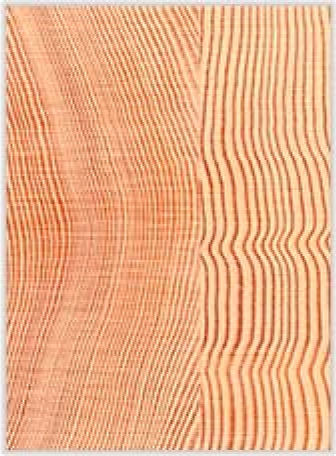
Hardwood: oak, across grain

Description

Image



Caption

1. Close-up of the material. 2. Oak table. © Jia Design,

The material

Hardwoods come from broad leave, deciduous, trees such as oak, ash, elm, sycamore, mahogany. Although most hardwoods are harder than softwoods, there are exceptions: balsa, for instance, is a hardwood. Wood must be seasoned before it is used. Seasoning is the process of drying the natural moisture out of the raw timber to make it dimensionally stable, allowing its use without shrinking or warping. In air-seasoning the wood is dried naturally in covered but open-sided structure. In kiln-drying the wood is artificially dried in an oven or kiln. Modern kilns are so designed that an accurate control of moisture is achieved. Wood has been used for construction and to make products since the earliest recorded time. The ancient Egyptians used it for furniture, sculpture and coffins before 2500 BC. The Greeks at the peak of their empire (700 BC) and the Romans at the peak of theirs (around 0 AD) made elaborate buildings, bridges, boats, chariots and weapons of wood, and established the craft of furniture making that is still with us today. More diversity of use appeared in Mediaeval times, with the use of wood for large-scale building, and mechanisms such as pumps, windmills, even clocks, so that, right up to end of the 17th century, wood was the principal material of engineering. Since then cast iron, steel and concrete have displaced it in some of its uses, but timber continues to be used on a massive scale, particularly in housing and small commercial buildings.

Compositional summary

Cellulose/Hemicellulose/Lignin/12%H2O

General properties

Density	850	-	1.13e3	kg/m^3
Price	* 0.66	-	0.73	USD/kg
Date first used	-10000			

Mechanical properties

Young's modulus	4.5	-	5.8	GPa
Shear modulus	* 1.5	-	1.8	GPa
Bulk modulus	2.5	-	2.8	GPa
Poisson's ratio	* 0.02	-	0.04	
Yield strength (elastic limit)	* 4	-	5.9	MPa

Tensile strength		7.1	-	8.7	MPa
Compressive strength	*	12.7	-	15.6	MPa
Elongation		1	-	1.5	% strain
Hardness - Vickers		10	-	12	HV
Fatigue strength at 10^7 cycles	*	2.1	-	2.6	MPa
Fracture toughness	*	0.8	-	1	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	0.02	-	0.05	

Thermal properties

Glass temperature		77	-	102	°C
Maximum service temperature		120	-	140	°C
Minimum service temperature	*	-100	-	-70	°C
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.16	-	0.2	W/m.°C
Specific heat capacity		1.66e3	-	1.71e3	J/kg.°C
Thermal expansion coefficient	*	37	-	49	µstrain/°C

Electrical properties

Electrical conductor or insulator?		Poor insulator			
Electrical resistivity	*	2.1e14	-	7e14	µohm.cm
Dielectric constant (relative permittivity)	*	5	-	6	
Dissipation factor (dielectric loss tangent)	*	0.1	-	0.15	
Dielectric strength (dielectric breakdown)	*	0.4	-	0.6	1000000 V/m

Optical properties

Transparency	Opaque

Processability

Moldability	2	-	3
Machinability	5		

Durability: water and aqueous solutions

Water (fresh)	Acceptable
Water (salt)	Acceptable
Soils, acidic (peat)	Acceptable
Soils, alkaline (clay)	Limited use
Wine	Acceptable

Durability: acids

Acetic acid (10%)	Acceptable
Acetic acid (glacial)	Acceptable
Citric acid (10%)	

	Acceptable
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Acceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Acceptable
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Acceptable
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

