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Full Length Research Paper

Mechanical grading of structural timber and species conservation in the forest of the Congo Basin

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The aim of the present work is to propose a non-destructive experimental approach, organizing the species of the Congo Basin in four; according to the likeness of their main mechanical properties, and is also to promote the subsistence of over-consumed species in our biodiversity. The assignment of a given specie to one of the four groups takes place in return for a homogeneity test of comparison of the random variables of species to the random variable of the group. The present grading shows that, some species can be interchangeably consumed in the construction industry, without altering the 5th percentile characteristic value of mechanical properties. For a lasting management of its forest, the application of the findings of this work promotes the exploitation of less-consumed species and the conservation of exotic biodiversity of the Congo Basin.

Key words: Vibratory method, characteristic value, test of homogeneity, group of species, grading, conservation.

INTRODUCTION

Exotic woods in the Congo Basin are strong, resistant and attractive and are widely used in commercial exchanges. In the Congo Basin, which represents the second largest tropical forest in the world, more than three hundred species were inventoried (Vivien and Faure, 1995). Among them, more than a hundred can be used as structural wood; however, only their half is exploited in an unbalance way (ATIBT, 2003). For example, six timber species namely ayous (*Triplochiton scleroxylon*), iroko (*Entandrophragma cylindricum*), sapelli (*Erythrophleum ivorense*), tali (*Lophira alata*), fraké (*Baillonella toxisperma*), and Azobé (*Chlorophora excelsa*) represent nearly 84% of the yearly logging (Figure 1). The natural regeneration of more commercialized species is supplanted to a dizzy rate by the pressure of their felling rhythm, which is traditionally the chronicle of an inexorable extinction of these species. It is therefore urgent to find replacement solutions or substitute with similar structural performances to these extinguishable species for the lasting management of the forest and the maintenance of its biodiversity (Ayina, 2002; Joyet, 2002). Grouping all species of the Congo Basin by a non-destructive vibratory method, according to the likeness of their main mechanical properties, maintains a lasting-provision of structural wood nationally and internationally. Convincing the wood user to choose, from a group of species with similar structural performances, a widely available non-extinguishable specie, instead of a most wanted extinguishable specie without loosing expected structural performances is the main objective of this work. For every group of species with similar structural performances, it is useful to provide mechanical characteristics taken into account by engineers and architects.

Indeed, the constraints of reliability and security are very important in the construction industry and require the mastery of mechanical features of the structures. Due to the variability of inter-species and intra-species characteristics (Joyet, 2002), a statistical evaluation is necessary. Objectives outlined by the mechanical grading of the species in the Congo Basin are: an adequate choice for the indicatory property; the arguments in favour of the number of groups; the justified assignment of a given specie to a group; the relevance of a sampling technique with a minimum cost and the rigor of the statistical

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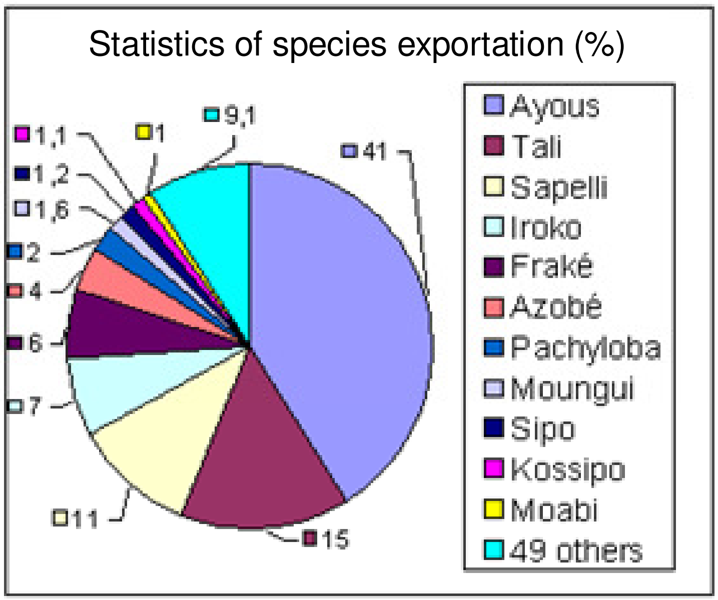

Figure 1. Volume of exported species from the Douala port (ATIBT, 2003).

exploitation of results. The thick forest of Cameroon is a representative ecosystem of the Congo Basin and it is the reason for which the survey is carried out using the species of Cameroon, the method being easily applicable to the entire Congo Basin.

EXPERIMENTAL EVALUATION METHODS

Non-destructive vibratory evaluation method

Non destructive control techniques help us to assess the breaking modulus of wood pieces without altering their characteristics by excessive loading. Well known traditional and modern vibratory evaluation methods include: the visual control, the control by mechanical testing, the control by machine testing, the ultrasound control method, and the vibratory control method. The longitudinal elasticity modulus is determined by spectral analysis of the frequency components of the transverse natural vibrations of tested wood elements simply supported by flexible supports (Figure 2). Taking into consideration the variability of inter-species and intra-species as specified by Noack (1972), test-samples were made from a wide diversity of wood specimens ordered from several sawyers and woodworkers of Yaoundé, where the timbers of the thick forest of Cameroon arrive. Otherwise, several sources of provision were established on the entire forest zone of Cameroon. A characterization is done on the basis of standard structural specimens UEF (Unité d'Evaluation Forrestière, Forest Evaluation Units) of the four given groups Gj measuring 20×20×400 mm. In civil engineering, the parameters that characterize wood mechanically for a structural use are the modulus of elasticity (MOE) and the breaking strength, which help to compute the breaking or rupture modulus (MOR), with the fact that, the rigidity of a structure or its resistance to distortion increases with the MOE. In small deflections theory, the bending of a frame structure for example, depends directly on the elastic modulus, provided that the bearing capacity of the material is not reached (Natterer, 2000). Bending stress distribution of wood was estimated adequately by the acoustoelastic method (Yasutoshi, 1998) and thus the correlation between various mechanical properties can be obtained by mechanical calculation. Therefore, in the subsequent investigations we adopt the modulus of elasticity, as an indicatory property of the mechanical grouping of the species, and we consider each specie's elastic modulus, Ei, as a random variable in the view point of statistical analysis.

The specimen modulus of elasticity is obtained from the vibratory analysis tests, using the Pico Technology package (ADC216; 16 bits) and a sample beam on flexible supports. Fundamental vibration modes are easily generated from one extreme of the beam with flexible supports, and are detected by an accelerometer glued to the other extreme. The Pico Technology package offers PC based test instruments, that offer all the functions of conventional equipment, thus replacing bulky and expensive test equipment. The package supplied with PicoScope software which turns the PC into a spectrum analyser and a meter, provides many advantages over conventional instruments, such as multiple views of the same signals and on-screen display of output variables (Figure 2b).

Experimental data analysis

The grouping is carried out among the most commercialized species: ayous (*T. scleroxylon*), sapelli (*E. cylindricum*), tali (*Erythrophleum suaveolens*) and azobé (*L. alata*) and others. For each of the selected species we fix the sample (or test-samples) size to 100 specimens and not to 2000 as required by the European Norm Project since, for preliminary research, a smaller amount can be considered (Lucas, 2006). The drying of specimens takes place during three months under shelter. The moisture content in a woody test-sample is expressed through the ratio of the mass of water present in it to the anhydrous mass. The mass of water is deduced by drying a sample in the steam room at 103 ± 2°C until a constant mass is obtained. For convenience we adopt the correction, for evaluation of the modulus of elasticity, of 12% (Guitard, 1987) in order to establish comparisons with standard values. Experimental results are obtained from a non-destructive test model, based on

