Original Research Article

MODULUS OF ELASTICITY, MODULUS OF RUPTURE AND COMPRESSION STRENGTH OF TWO THERMALLY TREATED GHANAIAN LESSER-USED WOOD SPECIES

ABSTRACT

Some lesser used wood species from the forests in Ghana are non-durable and have low dimensional stability. These wood species can be modified to improve such properties. Thermal treatment of wood can improve wood properties such as durability and dimensional changes but has adverse effect on strength properties. The objective of this study was to thermally treat and evaluate its impact on Modulus of elasticity (MOE), Modulus of rupture (MOR) and compression parallel to the grain (CP) of two Ghanaian Lesser-Used wood species Wawabima (*Sterculia rhinopetala)* and Niangon (*Heritiera utilis*. Thermal treatment of the two species showed that the MOE, MOR and CP decreased with increased heating temperature. The MOE of *Sterculia rhinopetala* decreased from 17,850.658 N/mm^2 to 16,520.002 N/mm^2 after thermal treatment from 150^{o}C to 240^{o}C. MOR decreased from 172.334 N/mm^2 to 70.181 N/mm^2 and CP from 75.246 to 57.934 N/mm^2. The MOE of *Heritiera utilis* decreased from 15,604.142 N/mm^2 to 9,155.977 N/mm^2, MOR from 144.465 N/mm^2 to 58.293 and CP from 52.842 to 39.103 N/mm^2.

Keywords: Thermal Treatment, Modulus of elasticity, Modulus of rupture, compression parallel to the grain.

1.0 Introduction

Wood treated above temperatures of 150°C permanently affects its physical and chemical properties. If wood is heated at high temperature, changes in swelling and shrinkages are reduced [1], and durability improves while wood strength reduces [2, 3]. According to [4 - 6], thermal treatment gives improvement of durability of the wood, and tends to reduce mechanical strength when treatment temperature is high [7]. Some researchers [8 - 12], have reported that both thermal and chemically modifying wood could be used to improve properties such as dimensional changes, and durability but have a negative impact in reducing mechanical properties. This reduces the use of such modified wood as a construction material [13]. The decrease in modulus of rupture (MOR) by heating is 50% more than that of modulus of elasticity (MOE) [7]. According to [14 - 19], changes of wood strength properties are affected by the species, heat treatment intensity, treatment temperature and duration.

Wawabima, (*Sterculia rhinopetala)* and Niangon (*Heritiera utilis)* are lesser used species in the forests of Ghana [20]. *Sterculia rhinopetala* has average density of between 720 and 890 kg/m^3 and is a very heavy wood with moderate durability [20]. *Heritiera utilis* is a heavy wood with density range between 625 and 700 kg/m^3, and is moderately resistant to decay [20]. These species could be thermally treated to improve their durability and reduce dimensional changes.

The objective of this study was to thermally treat and evaluate the impact of the treatment on modulus of elasticity (MOE), modulus of rupture (MOR) and compression parallel to the grain (CP) of two Lesser-Used wood species in Ghana.

2.0 Materials and Methods

2.1 Sources of Materials

The *Sterculia rhinopetala* and *Heritiera utilis* logs were obtained from Sewhi Wiawso located in the Western region of Ghana.

2.2 Wood Samples Preparation

The logs were processed at the John Bitar Sawmill Company located in Takoradi in Ghana.
Wood samples were taken within 5 metres above the breast height diameter of 1.3m. Small and clear samples free from defects were taken from the heartwood. Sample sizes for MOE and MOR were 20×20×300mm and 20×20×60mm for CP. Five sets were prepared each of the strength tests. Each set had 30 replicates. The samples were air dried to a moisture content of 12%.

2.3 Thermal treatment

One set of the wood samples was used as the control for MOE and MOR and another set as control for the CP test. The sets of the wood samples were thermally treated in the absence of oxygen to avoid burning. The sets of samples were treated for 6 hours at varied temperatures of 150^{o}C, 210^{o}C, 180^{o}C, 210^{o}C and 240^{o}C.

2.4 Percentage weight loss

The percentage weight loss (%WL) of samples at each heating temperature was calculated by the formula stated in equation 1.

$$\%WL = W_2\text{-}W_1/W_2 \qquad \text{equation 1}$$

where W_2 is the initial weight of the sample and W_1 is the weight of sample after heating at a particular temperature.

