INVESTIGATING THE USE OF GUM ARABIC BIOPOLYMER AS BITUMEN MODIFIER

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Abstract

Polymer modification of bitumen is increasingly popular for enhancing pavement performance to meet global construction standards. Conventional binders often fail due to issues like rutting, cracking, and temperature susceptibility. Due to environmental, safety, and economic concerns with petroleum-based polymers, biopolymers like Gum Arabic are becoming preferred alternatives. Gum Arabic biopolymer is used to modify bitumen to improve its engineering, mechanical, thermal, and rheological properties. Tests such as Penetration, Softening Point, Ductility, and Marshall Stability are conducted on both virgin and modified binders, with Gum Arabic added in varying percentages (2%, 4%, 6%, 8%, and 10%).The study found that adding up to 4% Gum Arabic (GA) improves the penetration grade of bitumen. However, ductility and softening point decrease as GA content increases, while flash point and viscosity increase. The fire point remains unaffected by GA. A 4% GA content is recommended for construction, though further research is needed to fully understand GA's effects in asphalt.

KEYWORDS: *Gum Arabic, Biopolymer. Bitumen,*

1.1 INTRODUCTION

Bitumen is a complex material with a complex response to stress. All bitumens show more or less pronounced viscoelastic behaviour. Their resistance to deformation is dependent on both the temperature and time during which a force is applied. Only under extreme conditions can a bitumen behave either as a typical elastic solid (low temperature very short loading time) or as a viscous liquid (high temperature, long loading time). Under normal temperature conditions, both viscous and elastic behaviour play their part. Bitumen is widely used in the construction of asphalt roads and bituminous membrane products. Bitumen is commonly used to build highways, motorways and rail networks. Bitumen has excellent water-proofing properties and is widely used for making roofing products along with a range of other household and industrial applications, from emulsion paints to sound-proofing. Penetration Bitumen and Bitumen Emulsions are used for the construction of railway tracks and by using special types of bitumen such as Polymer Modified Bitumen, the vibration and noise levels are reduced due to a dampening effect. Bitumen has been proven to be effective on both high-speed railway tracks and heavy load railway tracks. Bitumen is also used for surfacing airfield runways and air strips.

Gum Arabic is dried exudates obtained from stems and branches of Acacia Senegal trees which are cultivated in the Sudan as a cash crop in agroforestry systems (Duke, 1981). Gum Arabic is named after its geographic location. Acacia trees are indeed present in a wide belt of semi-arid land stretching across sub-Saharan Africa, Sudan being the largest producer (Islam *et al*, 1997). Gum Arabic is a natural product complex mixture of hydrophilic carbohydrate and hydrophobic protein components (FAO, 1990). Gum Arabic is used as an emulsifier and stabilizer in the food and pharmaceutical industries (Osman *et al.,* 1993).The gum Arabic agroforestry system is practiced as a means of restoring the soil fertility and promoting gum Arabic production (FAO, 2007).Gum Arabic is regarded as sustainable in terms of its environmental, social and economic benefits (Franzel*et al*., 2001). In addition, Ashraf (2001) investigated the effect of Gum Arabic liquid in concrete mixes to obtain high compressive strength concrete and good workability.

Extensive studies have shown that gum is useful in industrial applications such as food and beverages, pharmaceuticals, cosmetics and textiles. The gum tree is known to offer a number of environmental benefits, the most important include its extensive lateral root system that reduces soil erosion and run off and as a leguminous tree it fixes nitrogen which improves soil fertility (Gambo, 2007). However, due to underutilization of gum Arabic, the population of gum Arabic species are believed to have reduced over the years, as a result of the increasing demands for fuel wood, fencing posts and overgrazing in the Sahelian zones of Nigeria (Giroh*et al.,* 2008). However, utilizing gum Arabic in civil Engineering material could encourage farmer to grow more trees and hence conservation of more species of trees.

