Engineered bamboo as reinforcement for structural concrete

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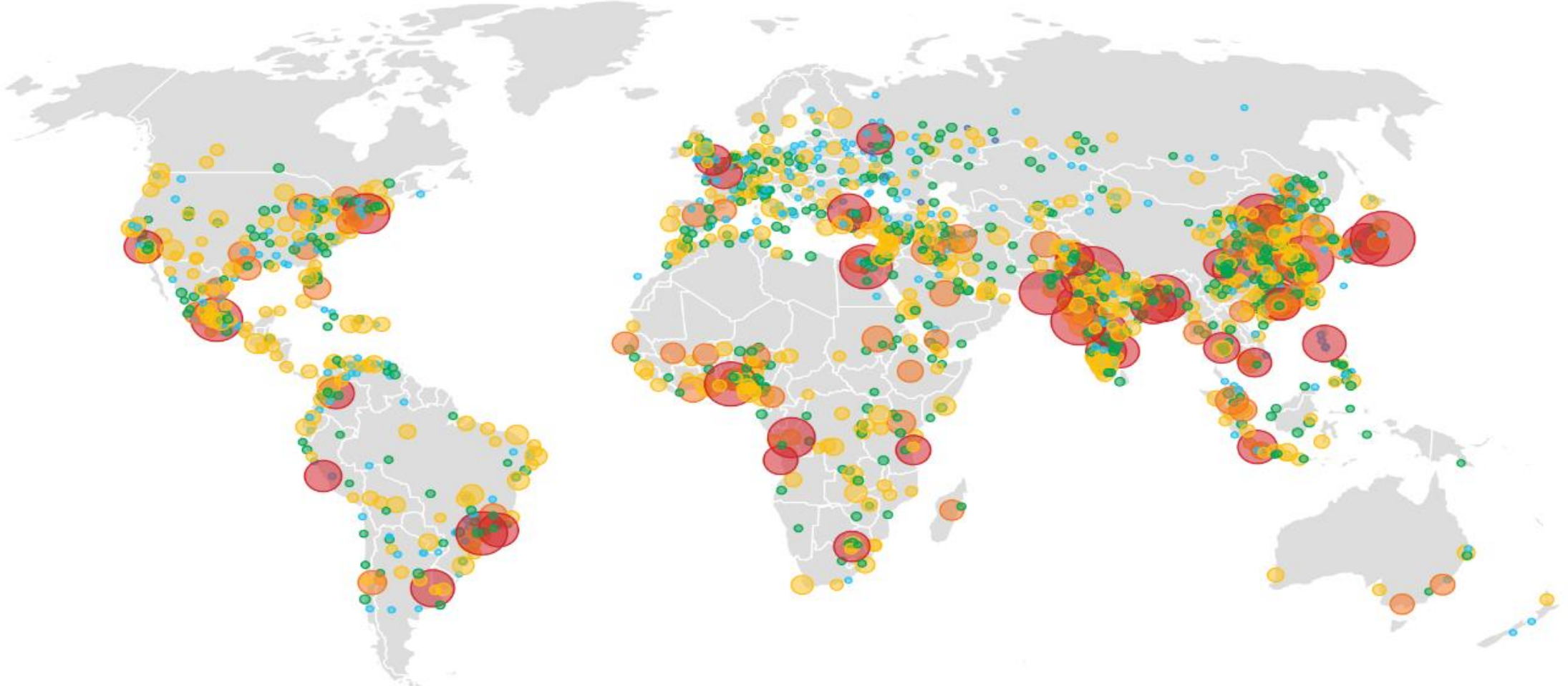
Urbanisation, 2030

Search cities

GLOBAL CITY POPULATIONS*

40.0%	23.0%	3.8%	6.1%	13.4%	5.2%	8.6%
Rural -	Other urban Fewer than 300,000	Smallest cities 300,000 to 500,000	Small cities 500,000 to 1m	Medium cities 1m to 5m	Large cities 5m to 10m	Megacities 10m or more



