

## 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% H<sub>2</sub>O

### General properties

Density	37.5	-	49.9	lb/ft <sup>3</sup>
Price	* 0.608	-	0.912	USD/lb
Date first used	-5000			

### Mechanical properties

Young's modulus	2.18	-	2.9	10 <sup>6</sup> psi
Shear modulus	0.116	-	0.197	10 <sup>6</sup> psi
Bulk modulus	0.112	-	0.16	10 <sup>6</sup> psi
Poisson's ratio	0.03	-	0.46	
Yield strength (elastic limit)	5.08	-	6.38	ksi
Tensile strength	5.22	-	6.53	ksi
Compressive strength	7.25	-	14.5	ksi
Elongation	2.88	-	5.5	% strain

Hardness - Vickers	2	-	12	HV
Fatigue strength at 10 <sup>7</sup> cycles	* 3.63	-	5.08	ksi
Fracture toughness	4.55	-	6.37	ksi.in <sup>0.5</sup>
Mechanical loss coefficient (tan delta)	0.012	-	0.022	

### Thermal properties

Glass temperature	170	-	215	°F
Maximum service temperature	242	-	278	°F
Minimum service temperature	* -99.7	-	-9.67	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0578	-	0.104	BTU.ft/h.ft <sup>2</sup> .F
Specific heat capacity	0.396	-	0.408	BTU/lb.°F
Thermal expansion coefficient	1.44	-	5.56	μstrain/°F

### 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)	* 12.7	-	25.4	V/mil

### Optical properties

Transparency	Opaque			
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### Processability

Moldability	1	-	2	
Machinability	4			

### Eco properties

Embodied energy, primary production	444	-	650	kcal/lb
CO2 footprint, primary production	0.299	-	0.33	lb/lb
Recycle	✗			

### 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.

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**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**

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Reference

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ProcessUniverse

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## General information

### Designation

Bamboo

### Typical uses

Building & construction; scaffolding; furniture; pulp & paper making; ropes; reinforcement for concrete; frames for early aircraft.

## Composition overview

### Compositional summary

Cellulose/Hemicellulose/Lignin/12% H<sub>2</sub>O

Material family	Natural		
Base material	Wood (other: monocot, bark)		
Renewable content	100		%

### Composition detail (polymers and natural materials)

Wood	100		%
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### Price

Price	* 0.608	-	0.912	USD/lb
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### Physical properties

Density	0.0217	-	0.0289	lb/in <sup>3</sup>
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### Mechanical properties

Young's modulus	0.218	-	0.29	10 <sup>6</sup> psi
Yield strength (elastic limit)	* 1.03	-	1.25	ksi
Tensile strength	3.63	-	7.25	ksi
Elongation	* 4.5	-	5.5	% strain
Compressive strength	7.25	-	13.1	ksi
Flexural modulus	0.247	-	0.319	10 <sup>6</sup> psi
Flexural strength (modulus of rupture)	3.63	-	7.25	ksi
Shear modulus	* 0.0245	-	0.0338	10 <sup>6</sup> psi
Shear strength	5.8	-	8.7	ksi
Bulk modulus	* 0.112	-	0.149	10 <sup>6</sup> psi
Poisson's ratio	0.03	-	0.05	
Shape factor	5.1			
Hardness - Brinell	* 5.24	-	7.01	ksi
Fatigue strength at 10 <sup>7</sup> cycles	1.33	-	1.78	ksi
Mechanical loss coefficient (tan delta)	0.012	-	0.022	
Radial shrinkage (green to oven-dry)	6.6	-	7.2	%

Tangential shrinkage (green to oven-dry)	4.1	-	8.2	%
Volumetric shrinkage (green to oven-dry)	10.9	-	15.8	%
Work to maximum strength	0.981	-	1.2	ft.lbf/in <sup>3</sup>

### Impact & fracture properties

Fracture toughness	* 0.48	-	0.586	ksi.in <sup>0.5</sup>
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### Thermal properties

Glass temperature	171	-	216	°F
Maximum service temperature	248	-	284	°F
Minimum service temperature	* -99.4	-	-9.4	°F
Thermal conductivity	0.0578	-	0.0636	BTU.ft/hr.ft <sup>2</sup> .°F
Specific heat capacity	0.396	-	0.408	BTU/lb.°F
Thermal expansion coefficient	23.7	-	30.3	µstrain/°F

### Electrical properties

Electrical resistivity	* 2.1e14	-	7e14	µohm.cm
Dielectric constant (relative permittivity)	4.5	-	5.5	
Dissipation factor (dielectric loss tangent)	0.09	-	0.11	
Dielectric strength (dielectric breakdown)	* 25.4	-	50.8	V/mil

### Magnetic properties

Magnetic type	Non-magnetic
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### Optical properties

Transparency	Opaque
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### Bio-data

Food contact	Yes
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### Restricted substances risk indicators

RoHS (EU) compliant grades?	✓
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### 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	6.15	-	6.79	BTU/lb
Sources 0.015 MJ/kg (Reiner, Pitterle and Whitaker, 2007)				
CO2 footprint, primary production	0.00194	-	0.00214	lb/lb
Sources 0.00204 kg/kg (Reiner, Pitterle and Whitaker, 2007)				
NOx creation	* 0.00118	-	0.0013	lb/lb
SOx creation	* 0.00283	-	0.00312	lb/lb
Water usage	* 1.84e4	-	2.03e4	in^3/lb

