THE WOOD COATINGS

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01 WOOD

Wood is a material of plant origin, obtained from the stems of plants. It is hard and resistant, consisting of cellulose fibre withheld by a lignin matrix.
In botany, the term "wood" means all plant tissues providing the plant with support. They are responsible for carrying the lymph from the roots to the leaves and therefore also include parts of the plant like the leaf veins.
Once cut, matured or dried, the wood can be used in a variety of ways:
1. It can be used to create wood pulp, if broken down, to make paper.
2. It can be worked and sculpted to create tools and objects: starting from the clubs and lances used at the dawn of civilisation, through to the canoes sculpted from tree trunks, hoes used in farming, and right through to the prestigious furnishing items we enjoy today.
3. Since the origins of humanity, it has always been an important material in construction.
4. It is a fuel for heating and cooking.

Figure 1 - Wood, a natural material

In this document, wood will be referred to considering the most common interpretation of the term, namely as the part of the plant that comes from the trunk and which is commercially important.
As wood is an organic material, it is by definition extremely variable, not only between different species but also between different individual examples of the same species. The way it behaves after working or being stressed may, therefore, vary considerably and by risk for the intended purpose. Knowledge of its structure and its elements is useful if we are to understand and forecast its behaviour during processing and use, thereby preventing defects of dimensional stability, workability and response to gluing and coating.

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1.1 Veins and structure on a macroscopic level.

The veins are morphological signs typical of wood, due to the unique structure of the material; they are basically vessels that vertically (i.e. from the stem to the leaves) carry water and mineral salts.
If wood is cut parallel to the trunk axis, the grain appears to be straight. In some types of trees, however, these "tubes" are spiral in form and, consequently, the grain intersects, yielding an effect that is also obtained by cutting in a non-parallel fashion in common plants.
In some varieties of wood, the characteristic seasonal rings are clearly visible.
When a tree reaches a certain height, its trunk becomes thicker. The part that matures is called the cambium and forms annually between the wood and the phloem, the membrane near the external bark.
In trees of temperate areas, the new cambium grows during the spring and summer and, generally speaking, the first wood is more porous and therefore lighter in colour than the next product.
Vital cells are disseminated throughout the whole of the tissue, despite the fact that the slim layer of cambium is the only part of the trunk involved in active growth.

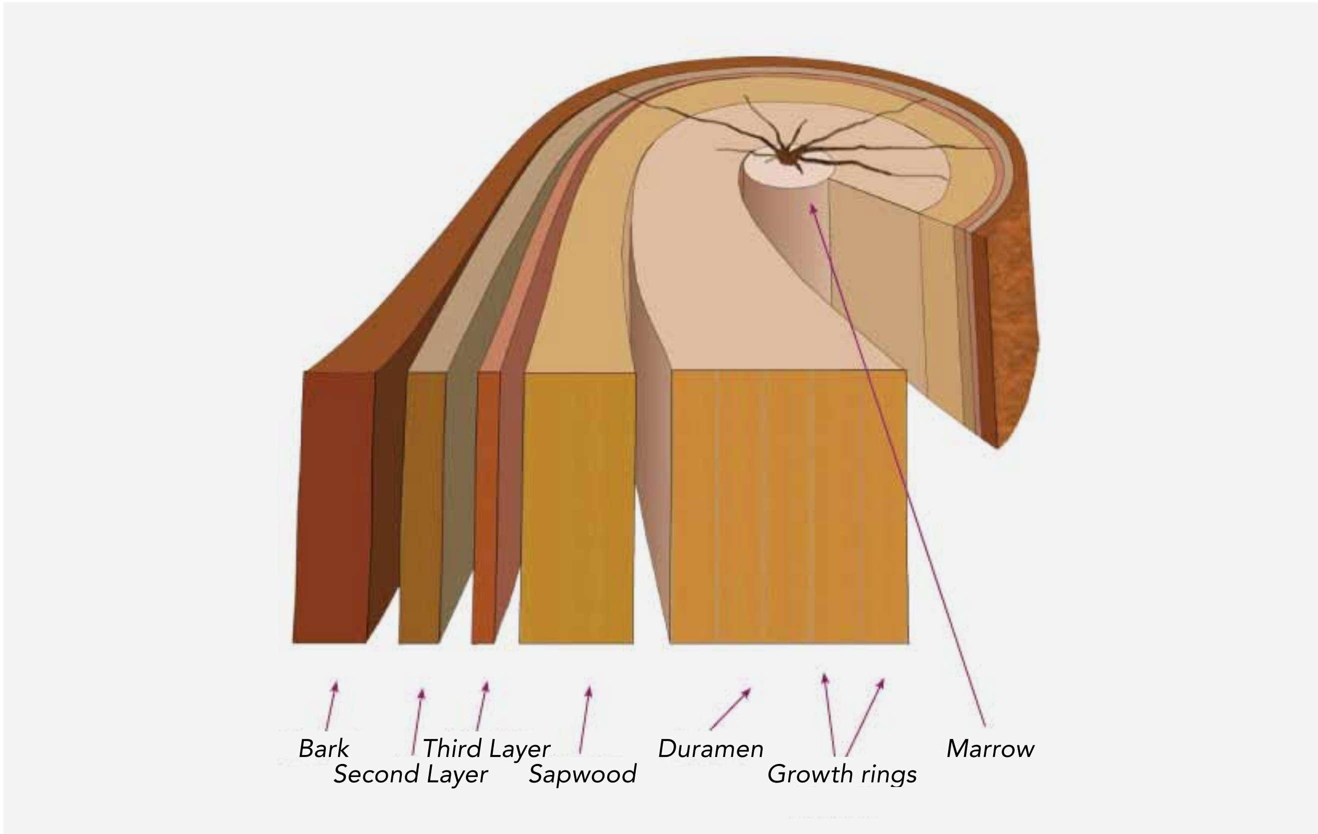

Figure 2 - Tree structure

The active part of the plant, consisting of cells, fibres and wood vessels, is called xylem.
When the tree has reached a certain age, the central part of the stem dies and the channels fill with rubber or resin, or simply air; this central part is called duramen.
The changes that take place within the trunk are accompanied by colour changes typical of the various species of trees, with the duramen that is usually darker than the sapwood, which is instead the younger part, which acts as a duct.
The term pith is used to identify the central part of the trunk, which is generally difficult to differentiate from the duramen holding it. It may be thinner or thicker depending on the type, but is often insignificant.
In the adult plant, it serves no purpose.

1.2 Structure of wood on a microscopic and molecular level.

Wood consists of approximately 50% carbon (C), 44% oxygen (O) and 6% hydrogen (H), with an ash content of 0.2-0.3%, including mineral substances, and a nitrogen content of less than 0.1%.

Clearly, as concerns the composition, we can only talk about approximate values, as it depends on the type of tree and may, at times, even differ within the same trunk. The different properties of the wood are not determined by the percentage content of chemical elements, but rather by the bonds in place between them.

Wood is therefore a composite material comprising the substances with a macromolecular structure forming the complex of the cell walls: cellulose, hemicellulose and lignin, present in large quantities, and substances of a different nature, referred to as extractive elements.

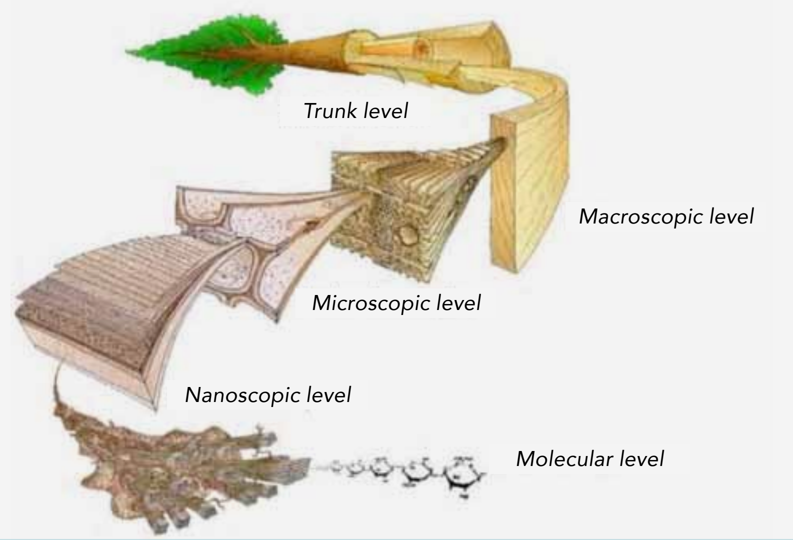

Figure 3 – Wood seen from a macroscopic and molecular viewpoint

The following table summarises all the chemical substances in wood.

	CONSTITUENTS PERCENTAGE IN WOOD	MAIN FUNCTION	
MAIN CONSTI-TUENTS	CELLULOSE: not branched long-chain macromolecule 41-51%	Most important constituents of the cell wall	Absorption of mechanical forces, above all traction
	HEMICELLULOSES: branched short-chain macromolecule 25-30% in conifer wood 27-40% in hardwood		Binding substance which guarantees flexibility
	LIGNIN: Three-dimensional macromolecule 28-41% in conifer wood 18-25% in hardwood	Binding substance in the primary structure of cellulose > lignification of cell walls, absorbtion of compression forces	
	PECTINE (almost exclusively in median lamella): Three-dimensional macromolecule 0,5% in conifer wood 1-2% in hardwood	Binding substance, it keeps the tissue cells linked	
SUBSTAN-CES WITH DIFFERENT NATURE	Micromolecular structure: 1-10% in temperate areas woods 2-30% in tropical woods	They have an influence on the chemical, biological, and physical features of the wood, i.e. solar exposure, flammability, durability (i.e. with phenols), smell (due to etheric oils)	

Table 1 – The main constituents of wood

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Cellulose, in other words polysaccharide formed of repeated units of glucose monomer, is the characteristic constituent of the cell walls of the plants and therefore determines their structure. It forms in the fibril structures of the cell wall, partly linked one to the other by means of a homogeneous matrix formed of pectin and hemicellulose. Cellulose can therefore be defined as the backbone of the cell wall which gives the cells a greater stability of shape and determines the resistance to cutting and the curvature.

Hemicelluloses represent, in their involvement with cellulose, the elastic part, which gives flexibility.

Lignin, on the other hand, is formed of long-chain molecules branching in all directions and amorphous. It is not elastic; it deposits encrustations during lignification in the last phase of the formation of the cell walls. In this way the lignin reduces the possibility of extending the cell walls, whilst rigidity and resistance to compression are kept at high levels.

The other substances contained in the wood belong to different chemical species and characterise the different types of wood. Although only small quantities are present, they have a great importance on the chemical, biological and physical characteristics of the wood, but not on its mechanical properties. Amongst these, the following substances should be mentioned because of the known problems which are encountered during coating: tannins and resins.

Tannins are phenolic compounds, present in all plants: they are contained in the wood but also in the leaves, bark and roots. They are soluble in water, alcohol and acetone; they vary in colour from yellow to red. When they are painted, woods which contain high quantities of tannin, in particular with water-based coating cycles, can have problems such as: difficulty in film formation of the coating product used, discolouration of the coating film, whitening.

Tannins can be removed by washing the surface with 130 volumes hydrogen peroxide or acetone.

Resins are secretions from some trees, such as conifers, umbrelliferae and euphorbiaceae, of various chemical compositions. They are very viscous fluids, amber and yellowish, containing essential oils, acids, alcohols and hydrocarbons.

Rosin is one of the most famous products obtained from plant resins. It is solid and yellow (abietic anhydride), transparent; it is obtained as a residue from the distillation of turpentine (resins from conifers Pinus Palustris and other pines in the family of Pinaceae). It was used, and is still used today, in the manufacture of coatings, soaps, adhesives, pitch for caulking, lubricants, inks, sealing wax, for electrical insulation, as a deoxidiser in solder and in the textile industry to obtain non creasing materials, linoleum.

Figure 4 – Rosin

Tubular structures in trees, called resin canals, are responsible for the formation of resin. They make the liquid flow out in response to traumatic external wounds so as to cover the lesion and facilitate healing. In conifers, around the node, the secretion of resin can take place even after working and coating. Such a phenomenon must be taken into consideration, choosing the appropriate coating cycle; this subject will be gone into in more depth further on in this volume.

Figure 5 - Tree resin

1.3 Cutting the trunk

According to ancient traditions, cutting of the wood cannot be done at any time: it is best to wait for the tree to have finished it Summer cycle. However, it can be cut up until February, before the Spring reawakening. The best months are those of November, December and January; already in February the trees are starting to reawaken, and suck up lymph. Autumn is better than Spring. In Spring it is definitely not advisable to cut the trees, nor when the moon is waning, since the influx of lymph in the vessels is so great. In Winter, on the other hand, the ground gives little nutrition, the vessels are restricted because of the cold, the wood becomes more condensed and therefore heavier. Wood is also cut with a waning moon, at the last quarter of the moon up to and including a black moon. There are those who say that they have found that wood cut at the wrong phase of the moon does not burn or burns badly and makes smoke and, if the trunk is used for making products, you can be certain that they will be attacked by woodworm.

When the trunks are felled, and then have their branches and bark removed, they can be reduced to boards according to different ways of cutting. The aim of the cut is to obtain the greatest number of planks with the least wastage of material, assuring nevertheless the production of high quality boards.

The ideal for obtaining excellent quality boards, not likely to be subject to distortion caused by various shrinkage of the fibre or owing to excessive load in the centre which makes it bend, is a cut perpendicular to the growth rings.

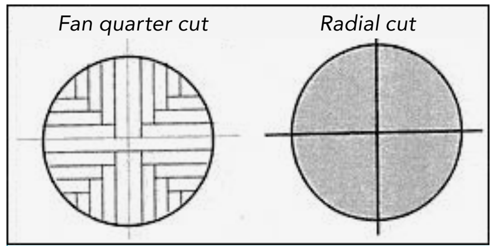


Figure 6 – Wood cuts

This type of cut, called in the figure quarter sawn, is the most expensive in economic terms since it involves high wastage of material. The most economic cut is the radial one, or plain sawn, which has little wood waste, but only the central boards will be stable, whilst those nearer the outside will be more likely to distort.

In summary, the most used cuts are:

Tangential cuts. These are used for economy, allowing low wastage of wood but the planks obtained are not high quality or consistent in appearance, since they vary greatly one from another, gradually as they come from farther away from the central part of the stem.

As one can easily imagine, the central plank keeps its transversal axis straight and gives surfaces with a nearly parallel grain, whilst the other planks are subject to warping and show large areas in the median with a grain which is notably different from that in the side parts, depending on the angle of the stem and the position of the planks within the stem itself. Furthermore, as well as removing from the wood part of its natural lustre, it also reduces its ability to vibrate correctly if it is destined to be used for making musical instruments.