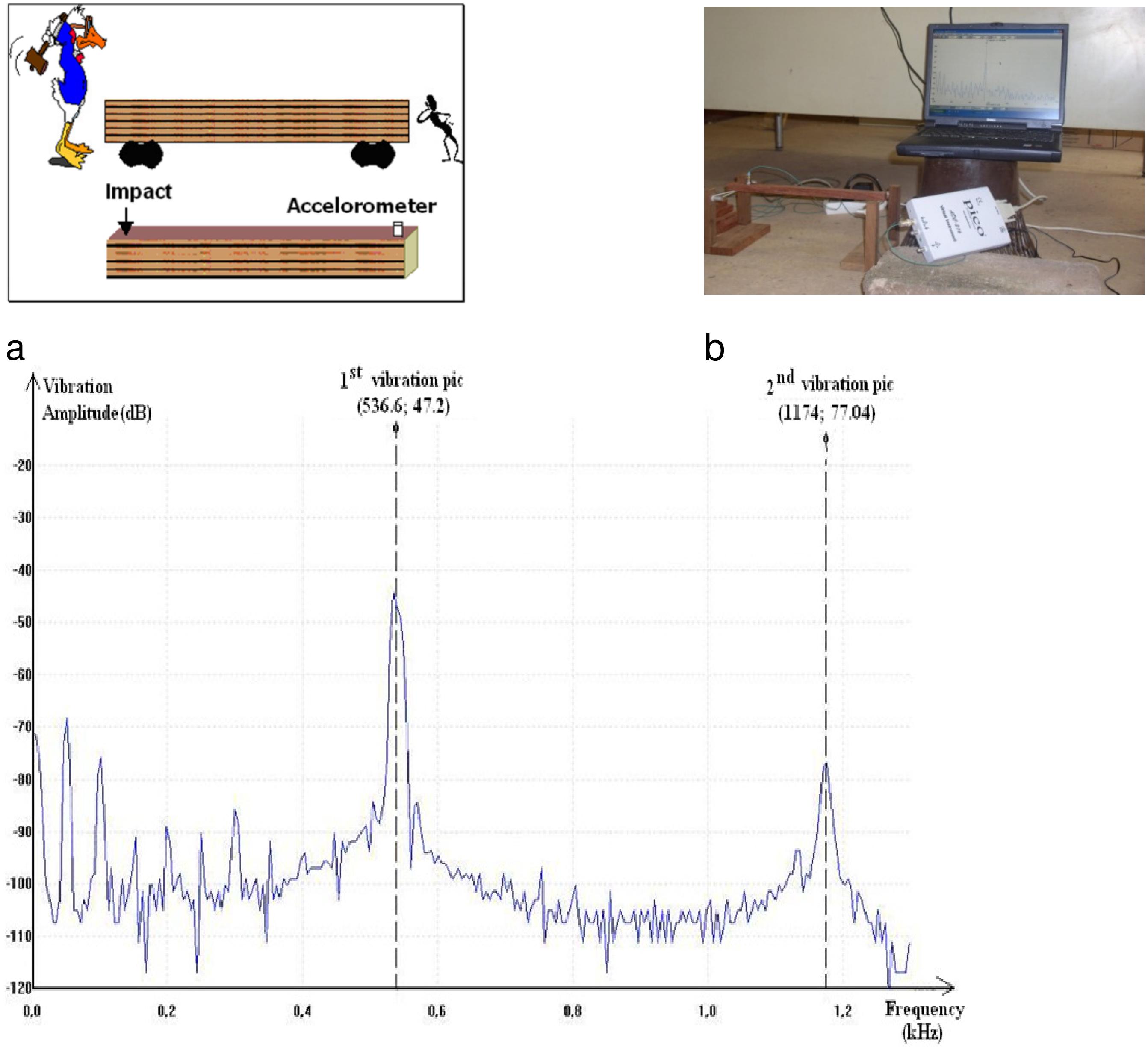

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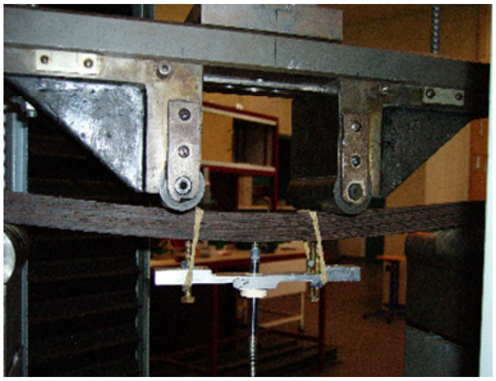
Figure 2. Instrumentation setup. a) Vibratory test setting b) Experimental setup c) Modal response output.

spectral analysis of the natural vibration of a beam. In bending, when the shear strain is neglected ($L/h \geq 20$), the Bernoulli model shows that the modulus of elasticity is given by (Casagrande, 1998):

$$E = \rho S \frac{\left(2\pi L^2 f_k\right)^2 / IX_k}{I\,X_k} \quad (1)$$

where ρ is the mass per unit volume; S is the area of the transverse section; L is the length of the beam; fk is the frequency of the k-th longitudinal mode of vibration; I is the moment of inertia of the transverse section; Xk is given by (Brancheriau, 2002) as xk = [(2k+1)π/2]4.

As a validation tool, the static longitudinal elastic module and the breaking stress are determined from data of static experiments according to the project of European norm (prEN 408, 2000) in the form of a four-point flexural test with the condition that, the tested wood specimen is subjected to a pseudo-static loading until its failure state (Figure 3). The given four-point flexural test was done in the Laboratoire de Rhéologie du Bois (Wood Rheology Laboratory) of Bordeaux in France with an adequate digital instrumentation composed of a computer-controlled test board with corresponding LVDT displacement meters and instrumentation.



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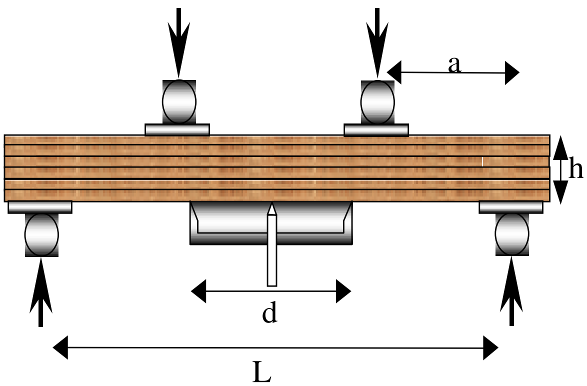

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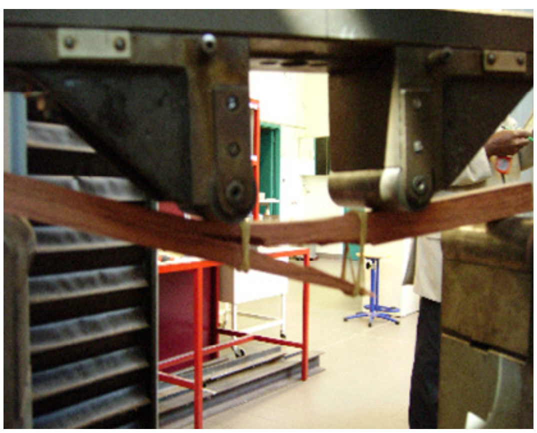

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Figure 3. Configuration of static flexural experimental setup. a) A specimen under a four-point static flexural testing b) Theoretical model of a four-point static flexural test c) Rupture d'une éprouvette par essai de flexion statique.

Two characteristics are generally obtained: the static modulus of elasticity Estat (MPa) and the breaking stress σR (MPa) and experimental results, based on the classical methods of the strength of materials, give us the following numerical expressions of these characteristics:

$$E_{stat} = \frac{ad^2}{16I}\frac{\Delta F}{\Delta w} \quad (2)$$

where : a is the distance from the first load to the exterior support (mm); d is the base width of the recording device under the specimen(mm); I is the moment of inertia of the transverse section (mm ^{4}); (ΔF/Δw) is the slope of the force/displacement diagram.

$$\sigma_R = \frac{3aF_{max}}{bh^2} \quad (3)$$

where : Fmax is the breaking load (N) ; b is the test specimen width (mm) ; h is the height of test specimen (mm).

ANALYTICAL ESTIMATION OF THE CHARACTERISTIC VALUE

Assigning species into groups

Assigning a given specie of order i to a specific group Gj (1 ≤ j ≤ 4) is done by means of a homogeneity test which the compares the average of species random variables E^i to the group's random variable Ej. It is natural to take the arithmetic average $\overline{E}_i$ of a sample random variable as an unknown mean m_{E_i} estimator; a realization $\overline{e}_i$ of the sample mean from observed values is an empiric average (Ruegg, 1988).

$$\overline{E}_i = \sum_{k=1}^{n_i} E_{i,k} \Big/ n_i \; ; \qquad \overline{e}_i = \sum_{k=1}^{n_i} e_{i,k} \Big/ n_i \quad (4)$$

where $\overline{E}_i$ is an unbiased estimator of m_{E_i} (or E[$\overline{E}_i$] = m_{E_i})

Otherwise the statistical value S_i^2 , with a numerical output s_i^2 , is the sample variance

$$S_i^2 = \frac{\sum_{k=1}^{n_i}(E_{i,k} - \overline{E}_i)^2}{n_i - 1} = \frac{\sum_{k=1}^{n_i} E_{i,k}^2 - \overline{E}_i^{\,2}}{n_i - 1} \; ;$$

$$s_i^2 = \frac{\sum_{k=1}^{n_i}(e_{i,k} - \overline{e}_i^{\,2})}{n_i - 1} = \frac{\sum_{k=1}^{n_i} e_{i,k}^2 - \overline{e}_i^{\,2}}{n_i - 1} \quad (5)$$

