1

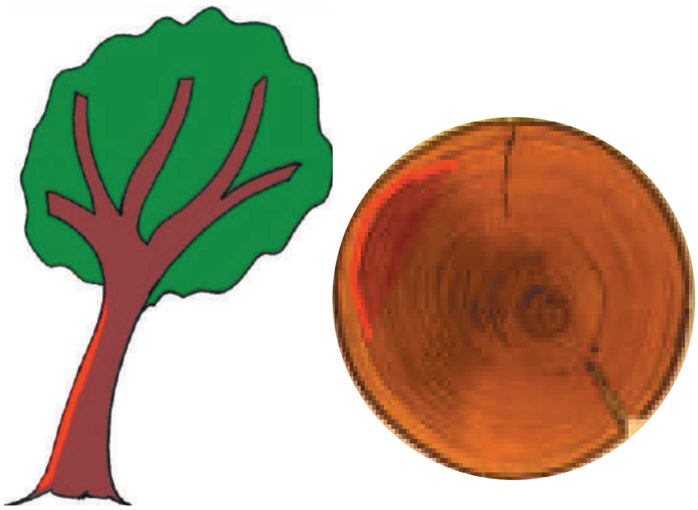
A FEW CLARIFICATIONS ARE IN ORDER!

REACTION TIMBER

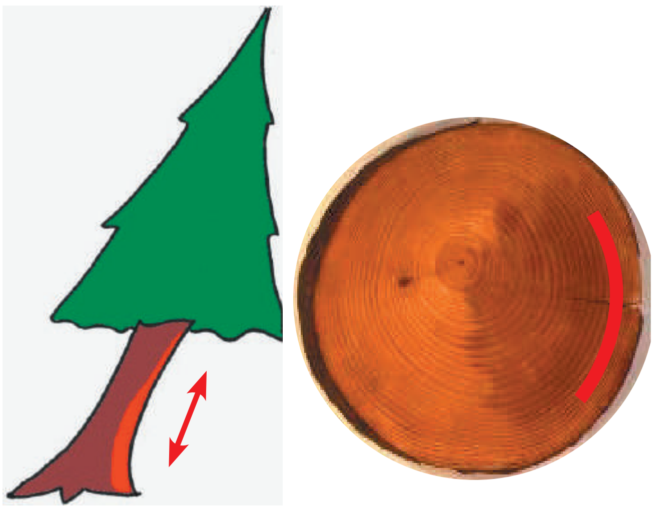
ORIGIN IN THE TREE

Throughout its growth, the tree produces its timber with a slight stress of tension (like springs stretched all around the tree). By pulling more or less on one side or the other, the tree adjusts its shape and maintains its verticality. When the tree undergoes an important imbalance (sloping ground, unidirectional wind, slight heaving following a storm, etc.) or has to support an inclined branch, it creates timber with a pre-stress that differs greatly from that of the opposite timber, generating a period of bending that balances the efforts. It therefore produces timber of a different nature than so-called "normal" timber; this is "reaction timber".

Softwoods and hardwoods have opted for two different strategies to achieve the same function. In hardwoods, the bending is produced by pulling harder on the upper face of the inclined axis than on the opposite side. This timber - which has a very strong pre-stress tension - is known as "**tension timber**". In softwoods, the bending is generated by pushing on the lower face, generating pre-stress compression timber known as "**compression timber**". In some species, reaction timber has a growth rate that is much higher than the opposite timber, which causes an offset of the pith. This growth differential increases the efficiency of the reaction via a "lever arm" effect.



Tension timber (hardwood)



Compression timber (softwood)

Reaction timber is systematically present in branches where mechanical stresses are very significant. It is for this reason in particular that the branches are not used for the production of lumber.

During a healing process (wound with or without inclusion of bark or inter-bark), the tree is also able to produce reaction timber locally. In the unstressed longer portion, the tree can also produce reaction timber via auxinic[1] actions, the mechanisms of which are not yet well known, and which may be linked to genetic aspects or to the environment.

Reaction timbers have a different cell structure and a different chemical composition, which sometimes make it visible to the naked eye. But above all, these differences in structure result in highly different mechanical and physical properties.

PARTICULARITIES OF THE CELLS

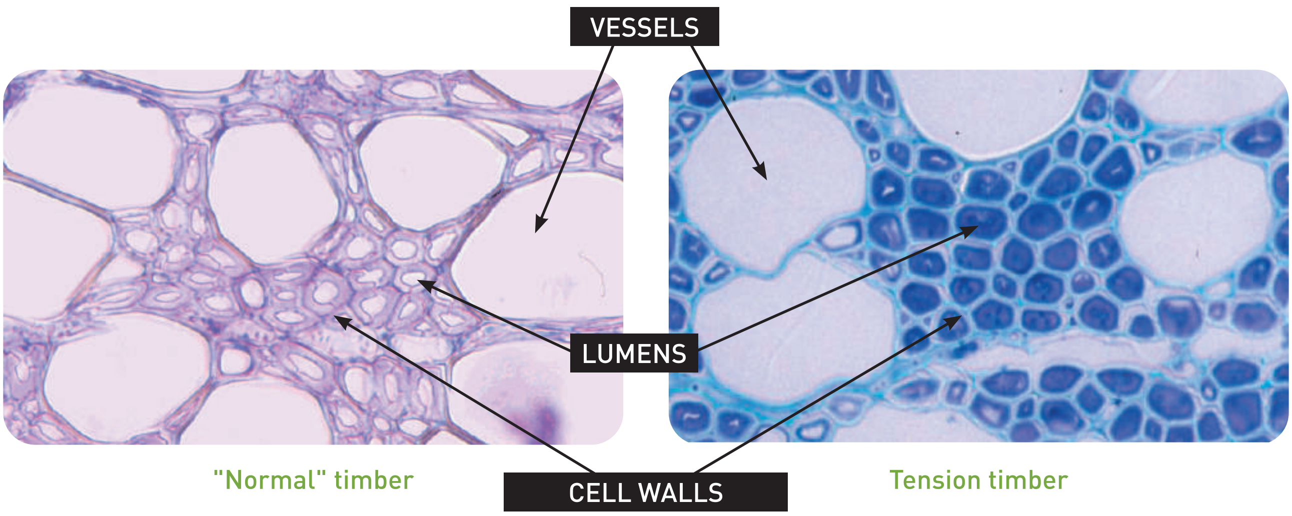
Reaction timber cells differ from regular cells in many respects, but in general:

In softwoods:

- the cells (tracheids) are shorter;
- the walls are thicker and more lignified;
- the cellulose micro-fibrils (organised in a spiral around the cell) are more inclined than in normal timber.

In hardwoods:

- there are fewer vessels (sap conducting cells);
- the fibres are longer and more cellulosic;
- the spiral inclination of the cellulose has a very small angle, close to the vertical;
- in some species, part of the fibre wall is replaced by a thick, lignin-free and highly hydrated layer.



"Normal" timber

Tension timber

1. Auxins are plant hormones, or phytohormones, found throughout the plant kingdom, which play a major role in controlling plant growth and development.

PROPERTIES OF REACTION TIMBER

Typically, compression timber is denser (reduced cell voids) and more coloured (high presence of lignin). This is not systematic in hardwoods. The compressive resistance properties of reaction timber are lower than those of normal timber. The shrinkage coefficients, especially those of axial shrinkage, can be ten times those observed in "normal" timber. Compression timber is less permeable, due to the thick cell walls and their sealed points, and is therefore harder to dry. In Sapelli, the reaction timber zones are called are known as **oily veins** (due to their oily appearance).

DETECTION

The detection and identification of reaction timber is not always obvious for loggers, both in terms of standing timber or green timber. It is usually during the drying process that the specificities of this timber become apparent. Under the microscope, one of the most effective colouring methods is the safranin[2] action, followed by green-light, which brings out red in normal timber and bright green in tension timber.

CONSEQUENCES FOR THE USE OF REACTION TIMBER

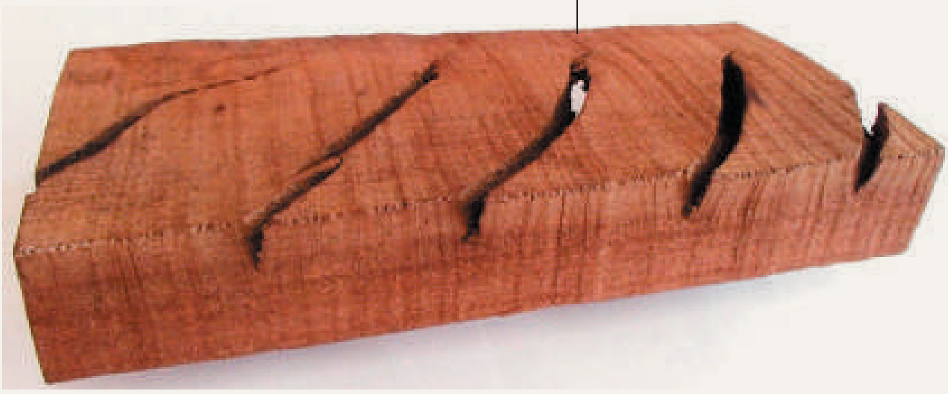
Apart from colour variations in dark red to brown tones, the most serious consequences in the use of reaction timber are revealed during drying, through localised breaks (cracks, honeycombs, etc.) and/or deformations (change in the shape of the section, bending, tiling, warping, etc.). The refractory nature of reaction timber during drying and very large dimensional shrinkage can provoke collapses. Collapses are a "breakdown[3]" of the cells which mainly occurs under both warm and humid conditions. In the case of reaction timber, collapses can occur during natural drying (without an increase in either temperature or humidity).

When reaction timber is located in localised areas, the defect appears as short, very wide cracks or deformations.

During peeling, the cells of reaction timber are crushed under the knife, resulting in a particularly fluffy surface.

Similarly, in reaction timber, the ends of the cells are less joined, which favours a fluffy texture of the cross-sections when the timber is being worked on.

2. Safranin is a dye.
3. The collapse of the cells is comparable to that of a tube undergoing an extreme vacuum.



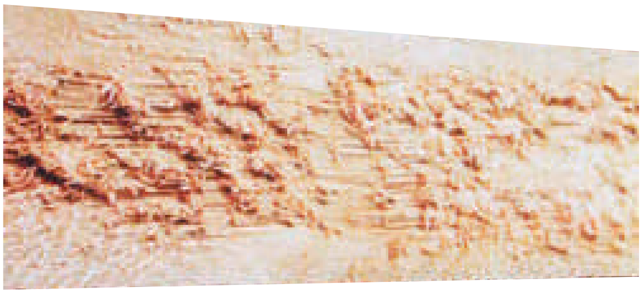
Oily vein on Sapelli. The cells of the reaction timber shrink in length until they break. (115x40 mm cut piece)

Oily vein on Sapelli. The reaction timber's cells favour collapse. (100x125 mm cut piece)

Oily vein on Sapelli. Transverse breaks. (120 mm wide piece)

Reaction timber inter-bark and pocket on Sapelli. (115 mm wide piece)

Deformation of a piece of Sapelli featuring an oily vein on one edge. (100x30 mm cut piece)



Rotary cutting of Poplar containing tension timber and causing a fluffy surface. (100 mm wide veneer)

Fair&Precious recommends the purchase of FSC® and PEFC-PAFC certified tropical timber.

2

A FEW CLARIFICATIONS ARE IN ORDER!

ABNORMAL TIMBER COLORATION

These defects are hardly discernible on logs unless they appear in the cuts, and even then they are very often located at different heights within the log. The defect may appear as discoloured or over-coloured areas.

ORIGIN IN THE TREE

These are growth anomalies that result either from a blockage of a tree's metabolism at a certain period of its life and in certain specific areas of its trunk, or as a reaction to an external aggression. The defects are quite specific for certain species:

- spot stains on Lati, Iroko
- discoloration of the timber on Sapelli, Moabi, Makoré
- black veins on Movingui
- light stains on Padouk

Note: this type of problem is specific to a tree and not to a geographical area.

CONSEQUENCE ON THE TIMBER

In addition to the aesthetic disorders that are part of this anomaly, these disturbances can have a negative effect on durability. On the other hand, the mechanical characteristics are not affected.

Stains on Iroko at the end of its life (a timber that is remarkably soft and easy to work)

Discoloration
of Sapelli

Stains on Makore

Stains on Bossé

Fair&Precious recommends the purchase of FSC® and PEFC-PAFC certified tropical timber.

TECHNICAL SHEETS

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3

SHRINKAGE OF TIMBER DURING DRYING

SHRINKAGE, DEFORMATION AND DRYING CRACKS

RETRAIT DU BOIS AU SHRINKAGE OF TIMBER DURING DRYING

Timber can contain several forms of water (see the Humidity in timber sheet). When its humidity rate content is below the fibre saturation point (FSP), humidity variations lead to dimensional changes. In a given direction of timber, total shrinkage is calculated as the ratio between the dimensional change between dry timber and timber at FSP on the dry timber dimension.

$$R=\frac{[Dim(PSF)-Dim(0\%)]}{Dim(0\%)}$$	Dimension with H ≥ FSP (PSF in diagram)	
		Dimension with H = 0%

The total shrinkage is variable depending on the timber and especially on the direction that is being considered. The total longitudinal shrinkage is the lowest (in the direction of the timber fibres), as low as 0.1%. The total radial shrinkage is more significant but remains limited by the presence of timber radii, and reaches 5% on average. Lastly, the total tangential shrinkage is the most significant because no cell is oriented in this direction, and reaches 10% on average.

$$\alpha=\frac{R}{PSF}$$

Shrinkage is proportional to the variation in humidity. The shrinkage coefficient α is defined by the dimensional change due to a 1% change in humidity content on the dimension of dry timber.

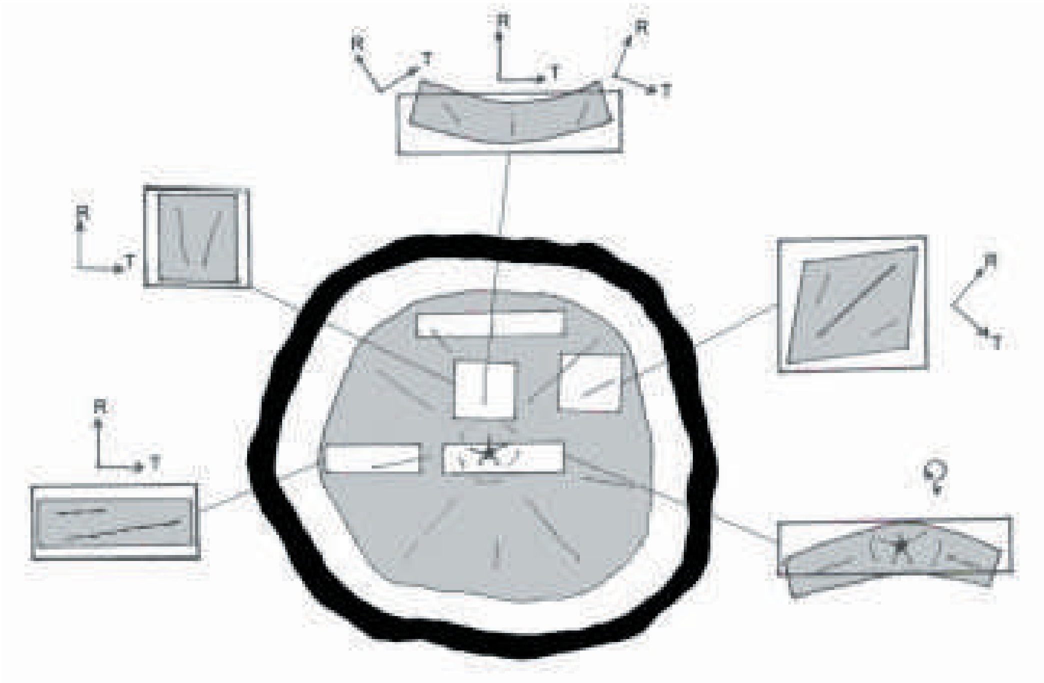
The dimensional variation is in fact easily calculated using the following formula:

$\Delta l = \frac{\alpha \times \Delta H \times l}{100}$		Dimension ℓ1 With humidity H1
		Dimension ℓ2 With humidity H2
Assuming that H1 and H2 are less than the FSP		$\Delta \ell = \ell 1 - \ell 2$ $\Delta H = H1 - H2$

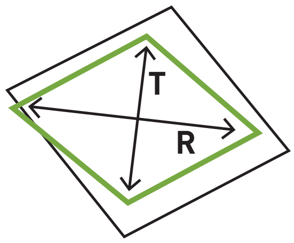
On this link, a basic calculation tool in Excel can be used to estimate dimensional variations.
Note: the calculations show average values. The variability of timber is subject to surprises, even when there is no reaction timber present (see the corresponding sheet).

CROSS-SECTIONAL DEFORMATIONS DURING DRYING

As a result of the differences in shrinkage in the R and T directions, the timber deforms unevenly as it dries. As shrinkage in the R-direction is less pronounced (than in the T-direction), the timber is said to "pull towards the heart" when drying. The opposite is true for the absorption of humidity.



The justification of the deformation is easy to calculate:
In the example of a square Niangon block cut (12 cm diagonal cross-section), cut in a half-quarter.
If it changes from a 28% to 12% humidity content.



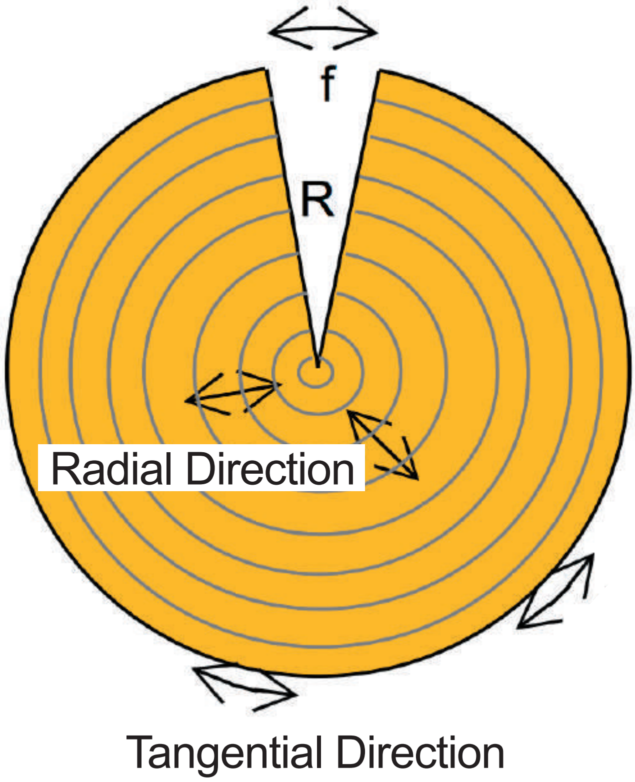
Radial shrinkage: **ΔR = 0,131 x (28-12) x 120/100 = 2,5 mm**
Tangential shrinkage: **ΔT = 0,275 x (28-12) x 120/100 = 5,3 mm**

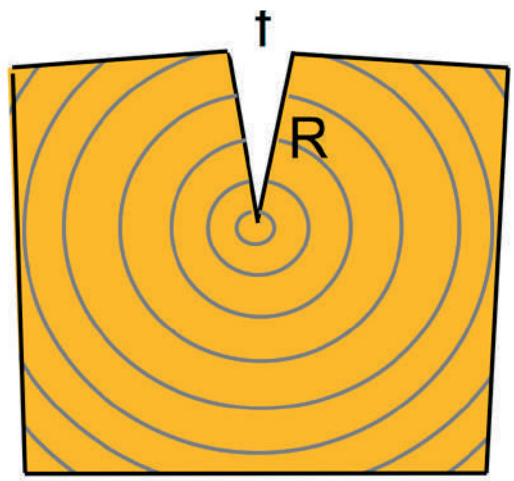
The diagonal in the T direction will be 2.8 mm smaller and will result in a diamond shape.

CLOSED HEART TIMBER CRACKS

In the case of a log where the heart of the timber is enclosed, and referred to as the "enclosed core", the differences in radial and tangential shrinkage mean that the periphery of a cut tends to shrink more than its radius. As a result, the timber is subjected to perpendicular tensile stresses in the tangential direction, or cracks will occur. As the perpendicular tensile strength of timber is low, cracks occur in most cases.

The width of the crack can even be predicted by calculation, and depends on the radius, the timber's humidity variation (from the FSP), and the difference between the radial and tangential shrinkages.





$$f = \frac{\pi \times R \times (\alpha T - \alpha R) \times \Delta H}{50}$$

The locations of cracks in round timber is hard to predict. They occur at the shortest distance between the heart and the edge, or in the more fragile areas (near knots, for example).

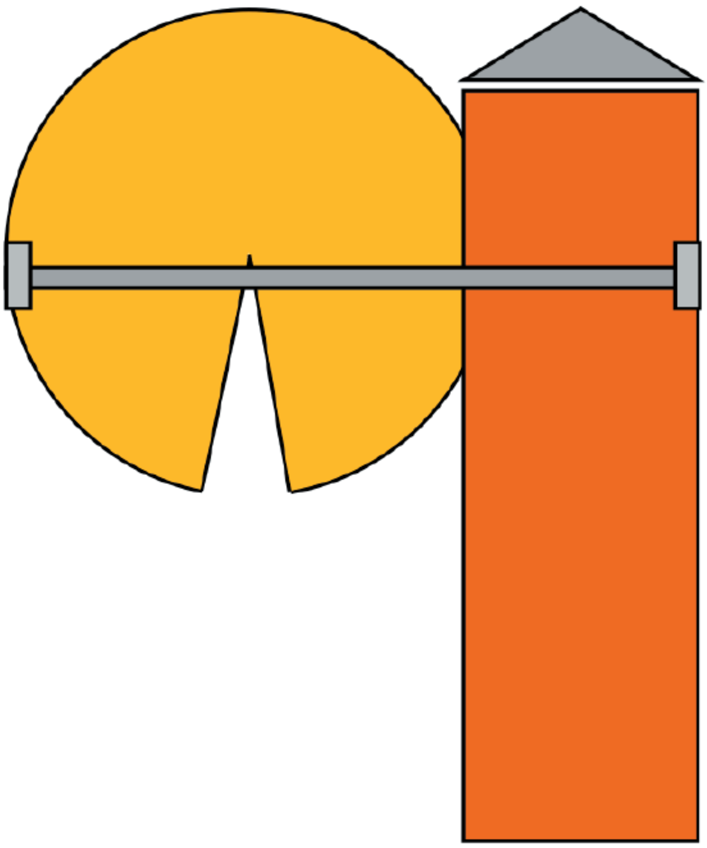
Example of an Azobe cant with a 300x300 mm cross-section, where the core is 100 mm from an edge, dried to a 15% humidity content.

f = π x 100 x (0,37 - 0,26) x (28 – 15) /50 = 9 mm

A crack should occur with a 9 mm opening on the side closest to the core.

These cracks generally have little effect on the mechanical strength of timber whose core is enclosed (except in bending when the crack is horizontal at the support points). The fibres of the timber are dissociated but not broken.
On the other hand, they can constitute water traps that can lead to fungal growth, as well as expose part of the timber that was not sufficiently durable or protected by a preservative treatment (surface protection or partial impregnation with a chemical product).

One technique used on road barriers is to deliberately create this crack by cutting a notch in the middle of the timber. This "notch" releases the deformation stresses and therefore limits the appearance of cracks in undesired areas (at assembly points, for example). The opening of the notch varies according to the humidity variations. It is generally done towards the bottom in order to not create a water trap.



Some large structural elements are reconstituted and are much more homogeneous. Their stability means that deformations are greatly reduced and that there are no (or few) problems with the appearance of cracks. These products are, among others: glued laminated timber, plywood...

4

A FEW CLARIFICATIONS ARE IN ORDER!

TIMBER DURABILITY

TIMBER DURABILITY

Durability is an intrinsic property of each species: it is their ability to resist attacks from biological degradation agents. Biological degradation agents are defined as: fungi, insects with **xylophagous**[1] larvae (abbreviated to ILX, such as hylotrupes and anobium), termites, marine **borer**[2] worms, etc.

Note: There is no such thing as **rot-proof**[3] timber. If this were the case, the forest would be a huge pile of dead and un-degraded timber that has been around for several million years. This is the way life is: all timber degrades at different rates depending on the conditions in which they are found. To evaluate this property, laboratory tests have been carried out on various species using a standardised protocol (EN 350-1). The most commonly used durability classes are those that relate to **lignivorous fungi**[4].

They are classified according to 5 levels:

Durability class	Description
1	Highly durable
2	Durable
3	Moderately durable
4	Slightly durable
5	Non-durable

Note: The tests are carried out on **duraminated**[5] timber. When referring to the durability of timber, only the heartwood is considered, as the sapwood is never durable.

1. Which eat timber.
2. Which make holes, which perforate.
3. Which does not rot.
4. Which feeds on damp timber, causing it to decay.
5. Timber consists of two parts: the sapwood (in which the raw sap rises) and the heartwood. In some species, the difference between these two parts is clearly visible (the sapwood being generally lighter), in others they cannot be distinguished (examples: fir, spruce).

Durabilities are presented in the EN 350-2 standard (see annex 2), along with:

- **Durability against fungi (1 to 5)**
- **Durability against xylophagous insects (S sensitive, or D durable)**
- **Durability against termites (S sensitive to D durable)**
- **Durability against marine borers (S sensitive to D durable)**
- **Impregnability (1 impregnable to 4 non-impregnable)**
- **Width of the sapwood (tf < 2 cm, f < 5 cm, m < 10 cm, l > 10 cm, x no distinction)**

Not all species are listed in this standard, but it is still possible to find acknowledged information in the **CIRAD**'s[6] technical sheets[7].
Note: in terms of durability against termites, the tests consist of enclosing the timber with starving termites. the timber with starving termites. This principle: «you either eat or you die» excludes the notion of palatability, i.e. «although this timber is nutritious, it isn't to my liking so I will go elsewhere».

USAGE CLASSES

Usage classes refer to timber usage situations.
They are defined in standard EN 335 (currently under revision), but slightly different definitions can be found in the NF B 50-105-3 and FD P 20-651 standards.
Note: for a long time they were referred to as «risk classes» (this was deemed too negative).

Usage class 1: Situation in which the timber is under shelter, fully protected from the weather and not exposed to humidification. Examples: flooring, furniture, panelling, etc.	
Usage class 2: Situation in which the timber is under shelter, fully protected from the weather, but where high ambient humidification may lead to occasional non-persistent humidification. Examples: frameworks, roofing elements, etc.	
Usage class 3A: Situation in which the timber is neither sheltered nor in contact with the ground. It is either continuously exposed to the weather, or sheltered but subject to frequent humidification. Examples: joinery, exterior cladding (partially sheltered), etc.	

6. CIRAD is a French research centre based in Montpellier that works with developing countries to address international agricultural and development issues.
7. See the TROPIX sheets.

Usage class 3B: Harsher conditions than in class 3A Examples: joinery, external cladding (exposed to the weather) etc.	
Usage class 4: Situation in which the timber is in contact with the ground or fresh water, and is thus permanently exposed to humidification. Examples: fences, posts, decks, etc.	
Usage class 5: Situation in which the timber is constantly in contact with salt water. Examples: jetties, pontoons, etc.	

With these usage classes, the life span of a species is not defined. For example: a poplar stake (designed to hold a tomato plant) is used in a situation falling under usage class 4. It is not recommended that poplar be used for usage class 4 if a service life of more than one year is desired.

The relationship between the durability of a timber and its usage class is solely based on the expected service life.

Commercially, usage classes are wrongly used to measure durability performance, especially when the timber is chemically treated without the service life being stated.

If the expected service life is defined, it is possible to establish a relationship between usage class and species. The EN 460 standard presents matches, but unfortunately they are still quite imprecise.

Note: Usage classes 1, 2, 3A, 3B, 4 are ranked in increasing order according to the ease with which fungus can degrade the timber. Usage class 5 is separate because it pertains to marine environments.

Example: Basralocus[8] can be used in usage class 5 because it resists well against marine borer worms, but it is not recommended for usage class 4 because fungi easily degrades it when it is in contact with the ground. It can be used for classes 1, 2, 3A, 3B and 5 but not 4.

8. Angelica, Guyana timber.

THE RIGHT TIMBER IN THE RIGHT PLACE

In practice, these usage class definitions remain difficult to grasp, for example, «exposed to bad weather» is a highly variable notion depending on whether they are the French cities of Montpellier or Brest[9].

The definitions have therefore been taken up in greater detail in the FD P 20-651 documentation booklet. They take into account the following aspects in particular:

- climate (for a detailed map of France, see annex 1);
- local conditions (coastal zones, valley beds not exposed to sunlight, proximity to sources of humidity generating recurrent periods of mist or fog;
- types of designs (rainwater run-off and desorption[10] conditions directly influence the durability of the part of the structure under consideration with regard to fungal risks[11]);
- the massiveness (the more massive the timber, the more limited its desorption capacity);
- exposure to the prevailing rain wind.

When the usage class is correctly defined, the choice of timber can be made according to the structure's expected service life.

L3: Lifespan of over 100 years;
L2: Lifespan between approximately 50 and 100 years in its originally intended use;
L1: Lifespan between approximately 10 and 50 years in its originally intended use;
N: Longevity uncertain and in any case less than 10 years (solutions not to be prescribed in the building).

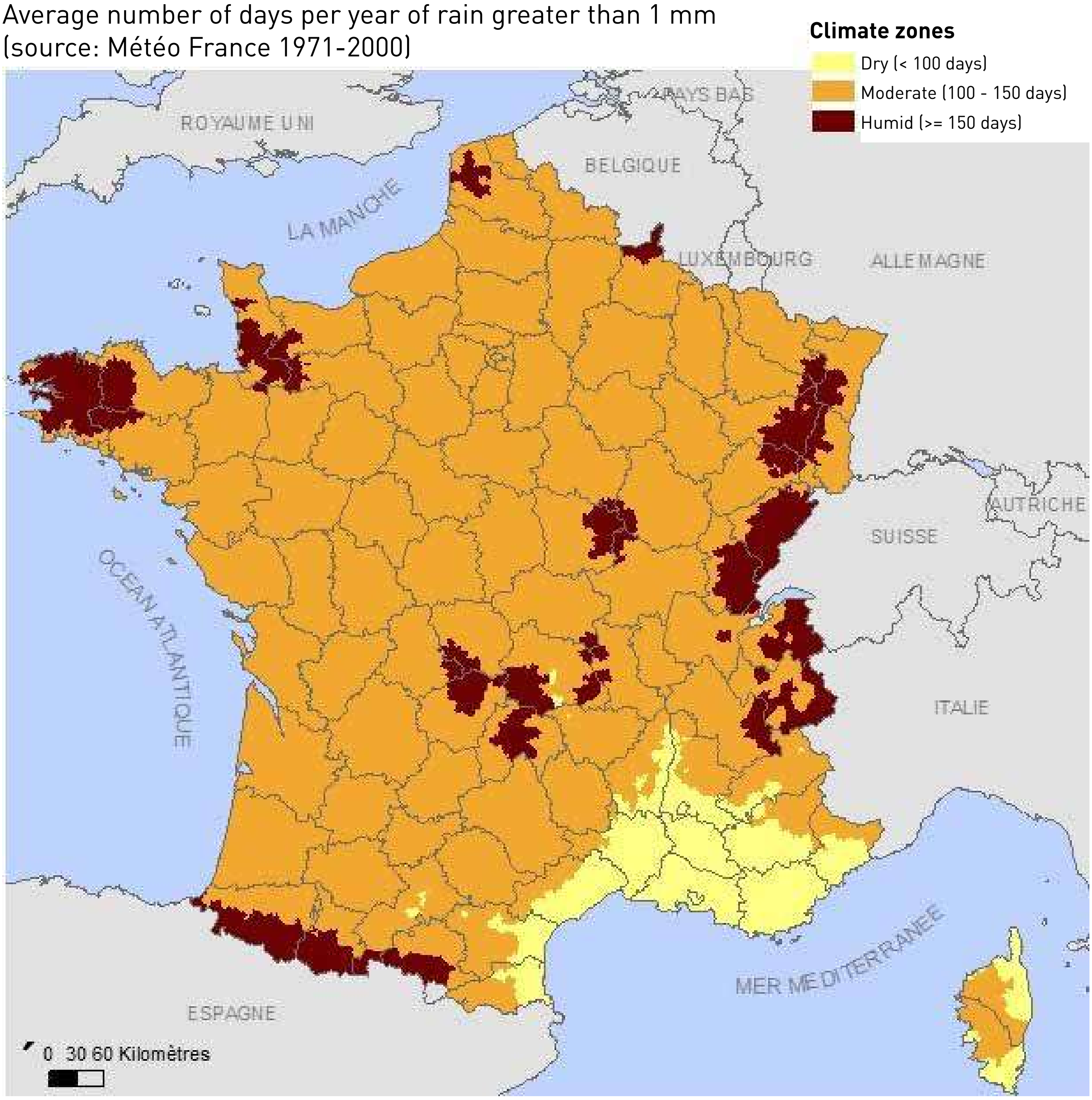
In any case, a highly durable timber, falling under durability class 1, can be used with an acceptable life span in an environment favourable to biological degradation agents, i.e. those falling under usage class 4.

Conversely, it is possible to use timber with a low level of durability, i.e. those falling under durability class 5, for usage class 1 purposes (without forgetting the risk of damage by xylophagous larvae insects and termites).

9. View the map of France on the final page.
10. Desorption is the opposite phenomenon of adsorption.
11. Relating to fungi.

