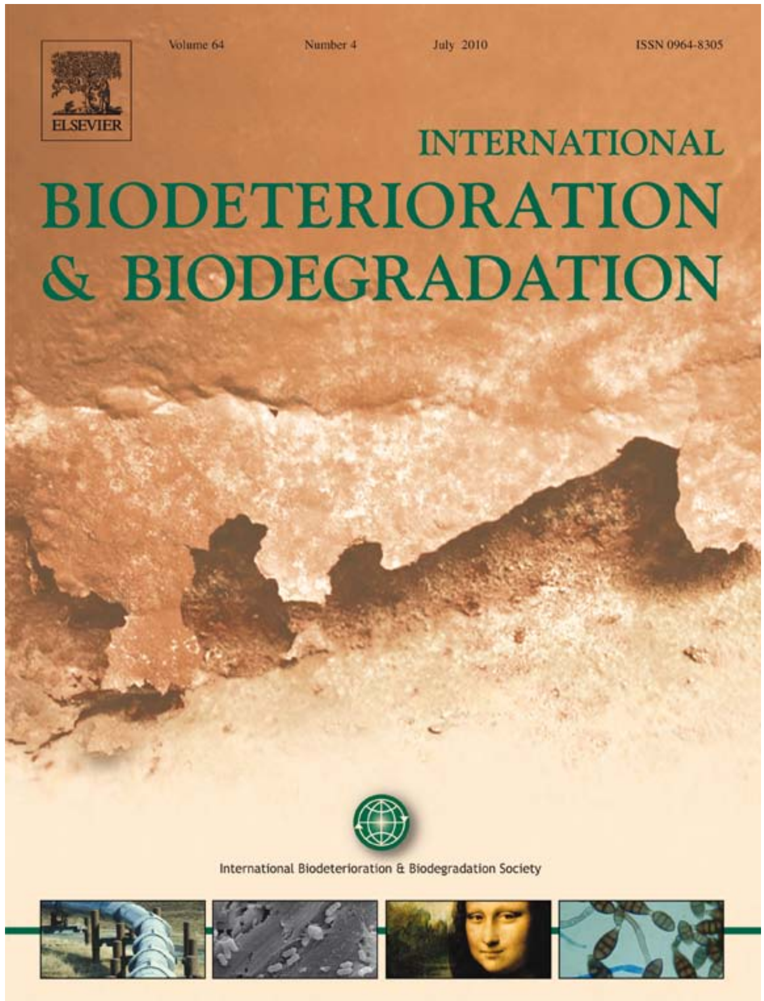
ELSEVIER
Volume 64
Number 4
July 2010
ISSN 0964-8305
INTERNATIONAL
BIODETERIORATION
& BIODEGRADATION
International Biodeterioration & Biodegradation Society

International Biodeterioration & Biodegradation 64 (2010) 267–273

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

# The effect of stake dimension on the field performance of two hardwoods with different durability classes

C. Antwi-Boasiako*, A. Allotey

*Department of Wood Science & Technology, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science & Technology, Kumasi, Ashanti, Ghana*

ARTICLE INFO

*Article history:*
Received 26 August 2009
Received in revised form
10 November 2009
Accepted 11 November 2009
Available online 22 April 2010

*Keywords:*
End-use
Mass loss
Service-life
Visual durability rating
Wood dimension

ABSTRACT

Timber diversity is associated with virtually all types of wood structures for various end-uses including bridges and railway-sleepers. Some timbers resist bio-degradation and are termed naturally durable. Wood durability is influenced by numerous extrinsic and intrinsic factors; however, knowledge is scant about the role stake dimension plays. Therefore, the field performance of replicates of four dimensions (500 × 50 × 25; 250 × 25 × 12.5; 125 × 12.5 × 6.25; and 62.5 × 6.25 × 3.13 mm) from two commercially important hardwoods (*Milicia excelsa* and *Sterculia rhinopetala*) of different durabilities (i.e., high and moderate, respectively) was investigated for 5 years using the graveyard method with non-durable *Ceiba pentandra* as a control. Durability parameters assessed were visual durability ratings, hardness, and mass losses. *C. pentandra* usually performed worst in all parameters. Generally, a steady increase exists in degradation from the thickest stakes (500 × 50 × 25 mm) to the thinnest (62.5 × 6.25 × 3.13 mm). Thus, the greater the stake dimension, the smaller its visual durability rating, mass and hardness losses (i.e. more durable). However, few discrepancies occurred, as the thinnest stakes were often buried deep in the soil, decreasing their chances of getting attacked. *M. excelsa* remained harder and more durable for stakes of all dimensions (especially the thickest) than those of *S. rhinopetala.* However, the thinnest *M. excelsa* stakes unexpectedly recorded mean mass loss of 4.9%, compared with 2.1% for *S. rhinopetala*. The study shows wood dimension significantly affects its durability, which would inform timber engineers about their wood dimension choices for appropriate end-uses.