We assume that random variables Ei and Ej are distributed according to the normal laws $N\left(m_{E_i};\sigma_{E_i}^2\right)$ and $N\left(m_{E_j};\sigma_{E_j}^2\right)$ respectively, m_{E_i} being the unknown true mean and $\overline{E}_i$ the mean of the specie sampling I. It is proved that the random variables $\overline{E}_i$

and $\overline{E}_j$ obey the normal distribution laws $N(m_{E_i};\sigma^2_{E_i}/n_i)$ and $N(m_{E_j};\sigma^2_{E_j}/n_j)$ respectively (Ruegg, 1988). Since the variability is not identical for all species, we suppose that the unknown variances $\sigma^2_{E_i}$ and $\sigma^2_{E_j}$ are significantly different and thus, we replace population variances by their estimates $\hat{\sigma}^2_{E_i}$ and $\hat{\sigma}^2_{E_j}$ calculated from sample values (Mouchiroud, 2003). Under the condition of dense populated samples ($n_i \geq 30$ and $n_j \geq 30$ approximately), a value ui,j of the obtained random variable is calculated as:

$$u_{i,j} = (\bar{e}_i - \bar{e}_j) / \sqrt{s_i^2/(n_i-1) + s_j^2/(n_j-1)} \quad (6)$$

In the case of a fixed risk of error α, we obtain a value uα such that

$$u_\alpha = F_u^{-1}(\alpha) \quad (7)$$

where F_u^{-1} is an inverse function of the reduced normal distribution function Fu; uα is a table value.

If $u_{i,j} \leq u_\alpha$, the hypothesis is true: the two samples are extracted from two populations having the same expectation. The observed difference between $\bar{e}_i$ and $\bar{e}_j$ is due to random fluctuations that cannot be completely suppressed. We start with i-th specie assigned to group Gj, since in case of an error risk α the mean mEi is not significantly different to the mean mEj. In other words for a given i-th specie, we compute the following four reels:

$$d_{i,j} = \left(\bar{e}_i - \bar{e}_j\right) \Big/ \sqrt{\frac{s_i^2}{n_i-1} + \frac{s_j^2}{n_j-1}} \text{, } (1 \leq j \leq 4) \quad (8)$$

The minimization of the reel $\left|d_{i,j}\right|$ defines the assignment of a i-th specie into group Gj.

A simple estimation of the characteristic value

The characteristic value eα of the modulus of elasticity E of a group of species is subjected to the condition that, the probability of E being smaller than eα is α. The objective is to estimate the upper bond eα, so that an α-percentile outcome of E should be smaller than eα. For example, an upper bond eα with α = 0.05 describes a situation where 5% of the population is under eα. A hypothesis formulation of a probability density model that better fits experimental values is necessary. The characteristic value eα depends on the distribution law of random variable E. With this hypothesis P[E< eα]=α. In practice, the values of the mean mE and the standard deviation are unknown, and we can only estimate them from an empirical sample of the random variable E. Thus a set of experimental results e1, e2,…, en lead to the determination of E. These measures can be considered like the output of a random sample composed of independent and identically distributed random variables E1, E2,…, En. Therefore instead of getting the exact value eα of the characteristic value, only an estimate is obtained. The estimator of the characteristic value itself is a random variable denoted $\hat{E}_\alpha$. The probability of the estimator $\hat{E}_\alpha$, being less than the exact value eα, can be numerically computed. As a result, the desired estimator of the characteristic value is given from the probability P[$\hat{E}_\alpha$ < eα].

Considering the case where the random variable E follows the normal law is validated by the central limit theorem, a simple estimator $\hat{E}_\alpha$ of the characteristic value is obtained from the following equation:

$$\hat{E}_\alpha = \overline{E} + SF_u^{-1}(\alpha) \quad (9)$$

Knowing an output $\bar{e}$ of $\overline{E}$ and an output s of S, we compute the numerical value $\hat{e}_\alpha$ of $\hat{E}_\alpha$ as

$$\hat{e}_\alpha = \bar{e} + sF_u^{-1}(\alpha) \quad (10)$$

A simple evaluation is very approximate because the correction factor is independent of the sample size. Practically, for this estimator $\hat{E}_\alpha$ to be reliable, a densely populated sample is appropriate (as n approaches infinity).

Interval and unbiased estimation of the characteristic value

The estimator of the characteristic value, for a normally distributed random variable, can be given through the confidence level P[$\hat{E}_{\alpha,\lambda}$ <e $^{\alpha}$], which is equal to the probability 1- αλ associated to this estimation at intervals. Equation 10 is reformulated by replacing the real $F_u^{-1}(\alpha)$ with the parameter λ, whose appropriate value is sufficient to compute the numerical value $\hat{e}_{\alpha,\lambda}$ from an empirical sample $\hat{e}_{\alpha,\lambda} = \bar{e} + \lambda s$. From Equation 9, we can obtain the unbiased estimator $\hat{E}_{\alpha,\varepsilon}$ = $\overline{E}$ + εS of the characteristic value eα= E[$\hat{E}_{\alpha,\varepsilon}$], with the parameter ε taken as a correction factor. Analytical results of the correction factors λ and -ε are computed by the software package MATLAB Version 6.5.1 and are given in Table 1 for different values of αλ (or α) and n.

RESULTS AND DISCUSSION

The results given in this paragraph and in the appendices concern nineteen species. The moisture content of the

Table 1. Correction factors λ and - ε for a sample of size n.

n	3	4	5	6	7	8	10	100
αλ	**Correction factors λ, α=0.05**							
0.50	1.938	1.830	1.780	1.750	1.732	1.719	1.702	1.650
0.10	5.311	3.957	3.400	3.092	2.894	2.754	2.568	1.861
0.05	7.656	5.144	4.203	3.708	3.400	3.187	2.911	1.927
0.01	17.370	9.083	6.578	5.406	4.728	4.285	3.738	2.056
α	**Correction factors -** ε **for an unbiased estimation**							
0.10	1.446	1.391	1.363	1.347	1.336	1.328	1.318	1.285
0.05	1.856	1.785	1.750	1.729	1.715	1.705	1.691	1.649
0.01	2.625	2.525	2.475	2.445	2.425	2.411	2.392	2.332

test-samples after three months of drying under shelter is about 15%. This value is reduced to 12% with respect to Equation 4, in order to conform to standard bibliographic values (ATIBT, 1986). The characterization process will be widened in the near future to about 60 species as mentioned earlier. The Fourier transform of an instantaneous signal in the frequency domain, shows picks of the given frequency range corresponding to natural frequencies response of that specimen. The k-th mode of vibration is characterised by its natural frequency fk, its characteristic shape, its amplitude and its damping coefficient. For a floating beam, we can identify a frequency from one of the natural modes of which we know the associated rank and then calculate the MOE (Equation 1).

Results and their correlation with bibliographic values

A comparison between these experimental values obtained from the given non-destructive vibratory test and those provided by Gérard (2004) is given in Figure 4 from CIRAD (International Cooperation Center in Agronomic Research for Development). The differences observed on the one hand between the databases themselves, and on the other hand between the databases and obtained experimental results of our investigations, are explained by the sampling protocol and by the modal response. Available data of tropical wood concern statistical tests on woods from mature timber. These test results can vary considerably according to the origin and the growth conditions of timbers. Our investigations take into account the wood variability, in terms of local demand and constraints, from which arise the need of grouping species and of computing required characteristic values of species expected in structural woods.

By comparing the MOE obtained from the vibration test with the one obtained from the static test in the same direction (Table 2), it comes out that numerical values of these two experimental characteristics have little differences with vibratory MOE being almost 6% higher than the static MOE. A situation that is understandable, since frequencies of longitudinal vibration, recorded for the vibratory MOE and squared in Equation 1, are more element-dependant and higher than frequencies of transverse flexural vibrations, recorded by a cursor on a local point of the flexural element. The vibratory MOE, thus takes into account the overall characteristics of the element while the static MOE takes into account local characteristics, as described by French normative documents (NF EN 408,1995). Taking into account only the first longitudinal vibration mode in the described Bernoulli Formula, the vibratory MOE slightly overestimates the exact MOE and thus, renders the presented non-destructive vibratory method simpler and more efficient, than the static flexural testing method.

From the database of CIRAD (Gérard, 2004) on static 4-point static experiments done on various species, we find mean values of their physical and mechanical properties that enabled us to establish correlations (Figure 4) between vibratory and static MOEs, and between static MOR and vibratory MOE of representative species of the Congo Basin. A look on obtained curves shows that, the breaking stress through the static MOR, is well correlated with vibratory MOE, and that each group's diagram of cumulative frequencies (Figure 5) depicts a distinct curve including species with the same characteristics and excluding species with different characteristics. These observations validate the vibratory non-destructive test, as a powerful grouping tool of structural wood in Cameroon and its neighbourhood. Thus, in practice, a wood practitioner can obtain the MOE through the vibratory non-destructive test and thereafter, deduce the MOR from the classic correlation curves. From these two structural design characteristics, a required minimal quality can be guaranteed by a given specie.

