A Sustainable Solution for Asphalt: Investigating the Mechanical Properties of Gum Arabic Modified Bitumen

Musa Zakariyawu[1]; Assia Aboubakar Mahamat[2,3*]; Ahmad Rufai Suleiman[1]; Adetimehin Ademola Edward[1]; Akintayo Ibitayo Taiwo[1]

[1]Department of Civil Engineering, Nile University of Nigeria, Abuja, Federal Capital Territory, Nigeria
[2]Department of Civil Engineering, African University of Science and Technology (AUST), Federal Capital Territory, Nigeria
[3]Departement de Gènie Civil, Ecole Nationale Supérieure des Travaux Publics (ENSTP), N'Djamena, Chad.

Corresponding Author: Assia Aboubakar Mahamat[2,3*]

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Abstract: Road infrastructure, including parking lots, runways at airports, and pavement, is frequently built using asphalt. Researching for substitute asphalt materials or enhancing the pavement's functionality has been going on. One of the main goals of contemporary society is to replace the ever-increasing amounts of products derived from petroleum, a non-renewable resource that is gradually running out, in order to promote both economic and environmental benefits. In this regard, the research aimed at better understand the effects of gum Arabic on the asphalt mix's properties and to improve asphalt performance in order to satisfy society's need for safe, reasonably priced building materials. After determining the optimum bitumen content using Marshall mix design, 20 samples were created to further test the modified mixture's characteristics (5 samples were used as a control, and the remaining 15 samples investigated the effects of changing the asphalt mixtures). The optimum amount of bitumen was found to be 6%. Six distinct percentages of gum Arabic with the optimum bitumen content were selected to modify the asphalt which include 10, 15, 25, 35, 45, and 55%. The Marshall properties of the bitumen-modified asphalt mix for the flexible pavement's wearing course were evaluated in the laboratory. The Marshall Stability, flow, and Voids in Mix (VIM) were measured as the gum Arabic percentage were increased. The experimental results showed that the optimal gum Arabic content of the asphalt mix was 45% by weight, which is the ideal amount of gum Arabic to add as a modifier. The asphalt mix modified with 45% gum Arabic by optimum bitumen content weight has a higher stability value (9.6kN) with respect to the standard asphalt mix (4.98kN). The asphalt mostly complied with the specifications, having bitumen-filled voids of less than 80%, flow within 2 to 4 mm, and stability exceeding 3.5 KN.

Keywords: *Gum Arabic, Modified Asphalt, Plasticity Index, Sustainable Modifier, Mechanical.*

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I. INTRODUCTION

- *Background and Challenges*

Asphalt, a ubiquitous material in road construction, from rural roads to expressways, is typically combined with aggregate to form asphalt mixtures for pavement layers and subgrades. It also plays a crucial role in road maintenance, addressing issues like cracks and potholes. However, conventional asphalt production relies heavily on petroleum-based materials, contributing significantly to greenhouse gas emissions and environmental degradation. To mitigate these concerns, researchers are exploring sustainable alternatives. One promising avenue is the utilization of natural biopolymers, such as gum Arabic. Chemically similar to asphalt binders, gum Arabic, a readily available and renewable resource, has garnered increasing attention as a potential asphalt modifier. Studies have shown that gum Arabic can effectively enhance the aging resistance of asphalt and positively influence its high-temperature rheological properties, low-temperature crack resistance, and fatigue resistance [1]. Gum Arabic, a major plant polymer after cellulose and lignin, finds limited application in high-value industries, primarily in the production of surfactants, adhesives, and dispersants. In contrast, (Asphalt Institute,

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2019) asphalt, a complex mixture of hydrocarbons and their derivatives, is a cornerstone of modern road construction. Its dark brown color and diverse molecular weight distribution contribute to its unique properties. [2].

➢ *Some of the Related Work Reviewed*

Gum arabic, a natural exudate from Acacia trees primarily found in the Sahel region, has been utilized for centuries. While the term "gum Arabic" doesn't specify a particular botanical source, it typically refers to the exudate from Senegalia Senegal and Vachellia seyal. Historically harvested from wild trees, Sudan is the leading producer, contributing significantly to the global supply. [3] Chemically, gum Arabic is a complex mixture of glycoproteins and polysaccharides, predominantly arabinose and galactose. This natural polymer possesses remarkable properties. It is a dietary fiber, largely indigestible in the human digestive tract. it is a palatable biopolymer obtained as exudates of mature trees of Acacia Senegal and Acacia seyal, which are found in the Sahel region. The exudate is a non-thick liquid, rich in fiber, and it spreads from the stems and branches and commonly occurs under anxiety conditions, for instance, dry season, poor soil fertility, and injury [4]. Gum Arabic chemical structure and useful properties are firmly identified with its structure, which decides, for instance, solubility, viscosity, the level of collaboration with water and oil in an emulsion, and microencapsulation capacity, among others [4]. The chemical structure of A. Senegal and A. seyal gums is contrasting. Both gums have similar sugar residues, yet A. seyal gum has a lower substance of rhamnose and glucuronic acid and a higher substance of arabinose and 4-O-methyl glucuronic acid than A. senegal gum (Blades A. et al., 2021).

