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**TECHNICAL PAPER
PRESENTATION**

TOPIC

**COMPARATIVE ANALYSIS OF
60/70 BITUMEN TO POLYMERIZED
MODIFIED BITUMEN (SASOBIT) IN
FLEXIBLE ROAD PAVEMENT**

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COMPARATIVE ANALYSIS OF 60/70 BITUMEN TO POLYMERIZED MODIFIED BITUMEN (SASOBIT) IN FLEXIBLE ROAD PAVEMENT

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Abstract

Nigeria roads are susceptible to rutting and fatigue crack caused by exceptionally high wheel loads, a wide temperature range between seasons, and sometimes even between day and night on the same day. To improve the properties of asphalt concrete as a whole, many types of modifier polymer have been added to asphalt materials. This study was conducted to investigate the effect of varying Sasobit content in bitumen on the properties of bitumen at intermediate temperatures. Thus, this research paper presents the result of the effect of modified bitumen on penetration, softening point, flash point, specific gravity and Marshall stability of polymerized modified bitumen for use in pavement construction. Grade 60/70 bitumen was chosen for this research and modified with 1%, 1.5%, 2%, 2.5%, 3%, 3.5% and 4% Sasobit content. The results show an increase in softening point from 49.3 °C at 0% to 85.4 °C at 4%, specific gravity ranging from 1.04 at 0% to 1.06 at 4% and Marshall stability from 9.9 kN at 0% to 13.9 kN at 4%, while penetration decreased from 63.2 at 0% to 22.0 at 4% as well as flash point where a retrogressing trend was recorded from 275 °C at 0% to 254 °C at 4% as Sasobit content increased. Therefore, Sasobit as bitumen modifier in asphalt production enhances the rheological, mechanical and viscoelastic properties of bitumen as well as the overall performance of flexible road pavement.

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ABSTRACT

Nigeria roads are susceptible to rutting and fatigue crack caused by exceptionally high wheel loads, a wide temperature range between seasons, and sometimes even between day and night on the same day. To improve the properties of asphalt concrete as a whole, many types of modifier polymer have been added to asphalt materials. This study was conducted to investigate the effect of varying Sasobit content in bitumen on the properties of bitumen at intermediate temperatures. Thus, this research paper presents the result of the effect of modified bitumen on penetration, softening point, flash point, specific gravity and Marshall stability of polymerized modified bitumen for use in pavement construction. Grade 60/70 bitumen was chosen for this research and modified with 1%, 1.5%, 2%, 2.5%, 3%, 3.5% and 4% Sasobit content. The results show an increase in softening point from 49.3°C at 0% to 85.4°C at 4%, specific gravity ranging from 1.04 at 0% to 1.06 at 4% and Marshall stability from 9.9 kN at 0% to 13.9 kN at 4%, while penetration decreased from 63.2 at 0% to 22.0 at 4% as well as flash point where a retrogressing trend was recorded from 275°C at 0% to 254°C at 4% as Sasobit content increased. Therefore, Sasobit as bitumen modifier in asphalt production enhances the rheological, mechanical and viscoelastic properties of bitumen as well as the overall performance of flexible road pavement. Hence, the research recommends Sasobit content at 2.5% for use as additive in asphaltic concrete. This recommendation is based on current industry practice and field experience.

Keywords: Hot Mix Asphalt; Sasobit; Polymerized bitumen; Viscoelastic; Marshall stability; Bitumen; Asphalt; Flashpoint; Penetration