Assigning species into groups

The suitability to regroup species in four groups, each represented by a leading-specie, according to the MOE,

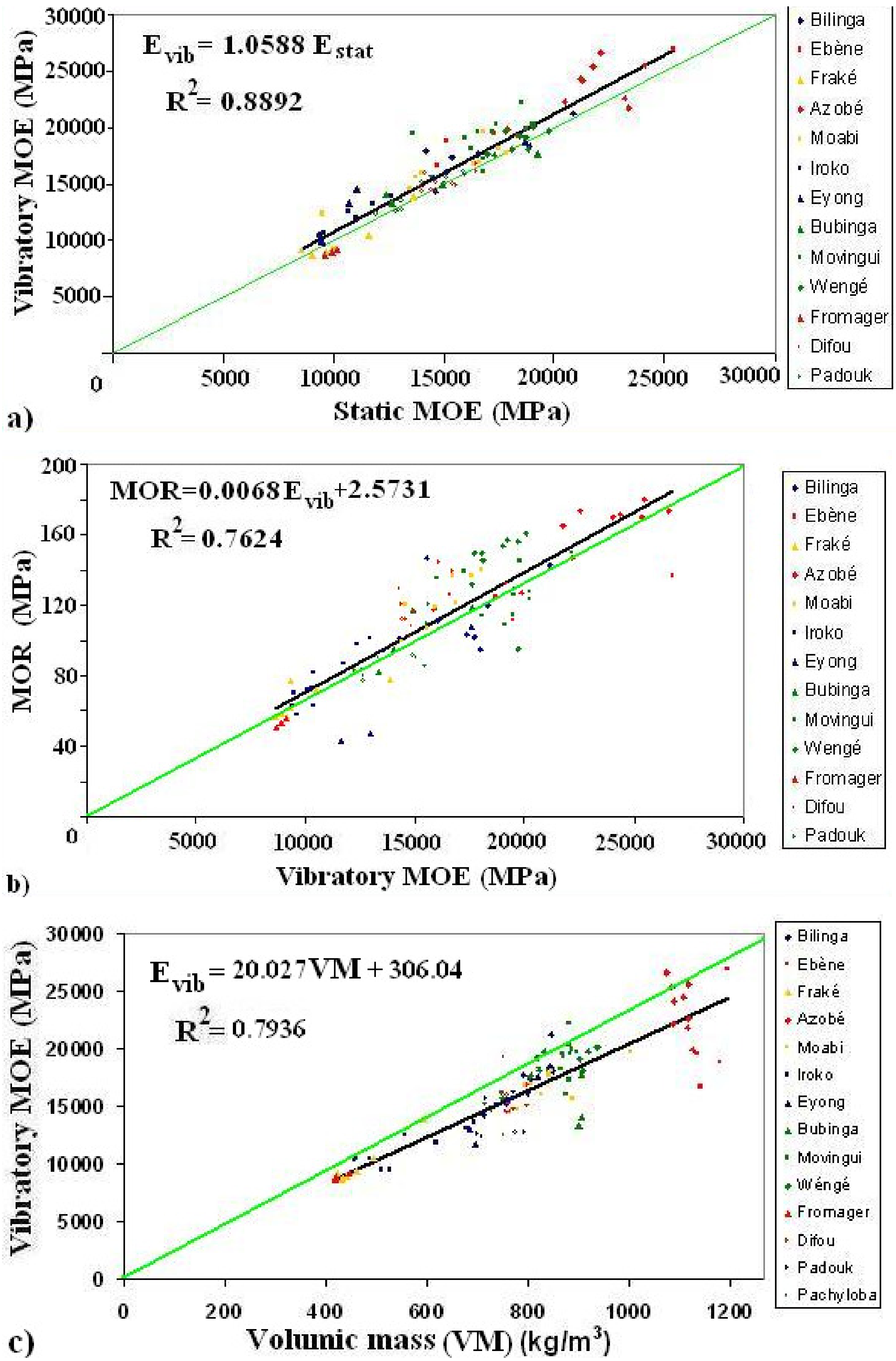

Figure 4. a) Correlation between vibratory and static experimental MOEs. b) Correlation between MOR and vibratory MOE. c) Correlation between vibratory MOE and the Volumic mass (VM).

Table 2. Vibratory non-destructive and static results from CIRAD (Gérard et al., 2004).

Specie local name	Specie botanic standard name	Vibratory MOE (MPa)		CIRAD MOE (MPa)	
		Mean	Standard deviation	Mean	Standard deviation
Ayous	*Triplochiton scleroxylon*	7035	1320	7260	1574
Sapelli	*Entandrophragma cylindricum*	12151	1400	13960	2403
Tali	*Erythrophleum ivorense*	17913	2093	19490	3224
Azobé	*Lophira alata*	23179	2169	21420	3539
Moabi	*Baillonella toxisperma*	16225	2754	21040	2630
Iroko	*Chlorophora excelsa*	11357	2091	12840	2496
Ebène	*Diospyros crassiflora*	18457	4988	18457	3500
Movingui	*Distemonanthus benthamianus*	18808	1509	18808	3053
Bubinga	*Guibourtia tessmannii*	16262	4092	20180	5592
Bibolo	*Lovoa trichilioides*	11517	1591	10460	946
Bété	*Mansonia altissima*	15614	1238	13620	1224
Wengé	*Milletia laurentii*	19423	1134	21050	695
Difou	*Morus mesozygia*	15914	1581	18490	2100
Bilinga	*Nauclea diderrichii*	16987	2249	14660	1934
Padouk	*Pterocarpus soyauxii*	14500	1518	15870	1885
Fraké	*Terminalia superba*	10203	1706	11750	2480
Eyong	*Eribroma oblonga*	14516	2591	17110	1910
Fromager	*Ceiba pentandra*	7860	1406	5130	1462
Pachyloba	*Afzelia pachyloba*	15691	1761	17020	2889

has been adopted. The leaders are four species among the more solicited ones: Ayous, Sapelli ,Tali and Azobe. These four species alone represent more than 60% of the total felling volume of wood in Cameroon. The idea behind this process is to find a replacement-specie or a structurally-possible substitute to each leader, while conserving needed main mechanical characteristics. A particular specie (Ebène with numbering order 7) might be used in more than one group, depending on the expected mechanical responses as seen in Table 3, allowing the present grouping to be a dynamic process. However, since groups 1 and 4 do not have many species falling into the group, a wider characterization and grading will be extended in the near future to additional species found in the Congo Basin.

The 5-th percentile characteristic value of species and groups

The characteristic value eα of the group of species MOE is the upper limit such that, a fraction α of the outcomes of the group of species MOE is lower than eα. For example, an upper limit eα with α = 0.05 describing a situation where 5% of the population are below eα. Table 4 gives the 5-th percentile characteristic value, for α =0.05, α_λ =0.5, and n=100, as a numerical application of the theory given earlier. Given the fact that various sample sizes are identical, we admit that the characteristic values of a given group are the arithmetic means of the characteristic values of that group of species. At intervals and unbiased simple estimators of the characteristic value are not significantly different. A fact that was foreseeable since by increasing indefinitely n and with α_λ =0.5, the values of λ and ε converge to $F_u^{-1}(0.05)$ =-1.645, which is constant in case of simple evaluation. The accuracy of characteristic values can be improved progressively by increasing the samples' size and taking more into account the species variability.