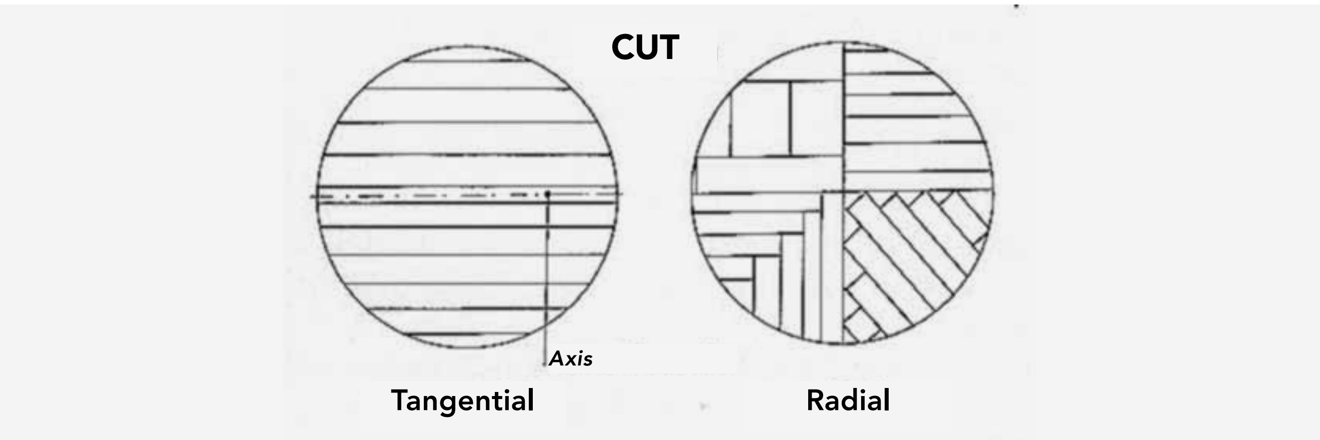


Figure 7 – Wood cuts

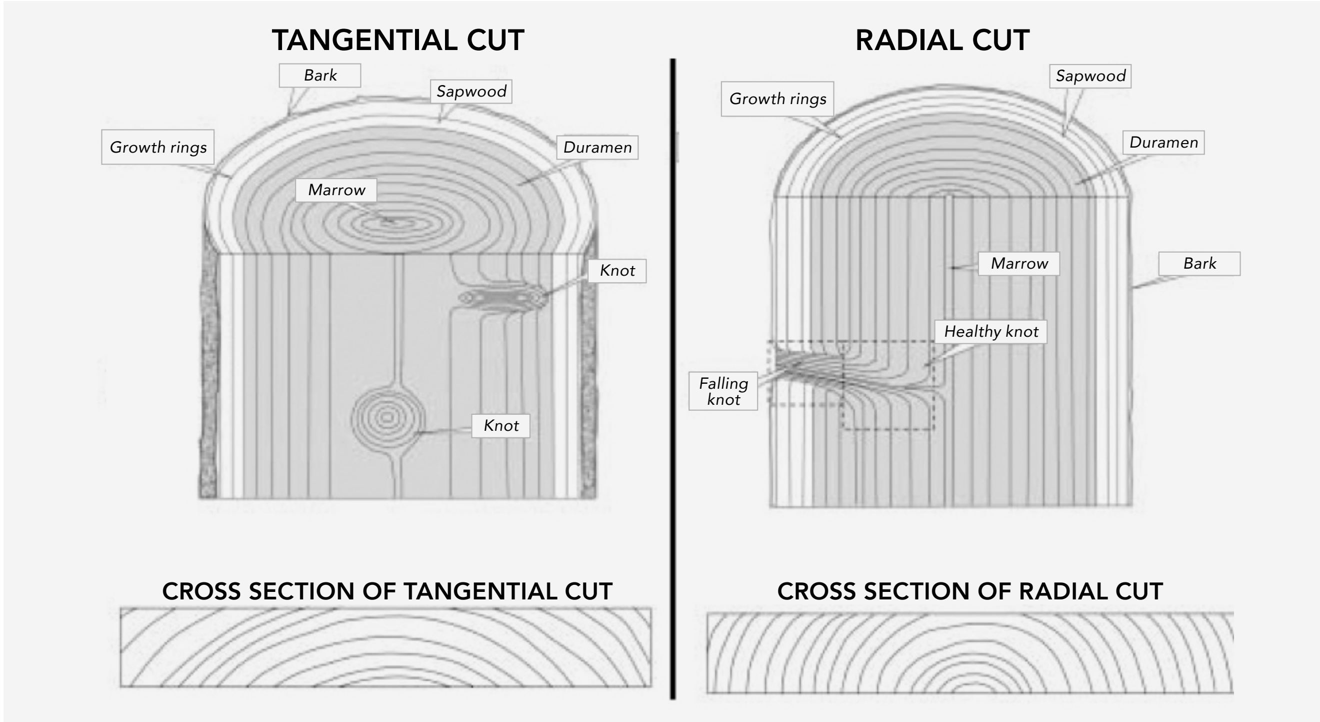


Figure 8 – Wood cuts

Radial or quarter cuts. Planks with dense grain, called "striped", are obtained with these cuts. A series of combinations of radial and quarter cuts create special cuts, always with the aim of obtaining the greatest amount of commercially useful semi-finished material, starting from the basic trunk. The planks are destined for various uses according to the part of the trunk from which they are obtained.

The quarter or radial cut is very important for mechanical purposes and wood stability since it is less subject to distortion and shrinking. The trunks are first sawn in four and then made into planks with radial cuts. In this way the grain being at 90° to the surface makes the wood more resistant to bending, something to be considered when making musical instruments.

This cut fits better with the course of the pith canals: the less the radii are split by the cut, the greater stability and resistance the plank has to sudden changes in humidity.

The thickness must be determined depending on the quality of the wood. If it is dense and thick, the plank must be thin. On the other hand, if it is not very dense and has wide fibres, it must be thicker.

With regard to hard woods, the pith canals are often not straight or at a regular angle, so the quarter cut may be less important in respect of stability. In this case, the cut is decided more from an aesthetic point of view.

The cut of the trunk is therefore made so as to obtain planks which distort as little as possible. Depending on the morphology and nature of the trunk and tree, different systems are applied, to avoid any splits and malformations in the planks.

In modern industry the cutting of timber is a very technological process. Sawmills have machines in series, linked to each other, which carry the incoming trunks to the various automated work stations. Then they are analysed by laser equipment which checks them one by one and then guides the blades in accordance with pre-determined programmes.

The quality of the boards is dependant on the closeness or distance from the pith, that is from the centre of the trunk itself. The internal part, called the heart or duramen, is regarded as the best. In cutting a trunk to make boards, the various types of cutting of which we have spoken are considered, so as to distribute good quality and defects equally and reduce waste.

1.4 Drying and ageing of the boards

Unlike other materials, such as for example metals, wood is a material which is not directly sensitive to temperature variations whilst, on the other hand, it is to variations in humidity.

We have seen that after chopping the tree down, the trunk is cut into planks and usually has a humidity equal to 1.8-2.5 times its own weight in dry timber volume. Over time the wood dries out to adjust to the surrounding environment, giving out humidity until it reaches a state of equilibrium with it.
This point usually corresponds to a humidity content in the plank from 1/10 to 1/20 of its own weight in very dry timber volume.

Figure 9 – Natural drying of wood

As we shall see in detail further on, wood can be dried in two different ways:

Natural drying fo wood

Natural drying of wood consists of leaving pieces of wood under shelter, in a dry and ventilated atmosphere, without using any machinery. The wood's moisture content reduces gradually and naturally. Natural drying is a very slow process which can even take several years. This type of ageing requires orderly stacking of the planks sheltered from rain and direct rays of the sun and the insertion, between one plank and the one placed on top of it, of suitable spacer strips which allow free circulation of the air needed for the gradual drying of the timber. It is obviously a very slow method. The drying time varies from type to type, depending on the starting humidity, the thickness of the planks and other factors. As a guideline, traditionally the time needed for good drying was considered as one year for each centimetre of thickness of the plank. However, generally with this method, the percentage humidity of the wood cannot be reduced below 12-15%. If you want to reduce this value, the timber must be dried indoors and not outside in the open.

Artificial drying of wood

Amongst the technologies dedicated to drying wood, traditional drying using hot air is certainly the most widespread, thanks to the excellent relationship between investment cost and productivity.
The traditional drying cells, based on fundamental principles of physics, use hot air as a carrier to extract the humidity from the wood and transfer it to the air.
Modern dryers apply this concept to within rooms built of aluminium and equipped with heating, ventilation, air recirculation and humidifying systems. In this way it is possible to change the temperature and degree of humidity of the air within the cell and, consequently, change the temperature and humidity of the wood.

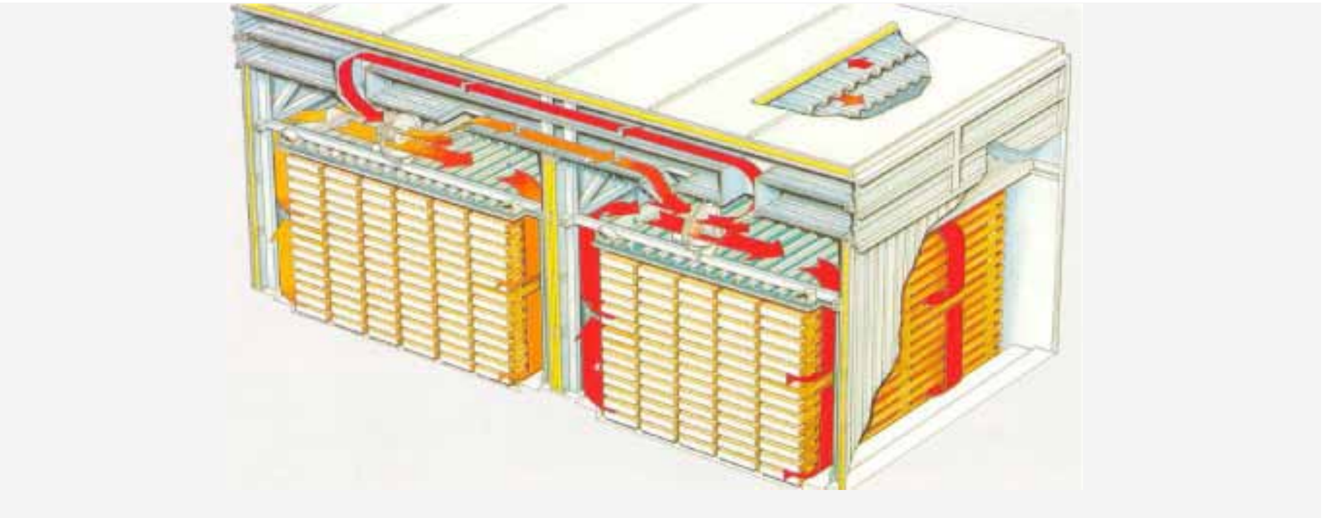
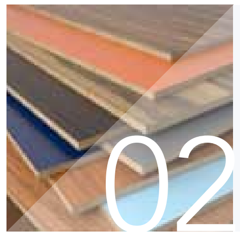


Figure 10 – Example of kiln for the artificial drying of wood. The red arrows indicate the flow of hot air

After ageing the wood has now arrived at hygroscopic balance with the surrounding environment and is not subject to movement if it is kept in constant climatic conditions. It changes its moisture content if the environment where it is changes its humidity, acting as a sponge which absorbs humidity from an environment which is damper and it dries out if the environment is drier than itself. There is also the technique of pre-drying, which enables the wood's humidity to be lowered from newly sawn at 20-25% through treatment in closed cells and at a constant temperature and humidity which is not too different from the place where it was cut. After this, of course, the other two above-mentioned of drying are used.



02 MATERIALS DERIVED FROM WOOD

2.1 Solid wood

When the wooden boards are used as they are, on talks of solid wood. This is defined as wood obtained by cutting the duramen in the shape of boards, beams and strips to make complete pieces which are then used to create high quality, valuable furniture.

Figure 11 – Classic solid wood furniture

2.2 Il legno lamellare

Laminated wood is also obtained from hard wood. This is made of strips of wood stuck together to form panels of various thicknesses and sizes. The structure of laminated wood is very robust. It can be used to make table or kitchen tops, various pieces of furniture and bookcases. If we compare a board of laminated wood with one of solid wood of the same size, the first one offers decidedly superior resistance and bending. Laminated wood is often used in public architecture to create large surfaces and beams which hold up roofs, particularly when constructing public buildings.

Figure 12 – Laminated wood boards

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Figure 13 – Public building with laminated wood roof

2.3 Plywood

Making plywood is a process which creates panels with fabricated components with sheets of wood only a few millimetres thick, usually obtained from softwood. An odd number of sheets are stuck together and placed with crossed fibres to compensate for the tendency of the wood to distort.

The trunk, mounted on the spindles of the plywood machine, is made to rotate on its own axis. A very sharp blade, which does not cause chips, creates a continuous sheet, of between one and three millimetres thick approximately, depending on the type and anticipated use, as wide as the trunk is long.

Particular attention is paid to the production of sheets for plywood destined for structural uses, to restricting the formation of cracks in the sheets, inevitably caused by the tension applied.

In Italy the types used are generally made from softwood, such as poplar, but also sometimes more compact woods such as beech and also some conifers.

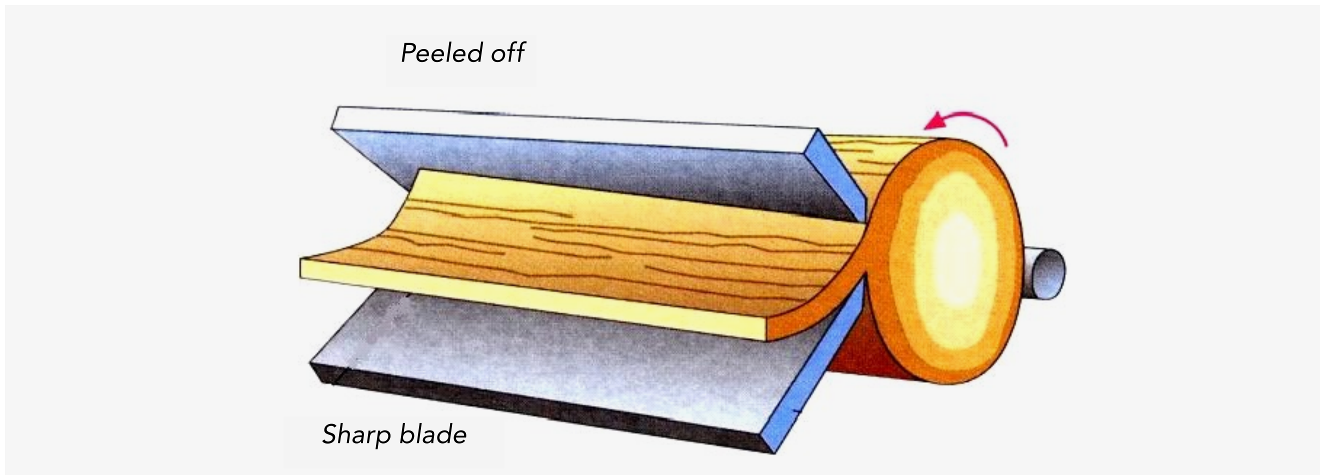


Figure 14 - The plywood machine

Any wood can be made into plywood sheets, but homogeneous wood is more suitable for this purpose. Various types are used throughout the world, provided that there is a suitable use for the sheets produced. Poplar plywood is used for furniture and packaging; curved beech plywood for seats, multi-layers of beech for floors and railway carriage partitions, multi-layers of birch, Douglas fir and pine for various structures and packaging, okoume or mahogany plywoods for "marine" uses or for use in any damp environment.

