Original Research Article

ANALYSING THE EFFECT OF ACETYLATION ON SOME STRENGTH PROPERTIES OF DANTA (*Nesogordonia papaverifera*) AND ANANTA (*Cynometra Ananta)*

Abstract

Dimensional stability and durability of wood can be improved by chemical modification. However, some strength properties are reduced, increased or not affected depending on the type of chemical used. Caution must be taken on longitudinal shrinkage of wood if it is to be used as engineering material in structure design since longitudinal stability is necessary. The two high density tropical hardwood species, *Nesogordonia papaverifera* and *Cynometra Ananta* which can be used for construction were acetylated and the impact of the modification on the modulus of elasticity (MOE), modulus of rupture (MOR) and compression parallel to the grain (CPG) were analysed. The results indicated that the weight percentage gain (WPG) of 15.92 and 15.20 for acetylated *Nesogordonia papaverifera* and *Cynometra Ananta* respectively had no significant change in MOE and MOR. The modification resulted in an increase in CPG by +15.71 and +12.92 for the modified *Nesogordonia papaverifera* and *Cynometra Ananta* respectively.

Keywords: Chemical modification, strength properties, modulus of elasticity, modulus of rupture, compression parallel to the grain

1.0 Introduction

Dimensional changes and durability are major factors that limit the application of wood especially when used as an engineering material. Some tropical lesser-used hardwood species which is available in the forests of Ghana in large quantities [1, 2] are associated with low dimensional stability [3]. Large number of these wood species are also non-durable, however, chemical modification improved the durability of *Celtis mildbraedii,* a lesser-used wood species which are in large quantities in the forest of Ghana [2, 3]. Most of these species are high density hardwoods that could be used for construction. According to [2], the range of total longitudinal shrinkage of some of these lesser-used species is between 0.2 and 0.3 and attention is therefore required when using these species as engineering materials in structural design where longitudinal stability is necessary. The range of total longitudinal shrinkage of Danta (*Nesogordonia papaverifera*) and Ananta (*Cynometra Ananta*) is between 0.2 and 0.3 [2].

The colours of the heartwood and sapwood of *Nesogordonia papaverifera* are red to brown and pale red to brown respectively with basic density of 740 kg/m^3 and is converted into lumber, veneer and plywood and it is used for joinery, flooring, cabinet, paneling and furniture [1].

The colours of the heartwood and sapwood of *Cynometra Ananta* are dark red with darker streaks and pink to brown respectively. It has a basic density ranging between 910 and 1000 kg/m3 and is used for conversion into lumber and poles [1]. It is used for flooring, heavy construction, furniture, joinery and furniture.

Acetylation is a chemical modifications process that results in a covalent bond [4] by substituting hydroxyl groups in the wood cell wall polymers and bulk the cell wall as well thereby reducing absorption of water by hydrogen bonding into the wood cell walls [4, 5]. Chemical modification of wood improves durability and reduces dimensional changes [4, 6, 7] and some researchers have reported an improvement in some strength properties with certain anhydrides [8]. Others have also reported reduction and no effect on some strength properties of wood with some anhydrides [7]. Acetylation of hardwoods and softwood gave products with high dimensional stability, improved durability and the strength properties did not reduce [8]. According to [9], information of the impact of chemical modification on mechanical properties of wood that is important when using the modified wood as engineering material is limited. According to [7], modification of fibre boards with malic anhydride using phenol formaldehyde as a binder reduced MOR but when polupropylene was used as a binder there was a general increased in mechanical properties. Modification with acetic anhydride and succinic anhydride showed no change on MOR [7]. The objective of this work was to acetylate *Nesogordonia papaverifera* and *Amphimas pterocarpoides,* and analyse its effect on their MOE, MOR and CPG.

2.0 Materials and methods

2.1 Wood source

The trees of the species were felled at the breast height diameter of 1.3 metres from the Bia District located in the Western region of Ghana. Logs for the work were processed at John Bitar sawmill Company located in Takoradi, Ghana.

2.2 Wood Samples Preparation

Small samples free from defects were taken from the heartwood. The samples were randomly taken at 5cm away from the sapwood toward the pith. Sample dimensions for the MOE and MOR were 20×20×300mm and for CPG were 20×20×60mm.

Chemical modification of wood samples.

