Forests and Forest Products Journal 10:52-59


# Assessment of Bitumen as Preservative for Treatment of Five Selected Nigerian Wood Species

OWOYEMI J. M., OWOLABI J. K. and ALADEJANA J. T.
Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria
Corresponding author: jacobmayowa@yahoo.com

**Abstract**

The search for a new preservative has been necessitated by concerns about the health and environmental hazards associated with use of conventional ones. Bituminous tar available in large quality in Nigeria was administered to evaluate its effect on resistance of *Albizia ferruginea* (ayinre), *Melicia excelsa* (iroko), *Pterygota macrocarpa* (Oporoporo), *Triplochiton sceleroxylon* (Obeche) and *Celtis zenkerii* (Ita) to termites. Wood samples of 35 × 35 × 450mm stakes were dried in the oven at 103 ± 2$^{o}$C for 24h and treated in hot bitumen at 200$^{o}$C for 6h and left overnight after the treatment. The stakes were planted at the termites' graveyard for visual and weight loss assessment after 12weeks. The bitumen attained boiling point of 200$^{o}$C with viscous flow of 0.4 $cm^3$/sec at 150°C which causes reduction in moisture content of the wood samples. Ita and Iroko had the higher density values of 565.28 and 506.7kg/$m^3$ respectively while Obeche had 405.99kg/$m^3$. There is significant difference between the resistance of treated and untreated samples at 5% level of significance. Pearson correlation coefficients of 0.922 and 0.920 for density and wood resistance showed that high density wood is more resistant to termites attack. Bitumen has proven potent as preservative for treating timber for external uses such as transmission poles, fence posts and wharf jetty.

**Keywords:** Heartwood; Sapwood; Termites; Bitumen; Graveyard

## Introduction

Termites pose a serious threat to timber products due to their wood eating habits. Termites can do great damage to unprotected buildings and other wooden structures, with damage cost running into millions dollars (Abdel and Skai, 2011). As a matter of fact, termites are known to cause more damage to woody and other ligno-cellulosic materials than any other tropical insect (Andrew, *et al.*, 1998). Therefore, there is need to adequately protect wooden materials against termite attacks, to increase their service life, reduce cost of replacement and reduce pressure on forest resources.

Extensive research has been carried out on wood treatment methods. Chemicals commonly used include creosote, chromated copper arsenate (CCA), boric acid, pentachlorophenol solution and ammoniacal copper among others (Ohio Department of Agriculture, 2003). The degree of protection achieved depends on the type of preservative used, degree of penetration and retention of preservative and the species of wood which is being treated.

In recent times research has been directed towards the use of unconventional and cheaper wood preservatives such as used engine oil and extracts from certain wood species which are resistant to termites attack (Ssemaganda *et al.*, 2011). However, little has been done on the use of bitumen for wood treatment. Nigeria has a proven bitumen reserve of 42 billion barrels spread along the 120-kilometre 'bitumen belt' running across from the mid-west to the western part of the country. This belt straddles Ondo, Ogun, Edo and Lagos states, ranking Nigeria high on a table of 15 countries that have significant deposits. So far Nigeria is believed to be the only African country boasting commercially viable residues (Nigeria First, 2003).

Bitumen is a black or dark brown, thermoplastic, hydrocarbon material that is derived from the processing of crude petroleum (Riley, 2004). It is a complex mixture of high molecular weight, non-volatile hydrocarbons which at ambient temperatures, exists as a solid. Bitumen and coal tar are often confused; they are however totally different. Bitumen is manufactured from crude oil by distillation under vacuum, whereas coal tar is derived from coal by destructive distillation at high temperatures. To facilitate ease of handling during manufacture, storage, transportation and use, it is heated and maintained in a molten state. Bitumen has a long history of safe use as a road construction and waterproofing material and has great potential for use as wood preservative. If found effective, its use will help reduce the cost and health hazards associated with wood preservation in Nigeria.

**Methods**

***The Study Area***

This research was conducted at the Department of Forestry and Wood Technology laboratory of the Federal University of Technology Akure, Ondo State, Nigeria and a timber grave yard situated within the university premises. Akure is located at longitude 5.09 °E and latitude 7.18 °N in the South-western part of Nigeria. Its average annual rainfall is about 1524 mm and temperature varies from 28 °C to 31 °C, while the mean annual relative humidity is about 80%.