Referring to various mathematical models given first by the MOR and the vibratory MOE correlation curve and secondly by the vibratory MOE and the volumic mass correlation curve, we can give in a tabular form basic mechanical and physical characteristics pertaining to each group (Table 5): the mean modulus of elasticity E0,m ; the 5-th percentile characteristic value of the modulus of elasticity E0,k; the 5-th percentile characteristic value of the breaking stress fm,k ; the 5-th percentile characteristic value of the volumic mass ρk ;

CONCLUSION

The mechanical grouping of the species of the Congo Basin was carried out in this work on the basis of a homogeneity test comparing the species averages of the MOE taken as random variable Ei. Considering the

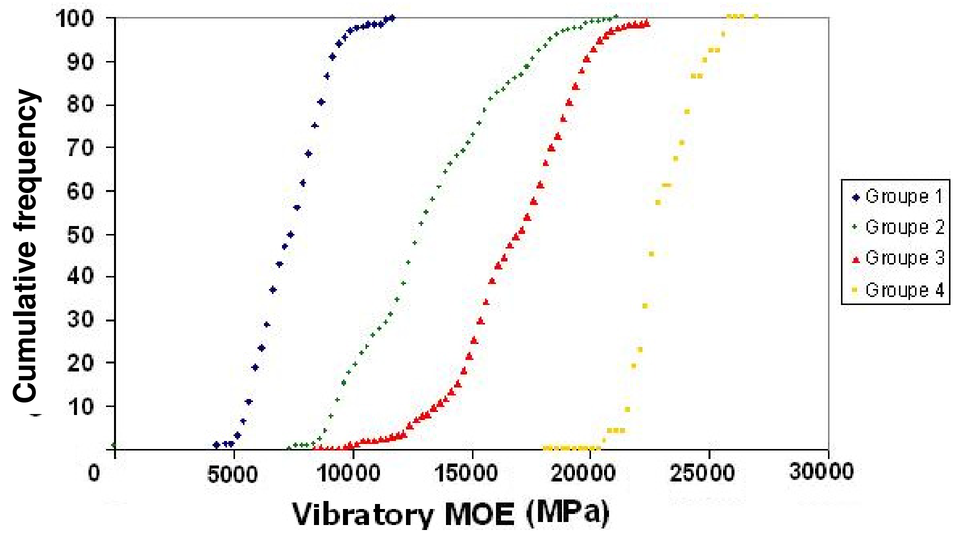

Figure 5. Cumulative Frequencies of experimental MOE for each group.

Table 3. Species assignment into one of the four groups.

Numbering order	Group specie	di,j, (i=specie order; j=group number)				Assigned groups
		Ayous (group 1)	Sapelli (group 2)	Tali (group 3)	Azobé (group 4)	
1	Ayous	0	-26.5	-43.7	-63.3	G1
2	Sapelli	26.5	0	-22.8	-42.6	G2
3	Tali	43.7	22.8	0	-17.4	G3
4	Azobé	63.3	42.6	17.4	0	G4 (G3)*
5	Moabi	29.9	13.1	-4.9	-19.7	G3 (G2)
6	Iroko	17.4	-3.1	-22.0	-39.0	G2 (G1)
7	Ebène	22.0	12.1	1.0	-8.6	G3 (G1, G2,G4)
8	Movingui	58.4	32.2	3.5	-16.5	G3 (G4)
9	Bubinga	21.4	9.5	-3,6	-14.9	G3 (G2, G4)
10	Bibolo	21.6	-3.0	-24.2	-43.1	G2
11	Bété	47.2	18.4	-9.4	-30.1	G3 (G2)
12	Wengué	70.8	40.1	6.3	-15.3	G3 (G4)
13	Difou	42.9	18.2	-3.0	-19.7	G3 (G2)
14	Bilinga	38.0	18.2	-3.0	-19.7	G3 (G2)
15	Padouk	36.9	11.3	-13.1	-32.6	G2 (G3)
16	Fraké	14.6	- 8.8	-24.4	-46.8	G2 (G1)
17	Eyong	25.6	8.0	-10.1	-25.5	G2 (G3)
18	Fromager	4.3	- 21.5	-39.7	-59.0	G1
19	Pachyloba	39.1	15.7	-8.1	-26.7	G3 (G2)

( ) : Structurally-possible substitute.

significance of the present research work and its eventual future development to the local wood industry, representative samples of species were tested in sufficient quantities to reliably establish the 5th percentile characteristic value of the species' MOE.

Some species with tested identical mechanical characteristics can be interchangeably used in the construction industry without altering structural expectations of the consumer. The frequency analysis of wood specimen and the present computational procedure allow us to group species with identical mechanical characteristics, in such a way that wood designers and constructors might have a wide variety of choices in their decision-making, while promoting less-consumed

Table 4. The 5th percentile characteristic value.

Species group	Species name	Mean MOE (MPa)	Characteristic value (MPa) estimation: Simple	At-intervals	Unbiased
			$\hat{e}_{0.05} = \bar{e}$ -1.645s	$\hat{e}_{0.05} = \bar{e}$ -1.650	$\hat{e}_{0.05} = \bar{e}$ -1.649
Group 1	Ayous	7035	4864	4857	4858
	Fromager	7860	5547	5540	5542
Properties of group 1		7447	5205	5198	5200
Group 2	Sapelli	12151	9848	9841	9842
	Iroko	11357	7917	7907	7909
	Bibolo	11517	8900	8892	8893
	Padouk	14500	12003	11995	11997
	Fraké	10203	7397	7388	7390
	Eyong	14516	10254	10241	10243
Properties of group 2		12374	9386	9377	9379
Group 3	Tali	17913	14470	14460	14462
	Moabi	16225	11695	11681	11684
	Ebène	18457	10252	10227	10232
	Movingui	18808	16326	16318	16320
	Bubinga	16262	9531	9510	9514
	Bété	15614	13577	13571	13573
	Wengué	19423	17558	17552	17553
	Difou	15914	13313	13305	13307
	Bilinga	16987	13287	13276	13278
	Pachyloba	15691	12794	12785	12787
Properties of group 3		17129	13280	13268	13271
Groupe 4	Azobé	23179	19611	19600	19602
Properties of group 4		23179	19611	19600	19602

Table 5. Group mechanical and physical characteristics.

Group characteristics		Group 1	Group 2	Group 3	Group 4
Modulus of elasticity (MPa)	E0,m	7447	12374	17129	23179
	E0,k	5205	9386	13280	19611
Breaking stress (MPa)	fm,k	38	66	93	136
Volumic mass (kg/m^3)	ρk	245	453	648	964

species, reducing the demand of traditionally most wanted extinguishable species, as well establishing a technical argument for their conservation. Since the objective of this work was not widely met for leader-species of group 1 and group 4, further studies must be done to include more local species in the present database not only for these two groups, but also for others.

This non-destructive grading method is a pushover, starting with the flexural behaviour of sample specimen to find the transverse mechanical characteristics (perpendicular to grain) of species. That will be extended in the near future to assess longitudinal and radial characteristics of wood for such behaviours like compression, shear and torsion.