Researchers have been conducted on the adoption and effects of gum Arabic agroforestry in Nigeria (Odo and Oleghe, 1988; Giro *et al*., 2008). However, there has not been any empirical study into the effects of gum Arabic on the properties of bitumen. This study was therefore, designed to assess the effects of gum Arabic boipolymer as modifier in bitumen.

2.0 REVIEW OF RELATED WORKS/FINDINGS

2.1 POLYMER MODIFIED BITUMEN

Modified bitumen with polymer offers a combination of performance related benefits the physical properties of the bitumen are improved without changing the chemical nature of it. These modified bituminous binders are reported to have produced softer mixtures at low service temperature to minimize non-load associated thermal cracking. Further, improved fatigue resistances of the bituminous mixes, overall improved performance in extreme climatic conditions and under heavy traffic conditions, reduced life cycle cost of the pavement have been also reported in the literature.

Polymer modified bitumen increases the elasticity of the mix and also increases viscosity at higher temperature (King *et al*.,1986). The viscosity helps to limit the deflection while the elastic recovery reduces the residual formation. The elastic surface layer bridges the cracks from unmodified layers underneath, thus, maintains the water-tight nature of the Asphalt and protects the underlying structure. (King *et al*., 1986**)** also carried out a test for testing the rutting resistance and it was found that the PMB was able to withstand 4-10 times more loading cycles before ruts of various specified depths.

Terrel and Walter (1986) have showed that polymers provide considerable improvement in the physical properties of binder –aggregate combinations. However, the improved properties of the PMB should be made use of in order to have increased servicelife and the thickness should not be reduced on the pretext of using PMB.

Valkcring *et al.* (1990) reported that the utility of the dynamic creep test for better prediction of the strain rate in polymer modified bituminous mixes. The rut depths were calculated under the wheel loading in the laboratory test track tests. It has been shown that satisfactory correlation between the rate of residual strain and rutting rate exists.

Collins *et al.* (1991) reported that selection of appropriate asphalt is essential to obtain a blend with optimal properties. Improved compatibility leads to many advantages. Further, it has been proved that the effectiveness of the added polymer in terms of elastic recovery dropped from a soft to a hard binder.

Lenoble and Nahas (1994) showed that the addition of polymer not only increases the application temperature range of asphaltic binders but also increases the traffic resistance. Further, it was also discussed that the thermal cracking resistance of a pavement is controlled by the temperature at which the binder reaches a modulus close to its glassy modulus.

Oliver and Tredrea (1997) presented test results of dynamic shear rheometer on PMB. It was found that long-term laboratory exposure at a temperature below the maximum encountered in pavement service resulted in large changes in the rheological behavior of the PMB and these changes were likely to reduce the advantages which fresh PMBs have over unmodified bitumen in service. Also, Kumar et al. (2004) carried out study for the properties of polymer modified binder and it has been shown that Styrene ButadieneStyrene (SBS) polymer modified binder has better elastic recovery as compared to LinearLow Density Polyetheylne (LLDPE) binder.

Punith *et al.* (2005) studied the effect of various factors on resilient modulus of elasticity under repeated load indirect tensile tests. These studies were carried out on conventional 80/100 grade bitumen and bitumen modified with polyethylene and crumb rubber separately.

2.2 GUM ARABIC

According to (Abdullahi, 2004), GUM ARABIC is the dried exudates obtained from the stems or branches of Acacia Senegal or closely related species. It is a natural gum harvested from the exterior of Acacia trees in the form of dry, hard nodules up to 50mm in diameter and ranging from almost colorless to brown.

The plant tolerates water deficit and therefore able to endure conditions of prolonged drought associated with the arid region of Nigeria. The Gum Arabic growing states, in Nigeria, include Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara states. Globally, the majority of Gum Arabic found in International markets originates from the Gum belt of sub-Saharan African with Sudan accounting for about 80% of the world production and 60% of the market. Nigeria is the second largest after Sudan. Gum Arabic plant serves as a fodder and for environmental protection including soil stabilization improvement, (Abdullahi, 2004).