Rather, A. seyal gum contains a lower extent of nitrogen, and specific rotations are additionally totally different. The evaluation of the last parameters may clearly detect the contrast between the two species [4]. Gum arabic is a group of polysaccharides acquired as a blended calcium, magnesium, and potassium salt. Its structure comprises of 1,3-linked β-D-galactopyranosyl units. The side chains are made out of two to five 1,3-linked β-D-galactopyranosyl units, joined to the primary chain by 1,6-linkages. Both the principle and the side chains contain units of β- l-arabinofuranosyl, β-l-rhamnopyranosyl, β-d-glucuronopyranosyl, and 4-Omethyl-β-d-glucuronopyranosyl, the last two, for the most part, as end units. The attributes of gum Arabic may change fundamentally, contingent upon the geological origin and age of the trees, climatic conditions, soil condition, and even the place of exudation on the tree [4]. It is a less consistent material than other hydrocolloids. Gum Arabic is a complex and variable mixture of Arabinogalcutain, Oligosaccharides, Polysaccharides and glycoprotein [5]. Gum Arabic consists of a mixture of lower molecular weight Polysaccharides (M.Wt 0.25×106 major component) and higher molecular weight hydroxyproline –rich glycoprotein (M.Wt 2.5×106), minor component. Gum Arabic glycoprotein possesses a flexible but compact conformation. It is readily soluble to give relatively low viscosity Newtonian solutions, even at higher concentration (20%- 30%wt/wt) [5]. However, it undergoes fermentation in the colon, producing short-chain fatty acids that can be utilized as an energy source. It is not destroyed in the small intestine only but also inflamed in the large intestine by microorganisms to short-chain oily acids, mainly propionic acid. Such humiliation products are absorbed in the human colon and subsequently utilized energetically in metabolism. The dietary fibers have no direct role in nutrition, but they play a main role in preventing certain common diseases such as colon cancer, diabetes mellitus, coronary thrombosis, obesity, chronic renal failure, and others [4]. Gum Arabic has many uses: in foodstuff and as an adhesive material due to its high viscosity, and it is also used as an additive to build a stable suspension mixture for medical syrups, lithography, textiles, paint, inks, and cosmetics [4]. Raw materials development is very important for any society that wants to develop technologically, Nigeria is a country endowed with a lot of solid minerals and material resources. The slow pace of technological development in Nigeria is attributable to inadequate attention to raw material development. Gum Arabic (E 414, Acacia gum is prepared from exudates of several species of trees is typical of gum that contain Arabin) [5]. Gum Arabic of finest quality is obtained from Acacia Senegal and Arabic found in the northern Africa. The gum forms a clear thick solution in water. The gum can also be collected from the stem and branches of sub-Saharan Sahel zone, Acacia Senegal and Acacia seyal (leguminosae) trees and produced naturally as noodles with brown and white colours or sometimes in powdery form during a process called gummosis. Organic admixtures based on polysaccharides are used in construction for modifying the properties of mortars and concretes [6]. GA is an example of a polysacharide-based biopolymer. According to [6], an investigation was done to determine the possibilities of improving the strength parameters of a binder paste based on hydrated lime and metakaolin. The paste was modified with powdered gum arabic at 1%, 3% and 5% (by mass) as a partial replacement for the binder mix. The influence of the admixture on the pore size distribution as well as flexural and compressive strength was investigated. The admixture enhanced the total porosity of the paste, increasing the pore diameter compared with the reference formulation. The increase in porosity, in turn, did not reduce the mechanical strength. Conversely, the admixture in the amount of 3% and 5% caused a significant increase in the flexural (by about 300% in relation to reference paste) and compressive strengths (by 25% and 60%, respectively) (al-samgh al-'arabi, Additives, 2013) [6]. The tested pastes were used as a binder in a composite based on hemp shives. The influence of binder modification on the water absorption and compressive strength of hemp concrete was tested. The strength of the composite soaked in water was also tested. The modification of the binder with gum arabic in the amount of 3% and 5% increased the compressive strength of hemp concrete (not soaked in water) by 53% and 92%, respectively and reduced the mass absorptivity by 6.6% and 10.4%, respectively (Murtoff, 2024, Zerbet & Benidire, 2025) [6].

This study focuses on investigating the feasibility of utilizing gum Arabic, a natural biopolymer, as a sustainable modifier for asphalt concrete in road construction. The research aims to evaluate the influence of gum Arabic on the

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physical properties of asphalt mixtures, particularly its impact on strength and its response to temperature variations. This research explores a novel approach to enhancing asphalt concrete by incorporating gum Arabic as a modifier. While previous studies have investigated the use of various additives in asphalt, this study specifically focuses on: (i) Utilizing gum Arabic: Exploiting the unique chemical structure of Gum Arabic, which is similar to that of asphalt, to potentially improve its performance. (ii) Comprehensive evaluation: Conducting a thorough investigation encompassing physical properties determination, optimum binder content determination, and an evaluation of the effects of varying gum Arabic percentages on asphalt properties. (iii) Temperature sensitivity analysis**:** Assessing the behavior of gum Arabic-modified asphalt under varying temperature conditions to understand its suitability for diverse climatic regions.

II. MATERIAL AND METHODOLOGY

➢ *Materials*

The materials used include 60/70 grade bitumen, which is black in appearance and sourced from Julius Berger PLC. Gum Arabic was sourced from Kogi State. Solid materials, comprising both fine and coarse aggregates, were obtained from the Civil Engineering Material and Concrete Laboratory at Nile University of Nigeria. The filler material, passing through a sieve size of 0.075mm and retained in the pan, was also sourced from the Civil Engineering Material and Concrete Laboratory at Nile University of Nigeria. Gum Arabic was manually collected from trees, dried, and ground into powder. Solid materials passed the abrasion and impact tests and were confirmed to be well-graded.

➢ *Experimental Design*

Los Angeles abrasion test-LAA was carried out to ascertain the aggregate's resistance to grinding, impact, and abrasion-induced fragmentation and degradation. The clean aggregates that made up the test sample were oven dried at 105 to 110°C, Table 1 & 2 indicates that the grading and number of charges. After being cleaned, the test sample was dried in the oven at 105°C to achieve a largely constant weight. After being divided into clear size fractions, the sample was recombined to give the B grading as in table 2, which almost exactly equals the range of sizes in the aggregate provided for the project. Prior to testing, the sample's weight was determined to the closest 1g (M1). The following equation was used to express the LAA value:

$$LAA = \left(\frac{M1-M2}{M2}\right) \times 100 \quad (1)$$

Where $M1$ is the test specimen's initial mass and $M2$ the final mass.

