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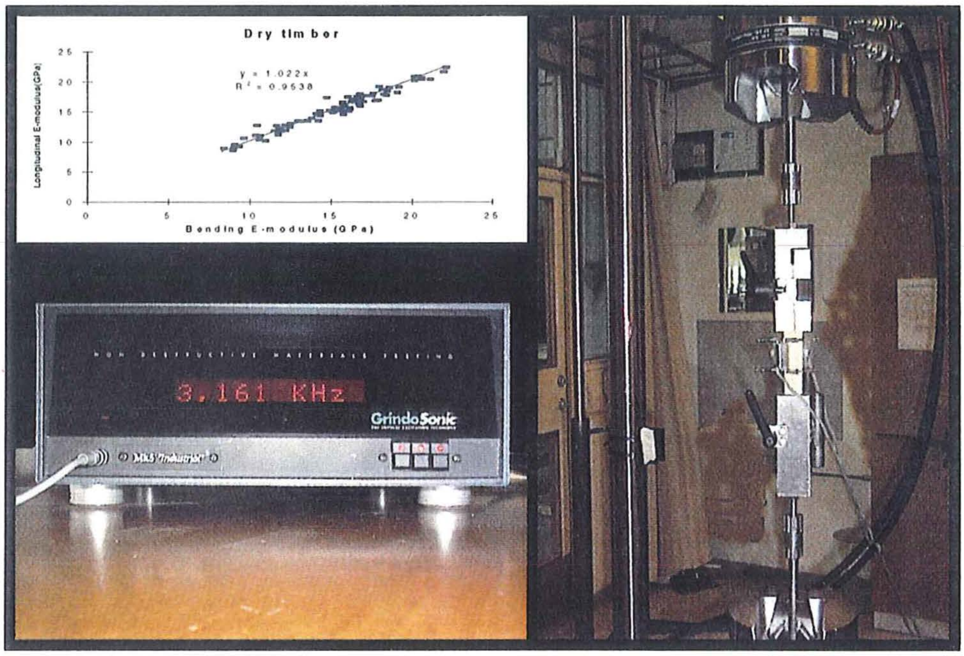

Modulus of Elasticity of Norway Spruce using Different Techniques

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PREFACE

This master thesis has been configured for the Department of Structural Engineering at the Lund Institute of Technology under control of my supervisor: Mohammed Alhasani.

It has been written in such a manner that the contents are comprehensible in a high level even though the person, who is reading this thesis, is not a specifically a structural engineer. Furthermore, this thesis reflects the difficulties that you can find studying the E-modulus in wood. It is written in a way to understand the difficulties found working with wood and the different factors affecting.

I want to give some thanks to the following: Mohammed Alhasani to be patience and really nice; Sven Thelandersson, for the generosity of his time to introduce myself in the good atmosphere of the department; Per-Olof Rosenkvist, for his friendship and help at the lab; and Annika Mårtensson for making my trip to Sweden easier.

Lund, September 1998
Israel Burón

SUMMARY

The porpuse of this thesis is to evlauate the utility of GrindoSonicMK5 instrument studying the modulus of elasticity in Norway Spruce and the factors affectting.

Dynamic methods provide rapid an accurate means to determine modulus of elasticity. For a high number of specimens GrindoSonicMK5 instrument provides a simpler, more rapidly performed alternative than the classical tension method.

The relation between those two methods is complicated and must be determined in function of the factors affecting the modulus of elasticity. The theories are presented in chapter two in a limited manner to introduce the unfamiliar reader to the principles and terms presented in this research.

In chapter three the experimental work is presented, with an exhaustive description of the different lines used in the testing procedure. The experimental work describes the methodology, follow up, scope, and aim of each line used in the testing procedure. Those lines represent the diferent points studied and aims carried out in this research with GrindoSonicMK5 instrument. However, in order to obtain a reliable conclussion of the dynamic results with GrindoSonicMK5 instrument, some of the lines were parallely conducted statically with the classical tension method.

In chapter four the test results are presented in order to make, easier to understand, why some decisions were chosen during the experimental work and how the factors affecting the E-modulus can affect.

Results presented show that a resonance flexural method yields higher values of modulus of elasticity than the classical tension method. The research provide a comparisson of the resonance longitudinal method, resonance flexural method, and the classical tension method as a function of moisture content and density.

In the final chapter of this thesis, important conclusions based on the results from the analysis of this thesis will be explained. Some suggestions will be given for further users of GrindoSonicMK5 instrument.

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NOTATION AND ABREVIATIONS

Roman letters		Units
R^2	Coefficient of determination	-
u	Moisture content	%
s	Stress	Kp / cm^2
b	Width	mm
h	Height	mm
d	Distance	mm
P	Force	N
A	Area	mm^2
Δ	Increment	-
L	Length	mm
f	Resonance frequency	Hz
m	Mass	g
E	Modulus of elasticity	GPa
x, y, z	Cartesian coordinates	mm
G	Shear modulus	GPa
N	Number of the planck	-
N′	Location in the longitudinal section	-
M	Moisture content	%
I_t	Section modulus in torsion	m^4

Greek letters

θ	Angle in the coordinate axes	^{o}
ϕ	Angle in the coordinate axes	^{o}
ρ	Density	g / cm^3
ε	Strain	-
σ	Stress	Kp / cm^2
v	Velocity of the stress pulse	m / s
k_t	Factor for the determination of I_t	-

Subscripts

b	Bending
L	Longitudinal
t	Torsion
dyn	Dynamic.
St	Static
x, y, z	Direction in a Cartesian coordinate system

Abbreviations

SEM	Static modulus of elasticity
DEM	Dynamic modulus of elasticity
MOE	Modulus of elasticity
Poly	Polynomial
St	Static
Dyn	Dynamic
RH	Relative humidity
T	Temperature

1 INTRODUCTION

Dynamic test methods has been devoloped in parallel with Static test methods for many types of solid materials including wood. This research tryes to evaluate the dynamic method to measure the MOE of wood by using the GrindoSonicMK5 instrument.

The objective of this research is to study the E-modulus of Norway Spruce and its relation to some other wooden properties using different methods. Because of that, factors as moisture content, and density were deeply studied in relation to the sawn timber.

The different stages of this research are conducted as a part of a bigger study concerning the growth stresses in this kind of tree. The research boards different fields:

- Dynamic methods.
- Static methods.
- Wooden properties affecting E-modulus.

Consequently, the research were divided in the following stages:

- Evaluate the possibility of measuring dynamic E-modulus using GrindoSonicMK5 instrument. The dynamic measurements were compare to static measurements obtained by MTS Apparatus in order to obtain a reliable conclusion of the dynamic measurements.

- Determine the effect of the moisture content, density, and location inside the log on the relation between the static and the dynamic E-modulus.

To fulfill these goals, more than 500 test were conducted statically and dynamically. However, the research were centrated on the study of dynamic E-modulus using GrindoSonicMK5 instrument. The main objective was to configurate the use of dynamic test with this instrument for future uses.

It is important to know the material which is going to be the protagonist of the research during all the time. Therefore, brief introduction of the material is presented in the following paragraphs.

Norway spruce is the common name of the tree. The scientific name is Picea abies. Abroad this tree can be called as: Epicea commun, Faux sapin, Pesse (French). Fichte, Rottanne, Weissfichte (German). Gewnow spar, Fijndsr, Kerstpar (Dutch). Picea comune, Abeto rosso (Italian). Abeto rojo (Spanish). Gran (Swedish). Kuusi (Finish). Jolka, Jalyna (Russian).

The territorial distribution is the center and north of Europe. In the center it appears as a mountain tree (Alps,Jura,Carpats…). In Scandinavian countries, Russia and north of Poland it is a plain tree. The different uses due to its ecological plasticity have produced the attack of different fungus and plagues like Lymantria monacha and Fommus annosus. This kind of wood is normally exported from Scandinavian countries, the main producers .

Visually, it is a tree with a big height. Its height can be 40 meters but it can reach up to 50 meters. It has cylindric straight trunk. The ramification is vertical. In each couple of vertex smaller branches of diffuse insertion appear.

The sawn timber of picea is straight and cylindrical. It is possible to obtain pieces of a big length (more than 10 m), and diameter (between 40 and 200 cm). It shows a high number of small knots. The sawn timber has white and red color. The green wood smells strong of resin.

The most common defects are the many knots and concentrations of resin. The sawn timber shows different criptogamous alterations such as the production of hearts and the attacks of Fomes annosus. The last can produce the dark rot from the basement of the trunk.

2 THEORIES

2.1.Factors affecting the Elastic properties of wood.

In the wood there are many factors affecting the elastic properties. The next sections give a global vision how those factors can affect the elastic properties of sawn timber.

Density

It is well known that mainly density is the principal factor affecting the elastic properties in wood. In figure 1 the effect of density on the E-modulus of Spruce is shown. Those results were carried out by KOLLMANN and KRECH (1960).

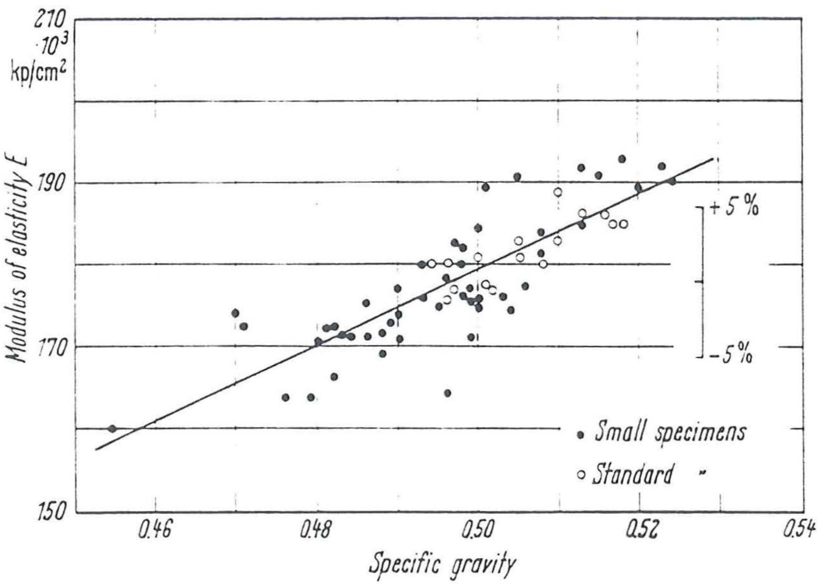

Fig. 1: *Effect of density on the E-modulus parralel to the grain of spruce. This graph is based on 14% moisture content. The graph shows that the relation is linear. From KOLLMANN (1941)*

The relationship between E-modulus and density are evidently linear for hardwoods. It is possible to see that the E-modulus increase with density. Similar studies with light balsa wood were carried out by DRAFFIN and MUHLENBRUCH (1937), also they found a linear relation between E-modulus and density. In figure 2 the same relation with oak is shown.

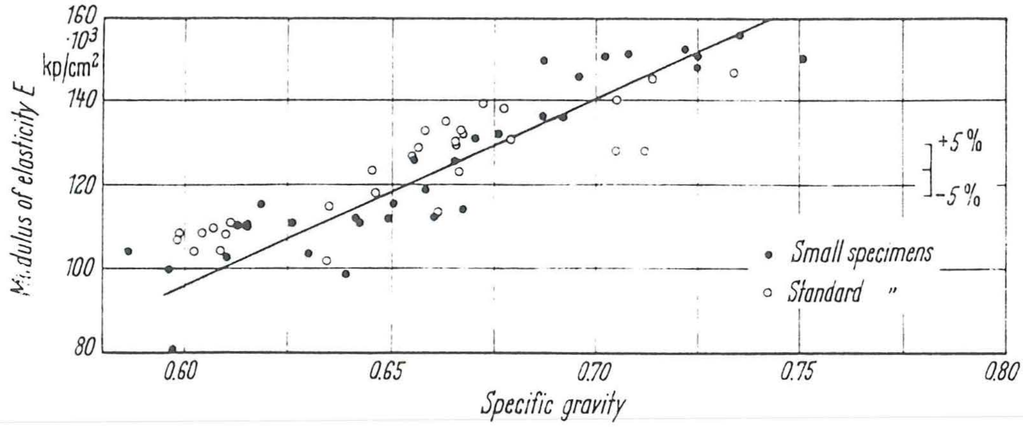

Fig. 2: *Effect of density on the E-modulus parallel to the grain of oak. This curve is based on 14- 15% of moisture content. The curve shows a linear relation. From KOLLMANN and KRECH (1960)*

As shown by the figure 1 the relation is linear. It is remarkable that the slope of the curve is lower for softwoods than hardwoods as oak.

The range of densities are 0.48-0.52 g $/cm^3$ for Norway spruce and 0.6-0.7 g $/cm^3$ for oak. Since density is influenced by the moisture content of the wood, comparisons of density can only be made at the same level of moisture content. Standard values of moisture content are from 0 till 15%. The variation of the density has to be studied as a function of moisture content. The studies carried out by KOLLMANN and KRECH were based on 14-15% of moisture content.

The influence of position in the tree on density is another factor affecting, and thereby strength properties. In spruce trees, the lowest density or specific gravity is always produced near the pith where wide rings are normally formed. The highest density is produced in wood located near the bark where the narrowest annual rings are located.

The variation of the density in the cross-section is less pronounced than are those in the height. According to VOLKERT (1941), the density in the based of trees with a cylindrical stem is greater than in one that is strongly tapered. Studies of the properties of second-growth Douglas fir carried out by WAANGAARD and ZUMWALT (1949) showed that the density of timber near the pith as well as at some distance from the pith was decreasing with increasing height above the ground.

The table 1 shows the E-modulus along the grain as a function of density, based on 14-15% of moisture content.

Property	Dimension	Spruce	Oak
Density	g /cm^3	0.492	0.663
Moisture content	%	14.3	15.1
Modulus of Elasticity	kp / cm^2	$E_y = 459\ \rho - 49.99$	$E_y = 444\ \rho - 169.9$

Table 1: *E-modulus of Spruce and Oak. From KOLLMANN and KRECH (1960)*

This table show the relationship between the E-modulus and the density.

The considerable influence of moisture on the elasticity properties of wood makes it necessary to reduce all values to a standard moisture content normally of 12%. This moisture content is reached when the specimen is directly in contact with the ambient conditions.

The density is defined as the mass per unit volume.

$$\rho = \frac{m}{V} = \left[g/cm^3 \right]$$

Where *m* is the oven-dry weight, and *V* the green or wet volume of the specimen.

Compression wood has a considerable higher density than normal wood. Data for carefully selected normal and several compression woods of nine conifers TIMELL (1982) suggest a density ratio of approximately 1:2.

Tension wood also exhibits a density difference compared to normal wood VON PECHMANN (1953); TRENDELENBURG (1955); KNIGGE (1958); OLLINMAA (1959), but less pronounced than compression wood.

Moisture content

Fiber saturation point is a good reference to understand how the moisture affects the elastic properties. Above the fiber saturation point, free liquid water exists in the lumen the coarser capillaries in vessels tracheids and other elements of the wooden tissues does not affect significantly elastic properties. Below the fiber saturation point, shrinkage or swelling occurs thus increasing or reducing cohesion and stiffness. After a desorption, below this point, to reach a point over the saturation point is impossible, anless timber is immersed in water, see figure 3.

The moisture content is a function of mass of dry specimen, and mass of the wet specimen. It is defined as the relation between water and wood inside the sawn timber.

$$M = \frac{m_{wet} - m_{dry}}{m_{dry}} = [\%] \qquad (1)$$

Where m_{wet} is the weight of the wet specimen ,and m_{dry} is the weight of the dry specimen.

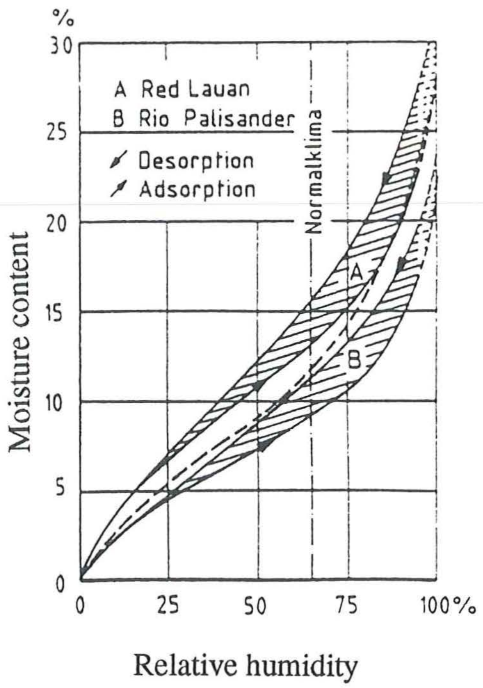

Fig. 3: *The moisture content as function of the relative humidity of the ambient air. The fiber saturation point is shown. The 20 ° C sorption isotherms are given for two different wood species (Red lauan and Rio palisander) and for the adsorption and desorption case.(From the lecture Holz and Holzwerkstoffe, ETH Zurich)*

The moisture is determined by weighing the sawn timber twice. The first time is to know the mass of the specimen when it is wet, and the second time is to know the mass when it is dry. Once the difference between the two weights is known, the formula is able to determinate the relation between the water and wood inside the sawn timber.

The range of moisture content can be from 0% when sawn timber is completely dry as high as 160% or even more wher the sawn timber is green.

The effect of moisture content on the E- modulus of Spruce is shown in figure 4. The most sensitive of the three E-modulus is apparently the E-modulus along the grain. The scale in which each curve was plotted shows that E-modulus along the grain E_L has reduced at least 6 times more than the others.

Figure 4 shows how the moisture content affects the E-modulus values. The relation between the E-modulus and the moisture content show an exponential decrement. The slope of this decrement is higher when the range is between 0 % and 30% below the fiber saturation point, where the strength and stiffness suffer important variations.

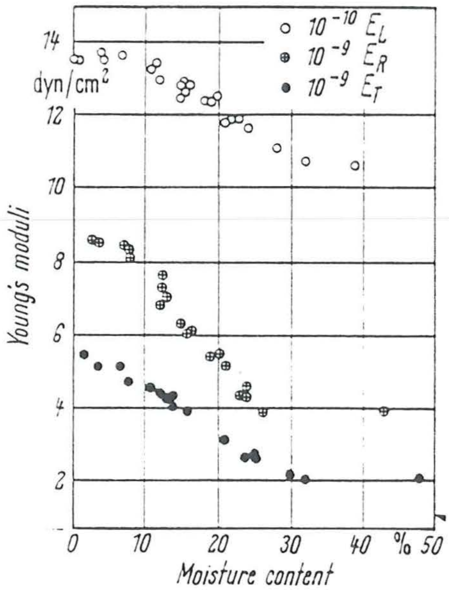

Fig. 4: *Effect of moisture content on elastic constants of Sitka spruce. There are a decrement of E-modulus against the increment of moisture content. From Carringtom (1922)*

According to the figure the E-modulus across the grain is higher in the radial direction than in the tangential direction. According to CARRINGTOM (1922) the maximum E-modulus is reached when the sawn timber is totally dry and when the strength and stiffness increase.

Compression wood

In Norway Spruce compression wood has a brown or red color and is composed of very wide zones of late wood. Compared to the normal wood, the density of compression wood is higher and MOE is lower, and a small percentage of compression wood can reduce the wood strength of Picea abies, only compression strength is higher than in normal wood.

Compression wood in green condition shows higher values of compression strength, toughness, and bending strength than normal wood does. Tensile strength is reduce almost 10%, and the E-modulus is reduced by 15%. This behavior has been noted by COCKRELL and KNUDSON (1973). The high compression strength and low tensile strength of compression wood would be expected to produce more brittle bending failures with no development of compression failures. That is because compression wood has a much higher strain at maximun stress. Therefore it allows the ultimate tensile stresses to develop without introducing fiber failures in the compression side. For tensile strength and modulus of elasticity drying of compression wood results in less increase of mechanical properties than is usual for normal wood. There are only small differences between strength properties of dry compression wood and dry normal wood. According to studies carried out by COCKRELL and KNUDSON (1973), the strength of dry compression wood tissue can be 10-15% lower than normal wood.

Knots

Knots are by far the single most important defect in the mechanical properties. The strength and the stiffness reducing effects of knots are related to the form, size, number, and position of knots. Even moisture and duration of the load affects the influence of knots.

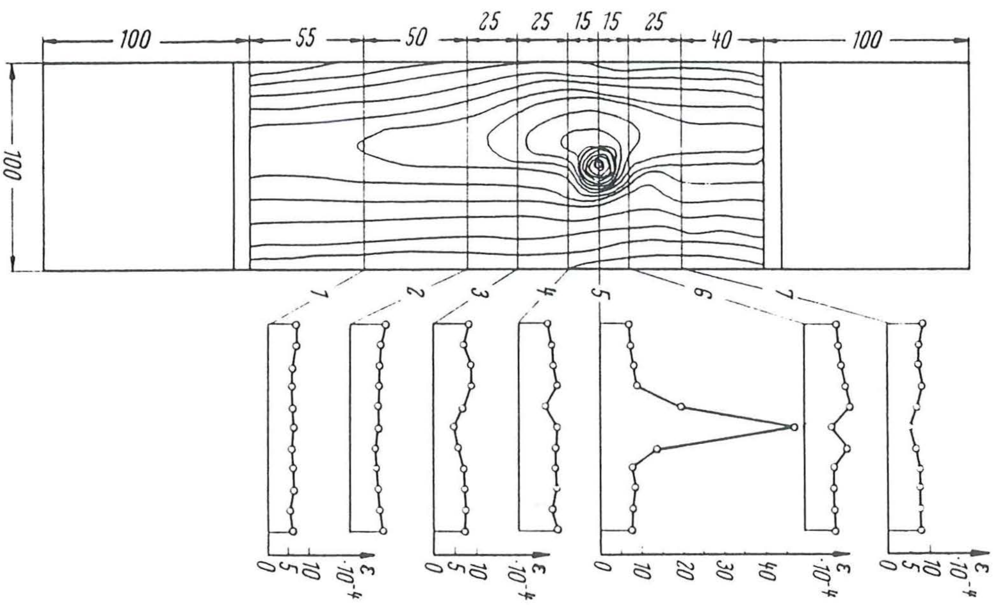

Fig. 5: *Strain distribution in a tension bar of pine wood in the vicinity of a knot. The strain distribution in the vicinity of knot is very complicated and really irregular. The elastic compliance in a knot of pine wood is seven times as high in the surrounding wood. From Ylinen (1942).*

The strength and stiffness is reduced due to the effect of the geometrical reduction of the cross section caused by the weak knot. Add to this, the general anisotropy of the wood and the results are an extremely complicated, see figure 5.

Compression strength is influenced by knots, but much less than tensile strength. Consequently, bending strength should be expected to be very sensitive to the position of the knots. Add to this, the direction in which the stress is applied on the knot can affect the results. See figure 6.

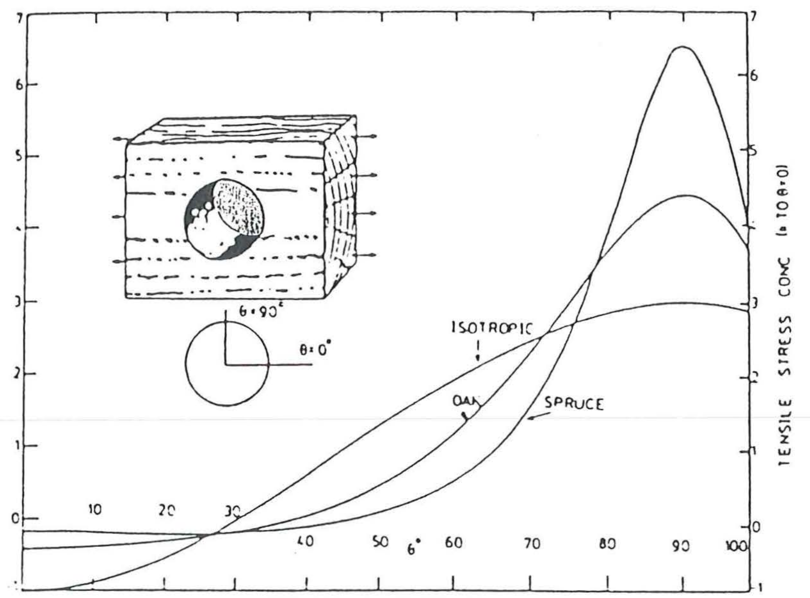

Fig. 6: *Calculation of the tensile stress concentration around hole in timber as function of θ, which is the angle between the direction in which the stress is applied and the longitudinal axe. The maximum tensile stress is reached when it is applied perpendicular to the longitudinal axe. Green and Taylor (1939-40).*

The lengthwise distribution of knots is governed by the growth characteristics of the tree. The growth characteristics of a tree also can be affected by external agents. Consequently, this material property is therefore dependent not only on species, but also to a high degree on the growth rate of the individual trees.

Temperature

Below the thermal decomposition point, strength and stiffness decrease with increasing temperature due to the thermal expansion of the crystal lattice of the cellulose and the increased intensity of the thermal molecular oscillation.

Temperature is an important factor at the time of drying the pieces due to the thermal molecular expansion, but also the speed of temperature increase is of importance.

Figure 8 shows the average percentage of E-modulus of six species for each moisture content against temperature. E-modulus of elasticity at 20°C is equal to 100%.

HEARMON (1953) pointed out that under practical conditions higher temperatures tend to dry out the wood, so the increase in E-modulus due to drying may well outweigh the reduction due to temperature alone.

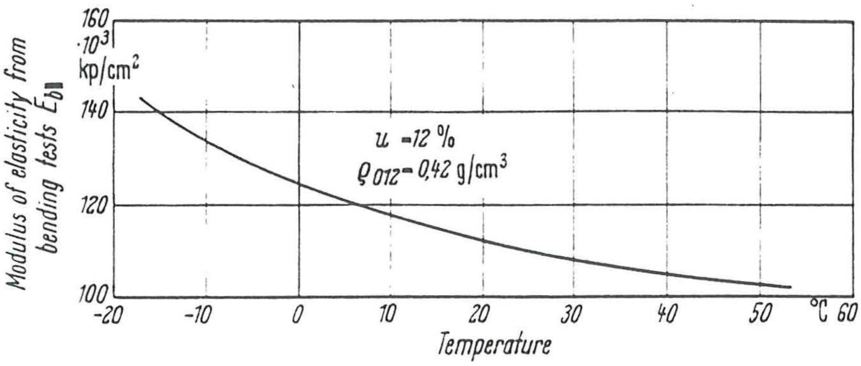

Fig. 7: *Relationship between modulus of elasticity from bending test of Swedish pine and temperature. There are a decrease of the modulus of elasticity along the grain in bending with increasing temperature in the range from 50°C to -20°C. From Thunell (1941)*

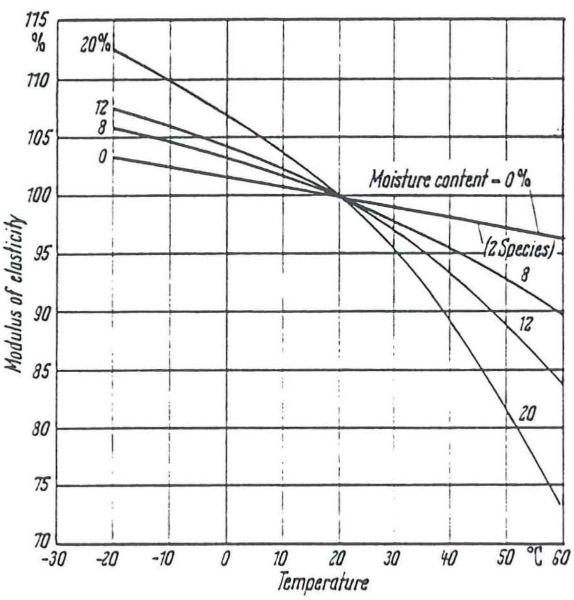

Fig. 8: *Average percentage of the modulus of elasticity of six species against temperature. The modulus of elasticity at 20°C is equal to 100%. From Sulzberger (1953)*

Grain angle

Grain angle in a piece of wood is characterized by the angle between fiber direction and the edge. Such slope of grain can result either from the way the lumber is cut from the log or from natural spiraling of the grain in the living tree.

The magnitude of spiraling varies widely in individual trees from pith to bark. Likewise, the spiral grain pattern changes depending on the height in the trunk of the tree. The tendency to spiral grain differs from species to species, and even from tree to tree of the same species.

From the observations on Picea Abies, it seems that the left helix spirality is often confined to the juvenile wood. Therefore, fast grown timber having relatively more juvenile wood than slow grown timber of the same dimensions tends to cause significantly more twisting.

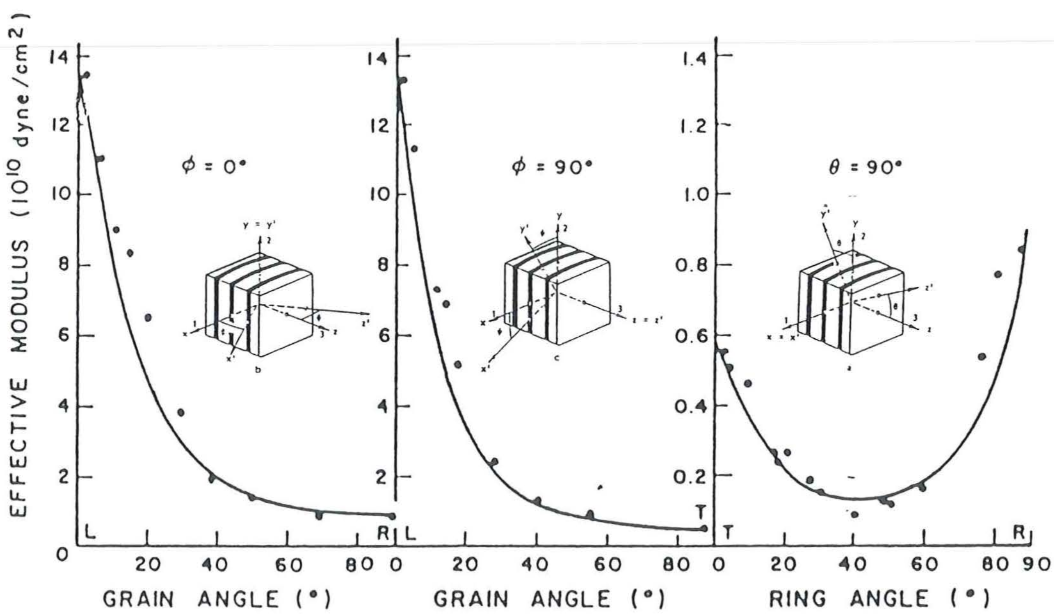

Fig. 9: *Effect of grain angle for sitka spruce and references of rotation coordinates in the principal plane. When sawn timber is subjected to a load of a orientation different from the orientation of the principal axes x, y, z, the elastic response changes. Bodig and Jayne (1982)*

Furthermore, the classical theory of linear elasticity can be very successfully applied to establish the relationship between the elastic parameters and the stress strain behavior in a rotated coordinate system, see figure 9.

Figure 10 describe this peculiar elastic behavior.

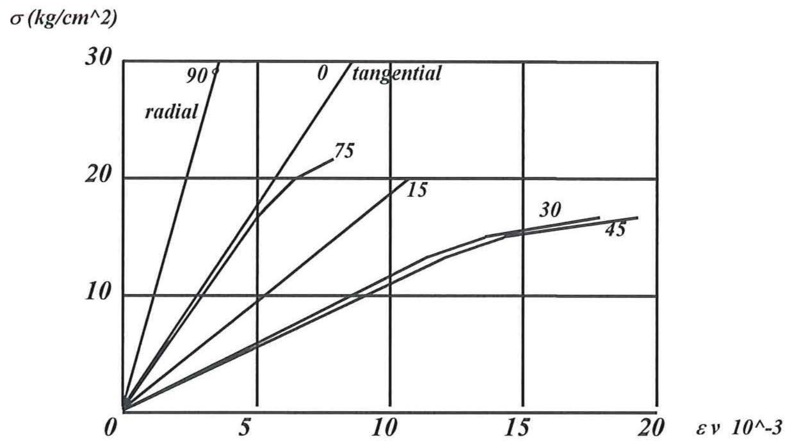

Fig. 10: *Stress- strain curves for Picea abies as a function of grain angle. Stress-strain curves subjected to compression perpendicular to the grain and with the ring angle ϕ varying from 0 to 90 degrees. Frey-Wyssling and Stussi (1948)*

2.2.Determination of E-modulus by different methods.

Dynamic test methods and static test methods have been developed in parallel during many years. Those methods have been proved with many materials, including wood. Dynamic test methods can often be performed more rapidly than static methods, particularly with the availability of digital systems and electronic equipments.

2.2.2.Dynamic methods.

Dynamic methods are based on the measurement of the natural frequency. Those methods obtain the information from the analysis of the transient vibration of the test object. That vibration appears when the exciting frequency equals the natural frequency of the material, the amplitude of the resulting oscillation reaches a maximun, that is to say, resonance occurs.

Depending on the type of excitation, the vibration can be different. It is possible to excite the specimen in three different ways; longitudinal, torsion, and bending. One obtains longitudinal, torsion, and bending vibration mode, respectively. The natural frequency is different for each possible type of excitation. That frequency is largely dependent on the elastic properties of the material.