## 1. Introduction

Wood durability depends on a number of factors, such as timber species, heartwood and sapwood distribution, extractive and lignin type, density, moisture content, and conditions of use (Panshin and de Zeew, 1980). The service-lives of wood products may depend primarily on their durability, a relevant factor, which contributes in reducing the rate of wood exploitation and replacement, thereby increasing its sustainability (Kollman and Côté, 1984). Wood selection from a durable or preservative-treated, non-durable timber is influenced by cost, end-use, required shape and size (i.e. its dimension). Westin et al. (2002) reported that field tests are costly and time consuming. They advocated for modified version of various field test standards (such as EN 252, EN 330 and ENV 12037) and proposed for the use of reduced stake size and how they are placed in the field so as to reduce the work-effort involved and the needed field test space. However, for most researches that employ different wood dimensions under the same test conditions, TRADA (1984) found the durability of wood in ground contact to be proportional to its thickness. Accordingly, Panshin and de Zeew (1980) expressed the need to investigate different wood species so as to establish how their dimensions would affect their durabilities. In this regard, two widely utilized indigenous species from two durability classes were employed to examine the relationship between specimen dimension and natural resistance to bio-degrading organisms in the field. *Milicia excelsa* (Welw.) C. C. Berg [iroko/odum] was selected to represent a wood species with high durability, while *Sterculia rhinopetala* K. Schum. [wawabima] is moderately durable. *Ceiba pentandra* (L.) Gaertn. (ceiba) was also employed as reference control. Average life of stakes, relative to the life of the reference stakes, and average corrected weight loss are the determining factors of durability for field and laboratory tests according to BS EN 350-1 (1994) and visual durability ranking (BS EN 252, 1989). For this study, hardness loss evaluation of wood is also considered as a parameter for determining durability. Furthermore, the four varying dimensions employed were adopted from the conventional measurement (i.e. 500 × 50 × 25 mm) stipulated by BS EN 252 (1989).

* Corresponding author. Tel.: +233 243771376; fax: +233 51 60137.
*E-mail addresses:* cantwiboasiako@gmail.com, cantwi-boasiako.frnr@knust.edu.gh (C. Antwi-Boasiako).

0964-8305/$ – see front matter © 2010 Published by Elsevier Ltd.
doi:10.1016/j.ibiod.2009.11.004

## 2. Materials and methods

### 2.1. Wood sample preparation

Heartwoods from logs of *M. excelsa* and *S. rhinopetala*, sampled 2 m from the forest ground, were sawn into stakes of four dimensions labelled A–D: A (500 × 50 × 25 mm), B (250 × 25 × 12.5 mm), C (125 × 12.5 × 6.25 mm) and D (62.5 × 6.25 × 3.13 mm). *C. pentandra* stakes of the same dimensions sampled from the same stem position served as controls. Ten clear replicates from each timber were weighed and the values taken as the initial or fresh weights. The depth of penetration of the pin of Pilodyn 6 J [Proceq SA wood density meter] into the stakes was determined at 12–14% mc as a measure of hardness [0 mm = softest and 40 mm = hardest] (Brunner and Grüsser, 2006). Two stakes of each dimension for the individual timbers were oven-dried at 103 ± 2 °C and their mean moisture contents (mcs) used to determine the corrected oven-dry weight (CODW) of each test stake to avoid the incidence of changes in their chemical structure and loss of volatile extractives through oven-drying (Antwi-Boasiako, 2004). The stakes were inserted vertically at random to one-third of their lengths and 50 cm from each other in accordance with BS EN 252 (1989) at a termite-prone site at the Demonstration Farm of the Faculty of Renewable Natural Resources (FRNR) of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi [Ghana]. Surrounding soil was pressed tight to each stake to create a good stake-soil contact. Stake performance was evaluated periodically for 5 years.

### 2.2. Durability parameters

Three parameters were employed to investigate stake performance as follow:

#### 2.2.1. Visual durability ratings

Stakes exposed to bio-degradation were examined regularly every three months for possible changes in strength, form or texture, alterations in colour and presence of wood-destroying fungal structures, making sure the stakes and their test positions were not damaged or changed after removal for inspection and during re-insertion respectively. Visual durability rating was based on BS EN 252 (1989) classification: 0 = no attack, 1 = slight attack, 2 = moderate attack, 3 = severe attack and 4 = failure.