Table 1 Number and Mass of Charges

Grading	Number of Spheres	Mass of Charge (g)
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15

Table 2 Grading of Sample

Sieve Size		Sieve Size Mass of Indicated Sizers (g)			
Passing	Retained on	Grading A (g)	Grading B (g)	Grading C (g)	Grading D (g)
37.5	25	1250 ± 25			
25	19	1250 ± 25			
19	12.5	1250 ± 10	2500 ± 10		
12.5	9.5	1250 ± 10	2500 ± 10		
9.5	6.3			2500 ± 10	
6.3	4.75			2500 ± 10	
4.75	2.36				5000 ± 10
Total		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10
Grading A: Suitable for Graded Crushed Stone and Natural Gravel for Base Course. Grading B: Suitable for chippings for Surface Dressing, nominal sizes 20 mm and 14 mm. Grading B: Suitable for chippings for Surface Dressing, nominal size 10 mm. Grading B: Suitable for chippings for Surface Dressing, nominal size 7 mm.					

Aggregate impact value test was carried out to find out the aggregate's resistance to shock and impact. Apparatus used included, Metal measuring cup (mould), tamping rod 10mm diameter, aggregate, set of Sieves (14 and 10mm sieve size with pan and cover), aggregate Impact test Equipment, balance, well-ventilated drying oven and metal tray. To prepare a test portion with sufficient weight to give two test specimens with a size fraction of 14 to 10 mm, the sample was reduced. For at least four hours, the sample was dried at 105 ± 5 °C temperatures. The sample was sieved to get rid of the undersize and oversize fractions, after allowing to cool to room temperature through 14 and 10mm sieve sizes. Two test specimens were created by dividing the resultant 14 to 10 mm fraction.

$$AIV = \left(\frac{M2}{M1}\right)100 \quad (2)$$

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Where:

M1 means the test specimen's weight (in grams);

M2 means the weight of the material that sieves pass the 2.36 mm test sieve (in grams).

Specific gravity test set was carried to ascertain the coarse aggregate's water absorption and specific gravity. Aggregates were thoroughly washed to remove dust and finer particles, a sample of aggregate weighing at least 2000g (14–10 mm) was allowed to drain and was put in the wire basket. It was then immersed in portable water that was 22 to 32°C, with a least of 5cm of water covering the basket's top. The sample's trapped air was extracted immediately the basket was immersed in water. The basket is raised 25mm above the tank's base and letting it fall same number of times for this to be accomplished, or roughly one drop per second. Following a 24-hour period of complete submersion, the basket and aggregate were again jolted and the weight in water was determined at a temperature of 22 to 32°C to get first weight (W1). The aggregate and basket were then taken out of the water and permitted to drain for a few minutes. The aggregate was then carefully poured out of the basket onto a piece of dried clothing, and the empty basket was then put back into the water, the trapped air was removed, and the water was weighed to determine the second weight (W2). When it became apparent that the first dry cloth was no longer able to remove moisture, the aggregate was moved to the second dry cloth, and it was again gently surface dried. After that, the aggregate was weighed and the third weight (W3). After that, the aggregate was put in the tray and placed in the oven at 105°C and kept there for 24 ± l/2 hours. After taking it out of the oven, it was allowed to cool in an airtight container before being weighed. This process was repeated until the weight (W4) remained constant. Equation 2.0 and 3.0 were used to determine the specific gravity and water adsorption.

$$\text{Sp. Gravity} = \frac{(w4)}{(w3-(w1-w2))} \tag{3}$$

Where:

W1 = weight of empty pycnometer (g)

W2 = weight of pycnometer + soil sample (g)

W3 = weight of pycnometer + soil + water (g)

W4 = weight of pycnometer filled with water only (g)

$$\text{Water absorption} = \left[\frac{(w3-w4)}{w4}\right] \text{x } 100 \tag{4}$$

Where:

W3 = = weight of oven-dried sample (g)

W4 = weight of surface-dry sample after immersion (g)

Determination of softening point of bitumen was carried out to know what temperature at which bituminous binders start to exhibit fluidity is determined and measured using the softening point test and material's propensity to flow at high temperatures experienced during operation is also indicated by the softening point. The sample was heated for no more than two hours at a temperature that did not surpass the anticipated softening temperature by more than 110°C. The heated ring that was resting on the pouring plate was then filled with the heated sample. After letting the specimen cool for at least half an hour, a hot knife was used to trim off any extra material. The device was put together with the thermometer and ring, and the transparent container was filled with cool clean water down to a depth of 102–108 mm. For 15min, the container's temperature was kept at (5 ±1)°C. After the balls were placed with forceps at a temperature of 50°C and the stirrer, heat was applied to raise the liquid's temperature by 50°C per minute. The thermometer's reading at the moment the ball touched the bottom was then recorded[7]. Marshall stability test was carried out to ascertain the characteristics of the asphalt mix that is produced. It aids in assessing the vehicle's resistance to deformation. Additionally, it can be used to find the ideal bitumen content that will yield the asphalt's maximum density, maximum stability, flow deflection, and minimum void percentage.

III. RESULTS AND DISCUSSION

The properties assessed include stability, flow, bulk density, percent air voids (voids in mix, VIM), voids in mineral aggregate (VMA), and voids filled with bitumen (VFB). Stability is defined as the maximum load carried by a compacted specimen tested at 60^{O}C at a loading rate of 2 in./min. The two primary factors in determining the stability are the angle of internal friction of the aggregate and the viscosity of the bitumen. The sudden increase in stability at 45% GA content could be attributed to increase in viscosity of the asphalt mastic (Figure 2). Beyond this modifier content, a decreasing trend could be observed in stability values of HMA samples. This decrease could likely be as a result of change in rheological properties of the bitumen occasioned by excess amount of polysaccharide (in the modifier). Porto et al.,[11] reported similar decrease in viscosity caused by excess polysaccharide content.