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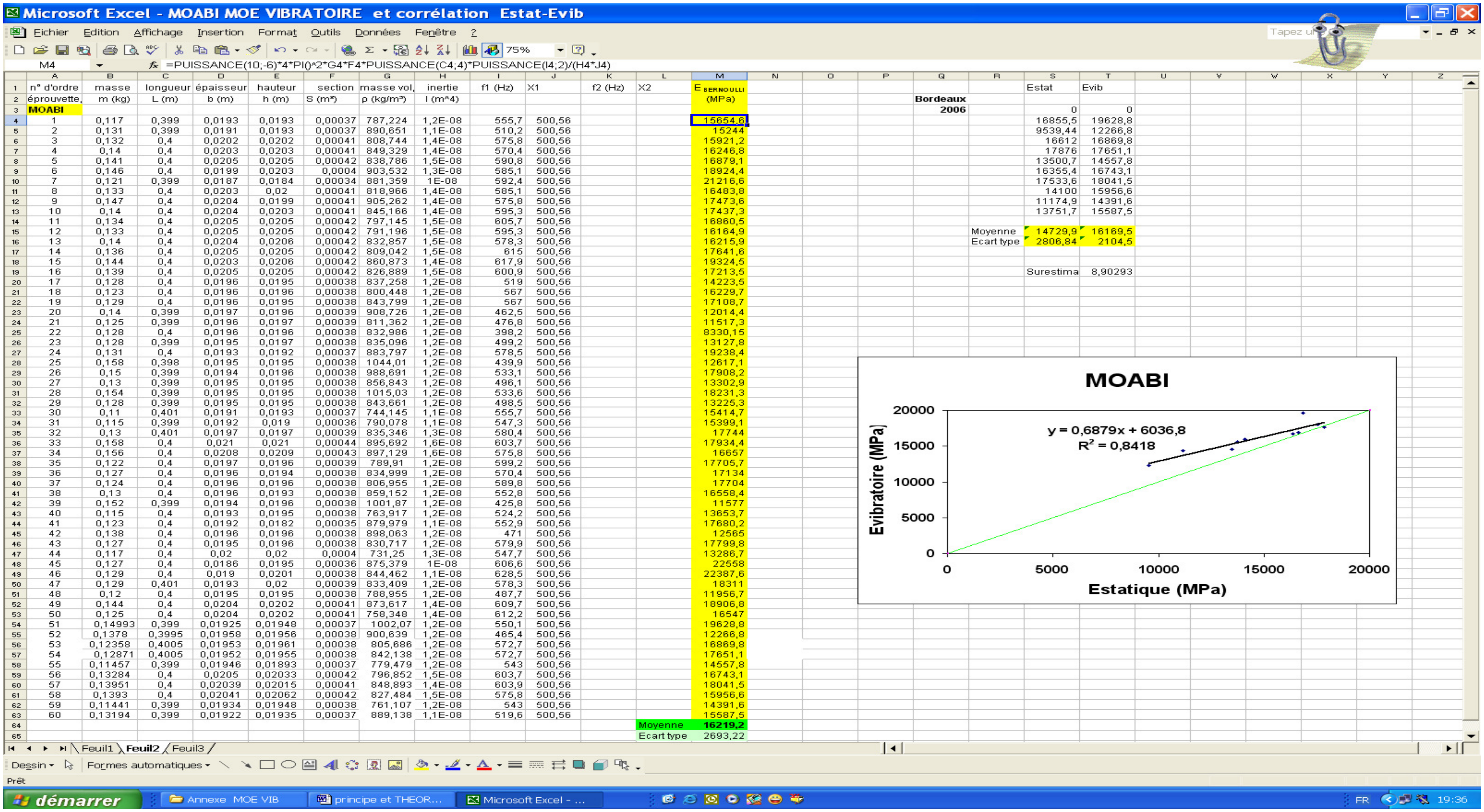
Appendices 1. Microsoft Excel sheet estimating the vibratory MOE of the Moabi (Baillonella toxisperma) specie from the theory developed in the present work.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	n° d'ordre	masse	longueur	épaisseur	hauteur	section	masse vol,	inertie	f1 (Hz)	X1	f2 (Hz)	X2	E BERNOULLI
2	éprouvette,	m (kg)	L (m)	b (m)	h (m)	S (m²)	ρ (kg/m³)	I (m^4)					(MPa)
3	MOABI												
4	1	0,117	0,399	0,0193	0,0193	0,00037	787,224	1,2E-08	555,7	500,56			15654,6
5	2	0,131	0,399	0,0191	0,0193	0,00037	890,651	1,1E-08	510,2	500,56			15244
6	3	0,132	0,4	0,0202	0,0202	0,00041	808,744	1,4E-08	575,8	500,56			15921,2
7	4	0,14	0,4	0,0203	0,0203	0,00041	849,329	1,4E-08	570,4	500,56			16246,8
8	5	0,141	0,4	0,0205	0,0205	0,00042	838,786	1,5E-08	590,8	500,56			16879,1
9	6	0,146	0,4	0,0199	0,0203	0,0004	903,532	1,3E-08	585,1	500,56			18924,4
10	7	0,121	0,399	0,0187	0,0184	0,00034	881,359	1E-08	592,4	500,56			21216,6
11	8	0,133	0,4	0,0203	0,02	0,00041	818,966	1,4E-08	585,1	500,56			16483,8
12	9	0,147	0,4	0,0204	0,0199	0,00041	905,262	1,4E-08	575,8	500,56			17473,6
13	10	0,14	0,4	0,0204	0,0203	0,00041	845,166	1,4E-08	595,3	500,56			17437,3
14	11	0,134	0,4	0,0205	0,0205	0,00042	797,145	1,5E-08	605,7	500,56			16860,5
15	12	0,133	0,4	0,0205	0,0205	0,00042	791,196	1,5E-08	595,3	500,56			16164,9
16	13	0,14	0,4	0,0204	0,0206	0,00042	832,857	1,5E-08	578,3	500,56			16215,9
17	14	0,136	0,4	0,0205	0,0205	0,00042	809,042	1,5E-08	615	500,56			17641,6
18	15	0,144	0,4	0,0203	0,0206	0,00042	860,873	1,4E-08	617,9	500,56			19324,5
19	16	0,139	0,4	0,0205	0,0205	0,00042	826,889	1,5E-08	600,9	500,56			17213,5
20	17	0,128	0,4	0,0196	0,0195	0,00038	837,258	1,2E-08	519	500,56			14223,5
21	18	0,123	0,4	0,0196	0,0196	0,00038	800,448	1,2E-08	567	500,56			16229,7
22	19	0,129	0,4	0,0196	0,0195	0,00038	843,799	1,2E-08	567	500,56			17108,7
23	20	0,14	0,399	0,0197	0,0196	0,00039	908,726	1,2E-08	462,5	500,56			12014,4
24	21	0,125	0,399	0,0196	0,0197	0,00039	811,362	1,2E-08	476,8	500,56			11517,3
25	22	0,128	0,4	0,0196	0,0196	0,00038	832,986	1,2E-08	398,2	500,56			8330,15
26	23	0,128	0,399	0,0195	0,0197	0,00038	835,096	1,2E-08	499,2	500,56			13127,8
27	24	0,131	0,4	0,0193	0,0192	0,00037	883,797	1,2E-08	578,5	500,56			19238,4
28	25	0,158	0,398	0,0195	0,0195	0,00038	1044,01	1,2E-08	439,9	500,56			12617,1
29	26	0,15	0,399	0,0194	0,0196	0,00038	988,691	1,2E-08	533,1	500,56			17908,2
30	27	0,13	0,399	0,0195	0,0195	0,00038	856,843	1,2E-08	496,1	500,56			13302,9
31	28	0,154	0,399	0,0195	0,0195	0,00038	1015,03	1,2E-08	533,6	500,56			18231,3
32	29	0,128	0,399	0,0195	0,0195	0,00038	843,661	1,2E-08	498,5	500,56			13225,3
33	30	0,11	0,401	0,0191	0,0193	0,00037	744,145	1,1E-08	555,7	500,56			15414,7
34	31	0,115	0,399	0,0192	0,019	0,00036	790,078	1,1E-08	547,3	500,56			15399,1
35	32	0,13	0,401	0,0197	0,0197	0,00039	835,346	1,3E-08	580,4	500,56			17744
36	33	0,158	0,4	0,021	0,021	0,00044	895,692	1,6E-08	603,7	500,56			17934,4
37	34	0,156	0,4	0,0208	0,0209	0,00043	897,129	1,6E-08	575,8	500,56			16657
38	35	0,122	0,4	0,0197	0,0196	0,00039	789,91	1,2E-08	599,2	500,56			17705,7
39	36	0,127	0,4	0,0196	0,0194	0,00038	834,999	1,2E-08	570,4	500,56			17134
40	37	0,124	0,4	0,0196	0,0196	0,00038	806,955	1,2E-08	589,8	500,56			17704
41	38	0,13	0,4	0,0196	0,0193	0,00038	859,152	1,2E-08	552,8	500,56			16558,4
42	39	0,152	0,399	0,0194	0,0196	0,00038	1001,87	1,2E-08	425,8	500,56			11577
43	40	0,115	0,4	0,0193	0,0195	0,00038	763,917	1,2E-08	524,2	500,56			13653,7
44	41	0,123	0,4	0,0192	0,0182	0,00035	879,979	1,1E-08	552,9	500,56			17680,2
45	42	0,138	0,4	0,0196	0,0196	0,00038	898,063	1,2E-08	471	500,56			12565
46	43	0,127	0,4	0,0195	0,0196	0,00038	830,717	1,2E-08	579,9	500,56			17799,8
47	44	0,117	0,4	0,02	0,02	0,0004	731,25	1,3E-08	547,7	500,56			13286,7
48	45	0,127	0,4	0,0186	0,0195	0,00036	875,379	1E-08	606,6	500,56			22558
49	46	0,129	0,4	0,019	0,0201	0,00038	844,462	1,1E-08	628,5	500,56			22387,6
50	47	0,129	0,401	0,0193	0,02	0,00039	833,409	1,2E-08	578,3	500,56			18311
51	48	0,12	0,4	0,0195	0,0195	0,00038	788,955	1,2E-08	487,7	500,56			11956,7
52	49	0,144	0,4	0,0204	0,0202	0,00041	873,617	1,4E-08	609,7	500,56			18906,8
53	50	0,125	0,4	0,0204	0,0202	0,00041	758,348	1,4E-08	612,2	500,56			16547
54	51	0,14993	0,399	0,01925	0,01948	0,00037	1002,07	1,2E-08	550,1	500,56			19628,8
55	52	0,1378	0,3995	0,01958	0,01956	0,00038	900,639	1,2E-08	465,4	500,56			12266,8
56	53	0,12358	0,4005	0,01953	0,01961	0,00038	805,686	1,2E-08	572,7	500,56			16869,8
57	54	0,12871	0,4005	0,01952	0,01955	0,00038	842,138	1,2E-08	572,7	500,56			17651,1
58	55	0,11457	0,399	0,01946	0,01893	0,00037	779,479	1,2E-08	543	500,56			14557,8
59	56	0,13284	0,4	0,0205	0,02033	0,00042	796,852	1,5E-08	603,7	500,56			16743,1
60	57	0,13951	0,4	0,02039	0,02015	0,00041	848,893	1,4E-08	603,9	500,56			18041,5
61	58	0,1393	0,4	0,02041	0,02062	0,00042	827,484	1,5E-08	575,8	500,56			15956,6
62	59	0,11441	0,399	0,01934	0,01948	0,00038	761,107	1,2E-08	543	500,56			14391,6
63	60	0,13194	0,399	0,01922	0,01935	0,00037	889,138	1,1E-08	519,6	500,56			15587,5
64												Moyenne	**16219,2**
65												Ecart type	2693,22

