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Potentials of Bitumen Tar Sand for Road Work: A Case Study of Kajola, Lamudifa Irele Local Government Area, Nigeria

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ABSTRACT

The persistent infrastructural deficit in Nigeria, exacerbated by the high cost of conventional road construction materials, necessitates the investigation of locally available alternatives. This study presents a comprehensive evaluation of the engineering properties of bitumen-rich tar sand sourced from Kajola in Ondo State, Nigeria, for potential application in asphalt pavement construction. The research methodology involved a series of standardized laboratory tests to characterize both the aggregate and binder components of a proposed Tar Sand Asphalt (TSA) composite. Critical aggregate strength parameters, including the Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), and Los Angeles Abrasion (LAA) value, were determined to be 28%, 23%, and 38%, respectively. These results fall within acceptable thresholds for use in flexible pavements, indicating good resistance to mechanical degradation and confirming the material's suitability for road surfacing in low to moderate-traffic scenarios. The bitumen extracted from the tar sand exhibited a very low penetration value of 17 mm, characterizing it as a hard binder with inherent resistance to rutting and bleeding, making it particularly advantageous for road construction in Nigeria's hot climatic regions. Furthermore, the Marshall mix design method was employed to optimize the asphalt composition, revealing that a mix incorporating 50% tar sand aggregate and an optimum bitumen content of 4.5% delivered the most favorable balance of stability and flow after the control mix. While the findings affirm the viability of Kajola tar sand for low-volume road construction, the study concludes that for broader applications, including high-traffic highways, the TSA composite would require performance-enhancing additives such as polymers, fibres, or crumb rubber. The successful deployment of this indigenous material promises to significantly reduce road construction costs and contribute to bridging the nation's infrastructure gap.

KEYWORDS: Tar Sand, Road Construction, Aggregate Crushing Value, Aggregate Impact Value, Los Angeles Abrasion, Bitumen Penetration

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1 | INTRODUCTION

Since independence, the Nigerian government has made significant investments in highway development to achieve good pavement performance (Audu & Adeiza, 2024). However, pavements wear down and break early in the form of rutting. Due to the high cost of building materials for roads and economic difficulties in Nigeria, its infrastructure deficit has become a great concern, as its infrastructure stock is 25% of GDP, far lower than the 70% benchmark of the IMF (Fagbemi et al., 2022). Getting high-quality construction materials for roads is becoming more difficult, particularly when all-weather roads are being developed in urban and rural areas with normally low traffic volumes (Biber-Freudenberger et al., 2025). The main building resources for roads are laterite, gravel, and bitumen, and in many areas, these materials have been heavily exploited and depleted due to ongoing construction and maintenance activities. The lack of good roads in rural regions makes it harder for locals to transport various natural resources and their agricultural products to city centres. Additionally, the nation's GDP is directly impacted by the state of its roadways, and cost-effective methods for building long-lasting pavements are eagerly sought. The economic abundance of the tar sands in South-west, Nigeria, presents an opportunity to mitigate the environmental impact and boost the economy by reducing costly road materials if the tested material achieves the desired engineering requirements. This study attempts to assess the suitability of using bitumen tar sand sourced from Ondo state as a road construction material through testing its engineering properties. Tar sand was described by Speight (2019) as sand that contains "an extremely viscous crude hydrocarbon component not recoverable in its natural form through a well by ordinary production procedures. It can be challenging to tell tar sands from sands that contain heavy crude oil (Al-Bazzaz et al., 2025; Hein, 2013). Tar sands are sedimentary rocks (consolidated or unconsolidated) that contain bitumen (solid or semisolid hydrocarbons) or other heavy petroleum that cannot be recovered from them in their natural state using conventional petroleum recovery techniques (Saborimanesh, 2021). Since tar is a viscous liquid with sticky qualities that is created by the destructive distillation of coal, wood, shale, and other minerals, tar sands academically is not a mixture of tar and sand. On the other hand, Bitumen refers to sticky, viscous liquids or solids that are dark brown or black in hue. They are soluble in carbon disulfide and mostly made of petroleum-derived hydrocarbons or hydrocarbons present in natural asphalt. The oil found in tar sands is now simply referred to as "bitumen," and Alberta's bitumen deposits are now referred to as "oil sands" instead of the old designation "tar sands (Ogiriki et al., 2018). Across the world, bituminous materials are often used in the construction of highways. These hydrocarbons can be produced as a byproduct of the distillation of crude petroleum or can be found in natural forms. The two types of bituminous materials used in the construction of roads are asphalts and tars. Bitumen is the main component of all bituminous compounds, which range in colour from dark brown to black and have strong adhesive properties. Although significant volumes of tar sands have been identified in south-western Nigeria, Adeyemi et al. (2013) claimed that detailed geological studies of various sites have not yet been carried out. Such studies help with quantitative evaluation and contribute to knowledge towards green exploration. The scope of the study covers tar sand usage in the asphalt wearing course for pavement. The Akure-Ijare road is about 12 kilometres long and connects Akure and Ijare, both in Ondo State, Nigeria. It is situated between longitudes 50 10' and 50 09' E and latitudes 70 21' and 70 17' north. Physically, this place is in the tropical rain forest belt of a hot, humid equatorial climatic area with alternating wet and dry seasons. Seasonal fluctuations in the rate of evaporation greatly affect this environment. The average annual rainfall is between 1000 and 1500 mm, and the average temperature is between 24°C and 27°C. There is a presence of tropical rainforest vegetation, which is characterised by a dense canopy of evergreen trees with big leaves. The dense vegetation is made up of cocoa trees, kola nut trees, and palm trees. The research location is inside the Nigerian Crystalline Basement Complex rocks in southwest Nigeria. The next section presents the method adopted in analysing the tar sand from this region to assess its usability for Tar Sand Asphalt (TSA) composite.