Table 3 Initial Test Findings on Bitumen Characteristics in Relation to their Code Specifications

EXPERIMENTS	**TEST STANDARDS (ASTM)**	**CODE SPECIFICATIONS 40/50**			**OBSERVED RESULTS**
		40/50	**60/70**	**80/100**	
Penetration at 25°C	D5-97	40-50	60-70	80-100	64
Flash point and Fire point °C	D92-02	232	232	219	230
Softening Point °C	D36-96	52/60	49/59	45/52	57

The bitumen tests indicated that the grade 60/70 bitumen was within the standard specifications, making it suitable for use. The penetration value at 25°C was 64, which aligns with ASTM D5-97 standards for 60/70 bitumen (60–70). The flash and fire points were recorded at 230°C, slightly below the 232°C standard but still acceptable within tolerances. The softening point was recorded at 57°C, within the 49–59°C range for 60/70 grade bitumen. According to Khosla and Harshavardhan (2020), penetration values for road bitumen should range between 60 and 70 for adequate flexibility. The obtained results confirm this, indicating good temperature susceptibility. Additionally, research by Airey (2018) shows that a softening point above 50°C enhances resistance to deformation, which aligns with the study's findings.

The aggregate's mechanical characteristics, as assessed by crushing and impact tests, are measured by strength properties, which are shown in the Table 4 below, while specific gravity is a measure of aggregate density. The specific gravity values of the filler, fine and coarse aggregates shown in Table 4 fall within the acceptable ranges suggested by the code specification. Additionally, the aggregate impact value of 27.7% falls within acceptable bounds, making it suitable for use on highway wear courses and deemed suitable for all engineering projects. According to the Nigerian General Specifications for Roads and Bridges (2020), aggregate crushing values greater than 30 are rarely utilized in road pavements.

Table 4 Test Comparison Findings on Aggregates Using Standards

Mineral Properties	Table Result	Code Used	Code Specification
Aggregate impact value (%)	27.7	BS:882 part 111	<30
Specific gravity (Coarse)	2.71	ASTMC139	2.6-2.9
Specific gravity (fine)	2.78	ASTMC139	2.6-2.9
Specific gravity (filler)	2.51	ASTM C188	2.37-2.55
Water absorption coarse (%)	0.75	BS:812 part 2	-

Road surfacing limits are as follows: <10% exceptional strength, 10–20% strong, 20–30% satisfactory, and >35% weak [8]. The results shown in Table 5 of the aggregate impact value test showed that the aggregate can be used for road surfacing, with a result of 27.7%, falling within the BS 812: Part 112 limits (20-30% satisfactory for road surfacing).

➢ *Los Angeles Abrasion Test*

The results of the Los Angeles Abrasion Test (LAA) in accordance with ASTM C131-89. Of these, 42% had an abrasion result below the 50% threshold, validating the aggregate for use in road construction.

➢ *Effects of Gum Arabic on Bitumen Properties*

The addition of Gum Arabic modified the bitumen's softening point, showing an increase at 10% substitution (60^0C) followed by a declined as the percentage increased. This suggests that minor modification enhance thermal stability, but excessive additions reduce effectiveness. AI-Hadidy and Tan (2019) found that bio-based additives, (Mezie et al., 2023) such as plant-based polymers, initially enhance softening point but can reduce stability if added in high amounts. Similarly, the findings here indicate that 10% substitutions improve bitumen stability, but excess modifications (≥ 15%) weakens it.

➢ *Marshal Test*

In accordance with ASTM guidelines, the Marshal Test was performed using bitumen percentages of 5.0, 5.5, 6.0, 6.5, and 7.0%. The outcomes were analyzed to determine the optimum bitumen content (OBC). The various elements that affect mix performance, including flow, mix, stability, etc., are taken into consideration.

Table 5 Outcome of the Marshall Test Results for Control Samples (0% Gum Arabic)

Bitumen %	Stability (KN)	Flow (mm)	Bulk Density kg/m^3	Air Void (%)
5	3.87	2.4	2.33	4
5.5	4.27	3.1	2.35	3.41
6	4.98	3.3	2.36	3.3
6.5	3.33	3.2	2.3	3.47
7	3.53	3	2.24	3.49

For the stability test, the highest load necessary to cause failure at 60°C under particular circumstances refers to stability. According to the stability results displayed in Figure 1, stability increases from 5% bitumen percentage to 6% bitumen percentage before starting to decline until it reaches 7% bitumen content. Additionally, the same chart indicates that the stability decreases with increasing bitumen content, reaching its lowest point at 3.33kN. The highest stability measured was 4.98kN. The maximum stability exceeds the least stability required by the Nigerian general specification for roads and bridges (NGSRB, 2020) when compared to the Marshal criteria in Table 7 above.

