General information

Designation

Quercus rubra (L)

Typical uses

Lumber; sleepers; mine timbers; fenceposts; veneer; pulpwood; fuelwood; flooring; furniture; general millwork; boxes; pallets & crates; agricultural implements; caskets; woodenware; handles; railroad cars;

Composition overview

Compositional summary

Cellulose/Hemicellulose/Lignin/12%H2O

Material family	Natural			
Base material	Wood (hardwood)			
Renewable content	100			%

Composition detail (polymers and natural materials)

Wood	100			%

Price

Price	* 0.912	-	1.22	USD/lb
Price per unit volume	* 36.5	-	59.2	USD/ft^3

Physical properties

Density	0.0231	-	0.0282	lb/in^3

Mechanical properties

Young's modulus	* 1.8	-	2.2	10^6 psi
Yield strength (elastic limit)	* 6.74	-	8.24	ksi
Tensile strength	* 12	-	14.6	ksi
Elongation	* 1.79	-	2.19	% strain
Compressive strength	6.08	-	7.44	ksi
Flexural modulus	1.64	-	2	10^6 psi
Flexural strength (modulus of rupture)	12.9	-	15.7	ksi
Shear modulus	* 0.133	-	0.162	10^6 psi
Shear strength	1.6	-	1.96	ksi
Bulk modulus	* 0.157	-	0.174	10^6 psi
Poisson's ratio	* 0.35	-	0.4	
Shape factor	5.3			
Hardness - Vickers	* 6.78	-	8.28	HV
Hardness - Brinell	* 45.4	-	55.4	HB
Hardness - Janka	* 1.52e3	-	1.86e3	lbf

Fatigue strength at 10^7 cycles	*	3.86	-	4.71	ksi
Mechanical loss coefficient (tan delta)	*	0.0067	-	0.0082	
Differential shrinkage (radial)		0.14	-	0.18	%
Differential shrinkage (tangential)		0.28	-	0.34	%
Radial shrinkage (green to oven-dry)		3.6	-	4.4	%
Tangential shrinkage (green to oven-dry)		7.7	-	9.5	%
Volumetric shrinkage (green to oven-dry)		12.3	-	15.1	%
Work to maximum strength		1.09	-	1.33	ft.lbf/in^3

Impact & fracture properties

Fracture toughness	*	5.28	-	6.46	ksi.in^0.5

Thermal properties

Glass temperature		171	-	216	°F
Maximum service temperature		248	-	284	°F
Minimum service temperature	*	-99.4	-	-9.4	°F
Thermal conductivity	*	0.179	-	0.214	BTU.ft/hr.ft^2.°F
Specific heat capacity		0.396	-	0.408	BTU/lb.°F
Thermal expansion coefficient	*	1.11	-	6.11	µstrain/°F

Electrical properties

Electrical resistivity		5e13	-	6.1e13	µohm.in
Dielectric constant (relative permittivity)	*	6.95	-	8.5	
Dissipation factor (dielectric loss tangent)	*	0.082	-	0.1	
Dielectric strength (dielectric breakdown)	*	10.2	-	15.2	V/mil

Magnetic properties

Magnetic type	Non-magnetic

Optical properties

Transparency	Opaque

Critical materials risk

Contains >5wt% critical elements?	No

Durability

Water (fresh)	Limited use
Water (salt)	Limited use
Weak acids	Limited use
Strong acids	Unacceptable
Weak alkalis	Acceptable
Strong alkalis	Unacceptable

Organic solvents	Acceptable			
Oxidation at 500C	Unacceptable			
UV radiation (sunlight)	Good			
Flammability	Highly flammable			

Primary production energy, CO2 and water

Embodied energy, primary production	4.99e3	-	5.5e3	BTU/lb

Sources

0.5 MJ/kg (Ximenes, 2006); 2 MJ/kg (Ximenes, 2006); 9.1 MJ/kg (Hammond and Jones, 2008); 11.6 MJ/kg (Hubbard and Bowe, 2010); 23.7 MJ/kg (Ecoinvent v2.2); 26 MJ/kg (Ecoinvent v2.2)

CO2 footprint, primary production	0.574	-	0.633	lb/lb

Sources

0.229 kg/kg (Ecoinvent v2.2); 0.412 kg/kg (Ecoinvent v2.2); 0.862 kg/kg (Hammond and Jones, 2008); 0.909 kg/kg (Hubbard and Bowe, 2010)

Water usage	* 1.84e4	-	2.03e4	in^3/lb

Processing energy, CO2 footprint & water

Coarse machining energy (per unit wt removed)	* 472	-	522	BTU/lb
Coarse machining CO2 (per unit wt removed)	* 0.0824	-	0.091	lb/lb
Fine machining energy (per unit wt removed)	* 2.88e3	-	3.19e3	BTU/lb
Fine machining CO2 (per unit wt removed)	* 0.503	-	0.556	lb/lb
Grinding energy (per unit wt removed)	* 5.56e3	-	6.15e3	BTU/lb
Grinding CO2 (per unit wt removed)	* 0.971	-	1.07	lb/lb

Recycling and end of life

Recycle	✗			
Recycle fraction in current supply	8.55	-	9.45	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 8.49e3	-	9.16e3	BTU/lb
Combustion CO2	* 1.69	-	1.78	lb/lb
Landfill	✓			
Biodegrade	✓			

Notes

Warning

All woods have properties which show variation; they depend principally on growth conditions and moisture

Links

ProcessUniverse
Reference
Shape