2.0 | LITERATURE REVIEW

The pursuit of sustainable and cost-effective construction materials is a central theme in modern civil engineering, particularly in developing nations grappling with infrastructural deficits. The high cost of conventional road construction materials, coupled with their increasing scarcity in many regions, has spurred significant research into alternative and locally available resources. Within this context, the utilization of tar sands, a naturally occurring hydrocarbon-saturated sand, has garnered attention as a potential partial or full replacement for conventional aggregates and bitumen in asphalt composites. This review synthesizes recent global and local research on the properties and performance of tar sands and analogous materials in road construction, providing a foundation for the present study's investigation into the Kajola tar sands.

2.1 The Global Imperative for Alternative Road Construction Materials

The critical link between robust infrastructure and economic development is well-established. In the Nigerian context, the infrastructural deficit, with a stock estimated at only 25% of GDP, remains a significant impediment to growth (Audu & Adeiza, 2024). A major component of this challenge is the high cost and limited availability of quality road construction materials. This issue is not unique to Nigeria; it is a pervasive concern across many developing economies. The search for locally sourced, economical alternatives is therefore not merely an academic exercise but a practical necessity for national development. The exploitation of indigenous natural resources like tar sands presents a strategic opportunity to reduce reliance on imported materials, lower construction costs, and address the pressing need for rural and urban road networks (Biber-Freudenberger et al., 2025). The conversion of such resources from "waste to wealth" aligns with principles of a circular economy, offering environmental and economic benefits.

2.2 Engineering Properties of Aggregates for Pavement Performance

The performance and longevity of asphalt pavements are fundamentally governed by the quality of their constituent aggregates. Key mechanical properties determine an aggregate's suitability for withstanding the stresses imposed by traffic and environmental loading. Recent research has continued to validate the importance of standardized tests in predicting field performance.The Aggregate Crushing Value (ACV) is a critical indicator of an aggregate's resistance to gradual compressive load, simulating the sub-base and base course conditions. Aggregates with lower ACV are preferred for high-stress applications. Similarly, the Aggregate Impact Value (AIV) measures resistance to sudden shock or impact, a common occurrence during traffic loading and construction activities. Studies have shown that aggregates with an AIV below 30% are generally considered strong and suitable for surface courses, while those with higher values may be limited to lower layers or low-traffic applications (Mannan & Alengaram, 2021). The Los Angeles Abrasion (LAA) test remains a globally accepted method for evaluating an aggregate's resistance to wear, degradation, and fragmentation. A lower LAA value indicates a harder, more durable aggregate that will resist polishing and breakdown under repeated wheel loads. Research by Teymen (2019) further established strong correlations between the LAA value and other mechanical properties like uniaxial compressive strength and P-wave velocity, reinforcing its utility as a comprehensive durability index. For surface courses in heavily trafficked roads, an LAA value below 35% is often specified, though values up to 40% may be acceptable for base courses or lower-volume roads.

2.3 Bitumen Characteristics and Performance in Varying Climates

The binder component, typically bitumen, acts as the glue in asphalt concrete, and its rheological properties are paramount to pavement performance. The penetration grade and softening point are two fundamental parameters defining bitumen consistency and temperature susceptibility. In regions experiencing high ambient temperatures, such as Nigeria, the risk of pavement rutting (permanent deformation) is elevated. Consequently, harder bitumen with a lower penetration value is preferred, as it offers higher viscosity and greater resistance to flow under heat (Hamdar et al., 2020).The global trend towards modifying bitumen with polymers or other additives to enhance its high-temperature performance underscores the limitations of conventional binders in extreme climates. For instance, Olalekan et al. (2024) investigated the reinforcement of Nigerian-sourced bitumen with polymer additives, reporting significant improvements in the softening point and rutting resistance. Their work highlights the potential for enhancing local bitumen sources, a finding that is directly relevant to the utilization of bitumen extracted from tar sands. The inherent hardness of native bitumen found in some tar sands, as indicated by a low penetration value, could be a natural advantage for road construction in hot climates, potentially reducing the need for extensive and costly polymer modification.

