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Research Article

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Laboratory Study of Bayelsa State Clay Modified Asphalt Concrete

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Abstract: This study investigates the use of Bayelsa State clay as a partial replacement for mineral filler in asphalt concrete production to improve its performance under water submersion, which is a common issue in the flood-prone Niger Delta region. Conventional asphalt often fails when submerged due to stripping. By replacing 2-14% of the mineral filler with Bayelsa clay, the study aimed to evaluate the effects on both un-soaked and soaked asphalt mixtures over 2, 4, and 7 days. The Marshall Mix Design method was used to determine the optimum bitumen content (5%) in line with Nigerian standards, and to prepare Marshall specimens. The clay, classified as organic low plasticity under AASHTO and USC systems, showed promise as an effective filler and modifier. Results indicated that the clay-modified asphalt increased the Marshall stability of the un-soaked sample by 102% at 8% clay content compared to conventional asphalt. The modified asphalt also maintained high stability under soaked conditions for 7 days. The study concludes that incorporating Bayelsa State clay into asphalt production could significantly enhance the durability of road surfaces in the Niger Delta, and recommends its adoption by industry and government.

Keywords: Bayelsa State, clay, flood, modified, asphalt, stability, Marshall

Introduction

Roads are important part of our daily lives as it affords us the opportunity to travel from one destination to another. There are more than 34 million kilometers of road globally as reported by NCHRP, [1]. Roads serve a crucial role in economy and social development, and entails huge financial resource, materials, energy, man-power in its construction and sustainability.

The highway pavement is a very important component of the road network but due to continuous use, subjected to fatigue, has resulted in rutting due to high temperature and cracking from low temperature [2]. In the Niger Delta, annual floods have caused the failure of asphalt pavements within a short time due to stripping in the asphalt.

In view of the challenges of conventional asphalt pavement, highway engineers are constantly in search of ways to improve the properties of asphalt by adding admixtures and modifiers to extend the service life of pavement [3]. Several researchers used fiber in order to improve cohesion properties, fatigue-based damages in medium temperatures for asphalt mixes. Similarly, other researchers used waste plastics and polymers to increase asphalt mixes' ability to withstand fatigue [4]. Hydrated lime is widely used as an airfield additive to reduce the moisture sensitivity of warm-mix asphalt as reported by Button and Epps [5].

Unfortunately, most conventional and modified asphalt mixtures struggle to meet both high-temperature stability and low-temperature cracking resistance simultaneously, which presents a significant challenge in asphalt performance [6]. Hence the introduction and use of other types of additives. Clay happens to be a promising modifier of asphalt concrete in this regard, which is used for the partial replacement of conventional fillers. Fillers in asphalt paving mixture are fine materials which interact with bitumen to form a mastic asphalt resulting in a new property of asphalt. Increased surface area of the filler material allows it to absorb more bitumen and results in a different performance of the asphalt concrete (Lotfy et al., [7]).

Iskender's [8] study reported that Nanoclay significantly improves rutting and fatigue resistance in asphalt mixtures and increased viscosity of asphalt binders. According to Alobaidi and Haider 1999, addition of 5-25% clay as a partial replacement of fine aggregates reduced the air voids and densified the asphalt concrete mixtures. Marshall stability values were also observed to increase significantly with clay contents above 10%.

Tarefder & Ahmed [9] optimized clay contents in hot mix asphalt and determined the optimal range as 7-12% by weight of aggregates. Mixtures containing 8-10% clay exhibited higher stiffness modulus, indirect tensile strength and resisted moisture damage better. Rutting and fatigue life were also prolonged with 10% clay modification compared to plain mixes.

Baker et al.,[10] studied how bentonite clay affects asphalt mix when used as partial filler replacement. They replaced filler with 5%, 10%, 15%, 20%, 25% and 30% bentonite clay and the samples were subjected to Marshall stability, flow, bulk density, hydraulic conductivity and indirect tensile strength tests. From the results obtained, density and stability increased for mixture containing 15% bentonite clay. The stability increased to 11.57 kN when compared with 9.17 kN for the control specimen. However, there was a 23% loss in stability when soaked in water for 24 hours. The results also showed increased flow and tensile strength, and decreased hydraulic conductivity in the modified mixture compared to the control specimen.