Other types of panelling created from plywood are summarised in the following table. The type of material used, its composition and main intended use are described.

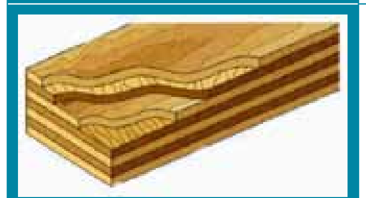
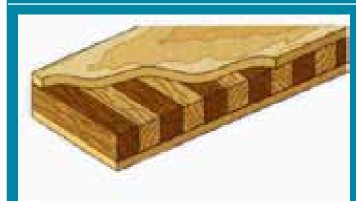
MATERIAL	DESCRIPTION	USE
 PLYWOOD	Is made of three sheet layers and has a minimum thickness of 3 mm and a maximum of 6 mm.	Bottom of drawers and cupboards.
 MULTI-LAYER	Formed of 5 or more sheets placed on top of each other, always an odd number of them. The thickness varies from 8 to 30 mm. It is a very resistant material which does not easily distort, but very expensive.	Tops of furniture, tables, shelves.
 HONEYCOMB	The perimeter is made from a structure of spruce or poplar strips, and in the centre alveolar cardboard. The external surfaces are plywood or thin chipboard variously covered and finished. Its lightness means that it has many uses.	Trade and exhibition stands. Dividing walls Backs of cupboards, dressers and bedside cabinets. Doors.
 BLOCKBOARD	It is a panel formed from two sheets on the outside which enclose many strips stuck together (core). It is light and resistant.	Tops of furniture, counters.

Table 2 – Type of panelling created from plywood

2.4 Chipboard panel

By chipboard panel is meant a panel made of chips of wood bonded together by means of synthetic thermosetting resins. The reasons behind the creation of this product are both historical and economical. At one time furniture was made directly with solid wood, after having transformed the trunks into sawn timber with a view to constructing containers. It was certainly fine furniture, but try to imagine how much they could make today using it, and at what cost. The scarcity of raw material combined with a high price led the producers to search for alternative materials. The first step occurs with the coming of the "honeycomb panel", which asserts itself on an industrial scale with the birth of plywood.
But soon even the honeycomb panel shows its limitations, as a result of a complexity of production, the need to use surfaces of a certain thickness and resistant pockets, from a lack of "flexibility" in the use

of the panel. The furniture industry therefore needed more finished and universal materials in order to increase its production. Thus the appearance of strip and multi-layer panels which, being continuous, are not limited in their usage.

At this point two contributing causes arose to push for research for an alternative material:
1. raw materials crisis and consequent price increase in the supply of exotic woods which form the basis of the above-mentioned panels.
2. need to eliminate cumbersome waste and residues from the various wood-working. This was possible either by using costly incinerators or by finding a convenient use for this available raw material.

In this way the so-called chipboard panel was born. It had a series of advantages, both for production and usage:
- It can be made from the most diverse raw materials, even not high grade, like brushwood, trimmings from the sawmill and various waste.
- It is a continuous material.
- It is large and has excellent stability.

The main problems which initially afflicted the chipboard mix were the unevenness of the internal layer and the unfinished look of the surfaces.
These problems were brilliantly overcome and the production cycle of the chipboard panel is exemplified in the following figure.

Figure 15 - Production cycle of the chipboard panel

The types of wood used as raw materials are very varied: poplar, birch, beech, white alder. On the other hand, hardwoods and exotic woods are not used because of the high content of tannic acid or because their timber structure is unsuitable.

2.5 Hardboard

Hardboard is a chipboard panelling made of compressed wood fibre, usually without the addition of adhesives.

The production of hardboard is very similar to the production of paper. The wood is broken up and made into a mush, mixed mainly with water and adhesives. This mixture, by means of a machine also used in paper mills (continues), is cut, placed on steel sheets with, above, a very fine stainless steel mesh, flattened and baked in a press.

The press has a variable temperature based on the thickness of the mixture and a pressure of about 300 bars. After the mixture has baked for a few minutes, the hardboard is ready and is cut to the desired size.

2.6 L'MDF

MDF – Medium Density fibreboard – is the most famous and widespread of the family of fibre panels which includes three distinct categories based on the process used and the density: low (LDF), medium (MDF) and high (HDF).

The raw material used can include many types of wood, whether round wood, scrap or processing waste, preferably of conifers.

It is produced starting with round wood, usually stripped of its bark, made into chips with the aid of a woodchipper or chopper, and then selected and checked to remove any extraneous matter and any pieces which are too large, having been badly chopped. In some cases the round wood is made into chips in the wood without having the bark removed, even if too great a percentage of bark tends to worsen the quality of the panel.

Refining to change the wood chips into fibre is carried out by grinding to break up the existing links and form a pulp of fibre, helped by immersing in water with the aid of steam and heat or by chemical treatment based on alkaline substances which weaken the links of the lignin, and can take place through two different processes: dry and wet.

MATERIAL	DESCRIPTION	USE
 CHIPBOARD	It is formed of bits of wood like chips. The thickness varies from 4 to 30 mm. It is a heavy material which cannot easily be bent. It is cheap.	Used a lot in industry for vertical walls and also for horizontal surfaces. Also used finished (see pictures at the bottom of the page).

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HARDBOARD	Synthetic wood obtained from sawmill waste which is macerated (soaked in water and baked) into a pulp and then pressed into boards.	Bottoms of drawers. Backs of cupboards, surfaces for painting. Bottoms of fruit crates.
 MEDIUM DENSITY (MDF)	It is a panel of fibres similar to paper which form a homogeneous and very compact structure. It costs more than chipboard but is of superior quality. Its smooth surface can be easily lacquered. It can be easily cut in any direction.	Vertical walls of furniture.

Table 3 – Other types of panelling

2.7 Veneered or finished panel.

It is usually made from a panel support of chips or fibre with one or both the surfaces covered in very thin melamine or quality veneer coatings.

It is usually used for shelves and furnishings which are not of particularly high quality. The finish also reproduces the grain of the woods mainly used in the furniture.

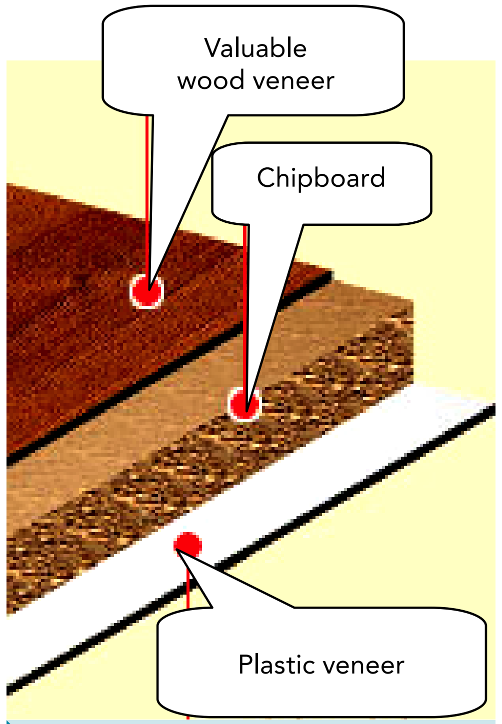

Figure 16 - Veneered panel

03 CHOICE OF MATERIAL FOR CONSTRUCTING WOODEN DOORS AND WINDOWS

3.1 Quality of the raw material, assessed on the finished product

The choice of suitable material for the design and construction of wooden doors and windows is essential for determining how long paint or varnish will last over time.
However, there is a specific standard which, if correctly used, allows for objective analysis and assessment of the most frequent defects, supposedly, which can be ascertained in wooden products. The standard in question is the UNI EN 942 "Timber in joinery - general classification of the quality of wood".
The European Standard UNI EN 942 enables the classification of timber used in joinery and therefore determines the grade of quality depending on the natural defects it can have, for example, knots, splits and resin pockets. The field of application relates to finished products such as: doors, windows, stairs, solid wood, wood strips, laminated wood and finger jointed.
The parts of the finished product which are subject to analysis are the visible faces. The non-visible areas are defined as "hidden faces", which do not affect the final classification, other than for defects which significantly limit the mechanical performance or which prevent correct usage.

The wood defects taken into consideration, and laid down by the standard are: knots, splits, resin pockets and layers of bark, discoloured sapwood, exposed pith, biological attacks, finger joints. The classes listed are, from best to worst, the following:

• J10, J30, J40 and J50 for products which use finger jointed materials, with strips and laminated.
• J2, J10, J30, J40 and J50 for all other joinery products.
• **KNOTS**: The size of the knots, in percentage terms, relate to the thickness or size of the piece. The limits are: Class J2: maximum size 2 mm; Class J10: 30% of the thickness of the piece and maximum size 10 mm; Class J30: 30% of the thickness of the piece and maximum size 30 mm; Class J40: 40% of the thickness of the piece and maximum size 40 mm; Class J50: 30% of the thickness of the piece and maximum size 50 mm. On the visible faces, the knots must be a maximum of 30% of the thickness of the piece and a maximum size of 10 mm with a distance between them of at least 150 mm;
• **SPLITS**: The maximum limits listed by the standard are: Class J2: no splits are allowed; Class J10: 0.5 mm maximum width, maximum depth equal to 1/8 of the thickness of the piece, 100 mm maximum length for each one and a total maximum length on each face equal to 10% of the thickness of the piece; Class J30: 0.5 mm maximum width, maximum depth equal to 1/8 of the thickness of the piece, 200 mm maximum length for each one and a total maximum length on each face equal to 25% of the thickness of the piece; Class J40 and J50: 1.5 mm maximum width if of good quality, maximum depth equal to 1/4 of the thickness of the piece, 300 mm maximum length for each one and a total maximum length on each face equal to 50%.
• **RESIN POCKETS AND LAYERS OF BARK**: These two defects have the same subdivisions which are as follows: Class J2: not allowed; Class J10: resin pockets and layers of bark are allowed when the maximum length is equal to 75 mm, only in places where there is a covering finish; Class J30, J40, J50: allowed only if good quality.

• **DISCOLOURED SAPWOOD**: Class J2, J10: not allowed; Class J30, J40, J50: allowed if not visible after decoration.
• **EXPOSED PITH**: Class J2, J10, J30: Exposed pith is not allowed; Class J40, J50: if it is good quality, it is allowed.
• **DAMAGE FROM INSECTS FROM NECTAR**: Class J2: not allowed; Class J10, J30, J40, J50: if it is good quality, it is allowed.
• **FINGER JOINTS**: this type of joint is allowed in lacquered finishes, whilst for transparent finishes agreement must be reached with the client. The joints must be made between similar woods. The distance between the centre of the joint and the end joints must be at least 150 mm.

3.2 The natural durability of wood

The term "natural durability" is taken to mean the resistance of a type of wood, to deterioration caused by biological xylophagous organisms (fungi, insects, bacteria, marine organisms) which, in the chemical constituents of the woody cell walls (cellulose, lignin, hemicelluloses) or in the reserve substances of the parenchymal cells (sugars, starches), find the source of their nutrition.

Natural durability is due to the presence in the wood of extracts[1] with fungicidal and/or insecticidal properties. They are mainly found in the duramen, whilst the sapwood has virtually none. As a consequence, woods are separated into two categories: with differentiated duramen (larch, pine, oak, Douglas fir, chestnut) and undifferentiated (white spruce and Norway spruce). The sapwood, as previously stated, is the part of the wood with very little resistance to biological attack, and therefore must be discarded when constructing doors and windows.
The natural durability of the wood is defined in accordance with standards UNI EN 350-1 and UNI EN 350-2, which lay down the methods for determining and classifying resistance to xylophagous organisms, fungi, insects (Coleoptera and Isoptera) and marine organisms.
Standard UNI EN 350 - 1 defines the 5 classes of natural durability regarding fungi (1 - Very durable, 2 - Durable, 3 - Moderately durable, 4 - Not very durable, 5 - Not durable).

Standard UNI EN 350 - 2 refers, in short, to the classes of natural durability, referring to the duramen, for the wood types most commonly used in the construction of doors and windows (Table 1).
Another characteristic of wood which must be taken into consideration is how easy it is to treat, or rather the ability of a wood to be penetrated by liquids, specifically by a preservative. From this it follows that a wood type with low permeability can absorb less humidity than others and therefore be less subject to the risk of biological degradation. The tendency to absorb humidity can be deduced from the classification of impregnability as reported in Table 1.

The producer must take into account these fundamental aspects, in order to correctly assess the possibility that a type of wood can undergo preservative and impregnating treatment. Resistance to deterioration caused by fungi supplies information on the possible uses of the wood in relation to the environmental conditions in which it will be used. In any event the length of time can vary between certain limits, depending on the conditions of use. Furthermore, with similar usage, environmental factors such as, in particular, temperature and humidity, have a significant influence on the distribution and action of the xylophagous organisms.

[1] *In wood chemistry, the term "extracts" indicates the compounds which are soluble in organic or aqueous solvents. They are "secondary non-structural components" present in the wood or bark of trees which represent on average less than 5% of the total components and are responsible for the colour, odour and durability of the wood itself.*

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NAME	ORIGIN	NATURAL DURABILITY				IMPREGNABILITÀ	
		WOOD FUNGI	HOUSE BEETLE	WOOD WORM	TERMITES	SAPWOOD	DURAMEN
White Spruce	Europe North America	4	NRH	NRH	NR	2-3	2v
Norway spruce	Europe	4	NRH	NRH	NR	3-4	3v
Chestnut	Europe	2	R	NR	MR	2	4
Douglas	North America; cultivated in Europe	3 3-4	NR NR	NR NR	NR NR	3 2-3	4 4
Hemlock	North America; cultivated in the United Kingdom	4 4	NR NR	NRH NRH	NR NR	2 1	3 2
Larch	Europe Japan	3-4	NR	NR	NR	2v	4
Dark Red Meranti	South-east Asia	2-4	R	n/d	MR	2	4v
Light Red Meranti	South-east Asia	3-4	R	n/d	NR	2	4v
Sapelli mahogany	Western Africa	3	R	n/d	MR	2	3
Niangon	Western Africa	3	R	n/d	MR	3	4
Okoume	Western Africa	4	R	n/d	NR	n/d	3
Scots pine	Europe	3-4	NR	NR	NR	1	3-4
Oak	Europe	2	R	NR	MR	1	4
Teak	Asia; cultivated in Asia and other countries	1 1-3	R R	n/d n/d	MR MR-NR	3 n/d	4 n/d
Yellow Pine	Either cultivated in North America or in Europe	4	NR	NRH	NR	1	2

Table 4 – Natural durability of wood

Key

Standard UNI EN 350-2 defines five classes of natural durability with regard to attack by wood fungi:
1 = very durable, 2 = durable, 3 = moderately durable, 4 = not very durable, 5 = not durable.

