EXPLANATORY NOTES ON TECHNICAL DATA SHEET INFORMATION

Nomenclature

Regarding the current botanical nomenclature of commercial wood, the genus name, species name, author, and family are included.

Example (mahogany):

Genus	Species	Author	Family
Swietenia	*macrophylla*	King	Meliaceae

The botanical names of trees are unique and universal, regardless of their origin, ensuring differentiation from any other wood species. This is not the case with common names, which may coincide and refer to two different wood species or, conversely, two different common names may refer to the same wood species.

In some cases, the acronym "spp." (= species pluralis, derived from Latin) has been used instead of the species name. This acronym indicates any number of species of the same genus that are marketed under a single common name.

Example: Poplar = Populus spp.

Sometimes the acronym "sp." (species, derived from Latin) has been used instead of the species name. This acronym indicates any single undetermined species among several belonging to the same genus.

Example: Pinus sp. (= pine)

Under the heading "Other names" there is a series of regional or local names used to market the wood in different regions or countries of its geographic distribution. Country codes follow ISO 3166 standard (http://www.iso.org/iso/country_codes/iso_3166_code_lists.htm)

Background

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora. This international organization is dedicated to the protection of endangered species, including some tree species that produce commercial woods. According to the level of danger, three protection levels (appendices) are distinguished against overexploitation:

Appendix I includes animal and plant species most endangered with extinction. They are threatened with extinction and CITES generally prohibits international trade of specimens of these species. However, trade may be authorized under exceptional circumstances, for example for scientific research. In this case, trade may be authorized by granting an export permit (or re-export certificate) and an import permit.
Example: Dalbergia nigra (Brazilian rosewood).

Appendix II includes species that are not necessarily threatened with extinction but could become so unless their trade is strictly controlled. This Appendix also includes so-called "look-alike species", i.e., species whose traded specimens resemble those of species included for conservation reasons. International trade in specimens of Appendix II species may be authorized by granting an export permit or re-export certificate; an import permit is not required. Permits or certificates should only be granted if the competent authorities have determined that certain conditions have been met, in particular that trade will not be detrimental to the survival of the species in the wild. Example: Swietenia spp. (mahogany), Guaiacum spp. (lignum vitae).

Appendix III lists species included by member countries that have already regulated trade of that species and need cooperation from other countries to prevent unsustainable or illegal exploitation. International trade in specimens of these species is only authorized with prior presentation of appropriate permits or certificates. Example: Cedrela odorata (cedar; PERU).

General Characteristics

Sapwood and Heartwood: Trees maintain variable volumes of sapwood - the physiologically active part of the trunk occupying the outermost area - to assume the functions of water conduction, carbohydrate storage and its ability to respond to external and internal injuries. On the other hand, the central part of the trunk gradually becomes heartwood which contains only dead cells without the ability to conduct water and store nutrients. The sapwood, generally lighter in color than heartwood, has its conductive elements free of obstructions by extractive deposits or tyloses. As new layers of sapwood are created, those closest to the heartwood lose their conductive function and become heartwood, a process characterized by morphological (anatomical) and chemical modifications, i.e., the formation of tyloses in some hardwoods and/or organic substances such as tannins or other coloring materials (extractives) that when oxidized give it its characteristic dark color.

The heartwood formation process protects the wood against fungal attacks by plugging the conduction pathways and impregnating the tissues with substances that have some antiseptic value. These characteristics that could be advantages for the natural use of wood, however, constitute a disadvantage for its drying and technical impregnation with chemical products. In summary, heartwood is not only sometimes darker, but can also be heavier and more resistant to attacks by fungi and insects, while the outer zone of the trunk, i.e., the sapwood, is lighter, more permeable and sometimes less valuable. However, from the point of view of technical treatments, sapwood is easier to treat and work in most processing and mechanical disintegration processes.

Physical and biological characterization of heartwood (in relation to sapwood)

1. May or may not have a different color.
2. Contains less water (lower moisture content).
3. May or may not have higher density due to accumulation of organic substances; however, this does not imply higher mechanical strength since these substances contribute only to weight.
4. May or may not have higher natural durability due to the antiseptic action of extractives deposited in its cells and cell walls.
5. Generally less permeable (up to practically impermeable) due to clogging of main conduits by organic substances or tyloses (only in some hardwoods).

Cross-Grained Wood (Interlocked Grain): When the axial tissues that make up the wood develop in an inclined form with respect to the central axis of the tree (spiral grain) and periodically change direction (angle). This phenomenon occurs frequently in tropical hardwoods (diagnostic) while being very rare in hardwoods from temperate climate zones. According to textbooks on wood anatomy and technology, interlocked grain does not occur in softwoods, however experience shows that there are few exceptions to this rule.