According to the studies carried out by D. LARSSON (1997), different formulas were used to determinate the longitudinal, bending E-modulus, and the shear modulus. The E-modulus is calculated as:

$$E_{b.dyn} = \frac{f_b^{\ 2}}{3.56^2} \cdot \frac{12 \cdot m \cdot L^3}{b \cdot h^3} \qquad (2)$$

Where m is the mass of the specimen in grams, L is the length of the specimen in millimeters , b the width in millimeters, h is the height of the specimen in millimeters, and f_b is the resonance frequency. The resonance frequency f_b belongs to the bending vibration mode. E_b is the E-modulus associated with bending.

$$E_{L.dyn} = f_l^2 \cdot \frac{4 \cdot m \cdot L}{b \cdot h} \qquad (3)$$

The resonance frequency f_l belongs to the longitudinal vibration mode. E_L is the E-modulus associated with longitudinal mode.

$$G_{t.dyn} = f_t \cdot \frac{m \cdot L}{3 \cdot k_t \cdot b \cdot h}\left(1 + \frac{b^2}{h^2}\right) \qquad (4)$$

k_t Varies non linearly from 0.14, for h/b=1, to 0.33 for $h/b \rightarrow \infty$. The resonance frequency f_t belongs to the torsion vibration mode. G_t is the shear modulus associated with torsion.

Equations (1), (2), and (3) are valid if the assumptions for the Euller-Bernoulli and St. Venant beam theories are fulfilled.

As mensioned earlier, the natural frequency of the material is largely dependent on the elastic properties of the material. In wood, the location of the knots, big concentrations of water inside the sawn timber when is wet or the compressive wood can affect the natural frequency of the material. Consequently, the dynamic E-modulus is affected. How they affect the dynamic E-modulus will be studied in the following chapters.

Many different dynamic methods have been developed. In the next paragraphs some of them are explained. The following methods were performed to measure the longitudinal vibration mode.

Resonance longitudinal vibration mode.

The longitudinal vibration mode is produced by striking one end of the specimen parallel to the length. The specimen is held in the hand close to its center. Figure 11 shows the scheme of the installation.

The specimen must be struck centrally at the end and directly in line with the length. The required time to perform the test is only a few seconds. E-modulus is calculated from the equation:

$$E = 4 \cdot \rho \cdot f_l^2 \cdot L^2 \qquad (5)$$

It is remarkable that equation 5 is similar to equation 3.

$$E = 4 \cdot \frac{m}{b \cdot h \cdot L} \cdot f_L \cdot L^2 \rightarrow \rho = \frac{m}{V} = \frac{m}{b \cdot h \cdot L}$$

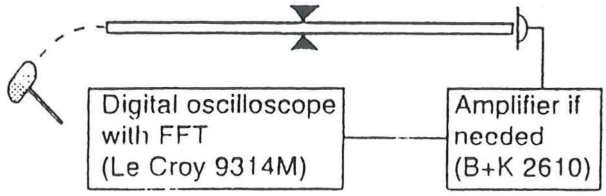

Fig. 11: *Resonance longitudinal test. The points of maxim motion are the two ends of the specimen. The opposite end is available for placement of the microphone nearby to receive the sound radiating. The signal is passed to the oscilloscope. From N. Sobue (1986).*

Ultrasonic longitudinal through-transmission mode.

The ultrasonic method requires the placement of two piezoelectric transducers in contact with the ends. One serves to emit a longitudinal stress pulse of very short duration which travels with the speed of sound in the wood to the transducers at the other end. Figure 10 shows the scheme of the installation of this experiment .The time of pulse travel for the standard specimen of spruce, and fir falls in the range between 60 and 85 microseconds.

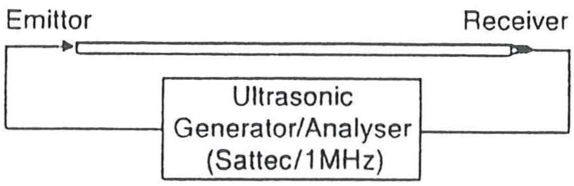

Fig. 12: *Ultrasonic longitudinal test. There are two piezo electric transducers in contact with each end, one to emit the signal, the other one transducer serves to receive the signal, which travels with the speed of sound. From V. Bucur (1985).*

With this time of travel and the known distance separating the transducers, the length of the specimen, the velocity of the stress pulse are calculated. v is the velocity of the stress along the grain. E-modulus is calculated from the equation:

$$E = \rho \cdot v^2 \qquad (6)$$

2.2.2.Static methods.

The static method is based on the analyze of the deformation by a certain external load applied in the specimen.

For longitudinal tension and compression a relative deformation is produced by a longitudinal load. This load is applied to the ends of the bar and parallel to the length. According to HOOKE´S law the following equation is valid for tension as well as for compression tests:

$$E_L = \frac{P \cdot L}{A_o \cdot \Delta L} \qquad (7)$$

Where E_L is the longitudinal E-modulus, P is the external force producing the stresses in Newton's, L is the length of the specimen in millimeters, A_o is the area of the initial cross section in square millimeters, and ΔL is the increment of the length in millimeters.
The modulus of elasticity is the slope of the straight part of the stress-strain curve which belongs to the elastic zone. Such a curve is shown in figure 13. Some testing machines are equipped with automatic stress-strain recorders.

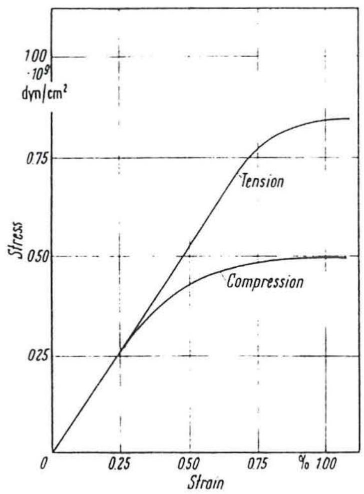

Fig. 13: *Stress- strain curves for wood. The elastic zone is different for compression and tension. From Meredith (1953)*

In bending the determination of the E-modulus is calculated by a central load in the specimen. The configuration of the specimen in bending is important, the range of the length to width of the specimen should be at least 14:1 .

The following equation is valid for bending:

$$E_b = \frac{P \cdot L^3}{4 \cdot y \cdot b \cdot h^3} \qquad (8)$$

Where E_b is the bending E-modulus, y is the deflection of the specimen in millimeters, P is the central load in Newton's, L is the length of the specimen in millimeters, b is the width in millimeters, and h is the height in millimeters. See figure 13.

It is well known that the bending stresses are affected by the shear stresses. The influence of shear stresses may be neglected only if $l/h \geq 20$. The ratio of E-modulus to the shear modulus G is the deciding factor. BAUMANN (1922) has taken the value of 17 as an average. When $E/G=17$ the E-modulus obtained by equation (8) for L/h values of 14, 15, and 20 are lowered by about 9.5, 8.8, and 4.8%, respectively. According to studies carried out by BAUMANN the influence of shear stresses can be considered approximately by the following equation:

$$E_b = \frac{P \cdot L^3}{4 \cdot y \cdot b \cdot h^3}\left[1 + 1.2 \cdot \frac{E}{G} \cdot \left(\frac{h}{L}\right)^2\right] \qquad (9)$$

Where E is the modulus elasticity obtained by equation (8), and G is the shear modulus obtained from torsion tests.

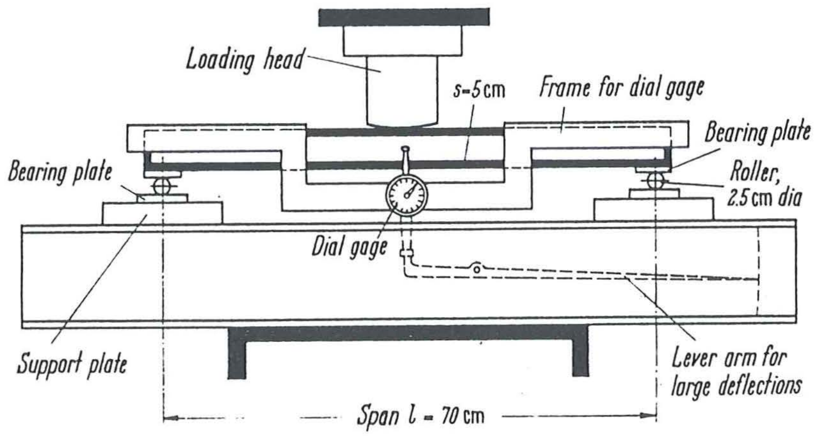

Fig. 14: *Installation of a beam for static bending by central load. All the parts of the installation are signpost. From Kollmann (1960)*

Another approximation is given by a formula developed by V. KÁRMÀN (1927) and SEEWALD (1927):

$$E_b = \frac{P \cdot L^3}{4 \cdot y \cdot b \cdot h^3}\left[1 + \left(\frac{h}{L}\right)^2 \cdot \left(\frac{1.5 \cdot E}{G} - \frac{1.5}{m} - 0.6\right)\right] \qquad (10)$$

While the measurements of longitudinal strains and lateral strains can be done easily, the determination of the shear strains are very difficult for anisotropy materials, like wood.

The most common arrangements in the static method were explained in this chapter but there are many different kind of arrangements. In the research will be used the longitudinal tension to determinate the E-modulus.

3

EXPERIMENTAL WORK

3.1. Measuring equipment

The measuring equipment was basically composed by GrindoSonicMK5 and MTS Apparatus. The first is used to measure the dynamic E-modulus and the later is used to measure the MOE statically. The testing equipment is also composed of other equipments to measure density and moisture content.

GrindoSonicMK5

The dynamic measurements of MOE were carried out by GrindoSonicMK5. This instrument measures the natural frequency of the test specimen.

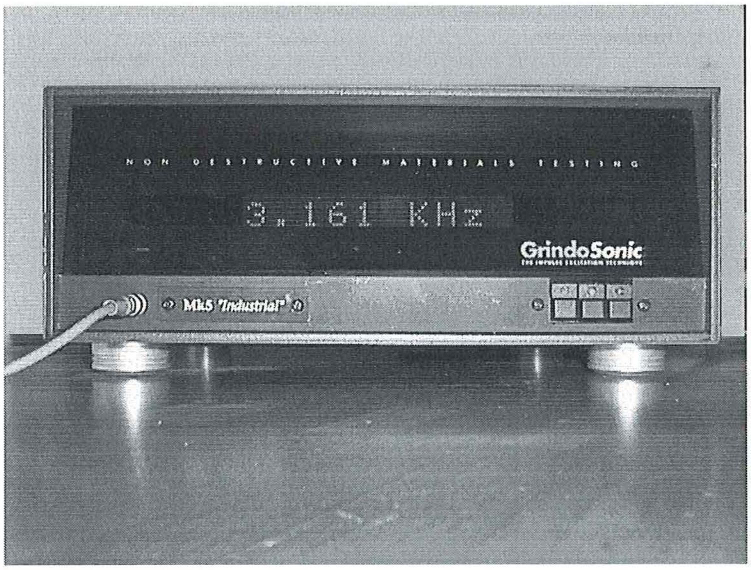

Fig. 15: *GrindoSonicMK5 instrument. The equipment consists of the piezo-electric detector, support, little hammer, acoustic microphone, and GrindoSonicMK5 apparatus.*

The measuring equipment of GrindoSonicMK5 should be able to measure E-modulus values in the order of 50 MPa to synthetic diamond with 750 GPa. This range includes many different materials like polymers, resins, wood, cement, graphite, concrete, etc.

The measurements are done in an extremely short duration. Most of them will require only a fraction of a second. Visual readout of the result takes about 750 miliseconds, which will generally limit the measuring rate to one per second. The exciting frequency must be indicated with an accuracy of ±1%. The measuring equipment in the experiments for the determination of the Dynamic E-modulus consist of:

1. Aparattus GrindoSonicMK5
2. Piezo-electric vibration detector.
3. Acoustic microphone.
4. Steel ham.
5. Supports.
6. Program EMOD v.9.15.

A mechanical vibration is generated by a pulse excitation. That is applied to the test specimen. The energy of the pulse is converted into the desired vibration mode, most effectively when it is given in an antinode of that specific mode. A light and elastic tap is required. It is purposed to cause a short vibration of the test piece. The measurement is completely independent of the force of the impact. A strong tap will only make the test piece jump on its support, causing an unnecessarily distorted signal. It is very important that the impulse is elastic. This means that the impacting body must be allowed to bounce away freely after reaching contact. This will make sure that the vibration body will be completely free during the relaxation.

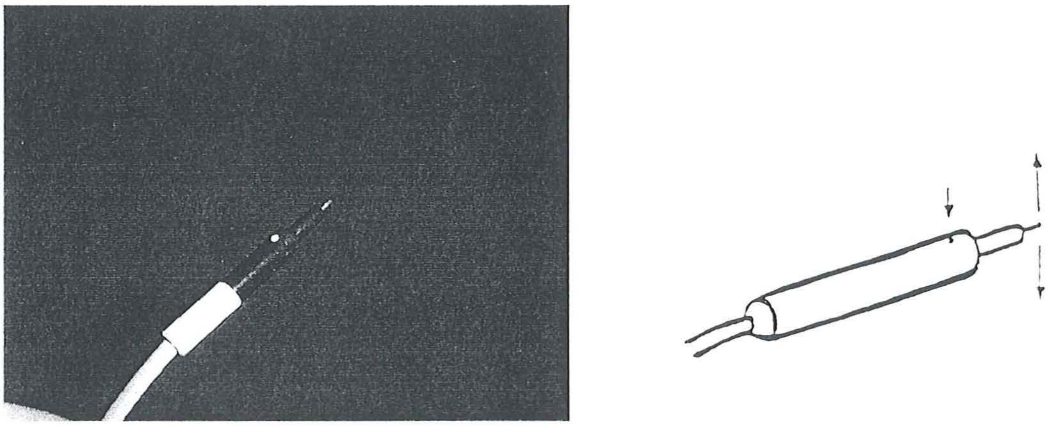

Fig. 16: *The piezo-electric vibration detector. It is made of a sensitive piezo-electric element and electronic pre-amplifier. The white dot indicates the direction of the maxim sensitivity. The dot should always be held in the direction of the vibration. The arrow. how the direction of the vibration.*

The tapping object is made in the form of a little steel hammer. The little hammer has a tiny steel sphere fixed at the end of a thin and flexible stem.

The mechanical vibration is picked up by the piezo-electric vibration detector or the acoustic microphone, depending on which one is being used. The detector converts the vibration detected into an electrical signal.

This detector covers a frequency range from 20 hertz up to 80 kilohertz. Figure 16 shows the piezo-electric detector. The piezo-electric vibration detector is a very versatile piece. It will cover the entire frequency range of GrindoSonicMK5. It is made of a sensitive piezoelectric element an electronic pre-amplifier. The piezo-electric detector contains a white dot. It indicates the direction of maxim sensitivity. It should always be held in the direction of the vibration.

The final receiver of the vibration is GrindoSonicMK5 itself. It shows the natural frequency of the test specimen on the screen.

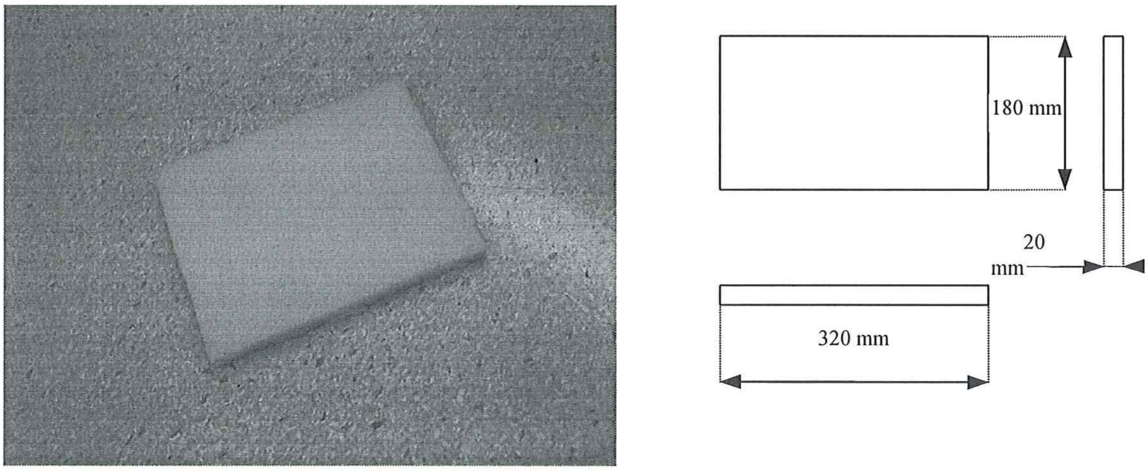

Fig. 17: *Support used in the dynamic method. The support is made of foam. This kind of material avoids all kind of disturb signals.*

It was necessary to support the test specimen with special supports to avoid distorted signals. The support was made of soft foam. All the surface of the test specimen was supported by the support. It did not disturb the resonance frequency. The support is shown in figure 17.

Program EMOD v.9.15 is a program for E-modulus calculations for a variety of object geometry's, starting from the object's physical characteristics (dimensions and mass) and its natural frequencies. This program was used as a support program for the GrindoSonicMK5 instrument. The results obtained from this program were a good reference to know in which range the results should be in the testing procedure.

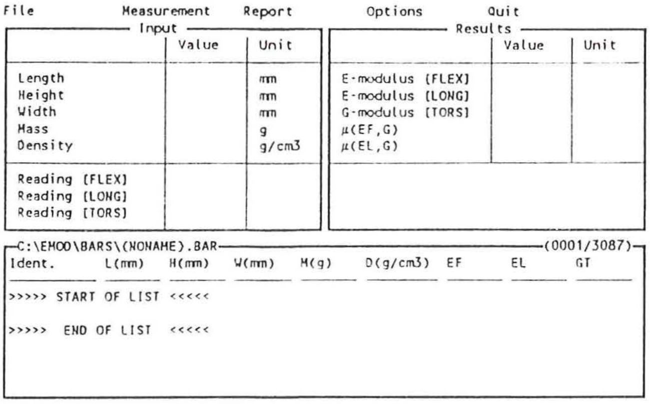

Fig. 18: *Screen of EMOD v.9.15. Emod is able to calculate the Longitudinal E-modulus, bending E-modulus, and the shear modulus.*

MTS apparatus

The static results were carried out by the MTS Apparatus. The static method is based on the analyze of the deformation by a certain load applied to the test specimen. The measuring equipment of MTS apparatus is composed of:

1.Load System MTS 810.

Load unit control panel.
Hydraulic system .
Specimen holders.

2.External sensors "HBM Dehnungsaufnehmerd 3".
3.Digital controller.
4.Work station computer.

The MTS Apparatus is able to measure pressure of 21MPa. The force capacity is of 100KN. The equipment works in a temperature range between -18°C to 65°C. The duration of the measurement depends on the material and its characteristics.

The main component of the measuring equipment in MTS Apparatus is the digital controller. It receives two signals. The first signal comes from the external sensors. They detect the deformation of the fibers when the load is applied. They are directly in contact with the specimens.

The second signal comes from the hydraulic system. It applies the tension load in the longitudinal direction of the test specimen. The test specimen is fixed to the hydraulic system by the specimen holders. see figure 19.

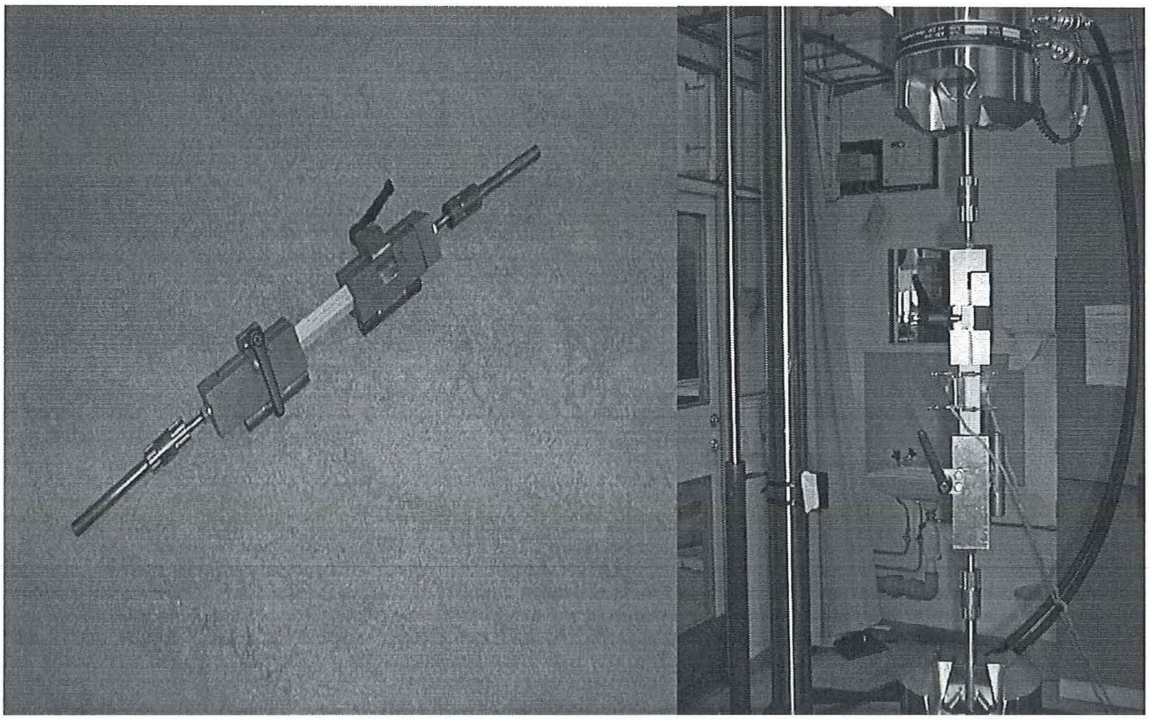

Fig. 19: *Test specimen fixed to the holders. The holders are directly connected to the hydraulic system. There are several types of holders. The holders used in this research are prepared to hold a beam with a square cross section. 20x20 mm, 15x15 mm, and 10x10 mm are the different square cross section they are able to hold.*

The hydraulic system is controlled by the load unit control. It sends a signal to the digital controller. The two signals are converted by the digital controller into electrical signals. The digital controller sends the electrical signal to the work station. See figure 19.

The software support of MTS Apparatus in the workstation is the TestStar II. During the Static test, it is possible to see graphically on the work station screen the relation between the deformation of the fiber and the load applied in the test specimen (see Appendix V).

The MOE of the specimens was measured many times under many different conditions. Thus, it was important not to load the specimens beyond their elastic limit. Another limitation came from the maximun load the specimen holders are able to stand without the specimens begin to slip.

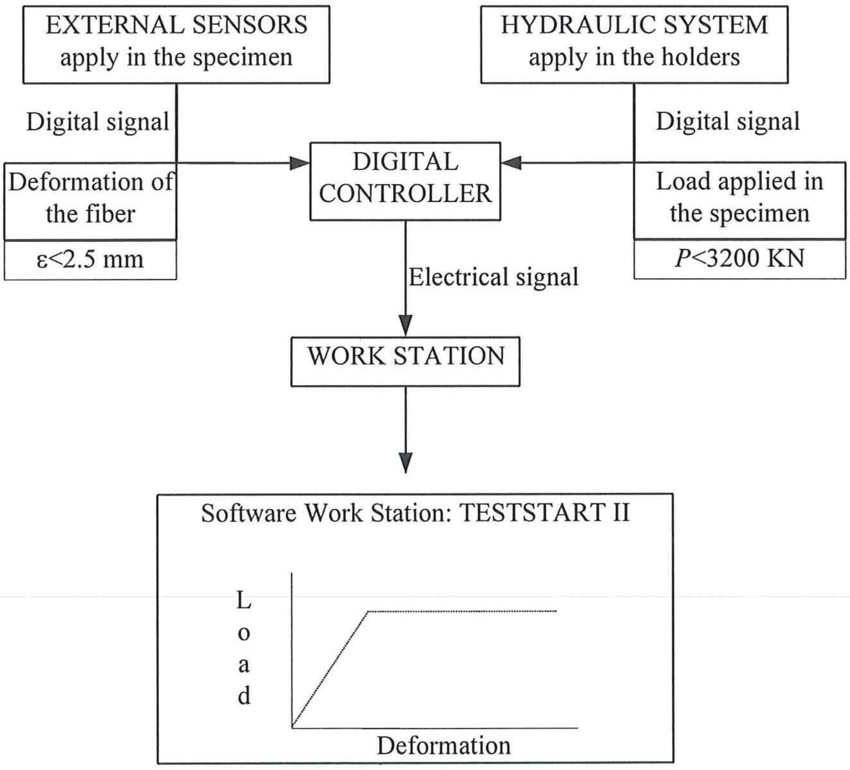

Fig. 20: *Scheme of the static process carried out by MTS Apparatus. The load system is connected to the digital controller by load unit control link. The digital controller is connected to the workstation by workstation link. The external sensors are connected directly to the digital controller. They are directly fixed in the specimen.*

3.2.Test specimen.

The test specimen was the real protagonist during all the test process. Defining the shape and dimensions of the test specimen was the first step.

Dimensions

The dimensions of the test specimen were 22x22x260 mm.

The following studies were carried out to define the dimensions:

- Study the length, width and height of the specimen inside the range where GrindoSonicMK5 works. It was necessary to be inside this range to avoid wrong readings of the natural frequency.

- Study the variation of the E-modulus in specimens with different dimensions.

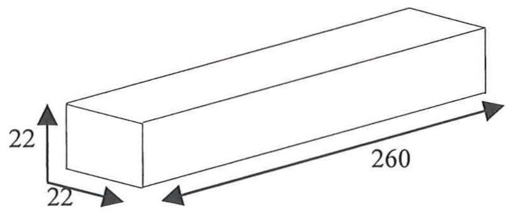

Fig. 21: *Test specimen dimensioned. The dimensions of the test specimen are 260x22x22mm.*

More than 500 specimen were tested with different dimensions. It was necessary to work with a square cross section due to the measuring equipment of MTS Apparatus. This measuring equipment is able to hold 20x20 mm, 15x15 mm, and 10x10 mm cross sections. The measuring equipment was one of the limitations at the time to choose the dimensions of the test specimen.

The second limitation was the range where GrindoSonicMK5 instrument works. This range is the relation between the height and the length of the test specimen. This relation has to be *L/h>4* (consult *"Operating instructions for the GrindoSonicMK5 " Industrial" instrument"*). Where *L* is the length of the test specimen and *h* the height of the test specimen. This relation will be deeply study in the research.

The third limitation was the length necessary to hold the specimen in the MTS Apparatus. It was necessary to have 80 mm between the holders to fix the external sensor to the specimen. There was a free space between the holders and the external sensors to avoid any contact between them. The minimun length able to work was 250 mm.

Once the minimun length to work was found out, it was necessary to check the range where GrindoSonicMK5 works.

It was necessary to think in all possible problems that we can find in the future such as the direction of the grain, the knots, the ambient temperature, and the variation of volume that the specimen suffers in the process.

The knots were an important problem. The wood was checked before it was cut to avoid having knots in the test specimen. However, great care was taken not to have knots within the area where the external sensors of MTS Apparatus were placed on the specimen.

When a knot was located in the specimen, the readings of the resonance frequency where higher. For example in a specimen without knot the resonance frequency belonging to the bending E-modulus was in a range of 1000-2000Hz. In a specimen with a knot located near where the excitation was carried out, the frequency was in a range of 3000-4000Hz.

In our results, the direction of grain did not have too much influence. This factor depends of how the timber is sawn and the spiral alignment of the fiber in the tree. In the research, the specimens were cut a long the grain, and too short for the variation of the grain angle to affect the results.

The change on the volume of the test specimen was another important factor. The volume decreased when the specimen was oven dried. The variation of the length was 1 to 100. In the cross section that variation was 1 to 10. It means that our cross section previously decided decreased to 18x18 when the specimen was oven dried. With this cross section the test specimen was not able to be held by the holders.

In the testing procedure, the temperature remained constant during all the process until the specimens were dried. When the specimens were dried, the volume decreased. Consequently, the new dimensions were measured.

The cross section selected was 22x22 mm. The holders That were designed to hold test specimens with cross sectional dimension of 20x20 mm, can take test specimen with cross sectional dimension of 22x22mm.

Finally, the dimensions were 22x22x260 mm. This length was selected to have a margin over the mimimun possible value. The next step was to check how the dimensions can affect the E-modulus. Several test specimens with different dimensions were tested. The variation of the length was the main dimension affecting the E-modulus. 546 test were carried out with GrindoSonicMK5 instrument. 78 test specimen were tested with seven different lengths. Those results will be explained in chapter 4.

Process to obtain the test specimen.

In this research, two logs were used namely Log 1311 and Log 1411. It was possible to obtain 89 from log 1311 and 207 test specimen from log 1411.

Figure 22 describes the process, when the test specimen was obtained from the beginning until it was ready for testing.

After this long and careful process, the specimens were kept in a freezer until they were tested. They were kept in the freezer below 0°C to avoid the lost of moisture content.

The process to obtain the test specimen after the Step 2 were carried out in ambient temperature. To avoid the lost of moisture content the sawn timber was sprayed with water all the time until the test specimens were kept in the freezer with a temperature below 0°C.

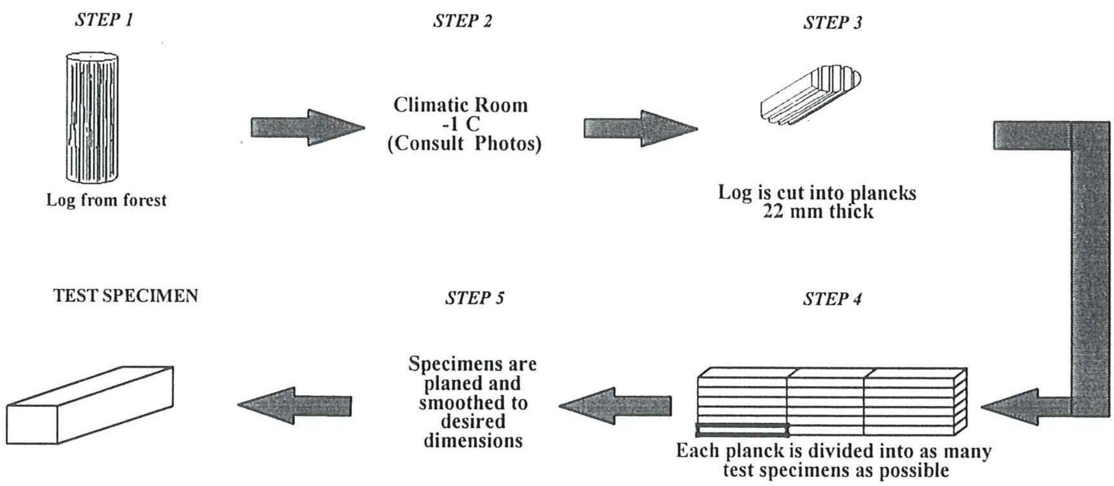

Fig. 22: *Process to obtain the test specimen. The process was started by keeping the log in the freezer. In the third step the log was cut a long the grain. In the fourth step the sawn timber was cut across the grain. In the same step the classification and location in the log was done. In the fifth step the pieces were planed. Finally, the specimen was ready to be tested.*

Classification of the specimens.

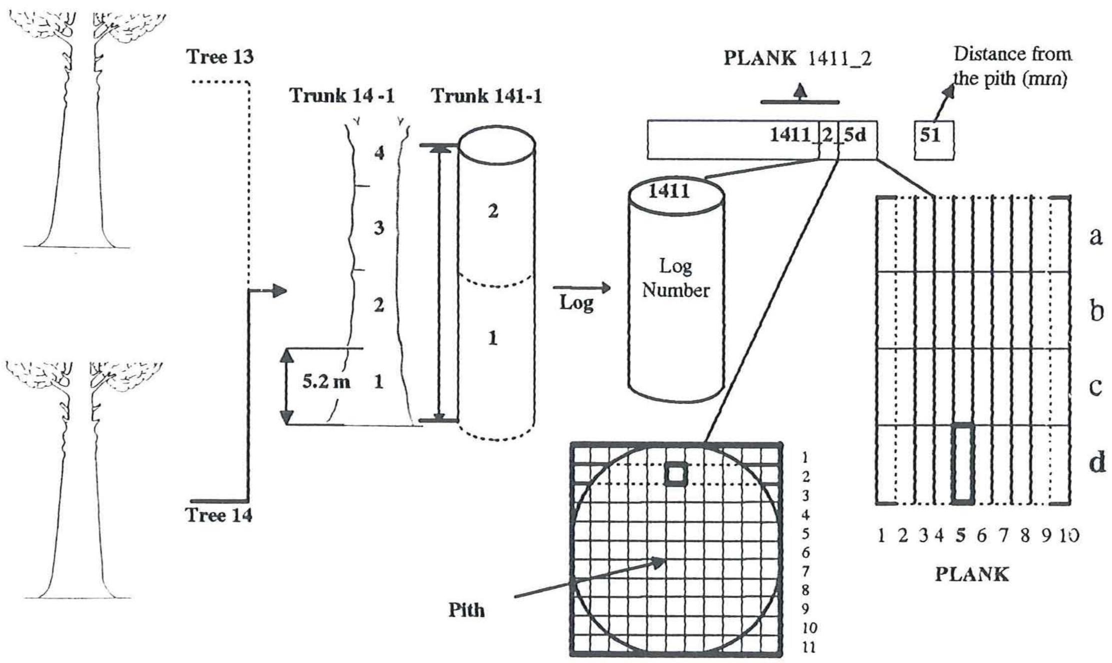

Fig. 23: *Classification and location of the specimen at the log. The first number belongs to the location of the log in the trunk. The second number belongs to the location of the specimen in the cross section. The third number and the letter belong to the location of the specimen in the longitudinal distribution. The number in the cross section is the distance from the pith to the place where the specimen is located at the log.*

During the process to obtain the test specimen, it was necessary to make a classification of the specimen. This classification indicated: the tree, the trunk, the plank, the location on the cross section of the trunk, and the location in the plank. Figure 23 shows the meaning of each number at the specimen.