Gum Arabic is unique among the natural hydrocolloids because of its extremely high solubility in water. Gum Arabic is insoluble in oil and in most organic solvents. It is soluble in aqueous ethanol up to a limit of about 60% ethanol. Limited solubility can also be obtained with glycerol and ethylene glycol. Whereas most gums form highly viscous solutions at low concentrations of about 1-5%. High viscosities are not obtained with Gum Arabic until concentrations of about 40-50% are obtained. This ability to form highly concentrated solution is responsible for the excellent stabilizing and emulsifying properties of Gum Arabic when incorporated with large amounts of insoluble matters. The viscosity of Gum Arabic solutions will depend upon the type and variety of the Gum Arabic used. At concentration up to 40%, Gum Arabic solutions exhibit typical Newtonian behavior. Above 40%, solution takes up pseudoplatic characteristics as denoted by a decrease in viscosity with increasing shearing stress, (Benecke, 2009). In Nigeria, Gum Arabic is classified into 3 grades namely. i. Acacia Senegal (grade 1) ii. Acacia Seyel (grade 2) iii. Combretum and other source, (Abubakar, 2004).

Gum Arabic is mainly produced from two Acacias that are found to a varying intensity in the belt of sub-Saharan Africa. The Acacias are; Acacia Senegal that produces hard gum and Acacia Seyel that produces friable gum, (Macrac and Miller, 2002).The Gum Arabic of commercial is water soluble exudates. The major source (95%) is Acacia Senegal while the remaining 5% is from Acacia Seyel, which are sold as an entirely separate product. Both trees species grow in various communities in the drier parts of Africa and Asia, Seifel (1969).

3.0 MATERIAL AND METHODS

3.1 Material

A. Gum Arabic: The gum Arabic was obtained in a popular known kurmi market in Kano, Nigeria. The gum Arabic was grounded in powder and diluted with water to form emulsion of equivalent penetration as the bitumen.

Gum Arabic

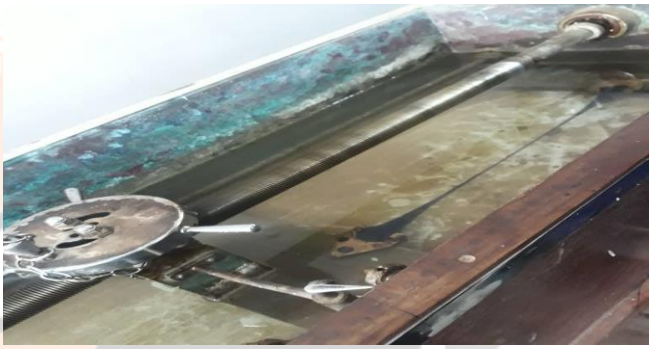
B. Bitumen: The bitumen used for this research is dark brown in colour. It was obtained from the bulk supply in Dantata and Sawoe Nigeria Ltd purchased for road construction.

Bitumen

3.2 Methods

For the purpose of this investigation, the following tests were conducted;

- **a)** Penetration Test:
- **b)** Ductility Test:
- **c)** Bitumen Tests-
- **d)** Softening Point Test:
- **e)** Viscosity Test:
- **e)** Bitumen Tests- Flash and Fire Point Test:.



CONDUCTING OF BITUMEN TESTS

4.0 TEST RESULTS AND DISCUSSION

Tests	**Gum Arabic (%)**					
	0	**2**	**4**	**6**	**8**	**10**
Penetration (mm)	58	54	50	59	66	78
Ductility (cm)	86	81	75	71	65	59
Softening point (ºC)	61	55	47	45	40	40
Viscosity (Seconds)	710	725	748	788	820	822
Flash point (ºC)	145	153	160	167	169	173
Fire point (ºC)	187	188	190	185	187	184

The results from the investigations were presented in Figure 3.1 to 3.5. Figure 3.1 shows that the penetration grade of bitumen was improved from 0 to 4 % Gum Arabic (GA) content and later decline. However, this trend is not same with the effects of GA on the ductility of the bitumen as shown in Figure 3.2. The figure shows that addition of GA reduces the ductility of bitumen.