***Procurement and Preparation of Wood Samples***

Five indigenous wood species namely: *Albizia ferruginea* (ayinre), *Melicia excelsa* (iroko), *Pterygota macrocarpa* (oporoporo), *Triplochiton sceleroxylon* (obeche) and *Celtiz zenkerii* (ita) were sourced from a sawmill in Akure. The sap and heart wood of these species were obtained from freshly sawn logs. Ten samples of the sap and heart wood for each wood species were cut into 35 × 35 × 450 mm. In addition, five samples of sap and heart wood of each species were cut into sizes 20 × 20 × 60 mm for density determination. All samples were planned to remove rough edges, labeled for easy identification and weighed using a weighing balance (green weight). The samples were then oven dried at 103 °C for 24 h.

***Wood Treatment***

Five samples of sap and heart wood of 35 × 35 × 450 mm dimension from each wood species were treated with bitumen while the remaining five sap and heart wood were used as control (without treatment). The bitumen was heated in a metallic pot until it completely melted and flowed easily. Treatment was done by dipping wood in a container of hot bitumen and leaving for 24 h to cool. The solidified bitumen was then reheated after 24 h to ensure easy removal of the wood samples. Treated samples were then allowed to drain, dry and cool. The treated samples were weighed and their percentage absorption was calculated using:

$$A = \left(\frac{T3 - T2}{T2}\right) \times 100 \ [\%]$$

equ. (1)

Where;

$A$ = absorption

$T_3$ = weight of sample after treatment (g)

$T_2$ = weight of sample before treatment (g)

Figure 1: Treated wood samples

***Determination of the Properties of Bitumen***

Tests were carried out on the bitumen used for this research to determine its viscosity, boiling point and density. The boiling point was determined by heating bitumen in a container and measuring the temperature at which bubbles were formed using a thermometer. To determine its density, one liter of bitumen was poured in a container whose weight had earlier been determined and then the total weight (bitumen + container) was measured using a digital weighing balance. The density of bitumen was then calculated using equation 2.

$$Density\ of\ Bitumen = \frac{Total\ mass - mass\ of\ container}{Volume\ of\ bitumen}\ [g]$$

equ. (2)

Viscosity test was carried out at 100 $^{o}$C using Zhan viscosity flow cup with an orifice diameter 3.00 mm in accordance with ASTM D 4212. The cup was filled with hot bitumen while blocking the orifice with metallic plate. Thereafter, the metallic plate was removed and bitumen flow was timed with a stop watch till the flow broke up. The volume of bitumen that flowed out of the Zhan cup was measured and the experiment was repeated thrice. The average value of viscosity was recorded in cm3/sec.

***Field Test***

Both treated and untreated wood samples (used as control) of each of the five wood species were buried at a depth of 225 mm below the ground surface and at a spacing of 100 mm by 100 mm. The samples were inspected weekly for a period of 12 weeks to assess their condition. The samples were rated visually for termite attack using ASTM (1980) on a scale of 0 to 10.

**Table 1: Visual Assessment of Wood Samples for Termite Attack:**

| Nature of Termite Attack | Rating |
|---|---|
| Sound, surface nibbles permitted | 10 |
| Light attack | 9 |
| Moderate attack | 7 |
| Heavy attack | 4 |
| Failure | 0 |

At the end of the twelve weeks, all the samples were re-weighed to assess the extent of attack by termites. Weight loss due to termites attack was calculated using;

$$WL = \left(\frac{T_3 - T_4}{T_3}\right) \times 100\ [\%]$$

equ. (3)

Where;

$WL$ = Weight loss

$T_3$ = weight after preservative treatment

$T_4$ = weight after termites attack

Figure 2: Field test at timber grave yard

**Statistical Analysis**

The data collected was subjected to descriptive statistics, while Analysis of Variance (ANOVA) carried out to determine whether there was significant difference in termite resistance between treated and untreated wood species at 5 % level of significance. Weight difference between exposed and unexposed wood samples was used as the response variable while wood species and treatment type were used as factors. Pearson correlation analysis was also carried out to determine whether there was a relationship between density of wood and its natural durability.

**Results and discussions**

***Properties of Bitumen and Wood Species***

Properties of bitumen obtained for this research is shown in Table 1. The bitumen had a density of 1007.97 kg/m$^3$ and attained a boiling point of 200°C. At 150°C bitumen had a viscosity of 0.4 cm$^3$/sec. The result of density determination for the five wood species is presented in Table 2. The mean density values of Ayinre, Iroko, Oporoporo, Obeche and Ita were 565.28 and 557.86 kg/m$^3$, 630.44 and 532.06 kg/m$^3$, 506.7 and 504.82 kg/m$^3$, 405.99 and 334.48 kg/m$^3$, 690.63 and 686.08 kg/m$^3$ for heartwood and sapwood respectively. It could be observed that for heart wood, Ita and iroko had highest density, Ayinre and Oporoporo had medium density while Obeche had a low density. On the other hand for sap wood, Ita had the highest density followed by Ayinre, Iroko, Oporoporo which had a medium density then Obeche with low density. The relationship between mean density, weight loss and ASTM rating of wood samples during 12 week exposure to termite showed that high density species had the lowest weight loss value and corresponding high ASTM values. These results are in consonance with Owoyemi *et al*., (2013) which classifies wood density into high, medium and low and that there is a strong relationship between ASTM and density of wood species stating that, high density wood species have a high ASTM value.