The classification was done simple and clear. The following table describe how many specimens were obtained from each log, the plank for each log, the number of specimens belonging to each plank, the uses.

LOG	PLANK	Number of specimens	USES
1311	1	2	Line 2 Line 3A
	2	15	Line 2 Line 3A
	3	15	Line 2 Line 3A
	4	9	Line 2 Line 3A
	5	15	Line 3A
	6	15	Line 3A
	7	18	Line 2
1411	2	24	Line 1 Line 4
	3	24	Line 1 Line 4
	4	30	Line 1 Line 4
	5	32	Line 4
	6	32	Line 4
	7	30	Line 4
	8	22	Line 4
	9	13	Line 4
Total number of specimens		296	

Table 2: *Classification of specimens and their different uses.*

3.3.Testing procedure.

To avoid the loss of moisture the specimens were kept in sealed, plastic bags, and sprayed with water during the testing process. Another important factor was the temperature. The temperature of 20°C remained constant during the process. The E-modulus at 20°C is taken as the standard MOE value, below 20°C the E-modulus values suffer an increment. The temperature during the test process of this research was not a factor affecting the results.

The testing procedure was divided in four different lines.

- **Line 1**. To determinate the dimensions of the test specimen and how they affect the E-modulus.

- **Line 2**. To compare Longitudinal E-modulus against Bending E-modulus both conducted dynamically.

- **Line 3**. To determinate E-modulus as a function of moisture content and density.

- **Line 4**. To determinate E-modulus in relation to the location inside the log.

In Line 1 and Line 2 the test specimens were tested only dynamically. In Line 3 and Line 4 the test specimen were tested statically and dynamically. It was to compare the dynamic results against the static results and see the possible difference.

Line 1

Line 1 was designed to determinate the dimensions of the specimen and how they can affect the E-modulus.

To study how the dimensions can affect the E-modulus, the test specimen were tested with seven different lengths. All those tests were done with oven-dry wood, see figure 24.

Figure 24 describes the different steps in Line 1, how many groups were tested, how many test specimen from each group were tested, the log used.

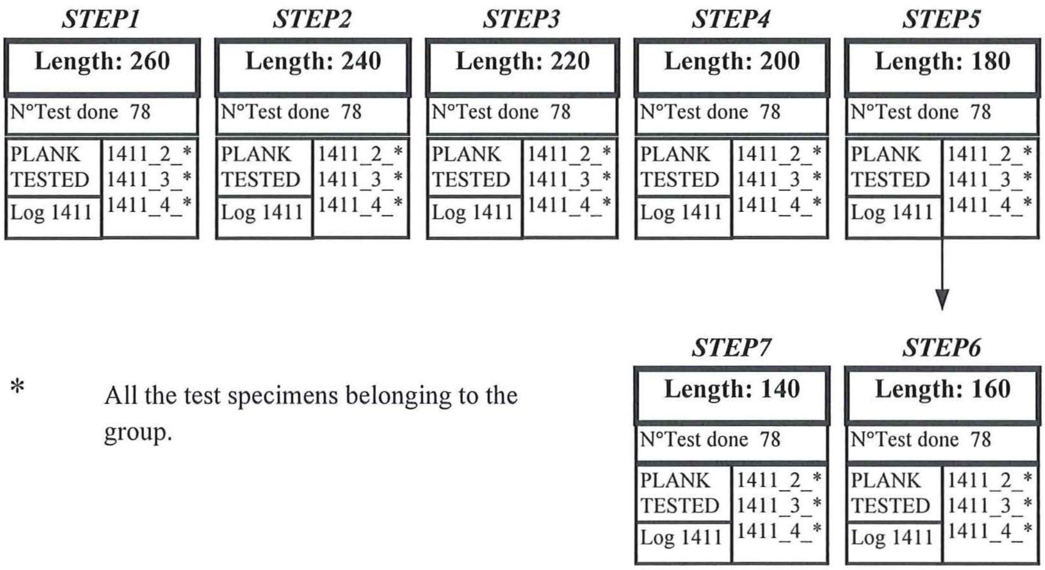

Fig. 25: *Different steps carried out in Line 1. In Line 1 was used Log 1411. Only few groups belonging to this log were used. The groups used were 1411_2, 1411_3, and 1411_4. All the test specimens were tested with 0 % of moisture content..*

As a total, 546 dynamic tests were carried out, using GrindoSonicMK5 instrument, on 78 test specimen. Each time the 78 specimens were tested with a different lengths. The different lengths used are shown in figure 25.

A table was designed with all the results. Table 3 shows the content and the classification of the values obtained from Line 1.

LOG	N	N`	*h*	*L*	*b*	Weight	%M	ρ	*fL*	DEML
1411	2	6a	21	260	21	47.9	0.00	0.5671	1403	10.302
			mm	mm	mm	g	%	g/cm^3	Hz	GPa

Table 3: *The table shows the classification of the values in the test procedure in Line 1. The table contents the location in the log of the specimen, the dimensions, the weight, the moisture content, the density, the flexural frequency, the dynamic bending E-modulus.*

Line 2

Line 2 was designed to compare the longitudinal E-modulus in front of the bending E-modulus both measured dynamically.

This line was thought to determinate the longitudinal E-modulus and the bending E-modulus with different levels of moisture content. The levels of moisture content were 0%, 9%, and 29 %.

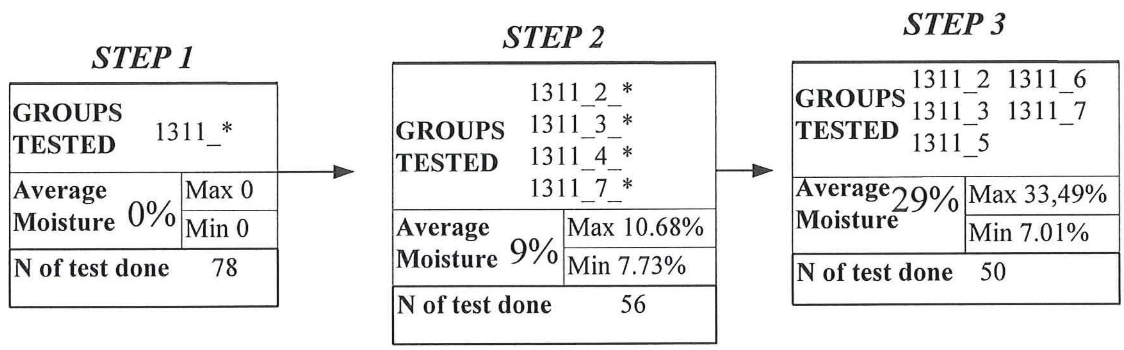

Fig. 26: *Different steps carried out in Line 2. Log 1311 was used in this line. All the groups belonging to this log were used. All the test specimens were tested with several levels of moisture content.*

Figure 26 shows the different steps in Line 2, how many groups were tested, average moisture in the step, and the maximun and minimun moisture contents found when the relevant step was conducted.

The dynamic bending E-modulus was obtained from the formula used by D. W. Haines, J. M. Leban and C. Herbé (1995). The longitudinal E-modulus was obtained from the formula used by D.LARSSON (1997). See references.

$$E_{f,dyn} = 0.946\frac{\rho \cdot f_b^2 \cdot L^4}{h^2} \tag{11}$$

$$E_{l,dyn} = f_L^2 \cdot \frac{4 \cdot m \cdot L}{h \cdot b} \tag{12}$$

Where f_l is the longitudinal frequency in Hertz, f_b is the flexural frequency in hertz, ρ is the density in g/cm^3, L is the length in millimeter, m is the mass of the specimen in grams, b is the width in millimeters, and h the height in millimeters of the test specimen.

The following paragraphs explain how the flexural natural frequency and the longitudinal natural frequency were obtained. Those frequencies belongs to the bending and longitudinal vibration mode, respectively.

The test specimen were excited in two different ways to obtain two different vibration modes.

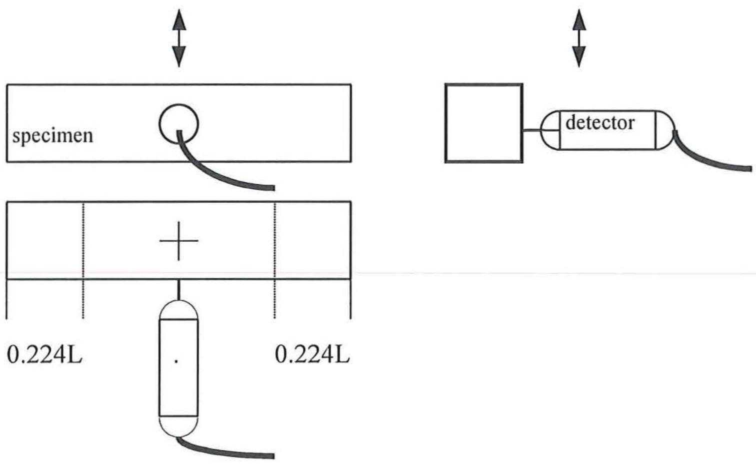

Fig. 27: *Location of piezo-electric detector and the steel hammer to obtain the bending vibration. The cross shows where the hammer must knock the specimen. In the fundamental mode for bending, the vibrations nodes appear at 0.224 of the length from the ends. The arrow shows the direction of the vibration. The dot must be in the same direction.*

The flexural frequency is obtained when a specimen is subjected to alternate flexural loading. Excitation is induced in a plane perpendicular to the longitudinal axes of the specimen. Consequently, the piezo-electric detector have to be set in the manner shown in the figure 27. The dot in the piezo-electric detector has to be in the direction of vibration. The arrow shows the direction of vibration. For the fundamental mode, the vibrations nodes appear at 0.224L from the ends of the specimen.

The longitudinal frequency is obtained when the direction of the vibration is parallel to the longitudinal axis. Consequently, acoustic microphone has to be set in the manner shown in the figure 28. For a prism, the fundamental mode of oscillation implies a node in the middle and anti nodes at the ends.

When the resonance frequencies were obtained, the specimen was quickly weighted and the dimensions were measured. With all these factors it was possible to calculate the density, the different E-modulus, and the moisture content.

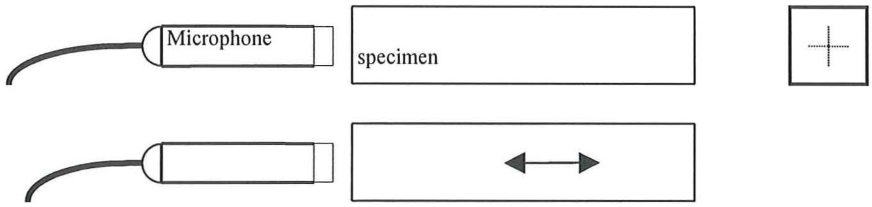

Fig. 28: *Location of the acoustic microphone and the steel hammer to obtain the torsion frequency. In the fundamental mode for longitudinal the vibration, nodes appear in the middle and the anti-nodes at the ends. The cross section shows where the hammer must knock the specimen. The arrow shows the direction of the vibration.*

A table was designed with all the results. Table 4 shows the different values obtained from Line 2.

LOG	N	N`	h	L	h	Weight	Weight	%M	ρ	f_b	f_L	DEM_F	DEM_L
1411	2	6a	21	260	21	47.9	66.31	27.76	0.5671	1403	1397	10.302	10.279
			mm	mm	mm	g	g	%	g/cm^3	Hz	Hz	GPa	GPa

Weight Weight belonging to the oven-dry specimen

Table 4: *The table shows the different values in the test procedure in Line 2. The table contents the location in the log of the specimen, the dimensions, the weight, the weight when the specimen was oven-dried, the moisture content, the density, the flexural frequency, the longitudinal frequency, the dynamic bending E-modulus, and the longitudinal E-modulus.*

212 dynamic test were carried out with GrindoSonicMK5 instrument in Line 2. 78 test specimens were used. The results will be presented in chapter 4.

Line 3

Line 3 was designed to determinate the E-modulus statically and dynamically as a function of moisture content and density.

The Line 3 was divided into different lines:

- **Line 3A** where 3 different climatic rooms were used to obtain different levels of moisture.

- **Line 3B** where the climatic chamber was used. 2 Levels of humidity were applied in the climatic chamber.

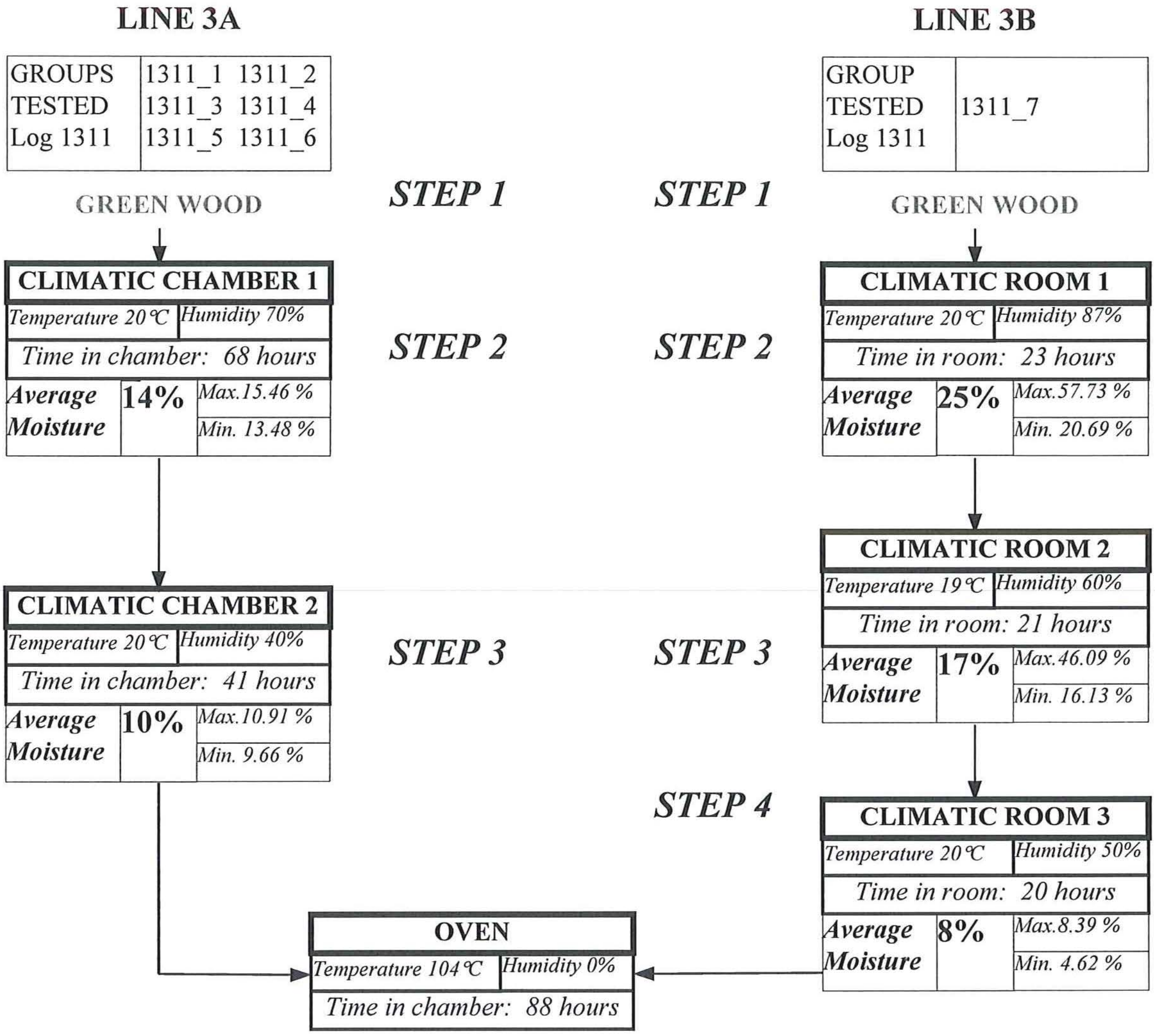

Fig. 29: *Line 3. The average moisture, the maxim moisture found, the minim moisture found, the temperature, the humidity inside the climatic chamber, and the time in the climatic situation are signpost in each step.*

The different Lines are shown in figure 29. A temperature of 20°C remained constant during all the process until the test specimen were dried in the oven with a temperature of 104 °C.

In Line 3A, a total of 76 test specimens were tested. Each one was tested three times. Each time, they were tested with a different level of moisture. In each level, the tests were conducted dynamically and statically.

In Line 3B, a total of 13 test specimens were tested in this process. Each one was tested four times in four different levels of moisture. The specimens were tested statically and dynamically just like in Line 3A.

The longitudinal E-moulus was determinate by MTS Apparatus and the Bending E-modulus was determinate by GrindoSonicMK5 instrument. It will be explained in the Test results why the bending E-modulus was determinate instead of Longitudinal E-modulus by GrindoSonicMK5 instrument.

A table was designed with all the results. Table 5 shows the different values obtained from Line 3.

LOG	N	N`	h	L	w	Weight	Weight	M	ρ	*fb*	DEMb	SEML
1311	2	6a	21 mm	260 mm	21 mm	47.9 g	66.31 g	27.76 %	0.5671 g/cm^3	1403 Hz	10.302 GPa	10.279 GPa

Weight Weight belonging to the oven-dry specimen

Table 5: *The table shows the different values in the test procedure in Line 3. The table contents the location in the log of the specimen, the dimensions, the wet weight, the weight when the specimen was oven-dry, the moisture content, the density, the flexural frequency, and the dynamic bending E-modulus.*

The different climatic rooms are identified in figure 29 as well as the climatic chamber. The time of the test specimen is pointed out in each climatic situation. At the end of the process, all the test specimens were dried to obtain the exact level of moisture content in each step.

Line 4

Line 4 was designed to obtain the E-modulus in relation to the location in the log. Consequently, an exhaustive classification of each specimen was necessary. This classification was explained in section 3.2.

Only two steps were necessary in Line 4. The first with green wood and the last with oven-dry wood.

Figure 30 shows the testing process follow in Line 4. The schemes show the average moisture, the maximum moisture, and the minimum moisture in each step.

The Log 1411 was used in Line 4. A total of 207 test specimens were obtained from Log 1411. Each specimen was tested dynamically and statically. The longitudinal E-modulus was determinate by MTS Apparatus and the dynamic bending E-modulus was determinate by GrindoSonicMK5 instrument. It will be explained in the Test results why the bending E-modulus was determinate instead of Longitudinal E-modulus by GrindoSonicMK5 instrument.

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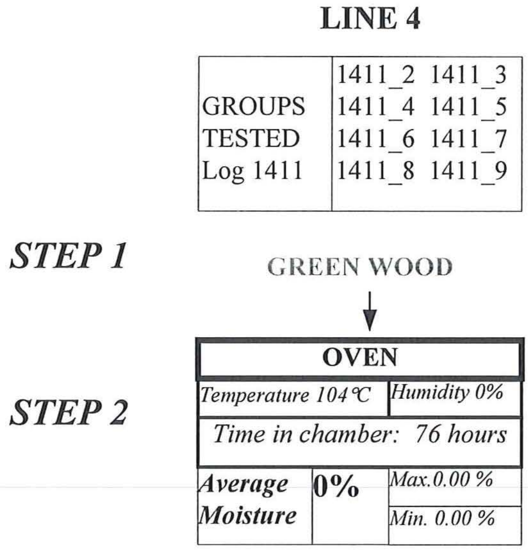

Fig. 30: *Line 4. In each step, it is pointed out the average moisture, the maxim moisture found, the minim moisture found, the temperature, the humidity inside the climatic chamber, and the time in the climatic situation.*

A table was designed with all the results. Table 6 shows the classification of the values obtained from Line 4.

LOG	N	N`	d	*h*	*L*	*b*	Weight	Weight	M	Density	*fb*	DEMb	SEML
1411	2	6a	25	21	260	21	47.9	56.31	27.7	0.567	1403	10.30	10.27
			mm	mm	mm	mm	g	g	%	g/cm^3	Hz	GPa	GPa

Weight Weight belonging to the oven-dry specimen

Table 6: *The table shows the classification of the values in the test procedure in Line 3. The table contents the location in the log of the specimen, the distance from the pith, the dimensions, the weight, the weight when the specimen was oven-dry, the moisture content, the density, the flexural frequency, the dynamic bending E-modulus, and the longitudinal E-modulus conducted dynamically.*

4 TEST RESULTS

A total of 1641 measurements were carried out using the GrindoSonicMK5 and the MTS Apparatus. The tests were carried out with 89 specimens from log 1311 and 206 specimens from log 1411, see table 7.

LOG	number of specimens	number of tests
1311	89	603
1411	207	1038
Total	295	1641

Table 7 : *Number of specimens and test carried out with each log used in the research.*

The results will be shown in the same order as they were obtained. The different lines of testing where the results were obtained will be indicated.

4.1. Effect of the length on the longitudinal modulus of elasticity.

546 dynamic test were carried out with seven different lengths to determine the effect of the dimensions on the E-modulus.

The results obtained from Line 1 were carried out with oven-dry specimens from Log 1411. The results shows that for lengths less than 160 mm the range of the E-modulus values are too big. See figure 31.

Test showed that in lengths between 260 and 160 mm ($8 < L / h < 12$) the readings of the frequency increase on decreasing the length. Below 160 mm, the readings start to vary from 6000 Hz till 22000 Hz.

Figure 31 show the different E-modulus values obtained with the different lengths. It is possible to see that below 160 mm the concentration of points starts to disperse. In lengths below 160 mm, the values of dynamic E-modulus were between 5 and 30 GPa. At this range, the GrindoSonicMK5 was giving highly unstable readings of the longitudinal resonance frequency. It means that GrindoSonicMK5 works when the relation between the length and height is higher than eight.

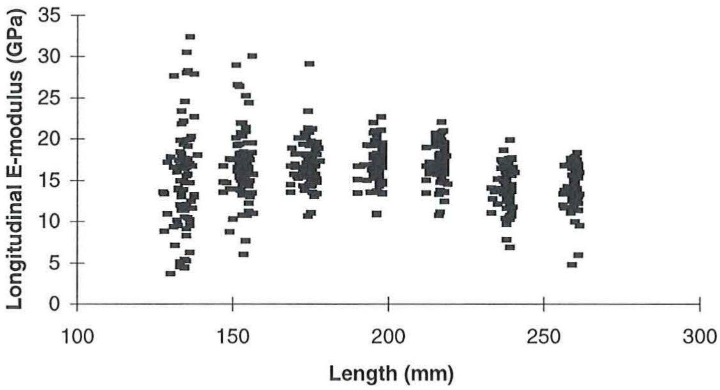

Fig. 31: *Longitudinal E-modulus as a function of seven different lengths applied to the specimens. In length below 160 mm, the readings of the resonance frequency given by GrindoSonicMk5 gave unacceptable E-modulus values. The results were obtained from 78 specimens tested 7 times.*

Figure 32 show the effect of length on the E-modulus of four of the specimens included in figure 31. This figure shows how the DMOE developes when the length is changed.

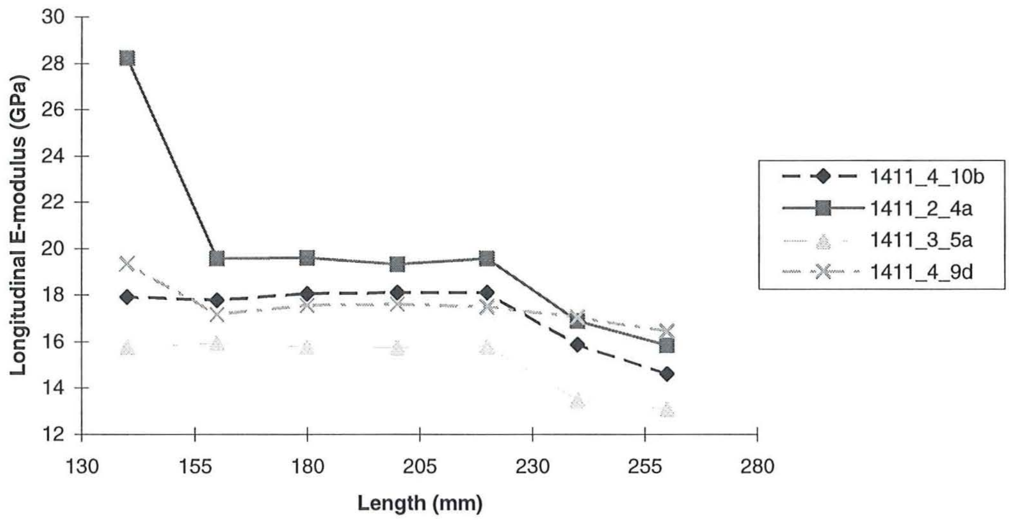

Fig. 32: *Longitudinal E-modulus as a function of the different length in four specimen. The specimens used in the graph are shown in the legend. Between 220 mm length and 160 mm (i.e. L / h=10, L / h=8) the dynamic MOE is constant for all the specimens.*

It is remarkable that the results obtained in a range of length between 160-220 mm remained constant in the four different lengths tested in each specimen. From this point, it is possible to say that the E-modulus values are not affected by the length when the relation between the length and the height is 8< L / h <10. When this relation is L / h >10 the values suffer a decrement between 2- 5%.

It should finally be noted that beside the effect of the change in length on the L / h ratio, its affects also the properties of the specimen itself as a whole due to the nonhomogennity of wood. This means that the deviation in dynamic MOE as shown in the previous figures contain also some actual deviation in the elastic properties of wood.

4.2. Longitudinal E-modulus as a function of bending E-modulus both conducted dynamically.

194 dynamic tests were carried out by grindoSonicMK5 in Line 2 to determinate the relation between the longitudinal and bending E-modulus.

Figure 33, 34, and 35 show the longitudinal E-modulus as a function of the bending E-modulus in a ranges of 0%, 8-10%, and 28-33% of moisture content, respectively.

The results with 0% of moisture content were obtained from Line 2-Step 1. The relation obtained from the results shows a high coefficient of determination (R^2 = 0.95) and the regression equation forms an almost 1:1 line.

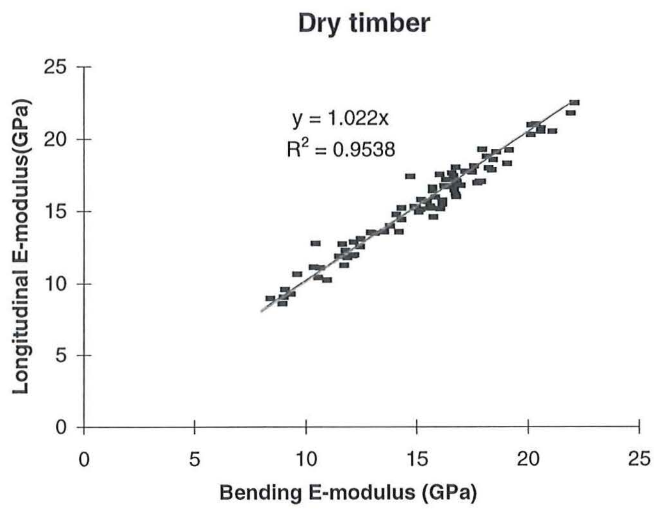

Fig. 33: *Longitudinal E-modulus as a function of the bending E-modulus in dry timber. The results were obtained from 78 test specimen. The specimens used are indicated in chapter 3.*

The results with 8-10% of moisture content were obtained from Line 2-Step 2. The relation obtained from the results shows a high coefficient of determination ($R^2 = 0.77$) and the regression equation forms an almost 1:1 line in the same manner as figure 33.

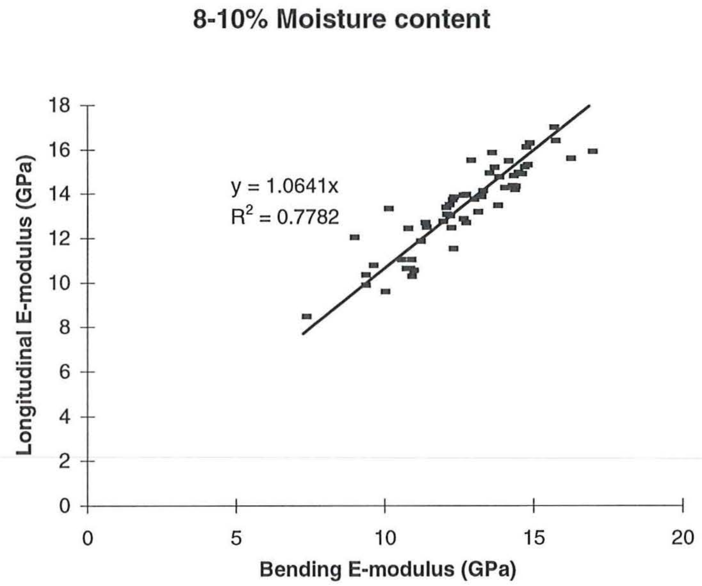

Fig. 34: *Longitudinal E-modulus as a function of the bending E-modulus in a range of 8-10% of moisture content. The results were obtained from 56 specimens. The specimens used are indicated in chapter 3.*

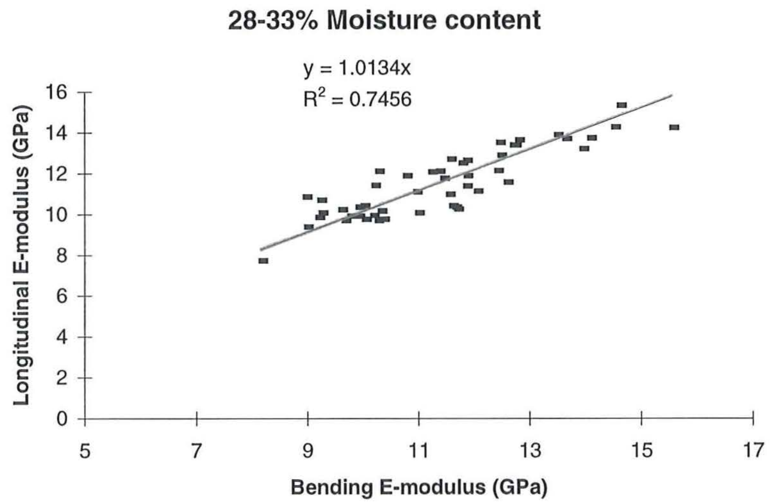

Fig. 35: *Longitudinal E-modulus as a function of the bending E-modulus in a range of 28-33% of moisture content. The results were obtained from 50 test specimens. The specimens used are indicated in chapter 3.*

Figure 34, and 35 show the same relation as figure 33. The results with 28-33% of moisture content were obtained from Line 2 Step 3. The coefficient of determination was

$R^2 = 0.74$. The regression equations form an almost 1:1 line in the same manner as figures before.

The longitudinal E-modulus conducted by GrindoSonicMK5 instrument must be compare to the longitudinal E-modulus conducted by MTS Apparatus in order to obtain a reliable conclusion of the values obtained by GrindoSonicMK5 instrument. However, the regression equation forms in the curves before shows an almost 1:1 line between the longitudinal and bending E-modulus conducted by GrindoSonicMK5 instrument. Therefore, bending E-modulus conducted by GrindoSonicMK5 instrument can also be used for that purpose and should be comparable to the longitudinal E-modulus conducted by MTS Apparatus.

That conclusion was used in Line 3 and Line 4 to determinate previously the bending E-modulus conducted by GrindoSonicMK5 and compare the bending E-modulus with the longitudinal E-modulus conducted by MTS Apparatus.

4.3.Determination of E-modulus conducted by GrindoSonicMK5 instrument.

In Line 1, the longitudinal E-modulus values were in a range of 4 -30 GPa. Why such high values were obtained, was explained in section 4.2. The range of the resonance frequency in the longitudinal vibration mode was 8000-22000 Hz.

In Line 2, the dynamic longitudinal E-modulus and the dynamic bending E-modulus were in a range of 5-25 GPa. In Line 3 and Line 4 was determined the bending E-modulus by GrindoSonicMK5 instrument. The range of the values was in the same order as Line 2.

4.4.Determination of E-modulus conducted by MTS Apparatus.

The MTS Apparatus was used in parallel with GrindoSonicMK5 instrument in Line 3 and Line 4. In order to obtain a reliable conclusion of the bending E-modulus values obtained by GrindoSonicMK5 instrument.

The maximum static value was 20.2 GPa and the minimum static value was 3.17 GPa. The E-modulus values obtained by MTS Apparatus were normally lower than the dynamic E-modulus values obtained by GrindoSonicMK5 instrument.

4.5.Dynamic E-modulus compared with the Static E-modulus.

The relation between the dynamic and static values was determined from the results obtained in Line 3 and Line 4. The static values were taken from the longitudinal E-modulus obtained by MTS Apparatus. The dynamic values were taken from the bending E-modulus carried out by GrindoSonicMK5 instrument.

The static E-modulus values are, as seen in figures 34-36, about 18-20% lower than the corresponding dynamic ones with an L/h ratio equal to 12.

Figure 36,37, and 39 show the relation between the Static and dynamic E-modulus in oven-dry timber, 10-25% of moisture content, and green timber, respectively.