Apart from mechanical properties, researchers have also explored effects of natural clay on permeability and thermal cracking characteristics of asphalt mixes. Ganjian et al., [11] ascertained that addition of 5-15% clay decreased the permeability of mixtures through pore blocking action and moisture proofing. Thermal cracking at low temperature was significantly reduced up to 10% clay filler due to augmented flexibility. Similar findings correlating lower air voids, permeability and improved low temperature cracking resistance with 5-15% clay additions were reported by Chang et al., [12].

Natural clay soil is abundantly available in the fresh water zones of the Niger Delta area of Nigeria. It becomes imperative to investigate the performance of Bayelsa State clay as an additive in the manufacture of hot-mix asphalt mixture by partial replacement of the mineral filler portion of aggregates and conditioned for 7 days, simulating flood condition that has not been studied.

Materials And Methods

A. Clay Soil

The clay soil was collected from the Niger Delta University campus and underwent Atterberg limit tests in the Department of Civil Engineering, Niger Delta University to identify the exact type of clay and its suitability for use as mineral filler in accordance with standard specifications.

B. Binder and Aggregates

The bitumen used for this study underwent several tests, such as penetration, flash point, softening point and specific gravity. The coarse aggregate used was crushed granite and sourced from Amassoma crushed granite dump. The fine aggregate was sourced from the Niger Delta University campus and used. Aggregate physical properties tests were conducted to determine their suitability for the study. The mineral filler used is Dangote Portland limestone cement.

C. Mix Preparation

The optimum bitumen content (OBC) was determined in accordance with the Marshall Mix Design procedure [13,14] and used to prepare Marshall samples for this study. The Marshall test method of mix designs requires three compacted samples to be subjected to Marshall tests.

Before batching, aggregates were washed, dried and sieved in compliance with ASTM D [15]. Oven-dried Bayelsa State clay was used to partially replace the mineral filler in asphalt mixtures at varying contents (0% control, 2%, 4%, 6%, 8%, 10%, 12%, 14%). The clay, coarse, and fine aggregates were preheated to 175°C and mixed according to the designed proportions. The Marshall molds are preheated and kept at 100 ºC to 145 ºC.

Preheated bitumen at 138 ºC is added to the mixture of aggregates and the mixture is manually mixed for 20 to 30 minutes until it becomes homogenous and well mixed at 160 ºC.

The mixture is carefully placed inside a Marshall mold and thoroughly compacted using a standard Marshall hammer, applying 75 blows on each side of the cylindrical specimen. The samples are extracted from the mold with asphalt sample extractor after a few minutes.

Each sample was prepared separately with great care to ensure the accuracy and reliability of the results. The conditioned specimens are submerged in water bath for varying lengths of time – 2, 4 and 7 days. The Marshall stability test is conducted on the Marshall specimen after immersing the specimen in water bath at a temperature of 60 ± 1 ºC for a duration of 30 minutes. After that, specimens are loaded into the Marshall stability testing apparatus at a steady rate of 5 mm of deformation per minute till failure. The stability value obtained is corrected where applicable, obtaining the standard thickness of 63.5 mm by applying the stability correction for thickness. The flow value is recorded for the deformation that occurred at maximum loading, measured in units of 0.25 mm increments.

Results & Discussion

Table 1 shows the primary soil type collected from the site, which adhered to the A6 and OL classifications for Bayelsa State, outlined by both the American Association of State Highway and Transportation Officials (AASTHO) and the Unified Soil Classification (USC) systems. It demonstrates the consistency and reliability of soil characterization across various classification methodologies. Referring to Table 1, Bayelsa State soil sample has 88% particle size distribution, with a liquid limit (LL) of 38% and 46% plasticity limit (PL). It is classified as OL (organic soil, low plasticity) in the AASTHTO system's A-6 group.