Interlocked grain cannot be detected on transverse or tangential surfaces, it can only be reliably detected on radial surfaces which show strips of different color (Fig. 1a,b). It is important to note that this apparent color difference is not due to wood pigmentation, but exclusively to an optical effect, that is, to the different reflection of incident light by adjacent strips cut at different grain angles. The best way to verify the presence of interlocked grain is by splitting the wood longitudinally in the radial plane. The split line shows a sinuous course, with alternating peaks and valleys (Fig. 2). On planed radial surfaces, the presence of interlocked grain is manifested by the periodic change of long vessel marks when the cutting plane is more or less parallel to the grain to short when the grain is cut at an angle (Fig.1b). Wood species with interlocked grain are generally more difficult to work on radial surfaces.

Figure 1a. Alternating light and dark strips caused by different reflection of incident light, for example in Sapele (Entandrophragma cylindricum)

Figure 1b. Zones with long vessel marks (cut parallel to grain) alternating with zones with short vessel marks (cut at an angle), for example in Parota (Enterolobium cyclocarpum)

Figure 2. Sinuous course of the radial longitudinal split and the resulting pattern of peaks and valleys on the radial surface of the two separated pieces, for example in African Bilinga wood (Nauclea diderrichii)

Texture: Refers to the size of cells and/or tissues, their distribution uniformity and their quantity in a given area and is only indicated as fine, medium and coarse (Fig. 3). The predominant parameter for this classification is the size of the pores and their marks on longitudinal surfaces which, depending on their size, give the surface a lesser or greater roughness. Secondarily, the size (height and width) of the rays and the quantity and distribution of axial parenchyma are also considered.

Figure 3. Ceiba (Ceiba pentandra) coarse texture (left), Cedrillo (Guarea sp.) medium texture (center) and Aile (Alnus glabrata) fine texture (right).

Conversion Factors For the presentation of numerical data of physical and mechanical properties, the metric system was chosen as it is the most widely recognized and accepted in most of the world. To facilitate the conversion of the presented data to the Anglo-American system, the following conversion factors were used:

- g/cm3 0.016 = lb/ft^3
- N/mm2 0.006895 = lb/in^2

Examples: The average density of an air-dried wood is 0.55 g/cm^3; dividing this value by the factor 0.016 will give an average density of approximately 34 lb/ft^3.

The range of bending strength of a wood is 64 - 74 N/mm^2; dividing these values by the factor 0.0068947 will give a range of 9280 - 10730 lb/in^2.

To convert values [N/mm^2] to values [kg/cm^2] multiply the former by the factor 10, that is, 97 N/mm^2 corresponds approximately to 970 kg/cm^2.

Regarding impact resistance, it is not possible to convert values obtained by the US standard into values according to the European standard. The methods of determining impact resistance used by the two standards are fundamentally different so they do not allow an approximate conversion. Where values obtained according to the European Standard [kJ/m^2] in air-dry condition (MC = 12-15%) were not found, values determined in green condition were entered (Torelli & Gorizek, 1995c). Lacking equivalents for impact resistance in kJ/m^2, they were estimated based on air-dry density (MC 12-15%) using the equation:

$a = C*\rho^n*100$ (Kollmann & Côté 1968) where:

a = Impact resistance [kJ/m²], C = constant ranging from 1.5 to 2.1 (average of 1.8 for wood at approx. 12% MC), ρ = density at approx. 12% MC, n = exponent that, as a general rule, takes a value of 2.

Hardness (side) values are presented according to the JANKA [kN] method commonly used in the US and Canada and BRINELL [N/mm²], method more frequently used in European countries.

Physical Properties

Green weight: Refers to the density of green wood (water-saturated) in kilograms per cubic meter [kg/m³]. This data is useful for transportation purposes of roundwood or green sawnwood, whose cost is generally calculated based on wet weight.

Example: Sawnwood with a green weight of 1200 kg/m³. 1 m³ of wood = 423 board feet. 1000 board feet of this wood corresponds to 2.36 m³, which equals a weight of 2837 kg.

Air-dry density: Refers to the density value of wood at a moisture content (MC) of 12% to 15%, which corresponds to most wood uses in service. This property allows the user to estimate the potential mechanical strength of the wood given the proportional relationship between density and the mechanical properties of wood.

Maximum shrinkage (max): Defined as the decrease in linear dimensions (longitudinal, radial and tangential) that occurs in a piece of wood when going from green to completely dry condition (MC = 0%), as illustrated in figure 4.