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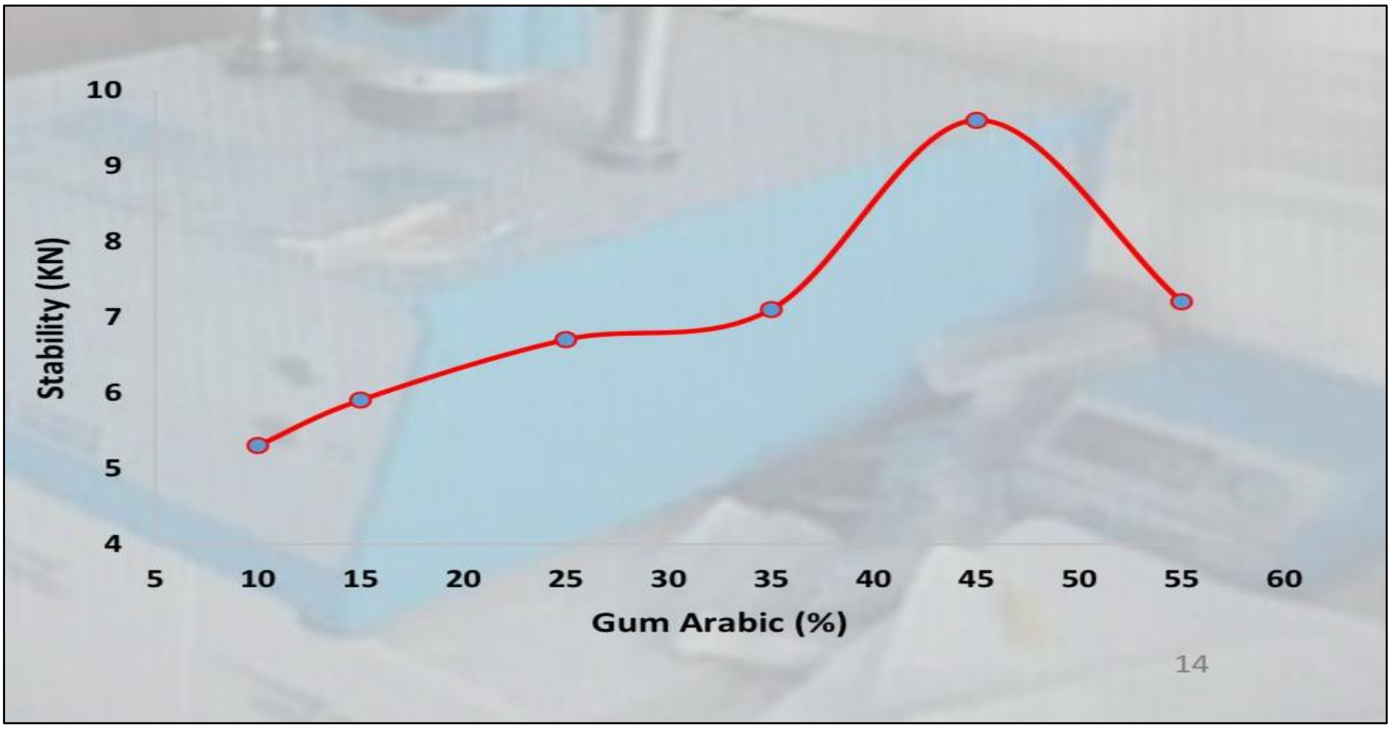

Fig 1 Stability Test (Marshal)

Figure 1 shows that the stability of modified asphalt blends with Gum Arabic is higher than that of the standard asphalt mix without a modifier. This increased stability is due to enhanced cohesion and internal friction, as viscosity rises. The stability peaks at 45% Gum Arabic replacement but begins to decrease when the amount reaches 55%. According to the Nigerian General Specification for Roads and Bridges (NGSRB, 1997), the required minimum stability is 3.5 kN, while the maximum observed stability is 9.6kN, indicating that up to 45% of the bitumen can be replaced with Gum Arabic.

➢ *Marshal Flow*

The Marshall Flow test results showed that flow values increased with bitumen content up to 6.0%, peaking at 3.3 mm, before a slight decline. The maximum flow observed was within the permissible limits for road construction, ensuring adequate deformation resistance. Lee et al. (2021) suggested that asphalt mixes should exhibit flow values between 2 mm and 4 mm for optimal performance. This study's findings fall within this range, indicating that the mix offers a good balance between flexibility and structural stability.