	Q	R	S	T
1			Estat	Evib
2	**Bordeaux**			
3	**2006**		0	0
4			16855,5	19628,8
5			9539,44	12266,8
6			16612	16869,8
7			17876	17651,1
8			13500,7	14557,8
9			16355,4	16743,1
10			17533,6	18041,5
11			14100	15956,6
12			11174,9	14391,6
13			13751,7	15587,5
15		Moyenne	14729,9	16169,5
16		Ecart type	2806,84	2104,5
19			Surestima	8,90293

Column A: Specimen number; column B: Specimen mass (kg); column C: Specimen length (m); column D: Specimen thickness (m); column E: Specimen height (m); Column F: Specimen cross-sectional area (m^2); column G: Specimen volumic mass (kg/m^3); column H: Specimen cross-sectional inertia modulus (m4); column I: Specimen (f1) frequency of the first longitudinal mode of vibration; column J: Parameter Xk (Equation 1); column M: Specimen vibratory MOE estimate. Line 64: Specie MOE average vibratory; line 65: Specie vibratory MOE standard variation. (a sample of 60 specimens and not 100). On the diagram: Correlation between vibratory and static MOEs; Evibratoire= vibratory MOE;Estatique= static experimental MOE

Appendices 2. Experimental data (vibratory MOE) recorded from the non-destructive vibratory test (MPA) of various species of the Congo Basin.

N° Eprouvette	AYOUS	BIBOLO	EBENE	SAPELLI	FRAKE	BILINGA	MOABI	IROKO	TALI	EYONG	AZOBE	BUBINGA	MOVINGUI	WENGE	FROMAGER	BETE	DIFOU	PADOUK	PACHYLOBA
1	5410	14765	18833	12906	9181	16638	15655	10859	12402	17576	25953	15802	18275	17743	7873	14933	15565	16069	12471
2	11459	11428	19012	12171	9307	16282	15244	15180	20329	12956	25953	23287	16654	19094	7705	16406	15605	15129	14525
3	6355	9864	26255	13959	8910	16115	15921	15465	17638	11647	25853	13832	18806	20834	8115	15177	17550	13592	18052
4	6531	11722	13442	12084	8647	17278	16247	9751	17551	17876	25853	18965	20814	19956	7573	16737	15036	12181	15471
5	7849	10886	10450	11053	13868	18611	16879	9959	17580	13256	25653	17543	19144	20955	7405	17180	19921	16789	15655
6	6400	10806	18692	12184	10476	19759	18924	10277	20122	11947	25653	15317	19651	17735	9115	17206	15604	15685	15027
7	5858	14865	16598	10222	9304	15395	21217	11103	19300	17476	25553	13488	18094	18055	9273	13658	15638	15575	18133
8	8885	11528	26808	13126	9481	17370	16484	14739	18984	12856	25553	23302	19493	18096	9105	15792	14836	15646	15933
9	10416	9964	19516	8763	9607	19818	17474	13075	15080	11547	25100	22615	19632	17611	9515	16053	14338	15106	12371
10	8258	11822	18633	11991	9210	14221	17437	10370	15875	17776	25000	18852	20239	19209	8973	16927	19153	15470	14425
11	7058	10986	18812	11934	8947	18998	16860	9570	17291	13156	24908	14729	20250	19021	8805	19024	14917	12656	17952
12	8632	10906	26055	13206	14168	19245	16165	12948	17400	11847	24890	13965	17242	19700	6415	14342	14437	16089	15371
13	9081	14565	13242	12471	10776	12895	16216	7357	19576	18076	24808	15209	19122	19713	5873	15489	15909	14941	15555
14	6378	11228	10250	14259	9604	14159	17642	9743	18928	13456	24800	12160	16013	20086	5705	15384	16749	12687	14927
15	5967	9664	18492	12384	9081	16985	19325	10172	19098	12147	24441	16603	19843	18043	6115	15583	14644	12594	18033
16	6557	11522	16398	11353	9207	17715	17213	9483	12702	18376	24441	16363	19552	19394	5573	14996	14458	13379	15833
17	7315	10686	26608	12484	8810	15572	14224	11081	20629	13756	24400	9753	22154	21134	5405	15383	15039	12283	12721
18	7577	10606	19316	10522	8547	18978	16230	8071	17938	12447	24341	11025	17975	20256	5815	14633	16126	15969	14775
19	6876	14665	18933	13426	13768	16128	17109	10340	17851	17976	24341	10412	16354	21255	5973	16106	15465	15029	18302
20	6000	11328	19112	9063	10376	11906	12014	9169	17880	13356	24340	19710	18506	18035	5805	14877	15505	13492	15721
21	6646	9764	26355	12291	9204	14582	11517	10165	20422	12047	24308	14966	20514	18355	6215	16437	17450	12081	15905
22	8074	11622	13542	12234	9381	17481	8330	11485	19600	18276	24240	20367	18844	18396	5673	16880	14936	16689	15277
23	7829	10786	10550	12806	9507	21044	13128	9198	19284	13656	24208	15945	19351	17911	5505	16906	19821	15585	18383
24	6354	10706	18792	12071	9110	15629	19238	10799	15380	12347	24141	18995	17794	19509	9250	13358	15504	15475	16183
25	4415	15065	16698	13859	8847	19822	12617	12676	16175	17376	24141	10259	19193	19321	9858	15492	15538	15546	12621
26	7090	11728	26908	11984	14068	17119	17908	10819	17591	12756	24041	16832	19332	20000	9690	15753	14736	15006	14675
27	6514	10164	19616	10953	10676	18331	13303	15922	17700	11447	24041	9769	19939	20013	10100	16627	14238	15370	18202
28	7113	12022	18733	12084	9504	17341	18231	9067	19876	17676	24040	18347	19950	20386	9558	18724	19053	12556	15621
29	5944	11186	18912	10122	9681	15553	13225	10779	19228	13056	24440	11109	16942	17643	9390	14042	14817	15989	15805
30	7058	11106	26155	13026	9807	21184	15415	12540	19398	11747	23998	15970	18822	18994	9800	15189	14337	14841	15177
31	5875	15165	13342	8663	9410	17978	15399	9812	12302	17276	23998	19327	15713	20734	9958	15084	15809	12587	18283
32	7009	11828	10350	11891	9147	20566	17744	10957	20229	12656	23898	12399	19543	19856	8855	15283	16649	12494	16083
33	6727	10264	18592	11834	14368	16098	17934	7504	17538	11347	23898	13820	19252	20855	9265	14696	14544	13279	12271
34	6109	12122	16498	13106	10976	14296	16657	9964	17451	17576	23739	30218	21854	17635	8723	15083	14358	12183	14325

Appendices 2. Contd.