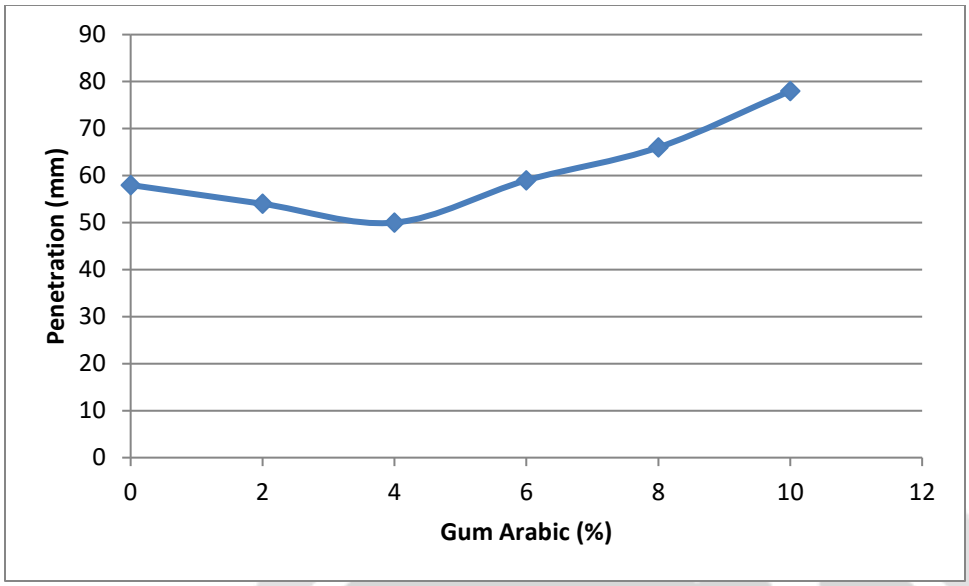


Figure 3.1: Effects of Gum Arabic on the Penetration of Bitumen

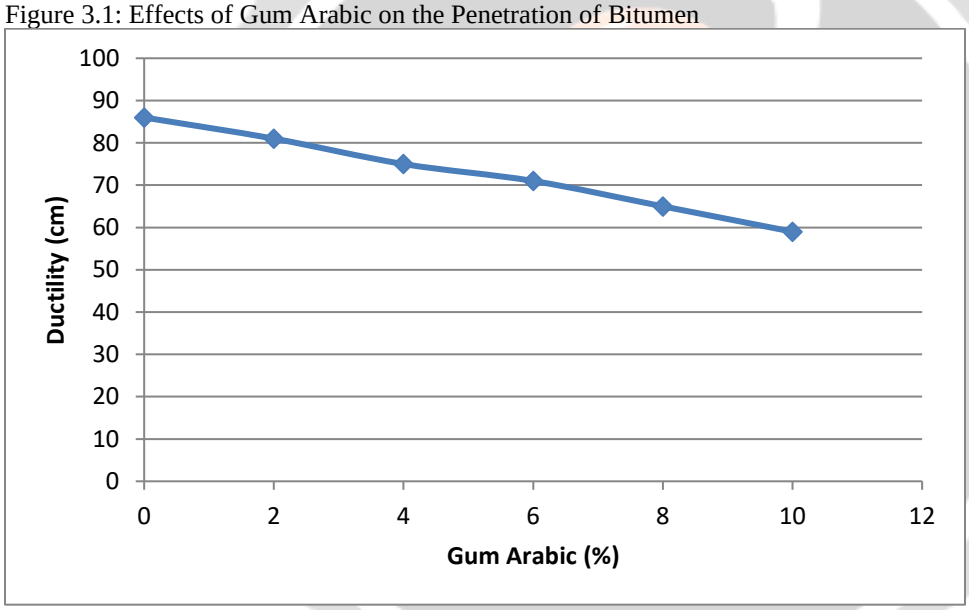


Figure 3.2: Effects of Gum Arabic on the Ductility of Bitumen

The effect of GA on the softening point of bitumen is presented in Figure 3.3. The figure shows that the softening temperature of the bitumen reduces with increase in GA content. The reduction could be attributed to dilution effect of the GA in water. GA is soluble in water. The solubility increases at higher temperature.

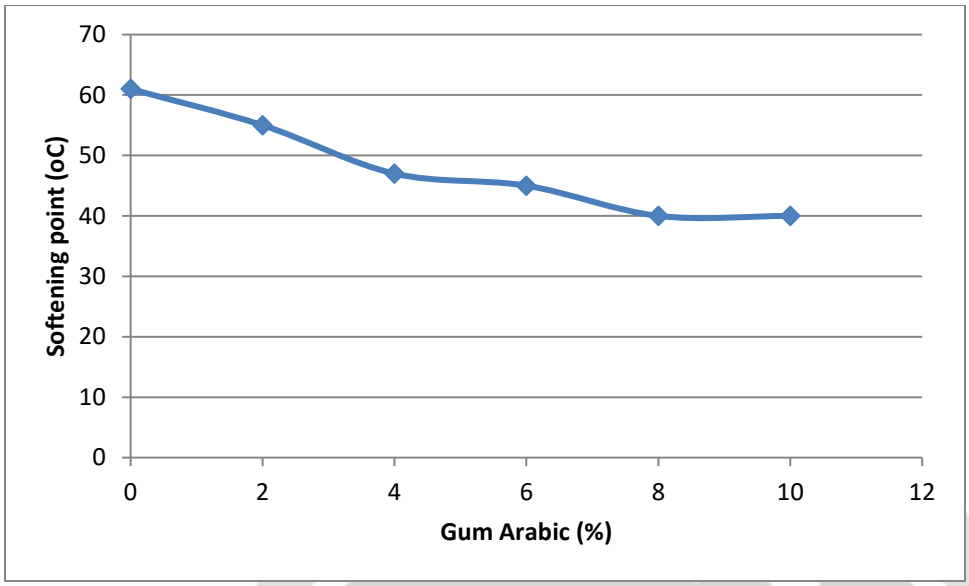


Figure 3.3: Effects of Gum Arabic on the Softening Point of Bitumen

The flash and fire points of GA modified bitumen is presented in Figure 3.4. The flash point increases with crease in GA content. The increase could be attributed to differential effect of temperature of the bitumen and GA. However, this behaviour is not so at higher temperature to an approximate fire point. The fire point was approximately constant. This could be attributed to the effect of complete decomposition of GA in the mixture.

The effects of GA on the viscosity of bitumen is Presented in Figure 3.5. The figure shows that the viscosity of the bitumen is improved with addition of GA. The improved viscosity could be attributed to effect of chemical reaction of the viscous GA solution with water.