#### 2.2.2. Hardness loss

After field exposure, the stakes were removed from the field, cleaned and dried to 12–14%mc. The final hardness was determined using the Pilodyn and the percentage loss in hardness expressed as:

$$\%\text{hardness loss} = \frac{\text{Final hardness} - \text{Initial hardness}}{\text{Final hardness}} \times 100.$$

#### 2.2.3. Mass loss

The stakes were oven-dried at 103 ± 2 °C to constant weights, which were taken as their final oven-dry weights. The percentage weight loss, that is, the percentage of the difference between the initial or corrected oven-dry weight (CODW) and the final oven-dry weight (FODW) of each stake was calculated, thus:

$$\%\,\text{weigh loss} = \frac{\text{CODW} - \text{FODW}}{\text{CODW}} \times 100.$$

The mean of the percentage weight losses of stakes for each dimension was determined and expressed as '*x*' based on EN 350-1:

$$x - \text{value} = \frac{\text{Average mass loss of test specimens}}{\text{Average mass loss of the refernce stakes}} \times 100.$$

The *x*-value was then compared to natural durability classes of wood against termite. Similarly, *x*-factor, based on lifetime of stakes according to BS EN 350-1 (1994), was also employed for the classification of the natural durability of the hardwoods after the field exposure (Rapp et al., 2002). The lifetime *x*-factor was estimated as:

$$x - \text{factor} = \frac{\text{Average life of test specimens}}{\text{Average life of the refernce stakes}} \times 100$$

Criteria for the assignment of Durability classes to stake dimensions of each hardwood based on their *x*-values are as presented in Table 1.

## 3. Results

### 3.1. Visual durability ratings

Fungal hyphae and termite runways were observed on the stakes, as it is shown for *C. pentandra* (Plate 1). There were changes in the original colour of the stakes, large splits and checks were observed as on many stakes of the controls, while several were eaten up. The level of deterioration exhibited by stakes of the various timbers is presented in Plates 1–3. *C. pentandra* (control) showed an apparent consistency in mean visual durability rating for all dimensions. Irrespective of the varied sizes, its stakes were seriously attacked and attained visual durability rating of 4 [i.e. failure] (Table 2, Fig. 1). Larger dimensions of *M. excelsa* and *S. rhinopetala* were slightly attacked compared to their smaller dimensions, some of which were buried and often had no attacks (Table 2). Although stakes of the two hardwoods were slightly attacked, the striking difference was their B (250 × 25 × 12.5 mm) stakes, where those of *M. excelsa* performed better than those of *S. rhinopetala*. Their C (125 × 12.5 × 6.25 mm) and D (62.5 × 6.25 × 3.13 mm) stakes were too small and often buried in the soil, especially those of D. For *M. excelsa*, the difference between the ratings for stakes of dimensions A (500 × 50 × 25 mm) and B (250 × 25 × 12.5 mm) was not significant ($p < 0.05$), unlike those of *S. rhinopetala*.

### 3.2. Hardness loss

Only the hardness losses for dimensions A (500 × 50 × 25 mm) and B (250 × 25 × 12.5 mm) were determined. Those for dimensions C (125 × 12.5 × 6.25 mm) and D (62.5 × 6.25 × 3.13 mm) could not be determined with the Pilodyn due to their small sizes. Consequently, the performance of stakes of these two dimensions was determined mainly by their mass loss (%) for the three timbers (Fig. 3). Meanwhile, several *C. pentandra* stakes disintegrated before the end of the study. Thus, they recorded the greatest hardness loss (100%) among the three timbers. *M. excelsa,* on the other hand, remained harder for stakes of dimensions A and B than those of *S. rhinopetala.* However, in both timbers, stakes of dimension A lost less hardness than those of B (Fig. 2). Dimension A stakes of

**Table 1**
Criteria for classification of natural durability according to BS EN 350-1 (1994).

| Durability class | Description | *x*-value based on mass loss in EN 113 | *x*-value based on average life in EN 252 field test[a] |
|---|---|---|---|
| 1 | Very durable | $x \le 0.15$ | $5 < x$ |
| 2 | Durable | $0.15 < x \le 0.30$ | $3 < x \le 5$ |
| 3 | Moderately durable | $0.30 < x \le 0.60$ | $2 < x \le 3$ |
| 4 | Slightly durable | $0.60 < x \le 0.90$ | $1.2 < x \le 2$ |
| 5 | Not durable | $0.90 < x$ | $x \le 1.2$ |

[a] Source: Rapp et al. (2002).

**Plate 1.** Termite runway (arrowed) on *C. pentandra* stake of Dimension A (500 × 50 × 25 mm) three weeks after field exposure [Left]; the few remaining failed stakes of A (500 × 50 × 25 mm) after 5 years of field exposure [Right].