ANNEX 1

Average number of days per year of rain greater than 1 mm
(source: Météo France 1971-2000)



ANNEXE 2

SOFTWOODS

French name	MV min kg/m³	MV kg/m³	MV max kg/m³	Fungus	Hylotrupes	Anobium	Termites	Impregnability	Sapwood	Sapwood width	Marine borers
Agathis	430	490	530	3_4	S	S	S	3	nd	x	
Douglas	510	530	550	3	S	S	S	4	3	f	
Douglas	470	510	520	3_4	S	S	S	4	2_3	f	
Epicéa	440	460	470	4	SH	SH	S	3_4	3v	x	
If	650	690	800	2	S	S	nd	3	2	tf	
Mélèze	470	600	650	3_4	S	S	S	4	2v	f	
Pin des Caraïbes	710	750	770	3	S	S	M_S	4	1	m	
Pin Laricio	510	580	650	4v	S	S	S	4v	1	m_l	
Pin maritime	530	540	550	3_4	S	S	S	4	1	l	
Pin de Parana	500	540	600	4_5	D	S	S	2	1	l	
Pin radiata	420	470	500	4_5	S	SH	S	2_3	1	l	
Pin sylvestre	500	520	540	3_4	S	S	S	3_4	1	f_m	
Pin weymouth	400	410	420	4	S	SH	S	2	1	l	
Pitchpin	650	660	670	3	S	S	M_S	3_4	1	m	
Pitchpin cultivé	400	450	500	4	S	S	S	3	1	m	
Pin de Murray	430	460	470	3_4	S	S	S	3_4	1	m	
Sapin	440	460	480	4	SH	SH	S	2_3	2v	x	
Sitka	400	440	450	4_5	S	SH	S	3	2_3	(x)	
Sugi (Cryptomeria)	280	340	400	5	D	nd	S	3	1	f	
Western red cedar	330	370	390	2	S	S	S	3_4	3	f	
Western red cedar	330	370	390	3	S	S	S	3_4	3	f	
Western hemlock	470	490	510	4	S	SH	S	3	2	x	
Western hemlock	470	490	510	4	S	SH	S	2	1	x	
Yellow Cedar	430	480	530	2_3	S	S	S	3	1	f	

HARDWOODS

French name	MV min kg/m³	MV kg/m³	MV max kg/m³	Fungus	Hylotrupes	Anobium	Termites	Impregnability	Sapwood	Sapwood width	Marine borers
Abura	550	560	600	5		nd	S	2	1	m	
Acajou d'Afrique	490	520	530	3		nd	S	4	2	f	
Afrormosia	680	690	710	1_2		nd	D	4	1	tf	M
Aiélé	490	500	530	5		nd	S	4	1	m	
Ako	430	450	460	5		nd	S	1	1	x	
Amarante	830	860	880	2_3		nd	D	4	1	f	
Andiroba	610	620	640	3_4		nd	M	3	nd	f	
Aniégré	540	580	630	4_5		nd	S	1	1	x	
Aulne	500	530	550	5		S	S	1	1	x	
Avodiré	540	550	560	4		nd	S	4	1	x	
Ayous	370	390	400	5		nd	S	3	1	x	
Azobé	950	1060	1100	2v		nd	D	4	2	f	M
Bangkirai	700	930	1150	2		nd	D	4	1_2	f	
Basralocus	720	750	790	2v		nd	M	4	2	f	D
Bilinga	740	750	780	1		nd	D	2	1	f	M
Bintangor	630	660	690	3		nd	M	4	2	f	
Blue Gum	700	750	800	5		nd	S	3	1	f	
Bouleau	640	660	670	5		S	S	1_2	1_2	x	
Bouleau jaune d'Amérique	550	670	710	5		S	S	1_2	1_2	x	
Bouleau à papier	580	620	740	5		S	S	1_2	1_2	x	
Bossé clair	570	580	630	2v		nd	S	4	1	m	
Bossé foncé	600	690	850	2		nd	S	4	1	m	
Bubinga	700	830	910	2		nd	D	4	1	f	
Cedro	450	490	600	2		nd	M	3_4	1_2	f	
Cerejeira	550	600	650	3		nd	M	2	2	m	
Charme	750	800	850	5		nd	S	1	1	x	
Chataignier	540	590	650	2		S	M	4	2	f	
Chêne chevelu	710	770	860	3		nd	M	4	1	l	

French name	MV min kg/m³	MV kg/m³	MV max kg/m³	Fungus	Hylotrupes	Anobium	Termites	Impregnability	Sapwood	Sapwood width	Marine borers
Chêne rouvre	670	710	760	2		S	M	4	1	f	
Chêne blanc d'Amérique	670	730	770	2_3		S	M	4	2	f	
Chêne rouge d'Amérique	650	700	790	4		nd	S	2_3	1	f	
Dibétou	520	550	590	3_4		nd	S	3_4	2	f	
Doussié	730	800	830	1		nd	D	4	2	f	
Erable sycomore	610	640	680	5		S	S	1	1	x	
Eyong	700	730	800	4		nd	S	3_4	1	x	
Faro	480	490	510	4_5		nd	S	2_3	1	l	
Framiré	520	550	560	2_3		nd	S	4	2	(x)	
Freijo	520	540	550	2		nd	M	3	1	f	
Frêne	680	700	750	5		S	S	2	2	(x)	
Fromager	290	320	350	5		nd	S	1	1	x	
Greenheart	980	1030	1150	1		nd	D	4	2	f	D
Hêtre	690	710	750	5		S	S	1_(4)	1	x	
Hickory	790	800	830	4		nd	S	2	1	x	
Ilomba	440	480	510	5		nd	S	1	1	x	
Iroko	630	650	670	1_2j		nd	D	4	1	m	
Jarrah	790	830	900	1		nd	M	4	1	f	
Kapur	630	700	790	1_2		nd	M	4	1	m	
Karri	800	880	900	2		nd	nd	4	1	f	
Kasai	650	710	750	3		nd	M	3_4	2	m	
Kempas	850	860	880	2		nd	S	3	1_2	f	
Keruing	740	750	780	3v		nd	S	3v	2	f	
Kondroti	470	480	490	5		nd	S	1	1	l	
Kosipo	640	670	720	2_3		nd	M	3	1	f	
Kotibé	710	730	760	3v		nd	M	3_4	1_2	f	
Koto	510	560	630	5		nd	S	1	1	x	
Lati	730	750	770	3		nd	M	4	2	m	
Lenga	530	540	550	5		nd	S	4	nd	f	
Limba	550	560	600	4		nd	S	2	1	(x)	

French name	MV min kg/m³	MV kg/ m³	MV max kg/m³	Fungus	Hylotrupes	Anobium	Termites	Impregnability	Sapwood	Sapwood width	Marine borers
Longhi	700	730	800	4		nd	M	2	1	x	
Louro vermelho	600	620	650	2		nd	D	4	2	m	
Mahogany	510	550	580	2		nd	S	4	2_3	m	
Makoré	620	660	720	1		nd	D	4	2	m	
Mansonia	610	620	630	1		nd	D	4	1	f	
Maronier d'Inde	500	540	590	5		SH	S	1	1	x	
Mengkulang	680	710	720	4		nd	S	3	2	f	
Meranti Dark red	600	680	730	2_4		nd	M	4v	2	f	
Meranti Light red	490	520	550	3_4		nd	S	4v	2	m	
Meranti Yellow	560	630	660	4		nd	S	3_4	2	m	
Meranti White	600	630	670	5		nd	S	3v	2	f	
Merbau	730	800	830	1_2		nd	M	4	nd	m	
Mersawa	520	650	740	4		nd	M	3_4	nd	x	
Moabi	770	800	830	1		nd	D	3_4	nd	m	
Moral	750	890	960	1		nd	D	3_4	nd	f	
Movingui	690	710	740	3		nd	M	4	nd	f	
Muhuhu	830	910	960	1		nd	S	4	nd	f	
Mutenyé	760	820	880	3		nd	M	3_4	2	f	
Niangon	670	680	710	3		nd	M	4	3	m	
Noyer	630	670	680	3		S	S	3	1	f	
Noyer d'Amérique	550	620	660	3		nd	nd	3_4	1	f	
Okan	850	920	960	1		nd	D	4	3	f	
Okoumé	430	440	450	4		nd	S	3	nd	f	
Olon	500	550	640	3		nd	M	2_3	2_3	x	
Orme	630	650	680	4		S	S	2_3	1	f	
Ovengkol	720	780	820	2		nd	D	3	1	m	
Padouk	720	740	820	1		nd	D	2	nd	m	
Pau Amarello	730	770	810	1		nd	D	3_4	nd	x	
Peroba rosa	650	750	800	3v		nd	S	3	1	f	
Peuplier	420	440	480	5		S	S	3v	1v	x	

French name	MV min kg/m³	MV kg/m³	MV max kg/m³	Fungus	Hylotrupes	Anobium	Termites	Impregnability	Sapwood	Sapwood width	Marine borers
Quaruba	450	490	510	4		nd	S	3	2	m	
Ramin	560	630	670	5		nd	S	1	1	x	
Rauli	530	580	610	4		nd	S	2	2	f	
Red Balau	750	800	900	3_4		nd	M	4v	2	f	
Robinier	720	740	800	1_2		S	D	4	1	tf	
Sapelli	640	650	700	3		nd	M	3	2	m	M
Sepetir	650	660	670	2		nd	S	4	2	l	
Sesendok	420	480	530	5		nd	S	1	1	nd	
Silver Beach	540		550	5		nd	nd	4	1	m	
Sipo	590	640	660	2_3		nd	M	4	2	m	
Tchitola	590	610	640	3		nd	M	3_4	1	l	
Teck	650	680	750	1		nd	M	4	3	f	M
Teck de plantation				1_3		nd	M_S	nd	nd	nd	
Tiama	550	560	570	3		nd	S	4	3	l	
Tilleul	520	540	560	5		nd	S	1	1	x	
Tola	480	500	510	2_3		nd	S	3	1	m	
Tornillo	370	520	660	3		nd	S	2_3	nd	f	
Virola	400	440	480	5		nd	S	1_2	1	x	
Walaba	890	900	910	1		nd	D	4	3	f	
Wengé	780	830	900	2		nd	D	4	nd	f	

Key for the above tables:
Durability against fungi: 1 = very durable; 2 = durable; 3 = moderately durable; 4 = slightly durable; 5 = not durable
Durability against xylophagous larvae insects, Hylotrupes (woodboring beetles) and Anobium (furniture beetles): S = sensitive, D = durable
Durability against termites: S = sensitive, M = moderately durable, D = durable
Durability against marine borers: S = sensitive, M = moderately durable, D = durable
Impregnability: 1 = impregnable, 2 = moderately impregnable, 3 = slightly impregnable, 4 = non-impregnable
Sapwood width: tf < 2 cm, f < 5 cm, m < 10 cm, l > 10 cm, x no distinction
Durability against marine borers: D = durable, M = moderately durable, S = sensitive.
«nd» = performance not determined

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A FEW CLARIFICATIONS ARE IN ORDER!

TIMBER HUMIDITY

HUMIDITY CONTENT OF TIMBER

The humidity of timber is defined by the EN 13183 standard as the ratio of the mass of water contained in the timber to the mass of dry timber:

H % = Mass of water / Mass of dry timber

Note: The humidity content of timber in standing trees varies between 60% and 200% depending on the species. There are two types of water present in timber: free water and bound water.

Free water is contained in the cells (the cell is similar to a tube, its interior space is called the cell void). It is easy to extract from the timber; in this case we speak of draining and drying.

Bound water is inside the cell walls and can only be extracted in the form of steam; this is referred to as drying.

Let's compare the behaviour of timber to that of a sponge. When the latter has just been immersed in water, it is soaked and swells, and a simple squeeze is enough to extract the «free» water from it. This operation does not make the sponge «dry», though, as it must be exposed to as dry an environment as possible in order to evacuate the «bound» water, and the sponge will often firm up while deforming itself. However, no matter the environment, a balance is reached between the water in the atmosphere and the water contained in the material (see the hygroscopic equilibrium nomogram).

Using the above humidity definition, we refer to the fibre saturation point as FSP, the timber humidity level at which the amount of bound water in the timber is at maximum without the presence of free water. This value is particularly important for shrinkage calculations, as below this value, humidity variations are accompanied by size variations. This phenomenon is also similar to the behaviour of a sponge. FSP = Saturated bound water mass / Mass of dry timber.

For temperate timbers (softwoods, oaks, sweet chestnut trees, ...), the FSP reaches a 30% humidity level and is considered to be equal to this value in most documents. In contrast, the FSP of tropical timber varies between 15% and 45% depending on the species.

The technical data sheets of each species provide information on the timber's FSP. The data are averages and it is therefore possible to find variations (+ or -) in terms of the average value that is given.

METHOD OF DETERMINING THE HUMIDITY LEVEL

The most reliable way to determine the humidity level in timber is by measuring differences in mass. A sample of timber of any shape (rather small in size, particularly in the longitudinal direction of the fibres, so as to reduce the drying time) is weighed and its wet mass is noted as Mh. This sample is then dried completely in a ventilated oven at 103°C (± 2°C to be above the boiling temperature of water but without degrading the timber). The sample is weighed regularly until it stabilises at its anhydrous weight; its anhydrous mass is noted as M0. The mass of water is deduced as the difference between the mass of the humid timber and that of the dry timber. Thus, the humidity content level is determined by:

$$H\% = (Mh - M0) / M0$$

Some devices allow you to measure the humidity content of timber without destruction, provided that they are correctly calibrated for the type of timber being examined.

There are two types of instruments, some of which some operate by measuring the resistivity and others by measuring the capacitive effect.

As timber is an insulating material par excellence (thermal, acoustic, electrical, etc.), water is quantified in proportion in the timber according to the behaviour of an electromagnetic field.

HYGROSCOPIC EQUILIBRIUM

Depending on the environment in which the timber is, its stabilising humidity content is defined by the air's temperature and relative humidity (the amount of water vapour in the air). This timber humidity is said to be in hygroscopic balance with its surroundings. These equilibrium humidity values are listed in a hygroscopic equilibrium nomogram. They have been calibrated for temperate timber whose fibre saturation point is 30% (equilibrium at 0°C and 100% air humidity).

For tropical timber, where the FSP is much more variable, the equilibrium humidity level isn't always exactly as shown on the nomogram.

For example, for timber with an FSP of 30% in an environment with a 20°C temperature and a relative air humidity level of 65%, its hygroscopic equilibrium humidity level is close to 12%.

The time required for the timber to reach the equilibrium humidity level varies according to the type of timber, its cross-section, and the humidity variations it is subjected to. It can be accelerated at higher temperatures (the artificial drying principle). In reality, an equilibrium humidity level is never reached, as humidity stabilises at about 1% above the equilibrium humidity level during drying and about 1% below the equilibrium humidity level during humidification.

TRADE NAMES

Humidity rate H	Denomination of timber at rate H	Form of water in the timber
> PSF	Green or fresh timber	Free water, impregnation water, combined water
PSF	Saturated timber	Saturation point: (without free water) impregnation water is at its maximum, combined water
22 à PSF %	Dried or semi-dry timber	Impregnation water and combined water
17 à 22 %	Commercially dry timber	
13 à 17 %	Air-dried timber	
< 13 %	Dried out timber	
0 %	Anhydrous timber	Combined water

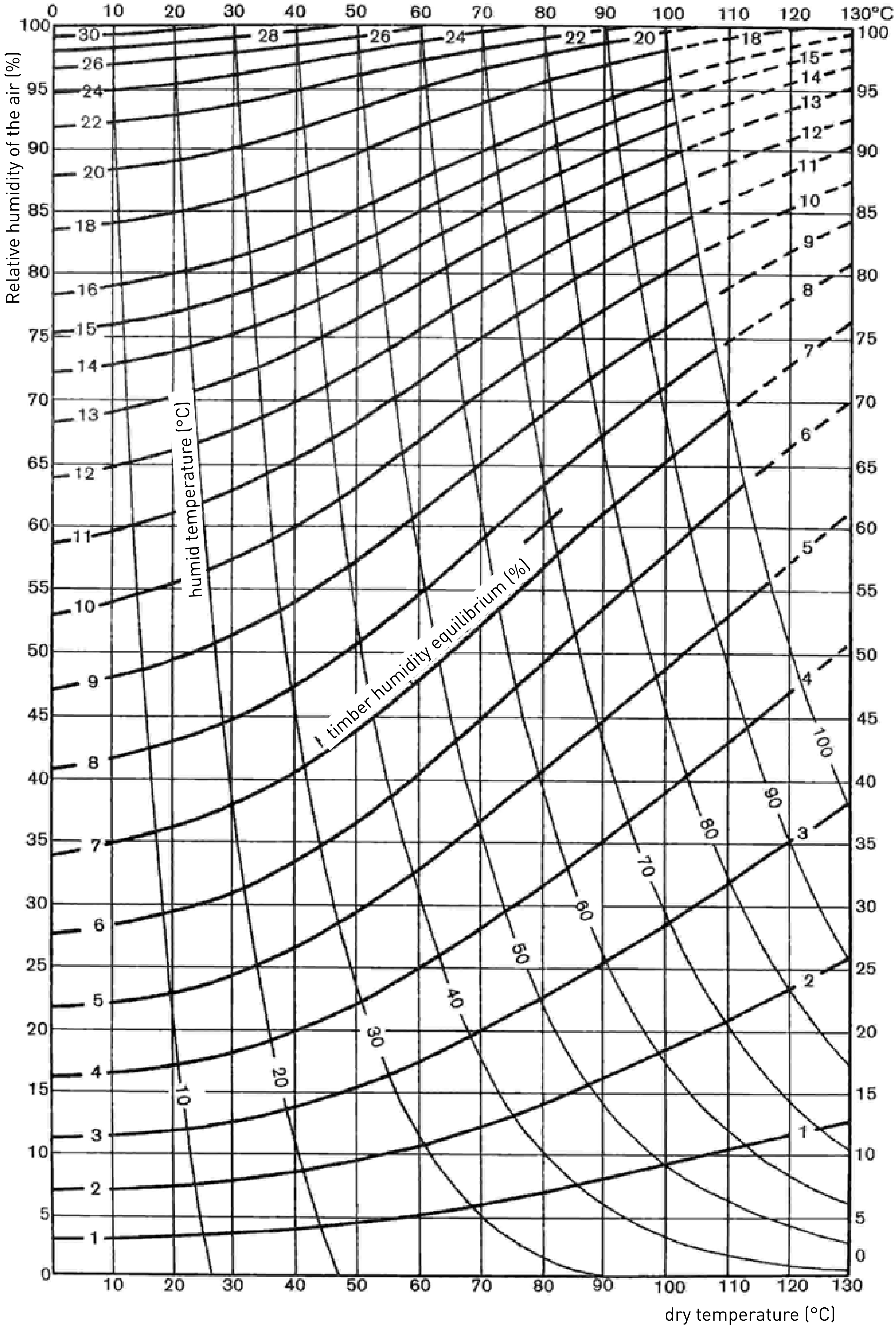
The trade names AD (Air Dried), KD (Kiln Dried) and «shipping dry» are frequently misused.

KD means «kiln dried». The humidity rate that is achieved must always be specified. It is usually set between 9% and 22%.

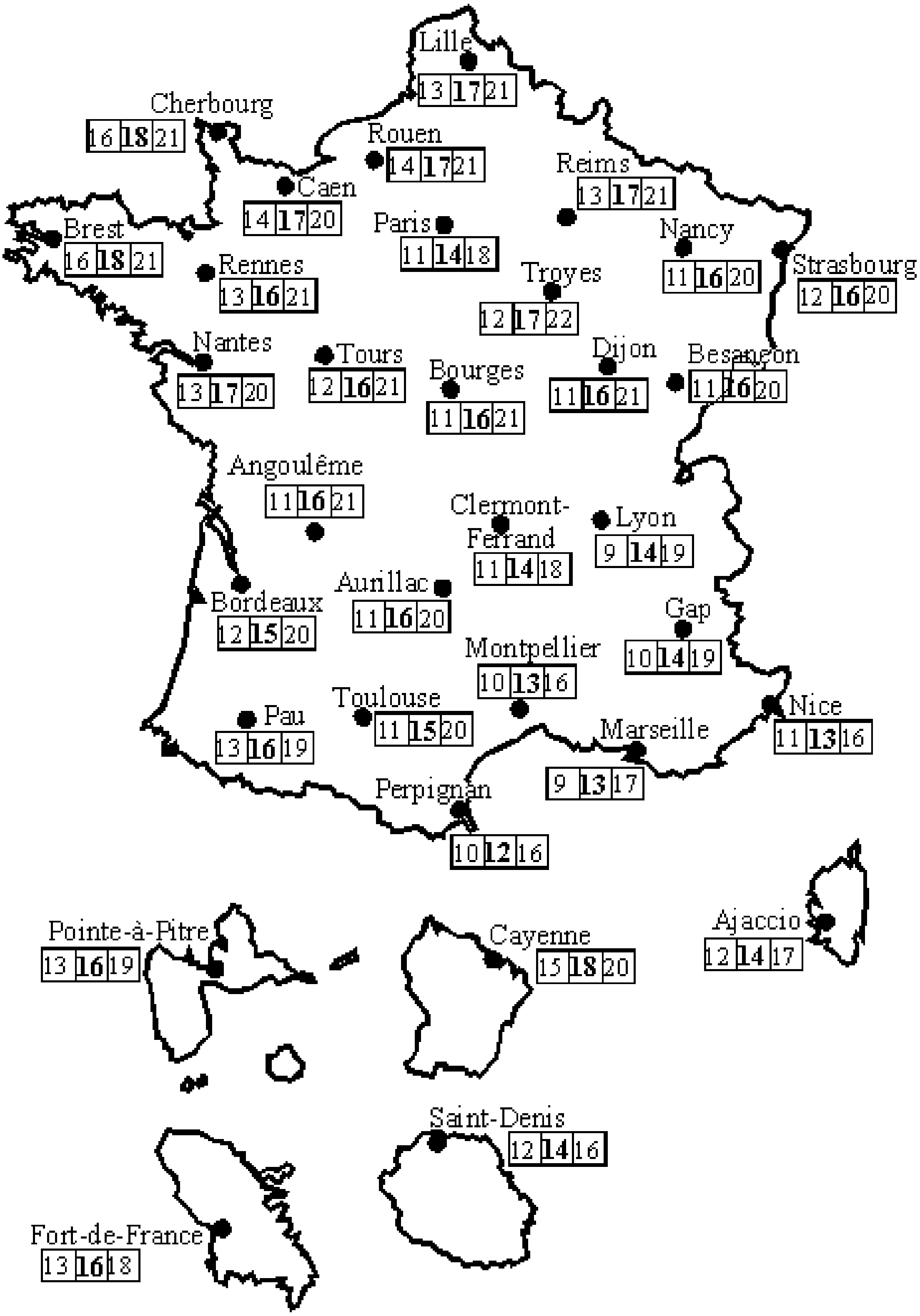
AD means «air-dried». According to the previous definitions, the humidity rate is between 13% and 17% here. The various European standards set the threshold at 20%. Please note: some producers and suppliers understand this term to mean «air-drying in progress», i.e. not necessarily dried. This misnomer can have serious repercussions; it is therefore necessary to be vigilant regarding the use of the term AD.

Shipping dry means «dry on board «. According to INCOTERMS, sawn timber must be dry enough to withstand transport without damage. It scientifically recognised that the timber humidity rate above which fungi can degrade the timber is 22%. Shipping dry indicates a timber humidity rate that is below 22%.

HYGROSCOPIC EQUILIBRIUM NOMOGRAM FOR TIMBER (30% FSP)



HYGROSCOPIC EQUILIBRIUM NOMOGRAM FOR TIMBER (30% FSP)



Key: equilibrium humidity in timber in %

A	B	C

A : minimum (average over 3 consecutive months)
B : average (annual average)
C : maximum (average over 3 consecutive months)

FSC PEFC

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LES NIVEAUX DE TRANSFORMATION DU BOIS

La commission technique de l'ATIBT définit par le présent document les niveaux de transformation du bois. Fruit d'un travail de compilation, les destinataires en seront notamment : les Ministères et autorités intéressées, les douanes, les entreprises et tout autre organisme impliqué dans la filière.

La filière bois comprend trois niveaux de transformation décrits ci-après. Ces niveaux sont indépendants du nombre d'étapes de transformation du produit.

PREMIÈRE TRANSFORMATION

La première transformation est l'ensemble de toutes les opérations directement effectuées sur les bois ronds qui permettent d'obtenir un autre produit. Les produits issus de la première transformation sont :

- Equarris,
- Equarris ou sciages de souches, fourches ou branches,
- Avivés bruts,
- Plots,
- Placages tranchés ou déroulés,
- Bois fendus,
- Plaquettes, sciures, copeaux,
- Pâte à papier,
- Bois de feu,
- Charbon de bois (en vrac).

SECONDE TRANSFORMATION

La seconde transformation du bois apporte de la valeur ajoutée aux produits issus de la première transformation sans aboutir aux produits finis. Les produits issus de la deuxième transformation sont :

- **Bois traités,**
- **Bois séchés artificiellement (KD),**
- **Bois rabotés, moulurés ou poncés,**
- **Lames de bois massif semi-finies,**
- **Bois tournés,**
- **Carrelets de menuiserie (lamellés collés et/ou aboutés),**
- **Pellets, briquettes et autres combustibles en vrac.**

TROISIÈME TRANSFORMATION

La troisième transformation se consacre à la fabrication des produits finis à partir des produits issus de la première ou de la deuxième transformation. Les produits issus de la troisième transformation sont :

- Objets sculptés,
- Instruments de musique et éléments d'instruments de musique,
- Meubles et éléments de meubles,
- Menuiseries (cadres, portes, fenêtres et éléments de cadres de fenêtres…),
- Lames et profilés finis (parquets, bardages, lambris, decking (terrasses), lambourdes),
- Marqueteries,
- Panneaux (massifs, de particules, de fibres, OSB, contreplaqués, lattés, BMR/CLT…),
- Plans de travail,
- Palettes et caisserie,
- Fermettes industrielles,
- Tonneaux,
- Pieux et piquets appointés,
- Traverses de chemin de fer façonnées (percées, entaillées, chanfreinées),
- Papier, carton, charbon de bois ensaché.

Exemples

Crédit photos Groutel / Wale

1ère transformation plot non séché

1ère transformation sciage avivé non séché

2ème transformation moulure

3ème transformation decking

3ème transformation pieux appointés

Fair&Precious recommande l'achat de bois tropical certifié FSC® et PEFC-PAFC.

Document réalisé par la commission Matériau-Bois-Normalisation de l'ATIBT par MM. Patrick Martin (Secrétaire) et Emmanuel Groutel (Président).

A FEW CLARIFICATIONS ARE IN ORDER!

TIMBER NAMES

INTRODUCTION AND ISSUES

As timber is derived from a tree, it is often accepted that it carry the Latin botanical name given to the tree by scientists. This can be summarised by its genus and its species. For the record, this name is given on the basis of criteria relating to the tree's leaves, flowers or fruits, but not the timber that it produces. Several difficulties arise at this level: the botanical name isn't easy to remember, and in the field, the woodcutter or person carrying out the forest inventory will have a hard time identifying the species with certainty.

At the practical level, **users are looking for the most homogeneous physical, mechanical or aesthetic properties possible.** The characteristics of a type of timber depend on the cellular arrangements of the timber and their structure. Usually, the botanical species (the tree) ensures that a user will know its expected properties. However, sometimes within the same species the timber will have characteristics that vary due to environmental factors (nature of the soil, sunlight, water, silviculture, etc.) of the place where the tree grows and **the botanical name criterion will no longer be sufficient.** Other criteria, such as density or colour, can be added to reduce this variability. Examples: plantation teak (Tectona grandis) won't have the same durability as a natural forest teak if forestry is intensive.

In addition, it is often the case that several species - of the same genus or of different genera - produce timber with relatively uniform characteristics. For this reason, and since ancient times, timbers have been marketed under **Variety** names, which can include several genera and species. Such naming is perfectly justified because it is specific to the timber itself. There are many examples of several genera and species being grouped together. One of the most obvious is Kedondong, which is the timber variety produced by some species of the Canarium genus, by all species of the Garuga, Protium and Santiria genera and by Dacryodes costata.

Cases where a variety relates to a single species, or all the species of a botanical genus, are very rare. Examples, Sapelli = *Entandrophragma cylindricum*, or Bungur = *Lagerstroemia* sp. pl. (all species of the genus).

Note that to identify several species falling under a genus, the abbreviation «sp. pl.» (which means *species pluralis*) was created. (Although equivalent to spp, sp. pl. is preferred to avoid further confusion with sp., ssp. or sspp. which don't mean species *pluralis*). Please note that this abbreviation doesn't mean that a variety covers all of the species of the genus. The same also applies to temperate varieties. For example, the European oak can be designated as Quercus sp. pl. (*Quercus robur, Quercus pedonculata,* etc.) but it would not be acceptable to mix holm oak (*Quercus ilex*) with it or cork oak (*Quercus suber*). Another example are the following varieties: Red Balau, Yellow Balau, Dark Red Meranti, Light Red Meranti, White Meranti, Yellow Meranti, which are all different and come from various species of the same Shorea genus.

The name of a variety is generally relayed in each country and region by common names given by the people, known as «**vernacular**» names or also «ordinary» or «trade» names. As there are many vernacular names out there, the risk of confusion is too great for the trade. It is not uncommon that - depending on the origin of the timber - a single vernacular name can apply to different varieties. For example, the Ipé, which means «bark» in Brazilian, is a vernacular name given to timbers whose trees have a characteristic bark. In fact, many timbers have the vernacular name Ipé without having the characteristics of the Ipé variety that European users expect.

BACKGROUND AND SOLUTION

To this end, 60 years ago ATIBT established a **nomenclature** of tropical timbers defining each variety by a unique internationally recognised **pilot name** with all of the botanical species that it includes. The merits of this nomenclature were fully understood by France's Ministry of Economy, Finance and Industry, which recognises ATIBT as the «guardian of the temple» in terms of tropical timber nomenclature. Regular updates are necessary to introduce or remove certain varieties according to market volumes, but also because botanical names can evolve. For example, the Tabebuia genus, some of whose species corresponded to the Ipé, has become Handrohantus to some extent.

This pilot name is the result of a choice made for practical reasons, using the usual name under which the timber is most commonly traded, adopted either by the main exporting country or by the main importing country. The determination of a variety's pilot name is crucial, as its commercialisation depends very largely on the adoption of this name by the public. In addition, protection of the name ensures that the properties of the variety it covers remain constant.

Another solution to simplify the names without risk of confusion would be to use the 4-letter code defined in European standard EN 13556. As with ATIBT's nomenclature, this classification of varieties defines the genera and species that are relevant in terms of the properties that are needed. For example, Azobé (*Lophira* sp.pl., L. *alata*, L. *procera*) is identified by LOAL.

Gaps and omissions make this standard difficult to use at the moment, but its revision is underway and ATIBT is highly committed to this effort.

THE TIMBER NAMES MENTIONED IN THE EUTR

The «trade name» and «common name» mentioned by the EUTR are both synonymous with the «vernacular name». Therefore, neither of them ensures the accuracy of the information.

Regarding «where appropriate», the need to add the scientific name of the variety in the information to be gathered is specified in the EUTR's implementing regulation. It appears in article 3 «Information on the supply of timber by the logger», paragraph 2: «*The full scientific name of the forest variety referred to in article 6, paragraph 1 (a) of (EC) regulation no. 995/2010 shall be communicated in cases where the use of a variety's common name is ambiguous*».

In this respect, if the vernacular name isn't the pilot name, ambiguity may occur, and «where appropriate» therefore becomes the rule. This rule is impossible to implement, because without a botanical analysis upstream of the logging operation or a downstream anatomical analysis (which cannot always be carried out until the species is determined), it is risky for a producer to specify a precise species.

CONCLUSION

The full scientific name is only necessary in the event of ambiguity and should therefore not be provided systematically.

In terms of timber designations, the name of a timber is always its variety name. **This variety name is defined by a multitude of vernacular names which can be ambiguous, and by a single pilot name that ATIBT has retained in order to eliminate confusion in trade.** This timber variety is generally from several types of trees, each individually defined by a botanical name (genus and species) in Latin. The relationship between varieties and botanical names is a link (more complex than it seems) that is dealt with in ATIBT's nomenclature.

ATIBT's latest nomenclature version dates from 1982. Along with several experts in the field, the association's technical director updates this nomenclature. Once completed, it will be available on ATIBT's website (www.atibt.org) and on the legal-timber.info website (www.legal-timber.info).

Key takeaways:
In order to meet EUTR requirements in terms of information on tropical timber varieties, ATIBT's timber variety pilot name is both necessary and sufficient. Moreover, the 5 April 2005 circular issued by France's Ministry of the Economy, Finance and Industry validated the usefulness of these pilot names: «... in the case of timber from tropical forests, the document must specify the variety's scientific name in Latin or, failing that, the pilot name set by ATIBT...». However, if you would like more information, the correspondence between the pilot names - vernacular names - botanical names can be found in ATIBT's nomenclature.

A FEW CLARIFICATIONS ARE IN ORDER!

WOODWORMED TIMBER

Some timber varieties may feature galleries (in the form of small holes) of varying sizes (3 to 16 mm in diameter), which are said to be «woodwormed».

ORIGIN IN THE TREE

These galleries are caused by insects or xylophagous larvae of the longhorn beetle or cerambycid type which perforate the timber in the forest, when the tree is still growing or has just been felled. The adult insects bore galleries to lay eggs. The larvae develop there according to a cycle specific to each type of insect, and the adult insects return to the outside through flight holes.

The galleries created by these insects can be several decades old, or even a century or more if the felled tree is very old.