2.4 Tar Sands and Heavy Oil Residues in Construction Applications

Internationally, the use of oil sands and heavy oil residues in construction has been explored, providing a valuable framework for assessing Nigerian tar sands. The characterization of these materials is crucial. Al-Bazzaz et al. (2025), in their comprehensive overview of extreme heavy oil recovery, emphasize the complex and highly viscous nature of these hydrocarbons, which aligns with the description of the bitumen component in tar sands. The primary challenge lies in effectively integrating this viscous material into a workable and durable asphalt mix.Research into similar materials has shown promising results. Studies on the use of naturally occurring asphaltites and heavy oil by-products have demonstrated that with proper mix design, they can produce asphalt concrete with satisfactory mechanical properties (Albayati & Abdulsattar, 2020). The key is often to optimize the binder content and aggregate gradation to compensate for the altered rheology of the non-conventional binder. The solvent extraction method, as employed in the current study, is a common technique for isolating bitumen from sand matrices for laboratory analysis, though the purity of the extracted bitumen can influence the test results, a limitation noted in several studies.

2.5 Synthesis and Research Gap

The extant literature firmly establishes the need for alternative construction materials and provides a robust methodological framework for evaluating aggregate and binder properties. Research on oil sands and heavy oils offers a precedent for the use of hydrocarbon-saturated sands in engineering applications. However, the specific application of tar sands from the Kajola, Lamudifa Irele region of Ondo State, Nigeria, requires localized and contemporary investigation. While the existence of these deposits is known, a detailed analysis of their engineering properties—specifically their ACV, AIV, LAA, and the characteristics of their native bitumen—in the context of modern pavement standards is necessary to validate their suitability. This study aims to fill this gap by providing a systematic evaluation of the Kajola tar sands, thereby contributing empirical data to the growing body of knowledge on indigenous Nigerian construction materials and their potential to mitigate the nation's infrastructural challenges.

3.0 | MATERIALS AND METHODS

To create a Tar Sand Asphalt TSA composite, tar sand (see Figure 1a) with virgin fine aggregate, virgin coarse aggregate, and bitumen was investigated. This was acquired from Kajola, Lamudifa Irele LGA in Ondo State. As shown in Figure 2 tests were conducted in line with the ASTM standard as well as British Standard Institution tests Sieve analysis (ASTM C136), Crushing Value (BS 812: part 110), Aggregate Impact Value (BS 813 : Part 112), Los Angeles Abrasion Test (ASTM C131:89), Bitumen Penetration Test (ASTM D5-2006) Softening Point(ASTMD36) Flash Point (D92-18), Fire point (ASTM D92-18) and Marshall Test (ASTM D6927).

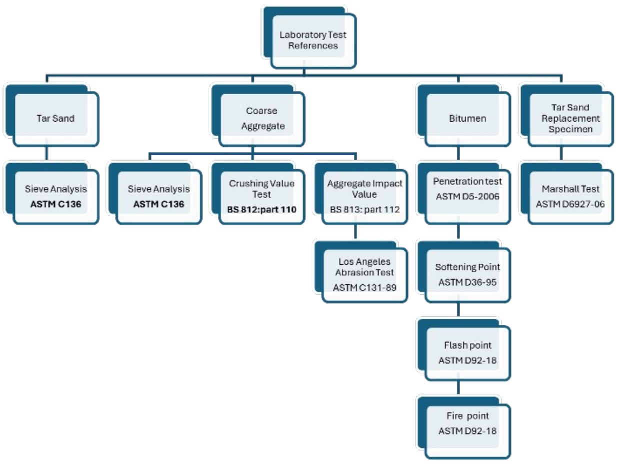

Figure *1*: Experimental Design

The solvent extraction technique extracted the bitumen samples from the tar sands (see Figure 1b). The Tar sands residue (Figure 1c) after processing could also be used for further production. The appropriate binder content for Asphalt Concretes (AC) was determined using the Marshall approach using the gravel coarse aggregate. The bitumen content samples were produced in 0.5% increments, ranging from 4% to 6%. For each binder content, three samples were made, and each sample received 75 compaction blows on each side. Samples for the Marshall test, resilient modulus, and indirect tensile strength tests were all condensed using the Marshall hammer. The combination for the beam fatigue samples was first compressed mechanically, and then specimens measuring 63 x 50 x 380 mm were cut.