The following classification divides woods into three classes with regard to attack by insects (house beetle and woodworm, shown in the table):
R = resistant; NR = not resistant; NRH = means duramen not resistant.

With regard to attack by termites, the standard defines three classes:
R = resistant; MR = moderately resistant; NR = not resistant.

With regard to the "impregnability" column, standard UNI EN 350 - 2 defines four classes:
1 = impregnable; 2 = moderately impregnable; 3 = not very impregnable; 4 = not impregnable

The notation "V" means that there is great variability for that type of wood
The notation N/A means that the available data is insufficient.

The application of a preliminary preservative treatment will be necessary whenever you want to increase the natural durability of the wood to bring it up to the level required by the risk class and by the performance in its desired usage (EN 460 and EN 599-1).

Treatment can be by brush, flow coating, immersion or using vacuum impregnation.

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3.3 Durability classes of the main woods


Spruce
- Colourless solid wood
- Low resin content
- Durability class: 4


Pine
- Solid wood and sapwood have a different colour
- Resinous
- Durability class: 3-4


Larch
- It is often redder than spruce
- Resinous
- Contains special extracts
- Durability class: 3-4


Oak
- Characteristic wood colour
- Very rich in extracts
- Durability class: 3


Mahogany
- Characteristic wood colour
- Very rich in extracts
- Durability class: 3


Eucalyptus
- Rapid growth of plantations
- Used increasingly for making windows
- Durability class: 3-4

3.4 Biodegradation of wood

By the term biodegradation we mean an undesired change in the wood's characteristics. Such a change is carried out either by macroscopic organisms such as coleoptera and woodworm, or by micro-organisms such as fungi and bacteria. Their action is often joint and can bring about different types of changes: from purely aesthetic effects to significant, and sometimes irreversible, changes (disintegration of materials and loss of mechanical characteristics)

Macroscopic organisms: Coleoptera and woodworm
Coleoptera: they are insects which lay their eggs in cracks in the wood, which is then attacked by the larvae which take their nutrition from it.
Woodworm: they principally attack the sapwood of the wood and are mainly found in areas with a maritime climate and with a high humidity level.


Figura 17 - Coleoptera


Figura 18 Woodwarm

Microscopic organisms: Chromogenic fungi and rot fungi.
Chromogenic fungi penetrate the wood where they feed on easily assimilated substances (starch, protein, sugars), which are found in the sapwood cells, giving the wood a blackish blue colour. They do not affect the mechanical properties of the wood but reduce its commercial value because of this abnormal colouration. Fungi of rot demolish the main constituents of the cell wall of the wood, causing changes in colour, chemical, physical and mechanical properties. Depending of the type of fungus from which it is being attacked, the wood can become lighter (white rot, attacks the lignin) or darker (brown rot, attacks the cellulose). The attacked wood becomes less heavy, more brittle to the touch and develops cracks which break up into vertical stripes.

3.5 Risk classes

As well as natural durability, there are also other risk factors, called classes, linked to conditions of use, which need to be considered when choosing the material.
The classes of risk from biological attack, defined in the European standard, serve, on the other hand, to highlight what the conditions of exposure are which can provoke an attack by various biological agents. These classes, to which we refer, are defined by the standards: UNI EN 335 - 1 which defines the classes of risk from biological attack - General (Table 2) and UNI EN 335 - 2 which defines the classes of risk from biological attack - Application to solid wood (Table 3), depending on the various situations of usage to which the wood can be exposed:

RISK CLASS	GENERAL USAGE SITUATION	DESCRIPTION OF EXPOSURE TO HUMIDIFICATION IN USE	DISTRIBUTION OF BIOLOGICAL AGENTS			
			FUNGI	INSECTS	TERMITES	MARINE ORGANISMS
1	Not in contact with the ground, covered (dry)	None	-	U	L	-
2	Not in contact with the ground, covered (risk of damp)	Occasional	U	U	L	-
3	Not in contact with the ground, not covered	Frequent	U	U	L	-
4	In contact with the ground or freshwater	Permanent	U	U	L	
5	In salt water	Permanent	U	U	L	

Table 5 - Summary of the risk classes, based on humidity and atmospheric agents (UNI EN 335-1)

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RISK CLASS	WOOD HUMIDITY	DISTRIBUTION OF BIOLOGICAL AGENTS					
		XYLOPHAGOUS FUNGI		COLOURING FUNGI (*)	INSECTS		MARINE ORGANISMS
		BASIDIO-MYCETES	SOFT ROT	BLUE STAINING	COLEOPTERA	TERMITES	
1	Maximum 20%	-	-	-	U	L	-
2	Occasionally > 20%	U	-	U	U	L	-
3	Frequently > 20%	U	-	U	U	L	-
4	Permanently > 20%	U	U	U	U	L	-
5	Permanently > 20%	U	U	U	U	L	-

Table 6 - Summary of the risk classes for solid wood, based on humidity and atmospheric agents (UNI EN 335-2)

U: Universally present in Europe
L: Locally present in Europe
(*) Mould: protection against mould can also be considered

3.6 Dimensional stability

Dimensional stability, that is the characteristic of the wood having reduced movement after absorbing humidity, is a fundamental property in the production of manufactured articles with precise dimensions, like doors and windows.

Dimensional stability depends on:
- type of wood chosen
- type of cut, timber with a radial cut (striped) is more stable than timber which has been cut tangentially (flat)
- type of drying which the timber has undergone

This defines how much a wooden article changes or can change its dimensions due to swelling and shrinking.
As a consequence of this, wooden building elements are classified as: dimensionally stable, with limited dimensional stability and not dimensionally stable.
Wooden building elements are dimensionally stable when only slight variations in dimensions are allowed. Windows, external doors and window shutters should be mentioned in this respect (Figure 19)


Figure 19 - Dimensionally stable wood

Wooden building elements have limited dimensional stability if variations in dimensions are allowed in a limited proportion. This applies, for example, to tongue and groove panelling, lattice structures, soffits and cornices as well as external entrances and doors (Figure 20).


Figure 20 - Wood with limited dimensional stability

Constructions are not dimensionally stable if variations in volume are not limited, like, for example, external furnishings, for example benches, platforms or fences (Figure 21).


Figure 21 - Not dimensionally stable wood

The processing of the wood used for the construction of doors and windows, must be carried out at a humidity of between 12 and 13% for elements such as windows, whilst between 13 and 15% for solid and slatted shutters. If necessary, the wood must undergo a preventative drying treatment, as seen above.
Wood dried using artificial drying, with hot air, is hygroscopically more stable than that dried using natural drying, with significant benefit from both a building and structural point of view.
Wood movement is directly proportional to its density: types of wood with low density (Pine, Spruce) show more limited movement compared to those with high density (Larch, Oak).
Another parameter linked to the porosity of the wood is the speed of exchange of humidity with the environment: the more porous the wood and the lower the specific weight like spruce, the greater is the capacity for exchanging humidity (high hygroscopic inertia). On the other hand, woods which show low porosity with a high specific weight such as oak, have a lower response time (low hygroscopic inertia).
The types of wood with a greater dimensional stability are: Chestnut, Hemlock, Douglas Fir and Teak; those with an average dimensional stability are: Oak, Pine, Norway Spruce and White Spruce.

3.7 Extractive elements

As we have seen in part above in chapter 1.2, wood can contain various organic elements: extracts or "substances which are extraneous to the cell wall".
These substances, in fact, are not part of the woody tissues, but are deposited mainly in the cell lights and in the spaces existing within the walls themselves. The first name, "extracts", in fact, refers to the possibility of extracting them from the wood (at least partially), using cold or hot water, steam or organic solvents such as benzene, acetone or various ethers and alcohols.
The extracts include substances of various chemical composition such as, for example:
- **polyphenols**, which encompass a group of compounds (lignin, tannin, flavones, quinones) which can give the wood a particular colour and natural durability;
- **terpenes**, which form the volatile part and the fatty acids of the wood resins and are found abundantly in many types of Pine;

In the wood of trees typical of regions with a temperate climate, the percentage of extracts, referring to the anhydrous weight of the sample in question, varies from values of less than 1% (in Poplar wood) to values greater than 10% (in that from Sequoias).
In some tropical species, their percentage, on the other hand, can reach values equal to 20%. Significant variations can be encountered not only between various types of wood, but also within the same plant, in particular between the sapwood part and that of the duramen.
Some inorganic substances, such as, for example, calcium salts and silica elements, are not soluble in the above-mentioned solvents, but are also considered amongst the extracts since they do not form part of the basic chemical composition of the cell wall. In this context, all the inorganic compounds present in the wood (which generally form its ash) can be included among the extracts.

The problems which the presence of extractive elements can cause in processing wood are:
- preventing the penetration and flow of preservatives/impregnating products
- inhibiting the drying of the coating film applied
- breaking down the coating film during exposure to the sun's rays

The presence of extracts can cause problems in transparent coating applications on Iroko and Russian Larch, inhibiting film formation, causing silvering of the pore, micro fractures of the coating film and the formation of small bubbles.
To avoid leakage of resin, coating must be carried out immediately after sanding, or else an insulating coat must be applied. (See Chapter 4.1).
The system of vacuum drying and that carried out in hot air, are very effective in reducing leakage of resin. To obtain the necessary release of resin, the drying temperature of the air must not be less than that used for the door and window joinery

04 CONSTRUCTION AND PREPARATION OF EXTERNAL WOODEN DOORS AND WINDOWS

4.1 Sanding bare wood

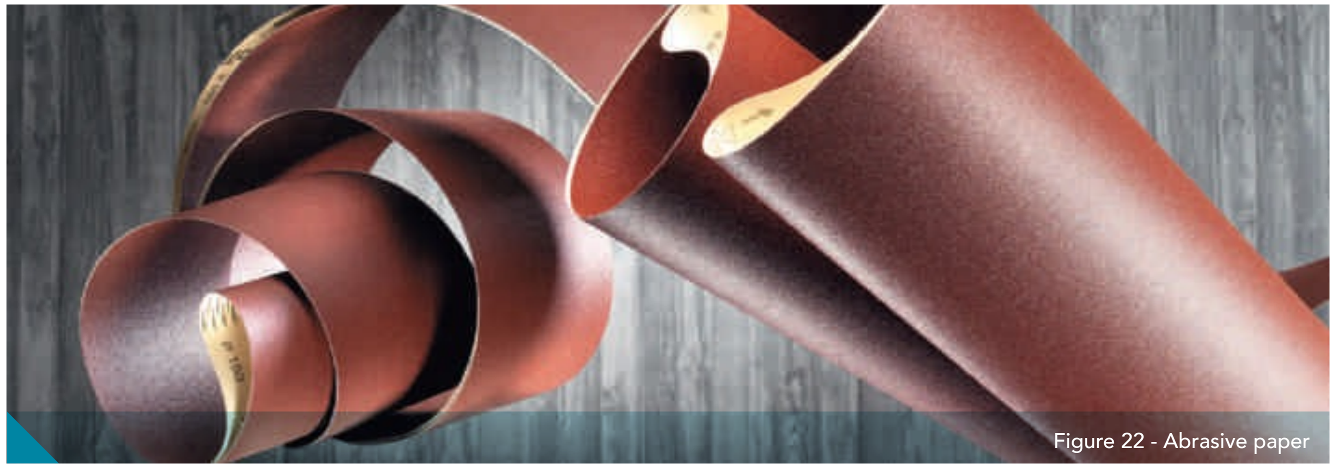

Figure 22 - Abrasive paper

Sanding is the operation to prepare to support the coating. It can be divided into two phases:

1. Rough sanding
This operation removes all traces of the cutting blade, any vibration of the tools which remains impressed in the wood; it is carried out with 60-80 grade abrasive paper.

2. Smoothing
After the rough sanding, marks left by the abrasive paper appear, since coarse grains are used which leave grooves in the wood, often visible even to the naked eye. Before the coating phase it is therefore necessary to use a finer grain abrasive paper, which goes from 120 to 250, depending on the type of wood and type of coating. For example, sanding of conifer wood (pine, larch, Douglas fir, spruce, hemlock) must start with grain 100 and finish with grain 120 or 150; whilst sanding of hardwood (oak, chestnut, meranti, mahogany, teak, okoume) must start with grain 100 or 120, continue with grain 150 and end with grain 180.

In particular, if you intend to carry out coating with a water-based coating, smoothing becomes essential. Whilst solvent-based coatings do not cause problems of swelling of the wood and therefore any excessive presence of hairs or compression of the fibres does not show, using water-based dispersions these defects are accentuated.

It is useful to remember that a good preparation of the rough surface greatly facilitates successive phases, with consequent advantages, both economic and environmental. Conversely, sloppy preparation of the surface often ultimately affects the coating. Some types of conifer wood may contain large quantities of resin which can affect the adhesion of the coating. In these situations, coating must be carried out

immediately after sanding or an insulating coat must be applied. Two-component systems are often used in cases such as these.

Abrasive paper
There are various types of abrasive paper on sale. In order to use it properly you need to know the characteristics.
Abrasive paper differs, one sort from another, depending on the substance applied on it, the size of the grains of that abrasive substance and the type of surface on which the substance is applied.
The surface can be paper but can also be cloth (and other flexible materials).
Abrasive granules are stuck on this, using a specially strong glue.
Changing the coarseness of the abrasive substance determines its ability to produce a finish which is smoother or not so smooth, with the removal of larger or smaller particles.

Abrasive minerals
Today the most used raw materials for making abrasive grain are: corundum, silicon carbide, zirconium.
Corundum ceramic and diamond are used more and more often.
On the other hand, the percentage usage of natural minerals, like emery, is rapidly decreasing. The hardness and resistance of the abrasive grain, based on the raw materials used, determines the characteristics and use of the abrasive.

Sanding methods
Sanding can be carried out with correct motorised tools such as an orbital sander, disc sander, belt sander or using modern motorised tools, such as automatic sanders and polishers (Figure 23).

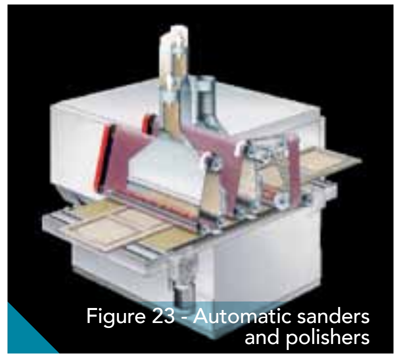

Figure 23 - Automatic sanders and polishers

4.2 Design features of windows

In the last few years, the production of external wooden doors and windows has been affected by increasing quality, stimulated by the issuing of specific technical regulations aimed at assessing and measuring the performance characteristics of all doors and windows as a whole.
It is clear that today the "window", as a manufactured article, must comply with a series of specific performance requirements, both because of the legal requirements - attributed to the essential requirements of the European Union directive 89/106 – and because of the specific requirements of the consumer who purchases it.
Satisfying such requirements, which can be measured through compliance tests and checks on the standards to be carried out on the product, is influenced to a great extent by design choices of the "window system". It is therefore useful to know the "state of the art" in that sense, to have a clear vision of the reasons which have led producers of windows to adopt certain design and building solutions rather than others.