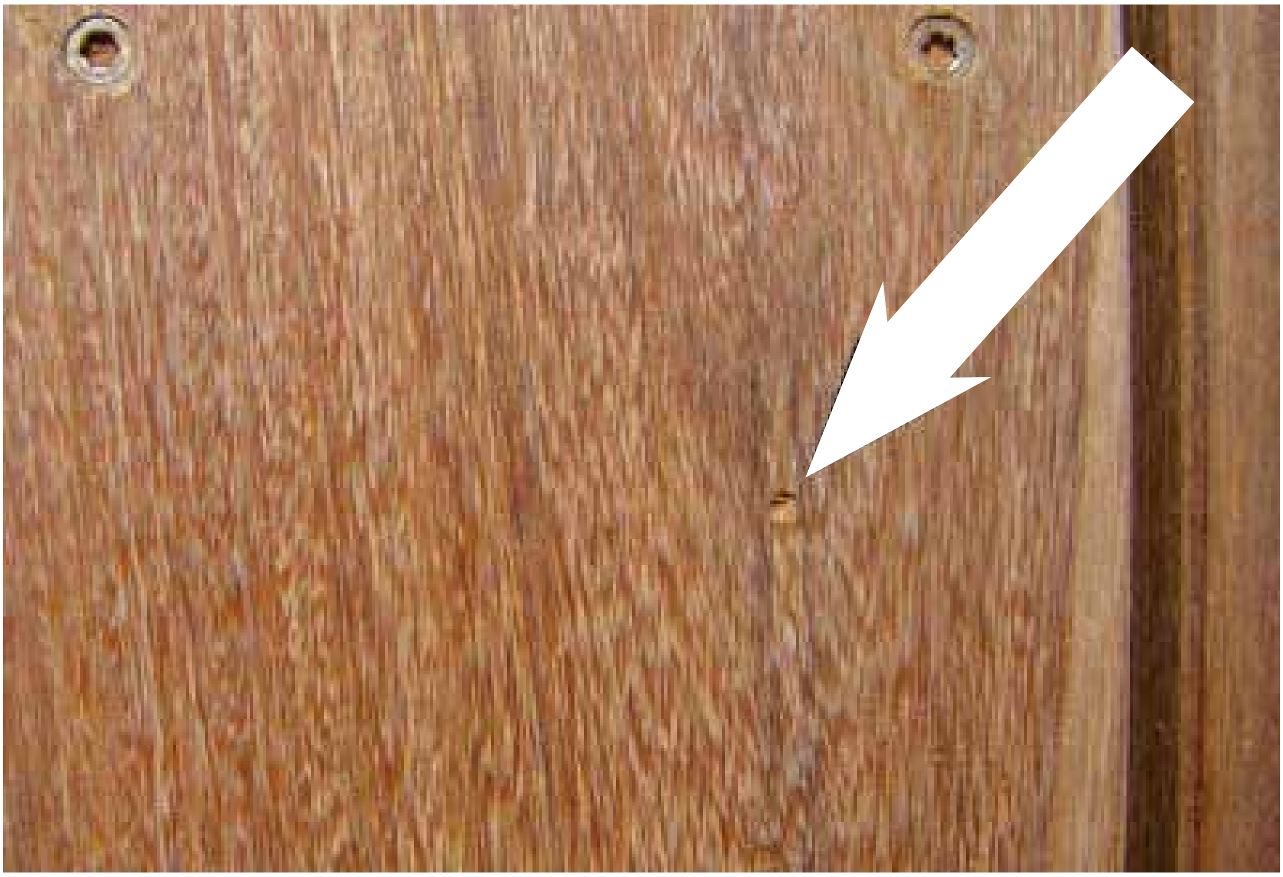
These insects only live and reproduce in tropical climates, they cannot survive and proliferate in temperate climates.

The holes visible on the Ipé boards either represent the perforations of the adult insects when they arrive to lay their eggs, or the galleries dug by the larvae or even the flight holes of the young insects following the pupal stage.

The galleries are often accompanied by abnormal staining that follows the grain of the timber, from and around the perforations.

The sometimes «late» and gradual appearance of the perforations has a simple explanation: the excrement and sawdust emitted by these timber borers often form a natural plug, or «putty», that will effectively block the hole in a durable manner. **Some insects voluntarily obstruct the galleries with these «plugs» in order to protect their egg-laying from external predators.**

Example of a perforation that is barely visible because it is still obstructed:



PARTICULARITIES OF THE CELLS

During machining operations, galleries aren't always visible; only possible discolorations that accompany them can attract attention. Once in use and with time, the galleries open up. Poor weather accelerates the appearance of these galleries by making the plugs «pop out». Occasional pine holes and galleries aren't considered to be critical defects in the tropical timber trade. Commercial batches of timber from Asia are often marked «PHND», which stands for «Pine Holes No Detect», to indicate that they are free from this type of defect.

CONCLUSION

These are small-diameter, occasional galleries that have no impact on the durability of the structure and cannot propagate. The phenomenon is purely aesthetic and is tolerated when the galleries are occasional and scattered on boards. «*Woodworming*» is a defect specific to certain varieties, such as the Ipé. The French NF B 54 040 standard «Characteristics of exterior timber decking boards» tolerates this defect when it is «occasional and in a scattered fashion».

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A FEW CLARIFICATIONS ARE IN ORDER!

DRYING

A standing tree can contain a very large amount of water necessary for its life and its development. In most cases, and in order for the timber to be used, most of this water must be removed to prevent excessive deformations and shrinkage, to reduce the risk of degradation by biological agents, to improve physical and mechanical properties, and to facilitate machining or gluing, as well as the application of finishes.
The timber's humidity content tends to naturally balance out in the environment in which it is found. The drying speed depends mainly on the timber's initial humidity content, the final equilibrium humidity content, the cross-section of the timber to be dried, the timber's variety, the exposure to weather, the renewal of air, etc.
Drying the timber to a humidity as close as possible to the equilibrium humidity that it will reach in the final structure is one of the basic rules that should be kept in mind to avoid a large number of incidents.

NATURAL DRYING

Air circulation generated by wind and local convection, as well as heat from solar energy, favour the evaporation of humidity contained in timber. In order to facilitate air circulation between planks, they should be spaced apart by means of spacer strips referred to as wooden spacers. In practice, the boards are stacked in several rows (or beds) and spaced apart by the height of the wooden spacers placed perpendicular to the length of the boards. This arrangement is also the most common way of packing packages (or stacks), taking into consideration both ease of handling and transport in addition to ventilation.
The size of the stacks must remain below 1.8 metres, otherwise the air circulation speed is insufficient. The height of the stacks is only limited by their stability. If the boards to be stacked are of different lengths, the longest ones should be placed in the first row and in descending order. Also, where lengths permit, it is possible to arrange several planks in one length by adding short wooden spacers to support the ends of the planks.

The most appropriate thickness of the wooden spacers for hardwoods is 19 mm and 27 mm for softwoods. In order to limit the risk of board deformation during the drying process, a maximum spacing of the wooden spacers between each row is defined according to the thickness of the boards and the timber's density or stiffness. For a stack to receive a new row of boards, the wooden spacers must be placed exactly on top of those supporting the previous row. The ends of the boards must be supported without overhang to avoid bending deformations during drying and to limit the speed of drying of these parts, which can lead to the appearance of cracks.

To further reduce splitting in timber ends, an anti-splitting paint can be applied to the ends of the boards (which may contain an emulsion wax). Or, brackets can be nailed into the ends of the boards, or metal strips, or S-shaped pieces of metal or plastic.

The boards should be arranged in each row with a gap between the edges of at least 1 cm.

Maximum spacing of wooden spacers:

Thickness of the boards	Greater than 50 mm	50 mm to 25 mm	Less than 25 mm
Soft timber	1 000 mm	600 mm	300 mm
Hard timber or with a tendency to deform	600 mm	400 mm	300 mm

The wooden spacers must be dried and possibly treated if they are not naturally durable.

One of the most important drying parameters to manage is the exposure of the stacks to bad weather. Frequent exposure to rain will not allow the timber to dry and may even favour the development of fungi. On the other hand, exposure of the timber to intense sun heat can cause deformations or cracks. Shelter under an open shed or with basic corrugated iron sheeting on the outside is therefore recommended to help the timber dry.

Piles of timber should be built on a stable and possibly drained foundation. The lower rows of the stack should be set well apart from the ground, as air circulation is greatly reduced at ground level and humidity is higher there. This distance should be at least 400 mm with a system that allows air to pass through. The pile can be supported by a structure consisting of lumber planks and/or joists. Regular inspections should be conducted to prevent vegetation from invading the piles, blocking air circulation and allowing insects (especially termites).

KILN DRYING

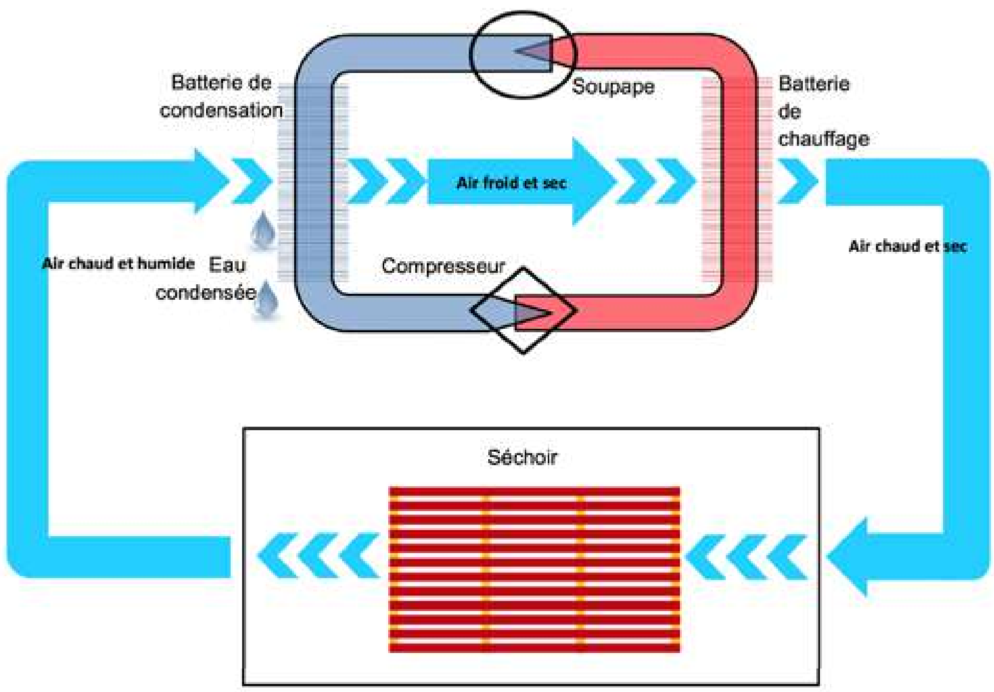
The most frequently encountered artificial drying method is placing piles of timber in an enclosure, called an kiln, where humidity, ventilation and heating are controlled in order to optimise the drying speed. The kilns are differentiated by the type of forced ventilation: longitudinal, top or lateral; and by the heating: steam, hot water, hot oil, hot air or electricity.

The pile is built up using 22 mm thick wooden spacers.

Maximum spacing of wooden spacers:

Thickness of the boards	Greater than 50 mm	50 mm to 25 mm	Less than 25 mm
Hard and soft timber	600 mm	300 mm	200 mm
Timber with a tendency to deform	300 mm	200 mm	200 mm

The optimal air speed for drying most varieties of timber is 3 metres per second. Steering the dryer requires the installation of probes on some of the boards in the stacks to measure the timber's humidity and temperature. Depending on the measurements, the humidity and air temperature are modified in order to keep extracting water from the timber. The humidity gradient, the difference between the timber's humidity and the humidity it should reach in the environment, is defined in a drying chart that is specific for each variety and thickness of timber to be dried.
The water extracted from the timber is found in the ventilation air and must then be extracted from the air. In order to limit the loss of energy in this stage, dehumidification of the air is carried out by condensation in a closed circuit and then by heating.



VACUUM DRYING

As the pressure decreases, the water evaporation temperature also decreases. This principle is used in vacuum dryers by means of a steel container similar to an impregnation tank to generate sub-atmospheric pressure[1]. As for the heat, it isn't introduced into the air, but is usually generated via hollow aluminium plates through which hot water flows. These plates replace the wooden spacers in the stacks. The water contained in the timber evaporates and when the produced water vapour steam comes into contact with the cold wall of the tank, it condenses before being extracted from the tank in a liquid state.

The benefit of this type of dryer compared to a traditional dryer is that it enables small quantities of timber to be dried very quickly. However, there are a few drawbacks: it requires more handling, it consumes more energy and the drying is more heterogeneous.

DRYING ANOMALIES

In addition to deformations of sections (bending, rhombus, etc.) and the deformations along the length of the boards (curvatures, warping, etc.) that occur during drying, the timber may release some of the internal stresses that the tree has accumulated during its growth in order to maintain its balance. This phenomenon is usually accompanied by a loss of material that cannot be predicted prior to the drying process.

End splitting occurs quite easily if the ends of the timber dry too quickly due to a large reduction in cross-section in this area. Timber boards enclosing the core are bound to split due to differences in radial and tangential shrinkage.

Although these imperfections are unavoidable even during careful drying, the following flaws are the result of over-drying:

Surface cracks are caused by a very dry surface (a shrunken layer of wood) of the timber), while the centre of the piece remains humid (and swollen).
Cementation remains the most severe drying flaw because it is imperceptible in appearance. On the surface of timber pieces, the timber becomes impermeable, blocking further drying. This phenomenon is irreversible and causes highly significant deformations during the processing of timber.

Collapses literally mean just that. During the drying process, as free water leaves the timber, surface tension forces are exerted on the cell walls, tending to crush them. When a vapour pocket is formed inside the timber, it exerts sufficient pressure to crush the neighbouring cells and release the vapour they contain, causing a chain reaction. As the timber cools, the vapour turns to water and creates depressions that are large enough to cause the timber to curl up, deforming it and leaving apparent pockets.

Lastly, darker chemical stains may appear during the drying process. The chemical reaction is a form of oxidation. During natural drying, this colouration is superficial, but during forced drying the change in colour can affect the timber in depth. This phenomenon occurs all the more easily on green timbers. To limit the occurrence of this flaw, partial air-drying to the point of fibre saturation is recommended to prevent staining of the timber.

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1. Below atmospheric pressure

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A FEW CLARIFICATIONS ARE IN ORDER!

TIMBER TREATMENTS

WHY TREAT TIMBER?

The purpose of treating timber is to improve its durability[1] when it is insufficient for a particular use; this is referred to as **preventive** treatment. This is not essential if the expected service life is low (e.g. a poplar stake for tomato plants).

It can also be carried out in order to get rid of degradation agents that the timber may contain; this is referred to as **curative** treatment.

The performance of the processes depends on the timber's impregnability[2], the technique that is used, the equipment and possibly even the product that is used. There are different types of treatment: chemical, thermal or a combination of the two.

BIOCIDAL CHEMICAL TREATMENTS

In general, the formulation of a chemical product is created with: biocidal active ingredients[3], molecules that will allow these active ingredients to be fixed onto the wood the timber, and a solvent (petroleum or water) which allows the product to be absorbed by the timber before evaporating. The active ingredients can be mineral substances (metal salts) or synthetic substances of varying degrees of complexity. Several molecules have been developed using molecules that are naturally present in timber: tannins, acids, terpenes, phenolic compounds, etc.

But the great difficulty lies in how we get them to penetrate into the timber and bond with it. This task is much easier with trees, which do it gradually throughout their life as they grow.

Very often, active ingredients target timber degradation agents: lignivorous fungi[4], Lignicolous fungi[5], xylophagous insects[6], termites, etc. Treatment products can combine several active ingredients and thus cover a wide spectrum of action.

1. The timber's resistance to biological degradation agents
2. The timber's ability to absorb liquid
3. Literally means «life-killing»
4. Feeds on timber
5. Lives in timber
6. Which eat timber

The product is applied using different techniques:

- Brushing (brush)
- Spraying (nozzle)
- Soaking (tank)
- Vacuum/pressure (autoclave[7])

«Treatment at the core» is rather misleading, because in most cases the treatment product doesn't make its way throughout the entire volume of the timber, but rather in the periphery over a variable depth. Even if this type of material allows for more effective application, the durability of the treated timber depends on, among other things its impregnability, the initial humidity of the timber, the chemical used, the pressures applied and the duration of the cycles. It is common to see the term «autoclaved timber» used by professionals as a miracle solution for marketing purposes - this term refers to an application process, not to the performance conferred upon the timber.

Another difficulty is that, due to standard requirements, the performance of treated timber is displayed by professionals via a usage class. Example: a «class 4 treated» timber is a timber with conferred durability adapted for usage class 4 (with a guarantee that varies between 3 and 5 years only). This misnomer creates confusion among users (see the durability sheet).

These same standards require that the person treating the timber must be able to provide a **treatment certificate**. This certificate is a declarative commitment that guarantees that the timber has been treated according to product, penetration and retention characteristics that can be verified afterwards as part of a compliance check..

As of 1 June 2007, the REACH (Registration, Evaluation, Authorisation and restriction of CHemical substances) regulations restrict the use of biocidal products via maximum permitted concentrations in timber, given the harmful effects on both humans and the environment.

In particular, the following undesirable elements are being sought by supervisory authorities:

- Pentachlorophenol (PCP);
- Polychlorinated biphenyls (PCBs);
- Carbendazine, chlorothalonil, etc.;
- Heavy metals: lead, cadmium, mercury, etc;
- Restricted substances listed in annex XVII of REACH (compounds made of creosote, arsenic, chromium and cadmium, and compounds made of boron and its derivatives).

France's DGCCRF agency considers that green coloured timber (colour in the mass) may be subject to inspections for traces of copper-based treatments, such as CCA (Copper Chromium Arsenic) or CCB (Copper Chromium Boron) type products, organic copper or that which is copper oxyquinoleate-based. Note: this green colour is sometimes found in new formulations in the form of a dye, only to remind consumers of the performance of products which are now banned in Europe.

7. The autoclave is an enclosure in which vacuum and pressure cycles (using the Bethell process) cause the chemical to penetrate the timber to a greater depth than by soaking.

Moreover, as part of a permanent challenge, chemists are forced to develop new solutions that are the least biocidal as possible in compliance with regulatory requirements and the most biocidal possible according to industrial requirements. The effectiveness of these solutions is to be demonstrated in the laboratory in the absence of feedback from the field.

These techniques make it possible to confer greater durability on timber of low natural durability or of lesser value. However, this conferred durability never reaches the level of the most naturally durable timbers in the long term (e.g. Azobé, Ipé, Teak, etc.), and any post-treatment machining exposes an area of timber whose durability will be lower than that expected. There is no way of restoring the initial level of protection in the field. (Dipping and autoclaving techniques are reserved for industrial preventive treatments, and not applicable to the re-treatment of cuts, which can only be done by spraying and brushing and which offers a lower level of protection).

CREOSOTE TREATMENT

Creosote is a commonly used product reserved exclusively for specific uses: the preservation of railway sleepers and railway sleepers and telephone poles. It differs from other chemicals in two main ways. First of all, the active substances are a collection of numerous molecules resulting from the distillation of coal (between 100°C and 500°C). Secondly, its application doesn't require any solvents; all of the introduced substance is intended to remain in the treated timber for the entire required service life.

The effectiveness of creosote is essentially due to the formation of toxic molecules and a few highly carcinogenic ones (soluble phenols and benzo[a]pyrenes in particular). Creosote treatments are regulated.

ISMP/NIMP 15 TREATMENTS

The International Standards for Phytosanitary Measures (ISPM/NIMP) are established by the International Plant Protection Convention (IPPC), which is part of the United Nation's Food and Agriculture Organization (FAO). This standard provides for measures to limit the risk that pests will appear and spread in timber packaging.

The treatment consists of heating the timber to a minimum core temperature of 56°C for at least 30 minutes. These conditions are lethal to insects in all their forms (eggs, larvae, pupae, imagos[8]). Kiln drying (KD, see the humidity sheet), is considered to satisfy this provision, provided that the prescribed target humidity values are achieved.

This is a **curative** treatment with no guarantee in time (non-preventive). Fumigation is another technique that meets this requirement.

FUMIGATION TREATMENT

Fumigation is a timber treatment that uses toxic gases: methyl bromide, hydrocyanic acid, hydrogen phosphide, ethylene oxide, carbon dioxide, etc. In France, this operation must be carried out by a company approved by the Ministry of Agriculture (list available from the DRAAF body).

8. Adult insect

THERMAL TREATMENT

The timber must first be dried before being placed in a controlled atmosphere, with inert gases (mainly nitrogen) and without oxygen to prevent the material from burning (oxidation). Then, the temperature is gradually increased to a maximum temperature of between 180°C and 250°C. The treatment modifies the most hydrophilic constituents. Lastly, the timber is cooled to room temperature. The total duration of the treatment varies between 10 and 25 hours depending on the timber variety, its thickness and the type of process that is used.

In this type of treatment, the cellulose molecules, starch and various sugars - which are the main food of decay fungi - are broken down. Also, humidity pick-up is greatly reduced and dimensional variations (shrinkage-swelling) are greatly reduced. For these reasons, the development of lignivorous or lignicolous fungi is generally more limited or even almost absent (depending on the thermal treatment process that is used). The timber is browner and smells «cooked». However, thermal treatment does not protect the timber from underground termite attacks.

⚠ Durability is further improved by the fact that the molecules that are preferentially eaten by xylophagous insects are broken down.

In this breakdown, the density, hardness and mechanical properties of the timber are reduced, which sometimes results in infestation by timber-boring organisms.
Singularities (cracks, knots, resin pockets, etc.) cause severe deterioration (deformations or cracks) during treatment. For this reason, timbers without any defects and that feature straight grain are usually selected. When growth rings are highly pronounced, ring detachment and splits are possible.
Full control of the homogeneity of the timber's density is a fundamental factor, without which the densest timbers will be «undercooked» and the least dense timbers will be «overcooked».
Lastly, the radicals that allow water molecules to cling are much rarer, which makes gluing or the application of finishes very difficult.

ⓘ Some manufacturers use the (sometimes protected) terms «retified wood» or «roasted wood» for this process.

ACETYLATION TREATMENT

Acetylation consists in the substitution of active hydrogen atoms (hydroxyl groups) for acetyl groups. Acetic anhydride is commonly used as an acetylating agent. It is also used in the synthesis of both aspirin and heroin.

The reaction of timber with acetic anhydride is an exothermic process9. The timber's temperature must be controlled in order to avoid thermal alteration. Also, the reaction generates acetic acid as a by-product, which must be extracted at the end of the treatment. Acetylation is a slow process that can be accelerated by the use of a solvent and/or a catalyst.

Timber varieties suitable for treatment by acetylation must have good impregnability. Timber varieties with low density (and low natural

ⓘ Some manufacturers market treated timber under a name that masks the original properties of the timber variety, for example: Accoya.

9. That releases heat

These same manufacturers claim that acetylation treatments provide «fast-growing timber varieties with properties equal to or superior to tropical timber varieties». However, the treatment is not effective throughout the entire mass (except in cases of thin layers and reconstituted timber), its stability over time remains to be demonstrated and the mechanical properties of acetylated timber will never reach those of tropical timber. Acetylation-treated products have only been introduced on the European market for less than a decade. It is therefore too early to guarantee performance over periods exceeding this time; the stability of acetyl groups facing temperature variations, UV rays or mechanical stresses (water erosion, pedestrian traffic, etc.) has yet to be demonstrated over the period of use.

FURFURYLATION TREATMENT

Furfurylation is a technique that impregnates timber with a furfuryl alcohol (and polyalcohol) solution which is then polymerised on the cell walls. Furfuryl alcohol is a derivative obtained from many plants (including bran, which carries the Latin name furfur).

Furfuryl alcohol molecules bind to timber under conditions of acidic pH and high temperatures (between 100°C and 150°C). Under these conditions, the lignin and cellulose that will receive the polymer breakdown. The furfurylated timber becomes hydrophobic and more durable against biological degradation agents. At the same time, this treatment leads to an increased density (WPG: Weight Percent Gain) of 0% to 125%, which is accompanied by enhanced hardness and mechanical properties and improved stability (reduced shrinkage coefficients).

Ts with acetylation, the industry has chosen to market furfurylated timber under names that mask the original properties of the timber variety, such as: VisorWood or Kebony.

These products have also recently been introduced on the market and their durability over time cannot yet be guaranteed.Even though the mechanical properties of timber treated by this process are improved, they don't match those of the most resistant tropical timbers. Although furfuryl alcohols are obtained from plants, the «green chemistry» notion used to reassure consumers commercially, however, requires procedures and careful verifications.Furthermore, the evolution over time of these products (both furfurylated and acetylated) isn't fully understood yet, so we still need to consider potential medium- and long-term health risks (direct contact with users' skin, the progressive release of volatile compounds, etc.).

ASSESSING DURABILITY

The principle of laboratory testing is to place a material in direct contact with a biological degradation agent under optimal development conditions and to measure the deterioration of the material (by loss of mass). The tests are repeated with different agents, but they cannot be exhaustive or take into account synergistic effects between agents or with the immediate environment. «Accelerated ageing» consists in placing the material in severe environments (heat, humidity, dryness, UV rays, etc.) in alternation and by cycle. These two methods can give an idea of the actual behaviour of timber under regular use, but biological agents are living organisms that need time to develop. The performance evaluated in the laboratory is not always equal to that expected in the field. The durability of tropical timber is known through a usage experience that extends over several centuries.

Fair&Precious recommends the purchase of FSC® and PEFC-PAFC certified tropical timber.

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A FEW CLARIFICATIONS ARE IN ORDER!

THE WARPING OF BOARDS

DEFINITION

«Warping» is the deformation of a cross-section of a planar element, giving it a curved tile shape (which would enable water to be channelled through). The elements associated with this deformation are timber boards used to produce surface structures such as: flooring, cladding and decking. The term «boards» is derived from their large width (up to 25 cm) and their reduced thickness (2 cm on average).

ORIGIN

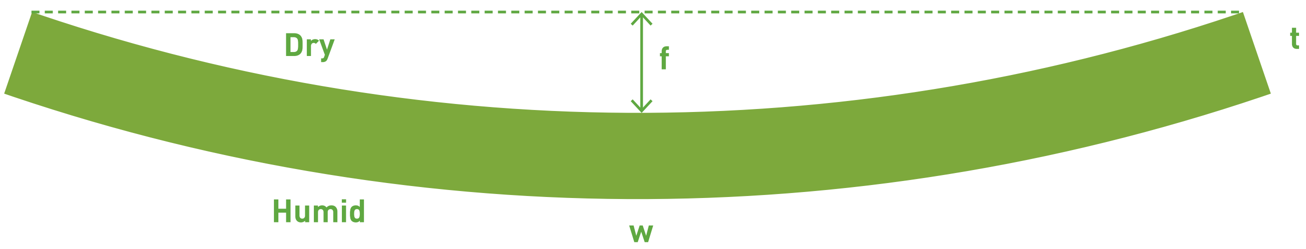
Boards cut on a slab may tile during the drying process due to differences in radial and tangential shrinkage (refer to the deformation sheet, the timber «pulls towards its core» as it dries).

Also, the warping of a cladding board can be caused by a difference in the humidity between the two sides. In fact, due to its function as a coating material, the board is subjected to a relatively dry environment on its face (by being exposed to sun, the wind or the air of a room that is regularly renewed), while its underside faces a confined environment (sheltered from light, or in the case of decking, close to the ground) that is more humid.

Note: the two phenomena can compensate for each other or be cumulative. For this reason, when the elements are cut on a slab, it is recommended that the core side be oriented outwards if possible in order to minimise the warping of the boards (bending will tend to occur in opposite directions).

The longest distance between the points on a face before and after deformation of a board is known as the warping sag (f).

Cross-section of a warped thin board:



The warping sag f can be estimated according to the following formula:	f =	$\frac{\alpha.e.w.\Delta H}{800}$

Where:

w is the width of the board in mm

t is the thickness of the board in mm

e (=w/t) is the elongation of the board

α is the shrinkage coefficient in % of dimension per % of humidity

ΔH is the difference in humidity content between the board's face and its backside in %.

Exemple : if w = 145 mm ; e = 7 ; α = 0,25%/% ; ΔH = 8%, then f = 2,5 mm.

This formula shows that a 1% change in humidity content between the surface and the underside is as important as a 1 point change in elongation.

Therefore, cladding should never be installed in a very dry or sunny climate with timber that has not been sufficiently dried. The difference in humidity content between the two sides would quickly become highly significant and result in unacceptable deformations.

It should be noted that during artificial drying, cladding boards are placed in more extreme climatic conditions (in terms of humidity and temperature) than those commonly encountered by the structures during their service life. The dryer has two benefits: it releases some of the timber's internal stresses by reducing the timber's absorption and desorption kinetics and it enables the identification of timber elements that are too nervy or that contain reaction timber that will deform during drying.

Artificial drying is required for flooring boards, but it is not necessary for many outdoor decking structures where the humidity content of both sides of the timber will balance out: humid or moderate climates, floor spacing, ventilation of the underside of the decking, drainage of the floor, installation in autumn, etc.

Given the wide variations in stability observed in timber varieties, maximum elongations have been defined for each of them, solely to limit the risk of post-installation board deformation.

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A FEW CLARIFICATIONS ARE IN ORDER!

GLUING TROPICAL TIMBER

Excerpt from: Carouge O., Gérard J., 2015. Collage des bois. Mémento du forestier tropical (Gluing timbers. Memento of the tropical forester), published by Quae, Versailles, section 10.4.7, pgs. 958-967 http://www.quae.com/fr/r4730-memento-du-forestier-tropical.html

PREAMBLE

In the timber industry, the gluing sector, especially the gluing of tropical timber, is probably the one that has developed the most since the 1980s. The introduction of new and more efficient adhesives enable the gluing of all types of timber, regardless of their characteristics, with increased requirements in terms of water resistance and mechanical resistance.

These technological advances make it possible to optimise the use of tropical timber by gluing a portion of the forest resource and cuts that are difficult to use in their current state: secondary timber varieties, poorly shaped or small-diameter logs, timber with major defects, downgraded timber, sawmill waste.

Reconstituted solid timber provides a stable and homogeneous material. The combination via gluing of timber varieties featuring highly different appearances offers new possibilities in terms of the further integration of timber into upscale projects (figure 1).

Figure 1: Tropical multi-species laminated panel (photo J. Gérard)

Gluing timber to other materials is now possible (figure 2)

Figure 2. Bubinga Ravier® crystal door (solid timber and acrylic glass combination), Amstelveen (Netherlands). Manufactured by Ravier SARL, Domblans (France). © Ravier SARL

The gluing of tropical timber appears to be limited by constraints linked to the specific characteristics of certain timber varieties and the need to comply with the rules of the trade. However, studies conducted by the CIRAD, in particular, have shown that the gluing of timber with defects or extreme characteristics produces satisfactory results if the recommended implementation conditions are used.

The choice of adhesive will depend on the final use of the bonded product, the production system, the required assembly time and the desired pressing time.

THE MAIN TYPES OF GLUE

Aminoplast adhesives

These single or two-component, thermosetting adhesives provide irreversible bonding that is obtained or accelerated by heat. These adhesives are not thermoplastic. There are 4 main categories:

- **Phenolic adhesives** (phenol-formaldehyde, = PF) are single-component and without hardener
- **Resorcinol adhesives** (resorcinol-phenol-formaldehyde, = RPF), which were the first industrial adhesives used for carpentry
- **Urea formaldehyde adhesives** (UF) which are two-component adhesives (resin + hardener) that are used either cold or hot
- **Melamine-urea-formaldehyde** (MUF) adhesives which are two-component adhesives (resin + hardener) that are used cold or hot

In 2015, new generations of formalin-free resins emerged, albeit in combination with urea formaldehyde and melamine urea formaldehyde technologies.

Thermoplastic adhesives

These adhesives are heat reversible; they fall into **four main categories.**

- **Vinyl adhesives** (vinyl acetate), or polyvinyl acetate, = PVAc) which are single or two-component (two-component with hardener with hardener for a D4 classification, see the following section).
- **Ethyl vinyl acetate** (EVA) adhesives which are single-component
- **Hot-melt adhesives**, based on EVA (ethyl-vinyl-acetate) which are thermo-fusible
- Solvent-based **neoprene adhesives** with an acetone base, which are tending to disappear in favour of aqua-spray neoprene adhesives (neoprene glue in aqueous phase)

Other adhesives

- **EPI adhesives** (Emulsion Polymer Isocyanates) which are a good compromise between vinyl and polyurethane adhesives.
- **Polyurethane adhesives** (PUR) which are single-component (react to humidity) or two-component (= PURbi, chemical reaction with hardener) thermosetting adhesives.
- **Polyurethane hot melt adhesives**, which are thermo-fusible and reactivatable while demonstrating the same qualities as polyurethanes.
- **Epoxy adhesives**, which are always two-component.

Adhesives from green chemistry

New adhesives based on green chemistry and manufactured using plants such as corn, potatoes, soybeans, etc., have been developed. However, the development of these adhesives remains limited by problems related to the regular supply and security of raw materials, as well as by the variability of their characteristics.

CLASSIFICATION OF BONDS

A classification of glues has been established according to their resistance against humidity and their stress tolerance. It is governed by the NF EN 204 standard (April 2002) *Classification of thermoplastic adhesives for non-structural timber* (= "D" classification) and the NF EN 12765 standard (April 2002) *Classification of thermosetting resin adhesives for non-structural timber* (="C" classification) which define 4 classes:

D1 and C1: indoor applications where the temperature will occasionally exceed 50°C for short periods of time; the humidity of the timber will not exceed 15%.

D2 and C2: indoor applications with occasional short periods of exposure to water or humid atmospheres; the timber's humidity content must not exceed 18%.

D3 and C3: indoor applications with frequent short-term exposure to dripping water, condensation, damp atmospheres, and/or with exposure to high humidity; outdoor applications, in sheltered areas not exposed to bad weather.

D4 and C4: indoor applications with long and frequent exposure to dripping water, condensation; outdoor applications with exposure to bad weather but with an adapted surface protection (varnish or paints).

MECHANISMS DETERMINING THE GLUING OF TIMBER

Current gluing technology enables us to avoid conventional mechanical assemblies, which are both expensive and time-consuming to implement. Glues ensure that adhesion and cohesion between two timber substrates are superior to those achieved using solid timber.

Proper gluing must take into account the intrinsic characteristics of the timber that is used: humidity content, density and wettability. Shaping and manufacturing conditions depend on the nature of the products and the adhesives that are chosen. The main parameters and mechanisms governing the gluing of timber are as follows:

- *Wettability*, glue weight and assembly time
- Glue penetration
- Gluing pressure
- Polymerisation of adhesives
- Stabilisation

OVERVIEW OF GLUING TECHNOLOGIES

The table below provides an overview of the main gluing technologies listed according to primary areas of application, defining for each the adhesives to be used and the type of gluing machines and presses to be used.