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1. Introduction

Transportation is more than the movement of goods and services, it is a bridge that links communities together as well as their activities (Shehu *et al.*, 2020). Transportation is done by several modes, one of which is by road. Road is an improved path for movement from one place to another by any means of conveyance (Kolo, 2021). Around the world, roads are regarded as one of the most important facilities. Continual research is being done to improve the functionality of the infrastructure for roads, and an estimated 40 billion tonnes of aggregate are needed just for building (Busari *et al.*, 2019). Recycling waste material is now a top priority in all technical fields, but particularly in the transportation sector. A pavement is a mixture of processed and unprocessed materials arranged over unimproved terrain and designed to accommodate all types of traffic (Shehu, 2019). Typically, the wearing course (asphalt concrete), base course, sub-base, and sub-grade layers are built from top to bottom to create flexible pavement structures. A tightly graded bitumen mixture that has been compacted to create the pavement surface makes up the asphaltic concrete layer. At high strain rate and low temperatures, the asphaltic concrete will crack under the fracture tensile stress (load). However, it collapses via plastic flow at high temperatures and low strain rate circumstances. Microcracking at a low strain rate and climatic circumstances is another potential source of failure for asphalt concrete (Chompoorat and Likitlersuang, 2015).

Bitumen is a thick, sticky, dark liquid or semi-solid that is made of petroleum. It is classified as a pitch, exists in nature as asphalt lakes and tars, and may be found in natural deposits or as a refined product. Bitumen is primarily employed (70%) in the construction of roads, where it serves as a glue or binder when combined with aggregate particles to make asphalt concrete. Its other primary functions include the creation of bituminous waterproofing goods like roofing felt and the sealing of flat roofs (Polaczyk *et al.*, 2019). In terms of cost and durability, modified bituminous material has a lot to offer highway construction and maintenance. This form of bitumen is created by altering the rheological and strength characteristics of the penetration graded bitumen. Rubber or plastic might be the polymer utilized. Even while bitumen in its pure form is acceptable for road building, it still has to be modified to get its optimal performance. Bitumen has been used in roads, highways, and airport runways since it was discovered as a by-product of the refining of petroleum in the early 20th century, and it has performed well in these applications. Bitumen receives around

2% of the overall product from the refinery. Recently, attempts have been undertaken to lower asphaltic pavement production prices.

Fontes et al (2010) used two distinct mixes of polymer generated using ambient and cryogenic procedures to demonstrate the impact of polymerized modified bitumen on permanent deformation of asphalt-polymer combination (continuous blend and terminal blend). To assess the rutting resistance of asphalt-polymer mixtures, the Repeated Simple Shear Test at Constant Height (RSST-CH) and the Accelerated Pavement Testing Simulator (wheel tracking) were performed at 60°C. The asphalt-polymer mixture was found to have less persistent deformation than the conventional mixture in both tests, with the majority of the permanent deformation occurring during the initial loading cycles. Thus, there is a need for investigation into Sasobit long-term viability as an asphalt additive.

Sasobit is therefore presented as a green alternative technology that may lower pavement manufacturing temperatures during mixing and compaction. A synthetic wax made from Fischer-Tropsch is called Sasobit. Since 1997, asphalt roads have been constructed effectively using Sasobit, a synthetic hard wax. This additive is produced by the Fischer-Tropsch method, which involves gasifying coal. Sasobit guarantees total process dependability for all applications of asphalt mix at all times, particularly in challenging circumstances. Lower construction temperatures are more ecologically friendly than standard hot mix asphalt (HMA) generated with unaltered bitumen in plants because they minimize fuel consumption and production costs (Solouki, 2015). A safer workplace for employees and other environmental benefits, such as a reduction in visible and invisible pollutants, might also be mentioned as advantages of bitumen modification (Hurley and Prowell, 2005). The addition of additives like Sasobit to bitumen is one of the ways modification technologies are used.