Figure 24 - A window

4.2.1 Internal installation of elements

Solar radiation, rain, high humidity and hail are amongst the factors which bear the greater responsibility for deterioration of wooden elements. Solar radiation can cause changes in colour of the doors and windows, which tend to fade or turn greyish. High temperatures are also a cause of surface cracking and, with conifer wood, of resin coming out from the wood which leads to the appearance of yellowish marks, particularly visible on light colours. Hail can cause huge physical damage to the manufactured article (dents, splits, breaks and cracks) which, at times, can be difficult to repair.

Figure 25 - Deterioration of wooden fixtures

That is why, when installing windows, it is very important to take into account a correct design, to reduce damage caused by atmospheric agents to a minimum, and give the items a longer life. Installing windows flush with the façade will cause extreme exposure to atmospheric agents (Figure 26). Installing them set back from the façade will expose the windows to normal exposure to atmospheric agents (Figure 27). If the roof overhangs considerably, it will give low exposure to atmospheric agents (Figure 28).

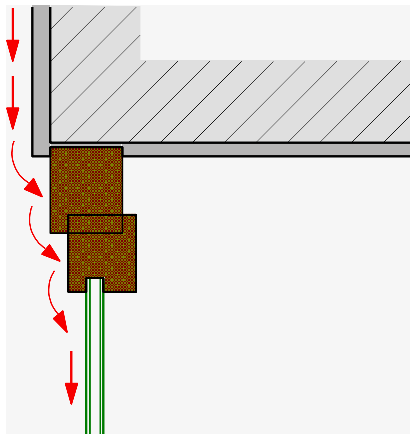

Figure 26 - Flush with the façade : extreme exposure to rain, sun and hail.

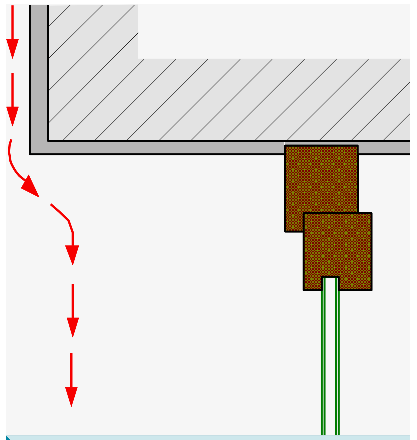

Figure 27 - Set back from the façade : normal exposure to rain, sun and hail.

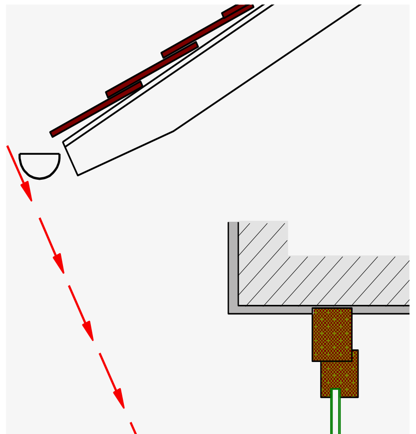

Figure 28 - Large overhand of the roof : low exposure to rain, sun and hail.

4.2.2 Tilt of the exposed surfaces

The window must be designed and constructed in accordance with the best available technical expertise, in compliance with the applicable EN standards, DIN 68121 parts 1 and 2, and the applicable guidelines of the Rosenheim Institute for Window Technology (IFT).

There must be no horizontal planes on the surfaces exposed to the atmospheric agents, in order to ensure the rapid outflow of rainwater and avoid any stagnation.

The minimum tilt of the surfaces must be at least 15°, as shown in figure 29, so as to allow the rainwater to run off. On horizontal structures, in fact, water stagnation is much higher compared with tilted structures, with the consequent possibility of it getting into the wood and then an increase in humidity which could encourage biological xylophagous organisms and negatively influence its dimensional stability.

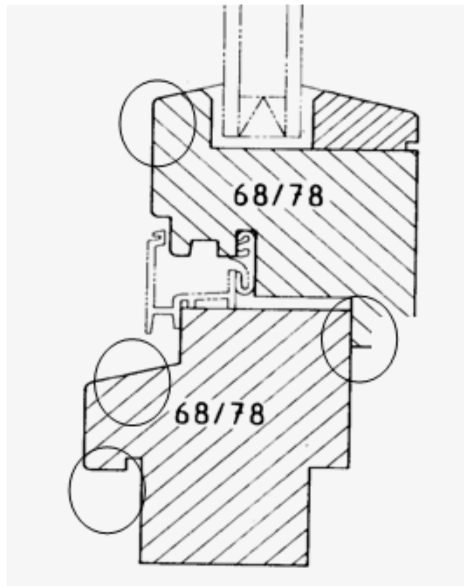

Figure 29 - Tilt of external surfaces

4.2.3 Radius of the corners of the profilesi

The corners of the external surface of the window must not have a radius of 90°, but rather the frame configuration must have a minimum curve radius of 2 mm in order to ensure the continuity of the protective film coating, as shown in figures 30 and 31. It is best to avoid any shaping involving any sharp corners or interruptions that could prejudice the adhesion of the coating to the surface with the consequent interruption of the film, which will lead to rapid deterioration.

On sharp corners (those measuring less than 45°), because of surface tension, the coating tends to draw back, leaving a thickness which is insufficient to give a guarantee of lasting over time.

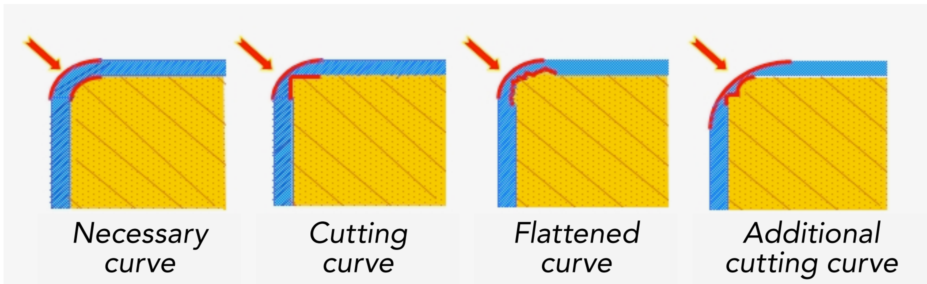

Figure 30 - Radius of the external corners to the window

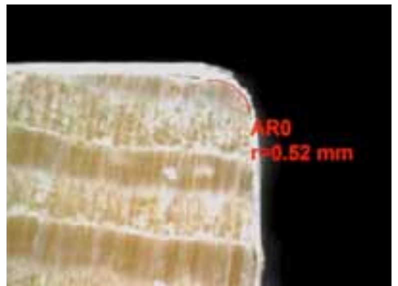

Figure 31 - Radius of the corners

4.2.4 Evacuation holes and slots

In order to avoid water stagnation, the evacuation chamber must have holes: if aluminium gutter channels are used, the slits must be at least 30 x 5 mm, at most 200 mm apart; if the evacuation holes are created in the lower part of the fixed frame, the evacuation holes must be at least 8 mm, at most 200 mm apart. We recommend creating the holes at the uprights in order to guarantee a more correct

evacuation of the water (see Figure 32).
The area used for collecting rainwater is characterised by the presence of specific slots, which allow any water which has come in to be drained outside, avoiding stagnation and water infiltration into the building.


Figure 32 – Evacuation holes and slot

4.2.5 Drip edge guide

The drip edge guide, which makes an important contribution to the performance of the watertight seal of the product shown diagrammatically in figure 33, must be on the outermost edge of the doors to avoid water spreading in a capillary fashion on the door edges: in this way it will be channelled into the evacuation chamber. The drip edge guide must be a suitable size (minimum width 7 mm and depth of at least 5 mm) in order to interrupt the flow of water; it must fall entirely within the drip edge working area.
If its size were too small or not adequate, it would not manage to stop the flow of water which tends to enter by sticking to the doors, becoming a real factor which acts as a bridge for the infiltration of water.
In order to prevent direct entry of water into the drip edge area, it is advised to design, in the lower transom of the door, an edge of about 10 mm.
The drip edge area is therefore aimed at performing the task of collecting incoming water, guiding it outside and avoiding any infiltration into the building.
The use of a small external seal, placed between the drip edge area and the doors, can often prove useful, in windows which are not very thick, in limiting direct infiltration of water and avoiding any deterioration of the coating caused by the edge between the wood and the aluminium part.

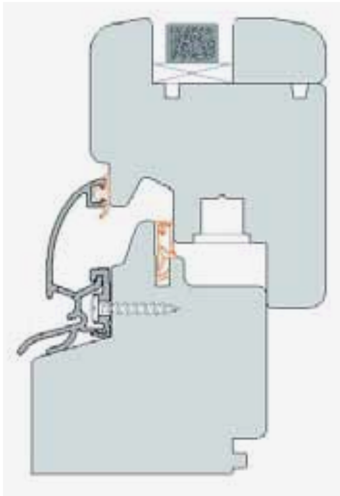
Figure 33 - Drip edge guide

4.2.6 Ventilation of the glass chamber

To protect the seal between the two glass panes from deteriorating, it is necessary to design ventilation holes in the bottom of the glass chamber. This must be carried out as shown in figure 34, with the aim of linking the glass chamber with the outside and preventing condensation from getting in.


Figure 34 - Ventilation of the glass chamber

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4.2.7 Sealing and seals

The sealing of the glass chamber can be carried out using silicone material or specific seals. The sealing is effective is the material used adheres well, both to the glass chamber and to the coating. Sealing materials must have good resistance to high and low temperatures, to humidity and ultraviolet rays, and have a low modulus of elasticity. With regard to seals, it should be remembered that they must be fixed well at the corners so as not to create breaks through which there might be infiltration.
Sealing with silicon must be carried out correctly, creating a good joint to which the silicone can be added. The joint must be suitable for guaranteeing the success of the seal and its durability over time. The site must be on the internal edge of the external glazing beads. It must be a suitable size - at least 4 x 4 mm - to increase the area of contact between silicon-glass and silicon-wood.
The thickness of the silicon on the site must be at least equal to half of its width in order to guarantee good adhesion to the site and to the glass chamber. The consistency of the sealant is important because it ensures greater elastic deformation of the seam and a greater resistance to stresses due to movement of the wood and glass.

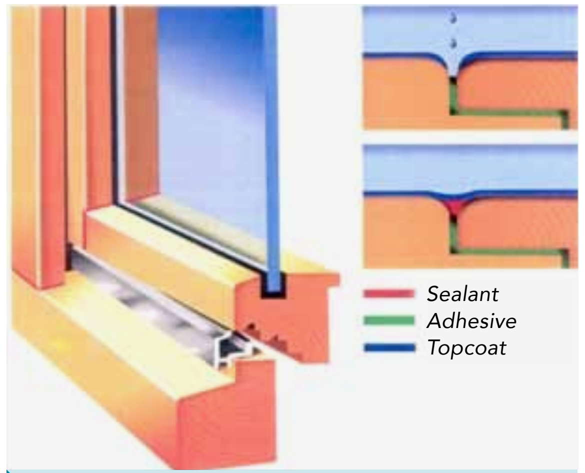

Figure 35 - Insulated grazing seal

With regard to seals, it is advisable to use Olefin type ones based on "Purine" or "Santoprene" and not PVC; these are elastic materials, not containing plasticisers and they avoid causing gluing problems between the coating and the seal itself. The seals must guarantee careful welding in the corners of the glass chamber.
Both where using silicone sealant and seals, adhesion and compatibility of products with the coating, must be tested.
The sealing of the glass chamber, done using perimeter sealing of the glass/frame door, is essential to ensure that driving rain is kept out.
Other methods which can guarantee this are larger sealing seams in suitable sites, however always on the outside, or the use of specific strong seals. The solution of only fixing silicon between the glass chamber and the inside of the base of the glass chamber itself is not normally sufficient to ensure optimal holding performance.


Figure 36 - Perimetral seal

4.2.8 Gluing

The choice and assessment of the best adhesive system suitable for constructing wooden doors and windows must have a primary feature to guarantee the profile an excellent holding, stability, resistance to bad weather and to sudden changes in humidity, and consequently great durability and stability over time, as shown in figures 37 and 38. The use and quality of the glue is dependent on the interaction of the materials to be joined and the adhesive to be used. This latter, in addition to fluidity and ease of application, must also react well with stresses, and have good resistance to temperature changes and humidity.
The minimum requirements that adhesives must meet in the construction of doors and windows are as follows:

- For normally stressed windows and shutters: class D3 in accordance with standard UNI EN 204 and UNI EN 205[2]
- For shutters which are more exposed to external stresses: class D4 in accordance with standard UNI EN 204 and UNI EN 205

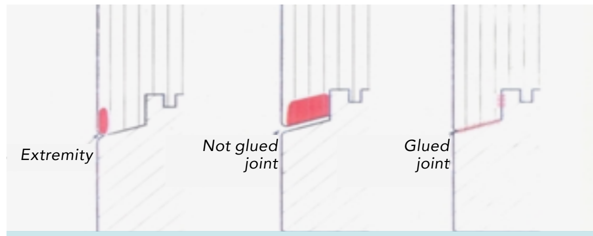

Figure 37 - Gluing the joint. A perfectly glued joint ensures long life and stability over time, preventing the passage of water, humidity and air

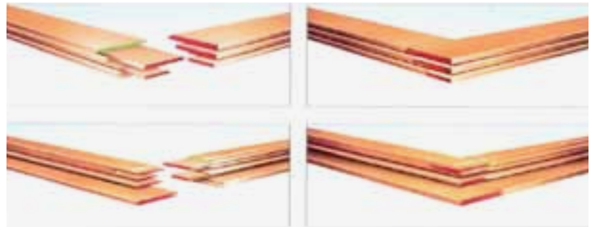

Figure 38 - Gluing the joint. Without a correct glue there would be deterioration and damage to the window

4.2.9 Filling defects

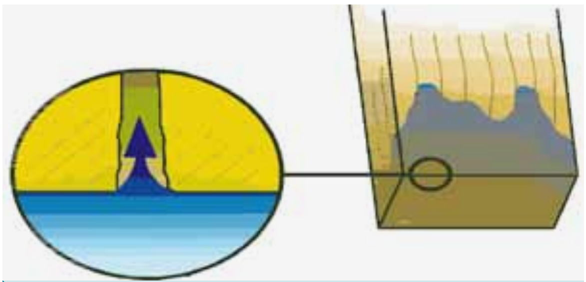

Figure 39 - Filling defects

As we have seen previously, a wooden item can have defects, not only through breakage in use, but also through the behaviour of micro-organisms which make the wood spongy or brittle, or through the presence of insects such as woodworm and termites. However atypical defects can occur, i.e. cracks, through the effect of differential shrinkage due to anisotropy of the wood. Even if drying has been carried out correctly, the damage can show itself if the conservative environment is subject to major, sudden changes in heat and humidity.
When selecting a filler, you must carefully assess the possibility of the filled wood being subjected to movement in the future, which could cause stress on the edge of the filler.