Application	Adhesive	Gluing machine	Press
Particleboard, OSB and fibreboard (MDF and high density)	UF, MUF, PUR	Spray gluing	Continuous strip press
Plywood panels	UF, MUF, PF	Roller gluing machine	Multi & single level board press
Calendering of decorative papers for standard furnishings	UF, PVAc	Roller gluing machine	Roll press
Doors (cellular, solid, insulating, fireproof, intrusion-proof, etc.)	UF, MUF, (PVAc, PUR)	Roller gluing machine	Multi & single level board press
Flooring	UF, MUF, PUR (PVAc)	Roller gluing machine	Single level board press
Seat shells, bed slats, skateboards, curved fittings	UF, MUF, (PVAc)	Roller gluing machine	Multi & single level presses with moulds
Construction: beams, frames	MUF, PRF, PUR	Curtain gluing machine	Lateral press with screws or cylinders
Solid casing or structural panels	UF, MUF, EPI, PUR	Roller gluing machine	Multi & single level board press
Solid panels for furniture, coffins, fittings, etc.	UF, MUF, PVAc, EPI	Cord gluing machine	Panelling machine for solid timber
Joinery, battens, square cuts, verandas	UF, MUF, PVAc, EPI, PUR	Roller gluing machine	Cylinder framing machine
Joinery assemblies (mortise and tenon, dowels, etc.)	UF, MUF, PVAc, EPI, epoxy	Cord gluing	Cylinder framing machine
Edgebanding and coatings for furniture, fittings, etc.	Hot-melt, PVAc, neoprene	Spray gluing	Multi-roller press for edgebanding and coating
Replating on shaped panels for kitchen doors and joinery	UF, PVAc	Roller gluing machine	Membrane press
Laminated kitchen door	Reactivatable PUR	Spray gluing	Vacuum press

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A FEW CLARIFICATIONS ARE IN ORDER!

QUALITY OF PLANTATION VARIETIES FOR USE AS LUMBER

Excerpt from: *Mémento du Forestier Tropical* (Memento of the Tropical Forester) - Editions Quae
Jean Gérard and Dominique Louppe

PREAMBLE

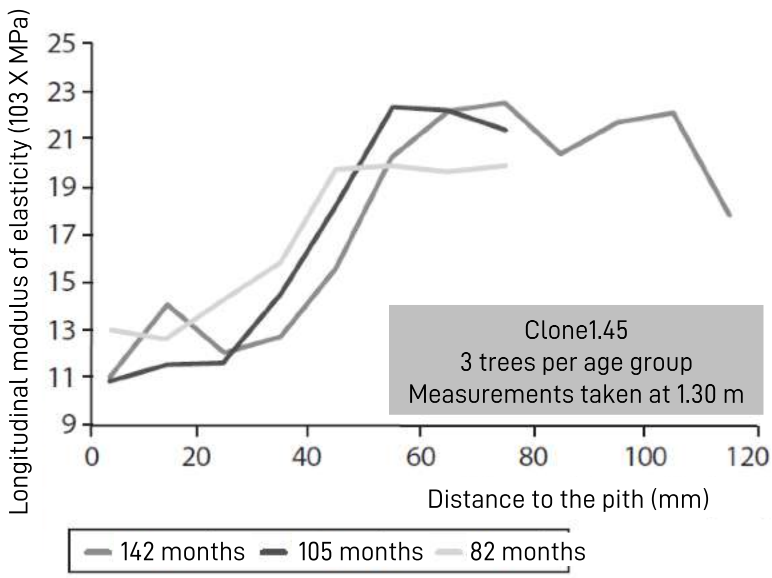
Timber production in natural tropical forests is steadily declining and this trend is likely to continue in the years to come. The tropical forestry industry is therefore naturally turning to plantation timber.

Plantation forestry requires a high level of investment that must be compensated for by the harvested forest products, for which quality is now as important as quantity. The technological properties of timber from plantation trees are different from those of the same varieties grown in a natural forest, which poses both technological and commercial problems.

In particular, the properties of plantation timber are very heterogeneous within a same tree, as trees are very often harvested before they have reached maturity. The observed differences vary according to the timber varieties: the effect of tension timber or juvenile timber on a timber's properties, the consequences of the release of growth constraints on the quality of sawn timber, the impact of branching on the visual grading of softwoods, the relationship between the immaturity of timber and its low natural durability, etc.

JUVENILE TIMBER AND ADULT TIMBER

Young trees (under 30 years old) have a greater or lesser proportion of so-called juvenile timber whose properties are inferior to those of mature timber. Thus, the properties of timber can vary greatly from the heartwood to the bark. The greatest variations are observed during the first years of growth (figure 1). The transition from juvenile timber to mature timber is never abrupt, but rather a "decrease in the timber's juvenility", from the heartwood to the periphery. The age ceiling for the formation of juvenile timber has been estimated at 20 years for *Eucalyptus regnans* and 10 years for *E. saligna*. However, these limits remain highly empirical.



Juvenile timber is concentrated in a core of approximately 8 cm in diameter

Figure 1: example of radial property variations (longitudinal modulus of elasticity) in a eucalyptus PF1. (Gérard et al., 1995)

TENSION TIMBER AND GROWTH CONSTRAINTS

The use of certain varieties of plantation timber, typically eucalyptus, but also fraké, framiré and other hardwoods, is limited by the timber's lack of stability during primary processing.

This type of defect is mainly due to the presence of tension timber coupled with high growth stress.

Tension timber is formed by the tree in response to external events. It induces radial and circumferential heterogeneities. Growth stresses allow the stem to withstand reorientations induced by changes in environmental conditions (sunny spells). Peripheral tension forces help to brace the stems so that they can resist the action of external forces.

The release of these growth constraints coupled with the heterogeneity of properties due to tension timber is the cause of defects that occur during occur during felling and primary processing (sawing):

- in hardwoods, heart splits appear after felling or chainsaw cutting, sometimes even splitting the logs; the sawn timber deforms due to the high longitudinal stresses on the periphery of the log;

- the sawn timber and veneers of hardwoods or softwoods deform (warping, buckling, etc.) and cracks appear during drying due to the accentuated heterogeneity of drying shrinkage. This is what we refer to as the "nervousness" of timber.

Reaction timber can also lead to other defects: the poor surface condition of timber after planing or sanding (in some timber varieties, tension timber is "fluffy"), abnormal discolorations ("green veins" or "fatty grain" due to the presence of tension timber, red compression timber in softwoods).

PRUNING AND NODOSITY

In plantation softwoods, the presence of knots is one of the main factors in the depreciation of timber quality. These knots are more or less abundant, more or less large, healthy, black, rotten, etc. Although knotty timber is considered more decorative for certain uses, knotty timber can cause difficulties in sawing and machining, in particular during planing, mortising, or shaping.

In addition, as the timber's grain is deflected in the vicinity of the knots, it can lead to localised deformations of sawn timber. In some tropical pine species such as Pinus caribaea or Pinus elliottii, the presence of penetrating knots from young branches next to the pith is associated with resin-infiltrated heartwood zones that have a traumatic origin due to winds, cyclones, or repeated fires.

Knots reduce the mechanical strength of timber, especially if they are numerous and have a large diameter. Natural or artificial pruning is a determining factor in the future quality of processed timber.

IMPACT OF PLANTATION TIMBER'S IMMATURITY ON ITS COLOUR AND NATURAL DURABILITY

In some tropical forest species, young plantation timber is lighter in colour than older timber or natural forest timber. Their natural durability is often lower, as their hardening is incomplete.

These differences can be seen in teak. The appearance of natural forest teak is characteristic and highly valued; the colour of its timber varies from beige-brown to golden brown with some olive tones; it darkens slightly in the light to take on a deeper colour with coppery highlights.

This colour can be uniform or streaked with a brown-black grain. In plantation teak, the colour and appearance of the timber can vary depending on its origin and its age. Improper silviculture can lead to very uneven colour, grain defects and even discolouration. Plantation teak timber under 10 years of age can be very pale - from yellowish white to pale beige - in colour due to the absence of mature timber, when the stems are almost entirely made up of sapwood.

Thus, the European NF EN 350-2 standard (2016) on the natural durability of timber makes a distinction between Asian teak (said to originate from natural forests) and cultivated teak:

- the former falls under class 1 of natural durability against fungi (the highest class) and under class M (medium durability) in terms of natural durability against termites;
- the latter falls under classes 1 to 3 of natural durability against fungi and under class M-S (medium to sensitive) natural durability against termites.

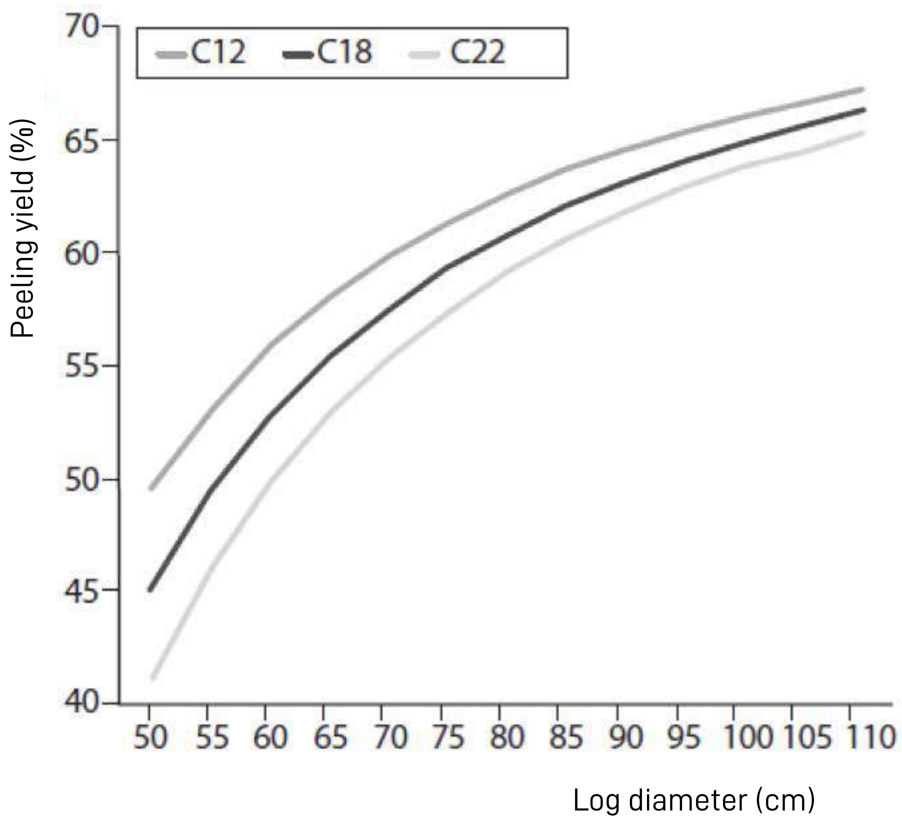
This distinction reflects the difference in quality, especially in natural durability, observed between the various teaks that are currently marketed. Some plantation teaks used for mid to low range garden furniture may have a natural durability lower than class 3. Others, on the other hand, are quite comparable in quality to natural forest teaks.

IMPORTANCE OF LOG SHAPES AND DIAMETERS ON PROCESSING YIELDS

The age of a harvested tree has an impact on the quality of the timber (the larger the diameter of the tree, the lower the rate of juvenile timber and the greater the hardening of perfect timber) and also on the overall yield of the raw material. The processing yield of peeling depends on three factors: the cylindricity of the log, its diameter and the tooling used to peel it to a core of varying diameter.

The specific conformation of the logs also plays a role in the quality and appearance of the obtained product (figure 2). It has an influence on the material yield. Defects in straightness and cylindricity generate more waste (e.g. rounding in peeling). Other defects in the log (e.g. off-centre cores, too steep a thread, etc.) lead to the elimination of the parts of the finished product that include these defects or considerably reduce its value because of the included defects (knots, splits, other defects).

Lumber silviculture should therefore be adapted as much as possible in order to obtain logs that are as straight as possible, with little splitting, no knots, no internal tensions and sufficiently hardened. This therefore involves medium to long-term silviculture which can only be profitable through the obtaining of a very high quality raw material.



The yield quickly decreases for log diameters below 60 cm:
e.g. with an 18 cm core (C18, old-style peeler), the yield is 45%
for a 50 cm diameter log under bark and 65% for a 100 cm diameter log.

Figure 2: Peeling yield as a function of log diameter and core diameter

CONCLUSIONS

Improving the quality of plantation timber in the tropics must be considered and conducted in conjunction with the development of processing industries.

Indeed, the time constraints inherent in production (except perhaps for very fast-growing plantations) mean that local and international timber markets must constantly use new raw materials, without any certainty that these can be adapted to an already defined production tool.

A basic, quick diagnosis of the properties of an exploitable resource should make it possible to improve its usability: for example sinewy timber should be cut up quickly and dried in the form of small pieces, using appropriate tools and with suitable cutting and drying methods.

Peeling can be an advantageous process for timbers with a strong contrast between juvenile and mature timber, since batches of homogeneous veneers can be reconstituted and matched when making plywood, and there are tools suitable for peeling small-diameter timber pieces.

Tropical timber plantations - Côte d'Ivoire

LES BOIS POUR OUVRAGES HYDRAULIQUES

PRÉAMBULE

Les notions de durabilité des bois et de classes d'emploi avaient été précédemment définies et expliquées par l'ATIBT dans le document intitulé *Quelques éclaircissements s'imposent : la durabilité du bois (Michel VERNAY, CIRAD, Emmanuel GROUTEL, WALE et Patrick MARTIN, ATIBT).*

L'étymologie du mot hydraulique vient d'un terme grec désignant un orgue qui fonctionnait au moyen de l'eau, terme dérivé de deux mots traduits par eau et tuyau : Ὑδραυλὶς, orgue qui marchait par le moyen de l'eau, de ὕδρ..., eau (voy. *HYDR*...) et αὐλὸς, tuyau.

Le présent document concerne les usages du bois qui dépendent de l'architecture hydraulique, avec pour objet les constructions dans l'eau ou le mouvement des eaux.

Pose d'une porte d'écluse en Azobé (Société Wijma – Deventer – Pays-Bas)

DÉFINITION GÉNÉRALE DES OUVRAGES HYDRAULIQUES

Une définition et une typologie « officielles » de ce type d'ouvrages sont données par le Ministère de la transition écologique qui indique que *les ouvrages hydrauliques regroupent plusieurs familles d'ouvrages :*

- les barrages,
- les canaux,
- les digues de protection contre les inondations ou contre les submersions,
- les systèmes de protection contre les inondations ou contre les submersions,
- les aménagements hydrauliques.

L'essentiel de cette typologie est axé sur des ouvrages en eau douce, seuls les aménagements hydrauliques faisant référence à des ouvrages maritimes[1].

Note : le terme travaux hydrauliques est aussi utilisé en lieu et place de ouvrages hydrauliques, il constitue la traduction directe du terme anglais *hydraulic works*.

Fabrication de portes d'écluses en Azobé (Société Wijma – Kampen – Pays-Bas)

1. Un aménagement hydraulique participe à la protection contre les inondations ou les submersions, mais comprend des ouvrages de rétention d'une partie des crues, comme les barrages écrêteurs de crue ou les casiers de rétention de crue, ou des ouvrages stockant d'autres écoulements pour qu'ils ne provoquent pas d'inondation, comme l'eau amenée par les vagues lors de tempêtes maritimes ou les eaux de ruissellement issues d'événements pluvieux intenses.

TYPOLOGIE DES OUVRAGES HYDRAULIQUES ASSOCIÉS À L'UTILISATION DE BOIS

Contrairement à la définition générale donnée précédemment, la typologie des ouvrages hydrauliques associés à l'utilisation de bois doit intégrer toutes les applications en milieu marin ou en eau saumâtre.

Langbour et Vernay (2002)[2] proposent trois typologies d'ouvrages où le bois présente un intérêt, associées pour parties aux ouvrages hydrauliques :

- Ouvrages structurels immergés : estacades, portes d'écluses, appontements, constructions sur pilotis, palplanches en bois, ducs-d'Albe[3] , pieux d'amarrage en bois, épis, pieux de rive et brise-lames.
- Ouvrages structurels hors d'eau : plateformes et passerelles.
- Équipement et habillage : aménagements de quais (défenses...) et de berges, platelages et bardage.

Une typologie spécifique aux ouvrages hydrauliques associés à l'utilisation de bois doit prendre en compte les deux éléments suivants :

- un ouvrage hydraulique est considéré comme tel s'il est dans son intégralité ou pour partie immergé en permanence ou de façon intermittente ; les ouvrages extérieurs tels que les passerelles, les platelages, ou les bardages ne sont donc pas considérés comme des ouvrages hydrauliques.
- une distinction doit être faite entre les ouvrages en eau douce d'une part, et les ouvrages en eau saumâtre ou en milieu marin d'autre part, distinction essentiellement liée aux risques d'endommagements dus aux térébrants marins[4].

La typologie proposée par Langbour et Vernay (2002) pourrait donc être adaptée en considérant quatre groupes d'ouvrages hydrauliques ou parties d'ouvrages hydrauliques :

Bois immergés en milieu marin ou en eau saumâtre		Bois immergés en eau douce	
de façon intermittente	en permanence	de façon intermittente	en permanence

Le plus souvent, certaines parties d'un même ouvrage hydraulique seront immergées en permanence tandis que d'autres seront immergées de façon intermittente.

Il est donc plus simple de considérer deux grand groupes d'ouvrages hydrauliques, ceux mis en œuvre **en eau douce** et ceux mis en œuvre **en eau saumâtre** ou **en milieu marin.**

2. Langbour P., Vernay M., 2002. Une production particulière : les bois équarris. Bois & Forêts des Tropiques, 271 (1): 111-113.
3. Le terme provient de Ferdinand Alvare de Tolède, troisième duc d'Albe, qui faisait amarrer ses bateaux à des pieux lors de ses séjours au Portugal.
4. En eau douce, quelques espèces de térébrants peuvent attaquer le bois pour y loger mais leur impact sur les performances structurelles des ouvrages reste négligeable.

OUVRAGES HYDRAULIQUES EN EAU SAUMATRE OU MILIEU MARIN
Estacades, wharf, appontements, constructions sur pilotis, ducs-d'Albe[5], pieux d'amarrage en bois, épis, pieux de rive et brise-lames, aménagements de quais, défenses de quais,

OUVRAGES HYDRAULIQUES EN EAU DOUCE
Portes d'écluses, appontements, constructions sur pilotis, pieux d'amarrage en bois, aménagements de quais et de berges

Note : par commodité mais par abus de langage, on peut accepter le terme ***bois hydrauliques*** en lieu et place de ***bois pour ouvrages/travaux hydrauliques.***

Pièces d'Azobé avec cœur enrobé pour la construction d'une défense spécifique
(Société Wijma – Kampen – Pays-Bas)

5. Faisceau de pieux plantés dans le fond d'un bassin ou d'un cours d'eau et auquel viennent s'amarrer les navires.

CONTRAINTES SPÉCIFIQUES AUXQUELLES SONT SOUMIS LES BOIS POUR OUVRAGES HYDRAULIQUES

Suivant le type d'ouvrage considéré, ces contraintes peuvent être de nature différente et/ou plus ou moins marquées. Cependant, les bois pour ouvrages hydrauliques nécessitent dans la majorité des cas :

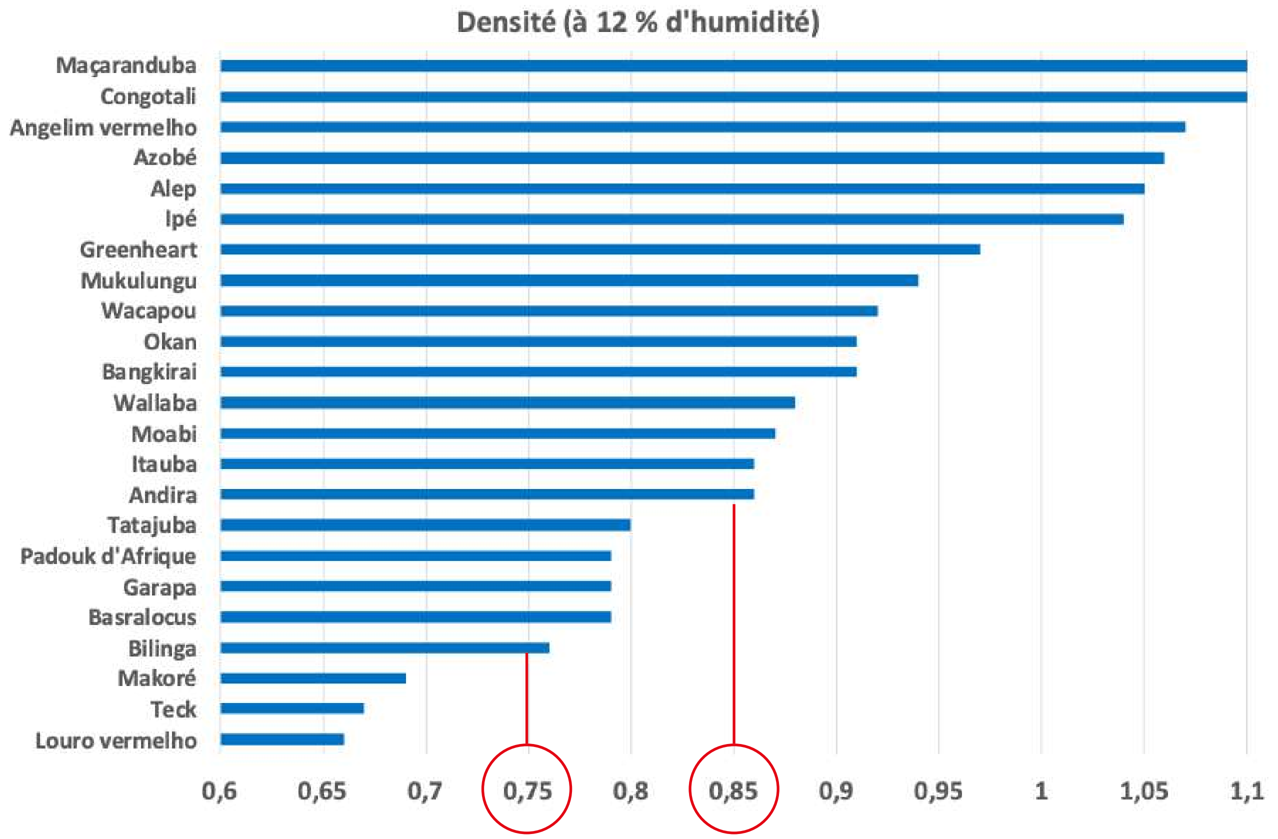
- De bonnes caractéristiques mécaniques (résistance en compression, au choc, en flexion, rigidité) car les ouvrages correspondant sont le plus souvent soumis à de fortes contraintes.
- Une bonne résistance aux attaques des agents biologiques de détérioration :
  - Résistance aux champignons lignivores pour les bois fréquemment émergés.
  - Résistance aux térébrants marins (ou foreurs marins) pour les bois immergés fréquemment ou en permanence en milieu marin ou en eau saumâtre.

Les pièces de bois destinées aux usages hydrauliques doivent être usinées à l'état frais de sciage ; en effet, leur séchage n'est pas envisageable tant sur un plan technique qu'économique. De plus et notamment dans les grosses sections le plus souvent nécessaires pour cette catégorie d'usages, ces bois très durs et très denses ne peuvent pas être usinés à l'état sec. Cet aspect doit être souligné auprès des autorités compétentes des pays producteurs (Ministères des Eaux & Forêts, Douanes, etc.) afin de ne pas rompre cette chaine d'approvisionnement spécifique.

Défense de berge – pièces de grosses section en Azobé (Société Wijma / Willemsunie - Pays-Bas)

CARACTÉRISTIQUES MÉCANIQUES

La plupart des bois utilisables pour des ouvrages hydrauliques en milieu marin[6] présentent une densité moyenne[7] supérieure à 0,75[8], cette densité moyenne étant le plus souvent supérieure à 0,85 (graphique 1).
Ces bois, pour la plupart lourds à très lourds[9], présentent corrélativement des caractéristiques mécaniques élevées.



Graphique 1. Répartition des densités des principaux bois commerciaux couvrant naturellement la classe d'emploi 5 (bois immergés dans l'eau salée de manière régulière ou permanente) - Source : Tropix 7

Seules trois espèces commerciales courantes présentent une densité modérée :

- le Teck (0,67) et le Makoré (0,69) peuvent être utilisés en milieu marin du fait de leurs performances techniques ; cependant, ces deux essences sont essentiellement destinées à des usages à plus haute valeur ajoutée ;
- le Louro vermelho (0,66) couvre aussi la classe d'emploi 5 ; cependant, en raison de sa densité faible à moyenne, il ne peut être mis en œuvre que sous sollicitations mécaniques modérées.

6. Bois utilisables en classe d'emploi 5 sans traitement de préservation, voir section suivante
7. Déterminée à 12 % d'humidité
8. Parmi ces bois, le Bilinga est celui dont la densité moyenne est la plus basse : 0,76
9. Selon la classification Cirad :
0,65 < densité < 0,80 : bois mi-lourd
0,80 < densité < 0,95 : bois lourd
0,95 < densité : bois très lourd

RÉSISTANCE AUX CHAMPIGNONS LIGNIVORES

Les bois utilisés pour des ouvrages hydrauliques, aussi bien en eau douce qu'en eau saumâtre ou en milieu marin, doivent couvrir la classe d'emploi 4 sans traitement de préservation[10].

Cette classe d'emploi correspond à des utilisations extérieures en contact avec le sol ou l'eau douce. Les situations correspondant à la classe d'emploi 4 sont caractérisées par des humidifications fréquentes ou permanentes, des rétentions et des stagnations d'eau. Les bois peuvent être également mis en œuvre en contact avec le sol ou immergés.

La définition de la notion de classe d'emploi est donnée en 2ème partie de **l'annexe 1.**

Pour couvrir la classe d'emploi 4 sans traitement de préservation, un bois devra présenter une classe de durabilité naturelle 1, éventuellement 2, exceptionnellement 3.

La définition de la notion de classe de durabilité naturelle est donnée en 1ère partie de **l'annexe 1.**

Il faut rappeler que les caractéristiques de durabilité concernent uniquement le duramen des bois arrivés à maturité. L'aubier doit toujours être considéré comme non durable vis-à-vis des agents de dégradation biologique du bois.

RÉSISTANCE AUX TÉRÉBRANTS MARINS (OU FOREURS MARINS)

Deux groupes d'invertébrés marins sont dits térébrants car ils peuvent perforer et dégrader les bois immergés : (1) les Tarets et les Pholades (mollusques bivalves) ; (2) différents petits crustacés, notamment du genre *Limnoria* qui est le plus répandu.

Les mollusques sont les plus destructeurs, notamment les Tarets dont la répartition géographique et la virulence dépendent de la salinité et de la température de l'eau. Ils sont présents dans toutes les mers mais sont particulièrement destructeurs en eaux tropicales. Du fait du dérèglement climatique à l'origine d'une élévation générale de la température des eaux marines, la virulence des térébrants marins tend à augmenter dans les eaux tempérées et les eaux froides.

La résistance naturelle de certaines essences tropicales aux térébrants marins est principalement liée à trois caractéristiques : (1) grain fin à très fin couplé à une densité élevée ; (2) taux de silice élevé ; (3) présence dans le bois de composés chimiques répulsifs (= métabolites secondaires ou extractibles). De ces trois caractéristiques, le taux de silice est la plus discriminante.

Ces bois peuvent être utilisés en classe d'emploi 5 sans traitement de préservation (bois immergés dans l'eau salée de manière régulière ou permanente).

Une essence qui couvre la classe d'emploi 5 couvre généralement la classe d'emploi 4, excepté quelques rares essences ne couvrant que la classe 3 ou la classe 2 (Basralocus, Garapa, Louro vermelho, Sougué).

10. Bois dits « de classe 4 » par commodité et par abus de langage

CORRESPONDANCE ENTRE LES CLASSES DE DURABILITÉ NATURELLES ET LES CLASSES D'EMPLOI

La norme européenne NF EN 460 (juillet 1994), **toujours en vigueur bien qu'en cours de révision,** propose un tableau de correspondances entre le niveau de durabilité naturelle des bois massifs et leurs possibilités d'utilisation dans une classe d'emploi donnée (tableau ci-après).

Note : En réalité, cette norme fait référence à la notion de classe de risque et non de classe d'emploi, notions quasiment équivalentes. Classe d'emploi est aujourd'hui le terme en vigueur, il est défini dans la norme française NF EN 335 (mai 2013). Dans le tableau de correspondances qui suit, on utilisera le terme classe d'emploi en cohérence avec la terminologie actuellement utilisée, même si ce terme n'est pas littéralement celui mentionné dans la norme française NF EN 460 de juillet 1994.

Pour les Pays-Bas, il est nécessaire de se référer à la norme NEN-EN 350 :2016[11].

Classes de durabilité naturelle selon la classe d'emploi

Classe d'emploi couverte par la durabilité naturelle	Classe de durabilité naturelle				
	1	2	3	4	5
1	Oui(1)	Oui	Oui	Oui	Oui
2	Oui	Oui	Oui	Oui mais	Oui mais
3	Oui	Oui	Oui mais	Au cas par cas(3)	Au cas par cas
4	Oui	Oui mais(2)	Non mais(4)	Non(5)	Non
5	Oui	Non mais	Non mais	Non	Non

(1) Oui : la durabilité naturelle couvre la classe d'emploi.

(2) Oui mais : la durabilité naturelle couvre normalement la classe d'emploi. Mais pour certains emplois, un traitement de préservation peut être recommandé.

(3) Au cas par cas : la durabilité naturelle peut être suffisante. Mais en fonction de l'essence du bois, de sa perméabilité et de son emploi final, un traitement de préservation peut être nécessaire.

(4) Non mais : un traitement de préservation est normalement recommandé. Mais pour certains emplois, la durabilité naturelle peut être suffisante pour couvrir la classe d'emploi.

(5) Non : la durabilité naturelle ne couvre pas la classe d'emploi ; un traitement de préservation est nécessaire.

Pour les classes d'emploi 2 à 5, les correspondances ne sont pas définies de manière précise pour certains niveaux de durabilité. Pour certaines essences, les classes d'emploi ne sont données qu'à titre indicatif. Les valeurs correspondantes doivent être utilisées avec précaution et professionnalisme.

11. https://www.nen.nl/nen-en-350-2016-en-224409

Pièces de portes d'écluses en Azobé (Société Wijma – Kampen – Pays-Bas)

Pont de Harderwijk (Société Wijma – Pays-Bas)

LES BOIS UTILISABLES POUR LES OUVRAGES HYDRAULIQUES

En 2000, Vernay et Fouquet[12] inventorient les principales essences tropicales à forte durabilité naturelle qui couvrent la classe de risque 4 et/ou qui couvrent la classe de risque 5.

Le recoupement de ces listes d'essences permet de définir les bois utilisables pour les ouvrages hydrauliques en conservant la même typologie définissant 4 catégories d'essences :

- Essences courantes commercialisées pour les ouvrages hydrauliques
- Essences techniquement utilisables pour les ouvrages hydrauliques mais dont l'aspect esthétique permet d'autres utilisations à plus haute valeur ajoutée
- Essences à fort potentiel, peu commercialisées
- Autres essences peu connues

En 20 ans, certaines essences ont émergé et sont aujourd'hui couramment commercialisées ; c'est le cas de l'Okan.

La liste des bois utilisables pour les ouvrages hydrauliques dans le tableau page suivante a donc été établie à partir des informations fournies par Vernay et Fouquet (2000) ajustées en tenant compte de l'évolution des marchés mais aussi de la disponibilité effective des bois en forêt.

Palplanches en Azobé (Société Wijma – Kampen – Pays-Bas)

12. Vernay M., Fouquet D., 2000. Essences tropicales à forte durabilité naturelle. Bois & Forêts des Tropiques, 264 (2): 73-76.