Drying shrinkage or normal shrinkage (ɓN): This is the dimensional change that occurs in wood in its main axes when its moisture content is reduced from a saturated state (MCÓ30%) to an approximate dry state of 12% MC, which corresponds to 65% relative air humidity (RH) and temperature of 20ÁC. It is usually useful to estimate width and thickness reinforcement in wood sawing and for calculating the anisotropy of normal shrinkage (AN).

Data

Wood species = Pinus leiophylla.
Width of the piece in the radial direction = 20 cm.
Thickness (tangential axis) = 2.5 cm
Moisture content before drying = use 30%, even if it were much higher.
Moisture content after drying = 12%
Tangential drying shrinkage (ɓNt) = 5%
Radial drying shrinkage = (ɓNr) = 2.2%

Calculation of the final width of the board after drying (Af)

Af = 20 - [(20 × 2.2) / 100] = 19.56 cm

Calculation of the final thickness of the board after drying (Ef)

Ef = 2.5 - [(2.5 × 5) / 100] = 2.375 cm

Differential swelling (q): Is the dimensional change in percentage that occurs in a piece of wood in its linear dimensions (longitudinal, radial and tangential) for each 1% variation in its moisture content, in the practical use range of 5% and 20% MC. It is expressed in %/%. It allows calculating the increase or decrease of a piece of wood or manufacture for each 1% modification of its MC, as the case may be.

Calculate the dimensional change (ɋd) of wood paneling made in Guadalajara city at 12% MC that will be installed in Puerto Vallarta, where its MC over time will reach 18%.

Data

Paneling width = 8.8 cm (considering tangential direction)
Oak wood (Quercus castanea)
MC1 = 12%
MC2 = 18%
qt = 0.476 %/%

$\Delta l = l \times (CH2 - CH1) \times (q/100)$

$\Delta l = 8.8 \times (18 - 12) \times (0.476/100)$

$\Delta l = 0.251$ cm.

Final paneling width = 8.8 + 0.25 = 9.05 cm at MC = 18%.

Shrinkage anisotropy (Aɓ): Technical term resulting from the quotient of tangential and radial shrinkage [ɓt/ɓr]. Depending on the wood species, its value fluctuates from 1.5 to 2.5 and even up to 3.0.
It is a very important index in practice, since the higher its value, the greater the tendency for cracks, splits and deformations to appear during the drying process. The numerical values of anisotropy are not included in the table of physical and mechanical properties in the data sheets. However, the respective quotients can be easily calculated based on the following relationships:

- Maximum (total) tangential shrinkage and maximum (total) radial shrinkage [ɓt/ɓr] or
- Drying (normal) tangential shrinkage and drying (normal) or radial shrinkage, [ɓNt/ɓN r]or
- Tangential differential swelling and radial differential swelling, [qt/qr].

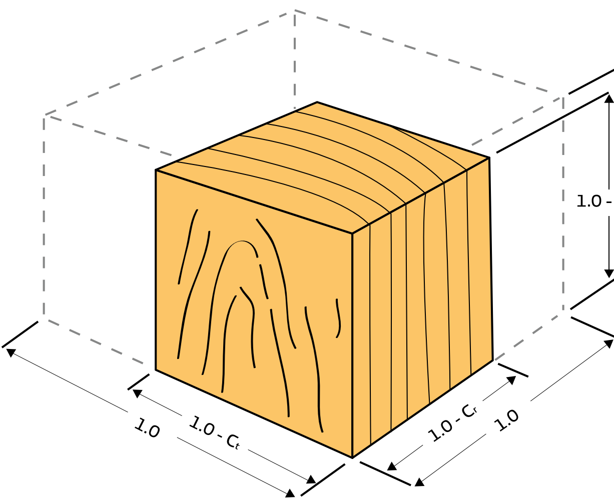

Figure 4. Illustration of wood shrinkage in each of its main axes. Ct = Tangential shrinkage, Cr = Radial shrinkage, Cl = Longitudinal shrinkage. Graph adapted from Otto Suchsland (2004). The swelling and shrinking of wood. A practical technology primer. Forest Products Society. Madison, Wi., 189 pp.

Dimensional Stability: Qualitative term used to qualify the behavior (movement) of wood in service exposed to cyclical changes in environmental conditions (relative humidity, temperature). It is defined by the following factors:

- The absolute values of shrinkage/swelling.
- The anisotropy of total shrinkage or differential swelling.
- The speed at which wood loses or absorbs moisture from the environment, a property that largely depends on its hygroscopicity and permeability.
- The grain deviation relative to the longitudinal axis of the wood piece.