Table 1: Classification of Soil

Test No	**PSD (%)**			**Atterberg Limit**		**USC System**	**AASTHTO Classification**
	Sieve No 10	Sieve No 10	Sieve No 10	LL	PI		
			Bayelsa Sate				
1	88	69	38	46	28	OL	A-6

The bitumen test results carried out in the Department of Civil Engineering's Highway Laboratory at the Niger Delta University shows a penetration grade of 60/70 conforming to the Nigeria General Specifications for Roads and Bridges 1997 {16], with a specific gravity at 25oC of 1.01 -1.06, flash point of 230oC, softening point of 46 – 54oC and the optimum bitumen content (OBC) to be 5%, while Table 2 displays the aggregates' physical properties.

Table 2: Physical Properties of Aggregates

Test Conducted	**Results**	**Code Referenced**	**Code Specification**	**Remark**
		Coarse Aggregate		
Specific gravity	2.5	(ASTM C128, 2022)	2.55 - 2.75	Ok
Water Absorption (%)	1.8	(BS 812-2, 1995)	<3.5%	Ok
		Fine Aggregates		
Specific gravity	2.65	(ASTM C128, 2022)	2.55 - 2.75	Ok
Water Absorption (%)	10	(BS 812-2, 1995)	<15%	Ok
		Conventional		
Fineness (%)	2.2	BS EN 196-6:2018	<5%	Ok
Specific gravity	5.5	ASTM C188, (2017)	≥ 3.15	Ok

Particle size distribution curves for fine and coarse aggregates are presented in Figures 1 and 2, respectively. These curves are important in determining the gradation of the aggregates and ensuring that they conform to necessary specifications. For the fine and coarse aggregates to be well graded in accordance with specifications, their coefficients of uniformity values must be greater than 6 and 4, respectively. From figures 1 and 2, the Cu values are 2.3 for fine aggregate and 2.1 for coarse aggregate, which indicates that the fine and coarse aggregate were uniformly graded.