Nom pilote	Nom botanique	Couverture de la classe d'emploi 5	Commentaires ; autres usages potentiels	Intérêt marché
Essences courantes commercialisées pour les ouvrages hydrauliques				
Angelim vermelho	*Dinizia excelsa*	Oui	Du fait de son odeur désa-gréable, à utiliser de préférence immergé en permanence	++
Azobé	*Lophira alata*	Oui	Pour certaines provenances, problème récurrent de bois intermédiaire peu durable aux champignons lignivores	+++
Basralocus	*Dicorynia guianensis* *Dicorynia paraensis*	Oui	Ne couvre pas la classe d'emploi 4	++
Bilinga	*Nauclea diderrichii* *Nauclea gilletii* *Nauclea xanthoxylon*	Oui	Fendif pour des emplois émergés, peu adapté au climat méditerranéen	+++
Greenheart	*Chlorocardium rodiei*	Oui		
Niové	*Staudtia kamerunensis*	Non	Platelage et decking	++
Okan (Adoum)	*Cylicodiscus gabunensis*	Oui		++
Padouk d'Afrique	*Pterocarpus osun* *Pterocarpus soyauxii* *Pterocarpus tinctorius*	Oui	Très utilisé en revête-ment de sol extérieur	+++
Tali	*Erythrophleum guineense* *Erythrophleum ivorense* *Erythrophleum suaveolens* *Erythrophleum* p.p.	M*	Platelage et decking	++
Wallaba	*Eperua falcata* *Eperua jenmanii* *Eperua rubiginosa* *Eperua* p.p.	Oui		
Essences techniquement utilisables pour les ouvrages hydrauliques mais dont l'aspect esthétique ou d'autres caractéristiques permettent d'autres utilisations à plus forte valeur ajoutée				
Bangkirai / Yellow Balau	*Shorea glauca* *Shorea laevis* *Shorea maxwelliana* *Shorea superba* *Shorea* subgen. *Eushorea* p.p.	Oui	Platelage et decking	+++
Billian / Ulin	*Eusideroxylon zwageri*	-	Platelage et decking, charpen-terie de marine, bardeaux	++
Chengal	*Neobalanocarpus heimii*	-	Platelage et decking	++
Cumaru	*Dipteryx alata* *Dipteryx micrantha* *Dipteryx odorata* *Dipteryx polyphylla* *Dipteryx* p.p.	Non	Peu adapté au climat méditerra-néen pour des emplois émergés	

Bois tropicaux sud-américains — **Bois tropicaux africains** — **Bois tropicaux sud-asiatiques**

Utilisables pour les ouvrages hydrauliques

Doussié rouge	*Afzelia bipindensis*	Non	Revêtements de sol haut de gamme	+++
Ipê	*Handroanthus heptaphylla* *Handroanthus impetiginosa* *Handroanthus serratifolia* *Handroanthus* p.p.	Oui	Platelage et decking	
Iroko	*Milicia excelsa* *Milicia regia*	Oui	Platelage et decking	
Itaúba	*Mezilaurus itauba* *Mezilaurus lindaviana* *Mezilaurus navalium* *Mezilaurus* p.p.	Oui	Platelage et decking	
Louro vermelho	*Sextonia rubra*	Oui	Platelage et decking	
Maçaranduba	*Manilkara bidentata* *Manilkara huberi* *Manilkara* p.p.	Oui	Platelage et decking	
Makoré	*Tieghemella heckelii*	Oui	Autres usages à plus forte valeur ajoutée en menuiserie	
Merbau	*Intsia bijuga* *Intsia palembanica* *Intsia* p.p.	-	Platelage et decking, construction navale	+++
Moabi	*Baillonella toxisperma*	Oui	Autres usages à plus forte valeur ajoutée en menuiserie	
Mukulungu	*Autranella congolensis*	Oui	Platelage et decking	
Tatajuba	*Bagassa guianensis*	Oui	Platelage et decking	
Teck	*Tectona grandis*	Oui	Nombreux usages haut de gamme	+++
Essences à fort potentiel, peu commercialisées				
Alep	*Desbordesia glaucescens*	Oui	Traverses de chemin de fer	
Congotali	*Letestua durissima*	Oui		
Dabéma	*Piptadeniastrum africanum*	Non		
Eveuss	*Klainedoxa gabonensis* *Klainedoxa trillesii*	Non	Parfois zones non duraminisées à l'intérieur du bois parfait	
Eyoum ou Omvong	*Dialium pachyphyllum*	-		
Osanga	*Pteleopsis hylodendron* *Pteleopsis myrtifolia*	M*	Platelage et decking	

Bois tropicaux sud-américains **Bois tropicaux africains** **Bois tropicaux sud-asiatiques**

Utilisables pour les ouvrages hydrauliques

Autres essences peu connues				
Araracanga	*Aspidosperma album* *Aspidosperma desmanthum* *Aspidosperma* p.p.	Oui		
Kanda brun	*Beilschmiedia congolana* *Beilschmiedia corbisieri* *Beilschmiedia letouzeyi* *Beilschmiedia oblongifolia* *Beilschmiedia* p.p.	-		
Kanda rose	*Beilschmiedia gabonensis* *Beilschmiedia grandifolia* *Beilschmiedia hutchinsonia* *Beilschmiedia mannii* *Beilschmiedia obscura* *Beilschmiedia* p.p.	-		
Landa	*Erythroxylum mannii*	-		
Monghinza	*Manilkara mabokeensis* *Manilkara obovata* *Manilkara* p.p.	Oui	Très fendif	
Nganga	*Cynometra ananta* *Cynometra hankei* *Cynometra* p.p.	-		
Oguomo	*Lecomtedoxa klaineana*	-		
Quebracho colorado	*Schinopsis balansae* *Schinopsis lorentzii*	-		
Rikio	*Uapaca guineensis* *Uapaca heudelotii* *Uapaca vanhouttei* *Uapaca* p.p.	-		
Oboto	*Mammea africana*	-		
Vésambata	*Oldfieldia africana*	-		
Wamba	*Tessmannia africana* *Tessmannia anomala* *Tessmannia lescrauwaetii*	-		

*** Essence considérée moyennement durable aux térébrants marins (M) selon la norme NF EN 350 : 2016**

Bois tropicaux sud-américains **Bois tropicaux africains** **Bois tropicaux sud-asiatiques**

Utilisables pour les ouvrages hydrauliques

Pieux appointés en Niové pour aménagements hydrauliques aux Pays-Bas
Compagnie des Bois du Gabon - Port-Gentil, Gabon (© Emmanuel Groutel, WALE)

Cheminement de quai en Azobé et Basralocus (Angélique)

Duc d'Albe en Azobé (Société Wijma – Kampen – Pays-Bas)

Proue en Bangkiraï d'un «perahu pinisi» (Goélette / Schooner) en construction (navire traditionnel de transport domestique de marchandises) - Chantier naval traditionnel Bugis - Bira, Bulukumba, Célèbes du Sud, Indonésie (© Benoît Gommet, France Timber)

Cale en Ulin (= Billian) d'un «perahu pinisi» (Goélette / Schooner) en construction (navire traditionnel de transport domestique de marchandises) - Chantier naval traditionnel Bugis Bira, Bulukumba, Célèbes du Sud, Indonésie (© Benoît Gommet, France Timber)

Document réalisé par la Commission Matériau-Bois-Normalisation de l'ATIBT
par MM. Jean Gérard / CIRAD (Secrétaire) et Emmanuel Groutel / WALE (Président).

ANNEXE 1 : EXTRAIT ADAPTÉ DE *L'ATLAS DES BOIS TROPICAUX (2016)*

DURABILITÉ NATURELLE

Sauf mention particulière relative à l'aubier, les caractéristiques de durabilité concernent le duramen des bois arrivés à maturité. L'aubier doit toujours être considéré comme non durable vis-à-vis des agents de dégradation biologique du bois. Un bois dont l'humidité en service est inférieure à environ 20 % présente peu de risques d'être attaqué par les champignons. Des températures inférieures à 5 °C environ empêchent tout développement des champignons. De même, des bois immergés ou portés à des températures élevées (de l'ordre de 60 °C) ne sont jamais attaqués par les champignons quelle que soit leur durabilité naturelle.

Résistance aux champignons

La résistance des bois aux champignons est déterminée sur des échantillons de dimensions normalisées mis en présence de souches de champignons dans des conditions ambiantes contrôlées. Ces essais durent plusieurs mois.
La norme NF EN 350, en cours de révision au moment de l'édition de cet ouvrage, définit des classes de durabilité naturelle du bois contre des champignons lignivores :

- bois très durables : classe DC1 (*durability class* 1), nommée « classe 1 » ;
- bois durables : classe DC2, nommée « classe 2 » ;
- bois moyennement durables : classe DC3, nommée « classe 3 » ;
- bois faiblement durables : classe DC4, nommée « classe 4 » ;
- bois non durables : classe DC5, nommée « classe 5 ».

Résistance aux insectes des bois secs (lyctus, bostryches, vrillettes)

La grande majorité des bois tropicaux commercialisés n'est pas attaquée par les insectes de bois sec, à condition que ces bois soient mis en œuvre sans aubier. Lorsque l'aubier est peu distinct, il est préférable de traiter les bois contre les insectes de bois sec. Certaines essences tropicales sont attaquées dans la totalité du bois et demandent des précautions particulières à l'état sec. Les bois sciés ou les produits finis ne sont attaqués que s'ils contiennent encore de l'aubier et une teneur en amidon suffisante.
Selon la norme NF EN 350, une essence est classée sensible (classe DC S, nommée « classe S ») si elle est attaquée pendant l'essai mené en laboratoire. Dans le cas contraire, elle est considérée comme durable (classe DC D, nommée « classe D »).

Résistance aux termites

Les conditions de détermination de la résistance des bois aux termites sont analogues à celles de la résistance aux champignons. Des échantillons de dimension normalisée sont mis en présence de termites. L'intensité de l'attaque des termites et, par conséquent, la résistance naturelle des bois sont quantifiées en mesurant la profondeur de pénétration des termites dans l'échantillon. La norme NF EN 350 définit trois classes de durabilité naturelle vis-à-vis des termites :

- bois durables : classe DC D (*durability class* D), nommée « classe D » ;
- bois moyennement durables : classe DC M, nommée « classe M » ;
- bois sensibles : classe DC S, nommée « classe S ».

CLASSE D'EMPLOI

La classe d'emploi correspond à un degré d'exposition aux différents agents de dégradation biologique découlant d'une situation en service d'un élément ou d'un ouvrage en bois. Elle peut changer après modification de la conception ou de la situation de l'ouvrage. Elle ne définit pas systématiquement une durée de service, mais seulement les conditions d'une attaque biologique potentielle. Dans une classe d'emploi, les spécifications de traitement et le choix de l'essence ont une incidence directe sur la durée de service.

La durée de service doit donc être interprétée en fonction des essences et de la sévérité des expositions. Elle dépend de la durabilité naturelle du bois, mais aussi d'autres facteurs tels que les détails de la conception d'un ouvrage (risques de pièges à eau, ventilation du bois...), la nature des entretiens prévus et les conditions climatiques locales.

L'utilisation d'un bois, dont la durabilité naturelle est supérieure à celle qui est préconisée par la norme NF EN 460 (juillet 1994) pour un emploi donné, permet d'allonger la durée de service de l'ouvrage. Réciproquement, pour des éléments d'ouvrage à durée de vie très courte (construction provisoire), des essences de durabilité naturelle inférieure à celle mentionnée dans la norme EN 460 peuvent être préconisées.

Note. **Ne pas confondre les notions de « classe de résistance aux champignons » et de « classe d'emploi » dont les barèmes de qualification sont différents.**

Les situations en service ont été regroupées en classes d'emplois (norme NF EN 335, mai 2013). Chaque classe correspond à une catégorie d'utilisations associée à des risques de dégradation biologique de même niveau.

Catégories regroupant les classes selon les conditions d'emploi

Classe d'emploi	Usage général
1	À l'intérieur, au sec
2	À l'intérieur ou sous abri, pas d'exposition aux intempéries. Possibilité de condensation d'eau
3	À l'extérieur, au-dessus du sol, exposé aux intempéries. La classe 3 peut être est subdivisée en 2 sous-classes : 3.1 Conditions d'humidification courtes 3.2 Conditions d'humidification prolongées
4	À l'extérieur en contact avec le sol ou l'eau douce
5	Immergé dans l'eau salée de manière régulière ou permanente

Spécificités de la classe 5.

L'appartenance d'une essence à la classe 5 est mentionnée séparément. Une essence qui couvre la classe 5 couvre généralement la classe 4, excepté quelques rares essences ne couvrant que la classe 3 ou la classe 2 (Basralocus, Garapa, Iroko, Louro vermelho, Sougué).

La norme européenne NF EN 460 (juillet 1994) propose un tableau de correspondance entre le niveau de durabilité naturelle des bois massifs et leurs possibilités d'emploi dans une classe de risque donnée (tableau ci-dessous). Cette norme est antérieure au remplacement de la notion de « classe de risque » par celle de « classe d'emploi » (NF EN 335, mai 2013), ces deux notions étant quasiment équivalentes.

EVOLUTION OF THE CLASSIFICATION OF AFRICAN COMMERCIAL SPECIES OF THE AFZELIA GENUS (DOUSSIÉ) AND THE PTEROCARPUS GENUS (PADAUK) IN THE GENERAL NOMENCLATURE OF TROPICAL TIMBER

AFRICAN SPECIES OF THE *AFZELIA* GENUS

Preamble - status of the *Afzelia* genus in Africa

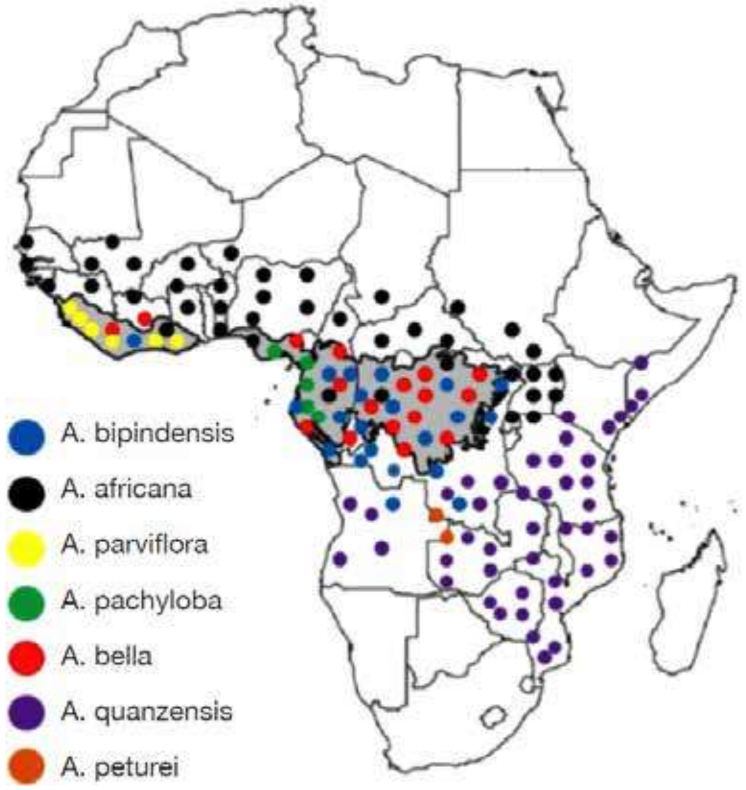
The below information and data are taken from the literature review on the subject by Donkpegan et al. (2014)[1] which mention:

* The genus *Afzelia* Smith (Fabaceae, Caesalpinioideae) consists of seven species in Africa, two of which are found in the open forests of the Zambezi region (A. *quanzensis Welw*. and *A. peturei* De Wild.); four others are endemic to the dense rainforests of the Guinean-Congolese region (*A. bella* Harms, *A. bipindensis* Harms, *A. pachyloba* Harms and *A. parviflora* [Vahl] Hepper) and the last one is mainly found in the Sudanian savannahs (*A. africana* Sm. ex Pers.)

* Four of these species (*A. africana, A. bella, A. bipindensis,* and *A. pachyloba*) are very similar morphologically and are generally sold under the name of "doussié", which is a very sought-after lumber in the forest industry. The morphological distinction of these species is difficult in the field, leading to confusion during forest inventories. This situation seems to be tacitly tolerated in the international tropical timber trade, although different technological properties are regularly reported by professionals (CTFT 1980[2]), especially in terms of the shrinkage observed in the timber.

1. Donkpegan A.S.L., Hardy O., Lejeune P., Oumorou M., Daïnou K., Doucet J-L., 2014. **A complex of Afzelia species from African forests of economic and ecological interest (bibliographic synthesis**.Biotechnol. Agron. Soc. Environ. 2014 18(2). https://orbi.uliege.be/bitstream/2268/168874/1/Donkpegan%20et%20al%202014.pdf

2. Tropical Forestry Technical Center, 1980. **Doussié**. Tropical Timber and Forests, 189: pgs. 37-54.



Based on Donkpegan et al (2014). The geographical distribution on the African continent of the seven African species of the *Afzelia* genus (map adapted from the database of the Geneva Conservatory of Botanical Gardens [CJBG], consulted on 06/11/2012, and White's map, 1986).

CLASSIFICATION AND CURRENT NAMES OF THE COMMERCIALISED *AFZELIA*

Four African species[3] of *Afzelia* are (more or less) commonly sold and exported for their timber: *A. africana*, *A. bella, A. bipindensis* and *A. pachyloba.*
These four species are sold under different names: Doussié, Afzelia (the Anglo-Saxon pilot name), as well as Lingué, Apa, Pachyloba, etc.
The *A. quanzensis* species located mainly in East Africa and called Chanfuta in Mozambique, is sometimes available on the international market.

In the General Nomenclature of Tropical Timber[4] the five commercial species of the *Afzelia* genus are all grouped under the name Doussié, as in many other reference documents, whether recent or older (Atlas of Tropical Timber[5], Atlas of Tropical Timber - volume I - Africa[6], Handbook of Hardwood[7], Tropical Timbers of the World[8]...). The correlations between the pilot name, the botanical names and vernacular names are presented as follows in the Nomenclature:

3. Two species of the *Afzelia* genus from Southeast Asia are traded: *A. rhomboidea* S. Vidal (pilot name: Tindalo) and *A. xylocarpa* Craib (pilot name: Makamong). In addition, *Afzelia bijuga* is a synonym of *Intsia bijuga* (pilot name: Merbau).
4. International Tropical Timber Technical Association, 2016. **General Nomenclature of Tropical Timber** - 7th edition French - English. ATIBT, 152 pgs.
5. Gérard J. et al., 2016. **Atlas of tropical Timber**. Practical Guide Collection, Editions QUAE, French version (paper, pdf, epub formats) and English version (pdf and epub formats), 999 pgs.
6. International Tropical Timber Technical Association, 1986. **Atlas of Tropical Timber Volume I - Africa**. ATIBT, 208 pgs.
7. Farmer R.H., (ed.), 1972. **Handbook of Hardwoods**. 2nd Edition. London: Her Majesty's Stationery Office, 243 pgs.
8. Chudnoff M., 1984. **Tropical Timbers of the World**. USDA, Forest Service, 464 pgs.

Pilot name	Botanical names	Vernacular names
Doussié	Afzelia africana Sm. Afzelia bella Harms Afzelia bipindensis Harms Afzelia pachyloba Harms Afzelia quanzensis Welw. (Syn. *Afzelia cuanzensis*) (Syn. *Intsia cuanzensis*)	Aligna (NG); Apa (NG); Azodau (CI); Bolengu (CD); Chanfuta (MZ); Doussié (CM); Edoumeuleu (GA); Kpakpatin (BJ); Kpendei (SL); Lingué (CI, SN); M'Banga (CM); Mbembakofi (TZ); Mkora (TZ); Mussacossa (MZ); N'Kokongo (AO, CG); Pakpajide (BJ); Papao (GH); Pau Conta (GW); Uvala (AO)[9]

The vernacular names and the countries where they are used aren't specifically associated with one or more of the five species, except for the Chanfuta name in Mozambique for *A. quanzensis*.

QUALITY DIFFERENCES BETWEEN THE COMMERCIAL *AFZELIA* SPECIES

The need to commercially differentiate between species of *Afzelia* and to no longer group them together under the single "Doussié" name is linked to the differences in log quality and in the intrinsic quality of the timber observed between the species.
Operators in the timber industry rank the main *Afzelia* species, from *Afzelia bipindensis*, the "true" Doussié, also known as *yellow powder,* the most stable one, up to the Lingué (*Afzelia africana*), the most typically Ivorian one, through the intermediate quality Pachyloba.
Currently, Pachyloba is the subject of much trafficking, particularly in Cameroon, in favour of Asian markets for the manufacture of parquet flooring.
Afzelia bipindensis is therefore considered as the species of the genus whose timber is of the best quality (its timber is considered the most stable) followed by *Afzelia pachyloba* and then *Afzelia africana*.

It appeared necessary to verify these differences in the timber's stability.
For these three species, the following table presents:

- two physical indicators of the timber's stability, the saturation point of the fibres and the total volume shrinkage during drying (average values extracted from the CIRAD's timber database[10]); **these two characteristics are all the lower the more stable the timber is.**
- two chemical characteristics (Gérard et al. 2019[11]), the average content of alcohol-benzene extracts and the content of water extracts (+ the sum of the two), characteristics that several studies have shown are also indicative of the stability of a timber; Kokutse et al. (2010)[12], Bossu et al. (2016)[13], and Hernandez and Almeida (2006)14 have indeed shown that **the higher the extract content of a timber, the more stable it is.**

9. NG: Nigeria; CI: Ivory Coast; CD: Democratic Republic of Congo; MZ: Mozambique; GA: Gabon; BJ: Benin; SL: Sierra Leone; SN: Senegal; CM: Cameroon; TZ: Tanzania; AO: Angola; CG: Congo; GH: Ghana; GW: Guinea Bissau

10. For *A. bella*, test results are only available for one tree, which is insufficient to compare it with the other three species.

11. Gérard J., Paradis S., Thibaut B., 2019. **CIRAD wood chemical composition database**, *https://doi.org/10.18167/DVN1/U1FTIU*, CIRAD Dataverse, V2.

12. Kokutse A. D., Brancheriau L., Chaix G., 2010. **Rapid prediction of shrinkage and fibre saturation point on teak** (Tectona grandis) **wood based on near-infrared spectroscopy**. Annals of Forest Science, 67 (4): 403. *https://www.afs-journal.org/articles/forest/abs/2010/04/f09144/f09144.html?mb=1*

13. Bossu J., Beauchêne J., Estevez Y., Duplais C., Clair B., 2016. **New Insights on Wood Dimensional Stability Influenced by Secondary Metabolites: The Case of a Fast-Growing Tropical Species *Bagassa guianensis* Aubl.**. PLoS ONE, Public Library of Science, 2016, 11. *https://hal.inrae.fr/hal-02636844*

14. Hernández R.E., Almeida G., 2007. **Effects of extraneous substances, wood density and interlocked grain on fiber saturation point of hardwoods**. Wood Material Science & Engineering 2: pgs. 45-53. *https://www.tandfonline.com/doi/full/10.1080/17480270701538425*

Espèce	Number of trees tested*	Density	Fibre saturation point (%)	Shrinkage volume (%)	Alcohol-benzene extracts (%)	Extracts with water (%)	Total extracts (%)
Afzelia bipindensis	8/5	0,83	19	7,1	20,1	2,4	11,2
Afzelia pachyloba	3/4	0,75	21	8,4	9	3,6	6,3
Afzelia africana	6/3	0,79	21	7,5	10,4	5,5	7,9

*: for the 3 physical characteristics / for the 3 chemical characteristics, respectively.

These results highlight *A. Bipindensis's* better position compared with the other two species: its fibre saturation point and its volume shrinkage are the lowest and its extract contents are the highest (extract content is the most discriminating characteristic for this species). For the other two species, simply taking these indicators into account doesn't enable us to clearly explain the differences in performance.

For the record, the stability of a timber is also related to other parameters such as variations in the grain's orientation (counter grain, twisted grain, oblique grain) and its sensitivity to humidity variations.

DISTINCTION BETWEEN THE *AFZELIA* SPECIES AND THE NEW PILOT NAMES

It therefore appeared necessary to stop grouping *Afzelia* species under the same "Doussié" pilot name and to assign a specific pilot name to them due to differences in geographical distribution, log quality, technological characteristics and commercial practices between these species.
Consequently, ATIBT's Materials and Standardisation Commission has validated the following names:

Afzelia bipindensis Harms : **Doussié**
Afzelia pachyloba Harms : **Pachyloba**
Afzelia africana Sm. : **Lingué**
Afzelia quanzensis Welw. : **Chanfuta**

The *Afzelia bella* Harms species wasn't taken into consideration due to the highly confidential nature of its trade.

These new correlations between botanical names and pilot names will be included in the next edition of the *General Nomenclature of Tropical Timber*; for the time being, however, they are an addendum.

AFRICAN SPECIES OF THE *PTEROCARPUS* GENUS

Preamble – current classifications and names of Padauk-type *Pterocarpus*

Approximately 20 *Pterocarpus* species are present in African tropical forests[15]. The consideration undertaken regarding the evolution of names of Pterocarpus species whose timber is sold cover these three species: *Pterocarpus osun*, *P. soyauxii* and P*. tinctorius,* which are grouped together under the pilot name **African Padauk** in the General Nomenclature of Tropical Timber.

As with Doussie, this grouping is found in the previously mentioned reference works.

Two African species that are traded are not included: *Pterocarpus angolensis* (pilot name: Muninga) and *Pterocarpus erinaceus*[16] (pilot name: Vene)[17].

In the Nomenclature, the vernacular names of the African Padauk and the countries where these names are used are not specifically associated with each of the three species, with the exception of the name Osun in Nigeria for *P. osun*:

Pilot name	Botanical names	Vernacular names
African padauk	Pterocarpus osun Craib Pterocarpus soyauxii Taub. Pterocarpus tinctorius Welw.	Kisésé (CG) ; M'Bèl (CM, GA) ; Mongola (CD) ; Mukula (CD) ; N'Gula (CD) ; Osun (NG) ; Padouk (CF) ; Palo rojo (GQ) ; Tacula (AO)[18]

DISTRIBUTION AND GENERAL CHARACTERISTICS OF *PTEROCARPUS SOYAUXII, PTEROCARPUS OSUN,* AND *PTEROCARPUS TINCTORIUS*

The distribution and general characteristics of the three Padauk species are taken from the book Prota - Lumber 1[19]:

15. Five species of the *Pterocarpus genus* from Southeast Asia are traded: *Pterocarpus macrocarpus* and *Pterocarpus marsupium* (pilot name: Padauk Burma); *Pterocarpus dalbergioides* and *Pterocarpus indicus* (pilot name: Padauk Amboina); *Pterocarpus santalinus* (trade name: false red sandalwood), a species listed in Annex II of the CITES (14 February 2021). The *Pterocarpus officinalis* species (pilot name: Drago) is harvested in South America.

16. Listed in Annex II of the CITES (version: 14 February 2021).

17. Two African Pterocarpus species that are not traded are cited in the reference literature*:
Pterocarpus tessmannii (Equatorial Guinea, Gabon, DRC), whose red timber could be found in commercial batches of African Padauk.
Pterocarpus mildbraedii (Liberia, Cameroon, Equatorial Guinea, Gabon) whose heartwood is white, hence the name "White Padauk" that is sometimes used in publications; this name is not used by operators in the sector.
*Sources: Flore du Gabon, Leguminosae - Papilionoideae (van der Maesen L., Sosef M., 2016); Useful trees of Gabon (Meunier Q., Moumbogou C., Doucet J.L., 2015); Trees of Central Africa's dense forests (Vivien J., Faure J.J., 2011); PROTA Lumber 1 (Louppe D. (ed.), Oteng-Amoako A.A. (ed.), Brink M. (ed.), 2008).

18. CG: Congo; CM: Cameroon; GA: Gabon; CD: Democratic Republic of Congo; NG: Nigeria; CF: Central African Republic; GQ: Equatorial Guinea; AO: Angola

19. Louppe D., Oteng-Amoako A.A., Brink M. (Publishers), 2008. **Plant Resources of Tropical Africa 7(1)**, Timbers 1. 2008. PROTA Foundation, Wageningen, Netherlands/Backhuys Publishers, Leiden, Netherlands/ CTA, Wageningen, Netherlands. 785 pgs.

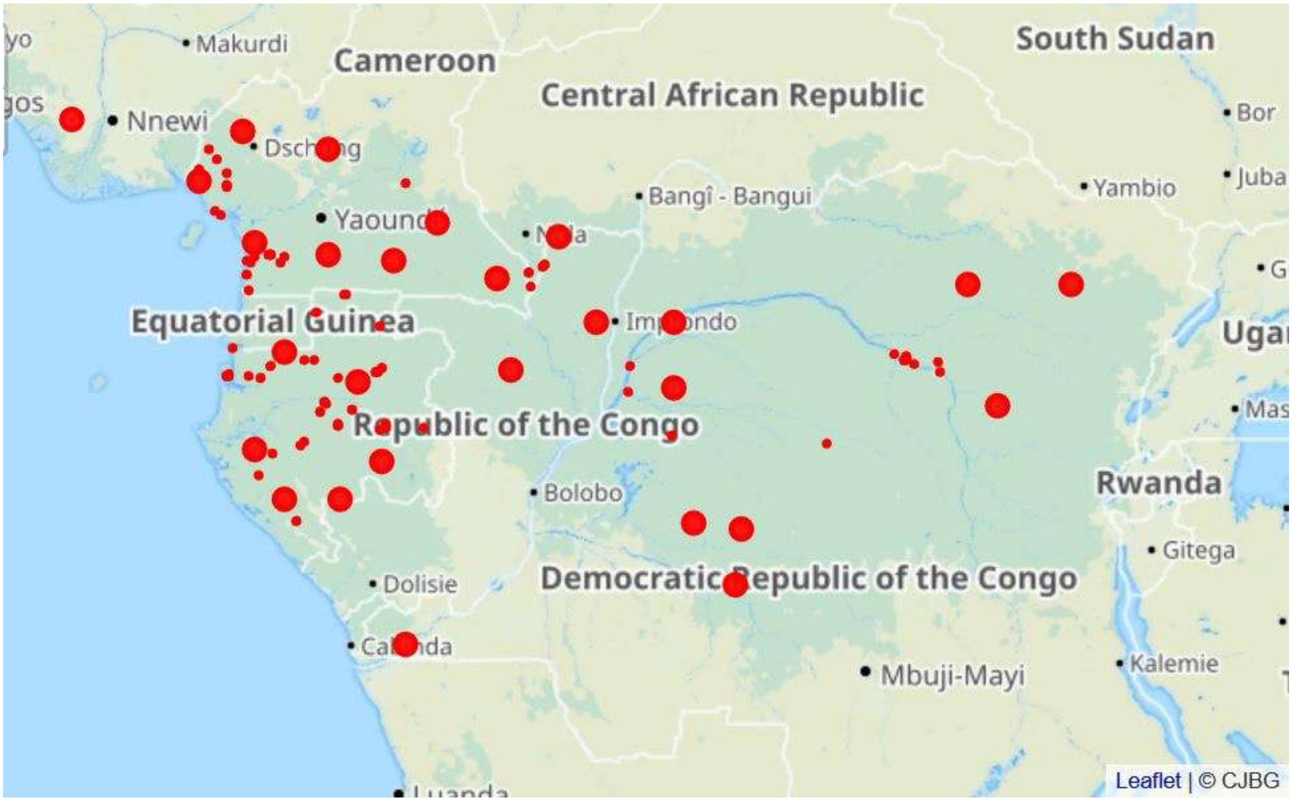
* *Pterocarpus soyauxii* is found from south-eastern Nigeria to eastern Democratic Republic of Congo, and southward to northern Angola. The tree can reach 55 m in height; its bole is straight and cylindrical, without branches up to 20 m, and reaches 1.4 m in diameter. This species is the most common of the three Padauk species and accounts for most of the volumes that are sold.

* *Pterocarpus osun* is endemic to southern Nigeria, Cameroon and Equatorial Guinea. The tree is small to medium in size, sometimes reaching 30 m in height but most often of a much smaller stature; its bole is often short and tortuous. The timber of the noblest boles is sold in small quantities, often in mixture with *Pterocarpus soyauxii*.

* *Pterocarpus tinctorius* is present in central, eastern and southern Africa, from the Congo and the Democratic Republic of Congo to Tanzania and southwards to Angola, Zambia, Malawi and Mozambique. This species is the most eastern of the three species of Padauk. The tree is small to medium in size medium size, reaching up to 25 m high; its bole, free of branches sometimes up to 15 m, is often straight and cylindrical, reaching 0.75 m in diameter. This timber is sold in small quantities on the international market.

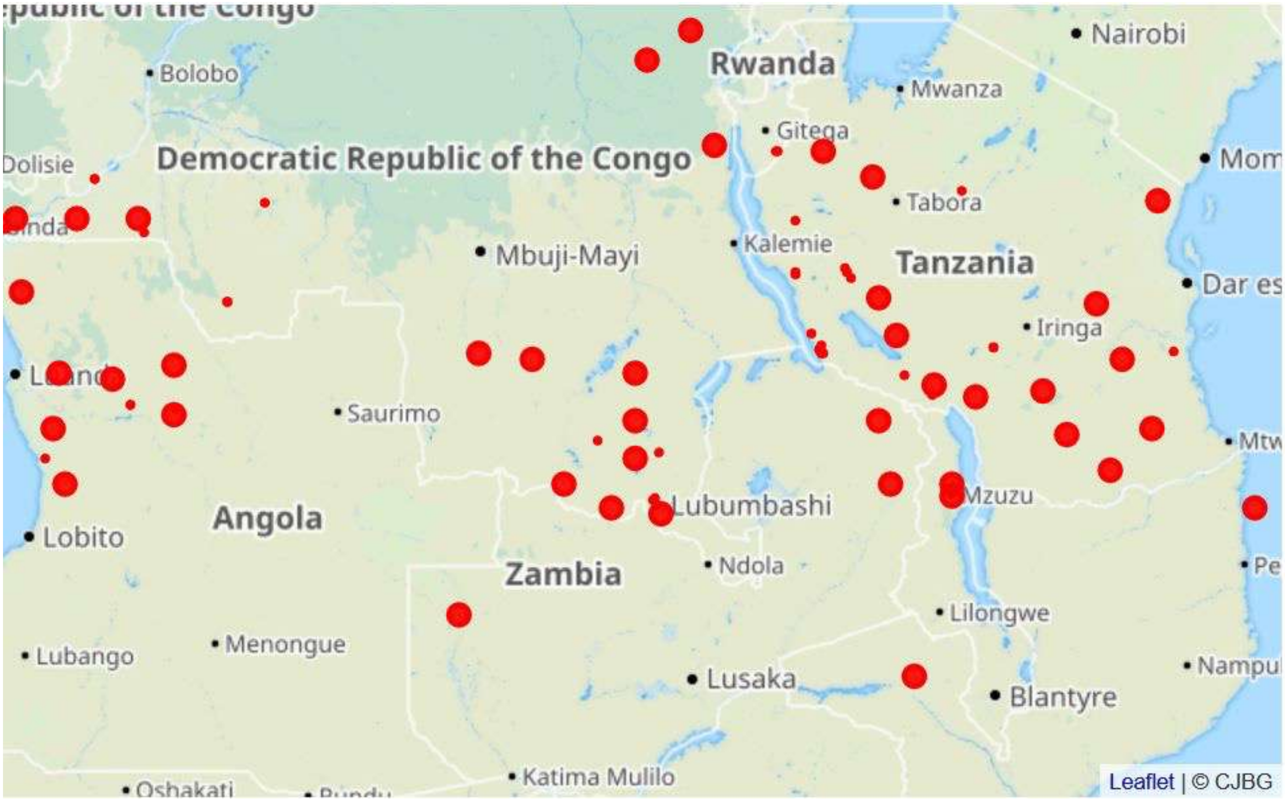
The following three maps show the geographical distribution of the three species in Africa (based on observations made in the framework of the **African Plant Database** project

https://africanplantdatabase.ch/



Geographical distribution of Pterocarpus soyauxii

Geographical distribution of Pterocarpus osun



Geographical distribution of Pterocarpus tinctorius

DISTINCTION BETWEEN THE *PTEROCARPUS* SPECIES AND NEW PILOT NAMES

Differences in geographical distribution, log quality, and availability between the three species of *Pterocarpus* lead to questions regarding the coherence of their grouping under the same pilot name.
The listing of the *Pterocarpus tinctorius* species in Annex II of the CITES (14 February 2021) was a triggering factor that made it necessary to distinguish it from the other two species of the genus.