*M. excelsa* lost 2.9% and 23.7% for B. Dimension B stakes of *S. rhinopetala* also lost greater hardness (26.2%) than those of A (13.9%).

### 3.3. Mass loss

The mean weight loss for *C. pentandra* is highest and shows a progressive increase in degradation from dimension A to D (Fig. 3). That is, the greater the stake dimension, the less its weight loss (i.e. more durable). The difference between mean weight losses for dimensions C and D is not significant ($p < 0.05$). However, for *M. excelsa* and *S. rhinopetala*, stakes of dimensions A and D recorded lower mean weight losses than those of B and C. For *M. excelsa*, its C stakes recorded the greatest mass losses followed by those of B and D respectively. Stakes of A recorded the least, thus performed best in the field. For *S. rhinopetala*, stakes of B lost the greatest mass and D the least. A and B stakes of *M. excelsa* performed better than those of *S. rhinopetala*; the reverse holds for stakes of dimensions C and D. For instance, for dimension D, *M. excelsa* recorded a mean percentage mass loss of 4.9%, while *S. rhinopetala* lost 2.1%. However, natural durability classification, according to BS EN 350-1 (1994), reveals stakes of all dimensions for *M. excelsa* are durable and those of *S. rhinopetala* moderately durable, apart from its C and D, which were classified durable (Table 3).

## 4. Discussion

Most frequently, field durability studies employ visual durability rating and mass loss tests as stipulated by BS EN 252 (1989). However, this study employs, in addition, loss in hardness recorded

**Plate 2.** Slightly attacked *S. rhinopetala* stakes of dimensions A (500 × 50 × 25 mm) after 5 years of field exposure [Left], and B (250 × 25 × 12.5 mm) showing increasing degrees of attack with Ratings 1, 2, 3 and 4 (left to right) respectively over the same period [Right].

**Plate 3.** *M. excelsa* stakes of dimensions B (250 × 25 × 12.5 mm) showing increasing degrees of attack; Ratings 1, 2, 3 and 4 (left to right) respectively [Left], and D (62.5 × 6.25 × 3.13 mm) showing few signs of attack after 5 years of field exposure (Right).

by the Pilodyn 6 J (Brunner and Grüsser, 2006) as one of the means of assessing durability of stakes of different dimensions.

### 4.1. Stake dimension and visual durability ratings

Normally, evaluation of the extent of attack is based on a number of observations, which could not be measured in absolute terms. However, assessment of the degree of attack by termites and fungi is made according to the grading system given by BS EN 252 (1989). Since these evaluations are perceptible and could be subjective, results based on visual observations could be biased and subject to challenge. As a result, visual durability ratings are often employed to complement the results from mass and hardness losses of stakes. Ratings from the current study have revealed that apparent conditions of replicate stakes varied slightly with time of inspection. These included profound changes in their natural colours. TRADA (1984) observed that the natural colour in wood is gradually washed out by rain, while surface checking assists in this leaching. Removal of water-soluble extractives (which possess biocidal properties) from stakes through leaching decreases their resistance to bio-deterioration, hence increase in their visual durability ratings (Antwi-Boasiako, 2004).

Although *C. pentandra* has the lowest strength, durability and density of 300 kg/m$^3$ (TEDB, 1994), it showed a clear trend in durability loss measured by the visual ratings and was observed that the larger and thicker stakes were comparatively least resistant. Contrary to the other hardwoods, majority of its D stakes were totally degraded by the time of first inspection (i.e. after 3 months of exposure). Their thinness and smaller biomass could be responsible for their faster degradation by the few bio-deteriogens below and those at the soil surface. However, for the stronger and more durable hardwoods [i.e. *M. excelsa,* which has medium strength, high durability and density of 550 kg/m$^3$ and *S. rhinopetala* also having high strength, moderate durability and high density of 750 kg/m$^3$ (TEDB, 1994)], their smaller stakes were similarly buried and after several rains, some of them had ratings of 0 (i.e. no attack). The thicker exposed stakes of *M. excelsa* only showed an increasing trend of degradation, as stake dimension decreased. Wagner et al. (1991) studied that drywood termites (e.g. Kalotermitidae – *Cryptotermes havilandi*) and subterranean or mound-builders (e.g. Rhinotermitidae, Hodotermitidae and Termitidae) are the commonest in Ghana, particularly at the Province of the test-site, which is endowed with many termitaria. The subterranean types constitute 80–90%, build a central nest either in the soil or mostly in contact with it and move out tunnelling up to the surface to get access to nearby wood food sources. Similarly, Termites 101 (2009) reported that the soil tunnelling type causes much damage (about 95% of the yearly damage by termites in the US), while the drywood termites prefer to live above the soil, taking up residence in wood structures. Harris (1961) asserted that termites employ 'opportunity' in assessing their food such that the larger and unburied stakes were greatly chanced upon and were accordingly degraded more than their buried, smaller counterparts. Besides, Desch and Dinwoodie (1966) reported that thicker stakes have the greatest chance of being influenced by the rate of adjustment of their moisture in relation to the relative humidity of the surrounding. Thus, the exposed larger stakes could absorb more water, such as from dew, to increase the volume of water in their lumina held by capillary forces, which contributed to their swelling and consequent degradation. During the day time or in the drier seasons, there was greater loss of water, which caused shrinkage leading to splitting as a result of differential expansion since the