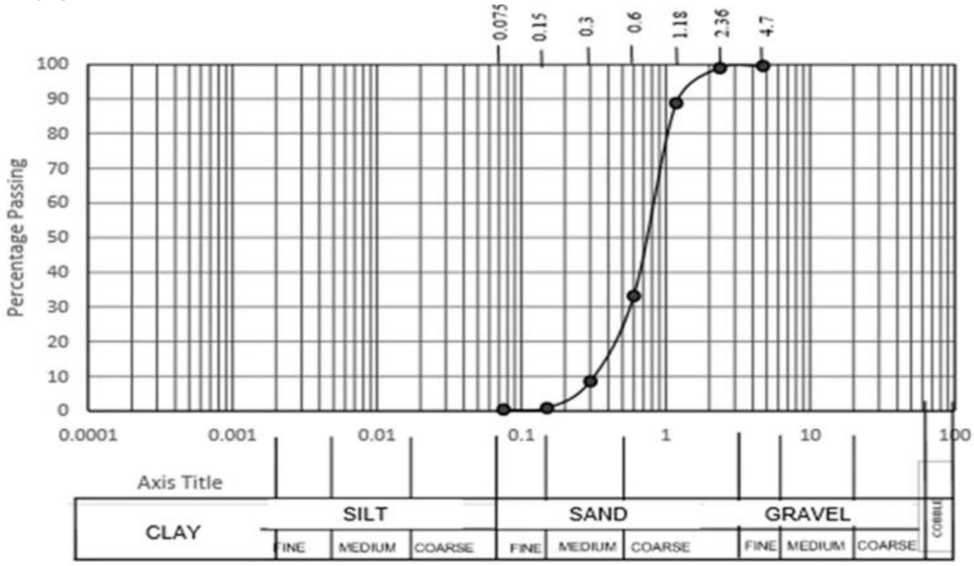

Figure 1: Particle Size Distribution of Fine Aggregate

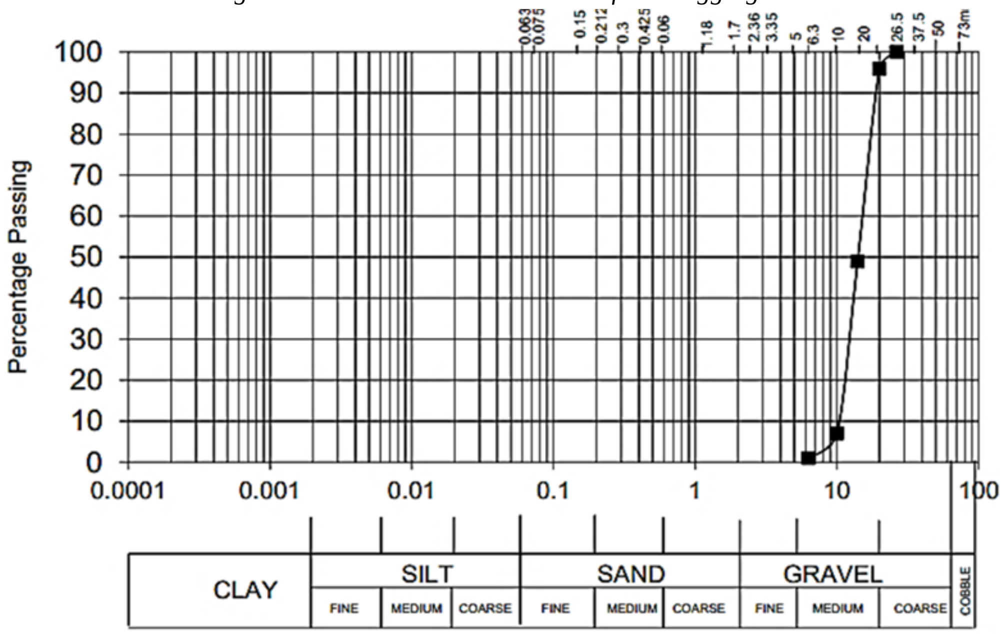

Figure 2: Particle Size Distribution of Coarse Aggregate

A. Mechanical and Volumetrics Properties

Table 3, in addition to Figures 3 to 6, provide a complete examination of the mechanical and volumetric parameters recorded in modified asphaltic concrete using Bayelsa Stata clay versus normal asphaltic concrete. This study was carried out with a steady 5% bitumen content. The findings in Figures 3 to 6 provide valuable insights into the influence of utilizing clay from Bayelsa State as a modifier on the properties of asphaltic concrete compositions.

Table 3: Un-soaked Mechanical and Volumetric Properties of Asphalt Modified with Bayelsa State Clay

% Clay	Unit Weight	Marshall Stability kN	Marshall Flow mm	% VTM	% VMA	% VFB
2	2.336	12.03	2.33	5.08	16.45	69.12
4	2.344	10.41	2.08	4.72	16.16	70.82
6	2.336	16.72	2.22	5	16.45	69.58
8	2.387	16.97	1.52	3.93	14.62	79.97
10	2.354	10.5	1.96	4.23	15.8	73.22
12	2.356	16.39	2.84	4.15	15.73	73.62
14	2.362	13.06	2.26	3.87	15.52	75.08

The NGS [16] established exact requirements for base courses, including Void in Total Mix (VTM) and Void Filled with Bitumen (VFB) ranging from 3-8% to 65-72%, respectively. Additionally, the bitumen content for the base course must be between 4.5 and 6.5. The outcome demonstrated that the VTM values were within the specified range, while the bitumen content remained within the prescribed limits.

Table 3 and Figure 6 show that the VFB values for asphalt concrete samples including clay from Bayelsa State met the standards outlined in the NGS ([16]. The optimal dosage is 8% clay, resulting in 16.97 kN stability. Modifying asphalt concrete with clay from Bayelsa State improves stability by approximately 102%. Figure 4 shows that as the clay content approaches 12%, the flow decreases, resulting in stiffer asphalt concrete. Figure 5 also shows the unit weight at a peak of 8% clay content.