As a result, ATIBT's *Materials and Standardisation Commission* has validated the following names:

Pterocarpus soyauxii Taub. et *Pterocarpus osun* Craib : **Padouk d'Afrique**
Pterocarpus tinctorius Welw. : **Tinctorius**[20]

These new correlations between botanical names and pilot names will be included in the next edition of the *General Nomenclature of Tropical Timber*. For the time being, they are an addendum.

Doussié

Bordeaux's Velodrome Stadium bicycle track - France (© APC Viaud - AXEL VEGA)

20. = Tinctorial in French

Doussié

Storefront facade cladding - Andorra
(© Michel Vernay, CIRAD)
Excerpt from Tropix V7

Pachyloba

Pachyloba pepper mill -
Brûlerie Moderne, Douala, Cameroon
(© Emmanuel Groutel, WALE)

Padauk

Facade of the Ministry of Water and Forests, Libreville - Gabon
(© Jean Gérard, CIRAD) Excerpt from the *Tropical Timber Atlas*

Padauk

Educational tower at the Raponda Walker Arboretum, Cap Esterias - Gabon. Ecowood manufacturing (© Emmanuel Groutel, WALE)
https://www.gabonreview.com/arc-demeraude-une-salle-de-classe-perchee-dans-les-arbres-a-larboretum-raponda-walker/

Padauk

Details of a post, railing, crossbeam and connectors of the Raponda Walker Arboretum's educational tower, Cap Esterias - Gabon Ecowood fabrication (© Emmanuel Groutel, WALE)

Padauk

Hub with Ipê spokes on a paddle wheel (or mill) feeding the hydraulic irrigation network for market gardening in Cazilhac, Hérault - France (© Michel Vernay, CIRAD)
Excerpt from Bois et Forêts des Tropiques num. 269 (3), pgs. 102-104

Document produced by ATIBT's Timber-Material-Standardisation Commission by Mr. Jean Gérard / CIRAD (Secretary) and Mr. Emmanuel Groutel / WALE (President). September 2022

TECHNICAL SHEETS

atibt

FOR THE SUSTAINABLE MANAGEMENT OF TROPICAL FORESTS

FAIR & PRECIOUS BY atibt ÉDITIONS

16

TIMBER UNDER RAILS AND RELATED USES

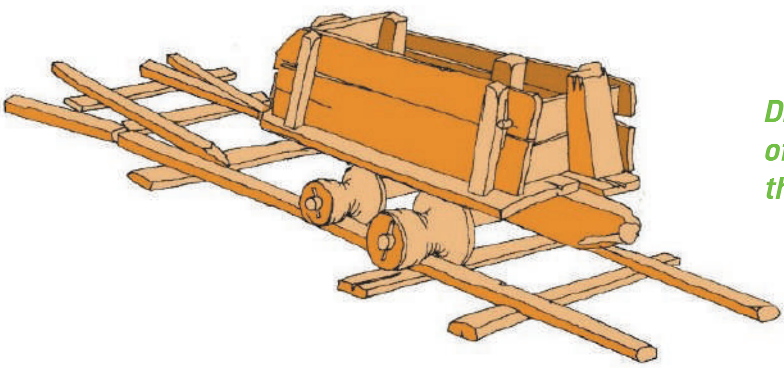
CONTENTS

Azobe sleepers (Photo by Emmanuel Groutel, WALE, Gabon)

PREAMBLE

The development of railways from the 19th century onwards is directly linked to the development of timber and the improvement of its implementation techniques.
However, as early as the 15th century, timber was already used to make rails for Central Europe's first mining "railways".

In its early days, the "iron" railway could have been called a "timber railway"; in the 19th century, whereas iron rails became more widespread, wooden rails still had their supporters.



Drawing (anonymous) of a mining wagon from the Renaissance era[1]

1. *The earliest historical mention of a guided transport system using rails is that of Sebastien Münster in his book "Cosmographie Universelle" published in Basel in 1550. The author describes the rail cart system operating in the mines of Leberthal (Alsace region), with carts pushed by miners in the galleries. The cart and its wheels are made of timber, and both tend to feature iron rolling parts to compensate for the wear and tear that inevitably digs into the wheel treads or reduces the height of the rails.* (**The timber of which railways are made**, Clive Lamming).
https://trainconsultant.com/2021/07/14/le-bois-dont-on-fait-les-chemins-de-fer/

Timber is now the world's most widely used material for the manufacture of railway sleepers and railway switches and crossings in general.

In Europe, four main species are used:

- Oak (pedunculate and sessile), France's most widely used species, both for sleepers and bearers in switch and crossing layouts.
- Beech, mainly used for sleepers, in German-speaking countries as well as in Central and Eastern Europe.
- Pine, used almost entirely in Scandinavia and Poland, as well as in the UK.
- Azobe, used in Western Europe for railway switches and crossings

In recent years in France, Okan has become the leading species used for sleepers.
The share of timber on the railway network has decreased during the last few decades, in favour of concrete.
Almost all sleepers laid on the main track are made of concrete.

However, timber still retains a significant market share for specific applications, such as:

- railway switches and railway junctions,
- engineering structures,
- the occasional replacement of sleepers on tracks that already use timber sleepers (no mix of timber and concrete on a same track),
- service tracks (access to workshops and terminals) which have derailment risks.

Sleepers made of Angelim (photo: Stéphane Glannaz, Mil Madeiras Preciosas Ltd. - Precious Woods Amazonas, Itacuatiara, State of Amazonas, Brazil)

1. TYPES OF TIMBER UNDER RAILS

The term *timber under rails* covers different types of products, mainly sleepers, but also technical components with very specific uses for various railway switches, and for which it is necessary to provide precise definitions.

- **Sleepers2 for plain lines**: a wooden beam that supports running rails, guard rails and conductor rails, perpendicular to its axis. Typically, the beam supports two running rails to form a track.

- **Bearers in switch and crossing layouts:** a timber beam similar to a sleeper but usually longer, which is used to support the running rails, guard rails, conductor rails, crossings and the systems used to manoeuvre the railway switches and crossings.

- **Longitudinal timber for bridges and pit roads:** This refers to timber placed underneath the railway rails and in line with the rails, to support them and to shift the loads to the infrastructure in the axis of the track.

- **Listed cuts that are specific to certain structures.**

The following specifications are largely based on the elements of the two referenced documents, "AFNOR 2011" (the European standard) and "SNCF 2018" (SNCF specifications IG4019 and IG4020). They concern "raw" timber pieces (that haven't been shaped or machined) intended for the manufacture of standard or narrow gauge track sleepers and standard gauge switch and crossing layouts.

Crossings made of Kempas (photo: Benoit Gommet, France Timber, Nagoya, Japan)

2. Or "ties" (USA)

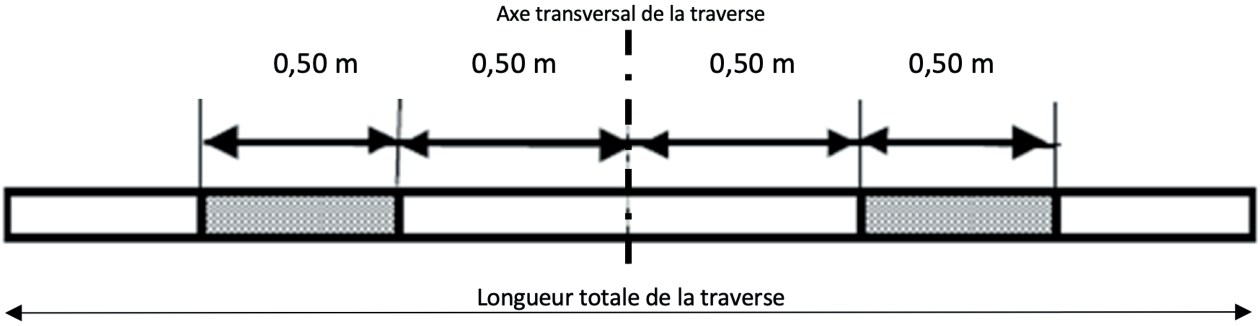
2. FORMAT AND DIMENSIONS

The following descriptions are based in part or in summary on those in the "SNCF 2018" document, which is the reference source.

2.1. IN FRANCE (SNCF RAILWAY OPERATOR)

2.1.1. Description of the supporting surface

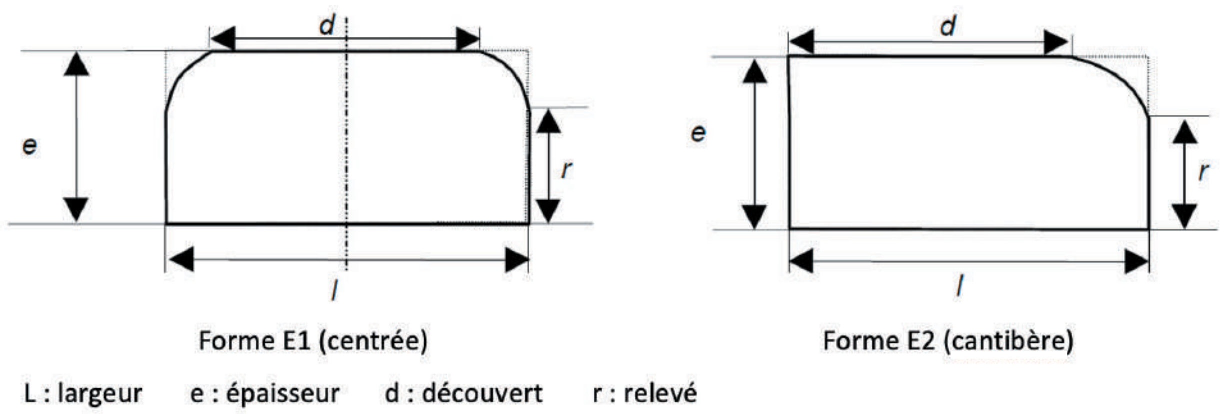
*** Timber support surface for standard track sleepers**
The bearing surface of timber for standard track sleepers covers a length of 50 cm from a distance of 50 cm on either side of the middle of the sleeper (see below diagram).



*** Timber support surface for bearers in switch and crossing layouts**
The timber support surface for bearers in switch and crossing layouts extends over the entire length of the timber piece.

2.1.2. Cross-section of sleepers

The sleepers must have a cross-section (transversal cut) in accordance with one of the two shapes below (taken from standard EN 13145+A1).

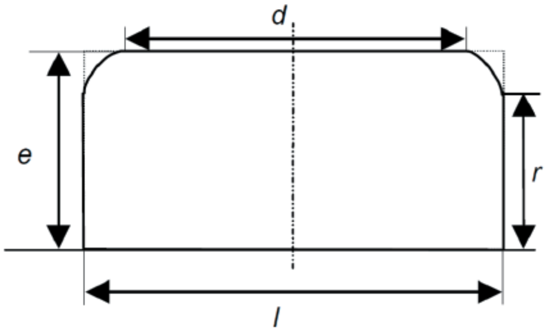


Outside of the supporting surface, shapes without relief or overhangs are accepted with nothing less in terms of width at the base and nothing less in terms of thickness [SNCF 2018].

2.1.3. Cross-section of railway switch bearers

*** Tropical species**
The parts for bearers in switch and crossing layouts made of tropical timber are 4-sided square-edged timber pieces (rectangular cross-section with sharp edges).

*** Temperate species**
The cross-section of the supports must comply with the shape shown on the right:



L : largeur   e : épaisseur   d : découvert   r : relevé

2.1.4. Names and dimensions of timbers for normal track sleepers (type G)

The names and dimensions (in mm) of the timbers for standard railway sleepers are given in the below table. The clearances and elevations are measured at the bearing surfaces.

Group	Width (l)	Thickness (e)	Length (L)	Minimum exposure (d)		Minimum elevation (r)
				Form E1	Form E2	Forms E1 and E2
G2	260	150	2600	170	200	80
G6	240	140	2600	160	180	70
G8	220	130	2600	150	160	50

Detail of the assembly of an Azobe part (rail/tyre) for metro line no. 6 in Paris (photo: Rail Europe)

2.1.5. Names and dimensions of timbers for bearers in switch and crossing layouts

The name of a timber bearer for switch and crossing layouts has 2 characteristics:
- a number from 1 to 3 designating the dimensions of its cross-section,
- a letter from A to U (excluding letters F, I, O, Q, L, T) designating its length.

The details of these designations in relation to the corresponding dimensions are available in the "SNCF 2018" document.
The below table summarises the dimensions **(cross-section dimensions in mm, lengths in m)** of timber for bearers of switch and crossing layouts. For tropical timber bearers, the parts are edged on 4 sides and therefore have no exposed or raised edges.

Width (l)	Thickness (e)	Length (L)	Minimum exposure (d)		Minimum elevation (r)
			Form E1	Form E2	
260	150	2,60 - 2,80 - 3,00 - 3,20 - 3,40 3,60 - 3,80 - 4,10 - 4,40 - 4,70 5,00 - 5,35 - 5,70 - 6,00 - 6,80	210	230	120
300	150		240	270	120
350	150	2,60 - 3,60 - 4,40 - 4,70 - 5,35	290	310	120

2.1.6. Dimensional tolerances

The tolerances defined by standard NF EN 13145 are applicable unless otherwise stipulated in the below table.

These specific tolerances apply to freshly sawn timber. An extra allowance is to be made for dimensional shrinkage during sawing, which may occur during storage at the supplier's stockyard and during shipping. If the inspection is carried out on dried tropical timber (more than 2 months after sawing), the tolerances to be applied to the vertical and horizontal curvatures are those defined in the NF EN 13145 standard increased by 50% (less strict tolerances).

All values are in mm:

Types of pieces (dimensions)	Length	Width and thickness	Maximum vertical curvature*	Maximum horizontal curvature**	Maximum split pass-through length
G2 (2600 x 260 x 150) G6 (2600 x 240 x 140) G8 (2600 x 220 x 130)	± 30	+15 0	7	50 (temperate) 6 (tropical)	200 (temperate) 100 (tropical)
A8 (2000 x 220 x 130)	± 30		5	40	200
Switch and crossing timber A (2.60 m) to C (3 m)			6	30 (temperate) 6 (tropical)	200 (temperate) 100 (tropical)
Switch and crossing timber D (3.20 m) to G (3.6 m)			7	35 (temperate) 7 (tropical)	
Switch and crossing timber G (3.80 m) to K (4.4 m)			8	40 (temperate) 9 (tropical)	
Switch and crossing timber M (4.70 m) to U (6.8 m)			10	50 (temperate) 11 (tropical)	

* = bow ** = spring

End through-splits with an opening greater than 5 mm are excluded. All splits or beginnings of splits at the ends must be consolidated by means of s-shaped hooks or connector plates. For the ends of the pieces, a maximum bias of 10 mm is tolerated.

Sleepers made of Kempas (photo: Benoit Gommet, France Timber, Nagoya, Japan)

Sleepers made of Angelim and Angelim vermelho (in the back) (photo: Stéphane Glannaz, Mil Madeiras Preciosas Ltd. - Precious Woods Amazonas, Itacuatiara, Amazonas State, Brazil)

Sleepers made of Okan (photo: Frédéric Viroux, Pallisco, Cameroon)

2.2. SPECIFICATIONS OF EUROPEAN STANDARD EN 13145+A1

The following descriptions are based on those of **standard NF EN 13145+A1** (December 2011) *Railway applications - Track - Timber sleepers and bearers*, which is the reference source.

2.2.1. Cross-sections of sleepers and bearers in switch and crossing layouts

Identical to those presented in section 2.1.

2.2.2. Most commonly used names and dimensions of sleepers

Group	l (mm)	e (mm)	d* (mm)		r* (mm)
			Shape E1	Shape E2	Shapes E1 et E2
1	260	160	160	200	80
2	260	150	160	200	80
3	260	130	130	170	60
4	240	150	160	180	70
5	240	160	160	180	80
6	240	140	160	180	70
7	240	130	130	170	60
8	220	130	130	160	50
9	250	125	205	230	100
10	305	125	255	280	100
11	305	150	255	280	125
12	250	130	200	225	105
13	300	130	250	275	105
14	200	120	110	140	40

*: minimum dimensions

2.2.3. Most commonly used names and dimensions for bearers in switch and crossing layouts

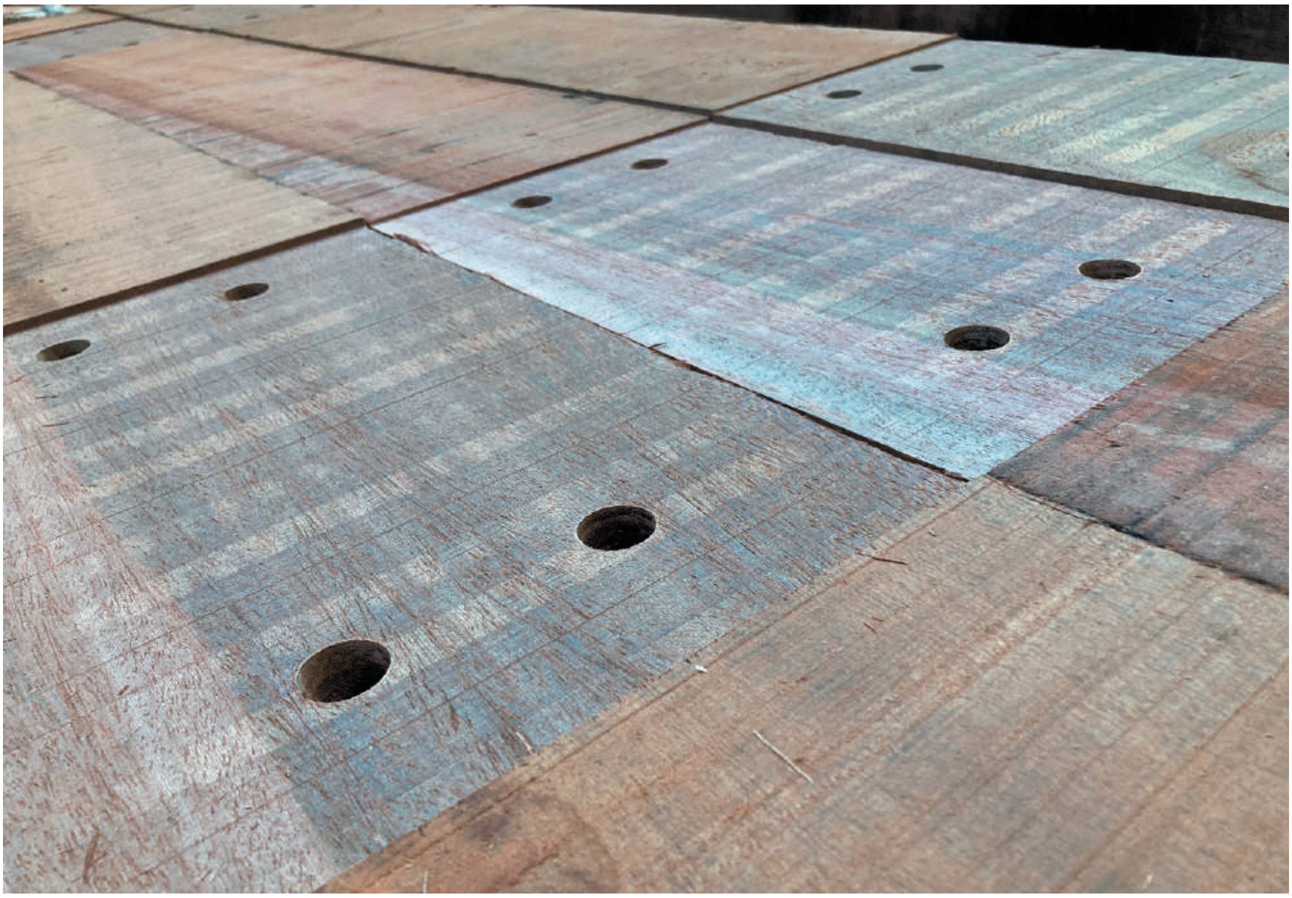
Group	l	e	d*	r*
1	300	150	240	120
2	280	140	220	120
3	260	160	200	100
4	260	150	210	120
5	240	150	200	90
6	240	160	160	80
7	240	140	200	80
8	300	130	200	80

*: minimum dimensions

Sleepers made of Azobe in the Cairo metro in Egypt (photo Rail Europe)

2.2.4. Dimensional tolerances

These tolerances apply to all sleepers and bearers ready for use and/or treatment:
Length: ± 30 mm
Width: + 10 mm / - 3 mm
Thickness: + 10 mm / - 3 mm
Cross-section cut (90°): maximum deviation of 3°
For the length tolerance to be permissible, the ends of the sleeper or bearer must be sawn at a right angle.



Preparation of Azobe sleepers (photo: Emmanuel Groutel, WALE, Gabon)

3. MAIN QUALITY REQUIREMENTS, DEFECT TOLERANCES

For timber that does not require a preservative treatment, the application of a so-called "anti-splitting" product to the cross-sections of the pieces is recommended.
The recommendations in the below table are based on, and sometimes adapted from, those mentioned in the "AFNOR 2011" and "SNCF 2018" documents.

DEFECT	TOLERANCES
Healthy sapwood (altered sapwood excluded)	***Recommendations in France / SNCF (SNCF 2018)*** * Sapwood allowed without limits for sleepers. * For temperate timber bearers, the volume of sapwood should be less than 1/3 of the volume present in the piece. The sapwood must not appear on the underside. * For tropical timber bearers, a sapwood tolerance of 25% of the nominal width for the entire length of the top side (standard EN 13145). The sapwood must not appear on the underside.
	Recommendations of European standard EN 13145 * For tropical hardwoods, sapwood is tolerated outside of the bearing surface with a maximum of 50% of the nominal width for sleepers, or 25% of the nominal width over the entire length of the top side for bearers in switch and crossing layouts. * For temperate hardwoods, sapwood is tolerated.

Thread	***Recommendations of European standard EN 13145*** Maximum permissible deviation from the longitudinal axis: 1/10 (deviation measured over a length of 600 mm)
Bark gap	Not allowed on the bearing surface. Tolerated outside of the bearing surface on one side only and over a maximum length of 150 mm.
Healthy knots	***Recommendations in France / SNCF (SNCF 2018)*** Tolerated except for sharp knots (knots appearing on the front and on the edge of sawn timber)
	Recommendations of European standard EN 13145 * European softwoods and tropical hardwoods: tolerated if adherent, with a diameter not exceeding 25% of the dimension of the front side for sleepers and bearers. Not tolerated in the support surface of sleepers * European hardwoods: tolerated if adherent
Chips and splits from surface drying	Tolerated
Splits that pass through	***Recommendations in France / SNCF (SNCF 2018)*** Length: see section 2.1.8. Dimensional tolerances Tolerated if the opening < 5 mm on freshly sawn timber Reminder: end splits that pass through with an opening greater than 5 mm are rejected; all end splits or the beginnings of splits must be adequately reinforced by means of s-shaped hooks or connector plates.
	Recommendations of European standard EN 13145 * European hardwoods: tolerated up to 250 mm from the ends * European softwoods: tolerated up to 75 mm from the ends * Tropical hardwoods: Tolerated up to 200 mm from the ends
Internal splits	Tolerated if they don't reach the top or lateral sides of the pieces
Curls	Tolerated if diameter ≤ 50 mm; not tolerated if visible on the top or on the lateral sides
Springs	***Recommendations in France / SNCF (SNCF 2018)*** See section 2.1.8. Dimensional tolerances
	Recommendations of European standard EN 13145 * Tropical hardwoods: max. 6 mm for sleepers, max. 2 mm/m for bearers * European hardwoods: max. 2% of the length for sleepers, max. 1% of the length for bearers * European softwoods: max. 0.5% of the length for sleepers and bearers
Bows	***Recommendations in France / SNCF (SNCF 2018)*** See section on Dimensional tolerances
	Recommendations of European standard EN 13145 Tolerated if the correct inclination of the saddle is ensured, but limited to: max. 0.6% of the total length for sleepers max. 0,2 % of the total length for bearers
Dead punctures	Tolerated if the sleeper or bearer's mechanical properties are not affected
Pith	Tolerated only in temperate timber
Felling cracks, sawing defects, double bends, warping, bowing, splitting, rotting, rotten knots, worm holes	Not tolerated

Timber pieces for sleepers and for bearers in switch and crossing layouts must be processed in the freshly sawn state; in fact, drying is not technically or economically feasible. Furthermore, and especially in the large sections that are most often necessary for these types of uses, these very hard and dense timbers cannot be processed in the dry state.

This aspect must be emphasised to the competent authorities of producing countries (Ministries of Water and Forests, Customs, etc.) so as not to break this specific supply chain.

Shaping of Azobe pieces for railway switch and crossing layouts, RATP, Paris (photo Rail Europe)

4. COMPARATIVE ADVANTAGES OF TIMBER COMPARED WITH COMPETING MATERIALS

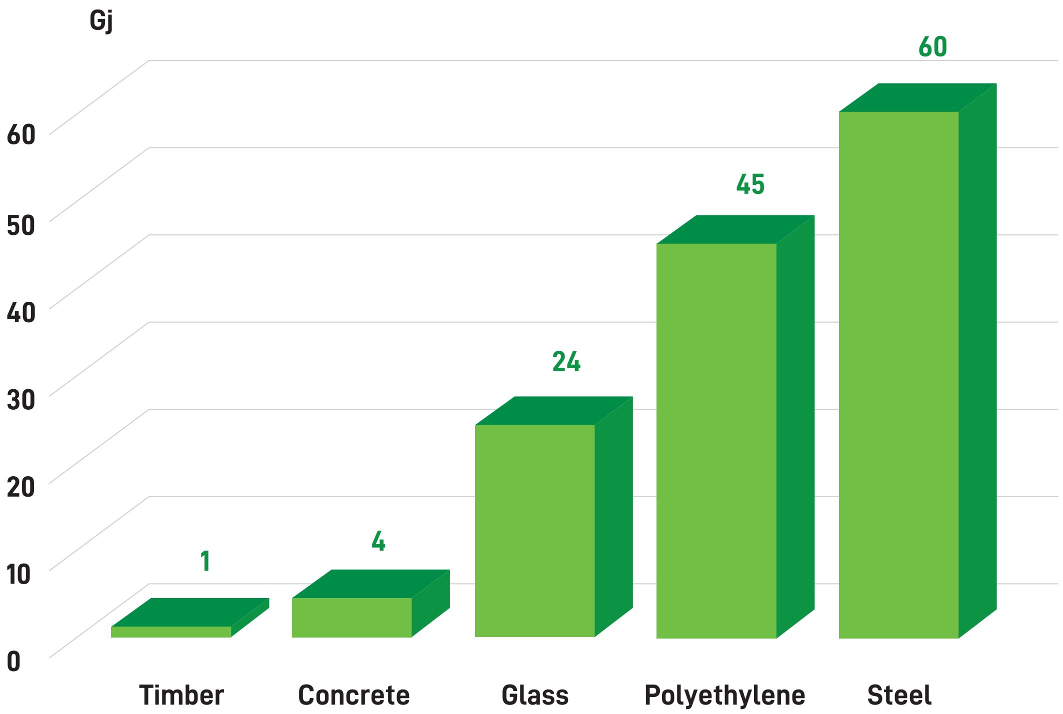
4.1. TIMBER AS A CARBON-SAVING AND ENERGY-EFFICIENT MATERIAL

Timber is an eco-material that on average consists of up to 50% carbon (by mass) from the CO_2 captured by trees from the atmosphere during photosynthesis.

Examples of the positive impact of trees and timber in terms of the capture of atmospheric CO_2

- **The production of one m^3 of timber is associated with the capture of one ton of atmospheric CO_2.**
- **Timber is the only material whose manufacture and use are associated with a negative balance of CO_2 production in the atmosphere.**
- **When the forest produces 1 m^3 of timber, it purifies the equivalent volume of air polluted by a plane carrying 600 people over a distance of 2,500 km.**
- **To produce one kilogram of timber, a tree must consume all of the CO_2 contained in 2,600 m^3 of air (2,600 m^3 represents the average volume occupied by a building housing 40 people).**
- **In France, one kilometre of track with timber sleepers stores on average about 60 tons of carbon, which is the amount of carbon contained in 220 tons of CO_2.**

Timber has a low energy cost as the following chart illustrates:



Energy required to manufacture 1 ton of material

4.2. THE TECHNICAL ADVANTAGES OF TIMBER FOR SLEEPERS AND BEARERS IN SWITCH AND CROSSING LAYOUTS

In addition to being environmentally friendly, the use of timber for railway sleepers and for other track bearers offers many technical advantages:

- The physical and mechanical characteristics of timber provide it with significant technical advantages:
- It's a good natural electrical insulator, and its use doesn't require the addition of an extra insulating element.
- The elasticity of timber allows sleepers to warp without breaking in the event of derailment.
- Timber sleepers are best suited for situations of high stress and impacts due to their high bending capacity and shear strength.
- Timber tends to absorb vibrations and sound waves, which is particularly useful in urban networks and at railway stations.

- Timber is a light material, which therefore makes it cheaper to transport and install, making it well suited for both bridges and sloped areas.

- The high density of tropical timber, up to 1.1 or 1.2, gives them good resistance: they can be used in track segments with high stresses such as railway switches.

- Timber is characterised by its high flexibility of use, as it can be shaped on site with basic portable tools. This is particularly ideal for maintenance in areas with various types of installations. Timber sleepers are custom-shaped for special areas such as tunnels or bridges.

- In old tunnels, it is sometimes impossible to install concrete sleepers because of issues linked to thickness: in fact, installations on timber sleepers are generally 10 cm thinner than those on concrete sleepers. The natural flexibility of the timber material allows it to adapt to variations in the ground, and therefore allows for a thinner ballast layer.

- In train stations, the heights of platforms are determined according to the thickness of the timber sleepers, and the extra height due to concrete sleepers poses technical problems.

- The use of timber is necessary in certain areas which have specific technical constraints:

- A need for direct fixing (a "rigid" installation) on specific bearers on metal bridges.
- Areas with a low curvature radius where the rails have mechanical joints (instead of "continuous welded" rails); installations on timber sleepers is necessary:
    - to avoid severe shocks that can affect the track and equipment, and which are also unpleasant for passengers,
    - to ensure that the two rails are worn in a more or less uniform manner,
    - to allow the rails to be spread out in very tight radii.

4.3. TIMBER UNDER RAILS AND ECO-CERTIFICATION

The use of timber - especially tropical species - for sleepers and for switch and crossing layouts goes hand in hand with the implementation of forestry eco-certification systems as tools for economic, social and cultural development, and the preservation of biodiversity.
The main labels (FSC®, PEFC-PAFC) thus ensure compliance with a set of requirements aimed at protecting the environment and local populations. The practices of certified forest management in natural tropical forests involve a great deal of investments in several areas:

- Socio-economic development at the local level
- Support for proper forest governance and law enforcement
- The preservation and conservation of forest ecosystems and biodiversity
- Involving local communities in forest management

They help limit imported deforestation and provide sustainable employment in the producing countries.

5. SPECIFIC CONSTRAINTS THAT APPLY TO TIMBER UNDER RAILS

No matter which product is considered, whether it's a standard sleeper or a more technical product such as bearers of railway switches or crossings, timber under rails requires:

- Solid mechanical characteristics due to the high stresses to which it is subjected (rigidity, resistance to transverse compression, impacts and longitudinal bending).
- High resistance to attacks by lignivorous fungi.

5.1. MECHANICAL CHARACTERISTICS

Among the species recommended by the standard NF EN 13145 and the NetworkRail document, temperate timbers have average densities and therefore average mechanical characteristics.
The two hardwoods referred to, oak and beech, have average densities of around 0.70 but the softwoods mentioned in the standard have weaker characteristics, with average densities of around 0.55 for Pine and Douglas timber, and up to 0.60 for Larch timber. On the other hand, the tropical timbers recommended present higher performances with an average density[3] that's higher than 0.75[4], this average density often reaching 0.85 (chart 1).
These timbers, which usually range from heavy to very heavy[5], correlatively present superior mechanical characteristics.