Amyl acetate	Limited use
Benzene	Limited use
Carbon tetrachloride	Limited use
Chloroform	Limited use
Crude oil	Limited use
Diesel oil	Acceptable
Lubricating oil	Acceptable
Paraffin oil (kerosene)	Acceptable
Petrol (gasoline)	Acceptable
Silicone fluids	Acceptable
Toluene	Acceptable
Turpentine	Excellent
Vegetable oils (general)	Acceptable
White spirit	Acceptable

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Acceptable
Acetone	Limited use
Ethyl alcohol (ethanol)	Acceptable
Ethylene glycol	Acceptable
Formaldehyde (40%)	Acceptable
Glycerol	Acceptable
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

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Chlorine gas (dry)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Limited use

Durability: built environments

Industrial atmosphere	Limited use
Rural atmosphere	Acceptable
Marine atmosphere	Acceptable
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Highly flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Acceptable
Tolerance up to 150 C (302 F)	Acceptable
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	9.82	-	10.9	MJ/kg
CO2 footprint, primary production	*	0.841	-	0.93	kg/kg
Water usage	*	665	-	735	l/kg
Eco-indicator 95		6.6			millipoints/kg
Eco-indicator 99		19.4			millipoints/kg

Material processing: energy

Coarse machining energy (per unit wt removed)	*	0.582	-	0.643	MJ/kg
Fine machining energy (per unit wt removed)	*	1.55	-	1.71	MJ/kg
Grinding energy (per unit wt removed)	*	2.62	-	2.89	MJ/kg

Material processing: CO2 footprint

Coarse machining CO2 (per unit wt removed)	*	0.0437	-	0.0482	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.116	-	0.128	kg/kg
Grinding CO2 (per unit wt removed)	*	0.196	-	0.217	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✗			
Recycle fraction in current supply	8	-	10	%

Downcycle	✔			
Combust for energy recovery	✔			
Heat of combustion (net)	* 19.8	-	21.3	MJ/kg
Combustion CO2	* 1.69	-	1.78	kg/kg
Landfill	✔			
Biodegrade	✔			
Toxicity rating	Non-toxic			
A renewable resource?	✔			

Environmental notes

Wood is a renewable resource, absorbing CO2 as it grows. Present day consumption for engineering purposes can readily be met by controlled planting and harvesting, making wood a truly sustainable material.

Supporting information

Design guidelines

Wood offers a remarkable combination of properties. It is light, and, parallel to the grain, it is stiff, strong and tough - as good, per unit weight, as any man-made material except CFRP. It is cheap, it is renewable, and the fossil-fuel energy needed to cultivate and harvest it is outweighed by the energy it captures from the sun during growth. It is easily machined, carved and joined, and - when laminated - it can be molded to complex shapes. And it is aesthetically pleasing, warm both in color and feel, and with associations of craftsmanship and quality.

Technical notes

The values for the mechanical properties given for woods require explanation. Wood-science laboratories measure the mean properties of high-quality "clear" wood samples: small specimens with no knots or other defects; the data for woods in the Level 3 CES database is of this type. This is not, however, the data needed for design. All engineering materials have some variability in quality and properties. To allow for this design handbooks list "allowables" - property values that will be met or exceeded by, say, 99% of all samples (meaning the mean value minus 2.33 standard deviations). Natural materials like wood show greater variability than man-made materials like steel, with the result that the allowable values for mechanical properties may be only 50% of the mean. There is a second problem: structures made of wood are much larger than the wood-science test samples. They contain knots, shakes and sloping grain, all of which degrade properties. To deal with this the wood is "stress-graded" by visual inspection or by automated methods, assigning each piece a stress grading G between 0 and 100: a grading of G means that properties are further knocked down by the factor G/100. Finally, in building construction, there is the usual requirement of sound practice - an overall safety factor, typically 2.25. The result is that the permitted stress for design may be as low as 20% of the value quoted in wood-science tabulations. The data in this record is for oak of medium density, and lists wood-science ranges for the properties of clear wood samples.
Wood prices are quoted in Board Feet (BF). 1 BF is 144 cubic inches. Here we list prices in the usual $/kg.

Typical uses

Flooring; stairways, furniture; handles; veneer; sculpture, wooden ware; sash; doors; general millwork; framing- but these are just a few. Almost every load-bearing and decorative object has, at one time or another, been made from wood.

Links

Reference	
ProcessUniverse	
Producers	