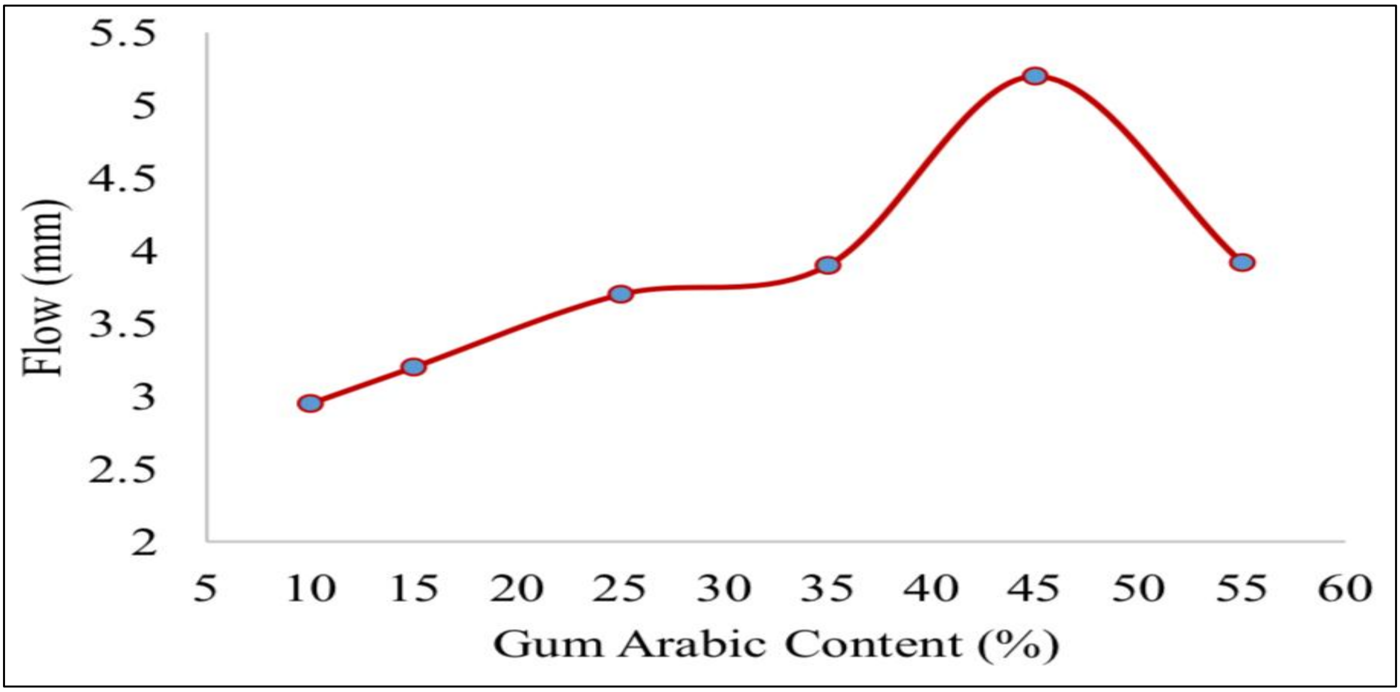

Fig 2 Marshall Flow

Figure 2 shows that the marshal flow increases with higher Gum Arabic content. In the mixture with Gum Arabic, the flow involves aggregate, bitumen, and Gum Arabic particles, whereas in the mixture without it, the flow occurs between aggregate and bitumen, which has lower viscosity. The maximum flow is 5.2mm at 45% Gum Arabic content, and the minimum flow is 2.95 mm at 10% Gum Arabic content. This range satisfies the 2-4 mm general specification for roads and bridges in Nigeria.

➢ *Percentage Air Void (Va)*

The air void percentage (Va%) represents the volume of air voids in a specimen or compacted asphalt mixture. the maximum air void content occurs at the lowest bitumen percentage. As bitumen content increases, the voids are filled with bitumen, causing Va% to decrease gradually. The air voids range from a maximum value of 4.55% at the lowest bitumen content to a minimum value of 3.0% at higher bitumen content.

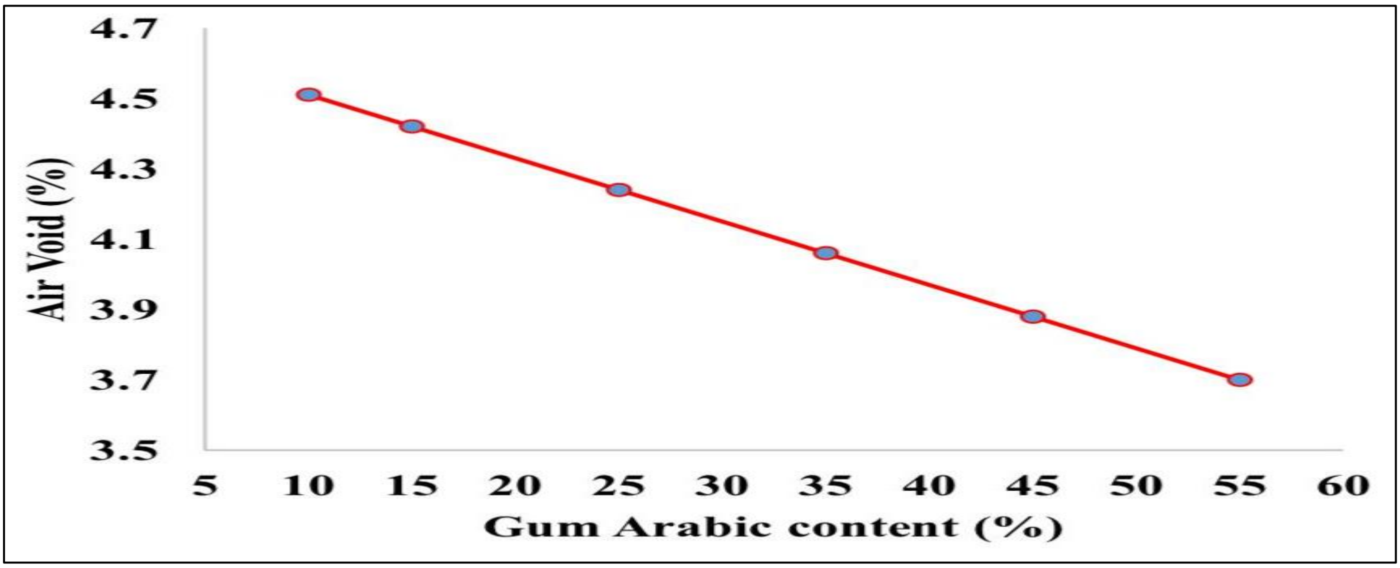

Fig 3 Percentage Air Void (Va).

Figure 3 illustrates that as the Gum Arabic content increases, the percentage of air voids in modified asphalt mixes gradually decreases. The graph shows that the air void percentage decreases until it reaches the minimum achievable void value, indicating a reduction in voids with higher Gum Arabic content.

➢ *Specific Gravity and Bulk Density of Asphalt Sample*

The bulk density of an asphalt sample refers to the actual density of the compacted mixture. As bitumen content increases, the bulk density rises, peaking at 5.8% bitumen content, after which it begins to decrease. The highest bulk density recorded is 2.36 kg/m³ at 5.8% bitumen. The decrease in density is attributed to the increase in bitumen content beyond this point.