35	6836	11286	26708	12371	9804	17711	17706	14380	17480	12956	23707	12427	18375	17955	8555	15033	14939	16369	17852
36	7399	11206	19416	14159	9981	16238	17134	10578	20022	11647	23698	18970	16754	17996	8965	16506	16026	15429	15271
37	6905	14865	18433	12284	10107	15882	17704	13465	19200	17876	23698	18172	18906	17511	8423	15277	15865	13892	15455
38	6843	11528	18612	11253	9710	15715	16558	13939	18884	13256	23647	13513	20914	19109	8255	16837	15905	12481	14827
39	5103	9964	25855	12384	9447	16878	11577	12301	14980	11947	23607	15091	19244	18921	8740	17280	17850	17089	17933
40	6603	11822	13042	10422	14668	18211	13654	14831	15775	18176	23098	19584	19751	19600	8198	17306	15336	15985	15733
41	7634	10986	10050	13326	11276	19359	17680	15903	17191	13556	23098	13589	18194	19613	8030	13758	20221	15875	12171
42	6846	10906	18292	8963	10104	14995	12565	9437	17300	12247	23047	22704	19593	19986	8440	15892	15904	15946	14225
43	5950	14965	16198	12191	9581	16970	17800	11515	19476	17776	23014	11552	19732	17943	8598	16153	15938	15406	17752
44	5510	11628	26408	12134	9707	19418	13287	10847	18828	13156	22989	15003	20339	19294	8430	17027	15136	15770	15171
45	11559	10064	19116	13406	9310	13821	22558	14210	18998	11847	22907	20330	20350	21034	8365	19124	14638	12956	15355
46	6455	11922	18233	12671	9047	18598	22388	14160	12602	18076	22889	18519	17342	20156	7823	14442	19453	16389	14727
47	6631	11086	18412	14459	14268	18845	18311	11320	20529	13456	22847	14057	19222	21155	7655	15589	15217	15241	17833
48	7949	11006	25655	12584	10876	12495	11957	9659	17838	12147	22807	13327	16113	17935	8065	15484	14737	12987	15633
49	6500	14365	12842	11553	9704	13759	18907	12480	17751	17976	22764	17645	19943	18255	8023	15683	16209	12894	12521
50	5958	11028	9850	12684	9881	16585	16547	10776	17780	13356	22747	14889	19652	18296	7855	15096	17049	13679	14575
51	8985	9464	18092	10722	10007	17315	19629	13516	20322	12047	22689	15902	22254	17811	8265	15483	14944	12583	18102
52	10516	11322	15998	13626	9610	15172	12267	14783	19500	18276	22864	23387	18075	19409	7723	14733	14758	16269	15521
53	8358	10486	26208	9263	9347	18578	16870	13159	19184	13656	22789	13932	16454	19221	7555	16206	15339	15329	15705
54	7158	10406	18916	12491	14568	15728	17651	13558	15280	12347	22664	19065	18606	19900	7965	14977	16426	13792	15077
55	8732	14465	18533	12434	11176	11506	14558	12855	16075	17876	22564	17643	20614	19913	8123	16537	15765	12381	18183
56	9181	11128	18712	13706	10004	14182	16743	10376	17491	13256	22880	15417	18944	20286	7955	16980	15805	16989	15983
57	6478	9564	25955	12971	9104	17081	18042	11778	17600	11947	22880	13588	19451	18243	8365	17006	17750	15885	12421
58	6067	11422	13142	14759	9281	20644	15957	9418	19776	18176	22780	23402	17894	19594	9223	13458	15236	15775	14475
59	6657	10586	10150	12884	9407	15229	14392	13586	19128	13556	22780	22715	19293	21334	9055	15592	20121	15846	18002
60	7415	10506	18392	11853	9010	19422	15588	12975	19298	12247	22580	18952	19432	20456	9465	15853	15804	15306	15421
61	7677	14165	16298	12984	8747	16719	17737	9652	12502	18476	22580	14829	20039	21455	8923	16727	15838	15670	15605
62	6976	10828	26508	11022	13968	17931	17160	12380	20429	13856	22480	14065	20050	18235	8755	18824	15036	12856	14977
63	6100	9264	19216	13926	10576	16941	16465	10300	17738	12547	22480	15309	17042	18555	9165	14142	14538	16289	18083
64	6746	11122	18333	9563	9404	15153	16516	10390	17651	18776	22478	12260	18922	18596	8623	15289	19353	15141	15883
65	8174	10286	18512	12791	8881	20784	17942	10128	17680	14156	22478	16703	15813	18111	8455	15184	15117	12887	12621
66	7929	10206	25755	12734	9007	17578	19625	9495	20222	12847	22178	16463	19643	19709	8865	15383	14637	12794	14675
67	6454	14265	12942	13306	8610	20166	17513	11059	19400	18376	22178	9853	19352	19521	9023	14796	16109	13579	18202
68	7215	10928	9950	12571	8347	15698	14524	15380	19084	13756	21978	11125	21954	20200	8855	15183	16949	12483	15621
69	7477	9364	18192	14359	13568	13896	16530	15665	15180	12447	21978	10512	17775	20213	9265	14989	14844	15919	15805
70	6776	11222	16098	12484	10176	17311	17409	9951	15975	18676	21958	19810	16154	20586	8723	14884	14658	14979	15177

Appendices 2. Contd.

71	5900	10386	26308	11453	9004	16738	12314	10159	17391	14056	21878	15066	18306	18543	4655	15083	15239	13442	18283
72	6546	10306	19016	12584	9181	16382	11817	10477	17500	12747	21878	20467	20314	19894	5065	14496	16326	12031	16083
73	7974	14665	18033	10622	9307	16215	8630	11303	19676	17776	22341	16045	18644	21634	5673	14883	15365	16639	12521
74	7729	11328	18212	13526	8910	17378	13428	14939	19028	13156	22341	19095	19151	20756	5505	14133	15405	15535	14575
75	6254	9764	25455	9163	8647	18711	19538	13275	19198	11847	22741	10359	17594	21755	5915	15606	17350	15425	18102
76	4315	11622	12642	12391	13868	19859	12917	10570	12802	18076	22741	16932	18993	18535	5373	14377	14836	15496	15521
77	6990	10786	9650	12334	10476	15495	18208	9770	20729	13456	22708	9869	19132	18855	5205	15937	19721	14956	15705
78	6414	10706	17892	13606	9304	17470	13603	13148	18038	12147	22608	18447	19739	18896	5615	16380	15404	15320	15077
79	7013	14765	15798	12871	9481	19918	18531	7557	17951	17676	22541	11209	19750	18411	5773	16406	15438	12506	18183
80	5844	11428	18233	14659	9607	14321	13525	9943	17980	13056	22541	16070	16742	20009	5605	12858	14636	15939	15983
81	6958	9864	18412	12784	9210	19098	15715	10372	20522	11747	22441	19427	18622	19821	6015	14992	14138	14791	12871
82	5775	11722	25655	11753	8947	19345	15699	9683	19700	17976	22441	12499	15513	20500	5473	15253	18953	12537	14925
83	6909	10886	12842	12884	14168	12995	18044	11281	19384	13356	22408	13920	19343	20513	5305	16127	14717	12444	18452
84	6627	10806	9850	10922	10776	14259	18234	8271	15480	12047	22308	30318	19052	20886	8915	18224	14237	13229	15871
85	6009	14465	18092	13826	9604	17085	16957	10540	16275	18276	22131	12527	21654	18143	8373	13542	15709	12133	16055
86	6736	11128	15998	9463	9781	17815	18006	9369	17691	13656	22031	19070	17475	19494	8205	14689	16549	15819	15427
87	7299	9564	26208	12691	9907	15672	17434	10365	17800	12347	21968	18272	15854	21234	8615	14584	14444	14879	18533
88	6805	11422	18916	12634	9510	19078	18004	11685	19976	18576	21968	13613	18006	20356	8073	14783	14258	13342	16333
89	6743	10586	18033	12706	9247	16228	16858	9398	19328	13956	21868	15191	20014	21355	7905	14196	14839	11931	12771
90	5003	10506	18212	11971	14468	12006	11877	10999	19498	12647	21868	19684	18344	18135	8315	14583	15926	16539	14825
91	6503	14565	25455	13759	11076	14682	13954	12876	12402	18176	21831	13689	18851	18455	8206	14533	15265	15435	18352
92	7534	11228	12642	11884	9904	17581	17980	11019	20329	13556	21731	22804	17294	18496	8038	16006	15305	15325	15771
93	6746	9664	9650	10853	9381	21144	12865	16122	17638	12247	21668	11652	18693	18011	8448	14777	17250	15396	15955
94	5850	11522	17892	11984	9507	15729	18100	9267	17551	18476	21668	15103	18832	19609	7906	16337	14736	14856	15327
95	7734	10686	15798	10022	9110	19922	13587	10979	17580	13856	21568	20430	19439	19421	7738	16780	19621	15220	18433
96	6946	10606	26008	12926	8847	17219	22858	12740	20122	12547	21568	18619	19450	20100	8148	16806	15304	12406	16233
97	6050	15265	18716	8563	14068	18431	22688	10012	19300	17226	20921	14157	16442	20113	8856	13258	15338	15839	12421
98	5310	11928	18333	11791	10676	17441	15955	11157	18984	12606	20821	13427	18322	20486	8688	15392	14536	14691	14475
99	11359	10364	18512	11734	9504	15653	15544	7704	15080	11297	20621	17745	15213	18443	9098	15653	14038	12437	18002
100	6255	12222	25755	13006	9681	21284	15021	10164	15875	17526	20521	14989	19043	19794	8556	16527	18853	12344	15421
Moyenne	**7035**	**11517**	**18457**	**12151**	**10203**	**16987**	**16225**	**11357**	**17913**	**14516**	**23179**	**16262**	**18808**	**19423**	**7860**	**15614**	**15914**	**14500**	**15691**
Ecart type	**1320**	**1591**	**4988**	**1400**	**1706**	**2249**	**2754**	**2091**	**2093**	**2591**	**2169**	**4092**	**1509**	**1134**	**1406**	**1238**	**1581**	**1518**	**1761**

First Line : Speice's local name (from 2nd to last column); First column : Wood specimen number of the considered specie.