**Table 2**
Visual durability ratings for different dimensions of the hardwoods tested.

| Hardwood species | Stake dimension (mm) and mean visual durability ratings[a] | | | |
|---|---|---|---|---|
| | A (500 × 50 × 25) | B (250 × 25 × 12.5) | C (125 × 12.5 × 6.3) | D (62.5 × 6.3 × 3.2) |
| *M. excelsa* | 1 | 1 | 0 | 0 |
| *S. rhinopetala* | 2 | 2 | 1 | 0 |
| *C. pentandra* | 4 | 4 | 4 | 4 |

[a] EN 252 Classification: 0 = no attack, 1 = slight attack, 2 = moderate attack, 3 = severe attack and 4 = failure (Anon., 1989).

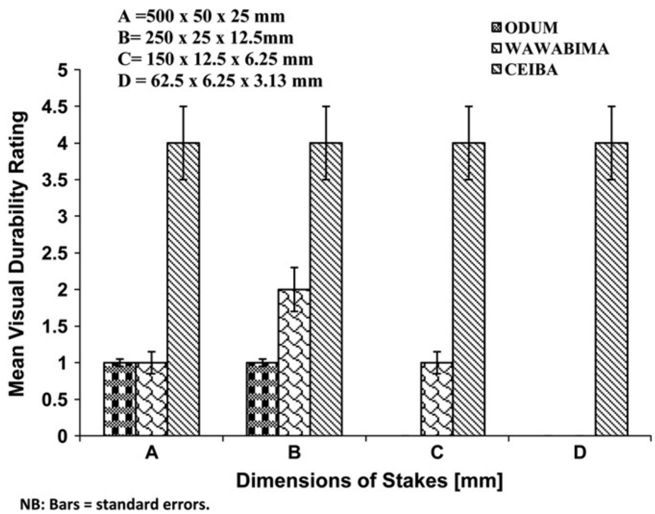


**Fig. 1.** Mean visual durability ratings for *M. excelsa*, *S. rhinopetala* and *C. pentandra* after 5 years of field exposure.

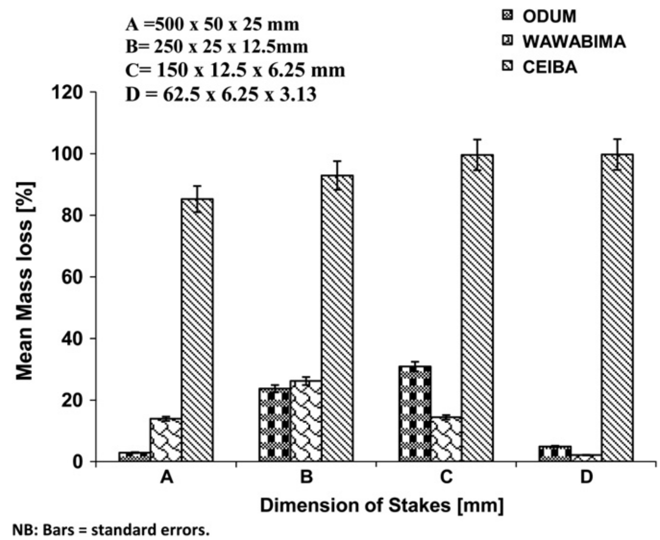


**Fig. 3.** Mean mass losses for *M. excelsa*, *S. rhinopetala* and *C. pentandra* after 5 years of field exposure.

inner parts could be wetter than the outer shells, which also exposed them to more deterioration (Haygreen and Bowyer, 1996). Thus, shrinkage and swelling would seem not to occur as quickly in larger wood dimensions. However, all these activities were also reduced more in the buried, smaller samples. There was a relative decrease in their degradation typified by lower visual durability ratings. However, for *M. excelsa* and *S. rhinopetala*, few discrepancies in their visual durability ratings occurred.