The impact of Sasobit on the rheological characteristics of bitumen has been examined in a number of research. Sasobit-modified asphalt's stiffness resistance has been shown to rise at intermediate testing temperatures. It has also been noted that softening point values have increased. However, Sasobit-modified bitumen lowers the Fraass breaking point, penetration, and viscosity of asphalt (Silva et al., 2010; Xiao et al., 2012; Jamshidi et al., 2013; Kheradmand et al., 2014). Additionally, there hasn't been a detailed investigation on how different mixing settings affect the marshal stability of modified asphalt. In lieu of the aforementioned, this research carried out a comparative

analysis of 60/70 bitumen to polymerized modified bitumen (Sasobit) in flexible road pavement aimed at improving the overall performance, efficiency, and service life of asphalt pavement through polymerized modified bitumen (Sasobit) and its general impact on the highway.

2. Materials and Methods

2.1. Materials

Materials used for this research were: bitumen of penetration grade (60/70) and conforms with BS EN 1426:2015, aggregates of blended gradation containing sand (0 – 4mm), stone dust (0 – 5mm), crushed stone (4 -8mm), crushed stone (8 – 16mm) maximum for wearing course and (16 – 22mm) maximum for binding course. The aggregates conform with BS EN 12620:2002+A1:2008 concrete specification and performance, Sasobit and trichloroethylene. Materials were sourced from Julius Berger asphalt plant and were taken to Julius Berger asphalt laboratory in Lagos, Nigeria for analysis. This research was carried out in stages to achieve the aforementioned aim and objectives of the study.

Table 1: The 60/70 Grade Bitumen Specification

Parameters	Results	Specifications	Standards
Penetration @ 25 °C, (1/10mm)	63.2	60-70	BS EN 1426
Softening Point (°C)	49.3	46-54	BS EN 1427
Flash point (°C)	275	>230	BS EN 22592
Specific Gravity @ 25 °C	1.04	1.01-1.06	BS EN 15326



Plate I: Bitumen 60/70

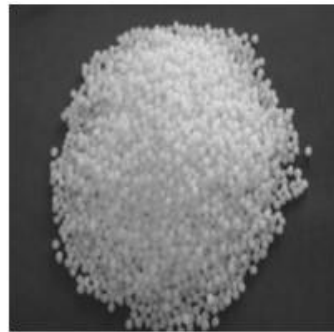


Plate II: Sasobit



Plate III: Trichloroethylene

2.2. Methods

Three samples were prepared for each of the mixes at 0%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, 3.5% and 4% Sasobit content. After being heated to pouring temperatures of 150°C, the resultant bituminous mixture was poured into the mould. The containers were put individually into an oil bath to prepare each sample. Using an electrical heater, the setup was then heated to 130°C, where

it remained during the blending process. After that, the mechanical stirrer was positioned within the container vertically, with a clearance height of 2 cm above the bottom. Additionally, for each mix, the specified Sasobit quantity was weighed based on binder weight and added gradually to the bitumen. Finally, the blending was begun for 20 minutes at the specified pace. For subsequent testing, the samples were cooled to room temperature. The mixes were tested for penetration in accordance to BS EN 1426:2015, softening point in accordance to BS EN 1427:2015, flash point which was in conformity with BS EN 22592:2000 and specific gravity in accordance to BS EN 15326:2007+A1:2009. For the Marshall test, the samples were prepared to contain aggregates and the mixes were varied with varying percentage of Sasobit content. The test procedures and methodologies were in accordance to BS EN 12697-34:2020. As such, standard Marshall cake were prepared for each of the mix. The gradation, specific gravity and absorption of aggregates were determined using British Standard guidelines: BS EN 12620:2002+A1:2008.



Plate IV: Softening point test in process machine



Plate V: Marshall cakes before loading on the machine



Plate VI Flash point test in process



Plate VII: Penetration test in process

2.3. Laboratory Tests

For purpose of the study, penetration, softening point, flash point, specific gravity and Marshall tests were carried out for both unmodified and modified bitumen.