(a)

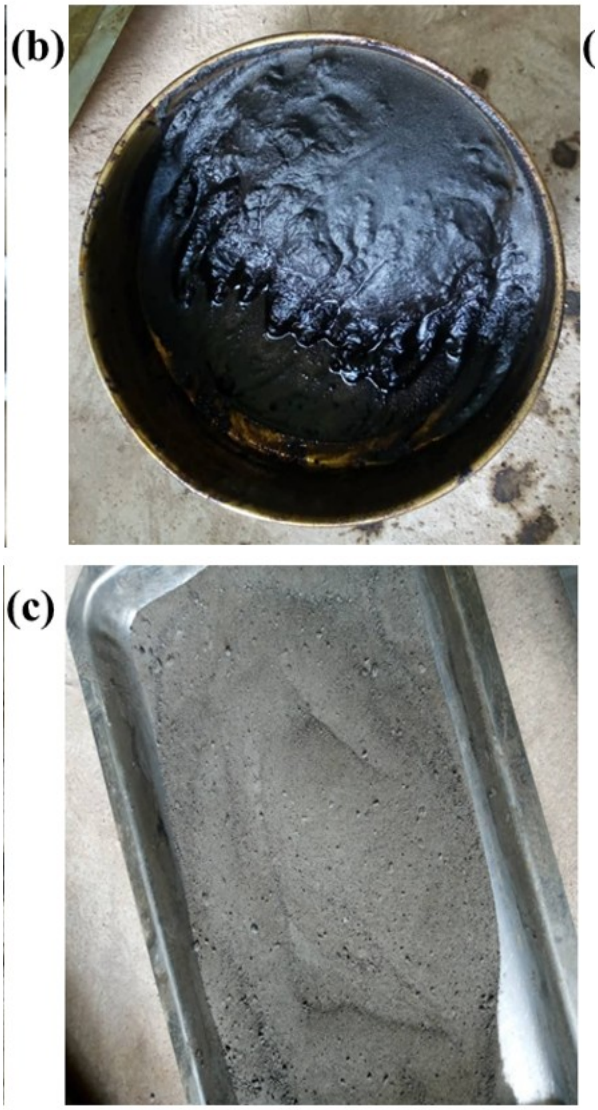

Figure 2: (a) Raw sample of tar sand (b) Tar sand soaked in kerosene for bitumen extraction (c) Tar sand remnant post extraction

Sharp sand with a specific gravity of 2.66 was used as the fine aggregate. These aggregates were bought from a local building supply store in Kuje, FCT, Nigeria. The aggregates were subjected to several laboratory experiments, including the Four-Point Beam Fatigue Test, the Indirect Tensile Strength Test, the Marshall Stability, Flow, and Marshall Quotient Tests, and the Indirect Tensile Strength and Resilient Modulus Tests.

For sieve analysis (using apparatus in Figure 3a), aggregate composed of up 90 to 95% by weight or approximately 75 to 85% by volume of tar-sand infused asphalt concrete mixture was sieved. This was to ensure that strong aggregate mixtures are used, as strong aggregate structure provides asphalt concrete mixtures of high resistance to failure due to cyclic loading (Albayati & Abdulsattar, 2020; Guan et al., 2018). For the Marshal Mix design, which was used to know the most suitable asphalt binder, and three samples of 4.5%, 5.0%& 5.5%, asphalt by dry weight were made, after which the Asphalt binder content vs. density, Asphalt binder content vs. Marshall stability and the Asphalt binder content vs. flow plots were made to determine the best asphalt binder content. The wearing course test was later conducted on the Tar sand, by first weighing in both air and water before being heated for 20–30 minutes at 140°F in a water bath to prepare for the performance test. The Marshall tester (Figure 3b) was used for compression, where the heated specimen was positioned between two semi-circular loading heads. After that, a steady 2 inch/min load is applied up until a peak load is identified as shown in Figure 3c. The Marshall stability is the greatest load (measured in pounds) recorded during the test, and the flow is the amount of head travel (measured in units of 0.01 inch) required to attain that load (see Figure 3c). We may infer from the plots the asphalt content that results in the highest unit weight, the most stability, and the asphalt content that results in exactly 4% air spaces. The ideal proportion of asphalt penetration 60/70 in the AC-WC mixture was determined by characterising the Marshall stability of the mixes without the additive Wetfix-Be. An anti-flaking additive of Wetfix-Be was employed with petroleum bitumen in penetration 60/70 at the ideal asphalt concentration. The performance of an AC-WC mixture containing the anti-flaking additive Wetfix-Be was investigated using Marshall tests with stability, flow Marshall quotient, VMA, and VFB.