The higher the total shrinkage, anisotropy and permeability, the lower the dimensional stability due to the fact that stronger, uneven and faster movement (dimensional change) can be expected.

Four descriptive categories are used for dimensional stability:

- Very good
- Good
- Fair
- Poor

Always taking into account in an estimated manner, the aforementioned criteria, regarding the behavior of wood under changing atmospheric conditions.

Mechanical Properties

In the data table of each sheet, the values of parallel compression strength, bending strength (MOR bending), modulus of elasticity (MOE bending), shear strength, impact resistance and hardness are presented. All expressed in the international system (SI) of units.

Compression strength parallel to grain (Modulus of Rupture = MORcompression)
Maximum stress [in N/mm²] that the wood can withstand under a crushing load applied along its longitudinal axis, as illustrated in figure 5.

Figure 5. Compression test

Bending strength (Modulus of Rupture = MORbending)
Maximum stress that wood can withstand when a load is applied perpendicular to its longitudinal axis up to the breaking point through a bending test, as shown in figure 6. It is expressed in N/mm^2.

Modulus of Elasticity (MOEbending)
It is a constant that represents the stiffness of wood when subjected to forces that attempt to modify its shape. Therefore it describes the relationship between the force (load) and the deformation (deflection) that occurs in wood, within its elastic field. The higher the modulus of elasticity value, the greater its resistance to deformation (stiffness) under load. The MOE is very useful data frequently used by engineers and architects to calculate the allowable load for pieces used in construction.

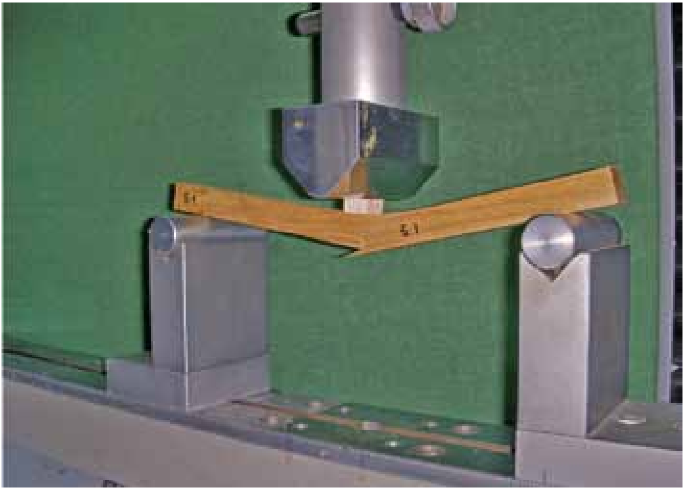

Figure 6. Bending test

Impact resistance

This term actually expresses the energy [kJ/m²] needed to break wood when subjected to a sudden stress (blow) perpendicular to its longitudinal axis, as shown in figure 7. The greater the energy absorption capacity of the wood, the greater its impact resistance and consequently the more pertinent its use for applications where it is subject to shock loads. It is also often called impact work, impact breaking energy, impact value and energy absorption.

Figure 7. Impact resistance test (pendulum)

Shear strength

Internal resistance [in N/mm²] that wood develops in response to a shear force parallel to the surface on which it acts, as shown in figure 8. It is also often called cutting resistance.

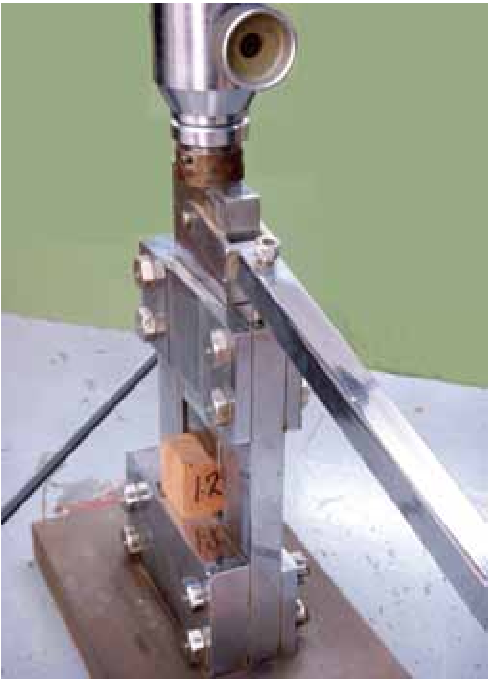

Figure 8. Shear (cutting) test

Hardness

The hardness of wood is usually determined both by the JANKA method (in North and South America), and by the BRINELL method (mainly in Europe). When determined by the JANKA method, the values are expressed in kN, and represent the force required to embed in the wood half of a metal ball with a diameter of 11.28 mm. For the case of BRINELL hardness, the values are expressed in N/mm², and represent the resistance that wood opposes to the penetration of a metal ball of 10 mm in diameter over a period of 45 seconds, referred to the penetration area (mark) occurred in the wood, as shown in figure 9.