Modification processes described by [10] was used. Soxhlet extraction of the samples was carried out using toluene: methanol: mixture in the ratio of 4:1:1 respectively for 8 hours. The samples were dried at a temperature of 105^{o}C (±5°C) overnight and allowed to cool to room temperature over silica gel. Weight of the samples were taken and impregnated with 1M solution of acetic anhydride in pyridine at 100°C (±5°C) for 8 h. After 8 hours impregnation, samples were placed in cold acetone to stop the reaction. Soxhlet extraction was carried out again to remove unreacted acetic anhydride. The control samples were carried out in the same processes described above but distilled water was used instead of the acetic anhydride. Samples were, oven dried, weighed and the percentage weight gain due to the modification was calculated as shown in equation1

Equation 1. Percentage gain due to modification (%WPG) = $[(W_{mo} - W_{unmo})/W_{unmo}] \times 100$

Where:

W_{mo} is the oven dry weight of the modified wood samples and M_{unmo} is the oven dry weight of the wood samples before modification.

2.3 Test for MOR, MOE and CPG

The [11] standards used for determination of maximum load using small clear samples were used for the determination of MOE, MOR and The CPG. After the strength tests, moisture content of the samples were checked and moisture content of samples different from 12% were recorded. Strength values for samples with moisture content above or below 12 %, were corrected using the formula by [12] (2009) as shown in equation 2

$\varphi 12 = \varphi\ n \{1 + \delta (N_2 - 12))$ equation 2

where:

$\varphi 12$ = strength at 12% moisture content (N/mm^2), φn = strength at moisture content different from 12% (N/mm^2), δ = constant value for relationship between strength and moisture content (δ = 0.05, 0.04, 0.02,) for CPG, MOR, and MOE respectively. N_2 = moisture content during test (%).

Table 1. Mean values MOE, MOR, CPG and WPG of *Nesogordonia papaverifera* and *Cynometra Ananta*

	WPG	MOE	MOR	CPG
Nesogordonia papaverifera modified (N/mm^2)	15.90	11, 400[a]	178.70[b]	75.21[c]
Percentage Change		- 1.13	- 0.20	+15.71
Nesogordonia papaverifera unmodified (N/mm^2)		11,530[a]	182.34[b]	65.00[d]
Cynometra Ananta Modifierd (N/mm^2)	15.20	16,406[e]	159.23[f]	89.00[g]
Percentage Change		-1.88	- 3.09	+12.92
Cynometra Ananta umodified (N/mm^2)		16,720[e]	164.30[f]	78.82[h]

***Means superscript with the different letters on a row are significantly different at P < 0.05**

3.0 Results and discussions

3.1 Evaluation of MOE, MOR and CPG of Modified and Unmodified *Nesogordonia papaverifera.*

Table 1 shows the MOE, MOR CPG of unmodified and modified *Nesogordonia papaverifera* with acetic anhydride. The unmodified *Nesogordonia papaverifera* had MOE, MOR and CPG values of 11,530, 182.34 and 65.00 respectively whilst the modified had MOE, MOR and CPG values of11, 400, 178.70 and 75.21 respectively. The result show no significant deviation in

MOE and MOR of the modified samples from the unmodified. This was in agreement with [7] report that modification of wood with acetic anhydride had no significant change in MOR. The result in Table 1 indicated a significant positive change in CPG which is in agreement with [8] report. The percentage change of the modified samples showed +15.71 positive change in the CPG over the unmodified samples while the MOE and the MOR showed no significant deviation of – 1.13 and – 0.20 respectively.

3.2 Evaluation of MOE, MOR and CPG of unmodified and modified *Cynometra Ananta*

Table 1 shows the MOE, MOR and CPG values modified and unmodified *Cynometra Ananta.* The MOE, MOR and CPG values of the unmodified were 16,720.00, 164.30 and 78.82 respectively. The MOE, MOR and CPG values of the modified *Cynometra Ananta* were 16,406.00, 159.23 and 89.00 respectively. The percentage change in MOE and MOR of the modified samples over the unmodified were -1.88, - 3.09 respectively which agrees with report by [7] that there is no significant change in MOR of acetylated wood. The modified samples had percentage of +12.92 in CPG which agrees with [8] report that acetylation improves strength properties of wood.

4.0 Conclusions

Two tropical lesser-used hardwood species, *Nesogordonia papaverifera* and *Cynometra Ananta*, were modified using acetic anhydride. The weight percentage gain of the modified *Nesogordonia papaverifera* and *Cynometra Ananta* were 15.92 and 15.20 respectively. The modification resulted in no significant change of their MOE and MOR but improvement in their CPG by +15.71 and +12.92 for *Nesogordonia papaverifera* and *Cynometra Ananta* respectively.

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