[2] *Standard UNI EN 205 describes the tests on adhesives for wood and wood derivatives, which enable their resistance to various influences of a physical nature to be checked. It does not cover adhesives for structural uses and for making panels and chipboard, fibre panels and plywood panels. Neither does it replace specific tests or tests for finished products. The method described highlights the assessment of suitability and the quality of the adhesive for wood and wood derivatives, the classification of these adhesives in accordance with classes from D1 to D4 in accordance with UNI EN 204, the assessment of the effects on the resistance of the glue, by the series of conditioning and treatments of the test items before and after gluing and the assessment of the resistance of the gluing carried out with thin or thick adhesive layers.*

At the same time, the mechanical resistance of the object must be assessed: a very rigid and strong filler, inserted into and fragile object which will move, will cause the object itself to break.
In this case it is therefore better to choose an elastic and not very adhesive filler, which, when the wood moves means that the filler will move similarly, or at least it separates from it, which can be repaired in the future, but damage to the original object is avoided.

We list below some of the characteristic properties which define an "ideal" filler:

- Minimal shrinkage on drying
- Does not affect the adhesion of the coating
- Chemical inertia in respect of the substrate
- Putty-like consistency, which hardens quickly
- Can be sanded and does not stain
- Good adhesion.
- Good workability after it is dry
- Lasts a long time
- Absence of shrinkage or swelling if coated with water-based products.

There are various types of filler on the market, ones ready to use, or ones which need preparing. Later we shall examine those which are more widely used in wood "restoration". They can be divided into two macro families: traditional and synthetic fillers.

Traditional fillers

These fillers, which are becoming less commonly used due to their limited chemical and physical characteristics, are based on mixtures of inert substances such as calcium carbonate and kaolin, with the classical aqueous binders such as leather glue, casein, bone glue, or else with other binders like linseed oil. The main ones are:

Fillers with a protein base. These have substantial shrinkage combined with poor adhesion to the surface. The hardness and rigidity of this type of filler, a characteristic which tends to increase over time, means that with the wood's movement it can separate from the wood or crack. It thus becomes impossible to carry out filling with a consistent volume.

Shellac fillers. They can only be used for filling very small holes, often used in furniture restoration. The shellac is combined with beeswax, a mixture which tends to give a softer filler, or natural resins such as rosin, which give greater hardness. The mixture is poured into the cracks where it quickly sets as it cools. It is only advised for surfaces to be polished after the shellac.

Wax fillers. They are used a lot for small cavities such as the eclosion holes made by woodworm. In this case the filling of cracks of more that a few millimetres leads to the filler pulling away from the hole or to the formation of cracks in the filler itself. The main problem of wax fillers is that they cause a tonal variation in the area around the filling, through the binder spreading. The problem persists, even if compounds like plaster or vegetable granules are mixed in.
With the coming of synthetic polymer and consequently synthetic fillers, many of the problems regarding the use of traditional fillers have now been overcome.

Synthetic fillers
Unlike traditional filler, synthetic fillers are now ever more widely used, specifically because of the excellent chemical and physical characteristics. They are based on mixtures of synthetic polymers. There is a description below of the most used synthetic fillers.

Epoxy fillers. They are characterised by high mechanical resistance and adhesive resistance. They are stable over time and without shrinkage. They were made for filling and restoring wooden articles intended for supporting significant loads, such as beams and ceilings. Once applied they are very difficult to remove and, if there is movement, their resistance would break the original article. Their use is justified therefore for work on objects which will be always be kept under safe thermohygrometric conditions.

Vinyl based fillers. They present problems of shrinkage during the evaporation of water stage, because of the slow and gradual hardening of the binder. The qualities of these fillers are, on the other hand, the easy workability and low cost, as well as being able to be removed not only using water, but also with solvents such as ethanol or acetone.

Acrylic fillers. They consist essentially of resin solutions in solvent, variously mixed. The advantage of working without water is partly counterbalanced by a separation of the inert substances from the mixture and shrinkage after evaporation of the solvent.

Polyurethane fillers. They are characterised by the use of polyurethane foams, used only as filling, given that these do not have any significant mechanical resistance. Among the limits of use is its toxicity and, in the case of application on fragile objects, the risk of breaking when the foam expands. Silicone fillers . They are obtained by loading silicone rubber with inert substances. These fillers are used for their main property of being really elastic, and, consequently, of not causing tensile stress in wood which has deteriorated. Their poor adhesive capacity, however, limits their use to only filling holes without any structural use.

Two-component epoxy based fillers. These are characterised by extreme lightness and reversibility, both mechanical and chemical, designed for gluing and filling fragile objects or ones subject to movement. Together with their low rigidity, these fillers also have a modulus of elasticity close to that of the wood; the slight shrinkage, less than 1%, during hardening makes this material ideal for injecting into objects with internal holes to be filled. The fact that this two-component filler is easily shaped makes reconstruction of missing wooden parts easy to carry out, and once hard it can be easily carved and sanded, and the paste can be coloured and surface coated.
Their lightness avoids excessively weighing down the structures to which they are applied.

4.2.10 Protection of the end grain wood
In Italy the construction of windows requires that the upright protrudes with respect to the horizontal: this solution makes the window aesthetically more pleasing, but defines the formation of a critical point for absorbing humidity from the wood. The wood at the top, finding itself on one side in contact with the sill, is in a very critical situation with regard to absorbing water which is therefore able to penetrate inside, where there is a greater possibility of water stagnating. The humidity is therefore transmitted to the tenon joint, the point where it is found that pressure caused by the increase in volume makes the joint itself open up. The best building solution to resolve the problem would be, therefore, to make the cross bar longer to reach the upright, so as to avoid the head of the wood turning up or down, with a consequent reduction in absorption of humidity in these delicate points.

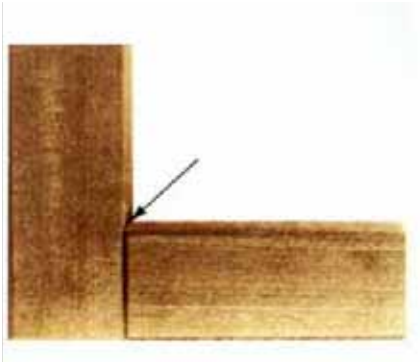
Figure 40 - Tenon joint with upright projecting; the arrow indicates the most critical point for the absorption of humidity

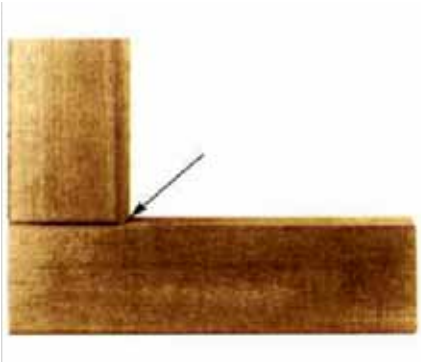
Figure 41 - Tenon joint with horizontal projecting; the arrow indicates the most critical point for the absorption of humidity

In the event of a configuration as in figure 40, it is necessary:
- That the joint is as tight as possible
- To apply a dipping/flow-coating primer

or else
- To apply a spray-on primer and a semi-transparent sealant after impregnation
- To ensure a suitable thickness of coating is applied.

4.3 Wooden shutters
In this paragraph we describe a few examples of shutters; for general building aspects it is necessary to follow those already described for windows (rounded corners, external profile tilted by at least 15°, protection of the heads, gluing and sanding); for coating cycles please see the following chapters.
For this type of manufactured article it is advisable to take some precautions in the design phase to prevent structural warping and consequently avoid any defects which are difficult to put right from arising.


Figure 42 - Wooden shutters

The steps to take are:

1. Leave a space, between tongue and groove, equal to about 1-2% of the width of the beads;
2. Leave a space between the staves of about 2 mm, inserting thicknesses of MDF: one in the upper part, one in the middle and one in the lower part of the shutter which will later be removed;
3. Use multi-layer panels.
4. Carefully avoid any water entering the crack between panel and frame, applying a bead of silicon, and similarly for the glass.
5. In the case of solid panels, it is necessary to leave a gap at the sides of the panel or use a multi-layer support.
6. Leave a space, between tongue and groove, equal to about 1-2% of the width of the beads;
7. Leave a space between the staves of about 2 mm, inserting thicknesses of MDF: one in the upper part, one in the middle and one in the lower part of the shutter which will later be removed;
8. Use multi-layer panels.
9. Carefully avoid any water entering the crack between panel and frame, applying a bead of silicon, and similarly for the glass.
10. In the case of solid panels, it is necessary to leave a gap at the sides of the panel or use a multi-layer support.

4.3.1 Slatted shutters and solid shutters: types and characteristics

Slatted shutters and solid shutters are particular types of fixtures which belong to the category of shutters, or external dark screens, and which serve to cover the outside part of a window so as to protect it from light and cold.
Slatted shutters, as opposed to solid shutters, are made of slats of various materials, tilted so as to allow the light in, but stopping rain and wind. Slatted shutters are available on the market in various types of material, and have different characteristics of resistance to atmospheric agents and thermal and acoustic insulation.

Below are the main types and characteristics:

Open louvre slatted shutter: constructed with one or two partitions of slats or louvres, oblique and tilted towards the outside; fixed to the frame at a regular intervals to allow for the passage of indirect light. The slats can be round or trapezoidal in cross-section, fixed or adjustable.

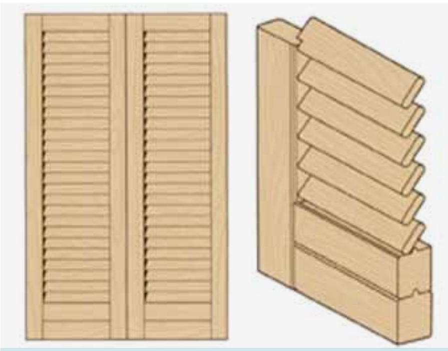
Figure 43 - Open louvre slatted shutter


Figure 44 - Another example of an open louvre slatted shutter

Closed louvre slatted shutter: they have a section for the frame of 45x80 mm, or 56x80 with fixed vanes of section 10x40 placed side by side to reduce the passage of light to a minimum. This type of fitting has similar characteristics to solid shutters, not allowing light to pass through the vanes, just as if it were an Antone with the aesthetic look of a classical shutter.

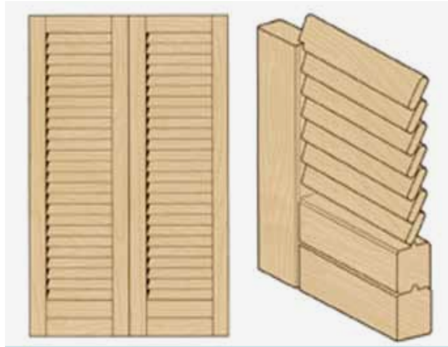
Figure 45 - Closed louvre slatted shutter


Figure 46 - Another example of a closed louvre slatted shutter

Shutter with double weathering: a feature of this type of fitting is that it does not filter the light into the building, characterised by a cross-section in the shape of a heart. The slats can be continuous so that one is placed above another to create a completely closed screen; the slats have a trapezoidal cross-section and are also called "swallow-tail".


Figure 47 - Shutter with double weathering


Figure 48 - Another example of a shutter with double weathering

Solid shutters are made from one single piece of wood, or several pieces joined together, without the light being able to filter through any crack. The material used is usually only solid wood or a combination of solid wood and multi-layer panels with cut-out moulding on the outside.
They can also be defined as "Antoni" or "dark Antoni" when they reach a certain thickness, generally more than 50 mm. The solid shutter (scuro) must be distinguished from the small blind (scuretto), which is a generally a smaller and lighter fixture which has the same function of obscuring light, but is positioned inside the window.

The solid shutter or Antone can generally be made in the following different ways:
- From one to four doors.
- With different opening systems: hinged, sliding or folding.
- With specific characteristics: arched or trapezoidal, asymmetric.

The solid shutter or Antone can generally be assembled in the following different ways:
- With the classic system.
- In one-piece with the window.
- In one-piece with sills.
- In a compact one-piece with cantilever hinges.


Figure 49 - Example of dark Antone

The staved shutter is made of vertical parts in solid wood joined to each other by a frame.
A significant consideration to concentrate on is the assembly of the staves: they must be put together without glue but the interlocking parts must have specific sections, with micro teeth to take up the wood's movement.
During assembly the staves must not be put under excessive pressure, so that the micro teeth are not crushed and lose their functionality.
The micro teeth will create a hole along the whole length of the shutter; this must be sealed after coating, with silicone to avoid water getting in. Water penetration would cause the wood to swell excessively, and extracts to run off, with possible aesthetic damage to the façade, in particular for woods with a lot of tannin.
For "Scandola" type shutters, made with staves going opposite ways, vertically on the outside and horizontally on the inside, fixed with screws, the place where the screw head sits is a break which causes water to penetrate into the wood, with the consequent and inevitable deterioration of the coating film. For this reason, this type of construction is not covered by our warranty.


Figure 50 - Staved Antone

4.3.2 Multi-layered solid shutters

Multi-layered marine or plywood solid shutters are semi-finished panels with strips of wood having the grain of the various layers lying crossways to each other. It is possible to obtaining a panel of this thanks to machines which can cut a thin layer of wood from the tree trunks.
Sticking the various sheets to each other, the grain of the crossways layers creates the mechanical characteristics of the wood, by definition one-directional, plywood - hence the name plywood - in orthogonal direction, so as to reduce as much as possible any warping of the material.

Solid shutters constructed with multi-layered panels are characterised by high stability and durability outside. Multi-layered solid shutters can incur warping if the following construction defects are present:
- If the internal glue for the layers has a break in it, there could be a loss of bond and consequently structural warping may arise;
- If the wood layers were to overlap, it would create internal localised thickening which when calibrating could lead to uneven areas, to changes in the porosity of the surface and a consequent different behaviour in the lustre of the protective coating film;
- Excess water, during the gluing phase, could cause delamination, with a consequent alteration in the stability of the panels.


Figure 51 - Examples of multi-layered solid shutters

The glue used for gluing the various layers can be phenolic (recognisable by the black colour between the layers) or melamine-based. When coating with water-based products it is advisable to use a melamine-based glue, so as to avoid salts from the glue possibly getting onto the surface and causing aesthetic damage to the coating. However, its performance will not be affected. If those defects arise, they can be easily removed using a damp cloth.

