%)	Combined Fillers (%)
100	0	0	0
90	0	100	10
80	10	90	20
70	20	80	30
60	30	70	40
50	40	60	50
40	50	50	60
30	60	40	70
20	70	30	80

10	80	20	90
0	90	10	100
0	100	0	100

2.5 Data Analysis

The data obtained from the experimental tests were systematically analyzed to evaluate the influence of Sorghum Husk Ash (SHA) and Corn Cob Ash (CCA) as partial fillers in asphaltic concrete. Statistical and graphical tools were employed to interpret the results from the various tests, including the Marshall Stability and Flow, Indirect Tensile Strength, and bitumen property assessments such as penetration, softening point, flash and fire point, and ductility. Comparative analysis was conducted between control samples (0% replacement) and modified samples to identify performance trends. The effect of varying filler proportions on mechanical strength, durability, and thermal resistance of the asphalt mix was examined to determine the optimal blend for construction use. Results were presented in tabular and graphical formats to highlight improvements or reductions in performance with increased ash content. The outcomes were then compared with standard specifications to evaluate the feasibility of SHA and CCA as sustainable alternatives to conventional mineral fillers.

3.0 RESULT AND DISCUSSIONS

3.1 Characterisation of Aggregate Materials Used for Asphalt Mix Production

The characterization of aggregate materials used in the asphalt mix production focused on evaluating the particle size distribution and physical properties of fine aggregates, coarse aggregates, and mineral fillers. Sieve analysis was carried out and the results, presented in Table 1, revealed important gradation properties. For the fine aggregates, the D10, D30, and D60 values were 0.33 mm, 0.56 mm, and 0.9 mm respectively, with coefficients of uniformity (Cu) and curvature (Cc) computed as 2.7 and 1.06. According to ASTM D-2487, this classifies the fine aggregates as poorly graded since Cu is less than 6. Conversely, the mineral filler showed D10, D30, and D60 values of 0.16 mm, 0.22 mm, and 0.25 mm, with Cu and Cc of 1.6 and 1.19 respectively. These values indicate a well-graded filler, as it satisfies the standard requirement of $1 \leq Cc \leq 3$. The mineral filler also met the specification of 85% passing the 75 µm sieve, recording an actual passing rate of 92%, further confirming its suitability (Adesoji et al., 2021; Nuguyen et al., 2025). For the coarse aggregates, the D10, D30, and D60 values were 5.3 mm, 6.85 mm, and 9 mm, with corresponding Cu and Cc values of 1.7 and 0.98. Although Cu is below 4, indicating a narrow range of sizes, the Cc falls within the acceptable range of $1 \leq Cc \leq 3$, suggesting a moderately well-graded coarse aggregate.

3.2 Physical and Mechanical Properties of the Coarse Aggregates

The physical and mechanical properties of the coarse aggregates, as shown in Table 2, provide critical insight into their suitability for asphalt mix production. Parameters such as specific gravity, water absorption, aggregate impact value (AIV), aggregate crushing value (ACV), and Los Angeles abrasion value are standard indicators of an aggregate's strength, durability, and performance under loading. A specific gravity value within the typical range of 2.5–2.9 confirms the aggregate's density and compatibility with bituminous materials, which is vital for ensuring adequate bonding and structural integrity in asphalt concrete. The low water absorption value suggests minimal porosity, indicating resistance to moisture-induced damage like stripping or degradation. Additionally, the AIV and ACV results fall within the acceptable limits set by ASTM and BS standards, signifying the aggregate's resistance to mechanical stress and its ability to maintain stability under repeated traffic loads. The Los Angeles abrasion value, which assesses toughness and resistance to wear, is also within permissible limits, implying that the coarse aggregate can endure the abrasion and polishing effects of vehicular movement over time (Skaf et al., 2025). Collectively, these results validate the coarse aggregates' mechanical soundness and robustness, affirming their appropriateness for use in both hot and warm asphalt mixes, especially in load-bearing applications such as roads and pavements.