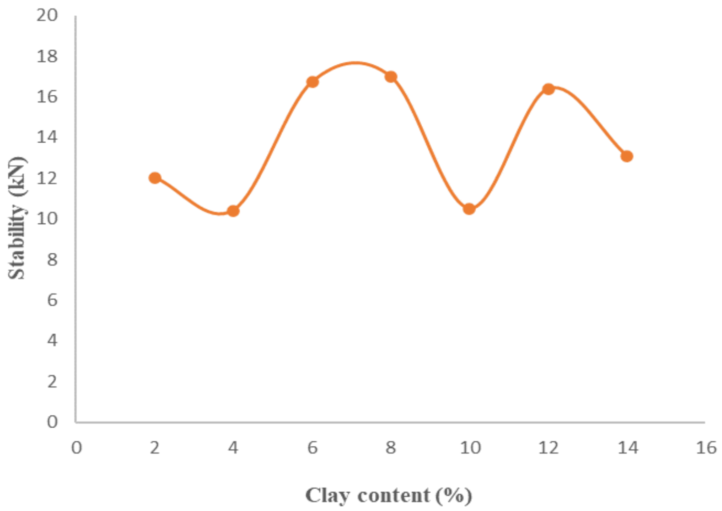

Figure 3: Stability versus Percent Bayelsa State Clay Content

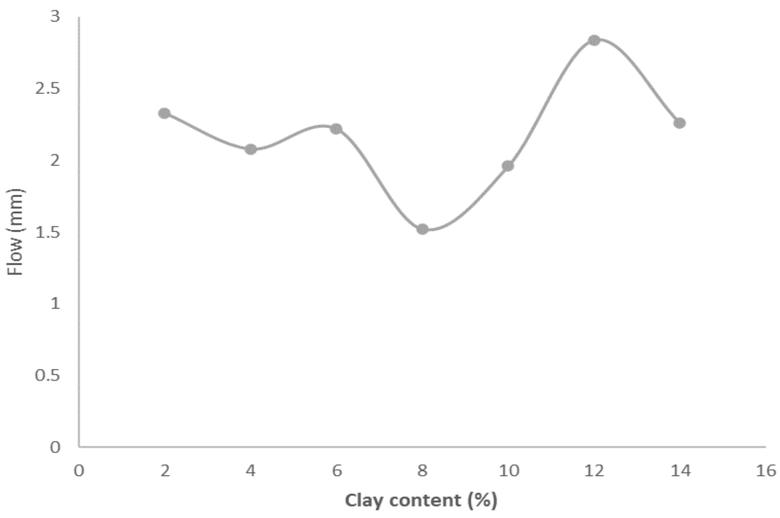

Figure 4: Flow versus Percent Bayelsa State Clay Content

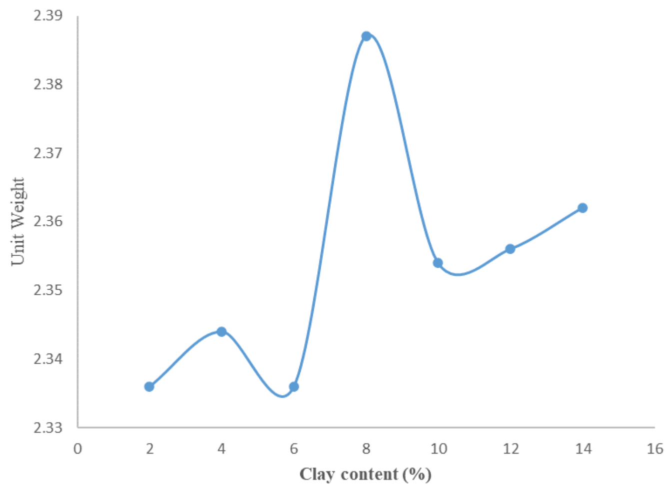

Figure 5: Unit Weight versus Percent Bayelsa State Clay Content

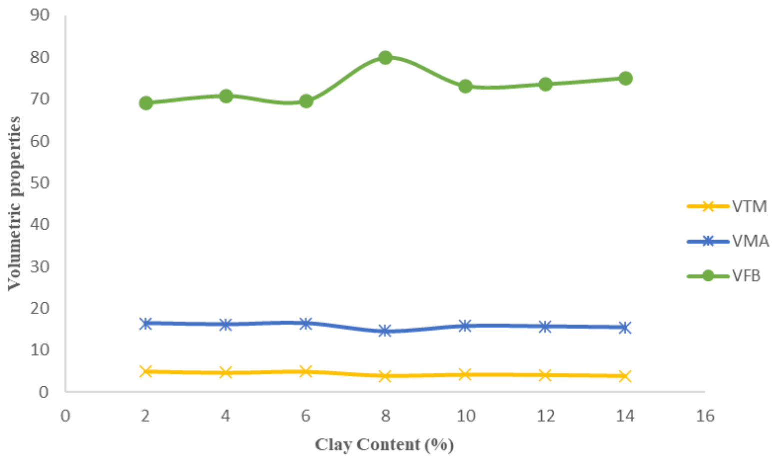

Figure 6: Asphalt Volumetrics versus Percent Bayelsa State Clay Content

Results of Soaked Mechanical Properties of Asphalt Concrete Modified with Clay from Bayelsa State

A. Marshall Stability Properties

Table 4 shows the Marshall Stability qualities of asphalt concrete created with traditional filler at 7% and 5% bitumen content, and further reinforced with clay derived from Bayelsa state and buried in water for 2, 4, and 7 days.

Table 4: Variation of Marshall Stability Due Percentage Replacement of Mineral Filler with Bayelsa State Clay

Bayelsa State Clay (%)	Marshall Stability (kN)							
	Un-soaked	% diff.	Soaked for 2Days	% diff.	Soaked for 4Days	% diff.	Soaked for 7Days	% diff.
0	8.4	-	5.35	-	5.10	-	4.73	-