4.4 Packaging and transport

Attention to the product does not stop at the end of production, but it continues until the window begins its important function in the home. Particular attention must be paid to packaging which, depending on the handling requirements on the site, may be for the whole assembled window or else for each of its unassembled parts.
For packaging of finished windows, the use of fully impermeable polystyrene based materials or PVC is not advised. It is preferable to us polyethylene based materials. The packaging must ensure that the surfaces are not in direct contact, respecting the stacking times specified in the technical sheets of the individual coated products. The windows or shutters must not be stored and transported in environments with high humidity.
Each window is identified by a label which contains, amongst other things, all the useful references for its location on the site.

4.5 Installation

The validity and effectiveness of a design can be affected by a wrong or careless installation which risks jeopardising reaching a high performance.
It is good to keep in mind that the correct insertion of the window in the wall space is not only determined by a good installation of the window itself: careful planning, which must evaluate the whole range of good rules for the best result, is very important.
Listed below is a series of useful technical considerations to be thought about before the effective installation of the window.
The fundamental problems depend on the compatibility between the window and the wall space. In

particular, there are three types of interface:
- **Geometric**: the dimensional tolerances for making the wall space and the production of the window must be defined;
- **Mechanical**: is the careful evaluation of the defects which the wall space and window will suffer when they are subjected to mechanical or environmental stresses;
- **Chemical and physical**: is concerned with the interactions between the various elements which make up the window system.

The connection between the wall space and the window is entrusted to the joint which must:
- Ensure the absorption of movement of a thermal, hygrometric and structural nature of one component with respect to the other;
- Permit the necessary adjustment between the building structure and the window;
- Prevent the passage of water, air, heat and noise.

The presence of a sub-frame, also called counterframe, allows the irregularities of the wall space to be absorbed and compensated for, which forms the reference for placing the window. For this reason, it is very important to check that it is coplanar, orthogonal and without any tensional variation compared with the wall surface.
The most common shapes of wall spaces allow for a tolerance for placing the fixed frame of 10-12 millimetres width and 5-6 millimetres height.
The assembly of the windows must be carried out professionally, at the end of which the surfaces must be checked: any damage to the coating film must be immediately repaired by carrying out maintenance operations which state that the coating film must be continuous.
The windows must be protected from plaster and wall painting by covering them with protective film secured with adhesive tape compatible with the coating applied.
Shutters must be placed at least 6 mm away from the wall mountings and the heads must be at least 6 mm away from the sill surface.

Figure 52 - Window setup

Any lowering of the shutter which causes it to drag on the sill must be avoided, in order to prevent friction taking away the coating film and direct contact of the shutter with the stagnant water on the sill. As well as the correct maintenance of the hinges and latches, it is advisable to apply, below the shutters, plastic spacers.
The windows must be left open for a few hours a day (for the first few days after installation) so that the coating becomes completely dry, even on the edges, and to prevent the humidity in the environment from getting above 70%; in this way abnormal swelling of the wood will be prevented along with the consequent problems of closing the window.

05 PROTECTION SYSTEMS AND APPLICATIVE CYCLES

5.1 Factors in the deterioration of windows

The main factors in deterioration, with regard to wooden windows, are:
- Factors of deterioration due to interaction with sunlight.
- Factors of deterioration due to variations in the humidity in the wood.
- Factors of deterioration due to infiltration of rainwater (and smog).
- Factors of deterioration due to sudden heat changes.
- Factors of biological deterioration, such as attack of the wooden parts by micro-organisms and insects

Factors of deterioration due to interaction with sunlight

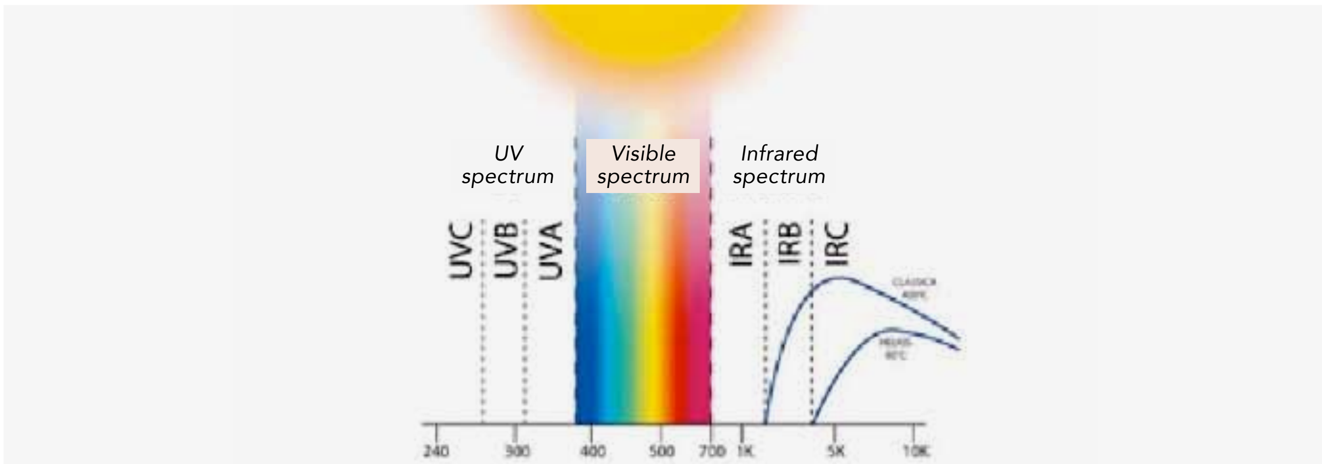

Figure 53 - The electromagnetic spectrum in the part near to the visible part

One of the factors which is most responsible for surface changes in wooden articles is sunlight which, interacting with the substances which make up the wood, cause significant changes in their characteristics. Over time its surface shows progressive changes in colour and general aspect which, as well as altering the aesthetic quality, can also lead to deterioration of this material, compromising performance irreversibly.
Solar radiation is formed of electromagnetic waves. In particular, ultraviolet waves (UV), transmitted over the surface of organic material (wood), supplies a quantity of energy sufficient to partially alter the molecular structure. Such energy translates into activity which damages the lignin which, in the presence of oxygen, will suffer photochemical oxidation with consequent variations both in chemical structure and in colour.
The chemical evidence of the wood-sunlight interaction is represented by the formation of free radical species with degrade the lignin. Such degraded products being soluble, they are then washed by water in its various forms, leaving the wood a grey colour attributable to the presence on the surface of only cellulose constituents.
The ultraviolet fraction of the light (UV rays), and in particular the length of the shortest waves, to be precise those corresponding to the blue-violet radiation with greatest energy, as well as the photolytic action on the wood, can then cause (in conjunction with a high temperature) polymerisation on the coating film, which therefore increases its compactness, becoming fragile at the same time.
From what has been explained above, it is clear that a first protection which the coatings can offer the wood is to repair it from the degrading effects of solar radiation (both from the ultraviolet part and from the visible part).

The degrading action due to solar radiation can occur:

- On the wood-coating system: in which the action of infra-red and ultraviolet radiation cause the degrading of this system; wood and coating have different expansion coefficients, so they can create tensions at the interface of the two materials which can then possibly separate.
- On the coating: the ultraviolet light can trigger degradation of the coating film which, through photo-oxidation, becomes ever more rigid. From a practical point of view one speaks of "stiffening of the coating film": losing its elasticity, it can no longer follow the movements of the wood and therefore more easily comes off. Ultraviolet radiation is also responsible for the variation in colour of transparent films of varnish which tend to take on a yellowish colour and become less transparent.
- On the wood: ultraviolet and visible radiation can cause changes to the colour of the surface due to the destruction of the lignin, with consequent loss of adhesion in the coating film.

Degrading phenomena as a result of the action of UV rays, like other conditions, are directly proportional to the intensity of the radiation which reaches the surface and the exposure time. They will therefore be more evident on films exposed at high levels, like in mountains, where the radiation is greater, and on those stressed by greater amounts of sunshine, that is, on surfaces facing south.

Factors of deterioration due to variations in the humidity in the wood

Wood, because cellulose is its main constituent, is a material with a great affinity for water, not only in liquid form, but also in the form of water vapour contained in the air.
As a result of its hydrophilic nature, wood always tends to balance the content of water absorbed in the cell walls with that of its environment: corresponding to the loss of humidity by the cell walls, the wood will shrink - a reduction in its size - conversely, increasing its internal humidity the wood will tend to swell up.
Since the variations in humidity are more rapid near the surface, the shrinkage and swelling will also be more rapid compared with internal parts. Tensions will therefore form within the mass of the wood, which will create longitudinal cracks and so on as the wood gradually disintegrates.
The absorption of humidity is not directly proportional to the humidity of the environment; in fact, for

a relative air humidity up to 70% the wood absorbs little, whilst in the humidity range from 70% to 100% the wood manages to absorb the molecules of water contained in the air to a greater extent, consequently causing those variations in size which are always unwanted in any manufactured article.
It is good to remember that the parts of the wooden article which are more subject to variations and to infiltration are the heads, the joints between uprights and cross bar, knots and lesions due to hail or accidental impacts.

Figure 54 - Factors of deterioration due to humidity

Factors of deterioration due to infiltration of rainwater and smog

Rain encourages the washing away of the coating film with a consequent reduction in its thickness and performance characteristics. Smog and smoke, particularly in industrial areas, combines with the rain, forming acidic solutions which degrade any material outside. The coating film becomes opaque and is eaten away. At a preventative level it is vitally important to keep the surface of the window frame clean so as to encourage a longer life for the film. A neutral detergent, preferably a rejuvenating one, should be used every 6-12 months.

Figure 55 - Factors of deterioration due to water leakage

Factors of deterioration due to sudden heat changes

Coatings have their own thermal expansion coefficient, generally higher than that of wood and, as a result of the temperature, the coating films increase their size to a greater extent compared with the surface to which they are attached. Since temperature changes between day and night can be considerable, the coatings are daily subjected to considerable wood/coating tensions, so as to cause the degradation of their polymer structure and peeling of the surface.

Factors of biological deterioration, such as attack of the wooden parts by fungi and insects

Figure 56 - Factors of biological deterioration

Figure 57 - Some examples of factors of biological deterioration - attack by insects

Figure 58 - Some examples of factors of biological deterioration - attack by moulds

Xylophagous fungi and insects can develop in the wood to the detriment of the tissue, depending on the type of wood, the degree of humidity and the temperature.
The most frequent damage is caused by xylophagous insects which develop in conditions of internal humidity above 20%. They can “hole” the coating film with the consequence that, in the holes created, water can penetrate inside the wood, accelerating their activity and causing other damage.

The main damages caused by xylophagous fungi are:

- Colour changes and moulds: caused by chromogenic fungi, which attack the sapwood, causing the original colour to change to a grey-blue shade, often accompanied by bluish-grey grain of variable intensity and depth. They spread when the humidity level in the wood ranges between 18 and 40%, creating damage that is exclusively aesthetic and does not prejudice the structure characteristics.

- Cavities: caused by the action of fungi that attack the cellulose and lignin of the cell walls, determining a loss of weight and mechanical resistance in the wood. Two main types of cavity can be distinguished: brown cavity - in which the attack damages the cellulose alone, fissuring the wood in dark cubes without consistency - and white cavity - in which both the cellulose and the lignin are deteriorated simultaneously, with the consequent transformation of the wood into a whitish coloured fibrous mass.

Xylophagous insects
Woodworm, as they are commonly called, are in actual fact numerous families of xylophagous insects, whose larva feed on wood to reach maturity. Their ideal habitat is found in the wood, where they develop thanks to the accumulated humidity. Not all species are equally dangerous. Some only attack the hard part of the wood, whilst others go as far as the soft part and can reduce the wood into a very fine powder, which falls to the ground as the adult woodworm come out.

Some of the more aggressive species towards wood are:

- Anobium punctatum (the common furniture beetle), with a high capacity to adapt to different types of wood.
- Lyctus brunneus, which mainly attacks hardwood.
- Hylotrupes bajulus (old-house borer): this attacks roofs, floors and fixtures. It is extremely dangerous because it attacks the wood from the inside, weakening its structure until it actually collapses, without any sign of it seen from the outside.
- Termites, also common in Europe, even if of tropical nature. They mainly feed on the cellulose contained in living wood and are fairly important to the ecosystem as their energetic jaws allow them to devour almost one third of the wood generated on the planet each year.


Figure 59 - Anobium punctatum


Figure 60 - Lyctus brunneus


Figure 61 - Hylotrupes bajulus


Figure 62 - Termites

5.2 Coating

5.2.1 Coating conifer woods

In accordance with standards UNI 2853, 2854 and 3917, conifer woods have growth rings, in other words very clear grain, without vessels[3] and rays[4] visible to the naked eye. Conifers are also known as needles.
As seen previously, conifer wood is not very resistant to attack by fungi and insects (Hylotrupes bajulus and Anobium punctatum), and the lignin easily deteriorates under UV light. the use of this wood in building fixtures needs careful, proper protection; coating these strains is not, however, overly difficult.
Conifers contain different quantities of resin, depending on their origin, the drying cycle and the cut of the plant. The exudation of resin can be a clear aesthetic problem in the case of white lacquered cycles or derivatives, because it causes yellowish colour marks; for dark stains, the problem is less evident, but it does become important when the resin leaks out and solidifies and whitens.
There is no product able to block this substance that is naturally present, the only option is to pay careful attention to the sanding of the raw product (Chapter 4.1) or, if leaks are small in size (1 or 2 mm), in colder periods, they can be mechanically removed using a very sharp blade: the resin crystallises in low temperatures and is therefore easier to remove.
For information on how to prepare the surface for coating and imbuing, please refer to the information given in chapter 4.1 and 3.3 above.

5.2.2 Coating hardwood

The term “hardwood” is used to refer to wood whose rings may or may not be clear but are in any case never marked, and the vessels and rays are always present - sometimes thinner or sometimes thicker - and always visible to the naked eye.
Coating these woods with water-based products takes several cycles, depending on the following specific aspects and issues:
- possible formation of inhomogeneous shades for the incorrect preparation of the substrate (see chapter 4.1).
- Difficulty in wetting pores.
- Prolonged drying time due to the reduced capacity of absorption in the surface.
- Formation of bubbles of water vapour as a result of the action of the sun’s rays for the formation of the wood-coating interface

Some hardwoods, like Meranti, Mahogany or Teak, have a naturally reddish colour: if exposed to the sunlight, they tend to lose this colour, which becomes greyish. For these types, please refer to that specified in the coating cycles.

If treated with water-based coatings, hardwoods like Oak and Chestnut may change to a greenish colour due to the extraction of the tannin by the coating.
In dark lacquers, the aesthetic problem is largely irrelevant, whilst for lighter colours reference must be made to the specifications of the coating cycles.

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[3] *The vessels are round or oval pores present in the transversal section of the wood.*
[4] *The rays are formed by layers of cells arranged in a radial direction.*

Items built from oak and chestnut may have aesthetic flaws due to the presence of tannin: if the design and/or coating cycle have not been carried out properly, the humidity penetrates through the film and once in contact with the wood, may extract the tanning resulting in marks on window sills. (Figure 63).