2.3.1. Penetration

Penetration of bitumen as presented in Emesiobi (2000) is defined as the distance in tenths of millimeter that a standard needle will penetrate into the bitumen under a load of 100g applied for 5 seconds at 25°C (77°F). The method of preparation involved the use of a penetrometer; where the hot bitumen in molten state was poured into a container and immersed in a water bath containing water at a temperature of 25°C for 30 minutes. After which the bitumen was allowed to cool and a needle of 1mm in diameter weighing 100g was allowed to touch the surface of the bitumen. The needle was released under gravity to pierce through the bitumen surface for 5 seconds and the distance in unit of millimeters was recorded as the penetration value of the bitumen. For the modified bitumen, the same procedure was adopted except that the Sasobit was heated to molten state before pouring into the molten bitumen and then mixed thoroughly before carrying out the penetration test. The procedure was repeated for varying amounts of Sasobit between 1% – 4% and the results obtained were recorded.

2.3.2. Softening point

Softening point of bitumen as presented in Mumah and Muktar (2001) is that property which determines the temperature at which bitumen changes from semi-solid to liquid under heat variation. The method of preparation involved placing two 9.33mm diameter steel balls on viscous bitumen sample placed in a steel ring immersed in a water bath. Heat was then applied to the water and its temperature increased until the point when the bitumen sample was sufficiently soft to allow the balls to pierce through and fall through a height of 25mm. the temperature at which the steel balls fell through the sample was recorded as the softening point of the unmodified bitumen. For the modified bitumen, the same procedure was adopted for each of the mix.

2.3.3. Flash point

The bitumen sample was taken in a beaker and heated to a temperature of 75 - 100°C above its approximate softening point. The bitumen was allowed to melt until it is converted completely into

a liquid state. The melted bitumen would be filled in the cup up to the filling mark indicated on the cup and placed on the burner. The thermometer was inserted and the test flame was placed to a size of a bead of about 4 mm diameter. The rate of the application of heat was controlled such that the temperature increases by 5 - 6°C per minute as recorded from the thermometer. The stirrer was turned at the rate of 60 rev/min. The first test flame was applied when the temperature reached approximately 17°C before the actual flash point. When the test flame was applied, the stirring was discontinued. The test flame was applied at every reading of the temperature up to 104°C in the multiples of 1°C. When the temperature exceeded 104°C, the test was carried out at an interval of 2°C. The temperature at which a distinct flash was observed is noted in the interior of the cup. For the modified bitumen, the same procedure was adopted for each of the mix.

2.3.4. Marshal stability

1200 grams of aggregate was blended in the desired proportions, measured and heated in the oven to the mixing temperature. Bitumen was added at the mixing temperature to produce viscosity of $170 \pm$ centistokes at various percentages. The materials were mixed in a heated pan with heated mixing tools. The mixture was returned to the oven and reheated to the compacting temperature (to produce viscosity of 280 ± 30 centi-stokes). The mixture was then placed in a heated Marshall cylindrical mould (diameter = 100mm and height = 60mm) with a collar and base and the mixture was spaded around the sides of the mould. A filter paper was placed under the sample and on top of the sample. The material was compacted with 50 blows of the hammer (or as specified), and the sample was inverted and compacted in the other face with same number of blows. After compaction, the mould was inverted and with collar on the bottom, the base was removed and the sample was extracted by pushing it out with the extractor. The sample was allowed to stand for the few hours to cool. The mass of the sample in air and when submerged was used to measure the density of specimen, so as to allow for the calculation of the void properties. Specimens were heated to $60 \pm 1^\circ\text{C}$ either in a water bath for 30 - 40 minutes or in an oven for minimum of 2 hours. The specimens were removed from the water bath or oven and place in lower segment of the breaking head. The upper segment of the breaking head of the specimen was placed in position and the complete assembly was placed in position on the testing machine. The flow meter was placed over one of the post and is adjusted to read zero. Load was applied at a rate of 50 mm per minute until the maximum load reading was obtained. The maximum load reading in Newton

would be observed. At the same instant the flow as recorded on the flow meter in units of mm was also noted. For the modified bitumen, the same procedure was adopted for each of the mix.