### 4.2. Relationship between stake dimension and hardness loss

Final hardness is employed in wood durability studies as a measure of its density and resistance to attack by bio-degraders such as fungi and also termites after laboratory and field tests. It is worth-stressing C and D stakes were so thin their hardness tests using Pilodyn were not achievable so they were rated on their mass losses and visual durability rankings. For the A and B stakes, the general reduction in hardness after exposure could be attributed to softening of their cell wall components by surrounding water and

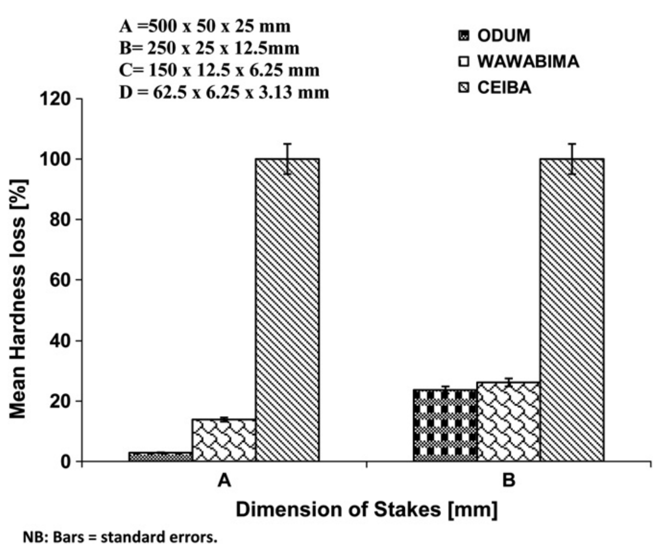


**Fig. 2.** Mean hardness losses for *M. excelsa*, *S. rhinopetala* and *C. pentandra* after 5 years of field exposure.

frequent wetting, which could cause detachment and reduction of their closely-packed arrangement and compactness (or firmness) of the cell components. The small checks and splits developed on the stakes enlarged with time. TRADA (1984) observed that when unprotected wood is exposed to the weather for a long time, its exposed surfaces develop raised grains, become rough, corrugated and fuzzy. Humidity variations cause their surface layers to shrink or swell and the individual fibres become partially detached and loosened. These adversely affect the wood hardness. Besides, Richardson (1978) reported that different wood dimensions of the same species under the same conditions have different movements (i.e. shrinkage or swelling) due to mc changes. These profoundly influence attack of wood by insects and fungi. Water vapour is lost or gained most rapidly through end-grain surfaces because of their permeability, a factor which encourages either its liquid absorption or loss. Wood softens as it swells, with a split as it shrinks, rendering it very susceptible in both cases. Thus, Desch and Dinwoodie (1966) and Haygreen and Bowyer (1996) reported that size and shape, initial mc of lumber and the rate of air circulation during drying, density and temperature are factors that influence the rate of adjustment of the moisture in wood in relation to humidity regarding shrinkage. For stakes of dimensions A and B of *M. excelsa* and *S. rhinopetala*, those of B, which had less end-grain surfaces were expected to have less water movement to give them better dimensional stability to overcome hygroscopic stresses than those of A. However, this was not the case, which means other factors might have accounted for poorer performance of B.

### 4.3. Stake dimension and mass loss

BS EN 460 (1994) reported that where attack caused by bio-degraders (including fungi) occurs on the lateral surfaces of stakes, the service-life of the timber component can be expected to increase in proportion to its thickness. This could therefore explain why the degradation caused by the wood-destroying organisms (mainly termites and fungi) increased with decreasing sizes of the stakes. Therefore, the respective increasing mean percentage mass losses of 2.9%, 23.7% and 30.9% for dimensions A, B and C stakes of *M. excelsa* are expected, which demonstrates that stakes with the largest dimensions were least grazed. However, the smallest D stakes were, most often, more resistant than even those of A and B

**Table 3**
Natural durability classes for *M. excelsa* and *S. rhinopetala* to termite attack based on BS EN 350-1 (1994).

| Hardwood species[a] | Stake dimension (mm) | $x$-Value based on mass loss in EN 113 | $x$-Value based on average life in EN 252 field test | Classification | Description |
|---|---|---|---|---|---|
| *M. excelsa* | $A = 500 \times 50 \times 25$ | 0.0 | $3 < x \leq 5$ | 2 | Durable |
| | $B = 250 \times 25 \times 12.5$ | 0.3 | $3 < x \leq 5$ | 2 | Durable |
| | $C = 150 \times 12.5 \times 6.25$ | 0.3 | $3 < x \leq 5$ | 2 | Durable |
| | $D = 62.5 \times 6.25 \times 3.13$ | 0.0 | $3 < x \leq 5$ | 2 | Durable |
| *S. rhinopetala* | $A = 500 \times 50 \times 25$ | 0.4 | $2 < x \leq 3$ | 3 | Moderately durable |
| | $B = 250 \times 25 \times 12.5$ | 0.5 | $2 < x \leq 3$ | 3 | Moderately durable |
| | $C = 150 \times 12.5 \times 6.25$ | 0.1 | $3 < x \leq 5$ | 2 | Durable |
| | $D = 62.5 \times 6.25 \times 3.13$ | 0.0 | $3 < x \leq 5$ | 2 | Durable |