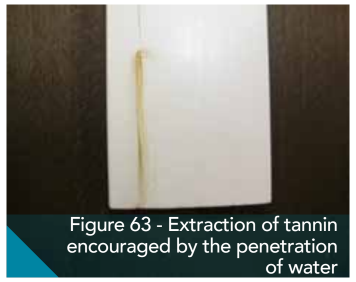
Figure 63 - Extraction of tannin encouraged by the penetration of water

5.2.3 Systems and parameters for application

The previous chapters reported that in order to guarantee the duration of fixtures over time, the manufacturer must pay attention to both design and construction, as well as to the application of the barrier coating system, which must be high performance and attractive to look at.
We will now therefore describe the various types of equipment that can be used in the coating processes, highlighting their main characteristics.

Spray coating (low pressure - air spray).
The first step in the industrial application of coatings is to use a spray gun or air spray. Schematically, in the spray gun, the coating is released at low pressure from a nozzle, strikes a jet of air at high speed, is pulverised by it and with this same air, projected against the item to be coated.
With this type of spray application, medium/low viscosity coatings must be used in order to obtain a sufficiently fine pulverisation and finish: if operating with high viscosity, the coating would become too "concentrated", thereby risking an uneven spread.
A gun with air pulverisation of the product enables thin layers of coating to be applied, and touch-ups to be performed without dripping, thereby assuring an excellent finish. The downside of using this type of gun is that it creates a great deal of coating "fog", meaning that effective ventilation booths are required and operators using suitable personal protection equipment.


Figure 64
Low pressure spray gun

Spray coating (high pressure - airless)
The next step in the industrial application of coating is to introduce airless sprays.
In airless guns, pulverisation takes place due to the hydrodynamic effect of the high pressure coating in the nozzle. With this application, any coating can be used - whether low, medium or high viscosity.
The equipment requires careful attention to be paid in use and coats will not be particularly thin. Touch-ups can often result in runs and nozzles wear quickly, with smaller nozzles used to reduce capacity resulting in frequent blockages and consequent time wasting.
For airless systems, we recommend using pumps with a compression ratio of at least 28:1, pressure of at least 90 bars and a gun with a nozzle that ranges from 1.1 to 1.3 mm.


Figure 65 - High pressure spray gun

Spray coating ("airmix")
This coating system is due to the combination of the two spray coating systems described previously. The coating is driven at a variable pressure of between 60 and 200 bar; a jet of air is added to the gun that aims to make it "rounder" and more controlled in its spray, increasing the fineness of pulverisation.
This equipment combines the advantages that can be obtained from the use of an air spray with those of the atomisation using an airless system, thereby overcoming the intrinsic flaws of the two systems. In practical terms, the coating is atomised using an airless system (same pump), but pulverisation and coating distribution is perfected, taking air to the sides of the nozzle using the same principle as the air spray (different gun).
Generally speaking, to ensure correct application, the recommended product pressure is at least 90 bar and that of the air is 1 or 2 bar, with a nozzle of 1.1 ÷ 1.3 mm.
In application, special attention must be paid to complying with temperature and humidity conditions in the workplace, the quantity applied and the humidity of the air during drying, as specified on the data sheets of the coating products used.
The film thickness must be even and continuous on the whole surface of the item, applied correctly, paying special attention to keeping the gun approximately 30 cm from the surface to be coated.
The images below, in the green boxes, highlight the correct spraying method, whilst those in red, show an incorrect method of application.

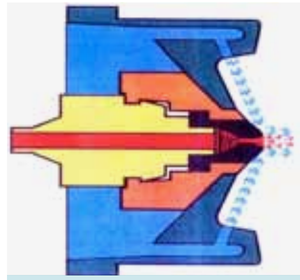
Figure 66 - Close-up of the nozzle of an airmix spray gun


Figure 67 - Correct application posture


Figure 68 - Incorrect application posture


Figure 69 - Correct application posture

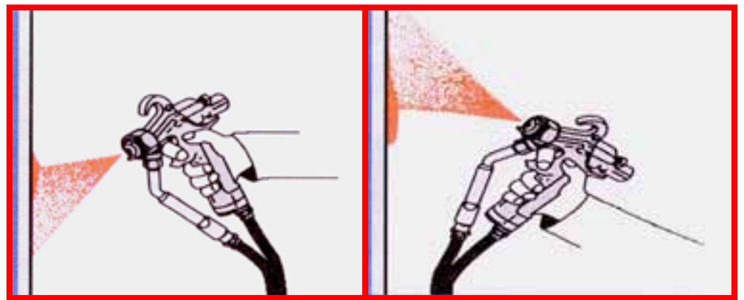
Figure 70 - Incorrect application posture

Electrostatic coating

Electrostatic spraying exploits the principle whereby particles charged with an opposite sign attract, whilst particles of the same sign, reject. The equipment consists of an airless pump and a special gun connected to an electrical appliance: using different systems - capitation or induction - a series of electrical charges of the same sign are deposited on the drop of coating that leaves the nozzle.

This generates two phenomena, of positive value, during coating:

1. Pressure is created inside the drop as a result of the fact that charges of the same sign tend to reject each other and, therefore, the drop is further divided. This subsequent atomisation is regardless of spray pressure: good pulverisation can therefore be obtained even at low pressures, with less wastage caused by the return of coating on the piece.

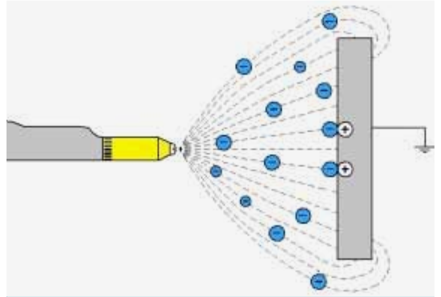

Figure 71 - Electrostatic application

2. By inducing an electrostatic charge of the opposite sign on the piece to be coated - or in any case a lesser electrostatic potential - the drops of coating that transit in the air around, will be attracted. The result is therefore a better overall coating of the piece, which is also coated at the back of the side on which the coating is being sprayed, thereby accordingly reducing waste.

The technical and ergonomic characteristics of the electrostatic system mean that it is widely used in the coating of mass produced fixtures by being assembled as part of the systems and plants involved in reading piece dimensions, even if recently, the advent of coating recovery systems has made the transfer efficiency aspect less important.

Equipment used for dipped application

This coating system has a very simple concept: it consists of dipping the pieces into a bath containing the coating product.

The equipment used in this case - the bath - is extremely simple indeed, whilst the difficulty lies in formulating the coating products, which must run along the piece without creating runs, shades, dips or accumulations.

At present, this application system is mainly used for products to be imbued into wood for outside use: with this technique the product better penetrates all parts of the piece, regardless of geometric construction.

Equipment used for the application of flow-coating

This is a system designed to eliminate certain defects in dip application and, at the same time, improve its advantages. It consists of equipment - much like a shower - which sprays at low pressure, through nozzles, applying the coating to the piece.

Pieces are generally transported using a continuous automatic system inside the plant, where they are completely and abundantly sprayed with the coating product. The equipment involves a system for collecting excess product, which, when drained from the piece, returns to the tank from which it was taken. This equipment is particularly -widespread for fixtures manufacturers.

Figure 72 - Flow coater

The measurement of the quantity of coating applied: use of the micrometer

The micrometer is a very important instrument, use of which allows the precise measurement of the quantity of coating applied.

It is a metal plate, with one or more scales of measurement, where each scale provides for two teeth on the sides, of equal length, which define the level.

Between these are other teeth of increasing distances from the level.

The measurement of the damp thickness of the product applied is taken by resting it on the surface to which the coating has just been applied: the two teeth to the side of reference become wet, as do the teeth with a distance from the lower surface to the thickness applied: it therefore suffices to read the value in microns corresponding to the last tooth that is wet.

Figura 73 - Thickness gauge

Coating cycles and damp thicknesses to be applied

The cycles described below will always specify the average value of damp thickness applied, but it is always necessary to apply the minimum guarantee thickness, according to the positioning of the item, as per the tables below.

The thickness must be measured on crossbeams and uprights, both inside and outside the doors and frame and stops.

WINDOWS

The minimum thicknesses guaranteed, according to the area, are:

	AREA	SIDE OF THE WINDOW	THICKNESS OF THE WET FILM
OPENING WINDOW	Lower and upper cross bar	Internal and external	300 μm
	Uprights	Internal and external	250 μm
	Edges	All sides	250 μm
FRAME	Lower and upper cross bar	Internal and external	300 μm
	Uprights	Internal and external	250 μm
	Edges		250 μm

The most critical point for the window is the lower crosspiece of the leaf and frame, that most exposed to water, both directly and by rebound.

BLINDS

In coating darkening shields, a thicker layer of coating must be applied, because it is more exposed to wear over time. More specifically, both the internal and external surfaces must be protected with at least a layer of damp coating that is 300 μm and the stops with one of at least 275 μm wet. If wishing to obtain greater protection, we recommend coating the item with two coats, each 175 μm.

SHUTTERS

Shutters are also more greatly exposed outdoors; minimum guarantee thicknesses, depending on area, are:

AREA	SIDE OF THE SHUTTER	THICKNESS OF THE WET FILM
Lower and upper cross bar	Internal and external	300 µm
Lower cross bar	Area in contact with the slat	300 µm
Central and side uprights	Internal and external	250 µm
Uprights	Area in contact with the slats	250 µm
Edges		275 µm
Slats	Internal and external	250 µm

As concerns temperature and humidity conditions in the workplace, in order to enable the correct filming of the coating, a temperature must be maintained of above 10 °C and humidity of no more than 65 %.
During drying, humidity must not exceed 80 % in order to allow the water contained in the film to evaporate; it is important that there is continuous air exchange in the drying area.
The water-coated item must not be exposed outdoors or installed for 72 hours after application.

06 CARE AND MAINTENANCE OF WOODEN FIXTURES

USEFUL ADVICE TO INCREASE THE DURATION OF YOUR FIXTURES

We have seen that wood can be nourishment for bacteria, moulds or fungi, or food for larvae or insects; it wears and is eroded by air, water, light and heat.
We have also seen that sunlight is by far the strongest form of attack and, in particular, its ultraviolet component; fixtures exposed to the south are those that first show signs of deterioration, because the UV rays can break down the very structure of the wood and the heat can, in some woods, cause the resins to dissolve and leak out on the surface.
Water is another aggressive enemy to fixtures: excess absorption of water or damp can cause the coloured substances that are naturally present in wood to leak out as well as causing fibres to swell and the fixture to consequently change in size.
The different Sirca coating systems suitable for coating all types of woods, both with transparent and lacquered cycles, protect your fixtures at length from the sun, smog and rain and guarantee the duration of the protective film over time, with no need for preventive extraordinary maintenance. To further improve the product performance and keep the look of fixtures unchanged, we recommend a few, simple, inexpensive operations that take up very little time but can make a big difference.

6.1 Cleaning and control

When cleaning windows, and in any case at least twice a year - in the spring and autumn - wash the coated surfaces using water and a neutral detergent, and then rinse.
Do not use aggressive detergents containing solvents (e.g. alcohol), acids (e.g. limescale remover), alkali (e.g. ammonia), abrasive substances or bleach.
Do not use products for furniture (e.g. wax or polish) or floors.

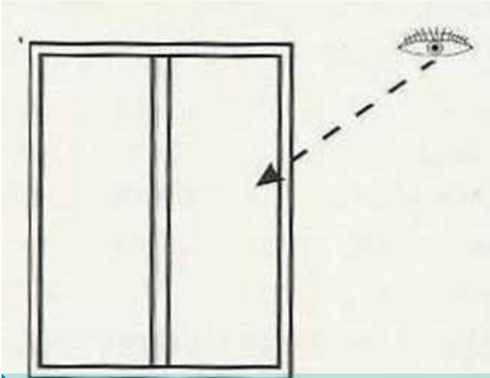

Figure 74 - Checking the condition of surfaces

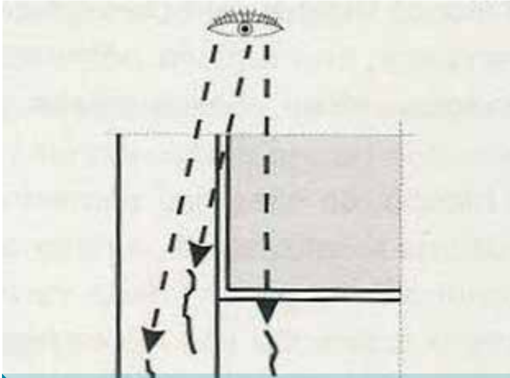

Figure 75 - Identifying the deterioration of surface

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After cleaning, it is important to check for cracks, cuts or signs left from hailstones or accidental impacts that cause a breakage in the film coating and/or may allow for the penetration of water beneath the protective film.
When performing a visual inspection, if the above situation is seen, it is important to restore the coating with a touch-up.
Failure to inspect and potentially touch up the protective film as required will result in forfeiture of the warranty.
Cleaning and control includes inspecting holes and slots for the drainage of water, checking seals, cleaning and greasing fittings. If the silicone glass seal should have parts that have become detached, restore immediately to prevent any water from seeping in.

6.2 Touch-up

Touching up is important where damage is seen caused by natural or accidental events, to restore the continuity of the film coating.
It should involve gentle sanding with grain 320 paper in the area to be restored and the application, using a brush, of a brush-on coating such as OWE 501.

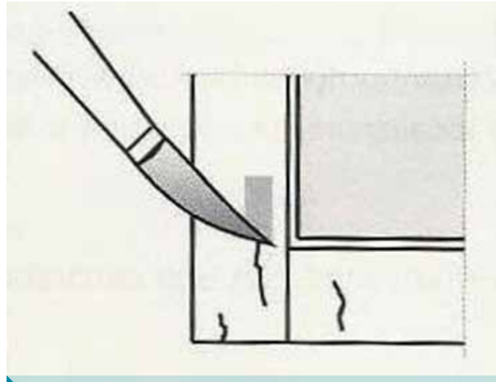

Figure 76 - The touch-up

6.3 Regeneration

Regeneration is recommended to lengthen the duration of the protection afforded by the coating, beyond the guaranteed period: when carrying out normal annual cleaning, a soft, dry cloth can be used to apply it that does not release lint, or a sponge.
This treatment will give the fixture a shine and excellent look, as it originally had, and can be carried out on both transparent and pigmented cycles.

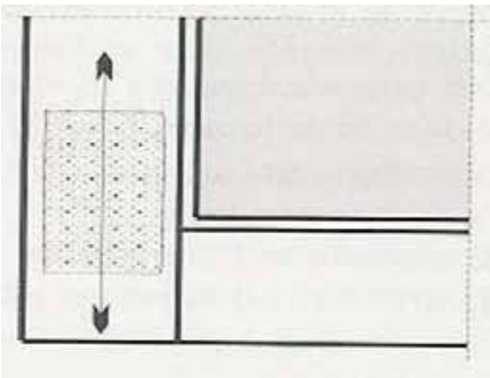

Figure 77 - Cleaning and regeneration