3. Results and Discussion

Table 2 presents the results of penetration, softening point, flash point and specific gravity of unmodified bitumen and modified bitumen containing (1% - 4%) Sasobit as well the Marshall stability of modified and unmodified bitumen in asphaltic mix. Softening point increased from 49.3°C at 0% Sasobit content to 85.4°C at 4% Sasobit content as its percentage increased in the modified bitumen. The hardening of the resulting mix from increased Sasobit content in modified bitumen is responsible for decreasing penetration. It can be said that modification of the 60/70 grade bitumen reduced penetration at 25°C from 63.2 per 10mm in the unmodified bitumen to 22 per 10mm at 4% Sasobit content. Flash point decreased with increasing Sasobit content from 275°C at 0% Sasobit content to 254°C at 4% Sasobit content. This is due to increasing polymer content in the bitumen which reduces flammability properties of the bitumen and hence flash point. The specific gravity of the bitumen increased from 1.04 to 1.06 with increasing Sasobit content in bitumen. In order to ensure the reliability of the data obtained from the penetration test, stability tests were conducted and the resulted presented as shown in Table 2. The results agreed with the penetration values where addition of Sasobit increased the hardening of the bitumen. The values of Marshall stability increased with increasing Sasobit content from 9.9 kN at 0% Sasobit content to 13.9 kN at 4% Sasobit content.

The increase in Marshall stability value of the modified bitumen will be beneficial to the service life of the pavement by increasing pavement resistance to rutting resulting from extreme wheel loads and high difference in temperature between seasons and even in day and night of the same day. The increasing polymer content will enhance the viscoelastic properties of the mix thereby reducing fatigue stress in the asphalt mix and increasing its ability to flow at high temperatures without cracking.

Table 2: Results of Modified Properties of Bitumen

Sasobit Content (%)	Penetration @ 25°C (1/10mm)	Softening Point (°C)	Flash Point (°C)	Specific Gravity @ 25°C	Marshall Stability (kN)
0%	63.2	49.3	275	1.04	9.9
1.0%	48.3	60.4	272	1.042	10.9
1.50%	44.8	64.6	272	1.045	11.4
2.0%	39.3	68.6	269	1.048	11.9
2.50%	33	74.6	269	1.05	12.4
3.0%	27	77.7	265	1.053	12.9
3.50%	25	83	260	1.055	13.4
4.0%	22	85.4	254	1.06	13.9

4. Conclusion

From the outcome of the research, the following are the conclusion:

- (1) Properties of bitumen such as softening point, specific gravity and Marshall stability increased with increasing Sasobit content in the modified bitumen, as such penetration and flash point decreased with increasing Sasobit content.
- (2) The decrease in softening point in the modified bitumen as Sasobit content increased can be attributed to increased melting point of the polymerized bitumen. This attribute will help mitigate the effect of temperature variation on bitumen especially in tropical regions like Nigeria.
- (3) The results show that a decrease in the penetration of bitumen due to the hardening of modified bitumen with increasing Sasobit content increases its resistance to shoving and rutting under direct wheel load.
- (4) Generally, modification of bitumen with Sasobit improves the rheological and strength properties of bitumen and hence enhances its use as wearing and binding course in road pavement.
- (5) By incorporating Sasobit modified bitumen into asphaltic concrete, it confers an advantage on it over an unmodified mix in terms of cost and elongation of pavement's service life.
- (6) Based on practice in the industry and field experience, the authors recommend Sasobit content at 2.5% for use as additive in road construction. Further research is recommended to determine how further increase in Sasobit content beyond the 4% as used in this study will affect the rheological and strength property of modified bitumen as well as ascertain the percentage of Sasobit in modified bitumen for use in asphaltic concrete that will be optimum.

