Bamboo

Description

Image



Caption

1. Bamboo bridge to the island of Kaoh Pen, Kampong Cham, Cambodia. © Rob Glover at Flickr - (CC BY-SA 2.0) 2. Bamboo scaffolding held together by nylon strips, Hong Kong. © Chong Fat at en.wikipedia - (CC BY-SA 3.0) 3. Bamboo scaffolding surrounding a skyscraper in Hong Kong. © Odessa3 at en.wikipedia - Public domain

The material

Bamboo is nature's gift to the construction industry. Think of it: a hollow tube, exceptionally strong and light, growing so fast that it can be harvested after a year, and - given a little longer - reaching a diameter of 0.3 meters and a height of 15 meters. This and its hard surface and ease of working makes it the most versatile of materials. Bamboo is used for building and scaffolding, for roofs and flooring, for pipes, buckets, baskets, walking sticks, fishing poles, window blinds, mats, arrows and furniture. Tonkin bamboo is strong and flexible (fishing poles); Tali bamboo is used for structural applications (houses or furniture); Eeta bamboo is the fastest growing and is used as a source of cellulose for the production of cellulose or Rayon.

Compositional summary

Cellulose/Hemicellulose/Lignin/12% H2O

General properties

Density	600	-	800	kg/m^3
Price	* 1.34	-	2.01	USD/kg
Date first used	-5000			

Mechanical properties

Young's modulus	15	-	20	GPa
Shear modulus	0.8	-	1.36	GPa
Bulk modulus	0.77	-	1.1	GPa
Poisson's ratio	0.03	-	0.46	
Yield strength (elastic limit)	35	-	44	MPa
Tensile strength	36	-	45	MPa
Compressive strength	50	-	100	MPa
Elongation	2.88	-	5.5	% strain

Hardness - Vickers		2	-	12	HV
Fatigue strength at 10^7 cycles	*	25	-	35	MPa
Fracture toughness		5	-	7	MPa.m^0.5
Mechanical loss coefficient (tan delta)		0.012	-	0.022	

Thermal properties

Glass temperature		76.9	-	102	°C
Maximum service temperature		117	-	137	°C
Minimum service temperature	*	-73.2	-	-23.2	°C
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.1	-	0.18	W/m.°C
Specific heat capacity		1.66e3	-	1.71e3	J/kg.°C
Thermal expansion coefficient		2.6	-	10	µstrain/°C

Electrical properties

Electrical conductor or insulator?		Poor insulator			
Electrical resistivity	*	6e13	-	7e14	µohm.cm
Dielectric constant (relative permittivity)	*	5	-	7	
Dissipation factor (dielectric loss tangent)	*	0.07	-	0.1	
Dielectric strength (dielectric breakdown)	*	0.5	-	1	1000000 V/m

Optical properties

Transparency		Opaque			

Processability

Moldability		1	-	2	
Machinability		4			

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)	Limited use
Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Limited use
Hydrofluoric acid (40%)	

	Limited use
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

Chlorine gas (dry)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable

Sulfur dioxide (gas)	Acceptable

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

Geo-economic data for principal component

Annual world production, principal component	1.2e7	-	1.25e7	tonne/yr

Primary material production: energy, CO2 and water

Embodied energy, primary production	4.1	-	6	MJ/kg
CO2 footprint, primary production	0.299	-	0.33	kg/kg
Water usage	* 665	-	735	l/kg
Eco-indicator 95	6.6			millipoints/kg
Eco-indicator 99	0.47			millipoints/kg

Material processing: energy

Coarse machining energy (per unit wt removed)	* 1.54	-	1.7	MJ/kg
Fine machining energy (per unit wt removed)	* 11.1	-	12.3	MJ/kg
Grinding energy (per unit wt removed)	* 21.7	-	24	MJ/kg

Material processing: CO2 footprint

Coarse machining CO2 (per unit wt removed)	* 0.115	-	0.127	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.832	-	0.92	kg/kg
Grinding CO2 (per unit wt removed)	* 1.63	-	1.8	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✖			
Recycle fraction in current supply	1	-	2	%

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

Bamboo is a renewable resource and is particularly fast growing, making it attractive from an environmental standpoint.

Supporting information

Design guidelines

The stems of bamboo are hollow and jointed, and have an extremely hard, durable, outer surface. Its natural tubular structure gives it excellent bending stiffness and strength at low weight. It is joined by binding; fasteners requiring holes must be avoided. The wood is visually appealing and hardwearing, making it attractive for flooring and furniture as well as its other diverse uses.

Technical notes

Bamboo is a grass, not a tree. It grows most commonly in Indonesia, The Philippines and Southern Asia where it is one of the principal structural materials.

Typical uses

Building & construction; scaffolding; furniture; pulp & paper making; ropes; reinforcement for concrete; frames for early aircraft, pipes, baskets, walking sticks, fishing poles, window blinds, mats, arrows and furniture.

Links

Reference

ProcessUniverse