**Table 2: Properties of Bitumen**

| Property | Value |
|---|---|
| Boiling Point | 200$^o$C |
| Density | 1007.97 kg/m$^3$ |
| Viscosity | 0.4 cm$^3$/sec at 150$^o$C |

**Table 3: Density of Wood Species**

| Specie | Heartwood (kg/m$^3$) | Sapwood (kg/m$^3$) |
|---|---|---|
| Ayinre | 565.28 | 557.86 |

| | | |
|---|---|---|
| Iroko | 630.44 | 532.06 |
| Oporoporo | 506.7 | 504.82 |
| Obeche | 405.99 | 334.48 |
| Ita | 690.63 | 686.08 |

***Absorption of bitumen preservative by the selected wood species***

The results of bitumen absorption by the wood samples are shown in Table 4. The preservative treated wood showed a decrease in weight as against the conventional increase. The decrease in weight could be attributed to further reduction in moisture content of the wood samples during hot preservative treatment with bitumen due to thermal modification. The high temperature of 200 °C at which bitumen boils imparted a level of thermal modification on the wood resulting in loss in weight of the wood samples. Validation test was carried out after this observation and the same result was confirmed, therefore, instead of percentage weight gain, there was decrease in weight. Visual observation of the cross section of treated species however showed that there was penetration of bitumen to the wood. Juanito *et al.*, (2011) stated that subjecting wood to temperatures that ranges between 180 °C to 260 °C for several hours brings about thermal modification of the wood. High temperatures initiate chemical reactions in the cell walls which result in degradation of cellulose, degradation of hemicelluloses, modification of lignin. Niemz *et al.*, (2010) also noted that equilibrium moisture content is lowered by thermal modification.

**Table 4: Absorption of Bitumen by Wood Samples**

| Species | Heartwood (%) | Sapwood (%) |
|---|---|---|
| Ayinre | - 12.47 | - 1.47 |
| Iroko | - 3.58 | - 2.58 |
| Oporoporo | - 8.67 | - 14.07 |
| Obeche | - 4.74 | - 6.01 |
| Ita | - 4.38 | - 5.27 |

***Resistance of the selected wood samples to termites attack***

A comparison of the 12th week visual rating of the wood species is shown in Figure 1. The results showed that treatment with bitumen greatly increased the termite resistance of the five wood species under study. It could be observed that Ita had the highest overall natural durability; the 12th week visual rating of the untreated heart and sapwood being 9.4 and 9 respectively. On the other hand, Obeche had the lowest natural durability, with a visual rating of 0 on the 12th week for both untreated sap and heartwood. Oporoporo and Ayinre had moderately high natural durability. The 12th week visual ratings of Oporoporo were 6.8 and 5.2 for untreated heart and sapwood respectively, while those of Ayinre were 6.6 and 6.4. The heartwood of Iroko had a very high natural durability (12th week rating of 9.8), however its sapwood is not very durable (12th week rating of 3.4). Comparing Table 3 and Figure 1, it was observed that higher density wood is more durable than lower density wood which is in consonance with the work of Owoyemi *et al.*, (2013) which deduced that the higher the density of a wood species, the greater the natural resistance. Pearson correlation coefficient for heartwood and sapwood were shown in Table 3 and 4. Pearson correlation coefficients of 0.922 for heartwood and 0.920 for sapwood showed that wood species with higher densities have higher natural durability. This result agrees with that of Owoyemi *et al.*, (2011).