For the coarse aggregate tests, the main aim was to assess the crushing strength of a given aggregate, which is following BS 812: Part 110. The laboratory sample was reduced to a test portion of sufficient mass into three test specimens of 15mm to 11 mm in size. The surface dry test portion was thoroughly sieved on the 14mm and 10mm test to separate the 14 mm to 10 mm fractions into three specimens, each of mass to achieve 100mm after tamping. Test specimens were dried by heating at a temperature of 105 ± 5 °C for 4 hours. After which they were cooled to room temperature, and the mass of material comprising the test specimens was determined before testing. The cylinder was placed on the base plate, and the test specimen was added in layers of three stages, approximately of equal depth, each layer subjected to 25 strokes of the tamping rod. Then, gently, the surface of the aggregate was levelled and the plunger was put so that it rests horizontally on its surface. The apparatus was inserted, with the test specimen prepared as stated above and plunger in position, to achieve 400kN within 9 min ± 30s. Then the load was added and the crushed material removed over a neat tray of known mass. Sieve the sample on the tray on the 2.35mm test sieve until no particles pass. Weigh and note the masses passing and retained (M2 and M3, respectively). This was repeated with a second test sample.

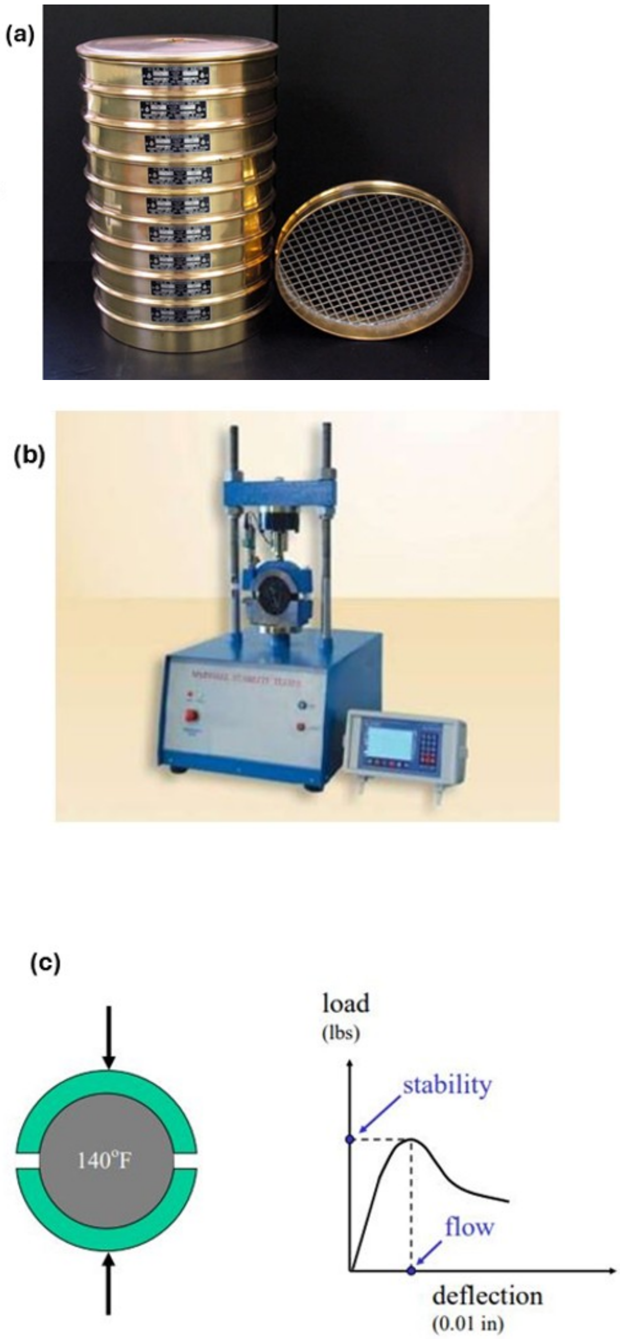

Figure *1*: Apparatus for (a) Sieve analysis (b) Marshall Test (c) Marshall tester mechanism

To calculate the Aggregate Crushing Value (ACV), **Eqn. 1** was used:

$$ACV = \frac{M_2}{M_1} \times 100$$

Where M_1 is the initial weight.