2	12.03	43	16.78	11	16.86	231	27.90	490
4	10.41	24	26.87	402	19.27	278	16.02	239
6	16.72	99	18.24	241	25.38	398	20.04	324
8	16.97	102	16.78	214	22.02	332	20.26	328
10	10.5	25	25.65	379	23.74	365	23.47	396
12	16.39	95	20.45	282	25.97	409	19.20	306
14	13.06	55	21.93	310	27.23	434	16.51	249

Figure 7 shows comprehensive graphical representations of results, providing insights into the material's performance under varied conditions of clay alteration and soaking periods. Table 6 show that both wet and dry samples regularly match these parameters. The stability values provided in Table 6 are greater than the minimum stability values of 3.5 kN, confirming the acceptability of clay as a modifier. Figures 7 further highlight the Marshall stability patterns for different clay content, revealing an ascending pattern as clay content increases. This complete research defines the material's clay-dependent behavior, which is critical for making educated road construction decisions.

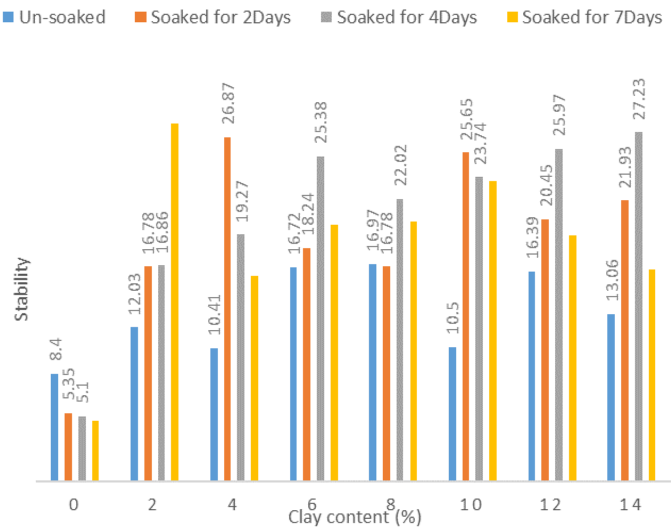

Figure 7: Variation of Stability with Percent Bayelsa State Clay Content – Soaked