2.5 MOR, MOE and CP determination

Determination of MOR, MOE and CP were conducted using the test procedure [21], which required using small clear wood specimens. At the end of the experimental processes the moisture content of the samples were determined and the moisture content (MC) of samples which differed from 12% were recorded.

Corrections for strength values for samples which differed from 12 % MC were corrected by the formula used by [22], as shown in equation 2.

$$\mu 12 = \mu n \{1 + \gamma (N_2 - 12)) \quad \text{equation 2}$$

where:

$\mu 12$ = strength at 12% moisture content (N/mm^2),

μn = strength at moisture content different from 12% (N/mm^2).

γ = constant value for relationship between strength and moisture content (γ = 0.05, 0.04, 0.02,) for compression strength parallel to the grain, MOR, and MOE respectively.

N_2 = moisture content during test (%).

3.0 Results and Discussions

Table 1 shows the mean values of MOE, MOR and CP of *Sterculia rhinopetala* and *Heritiera utilis* samples treated at heating temperatures of 150^{o}C, 180^{o}C, 210^{o}C and 240^{o}C.

Table 1. Mean vales of Weight Loss, MOE, MOR and CP of *Sterculia rhinopetala (Sr)*, and *Heritiera utilis (Hu)*

	No Treatment	150°C	180°C	210°C	240°C
(Sr) MOE (N/mm^2).	17,850.658	15,727.600	14,021.568	12,660.024	10,520.002
(Sr) Weight loss (%) after heating.		5.023	8.042	15.568	18.920
(Sr) Percentage change in MOE after heating.		11.893^a	21.451^b	29.078^c	41.067^d
(Hu) MOE (N/mm^2).	15,604.142	13,575.604	11,703.197	10,610.817	9,155.977
(Hu) Weight loss (%) after Heating.		4.522	6.042	12.546	15.222
(Hu) Percentage change in MOE after heating.		13.000^a	25.000^b	32.000^c	41.323^d
(Sr) MOR (N/mm^2).	172.334	143.244	107.657	71.002	70.181
(Sr) Percentage change in MOR after heating.		16.886^a	37.530^b	58.800^c	59.276^d

(Hu) MOR (N/mm^2)	144.465	117.306	90.076	61.740	58.293
(Hu) Percentage change in MOR after heating.		18.700^{a}	37.649^{b}	57.263^{c}	59.649^{d}
(Sr) CP (N/mm^2).	75.246	69.331	68.264	64.801	57.939
(Sr) Percentage change in CP after heating.		7.860^{a}	9.289^{b}	13.811^{c}	23.000^{d}
(Hu) CP (N/mm^2).	52.842	48.086	45.973	41.798	39.103
(Hu) Percentage change in CP after heating.		9.000^{a}	12.100^{b}	20.900^{c}	26.000^{d}

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

3.1 Evaluation of MOE

In Table 1, *Sterculia rhinopetala* with MOE of 17,850.658 N/mm^2 before treatment, decreased to 15,727.600 N/mm^2, 14,021.568 N/mm^2, 12,660.024 N/mm^2 and 10,520.002 N/mm^2 when treated at temperatures 150^{o}C, 180C, 210^{o}C, 240^{o}C respectively. The Percentage change in MOE from the control at heating temperatures 150^{o}C, 180^{o}C, 210^{o}C, and 240^{o}C were 11.893^{a}, 21.451^{b}, 29.078^{c,} and 41.067^{d} respectively. The *Sterculia rhinopetala* samples lost percentage weight of 5.023 at the heating temperature 150^{o}C and percentage weight loss increased to18.92 at temperature of 240^{o}C. The result indicated that the MOE decreased while the weight loss and percentage change in MOE from the control also increased as the heating temperature increased. Similar trend of change in properties of *Sterculia rhinopetala* was observed in *Heritiera utilis*. The MOE reduced from 15,604.142 N/mm^{2} before heating to 13,575.604 N/mm^{2}, 11,703.197 N/mm^{2}, 10,610.817 N/mm^{2}, and 9,155.977 N/mm^{2} at heating temperatures of 150^{o}C, 180C, 210^{o}C, 240^{o}C respectively. Weight loss increased from 4.522, 6.042, 12.546 and 15.222 at heating temperatures of 150^{o}C, 180^{o}C, 210^{o}C, 240^{o}C respectively. The percentage change in MOE from the control samples increased in the order of 13.000^{a}, 25.000^{b}, 32.000^{c}, and 41.323^{d} as temperature increased from150^{o}C, 180C, 210C, 240^{o}C respectively. Percentage change in weight loss increased as heating temperature increased. This trend agrees with [7, 15 - 17], who reported that wood treated at higher temperatures for longer periods can cause severe loss in mechanical properties With the exception of temperature at 240^{o}C where *Sterculia rhinopetala* and *Heritiera utilis* had similar percentage change in MOE from the control, *Heritiera utilis* which is a heavy wood species had a higher percentage change in MOE from the control than *Sterculia rhinopetala*, a very heavy wood species. The result was in agreement with [14 - 19], who reported that degradation of wood strength properties depend on the species, heat treatment intensity, treatment temperature and duration.