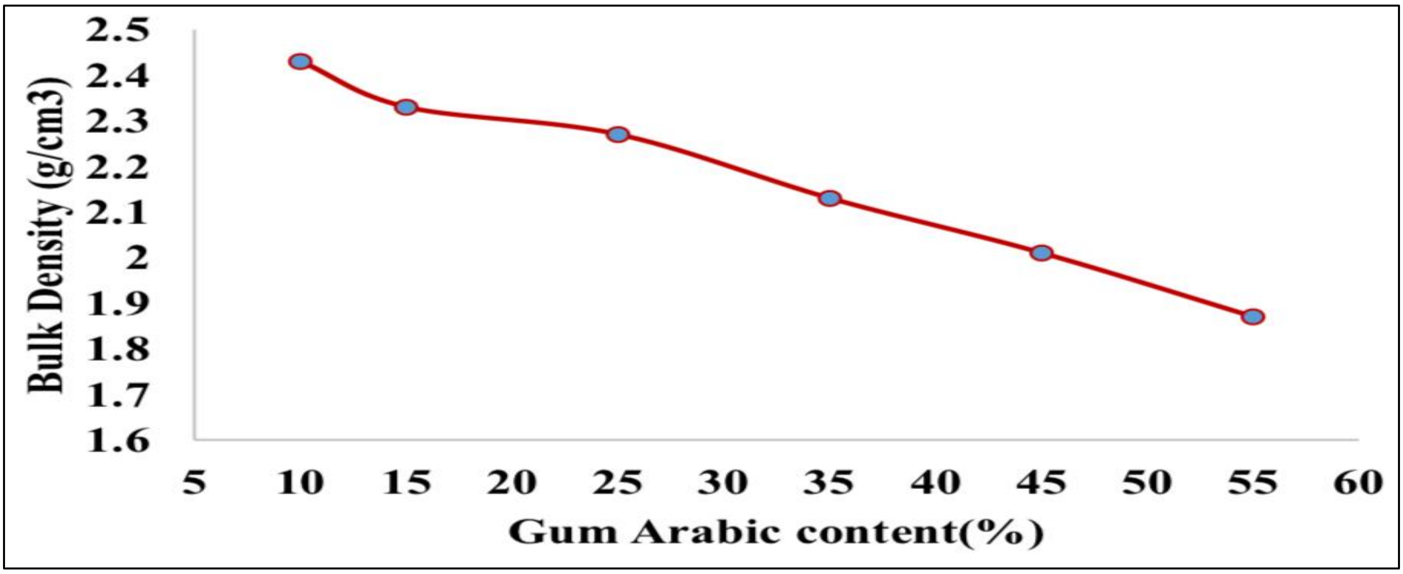

Fig 4 Bulk Density of Asphalt Sample

Figure 4 shows that the bulk density of asphalt concrete decreases as the amount of Gum Arabic increases. The highest bulk density is 2.43 g/cm³ at 10% Gum Arabian content, while the lowest is 1.87 g/cm³ at 55% Gum Arabic content. This decrease is due to the lower specific gravity of Gum Arabic compared to the aggregate, which significantly affects the maximum density. (Nwaobakata C, 2018) Similar study stated that specific gravity is a crucial indicator of an asphalt mix's durability, and a peak bulk density at optimum bitumen content is a standard trend. This aligns with the findings in this study, confirming that 6.0% bitumen content provided the most compacted structure before binder over-saturation led to reduced density Ali et al. (2020).

IV. CONCLUSION

This study investigated the potential of Gum Arabic as a sustainable modifier for asphalt concrete in road construction. The research was motivated by the growing need to reduce reliance on petroleum-based bitumen and to develop eco-friendly alternatives that enhance pavement performance.

The methodology involved collecting 60/70 grade bitumen, aggregates, and Gum Arabic, followed by the preparation of modified asphalt samples using the Marshall mix design. Laboratory tests were conducted on aggregates (impact, abrasion, and specific gravity), bitumen (penetration and softening point), and asphalt mixes (stability, flow, bulk density, and air voids).

➢ *Key Results:*

- The optimum bitumen content (OBC) was determined to be 6%.
- Gum Arabic was incorporated at different proportions (10%, 15%, 25%, 35%, 45%, and 55%).
- The asphalt mix modified with 45% Gum Arabic achieved the best performance:

✓ Stability of 9.6 kN, compared with 4.98 kN for the control mix.
✓ Flow values within the 2–4 mm specification.
✓ Voids filled with bitumen (VFB) less than 80%, meeting standard requirements.

- Aggregate properties (impact value 27.7%, specific gravity 2.6–2.9) fell within acceptable limits.
- Excessive Gum Arabic content (>45%) resulted in reduced performance due to changes in viscosity and rheology.
- In conclusion, Gum Arabic has proven to be a viable and environmentally friendly modifier that improves the stability and durability of asphalt mixes. Its optimal use at 45% can significantly enhance pavement performance while contributing to sustainability in road construction.

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- Data Availability Statement: Dataset available on request from the authors. The raw data supporting the conclusions of this article will be made available by the authors on request.

- Conflicts of Interest: The authors declare no conflicts of interest.