B. Marshall flow Properties

Table 8 and Figure 9 shows the flow parameters of asphalt concrete treated with clay. This comparative investigation gives light on the flow parameters of the asphaltic concrete compositions in question. According to the NGS (1997), base courses must have a flow value between 2 and 6 mm. The results provided in table 8 and Figure 9 show that both soaked and un-soaked clay-modified samples met the NGS [16]. The unmodified asphalt concretes continue to increase in flow value. However, between 6-8% dosage seem to be the appropriate amount of clay to be within the NGS [16].

Table 5: Variation of Marshall Flow Due Percentage Replacement of Mineral Filler with Bayelsa State Clay

Bayelsa State Clay (%)	Marshall Flow (mm)			
	Un-soaked	Soaked for 2Days	Soaked for 4Days	Soaked for 7Days
0	2.2	2.48	2.55	2.75
2	2.33	2.78	3.44	3.04
4	2.08	3.73	2.55	3.06
6	2.22	2.81	2.50	3.30
8	1.52	3.14	2.16	3.62
10	1.96	3.48	1.80	3.05
12	2.84	3.37	2.15	3.11
14	2.26	3.09	3.30	2.20

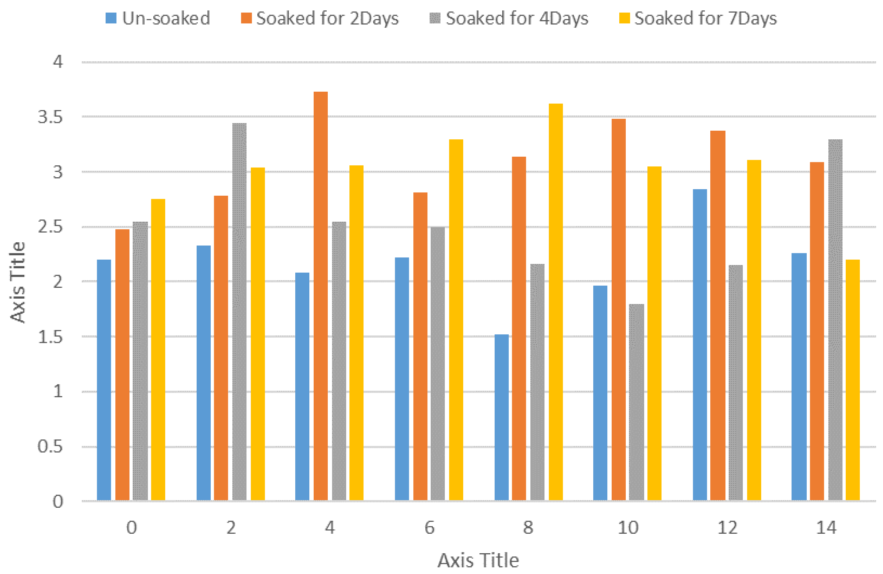

Figure 9: Variation of Flow with Percent Bayelsa State Clay Content – Soaked

Conclusion

The laboratory test conducted by partially replacing the mineral filler portion of aggregates in the asphalt mixture with Bayelsa State clay allows for the following conclusions to be drawn, highlighting various outcomes and effects observed during the experimentation.

The addition of clay from Bayelsa State leads to an increase in Marshall stability of the un-soaked samples, up to a certain point. Specifically:

Marshall stability Values.

i. Maximum Marshall Stability: The highest value of Marshall stability recorded was 16.97 kN at 8% clay content. This represents a 102% increase compared to the control asphalt mix.

ii. Decrease After 8%: Beyond 8% clay content, the Marshall stability starts to decrease, indicating that while moderate clay content improves the mix's stability, too much clay can negatively affect the asphalt's performance.

iii. The Marshall stability values of soaked Bayelsa State clay-modified asphalt demonstrate significant strength consistently throughout the entire 7-day soaking period above the minimum limit stipulated by the NGS (1997).

iv. The flow values across all conditions fall within the 2-6 range as specified in the NGS (1997). This pattern suggests that there is an optimal level of clay content for enhancing the properties of asphalt. Exceeding this optimal content can lead to diminishing returns and possibly compromise the material's overall stability.