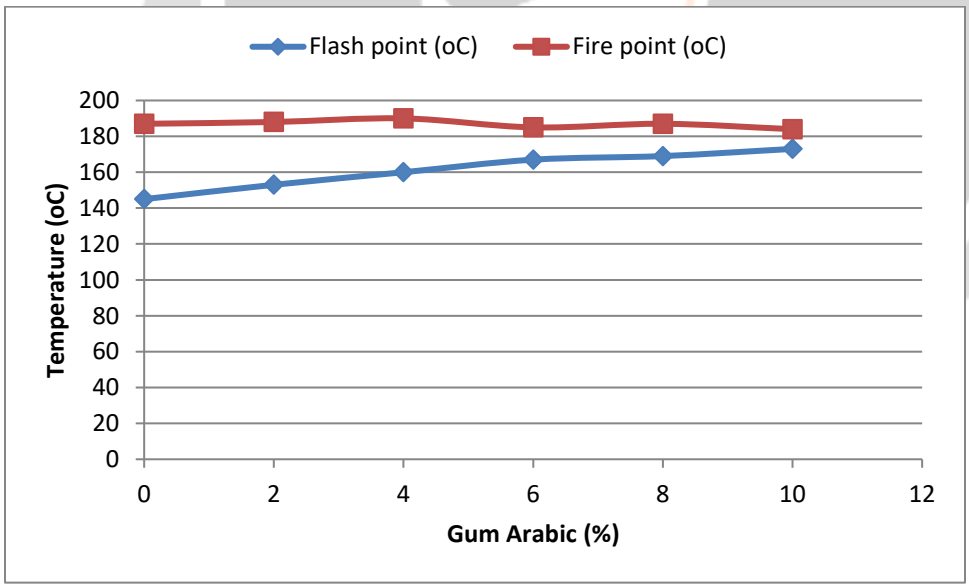


Figure 3.4: Effects of Gum Arabic on the Flash and Fire Points of Bitumen

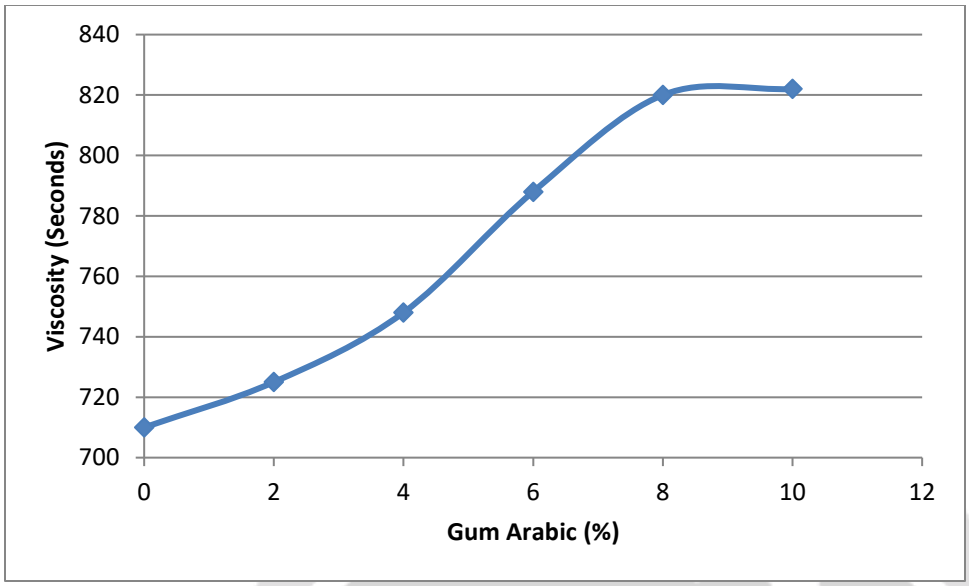


Figure 3.5: Effects of Gum Arabic on the Viscosity of Bitumen

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Base on the findings of the investigation on the properties of bitumen modified with gum Arabic biopolymer, the following deductions were made;

1. The pure bitumen was found to be grade 60/70
2. The pure bitumen test results comply with standards and within code specifications and can be used for any bituminous mix design
3. The ductility of the modified bitumen was found to increase positively, thereby increasing the resistance to cracks and ravelling.
4. The penetration grade of bitumen can be improved with up to 4 % Gum Arabic (GA) content.
5. The ductility and softening point of bitumen reduces with increase in GA.
6. The flash point and viscosity of bitumen increases with increase in GA.
7. Fire point of bitumen is not affected by addition of GA.

5.2 Recommendations

Base of the deductions of the findings, 4 % GA is recommended for use in construction. However, this is subject to further investigation of the properties of GA in bitumen when use in asphalt.

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