3. Obtained at 12% humidity
4. Of these timbers, Bilinga has the lowest average density: 0.76
5. According to CIRAD classification:
   0.65 < density < 0.80: medium-heavy timber
   0.80 < D < 0.95: heavy timber
   0.95 < D: very heavy timber

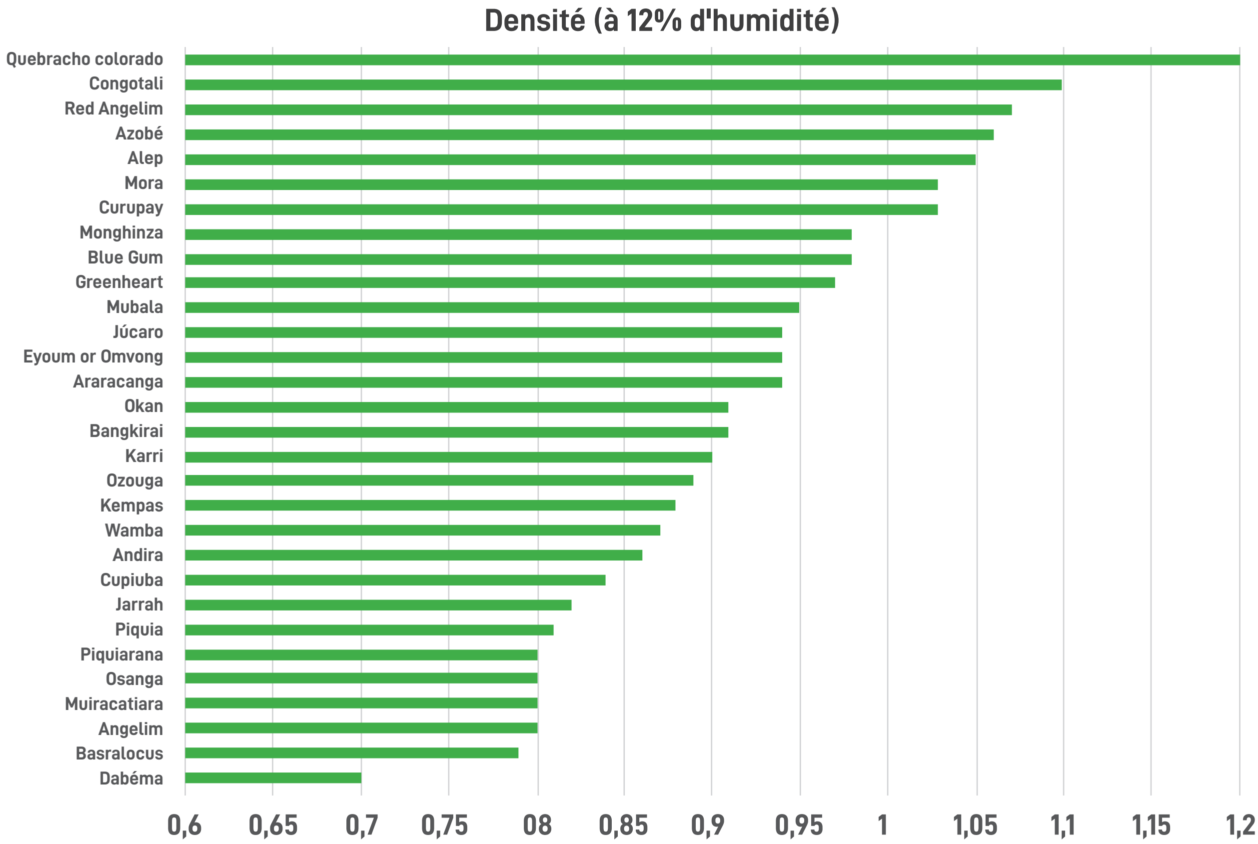


Figure 1. Distribution of densities of the main tropical species recommended for use in timber under rails - Source: Tropix 7 and CIRAD database

5.2. RESISTANCE TO LIGNIVOROUS FUNGI

Given the constraints which it is subjected to through its use in contact with the ground, timber used under rails must have a natural or conferred durability (after preservation treatment) that allows it to be used in risk class 4 as defined by the EN 335 standard (May 2013).

This usage class corresponds to outdoor uses in contact with the ground or fresh water characterised by frequent or permanent wetting, water retention and water stagnation.

The definitions of notions relating to natural durability classes, usage classes, and the relationships between natural durability classes and usage classes had been explained in the technical document entitled *Timber for hydraulic structures* (ATIBT 2021[6]).

It seemed appropriate to present these concepts again in this document as they are the basis for a rational use of timber. The definition of natural durability classes is given in the first part of Annex 1, and the definition of usage classes is given in the second part of this Annex.

The NF EN 13145 standard *mentions that timber with a natural durability of class 1 or 2* (according to EN 350-2) *has a natural durability that allows for its use in risk class 4.*

However, the European standard NF EN 460 (July 1994), which is still in effect, although it is currently under revision, states that for timber with class 2 natural durability, *the natural durability usually covers the usage class but for certain uses, a protective treatment may be recommended* (see box below).

6. https://www.atibt.org/files/upload/14-LES-BOIS-POUR-OUVRAGES-HYDRAULIQUES.pdf

Given the very high risk of attacks by lignivorous fungi that they are confronted with, we will consider that only timber falling under class 1 of natural durability can be used without a protective treatment.

For the record, durability characteristics only relate to the heartwood of mature timber. The sapwood must always be considered as non-durable against biological timber degradation agents.

Relationship between natural durability classes and usage classes

The European standard NF EN 460 (July 1994), **which is still in effect although it's undergoing revision** (draft prEN 460, December 2021), proposes a table of relationships between the natural durability levels of solid timber and their possible uses in a given usage class (see below table).

Note: In reality, this standard refers to the notion of *risk class* and not of *usage class*, notions that are almost equivalent. *Usage class* is the term that's currently in effect; it is defined in the French standard NF EN 335 (May 2013). In the following table, we will use the term "usage class" in accordance with the terminology that is currently used, even if this term is not the one mentioned in French standard NF EN 460 of July 1994.

For the Netherlands, it is necessary to refer to the NEN-EN 350:2016[7] standard.

Natural durability classes according to usage class

Usage class covered by natural durability	Natural durability class				
	1	**2**	**3**	**4**	**5**
1	Yes(1)	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes but	Yes but
3	Yes	Yes	Yes but	On a case by case basis(3)	On a case by case basis
4	Yes	Yes but(2)	No but(4)	No(5)	No
5	Yes	No but	No but	No	No

(1) Yes: the natural durability covers the usage class.
(2) Yes but: the natural durability usually covers the usage class. But for certain uses, a preservative treatment may be recommended.
(3) On a case by case basis: the natural durability may be sufficient. But depending on the timber species, its permeability and its end use, a preservative treatment may be necessary.
(4) No but: a preservative treatment is usually recommended. But for certain uses, the natural durability may be sufficient to cover the usage class.
(5) No: the natural durability doesn't cover the usage class; a preservative treatment is necessary.

For usage classes 2 to 5, the equivalences aren't precisely defined for certain durability levels.

7. https://www.nen.nl/nen-en-350-2016-en-224409

6. SPECIES USED AND USABLE FOR TIMBER UNDER RAILS

Many species are potentially usable for the manufacture of railway sleepers and switch and crossing layouts.

In practice, the choice of species remains limited because it must simultaneously take into account several criteria:

1. The logs' diameter and physical composition, which must enable the cutting of large cross-section pieces. The amount of sapwood and non-hardened parts are also important factors.
2. The intrinsic characteristics of the timber in relation to the performance required for this type of use (mechanical strength, natural durability).
3. The price of timber whose prospects for use in sleepers and switch and crossing layouts may be limited by higher value applications.
4. Compliance with international standards, including the Washington Convention on protected species (CITES).

In the following two tables, the species commonly used for railway sleepers and for bearers in switch and crossing layouts in their production regions or in regions with a regular export flow are shown in green.

Species shown in black are of potential interest for these uses or are mentioned in reference documents.
The FD P20-651 Documentation Booklet "*Durabilité des éléments et ouvrages en bois*" (Durability of timber elements and structures) (July 2011) defines assessments of a wide range of tropical and temperate species in terms of their longevity against fungal risks, by usage class8.
These ratings are defined as follows:
L3: Longevity greater than 100 years,
L2: Longevity of approximately 50 to 100 years for its originally intended use,
L1: Longevity of approximately 10 and 50 years for its originally intended use,
N: Longevity uncertain and always under 10 years, these solutions are not to be recommended.

6.1. SPECIES REQUIRING A PRESERVATIVE TREATMENT

The main recommendations mentioned in the standards and technical documents for preservation treatment operations are as follows:

Treatment
The timber must be free of any peculiarities that prevent the proper application of the preservative treatment. All straightening, pre-cutting, notching, planing and drilling operations must be carried out prior to the preservative treatment. If local machining is required after the treatment, a local protective treatment should be provided. Prior to planing, drilling or the preservative treatment, the timber's humidity content must be within the range required by the preservative and by the treatment method that is used.

8. Refer to it for the species mentioned hereafter

Preservatives
The preservatives used must be creosote or comply with the performance requirements of risk class 4 products according to the 599+A1 standard.
Product penetration
After a preservation treatment, impregnated sleepers and bearers must meet the class 8 (P8: full sapwood penetration) penetration requirements the EN 351-1 standard.
Retention
After a preservation treatment, the minimum retention requirement shall be the critical value of risk class 4 of the preservative used as defined by the 599+A1 standard.

Pilot name	Botanical name	Density[9]	Origin	Comments
European oak	*Quercus robur* *Quercus petraea* *Quercus pubescens*	0,74	Temperate	Mentioned in the EN 13145 standard
American white oaks	*Quercus alba* *Quercus lobata* *Quercus michauxii*	0,73	Temperate	
Douglas	*Pseudotsuga menziesii*	0,54	Temperate	Mentioned in the EN 13145 standard
Beech	*Fagus sylvatica*	0,71	Temperate	Mentioned in the EN 13145 standard
Larch	*Larix* p.p.	0,60	Temperate	Mentioned in the EN 13145 standard
Pinus nigra	*Pinus nigra*	0,58	Temperate	Mentioned in the EN 13145 standard
Maritime pine[10]	*Pinus pinaster*	0,55	Temperate	Mentioned in the EN 13145 standard
Parasol pine[10]	*Pinus pinea*	0,58	Temperate	Mentioned in the EN 13145 standard
Scots pine	*Pinus sylvestris*	0,55	Temperate	Mentioned in the EN 13145 standard
Andira	*Andira coriacea* *Andira inermis* *Andira parviflora* *Andira* p.p.	0,86	South America	
Angelim (= Angelim pedra)	*Hymenolobium elatum* *Hymenolobium excelsum* *Hymenolobium petraeum* *Hymenolobium* p.p.	0,80	South America	
Cupiuba	*Goupia glabra*	0,84	South America	
Dabéma	*Piptadeniastrum africanum*	0,70	Africa	
Piquia	*Caryocar nuciferum* *Caryocar villosum* *Caryocar* p.p.	0,81	South America	
Piquiarana	*Caryocar glabrum*	0,80	South America	
Blue Gum	*Eucalyptus microcorys*	0,98	Asie	

9. Average density at 12% humidity..
The density of timber in temperate hardwood and softwood species varies according to their growth rates, sometimes with opposite effects depending on the species; some species are denser the faster they grow (e.g. Oak), whereas the opposite effect is observed in others (as in the case of Larch); this phenomenon should be taken into account when selecting a temperate species for use in timber under rails.
10. They are anecdotal in nature.

6.2. SPECIES NOT REQUIRING A PRESERVATIVE TREATMENT (4-SIDED EDGED TIMBER)

Pilot name	Botanical name	Density[9]	Origin	Comments
Alep	*Desbordesia glaucescens*	1,05	Africa	Thick sapwood
Angelim vermelho	*Dinizia excelsa*	1,07	South America	
Araracanga	*Aspidosperma album* *Aspidosperma desmanthum* *Aspidosperma* p.p.	0,94	South America	
Azobé	*Lophira alata*	1,06	Africa	
Bangkirai / Yellow Balau	*Shorea glauca* *Shorea laevis* *Shorea maxwelliana* *Shorea superba* *Shorea* subgen. *Eushorea* p.p.	0,91	Asia	Mentioned in the EN 13145 standard but sold for other higher value uses
Basralocus	*Dicorynia guianensis* *Dicorynia paraensis*	0,79	South America	Mentioned in the EN 13145 standard but sold for other higher value uses
Congotali	*Letestua durissima*	1,1	Africa	
Curupay	*Anadenanthera colubrina*	1,03	South America	
Eyoum or Omvong	*Dialium pachyphyllum*	0,94	Africa	Very high hardness level, need for adapted sawing. To be validated.
Greenheart	*Chlorocardium rodiei*	0,97	South America	Mentioned in the EN 13145 standard
Jarrah	*Eucalyptus marginata*[12]	0,82	Asie et Océanie	Mentioned in the EN 13145 standard
Júcaro	*Terminalia buceras*	0,94	South America	
Karri	*Eucalyptus diversicolor*	0,90	Asie et Océanie	Mentioned in the EN 13145 standard
Kempas	*Koompassia malaccensis*	0,88	Asia	
Monghinza	*Manilkara mabokeensis* *Manilkara obovata* *Manilkara* p.p.	0,98	Africa	
Mora	*Mora excelsa* *Mora paraensis* *Mora* p.p.	1,03	South America	Mentioned in the EN 13145 standard
Mubala	*Pentaclethra macrophylla*	0,95	Africa	
Muiracatiara	*Astronium fraxinifolium* *Astronium graveolens* *Astronium lecointei* *Astronium* p.p.	0,80	South America	

11. Average density at 12% humidity.
12. In Australia, a wide range of Eucalyptus species are used for railroad sleepers, https://extranet.artc.com.au/docs/eng/track-civil/procedures/sf/ETA-02-01.pdf

Okan (= Adoum)	*Cylicodiscus gabunensis*	0,91	Africa	
Osanga	*Pteleopsis hylodendron* *Pteleopsis myrtifolia*	0,80	Africa	
Ozouga	*Sacoglottis gabonensis*	0,89	Africa	
Quebracho colorado	*Schinopsis balansae* *Schinopsis lorentzii*	1,20	South America	
Wamba	*Tessmannia africana* *Tessmannia anomala* *Tessmannia lescrauwaetii*	0,87	Africa	

- Some species have the technical characteristics that are required for use under rails (mechanical resistance, natural durability, etc.) but aren't mentioned in the above list for the following reasons:
- they are species used for applications with higher added value and therefore more profitable than timber under rails, in particular in interior and exterior flooring, and in joinery (Cumaru, Doussié, Ipé, Itauba, Maçaranduba, Moabi, Mukulungu, Padauk, Tali...),
- they are species used locally for uses other than timber (example: the Coula whose fruits play an important role in the diets of local populations),
- their logs have an insufficient diameter for large cross-section cuts (example: Niové),
- their logs have non-hardened internal areas (example: Eveuss).

- For the manufacture of sleepers or for bearers in switch and crossing layouts, certain little-known and hardly-used African species could be of potential interest. However, their use for this type of product remains to be validated: Brown Kanda (*Beilschmiedia congolana, B. corbisieri, B. letouzeyi, B. oblongifolia, Beilschmiedia p.p.*), Pink Kanda (B*eilschmiedia gabonensis, B. grandifolia, B. hutchinsonia, B. mannii, B. obscura, Beilschmiedia p.p.*), Nganga (*Cynometra ananta, C. hankei, Cynometra p.p.*), Oguomo (*Lecomtedoxa klaineana*), Rikio (*Uapaca guineensis, U. heudelotii, U. vanhouttei, Uapaca p.p.*), Vesambata (*Oldfieldia africana*)...

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September 2022

ANNEX 1 : EXCERPT ADAPTED FROM THE TROPICAL TIMBER ATLAS (2016)

NATURAL DURABILITY

Unless specifically mentioned in relation to the sapwood, the durability characteristics relate to the heartwood of mature timber. Sapwood should always be considered as being non-durable with respect to biological timber degradation agents. Timber whose current moisture content is less than approximately 20% it is unlikely to be attacked by fungi. Temperatures below approximately 5°C prevent the growth of fungi. Timber that has been immersed in water or brought to high temperatures (around 60°C) are never attacked by fungi, regardless of their natural durability.

Resistance to fungi

The resistance of timber to fungi is determined using samples of standard dimensions in the presence of fungal strains under controlled environmental conditions. These tests take several months.
The NF EN 350 standard, which is being revised at the time of publication, defines classes of natural timber durability against lignivorous fungi:

- highly durable timber: class DC1 (durability class 1), named "class 1";
- durable timber: class DC2, named "class 2";
- moderately durable timber: class DC3, named "class 3";
- poorly durable timber: class DC4, named "class 4";
- non-durable timber: class DC5, named "class 5".

Resistance against dry timber insects (lyctus, bostrychus, beetles)

The vast majority of tropical timber on the market is not attacked by dry timber insects, provided that the timber is used without sapwood. When sapwood is not very distinct, it is preferable to treat the timber against dry timber insects. Some tropical species are attacked throughout the timber and require special care in their dry state. Sawn timber or finished products are only attacked if they still contain sapwood and sufficient starch content. According to the EN 350 standard, a species is classified as vulnerable (class DC S, named "class S") if it is attacked during the laboratory test. If it is not, it is considered to be durable (class DC D, named "class D").

Resistance against termites

The conditions for determining the resistance of timber against termites are similar to those for determining resistance against fungi. Samples of standard dimensions are exposed to termites. The intensity of the termite attacks and therefore the natural resistance of the timber is quantified by measuring the depth of the timber's penetration in the sample. The EN 350 standard defines three classes of natural durability against termites:

- durable timber: class DC D (durability class D), named "class D";
- moderately durable timber: class DC M, named "class M";
- vulnerable timber: class DC S, named "class S".

USAGE CLASS

The usage class refers to a degree of exposure to various biological degradation agents resulting from the situational use of a timber element or structure. It may change after modification of the structure's design or situation. It doesn't systematically define a service life, but simply the conditions of a potential biological attack. Within a usage class, the treatment specifications and the choice of species have a direct impact on the service life.

The service life must therefore be interpreted according to the species and the severity of the exposures. It depends on the timber's natural durability, but also other factors such as a structure's design details (risk of water traps, ventilation of the timber, etc.), the nature of planned maintenance and local climatic conditions.

The use of a timber with a natural durability that is greater than that which is recommended by standard NF EN 460 (July 1994) for a given use, allows the service life of the structure to be extended. Conversely, for elements with a very short service life (temporary construction) temporary construction), species with a natural durability lower than that which is specified in standard EN 460 may be recommended.

Note. **Do not confuse the notions of "fungus resistance class" and "usage class", which have different qualification scales.**

The timber usage situations have been grouped into usage classes (standard NF EN 335, May 2013). Each class refers to a category of use associated with a risk of biological degradation of the same level.

Categories grouping classes according to employment conditions

Usage class	General use
1	Indoors, in a dry environment
2	Indoors or under shelter, no exposure to bad weather. Water condensation may occur.
3	Outside, above ground, exposure to bad weather. Class 3 can be subdivided into 2 subclasses: 3.1 Short wetting conditions 3.2 Prolonged wetting conditions
4	Outside, with contact with the ground or fresh water
5	Immersed in salt water on a regular or permanent basis

Specificities of class 5

The classification of a species in class 5 is mentioned separately. A species that covers class 5 generally covers class 4, except for a few rare species that only cover class 3 or class 2 (Basralocus, Garapa, Iroko, Louro vermelho, Sougué).

The European standard NF EN 460 (July 1994) proposes a correlation table between the natural durability of solid timber and their potential uses within a given risk class (above table). This standard predates the replacement of the "risk class" notion by that of a "usage class" (NF EN 335, May 2013), as these two notions are almost equivalent.

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POUR UNE GESTION DURABLE DES FORÊTS TROPICALES
FAIR & PRECIOUS BY atibt ÉDITIONS
17

SYNTHÈSE SUR LES ACAJOUS ET LES ESPÈCES DU GENRE *KHAYA* D'AFRIQUE CONTINENTALE

PRÉAMBULE ET ÉTYMOLOGIE

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La récente inscription en annexe II de la CITES des espèces du genre *Khaya*[1], les Acajous d'Afrique, couplée aux nombreuses confusions sur ces essences et aux amalgames entre les différents genres botaniques de la famille des Méliacées aux propriétés parfois voisines, est à l'origine de ce document.

Cette synthèse sur les Acajous et les espèces du genre *Khaya* d'Afrique continentale se veut non exhaustive, elle a pour objectif de rappeler quelques fondamentaux sur ce groupe d'espèces.

Il est apparu nécessaire de revenir sur les particularités de chacune des principales espèces du genre, les caractéristiques qui les discriminent, l'intérêt qu'elles présentent pour la production de bois d'œuvre, tant pour les bois issus de peuplements naturels que de plantations en Afrique, en Asie et en Amérique du sud.

Ce document s'appuie notamment sur les résultats des importants travaux conduits par Gaël Ulrich Dipelet Bouka sur la structuration de la diversité du genre *Khaya*, travaux cités dans le texte.

1. Les espèces du genre Khaya sont de plus classées comme vulnérables sur la liste rouge de l'International Union for Conservation of Nature (UICN)

De l'origine de l'appellation Khaya

Dans son ouvrage *Timber – A historical Survey of its Development and Distribution* (1957)[2], Bryan Latham donne l'origine, assez étonnante, de l'appellation *Khaya* :

(traduit en français) ...*Cependant, M. Balfour Gourlay nous donne une explication de l'origine du terme "Khaya" pour désigner les Acajous d'Afrique de l'Ouest. Un botaniste du XIXe siècle, dit-il, lors d'une expédition en Afrique de l'Ouest qui venait d'être ouverte aux explorateurs, vit un arbre qu'il ne pouvait pas identifier. Demandant son nom aux indigènes, ceux-ci répondirent unanimement "Khaya". Un spécimen fut donc envoyé à Kew en mentionnant que le nom indigène était « Khaya ». Les scientifiques de Kew ont découvert que l'échantillon appartenait à un genre de la famille des Meliaceae jusqu'alors inconnu. La nouvelle espèce fut donc nommée Khaya senegalensis. Ce n'est que lors d'une nouvelle visite en Afrique de l'Ouest que le botaniste découvrit avec surprise et consternation que "Khaya" signifiait en anglais "I don't know" (je ne sais pas) !*

KHAYA *VERSUS* SWIETENIA

Dans le commerce international des bois tropicaux, le nom pilote Acajou peut être appliqué aussi bien aux Acajous d'Afrique, les espèces du genre *Khaya*, qu'aux Acajous d'Amérique, les espèces du genre *Swietenia*.

Dans le monde des bois tropicaux, il s'agit de l'unique cas d'une même appellation acceptée pour deux groupes d'espèces différentes.

Cette situation est notamment liée au fait que ces deux groupes d'espèces, de la famille des Méliacées, ont des caractéristiques technologiques et d'aspect très voisines.

Botaniquement, le genre *Khaya* appartient à la sous-famille des *Swietenoideae* et semblerait être étroitement apparenté aux genres *Carapa* et *Swietenia*.

Le bois de *Khaya grandifoliola* ressemble davantage à ceux des *Swietenia* qu'à ceux de *Khaya anthotheca* et *Khaya ivorensis*.

L'appellation Acajou ne désignait originellement que le genre Swietenia du continent américain. Elle a été étendue à l'Afrique après la découverte de deux espèces de Méliacées, *Khaya senegalensis* et *Entandrophragma angolense*, initialement dénommées *Swietenia senegalensis* et *S. angolensis*.

Dans la Nomenclature générale des bois tropicaux (ATIBT 2016), le nom pilote *Mahogany* est utilisé pour désigner les quatre espèces de *Swietenia* : *S. humilis, S. krukovii, S. macrophylla, et S. mahagoni.* Le nom pilote *Mahogany* dérive du nom de cette dernière espèce (ou réciproquement ?).

Il faut rappeler que *Mahogany* est la traduction en anglais du mot Acajou.

L'appellation Acajou est encore fréquemment utilisée, à tort, pour des espèces du genre *Entandrophragma*, notamment le Sapelli (*E. cylindricum*) mais aussi le Sipo *(E. utile*). Cet élargissement de l'appellation Acajou, source de confusion, est repris dans la base de données wood-database.com[3]...

2. Latham B., 1957. Timber - A Historical Survey of Its Development and Distribution. Edit. George G. Harrap & Co., London, 303 p.

3. https://www.wood-database.com/wp-content/uploads/mahogany-families.pdf

Plantation de *Swietenia* - Amérique centrale (© E. Groutel, WALE)

CLASSIFICATION ET DÉNOMINATIONS ACTUELLES DES ESPÈCES DU GENRE *KHAYA*

En Afrique continentale, on distingue actuellement quatre espèces de *Khaya* morphologiquement proches : *Khaya anthotheca, K. grandifoliola, K. ivorensis* et *K. senegalensis.*

Une cinquième espèce, *K. madagascariensis*, est endémique de Madagascar et des Comores.

Le nombre d'espèces du genre *Khaya* a varié au cours du temps.

Dipelet Bouka et *al.* (2019)[4] ont ainsi montré que *K. ivorensis, K. grandifoliola* et *K. senegalensis* seraient des espèces à part entière mais dont les limites taxonomiques doivent encore être précisées.

Khaya nyasica serait également une espèce qui devrait être séparée de *K. anthotheca* qui constitue un complexe de cinq groupes génétiques distincts, pouvant recouvrir un ensemble d'au moins deux autres espèces ou sous-espèces qui restent aussi à préciser (Bouka Dipelet 2017[5], 2022[6]).

Cependant, l'*African Plant Database*[7] ne considère actuellement que quatre espèces en Afrique continentale : *K. anthotheca, K. grandifoliola, K. ivorensis* et *K. senegalensis.*

La dernière version (2016) de la Nomenclature générale des bois tropicaux distingue ainsi l'Acajou d'Afrique de l'Acajou Cailcédrat et de l'Acajou Umbaua[8], associés aux espèces botaniques et aux appellations vernaculaires suivantes :

Nom pilote	Noms botaniques	Appellations vernaculaires
Acajou d'Afrique	*Khaya anthotheca* C. DC. *Khaya grandifoliola* C. DC. *Khaya ivorensis* A. Chev. (Syn. *Khaya klainei)*	Acajou Bassam (CI) ; Acajou blanc (CI) ; Acajou rouge (GA) ; African Mahogany (GH) ; Ahafo (GH) ; Akuk (NG) ; Benin Mahogany (NG) ; Caoba del Galon (GQ) ; Déké (CF) ; Eri Kire (UG) ; Kaju (BJ) ; Krala (CI) ; Mangona (CM) ; Munyama (UG) ; N'Dola (AO, CG) ; N'Gollon (CM) ; Ogwango (NG) ; Takoradi Mahogany (GH) ; Undia Nunu (AO) ; Zamanguila (GQ) ; Zaminguila (GA)[9]
Acajou Cailcédrat	*Khaya senegalensis* A. Juss.	Abgo (BJ) ; Acajou Bissilom (ML) ; Acajou Cailcedrat (BJ, CI) ; Bissilom (GW, SN) ; Diala (GN) ; Zunzatin (BJ)
Acajou Umbaua	*Khaya nyasica* Stapf	Acajou Umbaua (MZ)

Le tableau ci-dessus mentionne que dans certains pays, une appellation commerciale locale est affectée individuellement aux trois espèces forestières, principalement : Acajou rouge ou Acajou Bassam pour *K. ivorensis*, Acajou blanc pour *K. anthotheca,* et Acajou à grandes feuilles pour *K. grandifoliola.*

4. Bouka Dipelet U. G., Doumenge C., Loumeto J. J., Florence J., Gonmadje C., McKey D., 2019. Des confusions entre espèces préjudiciables à la gestion durable des essences forestières : l'exemple des acajous d'Afrique (*Khaya*, Meliaceae). Bois et Forêts des Tropiques, 339 : 17-32. https://doi.org/10.19182/bft2019.339.a31714
5. Bouka Dipelet G. U., 2017. Structuration de la biodiversité des forêts africaines et changements climatiques : une étude à travers le genre *Khaya* (Meliaceae). Thèse de Doctorat, Ecole doctorale Gaïa, Spécialité : Écologie, Évolution, Ressources Génétiques, Paléobiologie ; Unité de recherche CEFE/F&S, CIRAD ; Université de Montpellier, 347 pages. https://theses.fr/en/2017MONTT165
6. Bouka Dipelet G.U., Doumenge C., Ekué M.R.M., Daïnou K., Florence J., Degen B., Loumeto J.J., McKey D., Hardy O.J., 2022. Khaya revisited: Genetic markers and morphological analysis reveal six species in the widespread taxon *K. anthotheca*. Taxon, Volume 71, Issue 4, 1-19. https://doi.org/10.1002/tax.12720
7. https://africanplantdatabase.ch/fr/nomen/genus/191809/khaya-a-juss
8. L'Acajou Cailcédrat n'était pas mentionné dans la Nomenclature 1982.
9. AO : Angola ; BJ : Bénin ; CD : République Démocratique du Congo ; CF : République centrafricaine ; CG : Congo ; CI : Côte d'Ivoire ; CM : Cameroun ; GA : Gabon ; GH : Ghana ; GN : Guinée ; GQ : Guinée équatoriale ; GW : Guinée Bissau ; ML : Mali ; MZ : Mozambique ; NG : Nigéria ; SN : Sénégal ; UG : Ouganda

Grume de *Khaya anthotheca* - OLAM, Pokola, République du Congo (© E. Groutel, WALE)

RÉPARTITION GÉOGRAPHIQUE DES QUATRE PRINCIPALES ESPÈCES DE *KHAYA* EN AFRIQUE CONTINENTALE, EN PEUPLEMENTS NATURELS ET EN PLANTATIONS.

La distribution et les caractéristiques générales des quatre espèces de *Khaya* sont reprises de l'ouvrage Prota - Bois d'œuvre 1[10]:

* *Khaya anthotheca* est présent depuis la Guinée-Bissau jusqu'en Ouganda et en Tanzanie, et vers le sud jusqu'en Angola, en Zambie, au Zimbabwe et au Mozambique.

Il est assez régulièrement cultivé en plantation sur son aire naturelle de répartition, mais également en Afrique du Sud, en Asie tropicale et en Amérique tropicale. *Khaya anthotheca* est aussi couramment planté comme arbre d'ombrage ornemental et d'alignement, et dans les systèmes agroforestiers. En plantation, il nécessite des sols fertiles profonds et de l'eau en abondance.

10. Louppe D., Oteng-Amoako A.A., Brink, M. (Editeurs), 2008. Ressources végétales de l'Afrique tropicale 7(1). Bois d'oeuvre 1. [Traduction de : Plant Resources of Tropical Africa 7(1). Timbers 1. 2008]. Fondation PROTA, Wageningen, Pays-Bas/Backhuys Publishers, Leiden, Pays-Bas/ CTA, Wageningen, Pays-Bas. 785 pp.

En Indonésie, *Khaya anthotheca* a été utilisé avec succès dans la méthode d'agroforesterie taungya[11], générant des profits économiques des cultures associées (riz, maïs, arachide) dès la seconde année de la plantation des arbres.

* *Khaya grandifoliola* est présent de la Guinée jusqu'au Soudan et en Ouganda. Cette espèce est parfois cultivée en plantation sur son aire naturelle de répartition, par exemple en Côte d'ivoire et au Ghana. Elle est aussi utilisée en arbre d'alignement et comme arbre d'ombrage ornemental. En Ouganda, elle est utilisée pour la stabilisation des berges de rivière. Des plantations expérimentales ont également été mises en place en Indonésie.

* *Khaya ivorensis* est présent de la Côte d'ivoire jusqu'au Cameroun et au Cabinda (Angola), sans doute aussi en Guinée, au Liberia, en République centrafricaine, et au Congo. Sa culture en plantation est assez courante sur son aire naturelle de répartition, mais également en Asie du sud-est et en Amérique tropicale.

  Khaya ivorensis est considérée comme l'une des plus importantes essences de bois d'œuvre pour les plantations, car elle associe croissance rapide et bois de bonne qualité. Cette espèce est notamment utilisée au Ghana en plantation où son utilisation en reboisement est encouragée et promue auprès des petits planteurs et des communautés locales[12],[13],[14].

* *Khaya senegalensis* est naturellement présent depuis la Mauritanie et le Sénégal jusqu'au nord de l'Ouganda. Cette espèce est couramment plantée sur son aire de répartition naturelle, surtout comme arbre d'ornement et d'alignement, mais aussi en dehors de cette région, au Cap-Vert, en Tanzanie, au Malawi, à Madagascar, à la Réunion, en Egypte, en Afrique du Sud, en Inde, en Indonésie, au Vietnam, en Australie et en Amérique tropicale.

Au Vietnam, des plantations d'enrichissement dans les forêts claires ont été pratiquées avec succès. Dans les régions sèches du Sri Lanka, il est privilégié en plantations de bois d'œuvre depuis le milieu des années 1990.

En Australie (Northern Territory), les bois issus de plantations clonales ont fait l'objet d'études approfondies, mettant en évidence l'intérêt majeur de cette espèce en reboisement dans les régions tropicales sèches du pays[15].