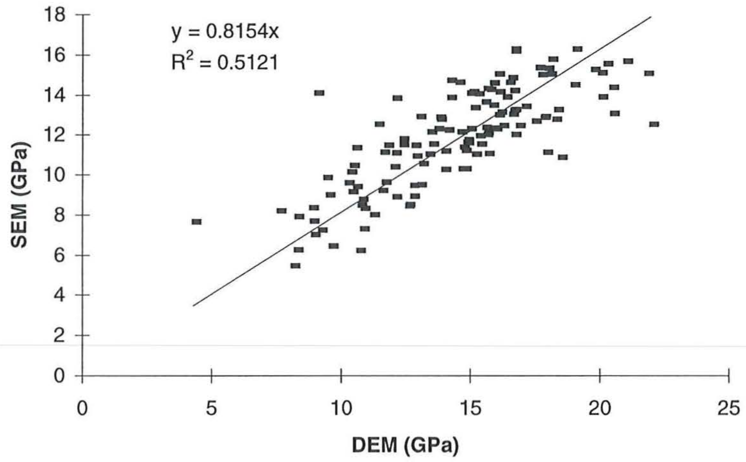

Fig. 36: *Relation between the Static and dynamic E-modulus in dry timber. The linear relation shows the static values 19% lower than the dynamic ones. The results were obtained from 89 specimens. The specimens used are indicated in chapter 3.*

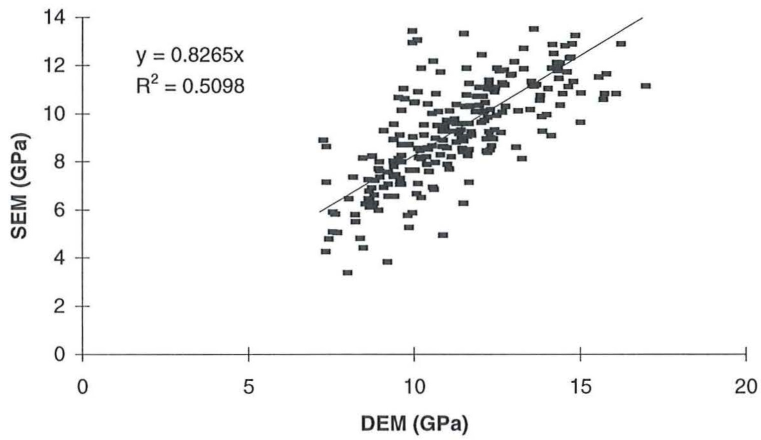

Fig. 37: *Relation between the Static and dynamic E-modulus in timber with a range of moisture content between 10-25%. The linear relation shows the static values 18% lower than the dynamic ones. The results were obtained from 89 specimens tested twice, each time with a different level of moisture content. The specimens used are indicated in chapter 3.*

The moisture content values are from 0% when wood is dry till 60% when wood is green. Inside this range the E-modulus values has been classified in two groups; dynamic values obtained from GrindoSonicMK5 instrument, and Static values obtained from MTS Apparatus. Both has been compared in each graph.

The percentage of total test done with each range of moisture content is shown in figure 39. The majority of the results are in the range between 20-30% of moisture content.

In the following figures, the dynamic and Static E-modulus are represented as a function of moisture content. Each curve belongs to a specific density.

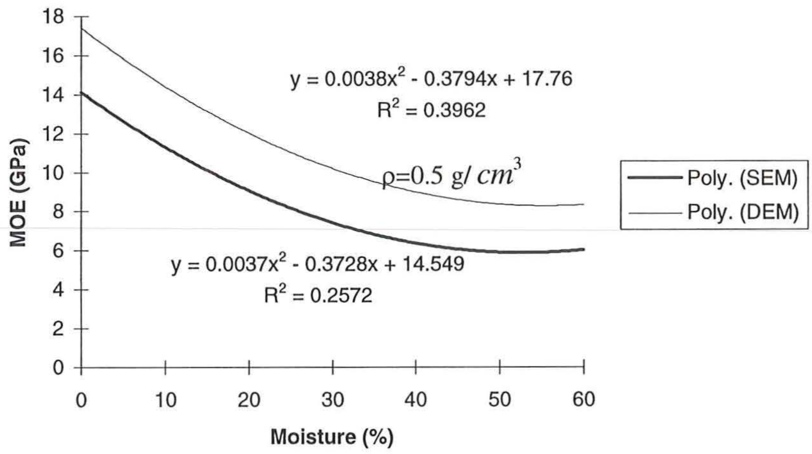

Fig. 40: *Effect of moisture content on the dynamic and Static E-modulus. The relation follows a decrement. Those curves belong to specimens with $\rho = 0.5\ g/cm^3$.*

A curve result from the relation of the E-modulus and the moisture content. The slope of this curves has a strong intensity just below 30% of moisture content.

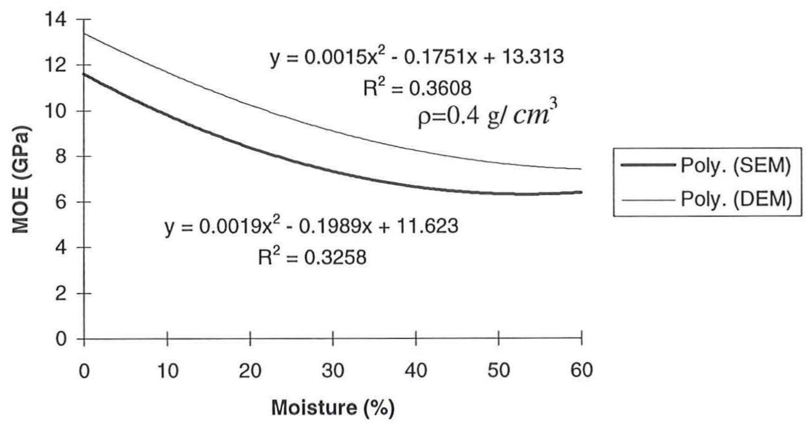

Fig. 41: *Effect of moisture content on the dynamic and Static E-modulus. There are a parallelism between the dynamic and Static values. Those curves belong to specimens with $\rho = 0.4\ g/cm^3$.*

The E-modulus is higher with the same moisture content when the density is higher. See figure 42.

The dynamic curve belonging to ρ =*0.4 g/cm*^{3} is compared with the dynamic curve belonging to ρ =*0.5 g/cm*^{3}, it is remarkable the higher values when the density is higher.

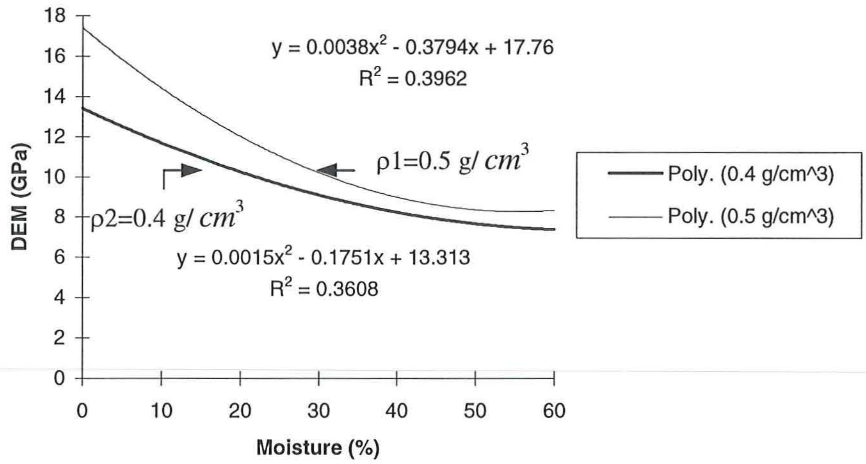

Fig. 42: *Dynamic E-modulus as a function of moisture content for two different densities,* ρ *1=0.4 g/cm*^{3}*, and* ρ *2=0.5 g/cm*^{3}*.*

In the following sections the density is studied deeply. It will be possible to see how the density can affect the E-modulus values with different levels of moisture content.

4.7. Effect of density in the E-modulus.

Line 3 and Line 4 were used to determine the E-modulus as a function of density. The range of densities used in this research was between 0.3 and 1.2 g/*cm*^{3}, belonging to green wood.

In the same manner as it was explained in the previous section. The percentage of total test done in relation with the density is shown in figure 43. 46% of the test were carried out with a density between 0.5-0.6 g/*cm*^{3}.

The effect of the density on the E-modulus was studied with oven-dry specimens, as it was explained in the theories. It was necessary to standardize the density in a level of moisture content.

4.8. E-modulus in relation to the location inside the log.

The Line 4 was used to determinate the distribution of the E-modulus inside the log. A total of 414 tests were carried out to determinate the E-modulus in relation to the location in the log. The results were classified in different ranges of moisture content. Those ranges were 0-10%, 10-20%, 20-30%, and Green wood.

Figure 45 shows the dynamic and static E-modulus in relation to the location inside the log with a range of moisture content of 0-10%.

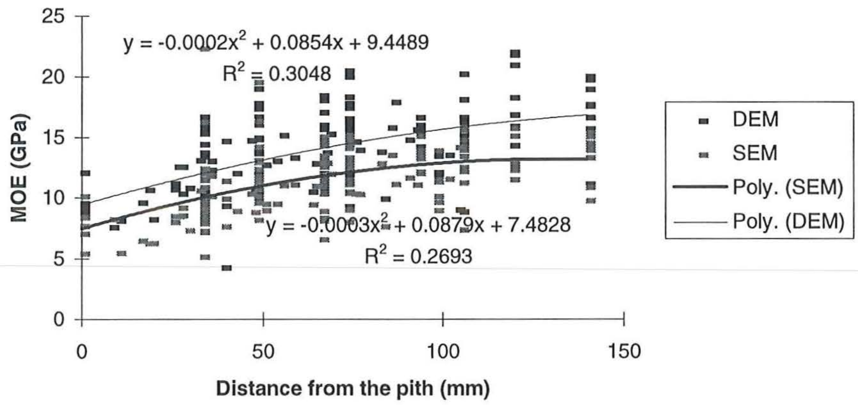

Fig. 45: *Dynamic and Static E-modulus as a function of the distance in a range of 0-10% of moisture content. The E-modulus values grow up when the distance from the pith increases.*

The E-modulus values grow up when the distance from the pith increase. The correlation in this curve is not so high ($R^2 = 0.30$). How it was remarked in other curves, there are a parallelism between the dynamic and static results.

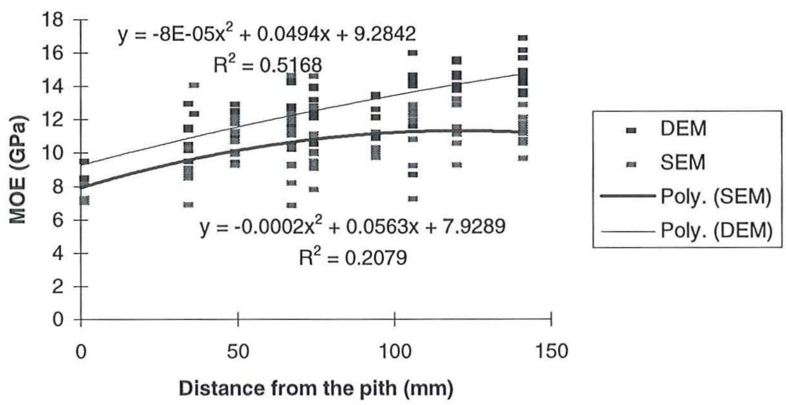

Fig. 46: *Dynamic and Static E-modulus as a function of the distance in a range of 10-20% of moisture content.*

Figure 46, 47, and 49 shows the same relation as figure 47 in a range of 10-20%,20-30% of moisture content, and green wood, respectively.

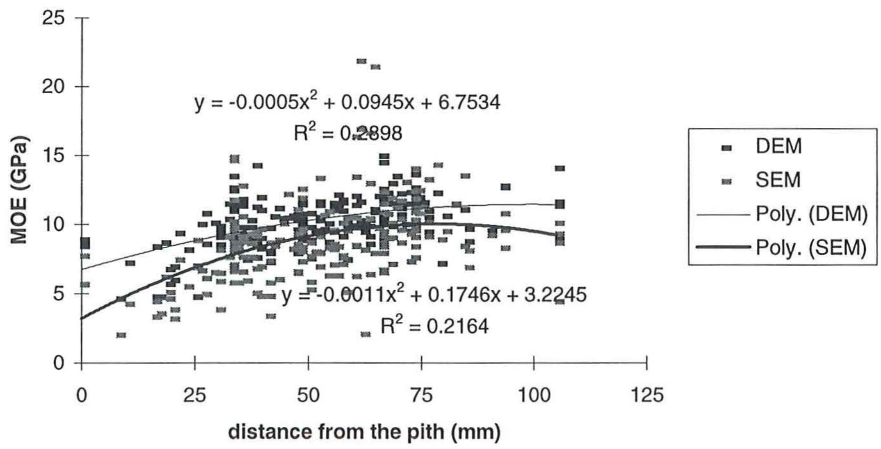

Fig. 47: *Dynamic and Static E-modulus as a function of the distance in a range of 20-30% of moisture content.*

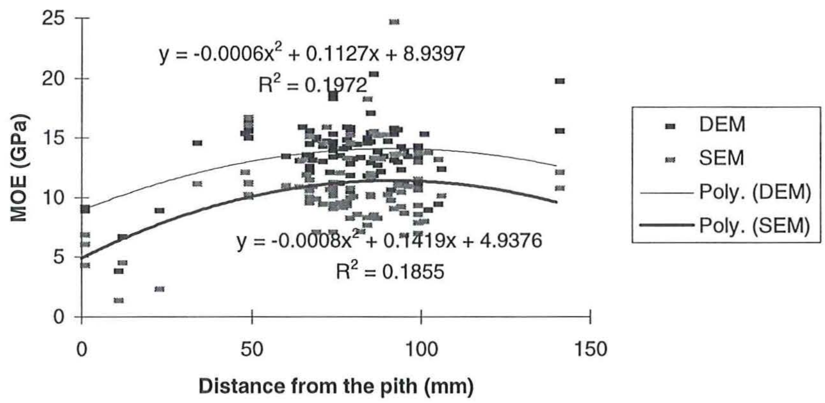

Fig. 49: *Dynamic and Static E-modulus as a function of the distance in Green wood.*

The minimun coefficient of determination obtained was $R^2 = 0.18$ in green wood.

5
CONCLUDING REMARKS

5.1. Discussion of the results.

In Appendix I,II,III, and IV, the results obtained from Line 1, 2, 3, and 4 are respectively shown. The moisture content (M) and the density (ρ) were the main factors affecting the results in the different lines of the research. Especially in the results from Line 3 and Line 4 destined to study the effect of the moisture content and the density on the modulus of elasticity as well as the relation between the statics and the dynamic E-modulus.

The effect of those factors on the E-modulus conducted by GrindoSonicMK5 instrument has been understood in such a manner that the future uses of this instrument will have a great reference to derterminate the E-modulus in relation with those factors.

In Line 1, changes or variabilities in material or structural features, which influence either the stiffness or the mass, can be indicated by observing changes in the longitudinal resonance frequencies. The results obtained from Line 1 show an increament of the resonance frequency belonging to the longitudinal vibration mode on decreasing the length of the specimen. When the relation between the length an the height is $8 < L / h < 10$ the E-modulus values remained almost constant. When the relation is $L / h > 10$ the values are 2-5% lower.

The change of the length can influence other factors affectting the longitudinal resonance frequency as for example the grain angle or the location of a knot inside the specimen.

The grain angle can be different along the specimen, this feature depends mainly on the way sawn timber is cut and of the spirally of the trunk.

The knot is a structural distorsion. In function where it is located, it can produce a disturb signal and can affect the longitudinal resonance.

There are many more features affectting the resonance frequency as for example the timber containing the pith. This wood has generally lower E-modulus values but higher values of the shear modulus than specimens cut further out in the trunks. It suffers a torsional deformation when they were oven-dry. The reason for the lower E-modulus can be attributed to anatomic changes affecting also another properties.

The results obtained in Line 2 shows a linear relation between Longitudinal E-modulus and Bending E-modulus both conducted by GrindoSonicMK5. See figures 31, 32, and 33. This relation forms an almost 1:1 line in all the different levels of moisture content reached. The coeficient of determination decreases on increasing the level of moisture content, this increase is not significantly affecting the results. The minimun coeficient of determination obtained in Line 2 was quite high $R^2 = 0.74$ .Even though It can be remarkable the minimun coeficient of determination is obtained in the level of moisture where the fiber saturation point in timber is located, the coeficient of determination still is too high to take different conclussions from the others curves with lower range of moisture content.

From this point, the most reliable conclusion according to the curves, it should be possible to compare the bending E-modulus in front of the longitudinal E-modulus obtained from the classic tension method by MTS Apparatus.

In Line 3, the study of the results were divided in two stages:

- The relation between the dynamic and static values carried out by GrindoSoncicMK5 instrument and MTS Apparatus, respectively.

- The effect of the moisture content and density on the E-modulus.

When the relation between the dynamic and Static values was studied, a similar relation was found between them in all the different ranges of moisture content applied. Those ranges of moisture content belong to the different climatic situation in Line 3A and Line 3B (see figure 29).

The Static values were always below the dynamic ones. They were 18% lower than the dynamic ones. It means that the difference between the static and the dynamic values is around 3 GPa.

Figure 51, 55 show the different levels of moisture content in Line 3 reached in each step as a function of the time in each climatic situation.

The Line 3B follows a softer decreament of the moisture content than Line 3A. The jump of the Relative humidity between consecutive steps was the determining factor of this decreament.

moisture content used for the analysi was the actual moisture content found in each specimen.

The effect of the moisture content on the E-modulus was studied in relation with two types of densities 0.5 - 0.4 g/cm^3 (see figure 38 and 39). The conclussion took from the relation between the static and dinamic values, was check in those curves. The curve belonging to the static values were around 3GPa below and parallel to the curve belonging to the dynamic values.

In a comparisson between the dynamic curves belonging to the different densities (see figure 40) it was detected that for a 0.5 g/cm^3 the E-modulus values were higher than the E-modulus values belonging to 0.4 g/cm^3. The two curves were almost parallel above 28% of moisture content where the fiber point saturation in timber is located. The values in this part differ 1 GPa. Below this point, the paralelism did not exist. The values differ from 1 GPa till 4 GPa for oven-dry timber (see figure 40).

Since density is influenced to a large extent by the moisture content. The realtion between the density and the E-modulus was linear. The coeficient of determination obtained was R^2=0.30. It was remarkable the paralelism between the dynamic and static values. In oven-dry specimens, the range of density were situated between 0.4 - 0.6 g/cm^3(see figure 42 and 43).

In relation with the effect of the density in the E-modulus, it is possible to check that the E-modulus increase on increasing the density.

In line 4, the results obtained were classified in different ranges of moisture content. The relation between the MOE and the location in the trunk show a polynomial relation of second order.

The results obtained from Line 4 show an increament on increasing the distance from the pith. The results show a polinomial relation. The minimun values obtained belong to green specimen and specimen with moisture content in a range of 20-30%. The minimun E-modulus value conducted dynamically belongs to wood close to the pith (6.75 GPa). The highest coeficient of determination obtained was R^2=0.51 with specimens in a range of moisture content of 10-20%.

5.2.Further research.

The use of dynamic methods to determine the E-modulus have increased the last decades. The methodology has been aplied to anisotropic material in different climatic situation for the determination of the E-modulus. The aplication of GrindoSonicMK5 instrument has been succesful in the determination of the E-modulus. The research and devolopment of the testing procedure can be divided in two orientations: (1) new means of testing procedure for the evaluation of the E-modulus by GrindoSonicMK5 instrument, (2) the application to a specific material.

The main point is certainly to test the wood in such a manner that the E-modulus should be determined as accuratly as possible.

In relation to the first orientation, wood in a parallelepipedic form have been investigated in other references. It would therefore be interesting to test wood cut in different forms. Such investigation can tell something about the anisotropic materials as wood.

In the evaluation of GrindosonicMK5 instrument is necessary to stablish a relation between the dynamic values and static values. Many studies have compared dynamically and statically establishing the E-modulus. Those studies show that the dynamic E-modulus are somewhat higher than the static ones. The reason for this difference has not yet found. Some researchers state that the difference depends on the viscoelastic nature of the wood.
Questions that can be presented are the following: Why this discrepance between the dynamic and static values? How much of the difference depends on other features as for example the measuring arrengements?

The application of the method suggested to wood make it possible to standardised labwork. Basic research like this should be adopted by other researchers to have a basic reliable reference. The devolopment of the testing procedure by GrindoSonicMK5 instrument requires many tests and verifying by other method, Static method in this research.

Importamt fields for further researches are the measuring arrengement, the range of validity of the equipment, the dimensions of the specimen, and the discrepance between the two methods used.

5.3. Conclussions.

- The described testing procedure is an adequate method (quite accurate) to measure the effect of density, moisture content, and other factors affecting on the E-modulus.
- GrindoSonicMK5 instrument gave wrong readings of the resonance frequency when the relation between the length and the heigth in the specimen was $L / h < 8$.
- The grain angle and the presence of knots causes the mass density and the E- modulus to vary along the grain. However, the variation is relatively small, because of that the formulas valid for homogeneous and isotropic materials can be used.
- Bending E-modulus conducted dynamically can perfectly be compared to the longitudinal E-modulus conducted statically.
- Static E-modulus showed 18% lower values than the dynamic ones.
- Each specimen has to be evaluate separetly as it was taken from a different part of the log and as it contents different level of moisture content.
- The high values of moisture content tend to stabilize the E-modulus. In the other hand, values below the fiber satuartion point tend to increase on decreasing the moisture content. The maximun E-modulus values were obtained with oven-dry specimens.
- Specimens with higher values of density and the same level of moisture content gave high values of the E-modulus.
- The specimens from the pith shows a torsional deformation and some fissures when they were oven-dried.
- The minimun E-modulus values were obtained from specimen close to the pith in green wood. The E-modulus values increase on increasing the distance from the pith. the maximun values were obtained from specimens located near the bark.
- The results obtained can be used by wood researchers as a reference to design their experimental work with GrindoSonicMK5 instrument.

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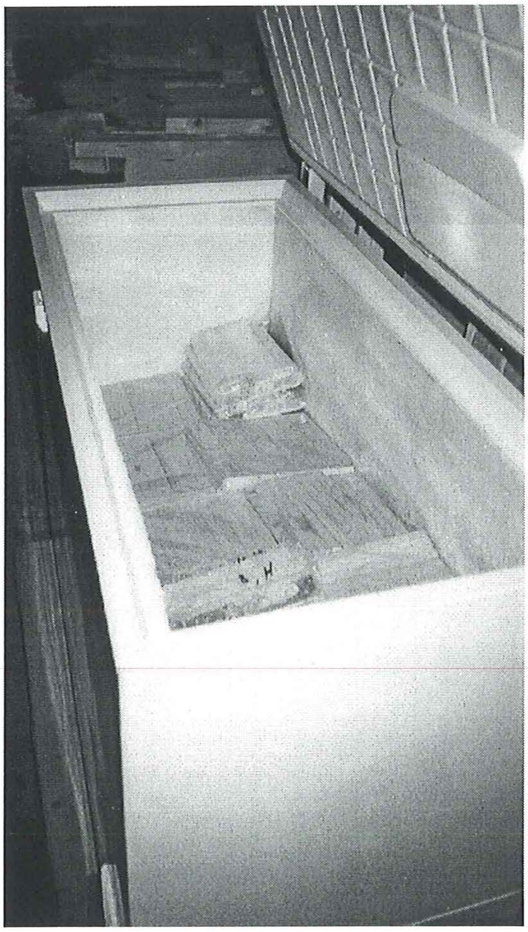

PHOTO1: Freezer where the specimens where kept until they were tested.

PHOTO2: Climatic room -1C where the logs where kept until they were cut.

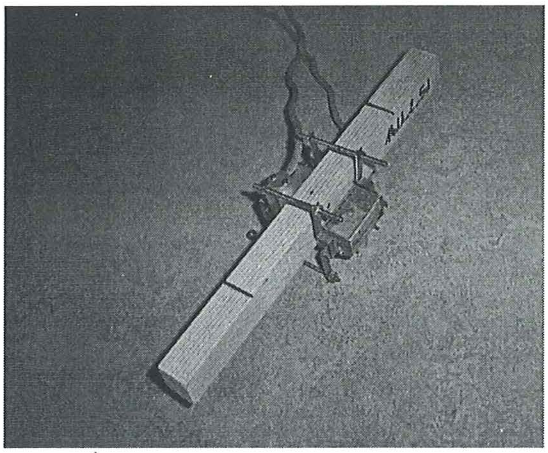

PHOTO3: Specimens whit the external sensors fixed.

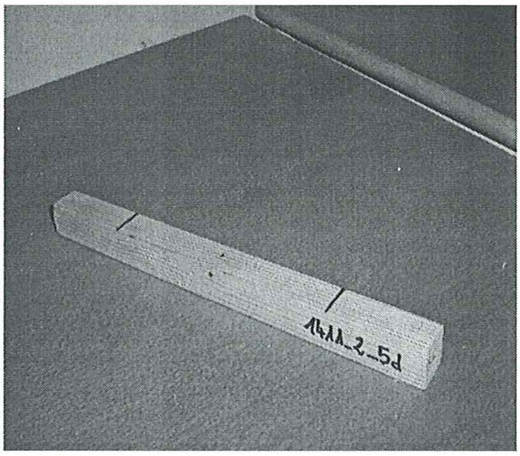

PHOTO4: Test specimens.

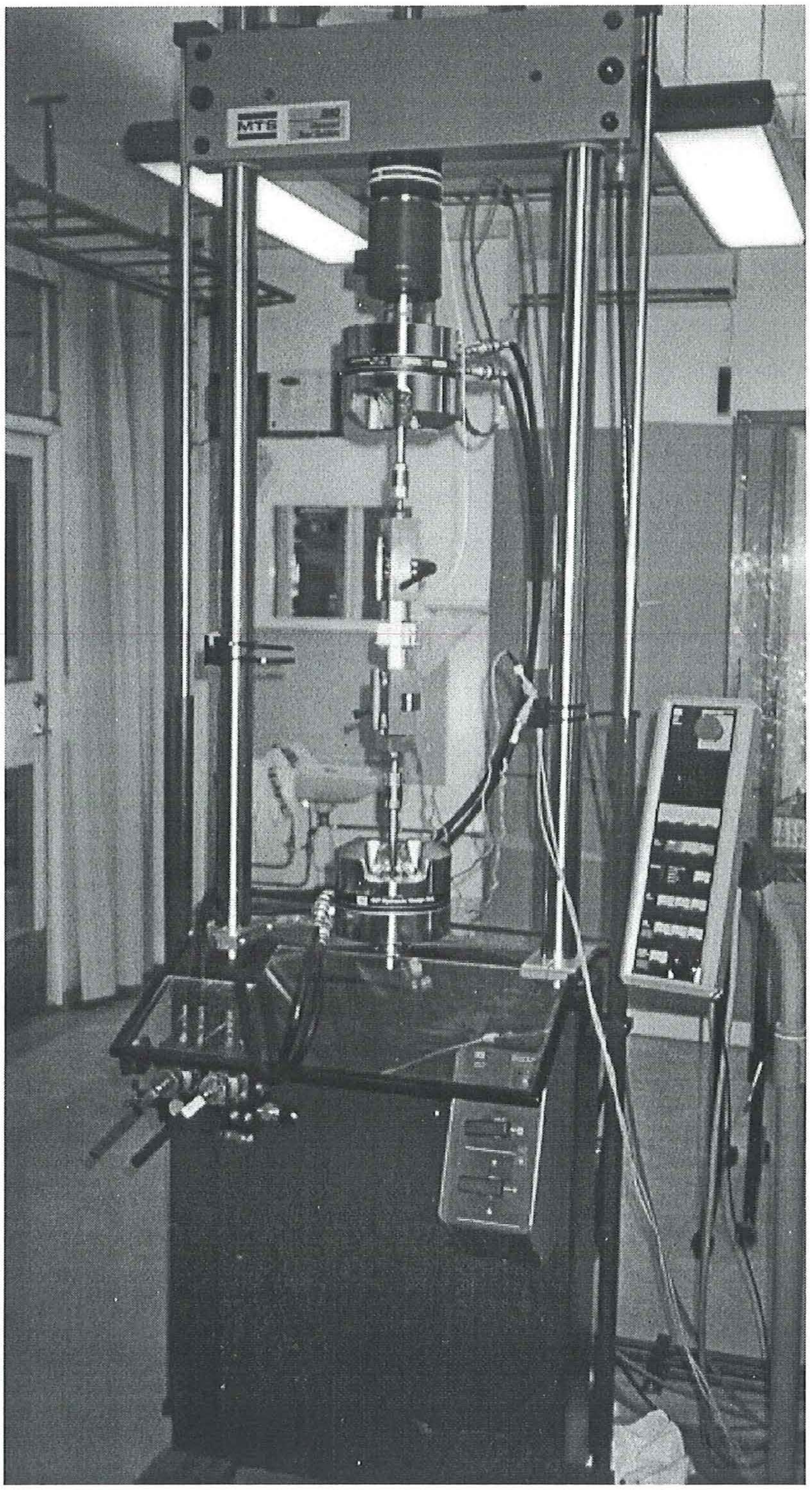

PHOTO5: MTS Apparatus.

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Appendix I

Hooke´s law
Calculation of the elastic constants

Hooke's generalised law gives the relation between an applied stress and the responding strain in terms of elastic constants. Usually the relation is written in a matrix formulation:

$$
\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{yz} \\ \gamma_{xz} \\ \gamma_{xy} \end{bmatrix} =
\begin{bmatrix}
\frac{1}{E_{xx}} & \frac{-\nu_{xy}}{E_{yy}} & \frac{-\nu_{xz}}{E_{zz}} & \frac{\eta_{x,yz}}{G_{yz}} & \frac{\eta_{x,zx}}{G_{xz}} & \frac{\eta_{x,xy}}{G_{xy}} \\
\frac{-\nu_{yx}}{E_{xx}} & \frac{1}{E_{yy}} & \frac{-\nu_{yz}}{E_{zz}} & \frac{\eta_{y,yz}}{G_{yz}} & \frac{\eta_{y,zx}}{G_{xz}} & \frac{\eta_{y,xy}}{G_{xy}} \\
\frac{-\nu_{zx}}{E_{xx}} & \frac{-\nu_{zy}}{E_{yy}} & \frac{1}{E_{zz}} & \frac{\eta_{z,yz}}{G_{yz}} & \frac{\eta_{z,zx}}{G_{xz}} & \frac{\eta_{z,xy}}{G_{xy}} \\
\frac{\eta_{yz,x}}{E_{xx}} & \frac{\eta_{yz,y}}{E_{yy}} & \frac{\eta_{yz,z}}{E_{zz}} & \frac{1}{G_{yz}} & \frac{\mu_{yz,zx}}{G_{xz}} & \frac{\mu_{yz,xy}}{G_{xy}} \\
\frac{\eta_{zx,x}}{E_{xx}} & \frac{\eta_{zx,y}}{E_{yy}} & \frac{\eta_{zx,z}}{E_{zz}} & \frac{\mu_{zx,yz}}{G_{yz}} & \frac{1}{G_{xz}} & \frac{\mu_{zx,xy}}{G_{xy}} \\
\frac{\eta_{xy,x}}{E_{xx}} & \frac{\eta_{xy,y}}{E_{yy}} & \frac{\eta_{xy,z}}{E_{zz}} & \frac{\mu_{xy,yz}}{G_{yz}} & \frac{\mu_{xy,zx}}{G_{xz}} & \frac{1}{G_{xy}}
\end{bmatrix} \cdot
\begin{bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{yz} \\ \tau_{xz} \\ \tau_{xy} \end{bmatrix}
\qquad (1.1)
$$

where E_{xx}, E_{yy}, and E_{zz} denote the E-modulus in the x, y, and z directions, repectively; and G_{yz}, G_{xz}, and G_{xy} present the shear modulus in the yz, xz, and the xy planes, respectively. The poisson ratio ν_{yx} is the value of the non dimensional relation between the strain in the y-diretion (ε_y) and the strain in the x-direction (ε_x), due to the normal stress in the x-direction (σ_x). Thus, a tension in the x-direction yields a contraction in the y-direction ($\varepsilon_y = -\nu_{yx} \cdot e_x$). The other poisson ratios are defined similarly. Corresponding relations for the shear strains and stresses are represented by μ - parameters. For instance, $\mu_{zx,yz}$ characterises the shear in the zx -plane caused by the stress τ_{yz} (Ambartsumyan, 1991). The μ -parameters are called the Chentsov coefficients. The $\mu_{ij\text{-}k}$ - constants are called the coefficients of mutual efffect of the first kind. For instance, $\mu_{xy\text{-}x}$ characterises the shear in the xy-plane due to a normal stress in the x-direction (σ_x). The coefficients of mutual effect of the second kind are denoted $\mu_{k\text{-}ij}$. The normal stress in the z-direction under the action of the shear stress τ_{xy} defines $\mu_{z\text{-}xy}$ (Ambartsumyan, 1991). Since the flexibility matrix is symetric, some valuable relations can be observed, especially that $\nu_{yx}/E_{xx} = \nu_{xy}/E_{yy}$.

To summarise above discussion, the elastic constants are used in this research are the elastic modulus E_i.