[1]

To calculate the Aggregate Impact Value (AIV) which is the resistance of the coarse aggregate to sudden shock in accordance with BS812: part 112, the **Eqn. 2** was used:

$$AIV = \frac{M_2}{M_1} \times 100$$

[2]

The LAA value, which is the aggregate resistance to fragmentation/degradation resulting from abrasion, impact and grinding following ASTM C131-89, is calculated using **Eqn. 3** using the LAA testing machine shown in **Fig. 4**. Aggregates were dried in an oven at 105°C – 110°C.

$$LAA\ Value = \frac{M_1 - M_2}{M_1} \times 100$$

[3]

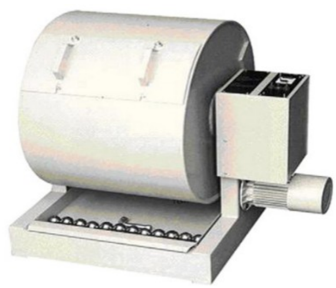

Figure *2*: LAA Testing Machine (Reprinted from Ugur et al. (2010))

The Bitumen Penetration test (ASTM D5-2006) was also conducted to measure consistency of bituminous materials expressed as the distance in tenths of millimeters that a standard needle vertically penetrates a sample of the materials under known conditions of loading, loading time and temperature. The Bitumen Softening Point (Ring and Ball Apparatus) was also measured to ascertain the temperature at which the bitumen binder shows fluidity. For this test, the sample was heated to achieve 110°C for not more than two (2) hours. The hot specimen was poured into the preheated ring lying on the plate. The sample was cooled for at least 30 minutes, then the excess was cut off with a spatula. The device was then assembled with the ring, thermometer and distilled water poured to a depth of 103 -109 mm. The basin temperature was maintained at

(4 ±1) °C for 15 minutes. Using forceps, the balls were placed, and the temperature was adjusted to 5°C, then the bitumen was heated to 50°C / min. The temperature was recorded as depicted by the thermometer upon touching the container.

4 | RESULTS AND DISCUSSIONS

sieve masses were used for the tar sand analysis (Average mass: 328g, 392g, 389.5g, 311.5g, 329g, 321g, 472g, 382g, and 360.5g) across three tests. The sieve analysis of the tar sand and the coarse aggregates from Table 1 generated the distribution curve in Figure 5. The outputs suggest two categories (fines as soil and the coarse aggregates as gravel), which were in line with the AASHTO Classification System. However, the tar sands cannot be used directly as soil-subgrade or embankment material for road subgrade based on pavement standards such as the Nigerian Highway Code.

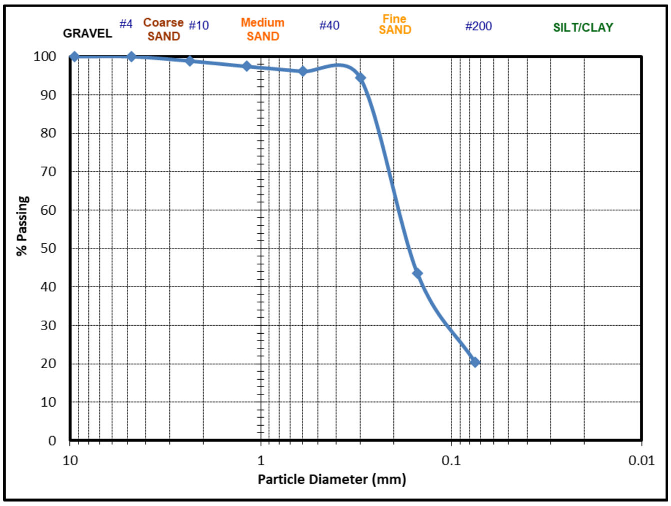

Figure 3: Gradation results of tar sand

For the three samples, ACV (see Table 2), AIV (see Table 3), and LAA (see Table 4) were measured and averaged. The results showed that the ACV was within the IS 2386(Part 4):1963 for rigid (concrete) and flexible (bituminous) pavements, as seen in Table 6 below. The ACV of 28% suggests that the aggregate made of tar sand has a relatively high strength and good resistance to crushing under load. The maximum ACV for bituminous macadam, dense-mix carpets and surface dressing is about 30%. This means 28% ACV of the tar sand aggregate may improve longevity, repeated loading, and lowered maintenance costs.

Table 1: ACV test results

	Sample 1 (g)	Sample 2 (g)	Sample 3 (g)
Mass of Empty Measure (W1)	1877	1877	1877
Mass of Empty Measure + Sample (W2)	4528.5	4529.3	4528.9
Mass of Sample (W2-W1) = M1	2651.5	2652.3	2651.9
Mass of Sample passing 2.36mm sieve M2	744	751	742
Mass of sample retained on 2.36mm sieve M3	1907.5	1901.3	1909.9
Aggregate Crushing Value (ACV) %	28.06	28.32	27.98
Average ACV (%)	28		