Table 1: Evaluation of Physical and Mechanical Properties of Coarse Aggregate for Asphalt Mixes

Test carried out	Obtained Test Results	Standard (Nigerian)	Remarks
Aggregate Impact value	19.2%	30% maximum	Adequate
Aggregate Crushing value	42.4%	45% maximum	Adequate
Los Angeles Abrasion	48.92	60% maximum	Adequate
Flakiness Index	28.62	30% maximum	Adequate
Elongation Index	29.53	30% maximum	Adequate
Density	1500.20 kg/m^3	-	-
Specific Gravity	3	3 Maximum	Adequate

3.3 Properties of Bitumen

Table 2 shows the properties of bitumen used for the study. From the table, the average penetration value is 70mm and this aligns with both FMW and ASTM standards for bitumen penetration which ranges from 60-70. Also, the softening point value of the bitumen complies with both the ASTM and FMW standards. Meanwhile, the ductility value of 90cm complies with the FMW and BIS standard. Furthermore, the specific gravity value of 0.97 falls within the range of ASTM standard but deviate from FMW standard. Additionally, flash point value falls within the specifications of FMW and ASTM standards while the viscosity shows compliance with the BIS standard. The overall result obtained showed that the bitumen's properties used for the study fall within the specification of the standards.

Table 2: Properties of the bitumen used for asphaltic production

	Penetration (mm)	Softening (°C)	Ductility (cm)	Viscosity (secs)	Flash Point (°C)	Fire Point (°C)	Specific Gravity
	70	48	90	76	255	308	0.97
FMW	60-70	48-56	≤100	-	Min.250	-	1.01-1.06
ASTM	60-70	47-58	-	-	Min. 230	-	0.97-1.06
BIS	-	-	≥75	≥70	-	-	-
AI	-	>50	5-100	-	-	-	

N.B.: FMW is Federal Ministry of Works (2007); ASTM is American Society of Testing and Materials, D5-97 for penetration, D36-95 for softening and D2041 for specific gravity; BIS is Bureau of Indian Standards (1986); and AI is Asphalt Institute (1991).

3.4 Marshall properties of Asphalt

The Marshall properties of the modified asphaltic concrete mixes at varying ash replacement levels (10%, 20%, 30%, and 40%) highlight the effects of substituting traditional aggregates with Corn Cob Ash (CCA) and Sorghum Husk Ash (SHA). Across all replacement levels, the trends in Marshall Stability and Marshall Quotient reveal that these properties tend to increase with the percentage of ash replacement, up to a certain level, suggesting an improvement in strength and stiffness of the mixes. At 30% ash replacement, stability values peaked, with Sample 30F showing the highest stability of 19.8 kN, reflecting an optimal blend of SDA-SHA mix. Flow values decreased slightly as the SDA content increased, yet remained within the standard range of 2–6 mm, indicating good resistance to deformation. For 40% ash replacement, stability values showed a slight decrease compared to the 30%

level, with Sample 40F reaching 18.4 kN, suggesting a diminishing return on stability after this point. However, the Marshall Quotient, indicating the mix's resistance to rutting, peaked at 6.1 kN/mm for Sample 30J. In contrast, the flow values decreased progressively as the SDA content increased, with the lowest value at 2.8 mm for 100% SDA (Sample 40K). Despite these fluctuations, all mixes met the Federal Ministry of Works and Housing (FMW&H) asphalt specifications, including stability, flow, and air voids requirements, and were deemed acceptable for practical use. The inclusion of both SDA and SHA improves the overall properties of the asphalt mix, with the 50:50 SDA-SHA mix proportions demonstrating the highest stability and optimal flow characteristics. The results further illustrate that the 30% replacement level offers the best balance of strength and workability, while higher replacement levels (40%) result in a slight drop in performance as shown in Table 3.

Table 3: Summary of Marshall Properties for Varying Ash Replacement Levels

Ash Replacement (%)	Avg. Weight in Water (kg)	Avg. Weight in Air (kg)	Avg. Stability (kN)	Avg. Flow (mm)	Avg. Marshall Quotient (kN/mm)
10%	0.703	1.147	15.87	3.35	4.87
20%	0.705	1.139	16.27	3.52	4.79
30%	0.684	1.126	18.05	3.38	5.39
40%	0.660	1.107	16.84	3.28	5.13

The study of asphaltic concrete with varying ash replacement levels (20%, 30%, and 40%) reveals that the optimal blend for enhanced performance is around the 30% ash replacement level. At this level, the stability value peaked at 19.8 kN with a 50:50 SDA-SHA mix, showing improved strength and stiffness. As the SDA content increased, the flow decreased, indicating better resistance to deformation. The stability values at 40% ash replacement showed a slight decrease to 18.4 kN, and flow continued to decrease, but remained within acceptable limits. These findings align with previous studies that highlight the positive impact of incorporating agricultural waste ashes like SDA and SHA in asphalt mixtures, improving mechanical properties while maintaining environmental sustainability. Ash content beyond 30% may not significantly enhance the stability, suggesting that there is an optimal range for the best balance of performance, strength, and workability, as reported in similar research by authors such as Alam et al. (2025); Ajayi et al. (2025) and Onsongo et al. (2025), who found that ash content improves asphalt properties up to a certain limit.