Appendix II

Results from Line 1

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	2	4a	20	259.5	20	55.43	0.00	0.534	10500	15.858
1411	2	5a	20	259	20	54.22	0.00	0.523	10750	16.228
1411	2	6a	20.5	258.5	20	53.33	0.00	0.503	10650	15.255
1411	2	7a	21	258	20	53.25	0.00	0.491	10950	15.688
1411	2	8a	20	258.5	20.5	50.54	0.00	0.477	10150	13.131
1411	2	9a	20.5	259	20.5	54.41	0.00	0.500	10550	14.929
1411	2	4b	20.5	257.5	20	56.9	0.00	0.539	8800	11.070
1411	2	5b	20.5	258.5	20	57.15	0.00	0.539	11000	17.440
1411	2	6b	20.5	258.5	19.5	54.57	0.00	0.528	10100	14.399
1411	2	7b	20.5	258.5	20	53.23	0.00	0.502	10130	13.776
1411	2	8b	20	258	20.5	51.92	0.00	0.491	10150	13.464
1411	2	9b	20.5	258.5	22	57.84	0.00	0.496	10050	13.394
1411	2	4c	19.5	257.5	20.5	59.26	0.00	0.576	10760	17.678
1411	2	5c	19.5	258	20.5	57.92	0.00	0.562	10520	16.548
1411	2	6c	20.5	258	20	54.41	0.00	0.514	10220	14.305
1411	2	7c	20	258.5	19.5	53.25	0.00	0.528	11220	17.773
1411	2	8c	20.5	258	20.5	52.33	0.00	0.483	9900	12.595
1411	2	9c	20	258.5	20	58.2	0.00	0.563	9950	14.895
1411	2	4d	20	257	20.5	54.23	0.00	0.515	11150	16.904
1411	2	5d	20.5	257.5	20	56.9	0.00	0.539	10930	17.077
1411	2	6d	21	257	20	57	0.00	0.528	9800	13.399
1411	2	7d	21	257.5	20	54	0.00	0.499	10090	13.482
1411	2	8d	20.5	258	20.5	53.42	0.00	0.493	9450	11.715
1411	2	9d	20.5	257.5	20.5	54.64	0.00	0.505	10260	14.097
1411	3	4a	20.5	258	20.5	52.74	0.00	0.486	10150	13.343
1411	3	5a	20.5	260	20.5	49.41	0.00	0.452	10350	13.098
1411	3	6a	20.5	259	19.5	47.9	0.00	0.463	10950	14.885
1411	3	7a	20.5	259	20.5	48.2	0.00	0.443	10850	13.988
1411	3	8a	20.5	260.5	20.5	48.12	0.00	0.440	8950	9.557
1411	3	9a	20.5	258.5	20.5	49.65	0.00	0.457	10550	13.597
1411	3	4b	20	260	20	55.18	0.00	0.531	10650	16.272
1411	3	5b	20.5	260	20	52.6	0.00	0.493	10720	15.333
1411	3	6b	20	260	20	51.04	0.00	0.491	11220	16.706
1411	3	7b	20	259.5	20	51.72	0.00	0.498	10220	14.018
1411	3	8b	20.5	258	20.5	49.52	0.00	0.457	10350	13.027
1411	3	9b	20.5	260	20.5	51.79	0.00	0.474	9450	11.446
1411	3	4c	20	260	20	55.6	0.00	0.535	10850	17.018
1411	3	5c	20	258.5	20	54.48	0.00	0.527	9200	11.920
1411	3	6c	20.5	259.5	20	50.91	0.00	0.478	9950	12.760
1411	3	7c	20.5	259.5	20	49.89	0.00	0.469	10350	13.530
1411	3	8c	20.5	259.5	20.5	50.13	0.00	0.460	10010	12.407
1411	3	9c	20.5	259.5	20.5	56.71	0.00	0.520	9010	11.371
1411	3	4d	20	260	20.5	52.53	0.00	0.493	9900	13.060
1411	3	5d	20.5	260	20.5	49.4	0.00	0.452	10020	12.274
1411	3	6d	20.5	260.5	19.5	51.03	0.00	0.490	10020	13.355
1411	3	7d	20.5	260.5	20	50.13	0.00	0.469	11200	15.982
1411	3	8d	20.5	259.5	20.5	50.54	0.00	0.463	10200	12.987
1411	3	9d	20	260	20.5	55.9	0.00	0.524	6500	5.991
1411	4	3a	20.5	255.5	20.5	54.75	0.00	0.510	11250	16.851
1411	4	4a	20.5	255	20.5	49.58	0.00	0.463	10000	12.034

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	5a	21	255.5	19.5	48.4	0.00	0.463	9850	11.720
1411	4	6a	20	255.5	19.5	49.72	0.00	0.499	10300	13.823
1411	4	7a	20	255	19.5	46.93	0.00	0.472	10450	13.404
1411	4	8a	19.5	259.5	19.5	54.35	0.00	0.551	10450	16.202
1411	4	9a	20	258.5	20.5	46.28	0.00	0.437	10050	11.789
1411	4	10a	20	258	20	51.44	0.00	0.498	11250	16.797
1411	4	3b	20	259	20.5	47.22	0.00	0.445	10250	12.536
1411	4	4b	19.5	259	19.5	51.89	0.00	0.527	11250	17.893
1411	4	5b	20	258	20	49.39	0.00	0.479	10450	13.915
1411	4	6b	20.5	257.5	19.5	49.36	0.00	0.480	10300	13.493
1411	4	7b	20	256.5	20	50.05	0.00	0.488	10550	14.289
1411	4	8b	20.5	259.5	20	47.94	0.00	0.451	10650	13.766
1411	4	9b	20	259	20	47.77	0.00	0.461	10450	13.511
1411	4	10b	19.5	259	20.5	53.93	0.00	0.521	10230	14.627
1411	4	5c	20.5	258	20.5	51.06	0.00	0.471	6200	4.820
1411	4	6c	20	259	19.5	49.94	0.00	0.494	9740	12.585
1411	4	7c	21	259	20	49.62	0.00	0.456	11040	14.918
1411	4	8c	20.5	258.5	20.5	49.4	0.00	0.455	10020	12.203
1411	4	9c	20	259	20.5	52.13	0.00	0.491	11250	16.671
1411	4	10c	20.5	259	20	57.51	0.00	0.542	10230	15.208
1411	4	3d	20.5	259.5	20.5	56.16	0.00	0.515	11250	17.556
1411	4	4d	21	259.5	20.5	48.57	0.00	0.435	10380	12.618
1411	4	5d	20.5	259	20.5	49.61	0.00	0.456	10360	13.126
1411	4	6d	21.5	259	19.5	51.34	0.00	0.473	8900	10.049
1411	4	7d	20.5	259	19.5	48.94	0.00	0.473	11050	15.487
1411	4	8d	19.5	258	20.5	46.89	0.00	0.455	12050	17.577
1411	4	9d	19.5	259.5	20	50.95	0.00	0.503	11020	16.468
1411	4	10d	19.5	259.5	20.5	58.88	0.00	0.568	10960	18.365
1411	2	4a	20	237.5	20	51.98	0.00	0.547	11700	16.899
1411	2	5a	20	237	20	50.83	0.00	0.536	11250	15.247
1411	2	6a	20.5	237	20	50.14	0.00	0.516	11120	14.336
1411	2	7a	21	237	20	49.94	0.00	0.502	11280	14.343
1411	2	8a	20	237	20.5	47.19	0.00	0.486	11010	13.227
1411	2	9a	20.5	237.5	20.5	50.88	0.00	0.510	11040	14.018
1411	2	4b	20.5	236.5	20	53.35	0.00	0.550	9200	10.419
1411	2	5b	20.5	237.5	20	53.85	0.00	0.553	11900	17.669
1411	2	6b	20.5	237	19.5	51.21	0.00	0.541	11250	15.370
1411	2	7b	20.5	236.5	20	49.7	0.00	0.513	11550	15.298
1411	2	8b	20	237.5	20.5	49.07	0.00	0.504	11150	14.135
1411	2	9b	20.5	237	22	54.04	0.00	0.506	11250	14.376
1411	2	4c	19.5	236	20.5	55.55	0.00	0.589	11950	18.733
1411	2	5c	19.5	236.5	20.5	54.44	0.00	0.576	11550	17.186
1411	2	6c	20.5	236.5	20	50.95	0.00	0.525	11150	14.615
1411	2	7c	20	237	19.5	49.9	0.00	0.540	11950	17.321
1411	2	8c	20.5	236.5	20.5	49.04	0.00	0.493	11250	13.971
1411	2	9c	20	236.5	20	54.53	0.00	0.576	11150	16.033
1411	2	4d	20	235	20.5	50.71	0.00	0.526	12290	17.561
1411	2	5d	20.5	235.5	20	53.14	0.00	0.550	11900	17.290
1411	2	6d	21	236	20	53.45	0.00	0.539	11800	16.728

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	2	7d	21	236.5	20	50.66	0.00	0.510	10950	13.682
1411	2	8d	20.5	237	20.5	50.16	0.00	0.504	10150	11.657
1411	2	9d	20.5	237	20.5	51.23	0.00	0.514	9150	9.675
1411	3	4a	20.5	237	20.5	49.66	0.00	0.499	11500	14.815
1411	3	5a	20.5	238	20.5	46.21	0.00	0.462	11350	13.485
1411	3	6a	20.5	238	19.5	44.93	0.00	0.472	11640	14.497
1411	3	7a	20.5	237.5	20.5	45.22	0.00	0.453	11820	14.282
1411	3	8a	20.5	238.5	20.5	45.23	0.00	0.451	10220	10.724
1411	3	9a	20.5	238	20.5	46.74	0.00	0.467	11220	13.329
1411	3	4b	20	238.5	20	51.66	0.00	0.542	12010	17.772
1411	3	5b	20.5	238.5	20	49.31	0.00	0.504	11020	13.934
1411	3	6b	20	239	20	48.01	0.00	0.502	12030	16.606
1411	3	7b	20	238.5	20	48.56	0.00	0.509	11950	16.539
1411	3	8b	20.5	238	20.5	46.78	0.00	0.468	10950	12.706
1411	3	9b	20.5	238.5	20.5	48.74	0.00	0.486	10330	11.807
1411	3	4c	20	238.5	20	52.24	0.00	0.548	11900	17.644
1411	3	5c	20	238	20	51.45	0.00	0.540	9900	12.001
1411	3	6c	20.5	238	20	47.77	0.00	0.490	10250	11.653
1411	3	7c	20.5	238.5	20	46.85	0.00	0.479	11230	13.748
1411	3	8c	20.5	238.5	20.5	46.95	0.00	0.468	10300	11.307
1411	3	9c	20.5	238	20.5	53.14	0.00	0.531	10230	12.598
1411	3	4d	20	238.5	20.5	49.14	0.00	0.503	11260	14.497
1411	3	5d	20.5	238	20.5	46.36	0.00	0.464	11350	13.529
1411	3	6d	20.5	239	19.5	47.9	0.00	0.501	10150	11.801
1411	3	7d	20.5	239.5	20	47.06	0.00	0.479	12050	15.966
1411	3	8d	20.5	238.5	20.5	47.45	0.00	0.473	12050	15.641
1411	3	9d	20	238	20.5	52.68	0.00	0.540	7500	6.881
1411	4	3a	20.5	235	20.5	51.56	0.00	0.522	11970	16.524
1411	4	4a	20.5	233	20.5	46.28	0.00	0.473	11550	13.692
1411	4	5a	21	234	19.5	45.22	0.00	0.472	10850	12.168
1411	4	6a	20	233.5	19.5	46.42	0.00	0.510	11250	14.070
1411	4	7a	20	234	19.5	43.82	0.00	0.480	12020	15.195
1411	4	8a	19.5	238	19.5	50.91	0.00	0.563	12500	19.915
1411	4	9a	20	232	20.5	43.3	0.00	0.455	10650	11.116
1411	4	10a	20	232	20	48.23	0.00	0.520	11250	14.162
1411	4	3b	20	232.5	20.5	44.04	0.00	0.462	11320	12.801
1411	4	4b	19.5	237.5	19.5	48.38	0.00	0.536	11850	16.973
1411	4	5b	20	237.5	20	46.09	0.00	0.485	9820	10.556
1411	4	6b	20.5	236	19.5	45.8	0.00	0.485	11150	13.446
1411	4	7b	20	235	20	46.47	0.00	0.494	11230	13.772
1411	4	8b	20.5	238	20	44.67	0.00	0.458	9990	10.351
1411	4	9b	20	237.5	20	44.44	0.00	0.468	11410	13.741
1411	4	10b	19.5	237	20.5	50.22	0.00	0.530	11550	15.888
1411	4	5c	20.5	235	20.5	49.81	0.00	0.504	11230	14.051
1411	4	6c	20	235.5	19.5	49.94	0.00	0.544	11260	15.294
1411	4	7c	21	237	20	47.87	0.00	0.481	8500	7.807
1411	4	8c	20.5	237	20.5	46.15	0.00	0.463	10950	12.482
1411	4	9c	20	237.5	20.5	48.25	0.00	0.496	11950	15.965
1411	4	10c	20.5	237.5	20	53.72	0.00	0.552	11550	16.605

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	3d	20.5	237.5	20.5	52.69	0.00	0.528	11460	15.643
1411	4	4d	21	237.5	20.5	45.69	0.00	0.447	11550	13.450
1411	4	5d	20.5	237.5	20.5	46.52	0.00	0.466	11680	14.346
1411	4	6d	21.5	238	19.5	48.36	0.00	0.485	9910	10.784
1411	4	7d	20.5	237.5	19.5	46.02	0.00	0.485	10950	13.113
1411	4	8d	19.5	236	20.5	44.1	0.00	0.467	11990	14.971
1411	4	9d	19.5	237.5	20	47.87	0.00	0.517	12100	17.072
1411	4	10d	19.5	237.5	20.5	55.48	0.00	0.584	11510	17.467
1411	2	4a	20	217	20	47.4	0.00	0.546	13800	19.588
1411	2	5a	20	217	20	46.55	0.00	0.536	13590	18.656
1411	2	6a	20.5	216.5	20	45.76	0.00	0.516	13510	17.641
1411	2	7a	21	217	20	45.61	0.00	0.500	13790	17.925
1411	2	8a	20	216	20.5	42.99	0.00	0.485	13650	16.880
1411	2	9a	20.5	215.5	20.5	46.28	0.00	0.511	13880	18.288
1411	2	4b	20.5	215	20	48.46	0.00	0.550	13930	19.724
1411	2	5b	20.5	216	20	48.94	0.00	0.553	14230	20.884
1411	2	6b	20.5	215	19.5	46.53	0.00	0.541	13370	17.894
1411	2	7b	20.5	215	20	44.51	0.00	0.505	13460	16.915
1411	2	8b	20	216	20.5	44.45	0.00	0.502	13520	17.122
1411	2	9b	20.5	215.5	22	49.17	0.00	0.506	13760	17.794
1411	2	4c	19.5	215.5	20.5	50.92	0.00	0.591	13600	20.309
1411	2	5c	19.5	214	20.5	49.4	0.00	0.577	13660	19.738
1411	2	6c	20.5	215	20	46.26	0.00	0.525	13670	18.132
1411	2	7c	20	215	19.5	45.18	0.00	0.539	13510	18.184
1411	2	8c	20.5	214	20.5	44.5	0.00	0.495	13210	15.817
1411	2	9c	20	214.5	20	49.64	0.00	0.579	13690	19.956
1411	2	4d	20	214	20.5	46.26	0.00	0.527	14660	20.757
1411	2	5d	20.5	214	20	48.37	0.00	0.551	13770	19.148
1411	2	6d	21	214.5	20	48.7	0.00	0.541	12590	15.770
1411	2	7d	21	215	20	46.11	0.00	0.511	11890	13.348
1411	2	8d	20.5	215.5	20.5	45.63	0.00	0.504	12600	14.859
1411	2	9d	20.5	216.5	20.5	46.86	0.00	0.515	13470	17.521
1411	3	4a	20.5	216	20.5	45.42	0.00	0.500	13740	17.629
1411	3	5a	20.5	217	20.5	42.22	0.00	0.463	13460	15.799
1411	3	6a	20.5	215.5	19.5	40.7	0.00	0.472	13600	16.233
1411	3	7a	20.5	216	20.5	40.98	0.00	0.451	13400	15.128
1411	3	8a	20.5	217	20.5	41.12	0.00	0.451	13230	14.866
1411	3	9a	20.5	216.5	20.5	42.61	0.00	0.468	13780	16.673
1411	3	4b	20	217	20	46.5	0.00	0.536	13660	18.828
1411	3	5b	20.5	216.5	20	44.63	0.00	0.503	13610	17.461
1411	3	6b	20	217	20	43.52	0.00	0.501	13390	16.932
1411	3	7b	20	216	20	43.04	0.00	0.498	13360	16.594
1411	3	8b	20.5	216	20.5	42.43	0.00	0.467	13790	16.589
1411	3	9b	20.5	216	20.5	44.29	0.00	0.488	13370	16.277
1411	3	4c	20	216.5	20	47.5	0.00	0.548	13830	19.670
1411	3	5c	20	216.5	20	47	0.00	0.543	12560	16.052
1411	3	6c	20.5	217	20	43.72	0.00	0.491	12620	14.741
1411	3	7c	20.5	217	20	42.68	0.00	0.480	13330	16.055
1411	3	8c	20.5	217	20.5	42.86	0.00	0.470	14000	17.351

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	3	9c	20.5	217	20.5	48.71	0.00	0.534	11160	12.530
1411	3	4d	20	217.5	20.5	44.72	0.00	0.501	13760	17.967
1411	3	5d	20.5	218	20.5	42.36	0.00	0.462	12880	14.581
1411	3	6d	20.5	217	19.5	43.34	0.00	0.500	12020	13.597
1411	3	7d	20.5	217	20	42.7	0.00	0.480	13540	16.573
1411	3	8d	20.5	217	20.5	43.24	0.00	0.474	13700	16.763
1411	3	9d	20	216.5	20.5	47.82	0.00	0.539	11620	13.638
1411	4	3a	20.5	214	20.5	46.98	0.00	0.522	14210	19.323
1411	4	4a	20.5	216.5	20.5	41.99	0.00	0.462	13730	16.312
1411	4	5a	21	212	19.5	41.08	0.00	0.473	13630	15.804
1411	4	6a	20	212	19.5	42.4	0.00	0.513	13680	17.253
1411	4	7a	20	212	19.5	39.64	0.00	0.479	13800	16.414
1411	4	8a	19.5	216	19.5	46.33	0.00	0.564	14490	22.103
1411	4	9a	20	211	20.5	39.47	0.00	0.456	12910	13.542
1411	4	10a	20	211	20	43.92	0.00	0.520	13460	16.789
1411	4	3b	20	211	20.5	39.81	0.00	0.460	13570	15.091
1411	4	4b	19.5	211	19.5	43.83	0.00	0.546	13980	19.013
1411	4	5b	20	215.5	20	40.74	0.00	0.473	12540	13.806
1411	4	6b	20.5	214	19.5	41.19	0.00	0.481	13540	16.170
1411	4	7b	20	213	20	41.08	0.00	0.482	13850	16.785
1411	4	8b	20.5	216	20	40.62	0.00	0.459	13570	15.763
1411	4	9b	20	215	20	40.13	0.00	0.467	13740	16.288
1411	4	10b	19.5	215.5	20.5	45.54	0.00	0.529	13580	18.110
1411	4	3c	19.5	214	20.5	45.28	0.00	0.529	14490	20.358
1411	4	4c	20.5	214	20.5	45.36	0.00	0.504	13650	17.215
1411	4	5c	20.5	215	20.5	43.79	0.00	0.485	10990	10.823
1411	4	6c	20	215.5	19.5	42.78	0.00	0.509	10870	11.172
1411	4	7c	21	215	20	42.59	0.00	0.472	13510	15.917
1411	4	8c	20.5	217	20.5	42.14	0.00	0.462	12520	13.643
1411	4	9c	20	215.5	20.5	43.51	0.00	0.492	14060	18.084
1411	4	10c	20.5	215.5	20	48.7	0.00	0.551	14090	20.327
1411	4	3d	20.5	216	20.5	47.81	0.00	0.527	14240	19.932
1411	4	4d	21	216	20.5	41.54	0.00	0.447	13700	15.648
1411	4	5d	20.5	215.5	20.5	42.33	0.00	0.467	13710	16.320
1411	4	6d	21.5	217	19.5	44.07	0.00	0.484	12770	14.879
1411	4	7d	20.5	216.5	19.5	41.9	0.00	0.484	13760	17.186
1411	4	8d	19.5	214	20.5	40.01	0.00	0.468	14070	16.961
1411	4	9d	19.5	216	20	43.49	0.00	0.516	13480	17.507
1411	4	10d	19.5	216.5	20.5	50.68	0.00	0.586	13830	21.000
1411	2	4a	20	197	20	43.44	0.00	0.551	15030	19.332
1411	2	5a	20	197	20	42.56	0.00	0.540	14900	18.614
1411	2	6a	20.5	196.5	20	41.68	0.00	0.517	14860	17.644
1411	2	7a	21	196	20	41.53	0.00	0.504	15200	17.911
1411	2	8a	20	195.5	20.5	38.92	0.00	0.486	15110	16.948
1411	2	9a	20.5	195	20.5	41.92	0.00	0.512	15350	18.333
1411	2	4b	20.5	194.5	20	43.88	0.00	0.550	15300	19.491
1411	2	5b	20.5	195	20	44.54	0.00	0.557	15650	20.753
1411	2	6b	20.5	194.5	19.5	42.33	0.00	0.544	13850	15.803
1411	2	7b	20.5	194.5	20	39.74	0.00	0.498	14990	16.944

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	2	8b	20	194	20.5	40.21	0.00	0.506	14930	16.964
1411	2	9b	20.5	194	22	44.5	0.00	0.509	15250	17.807
1411	2	4c	19.5	194.5	20.5	46.28	0.00	0.595	15280	21.030
1411	2	5c	19.5	194.5	20.5	44.6	0.00	0.574	15140	19.897
1411	2	6c	20.5	194	20	41.84	0.00	0.526	15110	18.080
1411	2	7c	20	195	19.5	40.89	0.00	0.538	14560	17.337
1411	2	8c	20.5	194	20.5	40.27	0.00	0.494	14400	15.419
1411	2	9c	20	194	20	45.11	0.00	0.581	13790	16.642
1411	2	4d	20	194	20.5	41.91	0.00	0.527	16190	20.792
1411	2	5d	20.5	195	20	43.92	0.00	0.549	15170	19.228
1411	2	6d	21	194.5	20	44.28	0.00	0.542	13940	15.939
1411	2	7d	21	195	20	41.67	0.00	0.509	13320	13.730
1411	2	8d	20.5	196	20.5	41.36	0.00	0.502	13820	14.737
1411	2	9d	20.5	197	20.5	42.48	0.00	0.513	14840	17.542
1411	3	4a	20.5	195.5	20.5	41.13	0.00	0.501	15220	17.729
1411	3	5a	20.5	196	20.5	38.23	0.00	0.464	14860	15.749
1411	3	6a	20.5	195	19.5	36.85	0.00	0.473	14940	16.049
1411	3	7a	20.5	196	20.5	37.04	0.00	0.450	14830	15.197
1411	3	8a	20.5	197	20.5	37.3	0.00	0.451	14580	14.868
1411	3	9a	20.5	196	20.5	38.69	0.00	0.470	15220	16.720
1411	3	4b	20	197	20	41.57	0.00	0.528	15270	19.095
1411	3	5b	20.5	196	20	40.34	0.00	0.502	15060	17.495
1411	3	6b	20	196	20	39.45	0.00	0.503	13880	14.896
1411	3	7b	20	196	20	38.39	0.00	0.490	15050	17.043
1411	3	8b	20.5	196	20.5	40.15	0.00	0.487	15190	17.283
1411	3	9b	20.5	196	20.5	38.5	0.00	0.467	14780	15.690
1411	3	4c	20	197	20	43.37	0.00	0.550	15130	19.558
1411	3	5c	20	196	20	42.79	0.00	0.546	13750	15.856
1411	3	6c	20.5	197	20	39.44	0.00	0.488	14020	14.900
1411	3	7c	20.5	196	20	38.68	0.00	0.481	14810	16.223
1411	3	8c	20.5	197	20.5	38.87	0.00	0.470	15080	16.574
1411	3	9c	20.5	197	20.5	44.48	0.00	0.537	12670	13.389
1411	3	4d	20	197	20.5	40.55	0.00	0.502	15220	18.054
1411	3	5d	20.5	197	20.5	38.4	0.00	0.464	14230	14.580
1411	3	6d	20.5	196	19.5	39.23	0.00	0.501	13650	14.335
1411	3	7d	20.5	197	20	38.2	0.00	0.473	15080	16.696
1411	3	8d	20.5	197	20.5	39.14	0.00	0.473	15160	16.867
1411	3	9d	20	195.5	20.5	43.09	0.00	0.538	12840	13.550
1411	4	3a	20.5	193	20.5	42.5	0.00	0.524	15690	19.220
1411	4	4a	20.5	194.5	20.5	39.93	0.00	0.489	14380	15.286
1411	4	5a	21	195	19.5	39.1	0.00	0.490	14320	15.272
1411	4	6a	20	196	19.5	40.44	0.00	0.529	14300	16.624
1411	4	7a	20	190	19.5	35.58	0.00	0.480	15540	16.744
1411	4	8a	19.5	194	19.5	41.69	0.00	0.565	16100	22.053
1411	4	9a	20	189	20.5	35.39	0.00	0.457	14380	13.494
1411	4	10a	20	189	20	39.39	0.00	0.521	15020	16.795
1411	4	3b	20	189	20.5	35.65	0.00	0.460	15170	15.128
1411	4	4b	19.5	192	19.5	39.18	0.00	0.537	15630	19.332
1411	4	5b	20	193	20	35.07	0.00	0.454	14170	13.590

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	6b	20.5	192	19.5	36.74	0.00	0.479	14590	15.025
1411	4	7b	20	191	20	36.56	0.00	0.479	15580	16.950
1411	4	8b	20.5	194	20	36.48	0.00	0.459	15140	15.826
1411	4	9b	20	193.5	20	36.1	0.00	0.466	15290	16.331
1411	4	10b	19.5	194	20.5	41.12	0.00	0.530	15070	18.128
1411	4	5c	20.5	195	20.5	39.65	0.00	0.484	12140	10.846
1411	4	6c	20	195	19.5	38.8	0.00	0.510	11930	11.044
1411	4	7c	21	196	20	38.61	0.00	0.469	14880	15.958
1411	4	8c	20.5	197	20.5	38.36	0.00	0.463	13690	13.480
1411	4	9c	20	195.5	20.5	39.43	0.00	0.492	15570	18.232
1411	4	10c	20.5	195	20	44.55	0.00	0.557	15580	20.573
1411	4	3d	20.5	195	20.5	43.21	0.00	0.527	15750	19.894
1411	4	4d	21	196	20.5	37.75	0.00	0.447	15110	15.696
1411	4	5d	20.5	194.5	20.5	38.29	0.00	0.468	15200	16.377
1411	4	6d	21.5	196.5	19.5	40	0.00	0.486	17420	22.757
1411	4	7d	20.5	196	19.5	37.76	0.00	0.482	15330	17.404
1411	4	8d	19.5	194.5	20.5	36.31	0.00	0.467	15470	16.912
1411	4	9d	19.5	195.5	20	39.21	0.00	0.514	14970	17.619
1411	4	10d	19.5	196.5	20.5	45.8	0.00	0.583	15300	21.081
1411	2	4a	20	176	20	38.66	0.00	0.549	16970	19.595
1411	2	5a	20	176.5	20	38.25	0.00	0.542	16740	18.919
1411	2	6a	20.5	177	20	37.56	0.00	0.518	16380	17.402
1411	2	7a	21	175.5	20	37.25	0.00	0.505	17220	18.462
1411	2	8a	20	173.5	20.5	34.6	0.00	0.486	16870	16.668
1411	2	9a	20.5	173.5	20.5	37.4	0.00	0.513	17170	18.208
1411	2	4b	20.5	173	20	39.03	0.00	0.550	18000	21.344
1411	2	5b	20.5	173.5	20	39.74	0.00	0.559	17610	20.860
1411	2	6b	20.5	173.5	19.5	37.71	0.00	0.544	21100	29.147
1411	2	7b	20.5	172.5	20	35.17	0.00	0.497	16830	16.765
1411	2	8b	20	173	20.5	35.83	0.00	0.505	16780	17.028
1411	2	9b	20.5	173.5	22	39.77	0.00	0.508	17040	17.770
1411	2	4c	19.5	173.5	20.5	41.56	0.00	0.599	17030	20.925
1411	2	5c	19.5	172.5	20.5	39.38	0.00	0.571	17230	20.179
1411	2	6c	20.5	173	20	37.39	0.00	0.527	16940	18.109
1411	2	7c	20	173.5	19.5	36.46	0.00	0.539	16350	17.344
1411	2	8c	20.5	172.5	20.5	35.94	0.00	0.496	16170	15.429
1411	2	9c	20	172.5	20	40.47	0.00	0.587	15260	16.257
1411	2	4d	20	172	20.5	37.45	0.00	0.531	18160	20.725
1411	2	5d	20.5	173.5	20	39.24	0.00	0.552	17010	19.218
1411	2	6d	21	172.5	20	39.64	0.00	0.547	15650	15.950
1411	2	7d	21	173	20	36.7	0.00	0.505	19690	23.443
1411	2	8d	20.5	173.5	20.5	36.87	0.00	0.506	15490	14.609
1411	2	9d	20.5	175.5	20.5	37.88	0.00	0.514	15560	15.320
1411	3	4a	20.5	174.5	20.5	36.75	0.00	0.501	17050	17.744
1411	3	5a	20.5	175.5	20.5	34.21	0.00	0.464	16610	15.766
1411	3	6a	20.5	174	19.5	32.92	0.00	0.473	17130	16.819
1411	3	7a	20.5	174	20.5	33.16	0.00	0.453	16610	15.151
1411	3	8a	20.5	176	20.5	33.42	0.00	0.452	16290	14.856
1411	3	9a	20.5	175	20.5	34.67	0.00	0.471	17030	16.748

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	3	4b	20	175.5	20	37.07	0.00	0.528	17180	19.202
1411	3	5b	20.5	174	20	35.94	0.00	0.504	17110	17.861
1411	3	6b	20	175	20	35.11	0.00	0.502	16670	17.074
1411	3	7b	20	175.5	20	34.39	0.00	0.490	16960	17.360
1411	3	8b	20.5	174.5	20.5	34.29	0.00	0.468	17110	16.673
1411	3	9b	20.5	174	20.5	35.81	0.00	0.490	16580	16.303
1411	3	4c	20	176	20	38.75	0.00	0.550	16960	19.617
1411	3	5c	20	174.5	20	38.32	0.00	0.549	17010	19.348
1411	3	6c	20.5	176	20	34.92	0.00	0.484	15920	15.197
1411	3	7c	20.5	174.5	20	34.5	0.00	0.482	16510	16.010
1411	3	8c	20.5	175	20.5	34.69	0.00	0.472	16160	15.090
1411	3	9c	20.5	176	20.5	40.02	0.00	0.541	14140	13.404
1411	3	4d	20	176	20.5	36.2	0.00	0.502	17080	18.133
1411	3	5d	20.5	176	20.5	34.3	0.00	0.464	15290	13.433
1411	3	6d	20.5	174	19.5	35.11	0.00	0.505	15310	14.329
1411	3	7d	20.5	175.5	20	34	0.00	0.473	17070	16.963
1411	3	8d	20.5	175.5	20.5	35.05	0.00	0.475	16960	16.841
1411	3	9d	20	174.5	20.5	38.45	0.00	0.537	14410	13.592
1411	4	3a	20.5	171.5	20.5	37.89	0.00	0.526	16170	16.172
1411	4	4a	20.5	168.5	20.5	33.47	0.00	0.473	17150	15.788
1411	4	5a	21	169	19.5	32.87	0.00	0.475	17480	16.580
1411	4	6a	20	169	19.5	34.1	0.00	0.517	17560	18.226
1411	4	7a	20	172	19.5	31.55	0.00	0.470	18100	18.234
1411	4	8a	19.5	168	19.5	37.14	0.00	0.581	16980	18.924
1411	4	9a	20	167.5	20.5	31.4	0.00	0.457	16250	13.550
1411	4	10a	20	167.5	20	34.97	0.00	0.522	16920	16.769
1411	4	3b	20	167.5	20.5	31.66	0.00	0.461	16740	14.498
1411	4	4b	19.5	171.5	19.5	34.79	0.00	0.533	17580	19.398
1411	4	5b	20	171.5	20	31.89	0.00	0.465	16200	14.353
1411	4	6b	20.5	170	19.5	32.24	0.00	0.474	16700	15.295
1411	4	7b	20	169	20	32.42	0.00	0.480	17610	16.991
1411	4	8b	20.5	172	20	32.44	0.00	0.460	17140	15.992
1411	4	9b	20	172	20	32.14	0.00	0.467	17340	16.622
1411	4	10b	19.5	172.5	20.5	36.58	0.00	0.530	16920	18.076
1411	4	3c	19.5	170	20.5	36.16	0.00	0.532	18120	20.196
1411	4	4c	20.5	172	20.5	36.48	0.00	0.505	15190	13.780
1411	4	5c	20.5	173	20.5	35.52	0.00	0.489	13520	10.691
1411	4	6c	20	174	19.5	34.29	0.00	0.505	13490	11.136
1411	4	7c	21	169.5	20	34.46	0.00	0.484	16700	15.514
1411	4	8c	20.5	175	20.5	34.31	0.00	0.467	15150	13.117
1411	4	9c	20	173	20.5	35.03	0.00	0.494	17510	18.127
1411	4	10c	20.5	172.5	20	38.98	0.00	0.551	17600	20.320
1411	4	3d	20.5	174	20.5	38.5	0.00	0.527	17620	19.796
1411	4	4d	21	174	20.5	33.65	0.00	0.449	16970	15.667
1411	4	5d	20.5	172	20.5	34.01	0.00	0.471	17120	16.319
1411	4	6d	21.5	174.5	19.5	35.59	0.00	0.486	15620	14.457
1411	4	7d	20.5	174	19.5	33.32	0.00	0.479	17430	17.625
1411	4	8d	19.5	172.5	20.5	32.23	0.00	0.467	17540	17.115
1411	4	9d	19.5	173	20	34.7	0.00	0.514	16890	17.564