Very durable: $x \leq 0.15$; Durable: $x > 0.15$ but $\leq 0.30$; Moderately durable: $x > 0.30$ but $\leq 0.60$; Slightly durable: $x > 0.60$ but $\leq 0.90$; Not durable: $x > 0.90$.
[a] NB: *C. pentandra* (i.e. reference) stakes are non-durable (i.e. all have failed).

due to their capacity to escape much attack, as they were buried in the soil. This reduced their contact with a greater number of aerobic bio-degraders located near the soil surface, thus making them less prone to attack. The bio-degraders (especially termites, which abound in the test-site (Antwi-Boasiako, 2004)) either concentrated on attacking the exposed stakes more than the buried or less of them are contained below the soil surface. This was also the situation for dimension D stakes of *S. rhinopetala*, which had the least weight loss of 2.1% compared with 2.6% for those of B. Not surprisingly, this shows that for the two hardwoods, their stakes were more predisposed to attack at the soil surface than within the soil. However, despite such irregularities, mass losses resulting from attack by bio-deteriogens generally relate to wood thickness such that the greater the wood dimension, the longer its service-life. Similarly, Kollman and Côté (1984) reported that the biomass of a stake can be influenced by its dimension hence the resistance of larger stakes against bio-deterioration. Therefore, it is anticipated that dimension A stakes of all the hardwoods would perform best in the field and would lose the least masses compared to stakes of B and C. This is against the backdrop that all the stakes had the same period of field exposure and interaction with bio-deteriorating factors and that it would take a longer time for stakes of greater biomasses to degrade completely than those with smaller weights of wood material. Moreover, wood has an absorptive nature and the ability to lose moisture easily to the environment until its moisture is in equilibrium with the surrounding air (Panshin and de Zeew, 1980). Observations made in BS EN 460 (1994) indicate that, in regions which experience long dry periods (such as in Africa), timber components often having a relatively small cross-section in ground contact are likely to have higher resistance against attack than similar components of larger cross-section due to the formers' ability to dry rapidly. The difference in the level of deterioration among the different dimensions of the three hardwoods could also be attributed to some unique characteristics of each wood species and the degrading agents they interact with. Thus, once again, the expectation is that *M. excelsa* and *S. rhinopetala*, which are heavier and stronger would perform better than the stakes of *C. pentandra*, the least durable, lightest (TEDB, 1994), softest and most degraded. Moreover, regarding the activities of the main bio-degraders in the tropical test-field (i.e. termites), Harris (1961) indicated that their ability to forage is influenced by three properties, namely palatability, opportunity and repellence. He emphasized that the most important, in relation to the dimension of 'food' substance (such as wood), is their 'opportunity' to cover the various factors making up the environment in which the timber is required to be durable and details of which are necessary, in considering the claims for termite resistance. This assertion shows termites vary greatly in their habit, particularly in their food preference and geographical distribution. Wagner et al. (1991) and Termites 101 (2009) reported that the subterranean and drywood termites that abound at the test-site respectively build nest from which they tunnel up to the surface for food or prefer to live above the soil to dwell in wood. All test samples were subjected to the same environmental conditions and assumed equal termite contact and distribution at every point on the field. However, as several of the C and D stakes were completely buried after a couple of rains, those of *M. excelsa* and *S. rhinopetala*, in particular, were often least attacked, while the termites had invariably greater opportunity to get into contact with the most displayed bigger stakes (i.e. A and B) above the soil. Most of the control stakes of C and D were eaten up by the third month before they could be buried.

Furthermore, high density wood species would shrink more per percent mc change than lower density timbers (Haygreen and Bowyer, 1996). As shrinkage results in checks, splits and cracks, which serve as courts for bio-degraders, *S. rhinopetala* stakes (750 $kg/m^3$) would generally be expected to shrink more and perform worse than those of *M. excelsa* (500 $kg/m^3$).