On the other hand, AIV according to Mannan et al. (2006) and Cala et al. (2019) estimates the resilience and performance of asphalt mixtures used in road construction. This study revealed that the Tar sand from Kajola contributes an AIV of 23%, as seen in Table 3. AIV of 23 is deemed acceptable for road surfacing as it falls in between the satisfactory range of 20 – 30% under the IS 2386(Part 4):1963. It presents moderate durability and has the potential for use in non-high-traffic areas, while less suitable for industrial roads, high-speed highways and heavy-duty transport lanes. In essence, the AIV suggest that we may not rely on just the ACV results, which suggest suitability for all types of road construction. Investigating further, the LAA result revealed 38%. This implies that the aggregate sample is suitable for all categories of pavement except bituminous-surface dressing and Bituminous surface course. According to Teymen (2019), as the LAAV increases, it is more likely that the aggregate will wear or degrade. However, 38% may be seen as satisfactory because it falls within 30% and 40%. Ugur et al. (2010) further revealed that the LAAV has a relationship with the bulk density, p-wave velocity, tensile strength, uniaxial compressive strength, Schmidt hardness, point load index and shore hardness of the aggregate. The study revealed that aggregates with similar properties, like andesite and limestone (like Tar sand) possess more resistance to abrasion.

Table 2: AIV test results

	Sampl e 1 (g)	Sampl e 2 (g)	Sampl e 3 (g)
Wt of Empty Mould (W1)	787.5	787.5	787.5
Wt of Empty Mould + Sample (W2)	1122	1121.3	1121.2
Wt of Sample (W2-W1) = M1	334.5	333.8	333.7
Wt of Sample passing 2.36mm sieve M2	76.4	75.5	76.1
Wt of sample retained on 2.36mm sieve M3	258.1	258.3	257.6
Aggregate Impact Value (AIV) %	22.84	22.62	22.80
Average AIV (%)	**23**		

Table *3*: Los Angeles Abrasion test results

	Sampl e 1 (g)	Sampl e 2 (g)	Sampl e 3 (g)
Mass of Sample (M1)	5000	5000	5000
Mass of Sample Retained (M2)	3088	3070	3085
Mass of Sample passing 1.70mm sieve (M3)	1912	1930	1915
Los Angeles Abrasion Value (LAAV) %	38.24	38.60	38.30
Average LAAV (%)	**38**		

From Fig. 6a, the curve shows that the density increased until a maximum value and then decreases as the bitumen content increases. It can be seen that the mixture produced the best mix after the control is the 50% tar sand aggregate replacement with 4.5% optimum bitumen content. 20% and 10% Tar sand aggregate had the weakest performance. Flow in Fig. 6b refers to the vertical deformation of the sample (measured from the start of loading to the point at which stability begins to decrease) in 0.25 mm. High flow values indicated a plastic mix that will experience permanent deformation under traffic, whereas low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability or one that may experience premature cracking due to mixture brittleness during the life of the pavement. Fig. 6b shows that the 50% tar sand aggregate replacement is still below the control but performs better than the lower percentage of tar sand. From the experiment conducted, a quadratic-shaped curve and a maximum point of stability can be identified from Fig. 7a. Figure 7b shows the final From **Fig. 6a**, the curve shows that the density increased until a maximum value and then decreases as the bitumen content increases. It can be seen that the mixture produced the best mix after the control is the 50% tar sand aggregate replacement with 4.5% optimum bitumen content. 20% and 10% Tar sand aggregate had the weakest performance. Flow in **Fig. 6b** refers to the vertical deformation of the sample (measured from the start of loading to the point at which stability begins to decrease) in 0.25 mm. High flow values indicated a plastic mix that will experience permanent deformation under traffic, whereas low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability or one that may experience premature cracking due to mixture brittleness during the life of the pavement. **Fig. 6b** shows that the 50% tar sand aggregate replacement is still below the control but performs better than the lower percentage of tar sand. From the experiment conducted, a quadratic-shaped curve and a maximum point of stability can be identified from **Fig. 7a**. Figure 7b shows the final

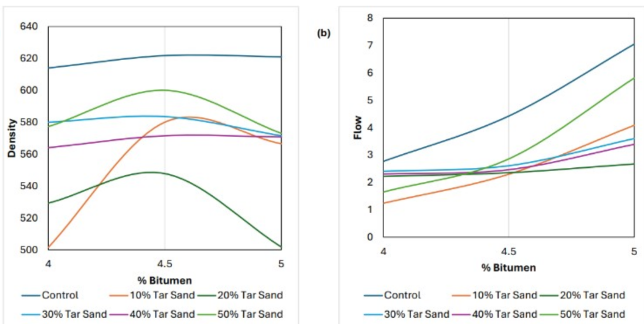

Figure 4: Comparison of %Tar Sand Aggregate in plots of (a) Density vs %Bitumen (b) Flow vs %Bitumen