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	10d	19.5	174.5	20.5	40.66	0.00	0.583	17310	21.273
1411	2	4a	20	154.5	20	33.89	0.00	0.548	19340	19.585
1411	2	5a	20	155	20	33.79	0.00	0.545	18730	18.374
1411	2	6a	20.5	155.5	20	33.03	0.00	0.518	14810	10.991
1411	2	7a	21	154.5	20	32.87	0.00	0.507	17610	14.999
1411	2	8a	20	154	20.5	30.52	0.00	0.483	18910	16.397
1411	2	9a	20.5	152	20.5	32.85	0.00	0.514	18170	15.691
1411	2	4b	20.5	151	20	34.05	0.00	0.550	18450	17.075
1411	2	5b	20.5	151.5	20	34.73	0.00	0.559	20120	20.780
1411	2	6b	20.5	151	19.5	32.67	0.00	0.541	23150	26.455
1411	2	7b	20.5	150.5	20	30.66	0.00	0.497	19210	16.613
1411	2	8b	20	151.5	20.5	31.41	0.00	0.506	17260	13.831
1411	2	9b	20.5	151.5	22	34.77	0.00	0.509	19460	17.692
1411	2	4c	19.5	151.5	20.5	36.53	0.00	0.603	19920	21.974
1411	2	5c	19.5	150	20.5	34.29	0.00	0.572	23750	29.031
1411	2	6c	20.5	151	20	32.65	0.00	0.527	19470	18.233
1411	2	7c	20	151.5	19.5	31.81	0.00	0.538	19230	18.278
1411	2	8c	20.5	151	20.5	31.3	0.00	0.493	18500	15.396
1411	2	9c	20	150.5	20	35.51	0.00	0.590	22320	26.624
1411	2	4d	20	150.5	20.5	32.8	0.00	0.532	18590	16.644
1411	2	5d	20.5	151	20	34.33	0.00	0.555	19600	19.428
1411	2	6d	21	150.5	20	34.81	0.00	0.551	17990	16.148
1411	2	7d	21	151.5	20	31.98	0.00	0.503	17340	13.874
1411	2	8d	20.5	152	20.5	32.19	0.00	0.504	17720	14.623
1411	2	9d	20.5	153.5	20.5	33.05	0.00	0.512	14950	10.792
1411	3	4a	20.5	152.5	20.5	32.24	0.00	0.503	19430	17.667
1411	3	5a	20.5	154	20.5	30.06	0.00	0.464	19020	15.940
1411	3	6a	20.5	152	19.5	28.88	0.00	0.475	17360	13.238
1411	3	7a	20.5	152	20.5	29	0.00	0.454	18970	15.098
1411	3	8a	20.5	154	20.5	29.45	0.00	0.455	18240	14.362
1411	3	9a	20.5	154	20.5	30.53	0.00	0.472	19270	16.617
1411	3	4b	20	153.5	20	32.58	0.00	0.531	19770	19.547
1411	3	5b	20.5	153	20	31.58	0.00	0.503	23150	25.263
1411	3	6b	20	153	20	30.52	0.00	0.499	19000	16.857
1411	3	7b	20	154	20	30.32	0.00	0.492	22880	24.443
1411	3	8b	20.5	153	20.5	30.18	0.00	0.469	19490	16.695
1411	3	9b	20.5	153	20.5	31.56	0.00	0.491	18720	16.106
1411	3	4c	20	155	20	34.12	0.00	0.550	23870	30.133
1411	3	5c	20	153.5	20	33.99	0.00	0.554	18050	16.999
1411	3	6c	20.5	155	20	30.82	0.00	0.485	18380	15.745
1411	3	7c	20.5	154	20	30.36	0.00	0.481	19730	17.756
1411	3	8c	20.5	154	20.5	30.51	0.00	0.471	15870	11.263
1411	3	9c	20.5	155	20.5	35.53	0.00	0.545	19310	19.545
1411	3	4d	20	155.5	20.5	32	0.00	0.502	18010	15.746
1411	3	5d	20.5	155	20.5	30.3	0.00	0.465	17360	13.472
1411	3	6d	20.5	153	19.5	31.15	0.00	0.509	21190	21.413
1411	3	7d	20.5	154.5	20	29.95	0.00	0.473	17010	13.062
1411	3	8d	20.5	154	20.5	30.85	0.00	0.477	16470	12.266
1411	3	9d	20	153	20.5	33.78	0.00	0.538	16370	13.512

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	3a	20.5	150.5	20.5	33.36	0.00	0.527	20060	19.230
1411	4	4a	20.5	148	20.5	29.38	0.00	0.472	18370	13.966
1411	4	5a	21	148	19.5	28.86	0.00	0.476	14470	8.736
1411	4	6a	20	149	19.5	29.86	0.00	0.514	19620	17.566
1411	4	7a	20	147	19.5	27.62	0.00	0.482	18830	14.765
1411	4	8a	19.5	152	19.5	32.89	0.00	0.569	20440	21.972
1411	4	9a	20	146	20.5	27.44	0.00	0.458	18630	13.566
1411	4	10a	20	146	20	30.55	0.00	0.523	19370	16.735
1411	4	3b	20	146	20.5	27.6	0.00	0.461	19440	14.857
1411	4	4b	19.5	150.5	19.5	30.48	0.00	0.533	20030	19.360
1411	4	5b	20	150.5	20	27.97	0.00	0.465	18240	14.005
1411	4	6b	20.5	149	19.5	28.15	0.00	0.473	15700	10.345
1411	4	7b	20	148	20	28.36	0.00	0.479	20490	17.622
1411	4	8b	20.5	151	20	28.45	0.00	0.460	19420	15.806
1411	4	9b	20	151	20	28.19	0.00	0.467	19520	16.219
1411	4	10b	19.5	151.5	20.5	32.11	0.00	0.530	19110	17.776
1411	4	3c	19.5	150	20.5	31.73	0.00	0.529	20590	20.190
1411	4	4c	20.5	151.5	20.5	32.07	0.00	0.504	18050	15.067
1411	4	5c	20.5	152	20.5	31.26	0.00	0.489	15450	10.795
1411	4	6c	20	153	19.5	30.04	0.00	0.503	12740	7.651
1411	4	7c	21	153.5	20	30.27	0.00	0.470	19041	16.044
1411	4	8c	20.5	154.5	20.5	30.43	0.00	0.469	19780	17.508
1411	4	9c	20	152.5	20.5	30.81	0.00	0.493	20060	18.446
1411	4	10c	20.5	152	20	34.27	0.00	0.550	20040	20.409
1411	4	3d	20.5	153	20.5	33.84	0.00	0.526	20620	20.953
1411	4	4d	21	153	20.5	29.65	0.00	0.450	19290	15.684
1411	4	5d	20.5	152.5	20.5	30.15	0.00	0.470	11780	6.073
1411	4	6d	21.5	154	19.5	31.69	0.00	0.491	17560	14.358
1411	4	7d	20.5	153	19.5	29.27	0.00	0.479	19840	17.639
1411	4	8d	19.5	152	20.5	28.31	0.00	0.466	19880	17.017
1411	4	9d	19.5	152.5	20	30.45	0.00	0.512	19000	17.193
1411	4	10d	19.5	153	20.5	35.79	0.00	0.585	19600	21.049
1411	2	4a	20	134.5	20	29.61	0.00	0.550	26670	28.327
1411	2	5a	20	136.5	20	29.89	0.00	0.547	26180	27.964
1411	2	6a	20.5	136	20	28.99	0.00	0.520	20860	16.738
1411	2	7a	21	135	20	28.91	0.00	0.510	12990	6.272
1411	2	8a	20	135	20.5	26.82	0.00	0.485	21970	17.050
1411	2	9a	20.5	133.5	20.5	28.96	0.00	0.516	16920	10.535
1411	2	4b	20.5	132	20	29.7	0.00	0.549	22790	19.865
1411	2	5b	20.5	132	20	30.31	0.00	0.560	11450	5.117
1411	2	6b	20.5	132.5	19.5	28.53	0.00	0.539	21960	18.241
1411	2	7b	20.5	132	20	26.92	0.00	0.497	22000	16.779
1411	2	8b	20	132.5	20.5	27.57	0.00	0.508	19590	13.677
1411	2	9b	20.5	133.5	22	30.66	0.00	0.509	22080	17.698
1411	2	4c	19.5	133.5	20.5	32.35	0.00	0.606	11180	5.401
1411	2	5c	19.5	130.5	20.5	29.88	0.00	0.573	13560	7.174
1411	2	6c	20.5	131	20	28.49	0.00	0.530	16700	10.155
1411	2	7c	20	132	19.5	27.72	0.00	0.538	22200	18.496
1411	2	8c	20.5	132.5	20.5	27.57	0.00	0.495	25970	23.450

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	2	9c	20	131.5	20	31.29	0.00	0.595	20580	17.427
1411	2	4d	20	131.5	20.5	28.73	0.00	0.533	19440	13.929
1411	2	5d	20.5	132.5	20	30.19	0.00	0.556	23700	21.921
1411	2	6d	21	131	20	30.67	0.00	0.557	20540	16.143
1411	2	7d	21	132	20	27.96	0.00	0.504	18500	12.030
1411	2	8d	20.5	132.5	20.5	28.13	0.00	0.505	19580	13.601
1411	2	9d	20.5	134	20.5	28.89	0.00	0.513	27620	28.109
1411	3	4a	20.5	133	20.5	28.18	0.00	0.504	22180	17.550
1411	3	5a	20.5	134.5	20.5	26.33	0.00	0.466	21640	15.785
1411	3	6a	20.5	132.5	19.5	25.32	0.00	0.478	18420	11.390
1411	3	7a	20.5	133	20.5	25.42	0.00	0.455	21550	14.944
1411	3	8a	20.5	135	20.5	25.87	0.00	0.456	21060	14.743
1411	3	9a	20.5	135	20.5	26.91	0.00	0.474	22120	16.919
1411	3	4b	20	134.5	20	28.62	0.00	0.532	22300	19.143
1411	3	5b	20.5	133.5	20	27.72	0.00	0.506	21690	16.985
1411	3	6b	20	134	20	26.7	0.00	0.498	21530	16.585
1411	3	7b	20	134.5	20	26.57	0.00	0.494	22200	17.612
1411	3	8b	20.5	133.5	20.5	26.44	0.00	0.471	11590	4.513
1411	3	9b	20.5	133.5	20.5	27.68	0.00	0.493	26460	24.625
1411	3	4c	20	135.5	20	30.04	0.00	0.554	22350	20.333
1411	3	5c	20	134	20	30.05	0.00	0.561	27550	30.563
1411	3	6c	20.5	136	20	27.07	0.00	0.485	18010	11.650
1411	3	7c	20.5	134	20	26.63	0.00	0.485	21190	15.632
1411	3	8c	20.5	135	20.5	26.92	0.00	0.474	22200	17.048
1411	3	9c	20.5	136.5	20.5	31.7	0.00	0.553	17940	13.255
1411	3	4d	20	137.5	20.5	28.4	0.00	0.504	21780	18.072
1411	3	5d	20.5	136.5	20.5	26.82	0.00	0.468	19370	13.074
1411	3	6d	20.5	133.5	19.5	27.56	0.00	0.516	21140	16.453
1411	3	7d	20.5	135	20	26.31	0.00	0.475	30580	32.405
1411	3	8d	20.5	135	20.5	27.14	0.00	0.478	17170	10.281
1411	3	9d	20	134	20.5	29.61	0.00	0.539	17680	12.100
1411	4	3a	20.5	136.5	20.5	29.15	0.00	0.508	24510	22.752
1411	4	4a	20.5	128	20.5	25.57	0.00	0.475	18760	10.964
1411	4	5a	21	129	19.5	25.14	0.00	0.476	10790	3.688
1411	4	6a	20	129	19.5	25.99	0.00	0.517	22770	17.829
1411	4	7a	20	128	19.5	24.11	0.00	0.483	23330	17.228
1411	4	8a	19.5	133	19.5	28.91	0.00	0.572	23440	22.223
1411	4	9a	20	126.5	20.5	23.89	0.00	0.461	21480	13.604
1411	4	10a	20	127	20	26.69	0.00	0.525	19880	13.396
1411	4	3b	20	127	20.5	23.96	0.00	0.460	17300	8.885
1411	4	4b	19.5	131	19.5	26.55	0.00	0.533	20930	16.027
1411	4	5b	20	131.5	20	24.43	0.00	0.464	20900	14.033
1411	4	6b	20.5	130	19.5	24.53	0.00	0.472	22840	16.646
1411	4	7b	20	130	20	24.93	0.00	0.479	29240	27.709
1411	4	8b	20.5	131.5	20	24.9	0.00	0.462	17310	9.572
1411	4	9b	20	132	20	24.68	0.00	0.467	11890	4.606
1411	4	10b	19.5	132.5	20.5	28.11	0.00	0.531	21930	17.924
1411	4	3c	19.5	130	20.5	27.71	0.00	0.533	16150	9.401
1411	4	4c	20.5	132	20.5	28.11	0.00	0.507	20580	14.958

Results obtained from LINE 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	M %	Density g/cm^3	*fL* Hz	DEML GPa
1411	4	5c	20.5	132.5	20.5	27.47	0.00	0.493	19400	13.039
1411	4	6c	20	133.5	19.5	26.45	0.00	0.508	11060	4.430
1411	4	7c	21	134.5	20	26.56	0.00	0.470	17530	10.455
1411	4	8c	20.5	135.5	20.5	26.87	0.00	0.472	18990	12.497
1411	4	9c	20	133.5	20.5	27	0.00	0.493	18040	11.444
1411	4	10c	20.5	133.5	20	30.03	0.00	0.549	19430	14.766
1411	4	3d	20.5	134	20.5	29.69	0.00	0.527	22940	19.928
1411	4	4d	21	134	20.5	26.1	0.00	0.452	15960	8.277
1411	4	5d	20.5	134	20.5	26.57	0.00	0.472	16460	9.181
1411	4	6d	21.5	135	19.5	28.07	0.00	0.496	16270	9.571
1411	4	7d	20.5	135	19.5	25.85	0.00	0.479	23950	20.030
1411	4	8d	19.5	133	20.5	24.87	0.00	0.468	20470	13.869
1411	4	9d	19.5	133	20	26.63	0.00	0.513	23088	19.364
1411	4	10d	19.5	134	20.5	31.34	0.00	0.585	11180	5.252

Appendix III

Results from Line 2

Result obtained from LINE 2 STEP 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	f_b Hz	f_l Hz	DEM_b Gpa	DEM_L Gpa
1311	2	1a	18	259	18.5	45.24	45.24	0.00	0.5245	1602	11010	17.687	17.061
1311	2	2a	19	259.5	18	41.49	41.49	0.00	0.4675	1597	10700	14.168	14.417
1311	2	3a	19.5	259	18	42.81	42.81	0.00	0.4709	1683	10880	14.932	14.957
1311	2	4a	19	259.5	18	43.89	43.89	0.00	0.4945	1633	10950	15.671	15.972
1311	2	5a	19	259.5	18.5	46.32	46.32	0.00	0.5078	1654	11290	16.509	17.435
1311	2	2b	18.5	260	18.5	42.41	42.41	0.00	0.4766	1660	11200	16.589	16.166
1311	2	3b	19	260.5	17.5	40.56	40.56	0.00	0.4683	1630	10920	15.014	15.157
1311	2	4b	18	261	17.5	45.6	45.6	0.00	0.5546	1566	11240	18.429	19.094
1311	2	5b	19.5	259.5	18.5	44.79	44.79	0.00	0.4785	1679	11040	15.216	15.708
1311	2	6b	18.5	259.5	19	45.19	45.19	0.00	0.4954	1583	11100	15.561	16.442
1311	2	1c	18	261	19	49.47	49.47	0.00	0.5542	1588	11000	18.936	18.273
1311	2	2c	19.5	260	19.5	45.09	45.09	0.00	0.4561	1728	11110	15.482	15.222
1311	2	3c	20	259.5	19	46.41	46.41	0.00	0.4706	1669	10350	14.060	13.580
1311	3	1a	19	257.5	19	42.6	42.6	0.00	0.4583	1638	11190	14.166	15.219
1311	3	2a	19.5	260	18.5	45.59	45.59	0.00	0.4861	1493	9990	12.318	13.117
1311	3	3a	19	260	18	42.23	42.23	0.00	0.4749	1620	10810	14.926	15.007
1311	3	4a	18.5	259.5	19	43.88	43.88	0.00	0.4811	1624	10830	15.903	15.198
1311	3	5a	17.5	257	18.5	43.16	43.16	0.00	0.5187	1594	11160	17.761	17.068
1311	3	1b	18.5	260.5	18.5	40.88	40.88	0.00	0.4585	1579	11820	14.551	17.389
1311	3	2b	18	260	18	42.72	42.72	0.00	0.5071	1644	11630	18.288	18.547
1311	3	3b	18	260.5	18	40.51	40.51	0.00	0.4800	1263	9900	10.294	12.769
1311	3	4b	18.5	260.5	19	43.18	43.18	0.00	0.4716	1605	10950	15.462	15.348
1311	3	5b	18	260.5	19	47.87	47.87	0.00	0.5373	1549	11020	17.334	17.712
1311	3	1c	19	259.5	18.5	44.49	44.49	0.00	0.4878	1612	10970	15.061	15.811
1311	3	2c	18.5	259.5	19	38.34	38.34	0.00	0.4203	1405	9600	10.400	10.434
1311	3	3c	18.5	260	18	41.61	41.61	0.00	0.4806	1500	10370	13.659	13.975
1311	3	4c	19	259	18	41.8	41.8	0.00	0.4719	1551	10360	13.386	13.590
1311	3	5c	18.5	261	18.5	45.32	45.32	0.00	0.5073	1594	10920	16.535	16.485
1311	4	1a	18	260.5	17.5	45.49	45.49	0.00	0.5544	1536	10620	17.586	16.972
1311	4	2a	17.5	261	17	44.57	44.57	0.00	0.5740	1634	11980	21.968	22.448
1311	4	3a	18	260.5	18	46.22	46.22	0.00	0.5476	1567	11000	18.080	17.986
1311	4	1b	18.5	261.5	17.5	46.07	46.07	0.00	0.5442	1538	10720	16.637	17.105
1311	4	2b	17.5	260.5	17.5	47.59	47.59	0.00	0.5965	1602	11590	21.777	21.751
1311	4	3b	19	261	17	45.8	45.8	0.00	0.5433	1585	11040	16.597	18.043
1311	4	1c	18	258	17.5	43.76	43.76	0.00	0.5385	1695	12090	20.013	20.956
1311	4	2c	17	258.5	19	47.42	47.42	0.00	0.5679	1589	11630	20.960	20.532
1311	4	3c	18	258.5	17	46.53	46.53	0.00	0.5882	1623	11560	20.201	21.011
1311	5	1a	18	259	18	44.46	44.46	0.00	0.5298	1511	11110	15.893	17.547
1311	5	2a	18.5	259	18	43.01	43.01	0.00	0.4987	1606	10760	15.998	15.492
1311	5	3a	18.5	260.5	18	42.16	42.16	0.00	0.4860	1629	11560	16.416	17.629
1311	5	4a	18	260.5	17.5	41.7	41.7	0.00	0.5082	1579	11350	17.036	17.770
1311	5	5a	17.5	260	18	46.73	46.73	0.00	0.5706	1593	11530	20.439	20.511
1311	5	1b	18.5	260	18	44.99	44.99	0.00	0.5196	1601	10930	16.824	16.786
1311	5	2b	18.5	261.5	17.5	42.49	42.49	0.00	0.5019	1550	10320	15.585	14.621
1311	5	3b	17.5	261.5	17	40.04	40.04	0.00	0.5147	1547	11700	17.792	19.271
1311	5	4b	18	261.5	18.5	42.8	42.8	0.00	0.4915	1544	10830	15.998	15.768
1311	5	5b	17.5	261.5	18	44.89	44.89	0.00	0.5450	1593	11670	19.976	20.301
1311	5	1c	18	261	18	47.1	47.1	0.00	0.5570	1554	10840	18.224	17.833
1311	5	2c	18	261	18	41.45	41.45	0.00	0.4902	1531	11170	15.567	16.664
1311	5	3c	17.5	262	17.5	39.67	39.67	0.00	0.4944	1556	11550	17.423	18.110
1311	5	4c	18	261.5	18.5	43.95	43.95	0.00	0.5047	1617	11670	18.018	18.801

Result obtained from LINE 2 STEP 1

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	f_b Hz	f_l Hz	DEM_b Gpa	DEM_L Gpa
1311	5	5c	17.5	260.5	18	43.54	43.54	0.00	0.5306	1646	12000	20.449	20.740
1311	6	1a	18	258	18	40.28	40.28	0.00	0.4819	1611	11580	16.179	17.204
1311	6	2a	18	259.5	17.5	35.57	35.57	0.00	0.4351	1418	9800	11.585	11.257
1311	6	3a	17.5	260	18	38.15	38.15	0.00	0.4658	1501	11020	14.814	15.296
1311	6	4a	17	260	17.5	37.37	37.37	0.00	0.4831	1517	11080	16.631	16.038
1311	6	5a	18	261.5	18	42.72	42.72	0.00	0.5042	1555	11100	16.646	16.993
1311	6	1b	16.5	261	17.5	36.27	36.27	0.00	0.4813	1449	11290	16.293	16.715
1311	6	2b	16.5	259.5	17.5	35.32	35.32	0.00	0.4714	1472	11480	16.093	16.733
1311	6	3b	16.5	259.5	17.5	34.82	34.82	0.00	0.4647	1423	11030	14.827	15.228
1311	6	4b	17.5	261	18	38.49	38.49	0.00	0.4682	1511	11090	15.322	15.689
1311	6	5b	17.5	261	16.5	40.17	40.17	0.00	0.5330	1577	11510	19.001	19.241
1311	6	1c	17.5	258.5	17.5	39.07	39.07	0.00	0.4935	1471	10780	14.730	15.329
1311	6	2c	18	260.5	18.5	37.69	37.69	0.00	0.4345	1431	10070	11.963	11.959
1311	6	3c	17	259	18	36.12	36.12	0.00	0.4557	1441	11000	13.939	14.797
1311	6	4c	17.5	260.5	17.5	39.57	39.57	0.00	0.4960	1536	11160	16.646	16.768
1311	7	1a	19.5	260.5	19.5	42.83	42.83	0.00	0.4324	1559	10100	12.040	11.973
1311	7	2a	19.5	261	19	39.62	39.62	0.00	0.4097	1550	10330	11.364	11.913
1311	7	3a	19.5	261	19	37.96	37.96	0.00	0.3926	1501	10210	10.210	11.150
1311	7	4a	19.5	261	18.5	40.81	40.81	0.00	0.4334	1330	8752	8.851	9.046
1311	7	5a	19	261.5	19	38.32	38.32	0.00	0.4059	1573	10630	12.308	12.546
1311	7	6a	19.5	262	19	41.54	41.54	0.00	0.4279	1597	10740	12.794	13.553
1311	7	1b	18	259.5	19.5	38.74	38.74	0.00	0.4253	1437	10360	11.629	12.296
1311	7	2b	19	260.5	19	37.83	37.83	0.00	0.4023	1492	9700	10.806	10.274
1311	7	3b	19	261	18.5	36.08	36.08	0.00	0.3933	1384	9300	9.160	9.268
1311	7	4b	19.5	261.5	18	39.25	39.25	0.00	0.4276	1331	8571	8.813	8.593
1311	7	5b	19	260	19	37.81	37.81	0.00	0.4028	1544	10820	11.500	12.752
1311	7	6b	19	262	19	39.74	39.74	0.00	0.4202	1522	10560	12.018	12.865
1311	7	1c	19	260.5	20	40.9	40.9	0.00	0.4132	1533	10270	11.717	11.829
1311	7	2c	19	260	19.5	38.91	38.91	0.00	0.4039	1473	10090	10.495	11.120
1311	7	3c	19.5	261	20	41.38	41.38	0.00	0.4065	1326	9000	8.252	8.972
1311	7	4c	19	261.5	19	42.29	42.29	0.00	0.4480	1274	8853	8.910	9.604
1311	7	5c	19.5	262	20	39.42	39.42	0.00	0.3858	1446	10030	9.456	10.657
1311	7	6c	18	261.5	19.5	41.07	41.07	0.00	0.4475	1457	10510	12.969	13.519

Results obtained from LINE 2 STEP 2

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	*fl* Hz	DEMb Gpa	DEML Gpa
1311	7	5a	19	261.5	19	38.32	41.53	7.73	0.4399	1555	10480	13.0351	13.2163
1311	7	6c	18	261.5	19.5	41.07	44.58	7.87	0.4857	1468	10390	14.29046	14.3415
1311	7	5b	19	260	19	37.81	41.11	8.03	0.4380	1524	10780	12.18188	13.7629
1311	7	6b	19	262	19	39.74	43.23	8.07	0.4571	1526	10520	13.14241	13.889
1311	7	5c	19.5	262	20	39.42	42.91	8.13	0.4199	1457	9790	10.45054	11.0515
1311	7	2c	19	260	19.5	38.91	42.36	8.14	0.4397	1430	9470	10.76822	10.6635
1311	7	2a	19.5	261	19	39.62	43.14	8.16	0.4461	1518	10250	11.86804	12.7714
1311	7	4a	19.5	261	18.5	40.81	44.44	8.17	0.4720	1322	9166	9.523006	10.8051
1311	7	6a	19.5	262	19	41.54	45.27	8.24	0.4664	1554	10510	13.20232	14.1445
1311	7	1b	18	259.5	19.5	38.74	42.22	8.24	0.4635	1403	10410	12.08049	13.5304
1311	7	3a	19.5	261	19	37.96	41.38	8.26	0.4279	1479	9730	10.80643	11.039
1311	7	2b	19	260.5	19	37.83	41.24	8.27	0.4385	1434	9420	10.8822	10.5628
1311	7	4c	19	261.5	19	42.29	46.11	8.28	0.4884	1244	8805	9.262489	10.3581
1311	7	3b	19	261	18.5	36.08	39.34	8.29	0.4288	1380	9070	9.930535	9.61223
1311	7	1c	19	260.5	20	40.9	44.6	8.30	0.4506	1486	10350	12.00594	13.1009
1311	7	3c	19.5	261	20	41.38	45.15	8.35	0.4436	1190	8392	7.251544	8.51186
1311	7	1a	19.5	260.5	19.5	42.83	46.75	8.39	0.4720	1576	10810	13.42981	14.9703
1311	3	2c	19.5	260	19.5	38.34	42.44	9.66	0.4293	1378	9240	9.267	9.91022
1311	3	3b	20	261	20	40.51	44.88	9.74	0.4299	1458	10670	10.029	13.3359
1311	3	1c	20	260	20	44.49	49.3	9.76	0.4740	1316	9700	8.873	12.0605
1311	3	3c	19.5	261	19.5	41.61	46.12	9.78	0.4647	1450	10020	11.280	12.7132
1311	3	4c	20	259.5	19.5	41.8	46.36	9.84	0.4581	1475	10050	10.688	12.4626
1311	3	4a	20.5	260	20	43.88	48.67	9.84	0.4566	1750	11020	14.383	14.9925
1311	3	4b	19.5	261	20.5	43.18	47.9	9.85	0.4591	1610	10870	13.739	14.7811
1311	3	1b	20	261	20	40.88	45.35	9.86	0.4344	1527	10020	11.116	11.8837
1311	3	1a	18	257	21	42.6	47.28	9.90	0.4867	1589	11300	15.652	16.4186
1311	3	2b	19.5	260.5	19	42.72	47.43	9.93	0.4914	1592	10320	14.269	14.2067
1311	3	3a	20	260	20	42.23	46.9	9.96	0.4510	1567	10480	11.967	13.3927
1311	2	3b	20	261.5	19	40.56	45.05	9.97	0.4534	1560	9649	12.201	11.5454
1311	3	5a	19.5	257	20.5	43.16	47.97	10.03	0.4669	1548	10060	12.144	12.4845
1311	2	2c	20.5	260.5	20.5	45.09	50.13	10.05	0.4579	1632	10120	12.643	12.7297
1311	2	5b	20	259.5	20	44.79	49.8	10.06	0.4798	1437	9080	10.625	10.6546
1311	2	3c	20.5	260.5	20.5	46.41	51.62	10.09	0.4715	1602	10040	12.544	12.9017
1311	2	3a	19.5	259	20	42.81	47.63	10.12	0.4715	1625	10630	13.939	14.2969
1311	2	2b	19.5	261	19.5	42.41	47.19	10.13	0.4755	1569	11070	13.514	15.8773
1311	2	6b	19	260.5	20	45.19	50.29	10.14	0.5080	1660	10750	16.894	15.9361
1311	2	4a	19.5	260.5	19.5	43.89	48.85	10.15	0.4932	1588	10530	14.248	14.8429
1311	2	4c	20.5	260.5	21	46.56	51.84	10.19	0.4623	1624	10560	12.638	13.9922
1311	2	5a	19.5	260.5	19.5	46.32	51.58	10.20	0.5207	1465	10480	12.804	15.524
1311	2	2a	20	260	20	41.49	46.21	10.21	0.4443	1588	10410	12.110	13.02
1311	3	5b	20	261	20	47.87	53.32	10.22	0.5107	1518	9950	12.916	13.7777
1311	4	1b	19	262	19.5	46.07	51.34	10.26	0.5289	1491	10140	14.518	14.9315
1311	4	1a	18.5	261	19.5	45.49	50.71	10.29	0.5386	1529	10320	16.150	15.6296
1311	4	1c	19	258	20	43.76	48.79	10.31	0.4977	1595	10760	14.700	15.3409
1311	4	3b	19.5	261	19	45.8	51.07	10.32	0.5281	1547	10290	14.592	15.2373
1311	2	4b	20.5	260.5	21	45.6	50.85	10.32	0.4534	1551	10090	11.307	12.5305
1311	4	2a	19.5	261	19.5	44.57	49.71	10.34	0.5009	1560	10660	14.072	15.5092
1311	4	3c	19.5	259	19	46.53	51.91	10.36	0.5410	1556	10540	14.662	16.1252
1311	2	5c	20.5	261	21	49.32	55.07	10.44	0.4901	1546	10190	12.237	13.8673
1311	4	3a	19.5	261	19.5	46.22	51.61	10.44	0.5200	1538	10070	14.201	14.3689

Results obtained from LINE 2 STEP 2

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	*fl* Hz	DEMb Gpa	DEML Gpa
1311	4	2c	19	259	20	47.42	52.98	10.49	0.5383	1568	10860	15.606	17.0352
1311	4	2b	19.5	261	19.5	47.59	53.18	10.51	0.5358	1545	10570	14.767	16.3128
1311	2	1c	20.5	261.5	19.5	49.47	55.3	10.54	0.5290	1569	9660	13.708	13.5028
1311	2	1a	19.5	259.5	20.5	45.24	50.65	10.68	0.4883	1571	10760	13.595	15.2269
1311	3	2a	21	261.5	20.5	45.59	51.06	10.71	0.4536	1543	9120	10.832	10.3188
1311	3	5c	20.5	261	19.5	45.32	50.87	10.91	0.4876	1570	10250	12.554	13.9579