3.2 Evaluation of MOR

The MOR of *Sterculia rhinopetala* before treatment was 172.334 N/mm^{2}. The MOR reduced to143.244 N/mm^{2}, 107.657 N/mm^{2}, 71.002 N/mm^{2}, and 70.181 N/mm^{2} when treated at150^{o}C, 180C, 210C, and 240^{o}C respectively. The percentage change in MOR from the control reduced from 16.886^{a}, 37.530^{b}, 58.800^{c}, to 59.276^{d} as the heating temperature increased by 150^{o}C, 180C, 210C, and 240^{o}C respectively.

Similarly, the MOR of the control samples of *Heritiera utilis* which was 144.465 N/mm^2 reduced to 117.306 N/mm^2, 90.076 N/mm^2, 61.740 N/mm^2, and 58.293 N/mm^2 as the heating temperatures increased from150^oC, 180C, 210C, to 240^oC respectively. The percentage change in MOR from the control also increased by18.700[a], 37.649b, 57.263[c], and 59.649[d] as heating temperatures increased from 150^oC, 180C, 210C, to 240^oC respectively. Even though the MOR of *Sterculia rhinopetala* reduced (143.244 N/mm^2, 107.657 N/mm^2, 71.002 N/mm^2, and 70.181 N/mm^2) as the temperature increased, they were comparatively higher than that of *Heritiera utilis* (117.306 N/mm^2, 90.076 N/mm^2, 61.740 N/mm^2, and 58.293 N/mm^2) respectively.

Apart from the heating temperature of 150^oC where ***Sterculia rhinopetala*** had a lower percentage change in MOR 16.886[a] from the control as compared to MOR of 18.700 for *Heritiera utilis*, there was no significant percentage change in MOR of *Sterculia rhinopetala* as compared to that of *Heritiera utilis*. Within the temperature range of 150^oC to 240^oC the percentage change in MOR from the control samples of *Sterculia rhinopetala* was in the range 29.569% to 50.548 % and higher than that of MOE in the range of 11.893 to 45.067 %. The percentage change in MOR from the control of *Heritiera utilis*, between the temperature range of 150^oC and 240^oC was 30.481% to 44.117% higher than that of the MOE (13.000% to 41.323 %). These findings were in agreement with [7], who reported that decrease in modulus of rupture (MOR) by heating is 50% more than that of modulus of elasticity (MOE).

3.3 Evaluation of compression parallel to the grain (CP)

The CP reduced as the treatment temperatures increased for both *Sterculia rhinopetala* and *Heritiera utilis* species. *Sterculia rhinopetala* CP decreased from the control 75.246 N/mm^2 to 69.331 N/mm^2, 68.264 N/mm^2, 64.801 N/mm^2 and 57.939 N/mm^2, and *Heritiera utilis* CP also decreased from control of 52.842 N/mm^2 to 48.086 N/mm^2, 45.973 N/mm^2, 41.798 N/mm^2 and 39.103 N/mm^2 at temperatures of 150^{o}C, 180C, 210^{o}C, and 240^{o}C respectively.

4.0 Conclusions

The findings showed that thermal modification had adverse effect on the mechanical properties of *Sterculia rhinopetala* and *Heritiera utilis*. The untreated samples of the two species had a higher MOE, MOR and CP than the treated. As the treatment temperature increased, the MOE, MOR and the CP for the two species decreased. The effect of the treatment reduced the MOR by almost 50% more than the MOE. The effect of the treatment on the MOE and MOR of the two species were the same while the effect on the CP of the *Sterculia rhinopetala* was lower than the *Heritiera utilis*.

There is therefore the need to consider the effects of thermal treatment on wood since strength properties are important when using wood as a construction material.

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