3.5 Stability

The study examined the stability and flow properties of asphaltic concrete with varying levels of ash replacement (10%, 20%, 30%, and 40%), revealing significant trends linked to the inclusion of SDA and SHA. Stability values increased as SDA content was introduced, peaking at a 50:50 SDA-SHA mix, before decreasing at higher SDA levels. The highest stability value of 19.8 kN was recorded at 30% ash replacement with a 50:50 SDA-SHA mix, suggesting that this blend offers optimal strength and resistance to deformation. These findings align with the research of Olusola et al. (2018) and Adewole et al. (2015), which demonstrated that SHA enhances stability but with diminishing returns at higher ash contents. The flow values, on the other hand, decreased as SDA content increased, indicating that SDA reduces the flexibility of asphaltic concrete, consistent with findings from Olusola et al. (2018); Nawaz et al. (2025). The addition of SHA improved flow values, and all mixes met the FMW (2016) specifications, although none satisfied the Asphalt Institute (AI) (1991) standards due to differing testing methods. Overall, the study supports the use of a 30% ash replacement for achieving a balance of stability, strength, and flow in asphaltic concrete production (Asebiomo et al., 2024, Akinleye et al., 2025b). Table 4 shows the summary table of the results for the stability and flow values at various ash replacement levels.

Table 4: Summary of Stability and Flow Results for Ash Replacement Levels

Ash Replacement (%)	Stability (kN)	Flow (mm)	Marshall Quotient (kN/mm)
10	15.87	3.35	3.5
20	16.27	3.52	4.8
30	19.80	3.39	6.1
40	16.84	3.28	5.1

This table encapsulates the key findings of stability and flow across various ash replacement percentages, showing the optimal balance of properties at 30% ash replacement.

3.6 Marshall Quotient

The Marshall Quotient (MQ) values for various ash replacement levels (10%, 20%, 30%, and 40%) revealed important trends related to stiffness and resistance to rutting in asphaltic concrete. As the percentage of SDA increased, the Marshall Quotient also increased, peaking at 30% ash replacement, with the highest value of 6.1 kN/mm recorded at 90% SDA replacement for the 30% ash mix. At the same time, lower Marshall Quotient values were observed at the 10% ash replacement, with the lowest value of 3.5 kN/mm at 0% SDA. The results indicate that higher SDA content significantly enhances stiffness, but excessive SDA may reduce workability and flexibility. These findings are consistent with previous studies by Adewole et al. (2015), highlighting the optimal combination of SDA and SHA for improved performance. Furthermore, the Marshall Quotient's role in measuring rutting resistance aligns with Choudhary et al. (2020), who emphasised its importance in evaluating the asphalt mix's ability to resist shear deformation and rutting. The higher the Marshall Quotient, the better the load distribution and stiffness, which helps prevent rutting and creep failure. Table 4 also shows the summary table of the Marshall Quotient values for each replacement level.This table reflects the optimal performance at 30% ash replacement, where the highest Marshall Quotient value was observed, signifying enhanced stiffness and resistance to deformation, thus ensuring better durability and load-bearing capacity of the asphaltic concrete.

4.0 CONCLUSION

This study evaluated the performance of asphaltic concrete incorporating Saw Dust Ash (SDA) and Sorghum Husk Ash (SHA) as filler materials, and several tests, including ductility, flash and fire points, softening point, Marshall stability and flow, and Marshall quotient, were conducted. The results showed that the index properties of aggregates and bitumen met standard specifications, leading to a mix design of 65.7:7:21:6.3 for coarse aggregate, fine aggregate, filler, and bitumen content. The Marshall stability and flow increased with higher proportions of SDA-SHA, with the highest stability (19.8 kN) and flow (3.3 mm) observed at the 30% ash replacement level, specifically in the 50% SDA and 50% SHA mix (Sample 30F). This mix also exhibited the highest Marshall quotient (6.0 kN/mm), indicating superior resistance to rutting and cracking. The study recommends using a 50% SDA and 50% SHA combination at a 30% replacement level as a natural filler in asphaltic concrete production in Nigeria. It also suggests further research into the durability of SDA and SHA asphalt mixes. The study contributes to knowledge by demonstrating that SDA and SHA can effectively replace conventional fillers in asphaltic concrete production and that a 30% replacement level offers the best stability and Marshall quotient performance.

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