Results obtained from LINE 2 STEP 3

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	f_b Hz	f_l Hz	DEMb Gpa	DEML Gpa
1311	3	4c	20	259.5	19.5	41.8	57.56	27.38	0.5687	1378	8250	11.582	10.427
1311	7	3c	19.5	261	20	41.38	57.34	27.83	0.5633	1119	7100	8.143	7.738
1311	6	2c	19	261.5	19	37.69	52.31	27.95	0.5541	1223	8100	10.156	9.944
1311	3	1c	20	260	20	44.49	61.75	27.95	0.5938	1182	7650	8.965	9.396
1311	7	2b	19	260.5	19	37.83	52.51	27.96	0.5584	1236	8200	10.294	10.191
1311	6	4c	19.5	261	18	39.57	54.95	27.99	0.5998	1340	9100	12.434	13.535
1311	7	2a	19.5	261	19	39.62	55.08	28.07	0.5696	1325	9050	11.545	12.712
1311	7	5b	19	260	19	37.81	52.61	28.13	0.5605	1278	8150	10.963	10.067
1311	3	2a	21	261.5	20.5	45.59	63.45	28.15	0.5636	1302	8150	9.584	10.240
1311	7	6c	18	261.5	19.5	41.07	57.22	28.22	0.6234	1305	9150	14.495	14.276
1311	3	3b	20	261	20	40.51	56.52	28.33	0.5414	1319	8140	10.337	9.774
1311	5	3c	19.5	262.5	19.5	39.67	55.4	28.39	0.5550	1219	8050	9.742	9.913
1311	7	5a	19	261.5	19	38.32	53.55	28.44	0.5673	1296	8140	11.675	10.281
1311	7	3b	19	261	18.5	36.08	50.42	28.44	0.5496	1175	8210	9.227	10.094
1311	3	2b	19.5	260.5	19	42.72	59.74	28.49	0.6190	1386	9030	13.622	13.700
1311	3	1b	20	261	20	40.88	57.17	28.49	0.5476	1374	9010	11.346	12.113
1311	3	2c	19.5	260	19.5	38.34	53.62	28.50	0.5424	1250	8130	9.634	9.693
1311	3	3a	20	260	20	42.23	59.08	28.52	0.5681	1384	9030	11.760	12.525
1311	6	4a	18	260.5	19	37.37	52.33	28.59	0.5874	1306	9340	13.470	13.909
1311	5	3b	20	262	18	40.04	56.07	28.59	0.5945	1337	8540	11.842	11.904
1311	7	2c	19	260	19.5	38.91	54.56	28.68	0.5664	1225	8640	10.178	11.433
1311	6	4b	19.5	261.5	19	38.49	53.99	28.71	0.5573	1235	8240	9.888	10.349
1311	7	5c	19.5	262	20	39.42	55.31	28.73	0.5413	1256	8110	10.010	9.776
1311	6	2a	19	260	19	35.57	49.91	28.73	0.5317	1268	8220	10.238	9.715
1311	2	3b	20	261.5	19	40.56	56.93	28.75	0.5729	1378	8430	12.031	11.136
1311	6	2b	17	261	19	35.32	49.68	28.90	0.5893	1150	8430	11.838	11.411
1311	6	3c	19.5	259.5	18.5	36.12	50.98	29.15	0.5446	1269	8230	9.894	9.936
1311	2	3c	20.5	260.5	20.5	46.41	65.54	29.19	0.5987	1363	8220	11.529	10.980
1311	7	3a	19.5	261	19	37.96	53.61	29.19	0.5544	1249	8310	9.984	10.432
1311	6	3b	18	260.5	18.5	34.82	49.2	29.23	0.5672	1224	8750	11.425	11.787
1311	3	3c	19.5	261	19.5	41.61	58.81	29.25	0.5926	1224	8660	10.249	12.109
1311	5	3a	19.5	261	19.5	42.16	59.61	29.27	0.6006	1340	8880	12.451	12.906
1311	7	6b	19	262	19	39.74	56.19	29.28	0.5941	1270	8810	11.832	12.661
1311	6	1b	18	261.5	18	36.27	51.39	29.42	0.6065	1303	9100	14.060	13.739
1311	5	2c	19.5	262	19.5	41.45	58.83	29.54	0.5905	1355	9090	12.710	13.397
1311	6	3a	19.5	261	19	38.15	54.21	29.63	0.5606	1289	8820	10.753	11.883
1311	6	1a	19.5	258.5	19.5	40.28	57.44	29.87	0.5844	1339	8150	11.639	10.375
1311	5	2a	19	260	19.5	43.01	61.34	29.88	0.6368	1294	8900	12.768	13.639
1311	5	2b	19	261.5	19.5	42.49	60.6	29.88	0.6255	1286	8850	12.676	13.400
1311	2	3a	19.5	259	20	42.81	61.71	30.63	0.6109	1427	8980	13.927	13.219
1311	7	4a	19.5	261	18.5	40.81	58.91	30.72	0.6257	1127	7610	9.174	9.873
1311	7	4c	19	261.5	19	42.29	61.06	30.74	0.6468	1062	7840	8.939	10.875
1311	3	1a	18	257	21	42.6	61.52	30.75	0.6333	1388	9230	15.540	14.253
1311	7	4b	19.5	261.5	18	39.25	56.91	31.03	0.6200	1130	7950	9.210	10.719
1311	7	6a	19.5	262	19	41.54	60.45	31.28	0.6227	1312	8230	12.566	11.582
1311	6	1c	19	259.5	18	39.07	57.73	32.32	0.6505	1266	8330	12.389	12.158
1311	7	1c	19	260.5	20	40.9	61.03	32.98	0.616527	1212	8150	10.92879	11.116
1311	2	4a	19.5	260.5	19.5	43.89	65.99	33.49	0.6662	1383	9210	14.598	15.339

Appendix IV

Results from Line 3

Results obtained from LINE 3A

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	f_b Hz	DEM_b GPa	SEM_L Gpa
1311	1	4b	19.5	259	20	46.8	116.88	59.96	1.1571	1366	24.171	20.200
1311	1	3c	19	260.5	20	45.38	111.22	59.20	1.1235	1287	22.458	11.290
1311	1	3c	18	260	17	45.38	45.38	0.00	0.5704	1610	19.727	15.283
1311	2	1a	19.5	259.5	20.5	45.24	104.33	56.64	1.0057	1368	21.234	14.779
1311	2	2a	20	260	20	41.49	63.31	34.47	0.6088	1369	12.330	9.258
1311	2	3a	19.5	259	20	42.81	61.71	30.63	0.6109	1427	13.927	10.382
1311	2	4a	19.5	260.5	19.5	43.89	65.99	33.49	0.6662	1383	14.598	11.149
1311	2	5a	19.5	260.5	19.5	46.32	104.17	55.53	1.0516	1248	18.765	11.081
1311	2	2b	19.5	261	19.5	42.41	66.15	35.89	0.6665	1361	14.253	10.466
1311	2	3b	20	261.5	19	40.56	56.93	28.75	0.5729	1378	12.031	9.091
1311	2	4b	20.5	260.5	21	45.6	106.65	57.24	0.9510	1258	15.601	10.785
1311	2	5b	20	259.5	20	44.79	72.24	38.00	0.6960	1341	13.422	9.066
1311	2	6b	19	260.5	20	45.19	74.53	39.37	0.7529	1430	15.601	10.785
1311	2	1c	20.5	261.5	19.5	49.47	119.94	58.75	1.1474	1291	20.129	13.394
1311	2	2c	20.5	260.5	20.5	45.09	77.44	41.77	0.7074	1365	13.662	13.692
1311	2	3c	20.5	260.5	20.5	46.41	65.54	29.19	0.5987	1363	11.529	9.550
1311	2	4c	20.5	260.5	21	46.56	72.43	35.72	0.6459	1346	12.129	9.549
1311	2	5c	20.5	261	21	49.32	122.53	59.75	1.0905	1268	18.315	13.553
1311	2	1a	19.5	259.5	20.5	45.24	50.65	10.68	0.4883	1571	13.595	11.229
1311	2	2a	20	260	20	41.49	46.21	10.21	0.4443	1588	12.110	9.861
1311	2	3a	19.5	259	20	42.81	47.63	10.12	0.4715	1625	13.939	11.069
1311	2	4a	19.5	260.5	19.5	43.89	48.85	10.15	0.4932	1588	14.248	11.902
1311	2	5a	19.5	260.5	19.5	46.32	51.58	10.20	0.5207	1465	12.804	14.621
1311	2	2b	19.5	261	19.5	42.41	47.19	10.13	0.4755	1569	13.514	11.245
1311	2	3b	20	261.5	19	40.56	45.05	9.97	0.4534	1560	12.201	9.004
1311	2	4b	20.5	260.5	21	45.6	50.85	10.32	0.4534	1551	11.307	9.322
1311	2	5b	20	259.5	20	44.79	49.8	10.06	0.4798	1437	10.625	10.101
1311	2	6b	19	260.5	20	45.19	50.29	10.14	0.5080	1660	16.894	11.167
1311	2	1c	20.5	261.5	19.5	49.47	55.3	10.54	0.5290	1569	13.708	10.774
1311	2	2c	20.5	260.5	20.5	45.09	50.13	10.05	0.4579	1632	12.643	10.318
1311	2	3c	20.5	260.5	20.5	46.41	51.62	10.09	0.4715	1602	12.544	10.063
1311	2	4c	20.5	260.5	21	46.56	51.84	10.19	0.4623	1624	12.638	11.208
1311	2	5c	20.5	261	21	49.32	55.07	10.44	0.4901	1546	12.237	11.116
1311	2	1a	19.5	259.5	20.5	45.24	53.51	15.46	0.5158	1534	13.694	10.582
1311	2	2a	20	260	20	41.49	48.27	14.05	0.4641	1473	10.884	9.734
1311	2	3a	19.5	259	20	42.81	49.73	13.92	0.4923	1595	14.022	9.107
1311	2	4a	19.5	260.5	19.5	43.89	51.01	13.96	0.5150	1557	14.302	12.126
1311	2	5a	19.5	260.5	19.5	46.32	54.18	14.51	0.5470	1452	13.211	12.727
1311	2	2b	19.5	261	19.5	42.41	49.24	13.87	0.4961	1529	13.391	10.176
1311	2	3b	20	261.5	19	40.56	46.98	13.67	0.4728	1547	12.513	9.223
1311	2	4b	20.5	260.5	21	45.6	53.18	14.25	0.4742	1534	11.567	10.354
1311	2	5b	20	259.5	20	44.79	51.93	13.75	0.5003	1516	12.331	10.930
1311	2	6b	19	260.5	20	45.19	52.63	14.14	0.5317	1564	15.694	11.678
1311	2	1c	20.5	261.5	19.5	49.47	57.87	14.52	0.5536	1523	13.516	11.167
1311	2	2c	20.5	260.5	20.5	45.09	52.34	13.85	0.4781	1568	12.185	10.185
1311	2	3c	20.5	260.5	20.5	46.41	53.77	13.69	0.4912	1552	12.264	11.042
1311	2	4c	20.5	260.5	21	46.56	54.06	13.87	0.4821	1559	12.145	11.394
1311	2	5c	20.5	261	21	49.32	57.86	14.76	0.5149	1501	12.119	11.069
1311	2	1a	18	259	18.5	45.24	45.24	0.00	0.5245	1602	17.687	15.028

Results obtained from LINE 3A

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*f*b Hz	DEMb GPa	SEML Gpa
1311	2	2a	19	259.5	18	41.49	41.49	0.00	0.4675	1597	14.168	13.902
1311	2	3a	19.5	259	18	42.81	42.81	0.00	0.4709	1683	14.932	14.112
1311	2	4a	19	259.5	18	43.89	43.89	0.00	0.4945	1633	15.671	14.303
1311	2	5a	19	259.5	18.5	46.32	46.32	0.00	0.5078	1654	16.509	14.887
1311	2	2b	18.5	260	18.5	42.41	42.41	0.00	0.4766	1660	16.589	13.242
1311	2	3b	19	260.5	17.5	40.56	40.56	0.00	0.4683	1630	15.014	14.172
1311	2	4b	18	261	17.5	45.6	45.6	0.00	0.5546	1566	18.429	10.908
1311	2	5b	19.5	259.5	18.5	44.79	44.79	0.00	0.4785	1679	15.216	14.080
1311	2	6b	18.5	259.5	19	45.19	45.19	0.00	0.4954	1583	15.561	14.323
1311	2	1c	18	261	19	49.47	49.47	0.00	0.5542	1588	18.936	14.525
1311	2	2c	19.5	260	19.5	45.09	45.09	0.00	0.4561	1728	15.482	13.673
1311	2	3c	20	259.5	19	46.41	46.41	0.00	0.4706	1669	14.060	12.266
1311	2	4c	20	260	19	46.56	46.56	0.00	0.4713	1686	14.478	14.646
1311	2	5c	19.5	260	19.5	49.32	49.32	0.00	0.4989	1669	15.798	14.624
1311	3	1a	18	257	21	42.6	61.52	30.75	0.6333	1388	15.540	16.002
1311	3	2a	21	261.5	20.5	45.59	63.45	28.15	0.5636	1302	9.584	14.032
1311	3	3a	20	260	20	42.23	59.08	28.52	0.5681	1384	11.760	9.485
1311	3	4a	20.5	260	20	43.88	60.12	27.01	0.5640	1390	11.209	9.659
1311	3	5a	19.5	257	20.5	43.16	76.5	43.58	0.7446	1362	14.992	10.066
1311	3	1b	20	261	20	40.88	57.17	28.49	0.5476	1374	11.346	9.290
1311	3	2b	19.5	260.5	19	42.72	59.74	28.49	0.6190	1386	13.622	9.857
1311	3	3b	20	261	20	40.51	56.52	28.33	0.5414	1319	10.337	7.318
1311	3	4b	19.5	261	20.5	43.18	59.07	26.90	0.5662	1390	12.628	10.061
1311	3	5b	20	261	20	47.87	100.04	52.15	0.9582	1194	14.993	10.278
1311	3	1c	20	260	20	44.49	61.75	27.95	0.5938	1182	8.965	4.422
1311	3	2c	19.5	260	19.5	38.34	53.62	28.50	0.5424	1250	9.634	7.593
1311	3	3c	19.5	261	19.5	41.61	58.81	29.25	0.5926	1224	10.249	8.252
1311	3	4c	20	259.5	19.5	41.8	57.56	27.38	0.5687	1378	11.582	8.646
1311	3	5c	20.5	261	19.5	45.32	90.48	49.91	0.8672	1312	15.593	11.266
1311	3	1a	18	257	21	42.6	47.28	9.90	0.4867	1589	15.652	10.850
1311	3	2a	21	261.5	20.5	45.59	51.06	10.71	0.4536	1543	10.832	9.511
1311	3	3a	20	260	20	42.23	46.9	9.96	0.4510	1567	11.967	10.746
1311	3	4a	20.5	260	20	43.88	48.67	9.84	0.4566	1750	14.383	10.850
1311	3	5a	19.5	257	20.5	43.16	47.97	10.03	0.4669	1548	12.144	11.206
1311	3	1b	20	261	20	40.88	45.35	9.86	0.4344	1527	11.116	9.779
1311	3	2b	19.5	260.5	19	42.72	47.43	9.93	0.4914	1592	14.269	11.475
1311	3	3b	20	261	20	40.51	44.88	9.74	0.4299	1458	10.029	8.201
1311	3	4b	19.5	261	20.5	43.18	47.9	9.85	0.4591	1610	13.739	9.881
1311	3	5b	20	261	20	47.87	53.32	10.22	0.5107	1518	12.916	12.163
1311	3	1c	20	260	20	44.49	49.3	9.76	0.4740	1316	8.873	7.383
1311	3	2c	19.5	260	19.5	38.34	42.44	9.66	0.4293	1378	9.267	8.031
1311	3	3c	19.5	261	19.5	41.61	46.12	9.78	0.4647	1450	11.280	9.597
1311	3	4c	20	259.5	19.5	41.8	46.36	9.84	0.4581	1475	10.688	8.289
1311	3	5c	20.5	261	19.5	45.32	50.87	10.91	0.4876	1570	12.554	11.293
1311	3	1a	18	257	21	42.6	49.31	13.61	0.5076	1573	15.997	10.840
1311	3	2a	21	261.5	20.5	45.59	53.23	14.35	0.4728	1492	10.558	10.852
1311	3	3a	20	260	20	42.23	48.87	13.59	0.4699	1536	11.982	10.085
1311	3	4a	20.5	260	20	43.88	50.72	13.49	0.4758	1529	11.442	10.318
1311	3	5a	19.5	257	20.5	43.16	50.06	13.78	0.4873	1536	12.477	11.786

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*f*b Hz	DEMb GPa	SEML Gpa
1311	3	1b	20	261	20	40.88	47.31	13.59	0.4532	1528	11.612	9.261
1311	3	2b	19.5	260.5	19	42.72	49.46	13.63	0.5125	1538	13.887	9.967
1311	3	3b	20	261	20	40.51	46.82	13.48	0.4485	1384	9.427	10.691
1311	3	4b	19.5	261	20.5	43.18	49.91	13.48	0.4784	1533	12.979	8.618
1311	3	5b	20	261	20	47.87	55.75	14.13	0.5340	1453	12.373	9.933
1311	3	1c	20	260	20	44.49	51.47	13.56	0.4949	1277	8.722	7.250
1311	3	2c	19.5	260	19.5	38.34	44.31	13.47	0.4482	1350	9.286	7.822
1311	3	3c	19.5	261	19.5	41.61	48.14	13.56	0.4851	1406	11.070	9.275
1311	3	4c	20	259.5	19.5	41.8	48.32	13.49	0.4774	1491	11.383	8.870
1311	3	5c	20.5	261	19.5	45.32	52.67	13.95	0.5048	1534	12.409	11.914
1311	3	1a	19	257.5	19	42.6	42.6	0.00	0.4583	1638	14.166	14.762
1311	3	2a	19.5	260	18.5	45.59	45.59	0.00	0.4861	1493	12.318	11.521
1311	3	3a	19	260	18	42.23	42.23	0.00	0.4749	1620	14.926	12.337
1311	3	4a	18.5	259.5	19	43.88	43.88	0.00	0.4811	1624	15.903	12.372
1311	3	5a	17.5	257	18.5	43.16	43.16	0.00	0.5187	1594	17.761	12.914
1311	3	1b	18.5	260.5	18.5	40.88	40.88	0.00	0.4585	1579	14.551	12.158
1311	3	2b	18	260	18	42.72	42.72	0.00	0.5071	1644	18.288	13.284
1311	3	3b	18	260.5	18	40.51	40.51	0.00	0.4800	1263	10.294	10.152
1311	3	4b	18.5	260.5	19	43.18	43.18	0.00	0.4716	1605	15.462	22.313
1311	3	5b	18	260.5	19	47.87	47.87	0.00	0.5373	1549	17.334	19.510
1311	3	1c	19	259.5	18.5	44.49	44.49	0.00	0.4878	1612	15.061	13.375
1311	3	2c	18.5	259.5	19	38.34	38.34	0.00	0.4203	1405	10.400	10.490
1311	3	3c	18.5	260	18	41.61	41.61	0.00	0.4806	1500	13.659	12.316
1311	3	4c	19	259	18	41.8	41.8	0.00	0.4719	1551	13.386	12.155
1311	3	5c	18.5	261	18.5	45.32	45.32	0.00	0.5073	1594	16.535	13.074
1311	4	1a	18.5	261	19.5	45.49	111.08	59.05	1.1797	1228	22.819	11.314
1311	4	2a	19.5	261	19.5	44.57	106.21	58.04	1.0702	1266	19.802	10.554
1311	4	3a	19.5	261	19.5	46.22	115.43	59.96	1.1631	1235	20.480	11.876
1311	4	1b	19	262	19.5	46.07	105.28	56.24	1.0846	1215	19.770	12.148
1311	4	2b	19.5	261	19.5	47.59	117.88	59.63	1.1878	1289	22.783	12.580
1311	4	3b	19.5	261	19	45.8	114.21	59.90	1.1811	1270	21.992	11.781
1311	4	1c	19	258	20	43.76	101.48	56.88	1.0351	1294	20.124	11.277
1311	4	2c	19	259	20	47.42	116.42	59.27	1.1829	1331	24.711	10.775
1311	4	3c	19.5	259	19	46.53	113.42	58.98	1.1820	1253	20.774	12.040
1311	4	1a	18.5	261	19.5	45.49	50.71	10.29	0.5386	1529	16.150	12.911
1311	4	2a	19.5	261	19.5	44.57	49.71	10.34	0.5009	1560	14.072	12.898
1311	4	3a	19.5	261	19.5	46.22	51.61	10.44	0.5200	1538	14.201	11.974
1311	4	1b	19	262	19.5	46.07	51.34	10.26	0.5289	1491	14.518	11.745
1311	4	2b	19.5	261	19.5	47.59	53.18	10.51	0.5358	1545	14.767	13.247
1311	4	3b	19.5	261	19	45.8	51.07	10.32	0.5281	1547	14.592	12.333
1311	4	1c	19	258	20	43.76	48.79	10.31	0.4977	1595	14.700	11.355
1311	4	2c	19	259	20	47.42	52.98	10.49	0.5383	1568	15.606	10.609
1311	4	3c	19.5	259	19	46.53	51.91	10.36	0.5410	1556	14.662	12.908
1311	4	1a	18.5	261	19.5	45.49	53.16	14.43	0.5646	1435	14.913	9.661
1311	4	2a	19.5	261	19.5	44.57	52.09	14.44	0.5249	1507	13.761	9.284
1311	4	3a	19.5	261	19.5	46.22	54.09	14.55	0.5450	1494	14.044	11.903
1311	4	1b	19	262	19.5	46.07	53.69	14.19	0.5531	1443	14.221	11.792
1311	4	2b	19.5	261	19.5	47.59	55.66	14.50	0.5608	1499	14.549	11.138
1311	4	3b	19.5	261	19	45.8	53.46	14.33	0.5528	1487	14.113	12.515

Results obtained from LINE 3A

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	f_b Hz	DEM_b GPa	SEM_L Gpa
1311	4	1c	19	258	20	43.76	51.06	14.30	0.5208	1533	14.211	12.141
1311	4	2c	19	259	20	47.42	55.39	14.39	0.5628	1527	15.474	11.545
1311	4	3c	19.5	259	19	46.53	54.28	14.28	0.5657	1511	14.458	12.830
1311	4	1a	18	260.5	17.5	45.49	45.49	0.00	0.5544	1536	17.586	15.373
1311	4	2a	17.5	261	17	44.57	44.57	0.00	0.5740	1634	21.968	12.542
1311	4	3a	18	260.5	18	46.22	46.22	0.00	0.5476	1567	18.080	15.816
1311	4	1b	18.5	261.5	17.5	46.07	46.07	0.00	0.5442	1538	16.637	13.279
1311	4	2b	17.5	260.5	17.5	47.59	47.59	0.00	0.5965	1602	21.777	15.095
1311	4	3b	19	261	17	45.8	45.8	0.00	0.5433	1585	16.597	14.249
1311	4	1c	18	258	17.5	43.76	43.76	0.00	0.5385	1695	20.013	13.910
1311	4	2c	17	258.5	19	47.42	47.42	0.00	0.5679	1589	20.960	15.703
1311	4	3c	18	258.5	17	46.53	46.53	0.00	0.5882	1623	20.201	15.581
1311	5	1a	19.5	259.5	20	44.46	107.36	58.59	1.0608	1259	18.970	11.886
1311	5	2a	19	260	19.5	43.01	61.34	29.88	0.6368	1294	12.768	10.773
1311	5	3a	19.5	261	19.5	42.16	59.61	29.27	0.6006	1340	12.451	10.314
1311	5	4a	19.5	261	19.5	41.7	74	43.65	0.7456	1300	14.548	9.777
1311	5	5a	19.5	261	19	46.73	112.24	58.37	1.1607	1148	17.660	10.732
1311	5	1b	20	261	20	44.99	112.18	59.89	1.0745	1222	17.610	9.758
1311	5	2b	19	261.5	19.5	42.49	60.6	29.88	0.6255	1286	12.676	8.304
1311	5	3b	20	262	18	40.04	56.07	28.59	0.5945	1337	11.842	9.940
1311	5	4b	20	262	19.5	42.8	65.42	34.58	0.6402	1329	12.602	15.091
1311	5	5b	19	262	20	44.89	97.68	54.04	0.9811	1229	18.298	11.282
1311	5	1c	19.5	261.5	20	47.1	115.01	59.05	1.1277	1222	19.591	12.285
1311	5	2c	19.5	262	19.5	41.45	58.83	29.54	0.5905	1355	12.710	9.585
1311	5	3c	19.5	262.5	19.5	39.67	55.4	28.39	0.5550	1219	9.742	11.173
1311	5	4c	19.5	262	19.5	43.95	67.23	34.63	0.6748	1308	13.534	10.561
1311	5	5c	20	261.5	20	43.54	83.88	48.09	0.8019	1276	14.439	10.674
1311	5	1a	18	259	18	44.46	44.46	0.00	0.5298	1511	15.893	12.314
1311	5	2a	18.5	259	18	43.01	43.01	0.00	0.4987	1606	15.998	15.076
1311	5	3a	18.5	260.5	18	42.16	42.16	0.00	0.4860	1629	16.416	14.657
1311	5	4a	18	260.5	17.5	41.7	41.7	0.00	0.5082	1579	17.036	13.435
1311	5	5a	17.5	260	18	46.73	46.73	0.00	0.5706	1593	20.439	14.388
1311	5	1b	18.5	260	18	44.99	44.99	0.00	0.5196	1601	16.824	12.474
1311	5	2b	18.5	261.5	17.5	42.49	42.49	0.00	0.5019	1550	15.585	12.122
1311	5	3b	17.5	261.5	17	40.04	40.04	0.00	0.5147	1547	17.792	12.932
1311	5	4b	18	261.5	18.5	42.8	42.8	0.00	0.4915	1544	15.998	13.034
1311	5	5b	17.5	261.5	18	44.89	44.89	0.00	0.5450	1593	19.976	15.126
1311	5	1c	18	261	18	47.1	47.1	0.00	0.5570	1554	18.224	12.798
1311	5	2c	18	261	18	41.45	41.45	0.00	0.4902	1531	15.567	12.031
1311	5	3c	17.5	262	17.5	39.67	39.67	0.00	0.4944	1556	17.423	12.727
1311	5	4c	18	261.5	18.5	43.95	43.95	0.00	0.5047	1617	18.018	15.055
1311	5	5c	17.5	260.5	18	43.54	43.54	0.00	0.5306	1646	20.449	13.099
1311	6	1a	19.5	258.5	19.5	40.28	57.44	29.87	0.5844	1339	11.639	10.097
1311	6	2a	19	260	19	35.57	49.91	28.73	0.5317	1268	10.238	12.398
1311	6	3a	19.5	261	19	38.15	54.21	29.63	0.5606	1289	10.753	12.548
1311	6	4a	18	260.5	19	37.37	52.33	28.59	0.5874	1306	13.470	14.621
1311	6	5a	19	261	19	42.72	80.06	46.64	0.8497	1259	16.378	16.086
1311	6	1b	18	261.5	18	36.27	51.39	29.42	0.6065	1303	14.060	8.663
1311	6	2b	17	261	19	35.32	49.68	28.90	0.5893	1150	11.838	10.901

Results obtained from LINE 3A

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1311	6	3b	18	260.5	18.5	34.82	49.2	29.23	0.5672	1224	11.425	9.630
1311	6	4b	19.5	261.5	19	38.49	53.99	28.71	0.5573	1235	9.888	8.637
1311	6	5b	19	261.5	18.5	40.17	79.76	49.64	0.8677	1215	15.697	11.138
1311	6	1c	19	259.5	18	39.07	57.73	32.32	0.6505	1266	12.389	10.174
1311	6	2c	19	261.5	19	37.69	52.31	27.95	0.5541	1223	10.156	8.357
1311	6	3c	19.5	259.5	18.5	36.12	50.98	29.15	0.5446	1269	9.894	8.313
1311	6	4c	19.5	261	18	39.57	54.95	27.99	0.5998	1340	12.434	11.779
1311	6	5c	19.5	261.5	19	43.41	80.41	46.01	0.8299	1250	15.086	16.723
1311	6	1a	18	258	18	40.28	40.28	0.00	0.4819	1611	16.179	12.500
1311	6	2a	18	259.5	17.5	35.57	35.57	0.00	0.4351	1418	11.585	11.140
1311	6	3a	17.5	260	18	38.15	38.15	0.00	0.4658	1501	14.814	11.614
1311	6	4a	17	260	17.5	37.37	37.37	0.00	0.4831	1517	16.631	16.229
1311	6	5a	18	261.5	18	42.72	42.72	0.00	0.5042	1555	16.646	16.297
1311	6	1b	16.5	261	17.5	36.27	36.27	0.00	0.4813	1449	16.293	13.933
1311	6	2b	16.5	259.5	17.5	35.32	35.32	0.00	0.4714	1472	16.093	13.156
1311	6	3b	16.5	259.5	17.5	34.82	34.82	0.00	0.4647	1423	14.827	11.779
1311	6	4b	17.5	261	18	38.49	38.49	0.00	0.4682	1511	15.322	11.549
1311	6	5b	17.5	261	16.5	40.17	40.17	0.00	0.5330	1577	19.001	16.315
1311	6	1c	17.5	258.5	17.5	39.07	39.07	0.00	0.4935	1471	14.730	11.242
1311	6	2c	18	260.5	18.5	37.69	37.69	0.00	0.4345	1431	11.963	10.412
1311	6	3c	17	259	18	36.12	36.12	0.00	0.4557	1441	13.939	11.225
1311	6	4c	17.5	260.5	17.5	39.57	39.57	0.00	0.4960	1536	16.646	12.035
1311	6	5c	18	261	18	43.41	43.41	0.00	0.5133	1518	16.027	14.167

Results obtained from LINE 3B

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1311	7	1a	19.5	260.5	19.5	42.83	104.26	58.92	1.0525	1303	20.473	11.112
1311	7	2a	19.5	261	19	39.62	55.08	28.07	0.5696	1325	11.545	9.175
1311	7	3a	19.5	261	19	37.96	53.61	29.19	0.5544	1249	9.984	8.133
1311	7	4a	19.5	261	18.5	40.81	58.91	30.72	0.6257	1127	9.174	6.896
1311	7	5a	19	261.5	19	38.32	53.55	28.44	0.5673	1296	11.675	12.777
1311	7	6a	19.5	262	19	41.54	60.45	31.28	0.6227	1312	12.566	10.03
1311	7	1b	18	259.5	19.5	38.74	80.1	51.64	0.8794	1074	13.430	8.614
1311	7	2b	19	260.5	19	37.83	52.51	27.96	0.5584	1236	10.294	6.718
1311	7	3b	19	261	18.5	36.08	50.42	28.44	0.5496	1175	9.227	6.748
1311	7	4b	19.5	261.5	18	39.25	56.91	31.03	0.6200	1130	9.210	6.081
1311	7	5b	19	260	19	37.81	52.61	28.13	0.5605	1278	10.963	8.031
1311	7	6b	19	262	19	39.74	56.19	29.28	0.5941	1270	11.832	9.256
1311	7	1c	19	260.5	20	40.9	84.43	51.56	0.8529	1140	13.376	7.915
1311	7	2c	19	260	19.5	38.91	54.56	28.68	0.5664	1225	10.178	7.925
1311	7	3c	19.5	261	20	41.38	57.34	27.83	0.5633	1119	8.143	5.785
1311	7	4c	19	261.5	19	42.29	61.06	30.74	0.6468	1062	8.939	4.319
1311	7	5c	19.5	262	20	39.42	55.31	28.73	0.5413	1256	10.010	9.406
1311	7	6c	18	261.5	19.5	41.07	57.22	28.22	0.6234	1305	14.495	11.489
1311	7	1a	19.5	260.5	19.5	42.83	101.33	57.73	1.022966	1091	13.9497	11.56
1311	7	2a	19.5	261	19	39.62	51.14	22.53	0.528849	1335	10.8812	9.278
1311	7	3a	19.5	261	19	37.96	49.76	23.71	0.514579	1299	10.0243	8.559
1311	7	4a	19.5	261	18.5	40.81	55.29	26.19	0.587219	1144	8.87229	5.667
1311	7	5a	19	261.5	19	38.32	50.05	23.44	0.530182	1348	11.8053	10.534
1311	7	6a	19.5	262	19	41.54	55.87	25.65	0.575558	1363	12.5345	9.499
1311	7	1b	18	259.5	19.5	38.74	74.51	48.01	0.818032	1018	11.2244	13.723
1311	7	2b	19	260.5	19	37.83	47.7	20.69	0.507228	1299	10.3285	6.548
1311	7	3b	19	261	18.5	36.08	45.81	21.24	0.499338	1225	9.11198	7.089
1311	7	4b	19.5	261.5	18	39.25	51.77	24.18	0.564026	1134	8.4379	7.747
1311	7	5b	19	260	19	37.81	48.45	21.96	0.516194	1356	11.3661	8.445
1311	7	6b	19	262	19	39.74	51.13	22.28	0.540589	1269	10.7493	8.635
1311	7	1c	19	260.5	20	40.9	77.44	47.18	0.782301	1089	11.1955	9.359
1311	7	2c	19	260	19.5	38.91	50.18	22.46	0.520918	1271	10.0771	8.488
1311	7	3c	19.5	261	20	41.38	53.45	22.58	0.525101	1198	8.70042	6.626
1311	7	4c	19	261.5	19	42.29	56.73	25.45	0.600944	1077	8.54154	5.686
1311	7	5c	19.5	262	20	39.42	51.21	23.02	0.501174	1273	9.52079	14.863
1311	7	6c	18	261.5	19.5	41.07	52.67	22.02	0.573832	1381	14.9419	10.876
1311	7	1a	19.5	260.5	19.5	42.83	79.45	46.09	0.802079	1249	14.3349	10.754
1311	7	2a	19.5	261	19	39.62	47.62	16.80	0.492448	1445	11.8708	11.1006
1311	7	3a	19.5	261	19	37.96	45.58	16.72	0.471352	1391	10.5289	8.997
1311	7	4a	19.5	261	18.5	40.81	49.6	17.72	0.526787	1251	9.51773	7.067
1311	7	5a	19	261.5	19	38.32	45.93	16.57	0.486539	1439	12.3455	14.092
1311	7	6a	19.5	262	19	41.54	50.48	17.71	0.520032	1451	12.8349	14.643
1311	7	1b	18	259.5	19.5	38.74	59.25	34.62	0.650495	1113	10.6691	7.015
1311	7	2b	19	260.5	19	37.83	45.5	16.86	0.483834	1341	10.4995	6.867
1311	7	3b	19	261	18.5	36.08	43.34	16.75	0.472414	1287	9.51538	8.711
1311	7	4b	19.5	261.5	18	39.25	47.84	17.96	0.52121	1174	8.35713	8.158
1311	7	5b	19	260	19	37.81	45.08	16.13	0.48029	1417	11.5484	8.516
1311	7	6b	19	262	19	39.74	47.83	16.91	0.505699	1395	12.1515	9.258
1311	7	1c	19	260.5	20	40.9	61.03	32.98	0.616527	1212	10.9288	12.988