REFERENCES

[1]. (NGSRB, 2020). (2025). Exploring the Effects of Compaction Conditions and Moisture on Bituminous Concrete: A Statistical Approach to Develop Performance and Predictive Rut Depth Model. International Journal of Pavement Research and Technology, 1–19. https://doi.org/10.1007/s42947-025-00617-1
[2]. Abd, N. I., & Latief, R. H. (2024). The Effects of Fibers on the Properties of Local Hot Asphalt Mixtures. Tikrit Journal of Engineering Sciences, 31(4), 146–157. https://doi.org/10.25130/tjes.31.4.15
[3]. Abdulbasit, 2023, Fawwad, A., Mustafa, N., Davey, T., Tahir, B., & Basit, A. (2023). Changes in the prevalence of diabetes, prediabetes and associated risk factors in rural Baluchistan; a secondary analysis from repeated surveys (2002–2017). PLoS ONE, 18(4 April), 1–14. https://doi.org/10.1371/journal.pone.0284441
[4]. al-samgh al-'arabi, Additives, F. (2013). Gum Arabic. In Cooking Innovations (Vol. 13, Issue 319, pp. 229–240). CRC Press. https://doi.org/10.1201/b15547-15
[5]. Blades A., J., Merdith, A. S., Williams, S. E., Collins, A. S., Tetley, M. G., Mulder, M. L., Young, A., Armistead, S. E., Cannon, J., Zahirovic, S., & Müller, R. D. (2021). Extending full-plate tectonic models into deep time: Linking the Neoproterozoic and the Phanerozoic. Earth-Science Reviews, 214(March), 103477. https://doi.org/10.1016/j.earscirev.2020.103477
[6]. Brown Trtik, P. (2024). Construction materials. Neutron Imaging: From Applied Materials Science to Industry, 43–65. https://doi.org/10.1088/978-0-7503-3495-2ch3
[7]. Brzyski, P. (2021). The influence of gum arabic admixture on the mechanical properties of lime-metakaolin paste used as binder in hemp concrete. Materials, 14(22), 1–6. https://doi.org/10.3390/ma14226775
[8]. Dusemund, B., Mortensen, A., & Aguilar, F. (2017). Re-evaluation of acacia gum (E 414) as a food additive Discover the world ' s research. E 414, 1–106.
[9]. Ekwe and Yahaya, 2024, Yusuf Kpalo, S., & Faiz Zainuddin, M. (2020). Briquettes from Agricultural Residues; An Alternative Clean and Sustainable Fuel for Domestic Cooking in Nasarawa State, Nigeria. Energy and Power, 10(2), 40–47. https://doi.org/10.5923/j.ep.20201002.03
[10]. Ferma. (2010). FERMA risk management benchmarking survey 2010.
[11]. Ibrahim and Thom, 1997, Shalan, A. A., Al-Sahaf, N. A., & Al-Hdabi, A. (2019). Investigation of Binder

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec325

Course Cold Asphalt Emulsion Mixture Properties Containing Cement and GGBS. IOP Conference Series: Materials Science and Engineering, 584(1). https://doi.org/10.1088/1757-899X/584/1/012014

[12]. Kowalski, K. J., Król, J., Radziszewski, P., Casado, R., Blanco, V., Pérez, D., Viñas, V. M., Brijsse, Y., Frosch, M., Le, D. M., & Wayman, M. (2016). Eco-friendly Materials for a New Concept of Asphalt Pavement. Transportation Research Procedia, 14, 3582–3591. https://doi.org/10.1016/j.trpro.2016.05.426

[13]. Levis, 2008, Alemayehu A. Endale, Gurmel S. Ghataora, & Burrow, M. P. N. (2022). Asphalt Pavement Cold Recycling and Basic Characteristics of RAP Materials and Their Application. Journal of Civil Engineering and Architecture, 16(1), 1–3. https://doi.org/10.17265/1934-7359/2022.01.004

[14]. Malesch, 2017, Zhang, W., Shen, S., Faheem, A., Basak, P., Wu, S., & Mohammad, L. (2017). Predictive quality of the pavement ME design program for field performance of warm mix asphalt pavements. Construction and Building Materials, 131(10), 400–410. https://doi.org/10.1016/j.conbuildmat.2016.11.086

[15]. Mezie, E. O., Nwaiwu, C. M. O., & Nwakaire, C. M. (2023). Effects of Partial Replacement of Cement and Lime with some Agrowaste Ashes on the Geotechnical Behaviour of Lateritic Soil. Saudi Journal of Civil Engineering, 7(04), 115–126. https://doi.org/10.36348/sjce.2023.v07i04.002

[16]. Murtoff, 2024, Zerbet, I., & Benidire, L. (2025). Gum Arabic. In Green Chemistry, Sustainable Processes, and Technologies (pp. 353–370). https://doi.org/10.4018/979-8-3693-9826-5.ch014

[17]. Needham, 1996; Ibrahim, 1998; Thanaya, 2003; and Thom, 2008, Riebel, U., Radtke, R., & Loos, R. (2002). An experimental investigation on corona quenching. Journal of Electrostatics, 54(2), 159–165. https://doi.org/10.1016/S0304-3886(01)00175-9

[18]. Needham, T., Yielding, G., & Jones, H. (1996). Sampling of fault populations using sub-surface data: a review. Journal of Structural Geology, 18(2–3), 135–146. https://doi.org/10.1016/S0191-8141(96)80039-3

[19]. Nugus, G. G., & Irena, M. E. (2020). Determinants of Active Tuberculosis Occurrences after ART Initiation among Adult HIV-Positive Clients in West Showa Zone Public Hospitals, Ethiopia: A Case-Control Study. Advances in Public Health, 2020(1), 1–8. https://doi.org/10.1155/2020/8237928

[20]. Nwaobakata C, E. B. D. (2018). Effect of Almond Ash as Partial Replacement of Lime Filler on the Performance of HMA. International Research Journal of Advanced Engineering and Science, 3(4), 197–201.

[21]. Ocheri, M. ., Umar, D. ., Wuyep, S. Z., Laka, I. S., Odoma, L. A. ., Ali, P., Onah, M. A., & Tarzoho, P. (2025). A Review of Morphometric Studies of Drainage Basins in Nigeria. British Journal of Earth Sciences Research, 13(2), 42–65. https://doi.org/10.37745/bjesr.2013/vol13n24265

[22]. Singh, S. and. (2023). MavMatrix MavMatrix Effect of Impurities in Plastic Waste on the Performance of Effect of Impurities in Plastic Waste on the Performance of Plastic road Plastic road. https://doi.org/https://mavmatrix.uta.edu/civilengineering_dissertations

[23]. Thanaya, I., & Zoorob, S. (2017). Improving the performance of cold bituminous emulsion mixtures (CBEMs) incorporating waste materials. Performance of Bituminous and Hydraulic Materials in Pavements, Oai Id, 237–249. https://doi.org/10.4324/9780203743928-36

[24]. Walker, Richard M.George, B., & Monster, J. (2019). Does Strategic Planning Improve Organizational Performance? A Meta-Analysis. Public Administration Review, 79(6), 810–819. https://doi.org/10.1111/puar.13104