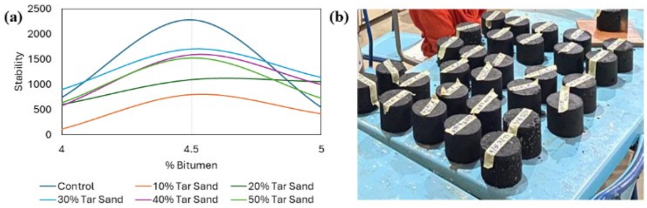

Figure 5: (a)Marshall Stability vs Asphalt Content (b) Tar sand asphalt aggregate

The 30% tar sand aggregate replacement with 1.7kN next to the control with 2.4kN performed better than other aggregates. It is understood that as the value of stability increases, the specimen will be able to withstand more loading imposed on it.

The average penetration value of the bitumen, as seen in Table 5 was very low (17mm), which makes it very suitable for road use in very hot regions. According to Gonçalves & Margarido (2015), the lower the penetration value, since the temperature in parts of Nigeria gets as high as 46.1 degrees (E.g. Maiduguri), this sample can be used in Nigeria without experiencing rutting and bleeding. The meteorological stations should be consulted for relevant data before embarking on the project. The result of the bitumen softening point also revealed that Ball A softens at 46°C while Ball B softens at 45°C, averaging at 45.5°C. These results were similar to those of unmodified asphalt binders in the works of Bonati et al. (2012) which reported softening points of 44.5°C 50.7°C and 52.0°C for B170, B70 and B50 respectively. Hamdar et al. (2020) further highlighted that the viscosity and softening point of the bitumen influence the overall rutting resistance and asphalt performance in hot climates. Table 6 finally presents the overall results of the tests conducted on the tar sand aggregates, suggesting that based on the ACV, AIV, LAA and bitumen penetration, the Kajola tar sand is satisfactory for use in construction, road surfacing, pavements and other civil work, but more reliable in hotter regions of Nigeria due to its low penetration and softening point.

Table 4: Bitumen Penetration Test Results

Penetrometer Dial gauge Reading	Test 1	Test 2	Test 3
Initial Reading (mm)	0	0	0
Final Reading (mm)	17.21	16.98	17.06
Penetration Value (mm)	17.21	16.98	17.06
Average Penetration Value (mm)	**17**		

Table 5: Comparative analysis of study data against acceptable standards

	Standards	This study
ACV (%) (IS 2386(Part 4):1963	30 – 50	28
AIV (%) (IS 2386(Part 4):1963)	20 – 30% (Satisfactory for road surfacing)	23
LAA (%)	30 – 40% (Satisfactory)	38
Bitumen Penetration (mm)		17

5 | CONCLUSION

In conclusion, the tar sand sourced from Ondo state, Nigeria, has been assessed and found to hold satisfactory potential as a material for road construction, especially in an asphalt wearing course. The potential of tar sands is gaining more traction due to the need for cost-effective and durable construction materials. The test conducted reveals its effectiveness for Nigerian roads, especially in high-temperature regions. The average ACV of 28% indicated that the tar sand aggregate falls within an acceptable range for rigid bituminous pavements with good resistance to crushing. The AIV and LAA of 23% and 38%, respectively, further highlighted the potential of the tar sand aggregate to possess moderate durability for road surfacing in low traffic areas. The low penetration value of bitumen (17mm) in this investigation was a key finding as it created a turning point, suggesting that tar sand bitumen is less likely to experience bleeding and rutting. This supports its long-term performance, stability and rut resistance when used in pavements. Due to limitations of funding, the extracted bitumen was not in its purest form; hence, the results' efficiency was slightly affected, having followed all laboratory standards and procedures, showing tar sand mix to be acceptable in the construction of low-volume roads, and failing to meet high-volume road requirements. To earn a wider range of applications, tar sand mix may need supplementary additives to meet major road construction applications. While this study demonstrated the value of tar sands, it also identified the need for further research and recommended that the local climates of the region be considered before using the Kajola tar sand for Tar Sand Asphalt. Also, applications in high-speed highways and industrial roads may be investigated. Overall, the incorporation of tar sands into road construction converts waste to wealth and reduces the road construction cost while addressing infrastructure challenges.

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List of Abbreviations

ABBREVIATION	FULL MEANING
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BS	British Standard
FCT	Federal Capital Territory
GDP	Gross Domestic Product
LAA	Los Angeles Abrasion
LAAV	Los Angeles Abrasion Value
LGA	Local Government Area
TSA	Tar Sand Asphalt
VFB	Voids Filled with Bitumen
VMA	Voids in Mineral Aggregate

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