Results obtained from LINE 3B

LOG	N	N´	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1311	7	2c	19	260	19.5	38.91	47.11	17.41	0.489048	1324	10.2661	8.217
1311	7	3c	19.5	261	20	41.38	50.09	17.39	0.492092	1232	8.62286	6.922
1311	7	4c	19	261.5	19	42.29	52.02	18.70	0.551051	1123	8.51573	7.277
1311	7	5c	19.5	262	20	39.42	47.58	17.15	0.465649	1366	10.1856	9.113
1311	7	6c	18	261.5	19.5	41.07	49.15	16.44	0.535482	1414	14.6176	12.368
1311	7	1a	19.5	260.5	19.5	42.83	46.75	8.39	0.471959	1576	13.4298	11.341
1311	7	2a	19.5	261	19	39.62	43.14	8.16	0.44612	1518	11.868	10.373
1311	7	3a	19.5	261	19	37.96	41.38	8.26	0.427919	1479	10.8064	9.332
1311	7	4a	19.5	261	18.5	40.81	44.44	8.17	0.471984	1322	9.52301	10.145
1311	7	5a	19	261.5	19	38.32	41.53	7.73	0.439929	1555	13.0351	10.13
1311	7	6a	19.5	262	19	41.54	45.27	8.24	0.46636	1554	13.2023	11.872
1311	7	1b	18	259.5	19.5	38.74	42.22	8.24	0.463526	1403	12.0805	8.967
1311	7	2b	19	260.5	19	37.83	41.24	8.27	0.438534	1434	10.8822	6.586
1311	7	3b	19	261	18.5	36.08	39.34	8.29	0.428814	1380	9.93054	7.67
1311	7	4b	19.5	261.5	18	39.25	41.15	4.62	0.448323	1522	12.0817	8.45
1311	7	5b	19	260	19	37.81	41.11	8.03	0.437993	1524	12.1819	8.503
1311	7	6b	19	262	19	39.74	43.23	8.07	0.457064	1526	13.1424	8.1375
1311	7	1c	19	260.5	20	40.9	44.6	8.30	0.450551	1486	12.0059	10.122
1311	7	2c	19	260	19.5	38.91	42.36	8.14	0.439738	1430	10.7682	8.904
1311	7	3c	19.5	261	20	41.38	45.15	8.35	0.44356	1190	7.25154	5.172
1311	7	4c	19	261.5	19	42.29	46.11	8.28	0.488446	1244	9.26249	5.409
1311	7	5c	19.5	262	20	39.42	42.91	8.13	0.419945	1457	10.4505	8.659
1311	7	6c	18	261.5	19.5	41.07	44.58	7.87	0.485692	1468	14.2905	10.363
1311	7	1a	19.5	260.5	19.5	42.83	42.83	0.00	0.432386	1559	12.0397	13.858
1311	7	2a	19.5	261	19	39.62	39.62	0.00	0.409719	1550	11.364	12.557
1311	7	3a	19.5	261	19	37.96	37.96	0.00	0.392552	1501	10.2104	9.621
1311	7	4a	19.5	261	18.5	40.81	40.81	0.00	0.433431	1330	8.8513	7.698
1311	7	5a	19	261.5	19	38.32	38.32	0.00	0.405926	1573	12.3076	11.806
1311	7	6a	19.5	262	19	41.54	41.54	0.00	0.427934	1597	12.7942	11.510
1311	7	1b	18	259.5	19.5	38.74	38.74	0.00	0.425319	1437	11.6285	9.643
1311	7	2b	19	260.5	19	37.83	37.83	0.00	0.402273	1492	10.8062	8.341
1311	7	3b	19	261	18.5	36.08	36.08	0.00	0.393279	1384	9.16049	7.255
1311	7	4b	19.5	261.5	18	39.25	39.25	0.00	0.427623	1331	8.81304	8.373
1311	7	5b	19	260	19	37.81	37.81	0.00	0.402834	1544	11.5	9.247
1311	7	6b	19	262	19	39.74	39.74	0.00	0.420165	1522	12.0182	11.114
1311	7	1c	19	260.5	20	40.9	40.9	0.00	0.413173	1533	11.7174	11.501
1311	7	2c	19	260	19.5	38.91	38.91	0.00	0.403924	1473	10.495	11.363
1311	7	3c	19.5	261	20	41.38	41.38	0.00	0.406523	1326	8.25195	7.931
1311	7	4c	19	261.5	19	42.29	42.29	0.00	0.44798	1274	8.90981	7.046
1311	7	5c	19.5	262	20	39.42	39.42	0.00	0.38579	1446	9.45615	9.021
1311	7	6c	18	261.5	19.5	41.07	41.07	0.00	0.447451	1457	12.9687	12.945

Appendix V

Results from Line 4

Results obtained from LINE 4

LOG	N	N´	*d* mm	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1411	2	7a	75	21	258	20	53.25	53.25	0.00	0.4914	1768	14.600	14.328
1411	2	8a	82	20	258.5	20.5	50.54	50.54	0.00	0.4769	1653	13.760	11.830
1411	2	9a	92	20.5	259	20.5	54.41	54.41	0.00	0.4999	1756	15.614	11.257
1411	2	4b	104	20.5	257.5	20	56.9	56.9	0.00	0.5390	1301	9.028	11.470
1411	2	7b	90	20.5	258.5	20	53.23	53.23	0.00	0.5022	1711	14.779	11.005
1411	2	9b	101	20.5	258.5	22	57.84	57.84	0.00	0.4961	1644	13.478	13.207
1411	2	4c	86	19.5	257.5	20.5	59.26	59.26	0.00	0.5757	1685	17.878	10.956
1411	2	6c	73	20.5	258	20	54.41	54.41	0.00	0.5144	1739	15.514	9.215
1411	3	7a	53	20.5	259	20.5	48.2	48.2	0.00	0.4428	1703	13.009	9.790
1411	3	8a	63	20.5	260.5	20.5	48.12	48.12	0.00	0.4396	1519	10.513	8.681
1411	3	9a	76	20.5	258.5	20.5	49.65	49.65	0.00	0.4570	1742	13.940	13.796
1411	3	4b	85	20	260	20	55.18	55.18	0.00	0.5306	1659	15.782	8.289
1411	3	6b	68	20	260	20	51.04	51.04	0.00	0.4908	1696	15.256	9.989
1411	3	6c	50	20.5	259.5	20	50.91	50.91	0.00	0.4785	1614	12.724	10.997
1411	3	8c	64	20.5	259.5	20.5	50.13	50.13	0.00	0.4597	1653	12.821	12.088
1411	3	6d	50	20.5	260.5	19.5	51.03	51.03	0.00	0.4900	1583	12.729	8.330
1411	3	7d	55	20.5	260.5	20	50.13	50.13	0.00	0.4694	1763	15.123	6.856
1411	3	8d	67	20.5	259.5	20.5	50.54	50.54	0.00	0.4634	1704	13.736	14.588
1411	4	5a	42	21	255.5	19.5	48.4	48.4	0.00	0.4626	1687	12.035	9.321
1411	4	7b	46	20	256.5	20	50.05	50.05	0.00	0.4878	1717	14.722	7.320
1411	4	5c	39	20.5	258	20.5	51.06	51.06	0.00	0.4709	954	4.275	13.221
1411	4	5d	32	20.5	259	20.5	49.61	49.61	0.00	0.4558	1683	13.077	10.800
1411	4	6d	29	21.5	259	19.5	51.34	51.34	0.00	0.4728	1575	10.801	7.988
1411	4	7d	39	20.5	259	19.5	48.94	48.94	0.00	0.4727	1750	14.663	10.387
1411	5	5a	27	19.5	259.5	20.5	48.33	48.33	0.00	0.4659	1546	12.563	9.543
1411	5	7a	19	20.5	256.5	20.5	44.03	44.03	0.00	0.4085	1439	8.242	7.908
1411	5	6b	25	20.5	258.5	20	46.94	46.94	0.00	0.4429	1585	11.184	10.631
1411	5	7b	25	20	259	20	46.84	46.84	0.00	0.4521	1490	10.682	12.958
1411	5	8b	39	20	259.5	20.5	50.1	50.1	0.00	0.4709	1361	9.354	10.140
1411	5	4c	47	20.5	257.5	20.5	48.85	48.85	0.00	0.4514	1551	10.747	13.327
1411	5	5c	27	20.5	258	20.5	49.26	49.26	0.00	0.4543	1511	10.346	10.794
1411	5	6c	10	20.5	258.5	20	46.99	46.99	0.00	0.4434	1350	8.122	7.108
1411	5	7c	18	20.5	259	20	48.03	48.03	0.00	0.4523	1524	10.641	11.914
1411	5	9c	58	20	260	20	48.17	48.17	0.00	0.4632	1631	13.316	12.468
1411	5	5d	16	21	257	20	47.33	47.33	0.00	0.4385	1528	9.580	13.524
1411	5	6d	8	20	258	20	48.4	48.4	0.00	0.4690	1241	7.569	10.088
1411	5	7d	26	20	259	20.5	46.36	46.36	0.00	0.4366	1642	12.527	6.281
1411	6	8a	38	21.5	260	21.5	59.51	78.49	24.18	0.6531	1114	7.580	7.704
1411	7	8a	47	21.5	258.5	21.5	51.63	68.48	24.61	0.5731	1231	7.936	8.275
1411	5	4b	59	21.5	260.5	21.5	49.39	65.89	25.04	0.5472	1387	9.920	7.900
1411	3	9c	79	21.5	260	22	56.71	75.79	25.17	0.6163	1115	7.165	8.908
1411	5	5c	27	21.5	258.5	21.5	49.26	65.96	25.32	0.5520	1302	8.551	10.483
1411	5	4c	47	21.5	258.5	21.5	48.85	65.48	25.40	0.5480	1349	9.113	6.941
1411	7	8b	37	22	258.5	21.5	49.32	66.2	25.50	0.5414	1438	9.771	5.826
1411	5	9a	60	21.5	255	21.5	45.04	60.49	25.54	0.5132	1377	8.420	8.558
1411	5	5b	41	21.5	259.5	21.5	51.12	68.71	25.60	0.5728	1168	7.252	8.961
1411	4	4d	35	22.5	259.5	21.5	48.57	65.29	25.61	0.5201	1488	9.758	6.911
1411	4	9c	65	21.5	259.5	21.5	52.13	70.18	25.72	0.5851	1488	12.022	9.565

Results obtained from LINE 4

LOG	N	N´	*d* mm	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1411	6	4b	51	22	257.5	21.5	47.94	64.55	25.73	0.5300	1446	9.522	7.725
1411	6	9a	58	21.5	260.5	22	49.7	66.92	25.73	0.5431	1206	7.444	8.443
1411	5	9b	57	21.5	260	21.5	49.92	67.29	25.81	0.5599	1319	9.110	5.889
1411	7	7a	36	22	258.5	22	52.94	71.39	25.84	0.5706	1223	7.449	10.174
1411	5	9c	58	21.5	260	21.5	48.17	65.05	25.95	0.5412	1399	9.907	12.130
1411	7	9a	60	21	258	21	52.45	70.83	25.95	0.6225	1387	11.383	6.407
1411	8	7b	47	22	259	21.5	49.88	67.42	26.02	0.5503	1458	10.289	8.446
1411	4	9d	72	21	260	21.5	50.95	68.87	26.02	0.5867	1464	12.326	8.120
1411	5	8a	38	21.5	255.5	22	46.77	63.22	26.02	0.5231	1369	8.550	11.187
1411	8	8b	57	21	258	21	50.13	67.77	26.03	0.5956	1440	11.739	6.276
1411	2	6d	72	22	258	21.5	57	77.1	26.07	0.6318	1316	9.476	11.067
1411	5	8b	39	21.5	259.5	21.5	50.1	67.81	26.12	0.5653	1309	8.989	8.177
1411	7	4c	57	21.5	258	21	50.59	68.49	26.14	0.5880	1472	11.552	8.282
1411	6	4a	48	21.5	260	21.5	46.48	62.93	26.14	0.5236	1437	10.112	9.050
1411	8	7c	63	22	258	22	52.55	71.15	26.14	0.5698	1358	9.100	8.540
1411	3	9a	76	21.5	259	21.5	49.65	67.28	26.20	0.5620	1455	10.956	4.816
1411	4	4a	57	21.5	255	21.5	49.58	67.2	26.22	0.5701	1490	10.952	3.854
1411	8	7a	61	21.5	258	21.5	48.97	66.43	26.28	0.5570	1426	10.271	9.079
1411	8	6b	44	21.5	258.5	21.5	46.9	63.66	26.33	0.5328	1464	10.434	5.264
1411	8	5b	52	21.5	258.5	21.5	48.07	65.26	26.34	0.5461	1512	11.410	9.719
1411	5	4a	50	21.5	260	21.5	48.31	65.59	26.35	0.5457	1454	10.790	11.535
1411	6	4c	48	21.5	258.5	21.5	47.29	64.21	26.35	0.5374	1343	8.857	9.371
1411	7	6a	41	22	259	21.5	52.44	71.22	26.37	0.5814	1198	7.338	8.718
1411	6	9c	62	21.5	258	21.5	51.4	69.83	26.39	0.5855	1335	9.462	9.057
1411	4	5c	39	21.5	258.5	21.5	51.06	69.38	26.41	0.5806	1248	8.264	6.510
1411	6	9b	55	21.5	258	21.5	47.6	64.68	26.41	0.5423	1497	11.021	9.647
1411	7	5c	43	21.5	258.5	21.5	47.65	64.75	26.41	0.5419	1336	8.838	9.591
1411	5	9d	67	21.5	259	21.5	50.96	69.26	26.42	0.5785	1487	11.780	9.328
1411	8	6d	61	21.5	257	21.5	51.09	69.48	26.47	0.5849	1493	11.639	11.110
1411	5	8c	37	21.5	260	21.5	48.8	66.38	26.48	0.5523	1412	10.298	10.127
1411	7	5a	52	21.5	263	21.5	47.66	64.85	26.51	0.5334	1420	10.532	8.640
1411	5	4d	35	21.5	256.5	21.5	48.52	66.05	26.54	0.5571	1374	9.316	4.970
1411	6	7a	20	21.5	260.5	21.5	54.27	73.88	26.54	0.6135	1015	5.957	1.399
1411	6	5b	32	22	258.5	22	50.29	68.5	26.58	0.5475	1472	10.354	5.102
1411	8	6a	60	21.5	258.5	21.5	47.04	64.08	26.59	0.5363	1417	9.840	6.796
1411	7	4b	45	22	258	22	50	68.12	26.60	0.5455	1489	10.474	6.266
1411	2	4a	70	22	258	22	52.74	71.86	26.61	0.5755	1497	11.168	9.507
1411	6	8b	34	21.5	258	21.5	47.41	64.6	26.61	0.5417	1286	8.123	15.289
1411	7	9b	56	21.5	260	21.5	50.54	68.89	26.64	0.5732	1503	12.110	10.498
1411	7	5b	39	21.5	258.5	21.5	47.29	64.5	26.68	0.5398	1494	11.010	8.635
1411	7	4d	54	22.5	257	21.5	47.63	64.97	26.69	0.5226	1534	10.025	8.832
1411	4	4b	69	21	260	20	51.89	70.79	26.70	0.6483	1455	13.453	6.894
1411	2	7a	75	21	259	22	53.25	72.65	26.70	0.6071	1404	11.553	6.936
1411	3	8c	64	21.5	260	21.5	50.13	68.4	26.71	0.5691	1431	10.899	7.583
1411	2	6a	73	21	259	22	53.33	72.79	26.73	0.6083	1466	12.620	9.132
1411	7	7b	23	21.5	258.5	21.5	50.91	69.49	26.74	0.5815	1238	8.145	10.958
1411	7	8c	55	21.5	259	21.5	48.38	66.07	26.77	0.5519	1364	9.455	6.583
1411	5	5a	27	20.5	259.5	21.5	48.33	66.01	26.78	0.5771	1352	10.769	6.127

Results obtained from LINE 4

LOG	N	N´	d mm	h mm	L mm	b mm	Weight g	Weight g	M %	Density g/cm^3	fb Hz	DEMb GPa	SEML Gpa
1411	4	5d	32	21.5	259.5	21.5	49.61	67.76	26.79	0.5649	1481	11.498	4.280
1411	6	8d	52	21	257.5	21	47.28	64.59	26.80	0.5688	1473	11.639	6.212
1411	4	9b	68	21.5	259.5	21.5	47.77	65.26	26.80	0.5440	1398	9.868	8.596
1411	6	4d	38	21.5	260	20.5	47.42	64.79	26.81	0.5654	1459	11.255	10.462
1411	8	6c	60	22	258	21.5	48.8	66.68	26.81	0.5464	1438	9.785	10.111
1411	5	10a	80	21.5	255	22	50.9	69.56	26.83	0.5767	1457	10.594	6.566
1411	5	8d	47	21.5	259	21.5	48.14	65.79	26.83	0.5495	1457	10.743	4.435
1411	6	5c	30	22	258.5	21.5	48.92	66.86	26.83	0.5468	1336	8.518	2.046
1411	5	10b	76	22	260	22	54.45	74.42	26.83	0.5914	1338	9.456	6.669
1411	7	4a	70	21.5	264	22	50.51	69.07	26.87	0.5531	1450	11.561	9.293
1411	3	4d	60	21.5	260	21.5	52.53	71.84	26.88	0.5977	1467	12.031	10.749
1411	8	5c	63	22	258	21.5	49.87	68.21	26.89	0.5589	1459	10.304	10.273
1411	7	7d	48	22	259	21.5	51.91	71.01	26.90	0.5796	1350	9.291	9.472
1411	8	5a	70	21.5	258.5	21.5	48.58	66.48	26.93	0.5564	1450	10.689	11.903
1411	3	6b	68	21.5	260	21.5	51.04	69.85	26.93	0.5812	1358	10.024	8.129
1411	8	7d	66	21.5	258.5	21.5	54.03	73.96	26.95	0.6190	1359	10.446	3.313
1411	4	6c	30	20.5	259.5	21.5	49.94	68.37	26.96	0.5978	1221	9.097	3.823
1411	3	5c	56	21.5	259	21.5	54.48	74.6	26.97	0.6231	1408	11.376	5.063
1411	3	5b	74	21	260.5	22	52.6	72.08	27.03	0.5989	1393	11.480	5.085
1411	3	6d	50	21.5	261	21.5	51.03	69.95	27.05	0.5798	1169	7.524	8.297
1411	4	6d	29	21.5	259.5	21.5	51.34	70.38	27.05	0.5867	1363	10.116	10.677
1411	7	9c	71	21.5	257.5	21.5	50.62	69.41	27.07	0.5831	1380	9.992	8.015
1411	6	8c	41	21.5	258.5	21.5	49.6	68.03	27.09	0.5693	1232	7.897	7.621
1411	4	9a	63	21.5	254	21.5	46.28	63.52	27.14	0.5410	1363	8.561	4.551
1411	7	5d	43	21.5	256	21.5	47.05	64.59	27.16	0.5458	1526	11.172	4.637
1411	6	9d	70	21.5	256	21.5	50.85	69.81	27.16	0.5899	1535	12.218	5.808
1411	3	5d	52	21	260	22	49.4	67.88	27.22	0.5651	1374	10.458	8.210
1411	3	7b	68	21	260	21.5	51.72	71.07	27.23	0.6054	1391	11.483	9.656
1411	7	8d	62	22	258	222	50.02	68.74	27.23	0.0546	1463	1.011	9.892
1411	7	6c	37	21.5	259	21.5	46.92	64.52	27.28	0.5389	1345	8.978	7.997
1411	4	8c	50	21.5	259	21.5	49.4	67.97	27.32	0.5677	1366	9.756	6.476
1411	4	8d	55	21.5	258.5	21.5	46.89	64.52	27.32	0.5400	1504	11.161	3.583
1411	4	7d	39	21.5	259.5	21.5	48.94	67.35	27.33	0.5615	1513	11.928	2.367
1411	4	5b	54	21.5	258	21.5	49.39	67.98	27.35	0.5700	1297	8.695	3.397
1411	3	8d	67	21.5	260	21.5	50.54	69.57	27.35	0.5789	1506	12.278	2.091
1411	3	8b	74	21.5	259.5	21.5	49.52	68.18	27.37	0.5684	1504	11.932	7.184
1411	4	6a	30	21.5	256	21.5	49.72	68.46	27.37	0.5785	1392	9.853	10.978
1411	2	6c	73	21.5	258.5	21.5	54.41	74.92	27.38	0.6270	1462	12.246	9.161
1411	3	9b	84	21	260.5	21.5	51.79	71.32	27.38	0.6064	1502	13.514	7.471
1411	7	7c	41	21.5	258.5	21.5	48.29	66.54	27.43	0.5569	1259	8.066	3.178
1411	5	5d	16	21.5	257	21.5	47.33	65.26	27.47	0.5493	1307	8.378	8.255
1411	8	5d	64	22	258	22	51.38	70.89	27.52	0.5677	1501	11.077	9.119
1411	4	7c	35	21.5	260	21.5	49.62	68.47	27.53	0.5697	1458	11.326	8.664
1411	3	6c	50	22	261	22	50.91	70.26	27.54	0.5562	1323	8.830	9.079
1411	7	6b	35	22	258.5	21.5	47.17	65.1	27.54	0.5324	1381	8.862	13.235
1411	3	7c	55	21.5	260	21.5	49.89	68.87	27.56	0.5730	1466	11.517	9.599
1411	6	5a	30	21	259	22	48.12	66.44	27.57	0.5552	1326	9.424	7.984
1411	2	5d	72	22	258	22	56.9	78.57	27.58	0.6292	1453	11.504	4.798

Results obtained from LINE 4

LOG	N	N´	*d* mm	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1411	3	7d	55	21.5	261	21.5	50.13	69.27	27.63	0.5742	1442	11.338	5.912
1411	6	7d	34	22	258.5	21.5	46.8	64.67	27.63	0.5289	1368	8.639	6.459
1411	3	7a	53	21.5	259.5	22	48.2	66.65	27.68	0.5430	1381	9.611	8.486
1411	3	5a	58	21.5	260	21.5	49.41	68.34	27.70	0.5686	1385	10.201	8.585
1411	7	6d	41	21.5	258	21.5	48.41	66.96	27.70	0.5615	1381	9.710	10.917
1411	5	6c	10	21.5	258.5	21.5	46.99	65.04	27.75	0.5443	1206	7.234	12.197
1411	3	6a	52	21.5	259	21	47.9	66.31	27.76	0.5671	1403	10.279	9.654
1411	5	7d	26	21.5	259.5	21.5	46.36	64.19	27.78	0.5351	1418	9.985	7.644
1411	4	6b	47	21.5	258	21.5	49.36	68.42	27.86	0.5737	1357	9.579	5.511
1411	4	8b	54	21.5	260	21.5	47.94	66.5	27.91	0.5533	1357	9.529	7.650
1411	3	8a	63	21	261	22	48.12	66.75	27.91	0.5536	1337	9.850	8.400
1411	6	5d	21	22	260	21.5	45.32	62.88	27.93	0.5113	1431	9.352	10.834
1411	2	5a	78	21	259	22	54.22	75.26	27.96	0.6290	1421	12.259	7.120
1411	5	7c	18	21.5	259	21.5	48.03	66.67	27.96	0.5569	1299	8.653	7.150
1411	4	3d	38	22	259.5	21	56.16	78.25	28.23	0.6527	1569	14.241	5.998
1411	4	7b	46	21.5	257	21.5	50.05	69.83	28.33	0.5878	1422	10.612	9.310
1411	2	7d	76	22	258	21.5	54	75.36	28.34	0.6175	1401	10.497	7.366
1411	4	3b	85	21.5	254	21.5	47.22	66.01	28.47	0.5622	1420	9.657	7.082
1411	6	6d	20	21.5	260	21.5	45.76	64	28.50	0.5325	1179	6.923	13.063
1411	5	6b	25	21.5	259	21.5	46.94	65.71	28.56	0.5489	1178	7.014	7.094
1411	2	8a	82	21	259	22	50.54	70.83	28.65	0.5919	1414	11.424	10.928
1411	5	7b	25	21	259.5	21.5	46.84	65.69	28.70	0.5607	937	4.787	8.829
1411	4	7a	33	21.5	256	21.5	46.93	65.82	28.70	0.5562	1414	9.775	5.783
1411	8	8a	66	21.5	257	21.5	50.43	70.92	28.89	0.5970	1406	10.536	9.564
1411	5	6d	8	22	258	22	48.4	68.28	29.12	0.5468	988	4.625	8.128
1411	5	7a	19	21	258	22	44.03	62.23	29.25	0.5221	1070	5.681	9.201
1411	3	4c	68	21.5	260	21.5	55.6	78.59	29.25	0.6539	1456	12.964	10.234
1411	6	6c	17	21.5	258.5	21.5	46.03	65.19	29.39	0.5456	976	4.748	11.733
1411	4	10a	84	21.5	253.5	21.5	51.44	72.92	29.46	0.6223	1452	11.088	13.441
1411	6	6a	16	21.5	258.5	22	44.93	63.79	29.57	0.5217	1002	4.787	16.894
1411	3	9d	85	21.5	260	21.5	55.9	79.42	29.61	0.6608	1190	8.751	12.363
1411	6	7b	19	22	257.5	21.5	44.71	63.53	29.62	0.5216	1226	6.737	9.360
1411	4	5a	42	21.5	256	21.5	48.4	68.98	29.83	0.5829	1436	10.565	11.464
1411	2	6b	90	22	259	22	54.57	77.79	29.85	0.6206	1322	9.539	13.328
1411	7	3a	87	22	263.5	21	54.58	78.07	30.09	0.6413	1420	12.184	10.033
1411	6	7c	22	21.5	258.5	21.5	46.43	66.47	30.15	0.5563	1325	8.924	8.559
1411	6	6b	11	21.5	258.5	21.5	45.25	64.8	30.17	0.5423	1165	6.726	10.097
1411	6	3d	59	21.5	260	21.5	52.68	75.58	30.30	0.6289	1514	13.481	9.446
1411	6	3a	70	21.5	260	21.5	52.33	75.62	30.80	0.6292	1487	13.011	10.428
1411	8	8c	71	21.5	257.5	21.5	51.08	74.41	31.35	0.6251	1462	12.023	16.355
1411	3	4b	85	21.5	261	21.5	55.18	80.82	31.72	0.6699	1373	11.993	16.607
1411	4	10b	85	21.5	259.5	21.5	53.93	79.85	32.46	0.6657	1387	11.884	22.473
1411	5	10c	79	21.5	259.5	21.5	54.27	80.69	32.74	0.6727	1458	13.270	15.937
1411	2	7c	75	22	258.5	23	53.25	81.42	34.60	0.6225	1438	11.234	21.426
1411	5	6a	10	21.5	260	22	51.21	78.46	34.73	0.6380	805	3.862	21.869
1411	5	3a	73	21.5	259.5	21.5	54.29	84.08	35.43	0.7009	1471	14.076	8.389
1411	5	3c	67	21.5	258.5	21.5	53.92	83.72	35.59	0.7006	1433	13.147	13.276
1411	2	7b	90	22	258.5	21.5	53.23	82.81	35.72	0.6773	1341	10.629	13.643

Results obtained from LINE 4

LOG	N	N´	*d* mm	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1411	6	10b	77	21.5	258.5	21.5	54.23	85.29	36.42	0.7138	1479	14.268	24.657
1411	4	3a	75	21.5	256	21.5	54.75	86.9	37.00	0.7343	1446	13.496	18.265
1411	2	5c	78	22	258	22	57.92	92.36	37.29	0.7396	1414	12.807	10.115
1411	7	3b	63	22	258.5	22	57.02	91.25	37.51	0.7293	1434	13.089	21.599
1411	6	10c	81	21.5	259	21.5	56.35	93.28	39.59	0.7791	1365	13.369	14.548
1411	7	3d	68	21.5	257.5	21.5	53.96	89.42	39.66	0.7512	1492	15.047	13.142
1411	2	8b	94	22	258.5	21	51.92	86.59	40.04	0.7250	1324	11.092	11.905
1411	8	9d	91	21.5	258	22	53.9	90.27	40.29	0.7397	1400	13.147	15.534
1411	2	5b	95	22	259	22	57.15	96.53	40.80	0.7700	1409	13.446	23.433
1411	8	4b	66	21.5	258	22	52.39	88.64	40.90	0.7264	1482	14.466	7.715
1411	2	8d	78	22	258.5	22	53.42	90.39	40.90	0.7225	1291	10.509	12.043
1411	8	4a	84	21.5	258.5	21.5	52.64	89.53	41.20	0.7493	1464	14.675	16.354
1411	6	3c	68	22	258	22	54.3	93.18	41.73	0.7462	1517	14.871	15.240
1411	7	3c	73	21.5	258.5	21.5	55.12	94.87	41.90	0.7939	1422	14.671	10.332
1411	6	3b	72	21.5	257.5	21.5	52.37	90.98	42.44	0.7643	1327	12.110	12.801
1411	5	3b	78	21.5	260	22	55.08	95.87	42.55	0.7796	1475	15.861	11.081
1411	2	8c	83	21.5	258.5	21.5	52.33	91.22	42.63	0.7634	1302	11.826	14.119
1411	7	9d	76	21.5	257	21.5	53.05	92.51	42.65	0.7787	1424	14.098	11.675
1411	6	10a	78	21.5	261	21.5	53.56	93.78	42.89	0.7773	1267	11.850	11.565
1411	9	7b	65	21.5	259	21.5	50.93	89.7	43.22	0.7492	1403	13.581	11.143
1411	4	10c	84	21.5	260	21.5	57.51	101.61	43.40	0.8454	1470	17.086	12.408
1411	8	8d	77	21	258.5	21	55.73	98.79	43.59	0.8666	1385	15.922	9.517
1411	2	4a	88	21	260	22	55.43	98.29	43.61	0.818265	1295	13.4518	15.284
1411	8	4c	73	21.5	259	21.5	53.41	96.25	44.51	0.8039	1438	15.309	9.427
1411	8	4d	71	21.5	258.5	21.5	51.63	93.52	44.79	0.7826	1435	14.727	10.288
1411	8	9a	77	21	257.5	21	53.61	97.38	44.95	0.8575	1356	14.871	13.495
1411	4	8a	47	21	260	21	54.35	98.95	45.07	0.8630	1349	15.395	11.966
1411	2	4c	86	22	258	22	59.26	108.08	45.17	0.8655	1359	13.843	9.494
1411	2	4d	78	21.5	257.5	21.5	54.23	99.23	45.35	0.8337	1443	15.619	10.956
1411	5	10d	89	21.5	259	22	57.61	107.18	46.25	0.8749	1352	14.727	8.951
1411	9	6b	64	20.5	258.5	21.5	50.67	94.53	46.40	0.8297	1381	15.905	11.04
1411	2	9a	92	21.5	259.5	22	54.41	102.19	46.76	0.8325	1295	12.957	12.893
1411	4	10d	92	22	259.5	22	58.88	112.23	47.54	0.8936	1408	15.701	8.934
1411	9	7a	84	22	261	22	54.06	104.58	48.31	0.8279	1433	15.419	10.327
1411	9	6a	83	22	261	21.5	53.55	104.07	48.54	0.8430	1380	14.561	7.672
1411	9	7c	83	21	258	22	55.99	110.18	49.18	0.9244	1308	15.031	10.581
1411	9	5a	91	22	262	21	52.39	104.94	50.08	0.8670	1386	15.338	7.342
1411	2	9c	94	21.5	259	21.5	58.2	116.64	50.10	0.9743	1243	13.862	11.408
1411	7	10b	76	21.5	258	21.5	53.83	108.18	50.24	0.9071	1413	16.422	8.542
1411	9	5b	70	21.5	259	22	50.25	102.5	50.98	0.8367	1362	14.293	6.28
1411	2	9b	101	22	258	22	57.84	119.79	51.72	0.9593	1039	8.968	8.019
1411	2	9d	100	22	258	22	54.64	116.73	53.19	0.9348	1376	15.328	8.512
1411	9	6c	82	20.5	258	20.5	52.04	111.62	53.38	1.0295	1450	21.588	9.891
1411	6	10d	91	21.5	255.5	20	50.61	108.73	53.45	0.9897	1354	15.824	8.783
1411	7	10a	80	22	257.5	22	53.24	117.43	54.66	0.9422	1337	14.474	9.191
1411	2	4b	104	21	258	22	56.9	126.36	54.97	1.0601	969	9.455	5.485
1411	9	5c	85	21	258	21	52.88	119.62	55.79	1.0513	1428	20.377	6.259
1411	9	7d	86	21.5	257	21.5	55.18	129.05	57.24	1.0863	1146	12.737	11.064

Results obtained from LINE 4

LOG	N	N´	*d* mm	*h* mm	*L* mm	*b* mm	Weight g	Weight g	M %	Density g/cm^3	*fb* Hz	DEMb GPa	SEML Gpa
1411	9	6d	83	21.5	257	21.5	53.51	128.64	58.40	1.0828	1373	18.224	6.464
1411	9	5d	84	21.5	258	21	51.33	124.27	58.69	1.0668	1155	12.905	8.204
1411	9	8a	86	22	257	21	51.27	126.13	59.35	1.0623	1433	18.600	8.48