It is worth-stressing that the results from all the durability parameters have established that wood dimension influences its durability. The implications of this study are that as far as natural durability is concerned, smaller stakes are under greater decay pressure due to increased surface area – especially for termites. Since stake tests are one of the most commonly used methods for evaluating the efficacy of new preservative formulations, a better understanding of smaller test specimens and how they shorten the time needed to evaluate new preservatives is significant. Incidentally, field trials with mini-stakes ($8 \times 20 \times 200$ mm) by Westin et al. (2002) established that their mini-stake EN 252 field testing is an economic alternative to conventional EN 252, which employs stakes of $25 \times 50 \times 500$ mm, especially if the intention is to screen many parameters with a limited amount of material and with limited field space available. Nonetheless, this work has remarkable implications for standardized test methods as well as wood dimension choice for end-uses and expected service-life of naturally durable wood species. Such information will guide stakeholders in the wood industry on decisions regarding wood dimensions and utilization. It is therefore anticipated that the findings would appropriately give background knowledge to wood workers in the structural and constructional industries, which would contribute to assist policy-makers to make informed decisions regarding the requisite wood dimensions for specific end-uses so as to enhance excellent service-lives of wood members in the field.

## Acknowledgement

We earnestly appreciate the technical assistance of the Department of Wood Science & Technology Workshop staff of the Kwame Nkrumah University of Science & Technology, Kumasi-Ghana and Mrs. Agnes Ankomah (Biometrician, Crops Research Institute, CSIR, Kumasi) for her statistical advice.

## References


Antwi-Boasiako, C., 2004. Assessment of Anatomy, Durability and Treatability of two Tropical Lesser-Utilised Species and two related Primary Species from Ghana. PhD thesis submitted to the University of Reading, Reading (UK), pp. 303.

Brunner, M.Y., Grüsser, F., 2006. Investigations on Lesser-Used Timber Species for the Construction of Light Bridges in Ghana. 1st Interim Report 2005–06, DEZA/SNSF. Biel, Switzerland.

BS EN 252, 1989. Field Test Method for Determining the Relative Protective Effectiveness of a Wood Preservative in Ground Contact. BS EN 252. European Committee for Standardization (CEN) [1989; BS 7282: 1990].

BS EN 350-1, 1994. Durability of Wood and Wood-based Products – Natural Durability of Solid Wood. Part 1. Guide to the Principles of Testing and Classification of the Natural Durability of Wood. European Committee for Standardization (CEN).

BS EN 460, 1994. Durability of Wood and Wood-based Products – Natural Durability of Solid Wood. Guide to Durability Requirements for Wood to be used in Hazard Classes. European Committee for Standardization (CEN).

Desch, H.E., Dinwoodie, J.M., 1966. Timber Structure, Properties, Conversion and Use, seventh ed. Macmillan Press Ltd, pp. 306.

Harris, W.V., 1961. Termite and Their Recognition and Control. John Wiley and Sons Inc, New York, pp. 118–132.

Haygreen, J.M., Bowyer, J.L., 1996. Forest Products and Wood Science: an Introduction, third ed. Iowa State University Press, AMES, USA.

Kollman, F.F.P., Côté Jr., W.A., 1984. Principles of Wood Science and Technology. In: Solid Wood, vol. 1. Springer-Verlag OHG, Berlin, Heidelberg, New York/Tokyo.

Panshin, A., de Zeew, C., 1980. Textbook of Wood Technology. Structure, Identification, Properties and Uses of the Commercial Woods of the United States and Canada, fourth ed. McGraw-Hill, Inc, New York, USA.

Rapp, A.O., Viitanen, H., Nilsson, T., 2002. Natural Durability of 4 different Species Tested in Soil Contact. The International Research Group on Wood Protection, IRG/WP 02–10434, IRG Secretariat, Sweden. Paper Prepared for the 33rd Annual Meeting, Cardiff, Wales, 12–17 May, 2002.

Richardson, B.A., 1978. Wood Preservation. The Construction Press Ltd, Lancaster, England.

TEDB, 1994. The Tropical Timbers of Ghana. Timber Export Development Board [TEDB], Takoradi, Ghana/London, UK, pp. 42.

Termites 101, 2009. Termites. KN's Writing. Last Modified: 25 July, 2009. Copyright 2003–2009. Conjecture Corporation, WiseGeek.

TRADA, 1984. Timber Pests and Their Control. Timber Research and Development Association (TRADA). Executive Press Limited, Burnham, Bucks, England.

Wagner, M.R., Atuahene, S.K.N., Cobbinah, J.R., 1991. Forest Entomology in West Tropical Africa: Forest Insects of Ghana (Chapter 7: Termites). Kluwer Academic Press, pp. 153–178.

Westin, M., Rapp, A.O., Hadi, Y.S., Nilsson, T., 2002. Field Trials with mini.stakes. The International Research Group on Wood Protection, IRG/WP 02–20244, IRG Secretariat, Sweden. Paper Prepared for the 33rd Annual Meeting, Cardiff, Wales, 12–17 May, 2002.