Figure 9. BRINELL hardness test

The JANKA hardness values can be converted to BRINELL according to the following equation (Schwab, 1990):

$$D_{Brinell} = 3.1 \times D_{Janka} + 7.3 [N/mm^2]^*$$

Example: If the JANKA hardness value of a wood species is 3.8 [kN], the corresponding BRINELL hardness value will be:

$$D_{Brinell} = 3.1 \times 3.8 + 7.3 = 19 [N/mm^2]$$

On the other hand, if the BRINELL hardness of a wood is known, for example =19 N/mm², the JANKA hardness can be estimated with the same equation as follows:

$$D_{Janka} = \frac{19 - 7.3}{3.1} = 3.8 [kN]$$

The BRINELL value can also be estimated based on the normal density of the wood (MC = 12%) by means of the following expression:

$$D_{Brinell} = 7.62 \times Density_N - 24.5 [N/mm^2]$$

Example: If the normal density of a wood species is 0.74 [g/cm³], the corresponding BRINELL hardness value will be:

$$D_{Brinell} = 7.62 \times 0.74 - 24.5 = 32 [N/mm^2]$$

Drying

Process by which the water contained both in the cavities and in the cell walls is extracted. Among the most common methods are air drying and conventional technical drying. Adequate handling and schedule to be used is important, otherwise it can cause defects such as cracks, warping, cupping and even collapses, which together reduce the volume of wood to be used. Drying is a fundamental part of the transformation process, clearly showing its influence on the workability, functionality and finish of the final product itself. Regarding drying times, this will depend on the wood's own structure, differing between species. Sotomayor (1987) presents a classification of wood drying with respect to its drying time (table 1)

Kiln drying time (hrs)	Air drying time (days)	Classification
Less than 150	Less than 100	Fast
151 – 300	101 – 150	Moderately fast
301 – 450	151 – 200	Moderately slow
More than 450	More than 200	Slow

Table 1. Wood classification based on drying times

Regarding the drying schedules proposed for the different species, in chapter 07 (drying schedules) of the book "Dry Kiln Operator's Manual" (181) the symbols and the way to use each drying schedule are described. Likewise, information on this can be found in the following publications:

- Andean Group Manual for Wood Drying (Simpson, 1981);
- Dry Kiln Schedules for Commercial Woods Temperate and Tropical (Boone & al., 1988);
- Kiln Operator's Handbook (Stevens & Pratt, 1952);
- Technical sheets of commercial woods, CIRAD-Forêt (2009);
- Handbook of Hardwoods (Farmer, 1988);
- Method to estimate dry-kiln schedules and species groupings (Simpson, 1996).

Natural Durability

The natural durability of wood defines its ability to resist degradation and/or deterioration caused by a range of biological, climatic and chemical agents (Cartwright & Findlay, 1958; Zabel & Morrell, 1992). In most species, heartwood has greater durability than sapwood, due to the presence of toxic extractives unique to heartwood (Bowyer & al., 2003).

For the purposes of this document, the natural durability of heartwood against fungi, organisms capable of causing its decay, is considered. Also, in some cases the natural resistance of wood to deterioration by marine borers and by insects such as termites is described.

The natural resistance data to decay are detailed according to the categories described by the standards ASTM D 2017-05 (ASTM, 2007) and EN 350-1 (CEN, 1994). Resistance to termites and marine borers is defined in terms of resistant, slightly resistant or susceptible.

Resistance class	Mass loss (%)
Highly resistant	0 to 10
Resistant	11 to 24
Moderately resistant	25 to 44
Slightly resistant	45 or higher

Table 2. Natural resistance categories against decay fungi based on mass loss of specimens according to ASTM D 2017-05 standard.

Resistance class	Resistance category	Mass loss (%)
1	Very durable	$0 \leq 5$
2	Durable	$5 \leq 10$
3	Moderately durable	$10 \leq 20$
4	Slightly durable	$20 \geq 30$
5	Not durable	> 30

Table 3. Natural resistance categories to decay fungi based on weight loss of specimens, according to EN 350-1 standard.