References

[1]. NCHRP 430. Cost-effective and Sustainable Road Slope Stabilization and Erosion Control, 2012.

[2]. Kamiya, S., Tasaka, S., Zhang, X., Dong, D. and Inagaki, N. (2001). Compatibilizer Role of styrene-butadiene-styrene triblock copolymer in asphalt. Polym. J. 33 (3): 209–213. https://doi.org/10.1295/polymj.33.209.

[3]. Ozen, H. (2011). Rutting Evaluation of Hydrated Lime and SBS Modified Asphalt Mixtures for Laboratory and Field Compacted Samples. Constr. Build. Mater. 25(2): 756-765. https://doi.org/10.1016/j.conbuildmat.2010.07.010.

[4]. Shafabakhsh, G. H., Taghipoor, M., Sadeghnejad, M. and Tahami, S. A. (2015). Evaluating the Effect of Additives on Improving Asphalt Mixtures Fatigue Behaviour. Constr. Build. Mater.90: 59-67. https://doi.org/10.1016/j.conbuildmat.2015.04.046.

[5]. Button, J.W. and Epps, J.A. (1983). Evaluation of methods of mixing lime in asphalt pavement mixtures. Interim Rep. No. RF 4773-1. College Station, TX: Texas Hot Asphalt Pavement Association.

[6]. Zhang, H. L., Su, M. M., Zhao, S. F. and Zhang, Z. P (2016). High and Low Temperature Properties of Nano-particles/Polymer modified Asphalt. Constr. Build. Mater. 114:323-332. https://doi.org/10.1016/j.conbuildmat.2016.03.118.

[7]. Lotfy, O. K., Ozbay, E., Hossain, K. M. and Lachemi, M. (2015). Effect of Kaaolin waste content on the properties of normal – weight concrete. Constr. Build. Mater. 83, 102-107.

[8]. (Iskender, E. (2016). Evaluation of Mechanical Properties of Nano-clay Modified Asphalt. Measurement 93 (Nov): 359-371. https://doi.org/10.1016/j.meaurement.2016.07.045.

[9]. Tarefder, R. A., & Ahmed, Z. (2014). Characterization of Conventional and Clay-modified Hot Mix Asphalt Mixtures. Construction and Building Materials, 52, 35-39. https://doi.org/10.1016/j.conbuildmat.2013.10.079.

[10]. Baker, M. I. B., Abendeh, R. M, and Obaidat, T. A. (2018). Employing Natural Bentonite Clay as Partial Replacement of Mineral Filler in Asphalt Mixtures. DOI:10.1061/(ASCE)MT.1943-5533.002375. 2018 American Society of Civil Engineers.

[11]. Ganjian, E., Kariatlis, C. A., and Pashias, N. (2009). Kinamatics of Fracture in Bituminous Mixtures Damaged by Moisture. Construction and building materials, 23(1), 422-430. https://doi.org/10.1016/j.conbuildmat.2007.10.009.

[12]. Chang, G. K., Maccarrone, S., and Tayfur, S. (2002). Effects of Fine Aggregate Silt and Clay Contents on Asphalt Concrete. Transportation Research Record: Journal of the Transportation Research Board, 1789(1), 74-82. https://doi.org/10.3141/1789-10.

[13]. ASTM D1559: Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus. ASTM 1989.

[14]. ASTM D2726): Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Asphalt Mixtures. ASTM 2011.

[15]. ASTM D3515-01. Standard Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures. https://www.astm.org.

[16]. Nigeria General Specifications for Roads and Bridges, Volume II, Revised 1997 (NGS 1997). https://www.pdfcoffee.com.