### Processing energy, CO2 footprint & water

Coarse machining energy (per unit wt removed)	* 600	-	663	BTU/lb
Coarse machining CO2 (per unit wt removed)	* 0.105	-	0.116	lb/lb
Fine machining energy (per unit wt removed)	* 4.16e3	-	4.6e3	BTU/lb
Fine machining CO2 (per unit wt removed)	* 0.726	-	0.802	lb/lb
Grinding energy (per unit wt removed)	* 8.11e3	-	8.97e3	BTU/lb
Grinding CO2 (per unit wt removed)	* 1.42	-	1.56	lb/lb

### Recycling and end of life

Recycle	✗			
Recycle fraction in current supply	1.34	-	1.48	%
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	✓			

### Geo-economic data for principal component

Principal component	Bamboo
Annual world production, principal component	1.18e9 - 1.31e9 ton/yr

### Main mining areas (metric tonnes per year)

China, India, Myanmar, Nigeria

### Eco-indicators for principal component

Eco-indicator 95	2.99		millipoints/lb
Eco-indicator 99	0.213		millipoints/lb
EPS value	62.7	-	69.3

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## Notes

### Warning

Properties depend strongly on moisture content.

## Links

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ProcessUniverse

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Reference

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Shape

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## General information

### Designation

Bamboo (L)

### Typical uses

Building & construction; scaffolding; furniture; pulp & paper making; ropes; reinforcement for concrete; frames for early aircraft.

## Composition overview

### Compositional summary

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### Physical properties

Density	0.0217	-	0.0289	lb/in <sup>3</sup>
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### Mechanical properties

Young's modulus	2.18	-	2.9	10 <sup>6</sup> psi
Yield strength (elastic limit)	* 5.21	-	6.37	ksi
Tensile strength	23.2	-	46.4	ksi
Elongation	* 2.88	-	3.52	% strain
Compressive strength	8.7	-	14.5	ksi
Flexural modulus	2.47	-	3.19	10 <sup>6</sup> psi
Flexural strength (modulus of rupture)	11.6	-	23.2	ksi
Shear modulus	* 0.175	-	0.197	10 <sup>6</sup> psi
Shear strength	1.45	-	2.9	ksi
Bulk modulus	* 0.112	-	0.149	10 <sup>6</sup> psi
Poisson's ratio	0.32	-	0.46	
Shape factor	5.6			
Hardness - Brinell	11.5	-	12.8	ksi
Fatigue strength at 10 <sup>7</sup> cycles	4.25	-	5.7	ksi
Mechanical loss coefficient (tan delta)	0.012	-	0.022	
Radial shrinkage (green to oven-dry)	6.6	-	7.2	%



Tangential shrinkage (green to oven-dry)	4.1	-	8.2	%
Volumetric shrinkage (green to oven-dry)	10.9	-	15.8	%
Work to maximum strength	1	-	1.23	ft.lbf/in <sup>3</sup>

### Impact & fracture properties

Fracture toughness	* 5.19	-	6.37	ksi.in <sup>0.5</sup>
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### Thermal properties

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Maximum service temperature	248	-	284	°F
Minimum service temperature	* -99.4	-	-9.4	°F
Thermal conductivity	0.0924	-	0.104	BTU.ft/hr.ft <sup>2</sup> .°F
Specific heat capacity	0.396	-	0.408	BTU/lb.°F
Thermal expansion coefficient	1.44	-	2.28	µstrain/°F

### Electrical properties

Electrical resistivity	* 6e13	-	2e14	µohm.cm
Dielectric constant (relative permittivity)	* 9	-	11	
Dissipation factor (dielectric loss tangent)	* 0.18	-	0.22	
Dielectric strength (dielectric breakdown)	* 10.2	-	15.2	V/mil

### Magnetic properties

Magnetic type	Non-magnetic
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### Optical properties

Transparency	Opaque
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### Bio-data

Food contact	Yes
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### Restricted substances risk indicators

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### Durability

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NOx creation	* 0.00118	-	0.0013	lb/lb
SOx creation	* 0.00283	-	0.00312	lb/lb
Water usage	* 1.84e4	-	2.03e4	in^3/lb

### Processing energy, CO2 footprint & water

Coarse machining energy (per unit wt removed)	* 661	-	730	BTU/lb
Coarse machining CO2 (per unit wt removed)	* 0.115	-	0.127	lb/lb
Fine machining energy (per unit wt removed)	* 4.77e3	-	5.27e3	BTU/lb
Fine machining CO2 (per unit wt removed)	* 0.832	-	0.92	lb/lb
Grinding energy (per unit wt removed)	* 9.34e3	-	1.03e4	BTU/lb
Grinding CO2 (per unit wt removed)	* 1.63	-	1.8	lb/lb

### Recycling and end of life

Recycle	✗			
Recycle fraction in current supply	1.34	-	1.48	%
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	✓			

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