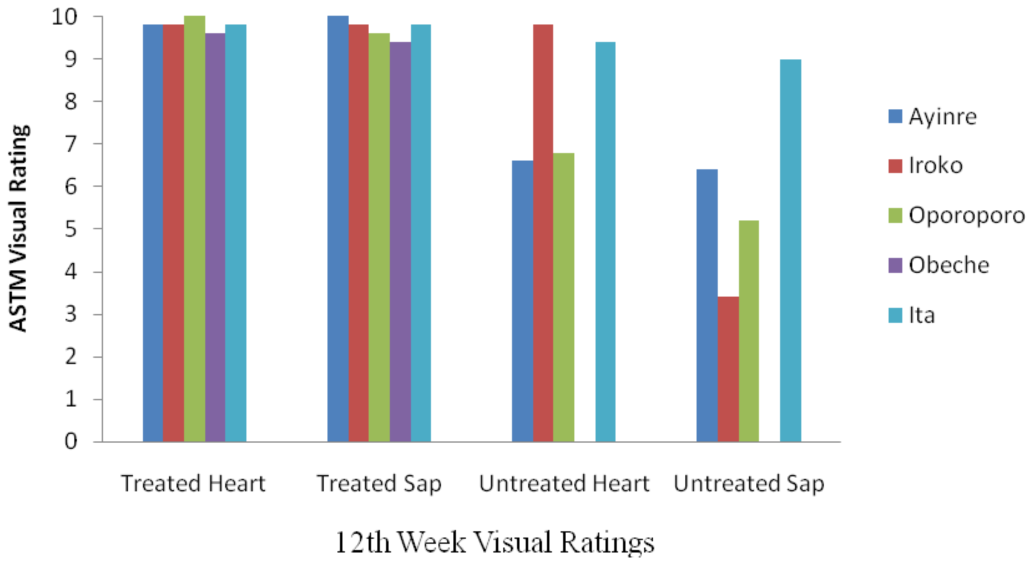


Figure 3: ASTM visual rating of the wood species after 12 weeks

**Table 5: Correlations for Heartwood**

| | | ASTM Rating | Density |
|---|---|---|---|
| Rating | Pearson Correlation | 1 | .922 |
| | Sig. (2-tailed) | | .026 |
| | N | 5 | 5 |
| Density | Pearson Correlation | .922 | 1 |
| | Sig. (2-tailed) | .026 | |
| | N | 5 | 5 |

**Table 6: Correlations for Sapwood**

| | | ASTM Rating | Density |
|---|---|---|---|
| Rating | Pearson Correlation | 1 | .920 |
| | Sig. (2-tailed) | | .027 |
| | N | 5 | 5 |
| Density | Pearson Correlation | .920 | 1 |
| | Sig. (2-tailed) | .027 | |
| | N | 5 | 5 |

***Effect of bitumen on the resistance of the treated wood species after 12 weeks of termites' exposure***

The result of Analysis of Variance carried out to determine whether there is significant difference in termite resistance between treated and untreated wood species is shown in Tables 7 and 8. The dependent variable used for ANOVA was the weight difference in the wood samples after termite exposure. The ANOVA results showed that termite resistance is dependent on wood treatment and there is significant difference between the resistance of treated and untreated samples ($P < 0.05$). Termite resistance is also dependent on the wood species ($P < 0.05$) for both heart and sap wood. Two way ANOVA test for interaction showed that termite resistance varied differently with wood treatment for various wood species and ($P < 0.05$) for both heart and sap wood.

**Table 7: ANOVA for comparing Termite Resistance of Sapwood of Treated and Untreated Species**

| Source | Df | Sum of Squares | Mean Square | F-cal |
|---|---|---|---|---|
| Treatment | 1 | 134480.240 | 134480.240 | 104.968* |
| Species | 4 | 26780.961 | 6695.240 | 5.226* |
| Treatment * Species | 4 | 27948.845 | 6987.211 | 5.454* |
| Error | 40 | 51246.224 | 1281.156 | |
| Corrected Total | 49 | 240456.271 | | |

*Significant (p<0.05) probability level

**Table 8: ANOVA for comparing Termite Resistance of Heart Wood of Treated and Untreated Species**

| Source | Df | Sum of Squares | Mean Square | F-cal |
|---|---|---|---|---|
| **Treatment** | 1 | 83303.007 | 83303.007 | 241.168* |
| **Species** | 4 | 42508.337 | 10627.084 | 30.766* |
| **Treatment * Species** | 4 | 41766.984 | 10441.746 | 30.230* |
| **Error** | 40 | 13816.592 | 345.415 | |
| **Total** | 49 | 181394.919 | | |

*Significant (p<0.05) probability level

**Conclusions**

Bitumen has proved potent as preservative for treating timber for external applications such as transmission poles, fence posts and wharf jetty. The field test results showed that treatment with bitumen greatly increased the termite resistance of the five wood species under study. From the results obtained, it is evident that bitumen is a very effective preservative for protection of wood against termite attack. Therefore, availability of bitumen in large quantity will be a viable means of preserving wood particularly for external applications.

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