References

- BS EN 1426:2015 - Method for determining the consistency of bitumen and bituminous binders
- BS EN 1427:2015. Bitumen and bituminous binders — Determination of the softening point — Ring and. Ball method.
- BS EN 12620:2002+A1:2008 – Specification for the properties of aggregates and filler aggregates obtained by processing natural, manufactured or recycled materials and mixtures of these aggregates for use in concrete.
- BS EN 12697-34:2020 - Specification for determination of the stability, flow and the Marshall quotient values of specimens of bituminous mixtures
- BS EN 15326:2007+A1:2009 – Specification for determination of density and specific gravity of bitumen and bituminous binders.
- BS EN 22592:2000 - Methods of test for petroleum and its products part 403. petroleum products - determination of flash and fire points - Cleveland open cup method
- Busari, A., Adeyanju, E., Loto, T., & Ademola, D. (2019). Recycled aggregate in pavement construction: Review of literatures. *Journal of Physics: Conference Series* 1378(2), 13p, DOI: 10.1088//1742-6596/1378/022026
- Chompoorat, T., & Likitlersuang, S. (2015). Laboratory Investigation of Hot Mix Asphalt Behaviour for Mechanistic-Empirical Pavement Design in Tropical Countries. 46, p. 8.
- Emesiobi, F. C. (2000). Bitumen and Tars Testing and Quality Control of Materials in Civil and Highway Engineering, Port Harcourt, Nigeria. Blue Print Limited, pp. 182-184.
- Fontes, L. P. T. L., Trichês, G., Pais, J. C., & Pereira, P. A. A. (2010). Evaluating permanent deformation in asphalt rubber mixtures. *J. Constr. Build. Mater.*, 24: 1193-1200.
- Hurley, G. C., & Prowell, B. D. (2005). Evaluation of Sasobit R for use in warm mix asphalt. Auburn, AL: National Center for Asphalt Technology (NCAT).
- Jamshidi, A., Hamzah, M. O., & You, Z. (2013). Performance of warm mix asphalt containing Sasobit R: State-of-the-art. *Constr. Build. Mater.* 38:530 - 0553.
- Kheradmand, B., Muniandy, M., Hua, L. T., Yunus, R. B., & Solouki, A. (2014). An overview of the emerging warm mix asphalt technology. *Int. J. Pavement Eng.* 15:79–94. doi:10.1080/10298436.2013.839791.
- Kolo, S. S. (2021). Highway and Transportation Engineering II class note. Civil Engineering department. Federal University of Technology, Minna.
- Mumma, S. N., & Muktar, S. (2001). Improving road pavements with natural rubber. *Journal of Engineering Technology and Industrial Applications*, (1)3; 208-220.

- Polaczyk, P., Huang, B., Shu, X., & Gong, H. (2019). Investigation into Locking Point of Asphalt Mixtures Utilizing the impact and Compactors method. *Construction and Building Materials*. ISSN 0950-0618. S2CID 115423703.
- Shehu, M. (2019). Highway and Transportation Engineering I class note. Civil Engineering department. Federal University of Technology, Minna.
- Shehu, M., Jimoh, O. D., Kolo, S. S., & Adeleke, O. O. (2020). Frequency and vehicle capacity determination of Bosso and Gidan Kwano campuses, Federal University of Technology, Minna: A literature review.
- Silva, H. M. R. D., Oliveira, J. R. M., Ferreira, C. I. G., & Pereira, P. A. A. (2010a). Assessment of the performance of warm mix asphalts in road pavements. *J. Pavement Res. Technol.* 3:119–127.
- Soloukia, A., Muniandya, R., Hassima, S., & Kheradmanda, B. (2015). Rheological Property Investigation of Various Sasobit-modified Bitumen. *Petroleum Science and Technology*, 33:7, 773-779.
- Xiao, F., Amirkhanian, S. N., & Zhang, R. (2012). Influence of short-term aging on rheological characteristics of nonfoaming WMA binders. *Journal of Performance of Constructed Facilities* 62:25–541.