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11. https://www.fao.org/3/83131f/83131f03.htm

12. Opuni-Frimpong E., Lartey Tekpetey S., Acheampong Owusu S., Darko Obiri B., Appiah-Kubi E., Opoku S., Yaa Nyarko-Duah N., Essien C., Mensah Opoku E., Storer Managing A.J., 2016. Managing Mahogany Plantations in the Tropics - Field Guide For Farmers. Published by CSIR-FORIG, Kumasi, Ghana, 106 p. https://www.itto.int/files/itto_project_db_input/2936/Technical/PD528-08Rev1%28F%29-Main-TechRep-Mahogany%20Book.pdf

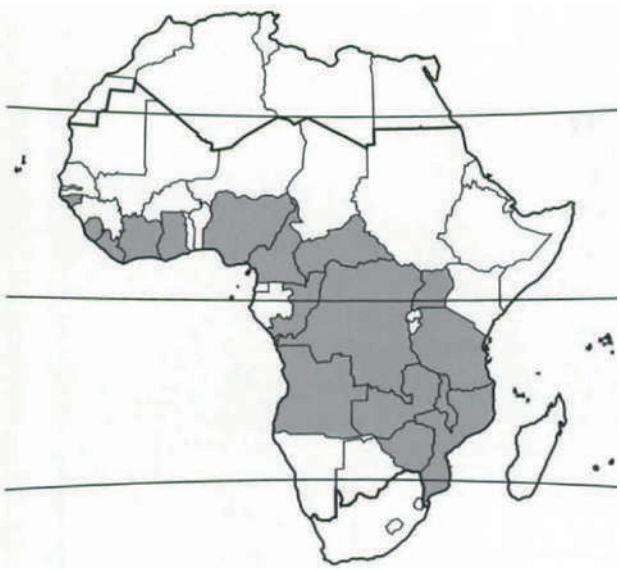
13. Lartey Tekpetey S., Appiah-Kubi E., Essien C., Opuni-Frimpong E., Korang J., Pentsil S., Owusu F.W., 2009. Wood and Lumber Quality of Plantation Grown *Khaya ivorensis*. ITTO PD 528/08 Rev.1 (F) - Towards sustainable indigenous Mahogany production in Ghana: Phase II, refining the silviculture "tool kit" and practical training for industrial-foresters and community farmers, 90 p. https://www.itto.int/files/itto_project_db_input/2936/Technical/PD528-08Rev1(F)Technical-Report%20Plantation-Lumber-Qlty-vs.pdf

14. Adubofour D., Opuni- Frimpong E., Adomako A. A., 2009. Provenance variation in two species of *Khaya* (*Khaya ivorensis* and *Khaya grandifoliola*) for growth and resistance to shoot borer in the wet evergreen forest zone of Ghana. PD 528/08 Rev.1 (F): Towards sustainable indigenous Mahogany production in Ghana: Phase II, refining the silviculture "tool kit" and practical training for industrial-foresters and community farmers, 10 p. https://www.itto.int/files/itto_project_db_input/2936/Technical/PD528-08Rev1(F)Technical-Paper-4-vs.pdf

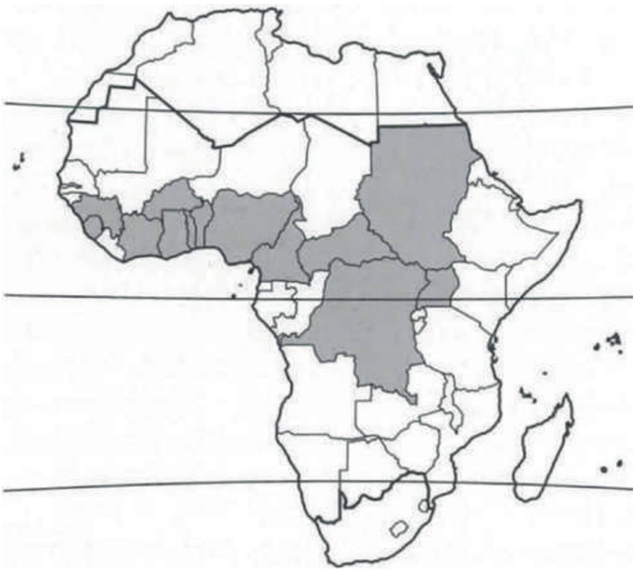
15. Reilly D.F., Robertson R.M., 2006. Evaluation of the Wood Quality and Utilisation Potential of Plantation grown *Khaya senegalensis* (African Mahogany). Rapport d'étude, RIRDC Project DNT32A, 93 p. https://www.nt.gov.au/_data/assets/pdf_file/0017/227600/ib6.pdf

***Khaya senegalensis* – Agroforestal, Nicaragua (© E. Groutel - WALE 2023)**

Les quatre cartes ci-après reprennent la distribution de chaque espèce par pays endémique (Prota 2008)[16].

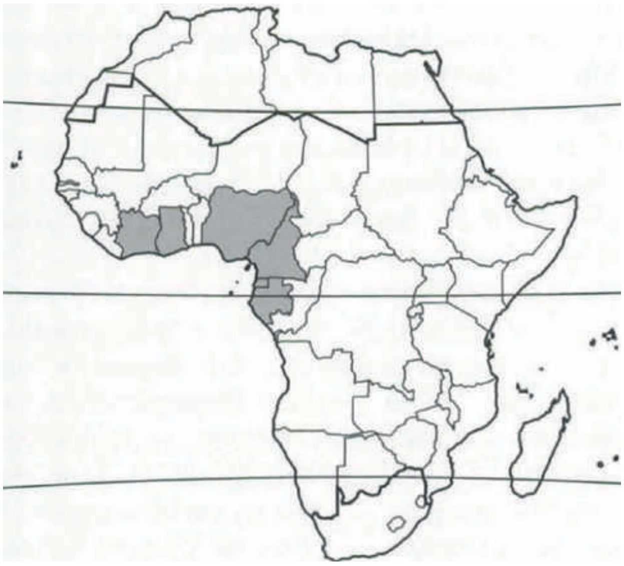


Distribution de *Khaya anthotheca* (forêt naturelle)

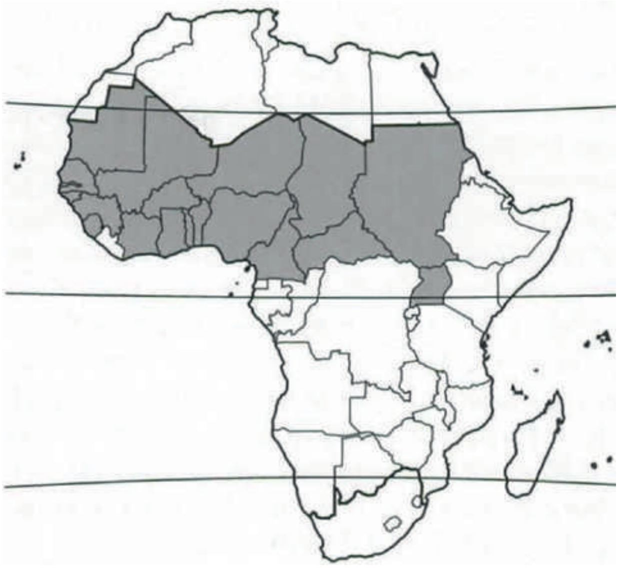


Distribution de *Khaya grandifoliola* (forêt naturelle)

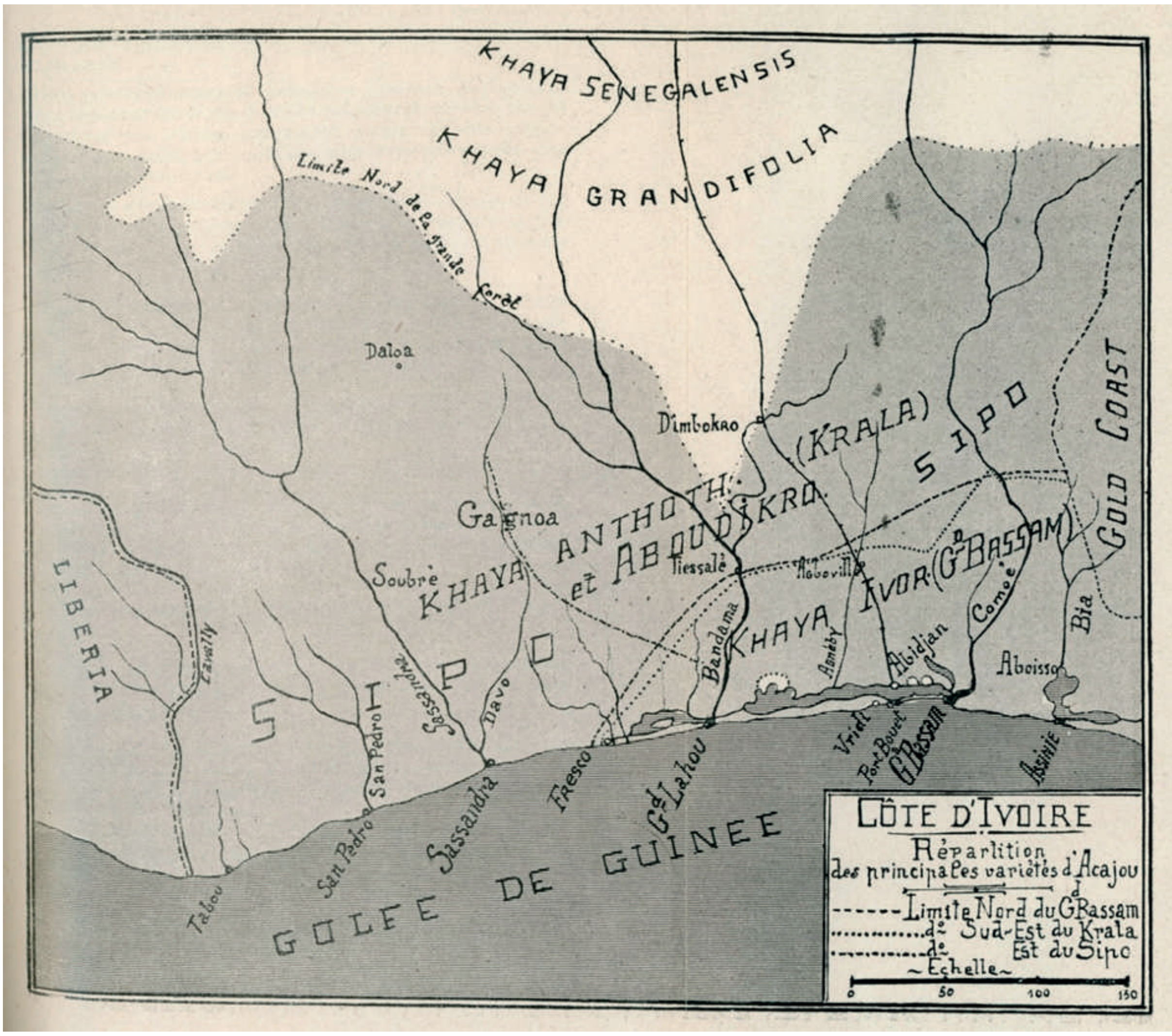
16. https://prota.prota4u.org/protav8.asp?g=pe&p=Khaya+senegalensis
https://prota.prota4u.org/protav8.asp?g=pe&p=Khaya%20anthotheca
https://prota.prota4u.org/protav8.asp?g=pe&p=Khaya+ivorensis
https://prota.prota4u.org/protav8.asp?g=pe&p=Khaya+grandifoliola



Distribution de *Khaya ivorensis* (forêt naturelle)



Distribution de *Khaya senegalensis* (forêt naturelle)



Carte de répartition des principales variétés d'Acajou (Méniaud, 1931[17])

17. Méniaud Jean, 1931. **Nos bois coloniaux.** Agence générale des colonies, 470 pages. https://issuu.com/scduag/docs/gad12017-1

DESCRIPTION DES BOIS D'ACAJOU D'AFRIQUE ET PRINCIPALES PROPRIÉTÉS TECHNOLOGIQUES

Cette description est reprise de la synthèse très complète réalisée par Bouka Dipele et *al.* (2019).

Les bois des Acajous africains sont de couleur brun rosé, plus ou moins rouge à l'abattage. Leurs propriétés physiques et mécaniques sont proches de celles des *Swietenia* américains.

Comme pour les caractères morphologiques, les caractères anatomiques et les propriétés des bois d'Acajous d'Afrique diffèrent selon les espèces, avec un recouvrement plus ou moins important.

Le bois de *K. anthotheca* serait moins coloré que celui de *K. ivorensis*, la seule espèce qui donne des bois figurés. Cependant, la différence de couleur du bois de ces deux espèces fait l'objet de controverses.

La densité du bois des Acajous d'Afrique varie de 0,42 à 0,90.

Le tableau ci-après, repris de Bouka Dipele *et al.* (2019), présente les principales caractéristiques botaniques et les principales propriétés physiques et mécaniques du bois des *Khaya* d'Afrique continentale (les sources des informations mentionnées dans ce tableau sont dans l'article original).

CARACTERES	*Khaya ivorensis*	*Khaya anthotheca*	*Khaya grandifoliola*	*Khaya senegalensis*
Dimensions				
Hauteur maximale (m)	60	55 (65)	45	35
Diamètre maximal du tronc (cm)	200 (250)	250 (500)	150	150 (200)
Tronc				
Base	Empattements ou contreforts épais, peu élevés (2,5 m)	Larges contreforts s'élevant à 3-4 m de hauteur	Contreforts larges, peu élevés	Empattements ou épaississements
Conformation	Très droite	Plus ou moins sinueuse	Généralement sinueuse	Courte et tortueuse
Couleur de l'écorce	Brune	Gris blanchâtre	Gris pâle à brun grisâtre	Brunâtre à gris foncé
Rhytidome	Légèrement rugueux, s'exfoliant en écailles subcirculaires en laissant des taches brunes	Lisse, s'exfoliant en écailles circulaires laissant une surface grêlée brun jaunâtre	Rugueuse, lisse vers le haut du tronc, tavelée de dépressions superficielles	Initialement lisse, mais devenant écailleuse, à minces écailles arrondies
Bois				
Couleur	Brun rose pâle à rouge clair, parfois figuré	Brun rosé à rouge foncé	Brun rosé à brun rougeâtre	Brun rosé à brun rougeâtre, violacée
Densité moyenne à 12% d'humidité* (kg/m^3)	(420-) 488 (-570)	(490-) 551 (-660)	(560-) 658 (-770)	(620-) 780 (-900)
Dureté (Chalais-Meudon)*	(1,3-) 1,65 (2,2)	(2,3-) 2,63 (-2,9)	(3,3-) 3,68 (-4,5)	(3,5-) 5,9 (-8,0)
Flexion statique (kg/cm^2)	861 - 1 187	1 008 - 1 130	1 107 - 1 344	827 - 1 528
Compression de fil (kg/cm^2)	364 - 481	454 -536	532 - 588	456 - 734

* : valeurs extrêmes entre parenthèses et valeur moyenne au centre

Khaya anthotheca

Khaya senegalensis

Swietenia macrophylla

Pour les 6 photos précédentes : © D. Guibal, CIRAD-BioWooEB

INSCRIPTION DES ESPÈCES DU GENRE *KHAYA* EN ANNEXE II DE LA CITES

En novembre 2022, lors de la COP 19 à Panama[18], la CITES a décidé d'ajouter plusieurs essences de bois en annexe II, générant ainsi des contraintes pour leur commercialisation.

Parmi les genres botaniques d'Afrique concernés avec un délai de mise en application de 90 jours, on trouve les espèces du genre *Khaya* (*Khaya* spp.), c'est-à-dire l'Acajou d'Afrique, l'Acajou Cailcédrat et l'Acajou Umbaua.

En particulier pour les essences africaines telles que les *Khaya*, de nouvelles obligations pèsent pour tous les bateaux expédiés à compter du 23 février 2023, avec notamment l'obligation de disposer d'un permis d'exportation du pays d'origine.

Les importations au sein de l'Union européenne nécessiteront la délivrance de permis d'importation avec une date d'application qui reste à préciser, vraisemblablement mi-avril 2024 (ATIBT 2023[19]).

Pour les espèces du genre *Khaya*, seules les populations d'Afrique sont concernées, les peuplements naturels et les plantations. Les plantations d'Asie du sud-est, d'Amérique du sud et d'Océanie ne sont pas touchées par ces mesures restrictives.

Dans l'Annexe II, le groupe *Khaya* spp. est associé au renvoi #17 qui signifie que les grumes, les bois sciés, les placages, les contreplaqués et le bois transformé sont concernés par les mesures CITES.

L'inscription des *Khaya* en annexe II de la CITES a suscité beaucoup d'incompréhensions, en particulier pour les peuplements d'Afrique centrale qui ne sont pas surexploités ni en danger, sachant que les pays proposants à la COP 19 ont été les pays d'Afrique de l'Ouest, Bénin, Côte d'Ivoire, Libéria, Sénégal, ainsi que l'Union européenne (CITES, 2022[20]).

LE MARCHÉ INTERNATIONAL DES ACAJOUS D'AFRIQUE

Au-delà des marchés locaux et régionaux, les Acajous d'Afrique sont régulièrement exportés, principalement du Cameroun mais aussi du Ghana, même si les volumes concernés restent limités.

Les USA sont les principaux destinataires des sciages d'Acajou, avec un volume importé de 9 000 à 10 000 m^3 en 2020 puis en 2021[21].

La République de Corée, l'Espagne, la France, la Suède, Chypre sont ensuite les principaux pays importateurs de grumes, sciages et placages d'Acajou, mais dans des volumes moindres que les USA, de quelques centaines à quelques milliers de m^3 par an[21].

Ces pays sont aussi ré-exportateurs de ces mêmes produits.

Certaines plantations d'Acajous africains mises en place en Afrique mais aussi dans d'autres régions tropicales, plantations principalement de *K. ivorensis, K. senegalensis,* et

18. Convention on International Trade in Endangered Species of Wild Fauna and Flora, Nineteenth meeting of the Conference of the Parties Panama City (Panama), 14 - 25 November 2022, Consideration of Proposals for Amendment of Appendices I and II https://cites.org/sites/default/files/documents/F-CoP19-Prop-51.pdf
19. FAQ CITES (23/02/2023) https://www.atibt.org/files/upload/news/CITES/FAQ_CITES_20230223_V2.pdf
20. CITES CoP19 Prop. 51, 2022. Consideration of Proposals for Amendment of Appendices I and II, 28 p. https://cites.org/sites/default/files/documents/F-CoP19-Prop-51.pdf
21. OIBT, 2023. Revue biennale et évaluation de la situation mondiale des bois 2021-2022. 199p. https://www.itto.int/fr/annual_review/

K. grandifoliola, et dans une moindre mesure de *K. anthotheca*, arrivent aujourd'hui à maturité et leurs bois commencent à être mis en marché.

Ainsi, les plantations brésiliennes de *K. ivorensis* sont mises aujourd'hui en production et influencent le marché de cette essence. Les producteurs brésiliens ont investi sur cette espèce qui constitue une bonne alternative aux *Swietenia*, notamment depuis l'inscription de ces espèces en annexe II de la CITES alors que les plantations de *Khaya* en dehors de leur aire naturelle de répartition (Afrique) ne sont pas touchées par cette inscription (cf. section précédente).

Au Brésil, plus de 65 000 ha d'Acajou d'Afrique ont été planté dans les États de Roraima, Minas Gerais, São Paulo, Goiás, Espírito Santo et Mato Grosso do Sul : 42 000 ha de *K. grandifoliola*, 23 000 ha de *K. senegalensis*, 800 ha de *K. anthotheca* et environ 500 hectares de *K. ivorensis*.

Environ 45 000 hectares de plantations arrivent aujourd'hui à un âge d'exploitation pour alimenter le marché national (bois d'éclaircie) mais aussi à des fins d'exportation (bois plus matures, de plus de 20 ans), notamment vers les Caraïbes[22].

Avivés de Khaya ivorensis - CBG, Port Gentil, Gabon (© E. Groutel, WALE)

22. ITTO, 2023. Tropical Timber Market Report - Volume 27 Number 5 1st – 15h March 2023. https://www.atibt.org/files/upload/news/ITTO/MIS_1-15_Mar2023.pdf

Avivés de Khaya senegalensis - Agroforestal, Nicaragua (© E. Groutel, WALE)

USAGES ET UTILISATIONS

Les espèces du genre *Khaya* sont exploitées industriellement pour leur bois depuis près de 200 ans du fait de leurs propriétés esthétiques (couleur, figuration), de leurs bonnes caractéristiques physiques (stabilité, faibles retraits de séchage) et de leur usinabilité.

Les similitudes entre leur bois et celui des espèces du genre *Swietenia*, les Acajous américains exploités depuis 500 ans, ont fortement contribué à la renommée de ces espèces et au fait qu'elles soient appréciées et recherchées.

Elles sont aussi largement employées dans la pharmacopée traditionnelle dans le traitement de nombreuses maladies (CTFT 1979[23], 1988[24]).

Dans les zones de production, le bois est traditionnellement utilisé pour fabriquer des pirogues monoxyles, des manches, des échelles, des bibelots, et en constructions légères.

Les Acajous sont particulièrement appréciés en ébénisterie, pour la fabrication de meubles, de boîtes et de coffrets décoratifs, et pour les placages.

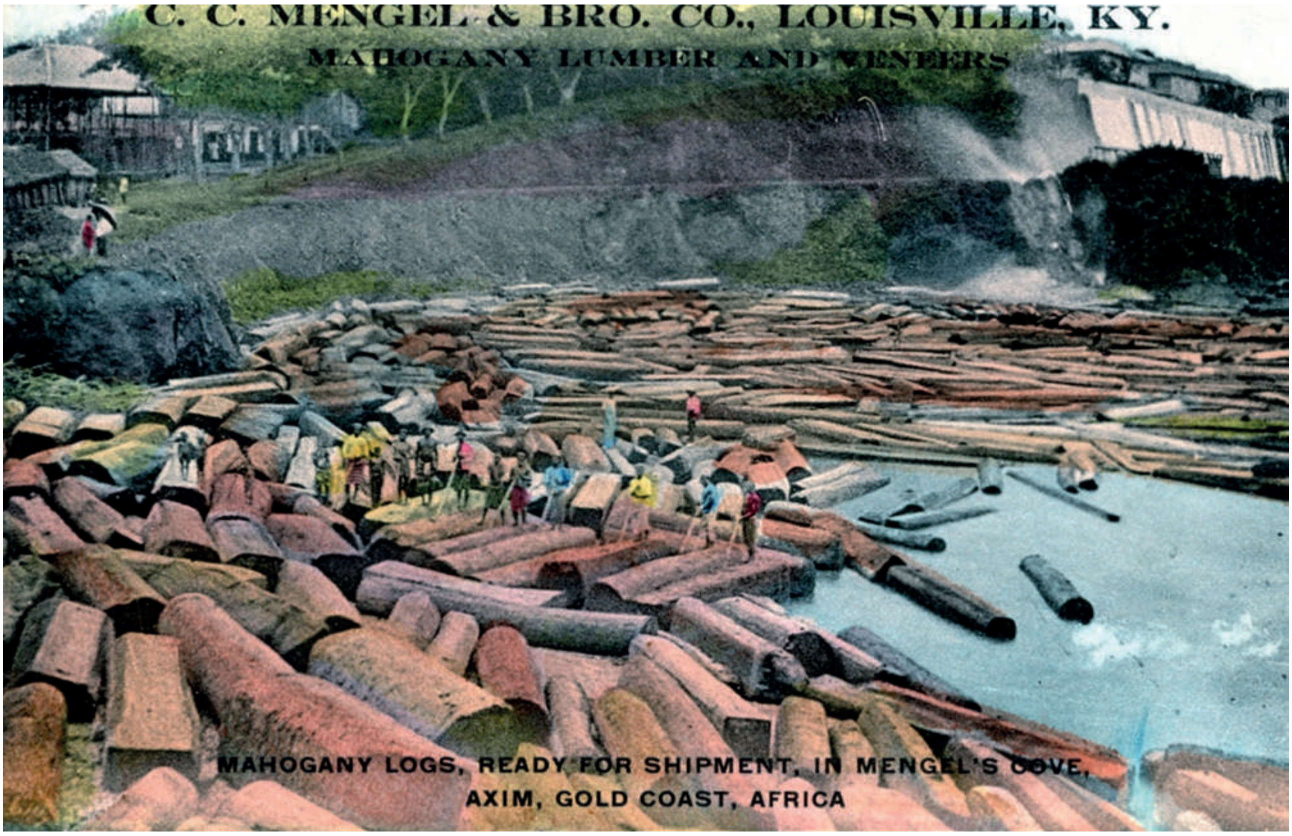
23. CTFT (Centre technique forestier tropical), 1979. Acajou d'Afrique. Bois et Forêts des Tropiques, 183 : 33-48 http://revues.cirad.fr/index.php/BFT/article/view/19394
24. CTFT (Centre technique forestier tropical), 1988. Khaya senegalensis (Desr.) A. Juss. Bois et Forêts des Tropiques, 218 : 43-56. https://revues.cirad.fr/index.php/BFT/article/view/19581

Ils sont aussi couramment utilisés pour les encadrements de fenêtres, les panneaux, les portes et les escaliers.

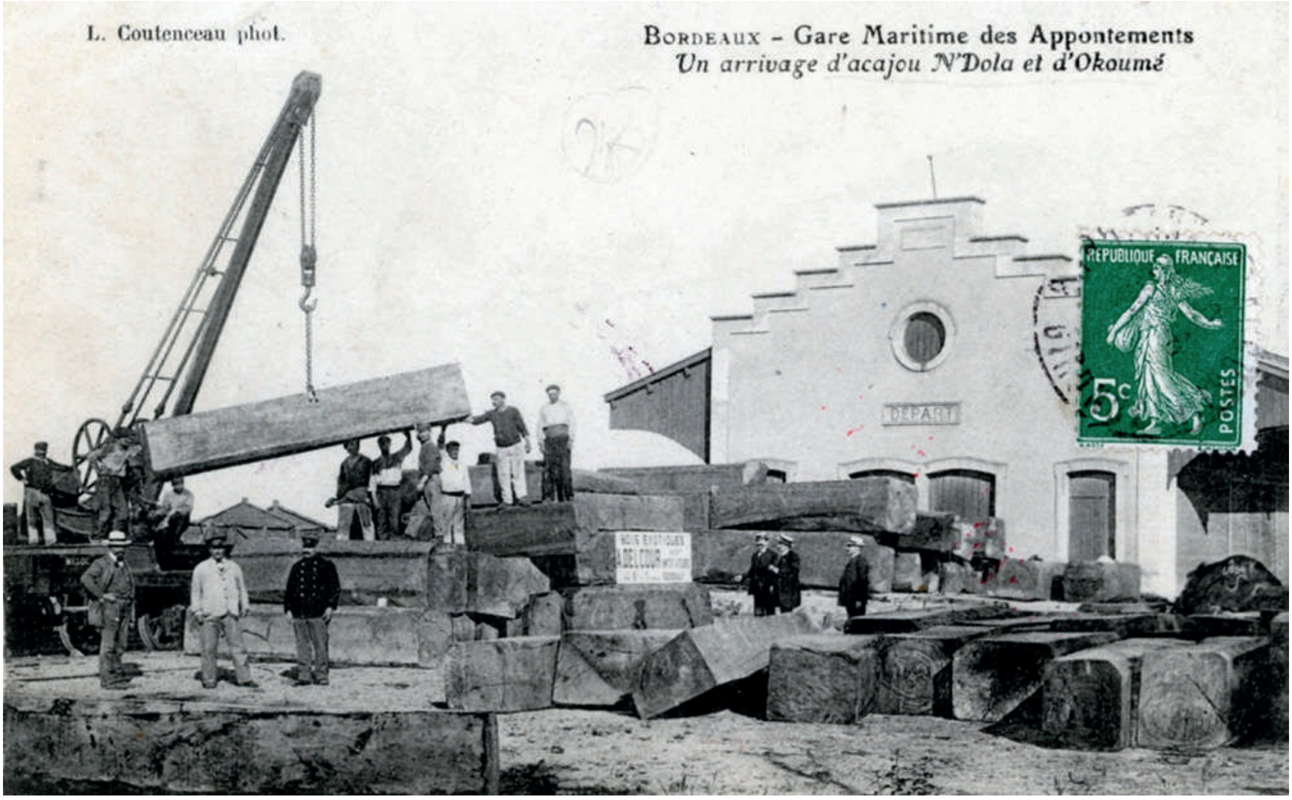
Ils conviennent pour les revêtements de sol légers, la construction navale, les articles de sport, les instruments de musique, les jouets, les outils de précision, la sculpture, et le tournage.

Les meilleures qualités d'Acajou sont particulièrement recherchées pour la fabrication des fonds ou des éclisses des guitares acoustiques du fait de leurs très bonnes caractéristiques acoustiques, mais aussi de toutes les autres pièces qui constituent ces instruments.

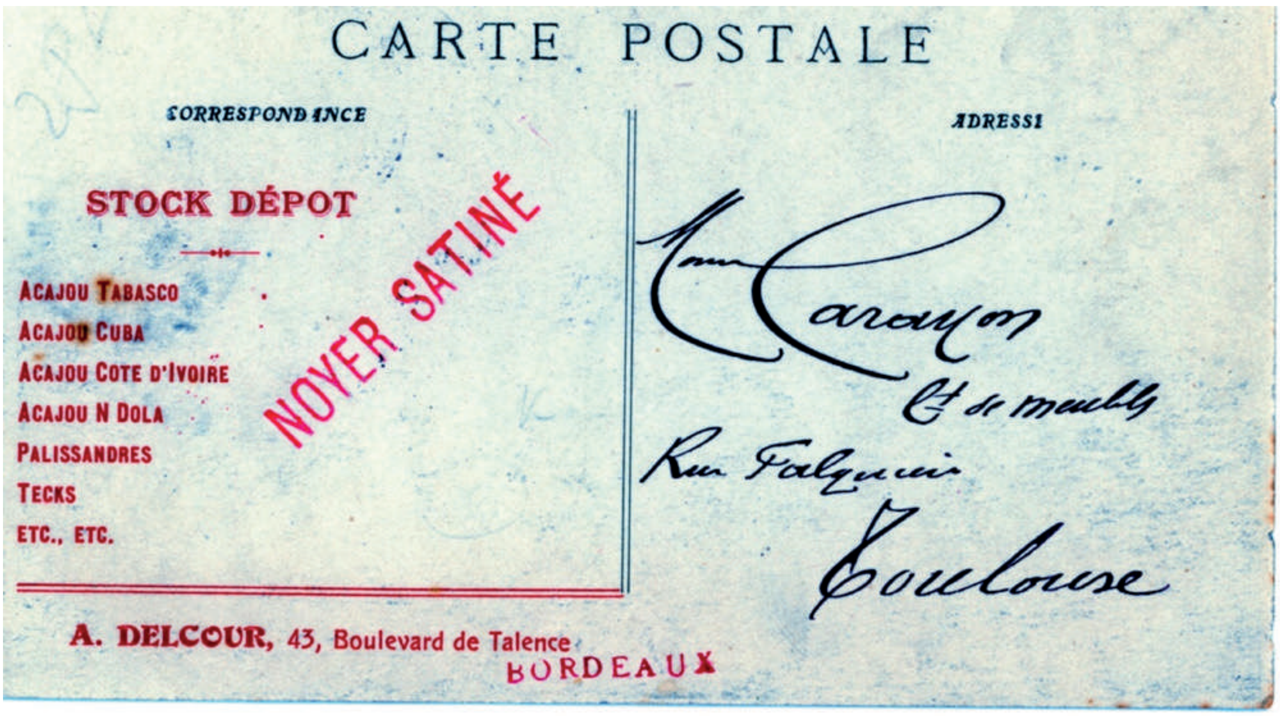
Ossature en Khaya senegalensis - Agroforestal, Nicaragua (© E. Groutel, WALE)



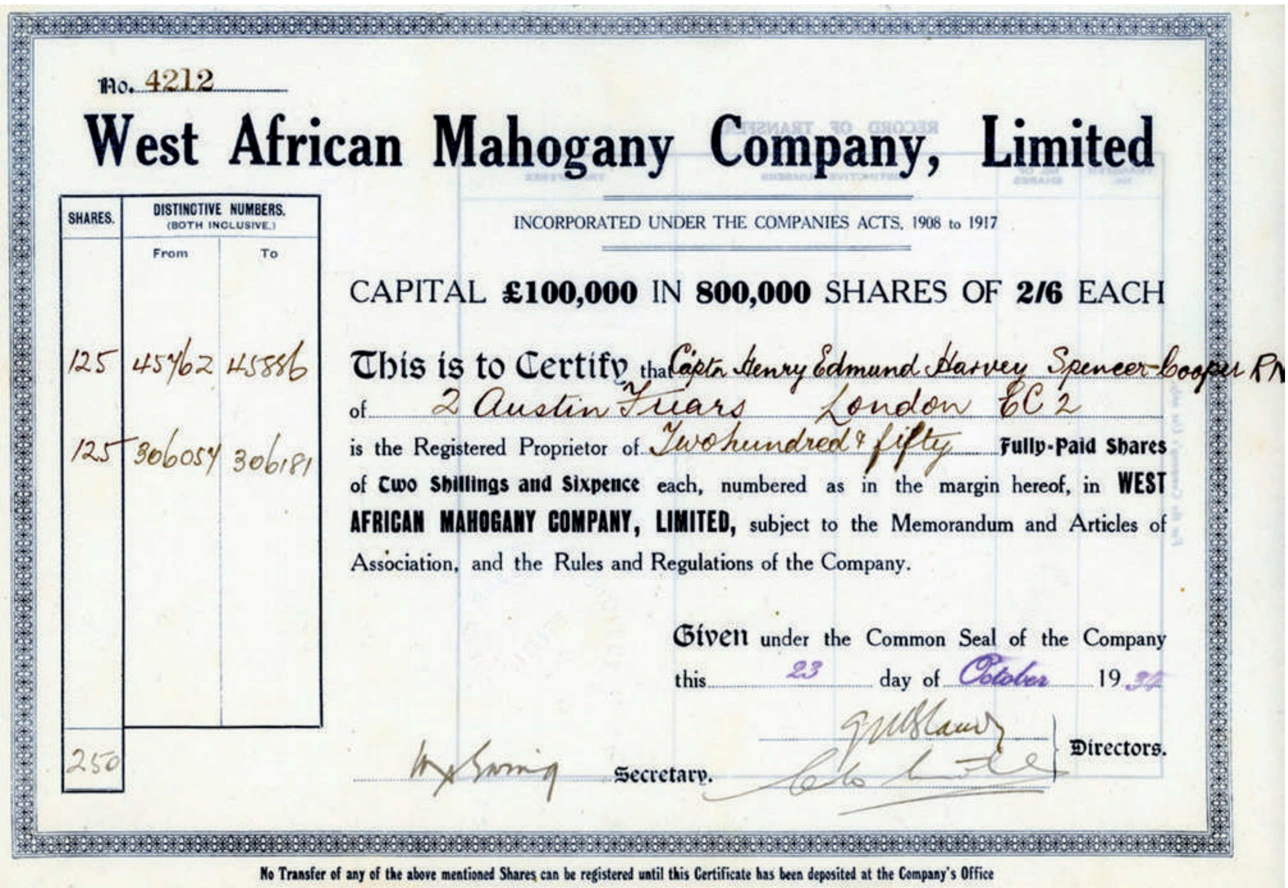
Grumes d'Acajou du Ghana (Gold Coast) prêtes pour expédition aux USA
(Illustrations fournies par Benoît Gommet, France Timber - Reproduction interdite)



Recto de la carte postale
Illustrations fournies par Benoît Gommet, France Timber - Reproduction interdite



Verso de la carte postale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Given under the Common Seal of the Company this 23 day of October 19 34

Secretary.

Directors.

No Transfer of any of the above mentioned Shares can be registered until this Certificate has been deposited at the Company's Office

Illustrations fournies par Benoît Gommet, France Timber - Reproduction interdite


Vue extérieure du BAR DE L'ÉTOILE, *63, Avenue de la Grande-Armée*
(Devanture en acajou, par L. M. A. Herold).

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Mai 2024