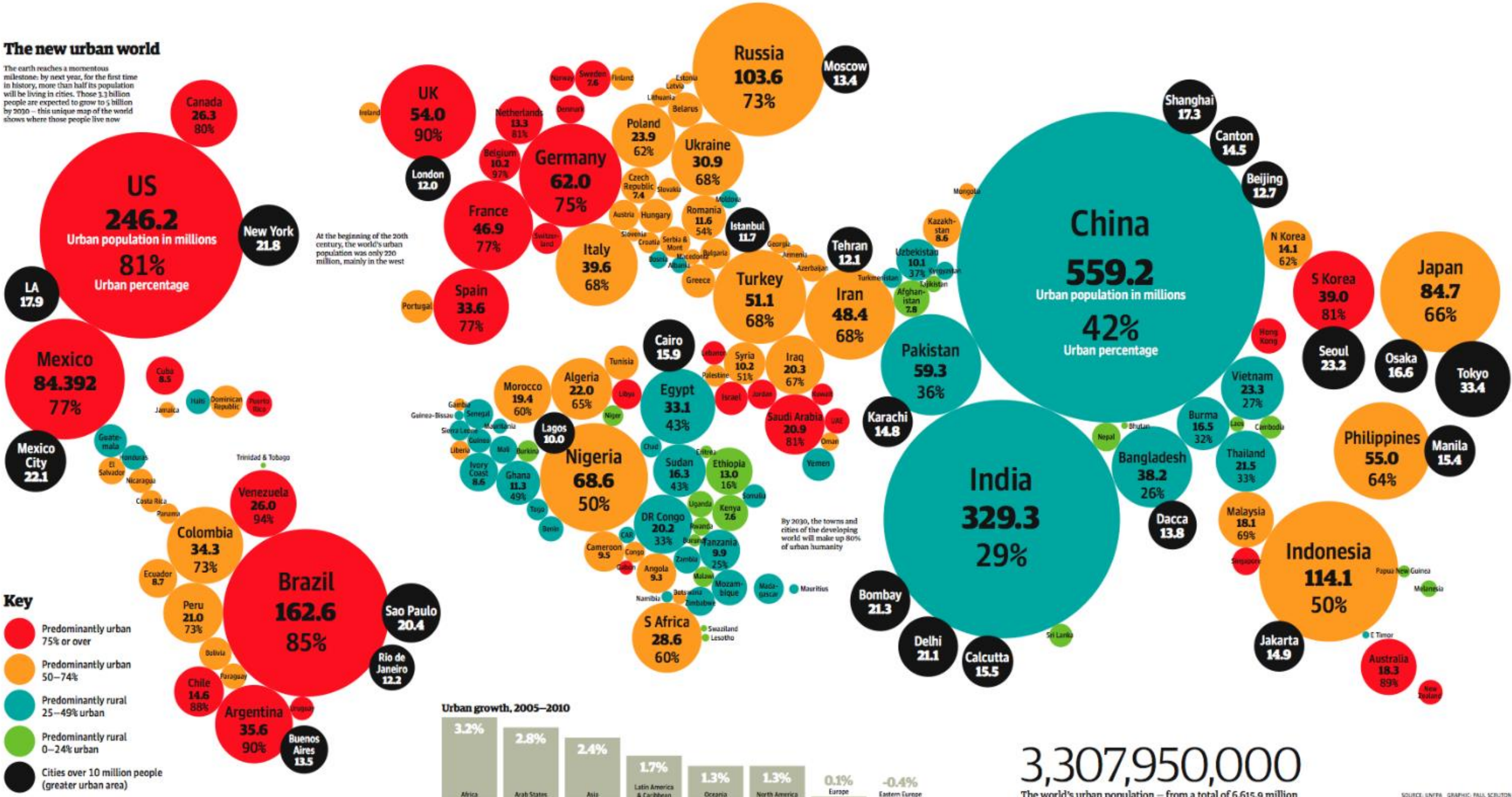
1950 1960 1970 1980 1990 2000 2010 2020 2030

Source: UN

*Dataset comprises urban agglomerations with 300,000 inhabitants or more in 2014.
Data are for countries existing in 2014, mapped on modern borders. Projections from 2014.

The new urban world

The earth reaches a momentous milestone: by next year, for the first time in history, more than half its population will be living in cities. Those 3.3 billion people are expected to grow to 5 billion by 2030 – this unique map of the world shows where those people live now



3,307,950,000

The world's urban population – from a total of 6,615.9 million

SOURCE: UNFPA GRAPHIC: PAUL SCRUTON

Problems

Large emission of Green House Gases

Construction is responsible for almost **40%** of global carbon emissions

Increasing demand for housing

2 Billion new housing units needed by **2100** globally

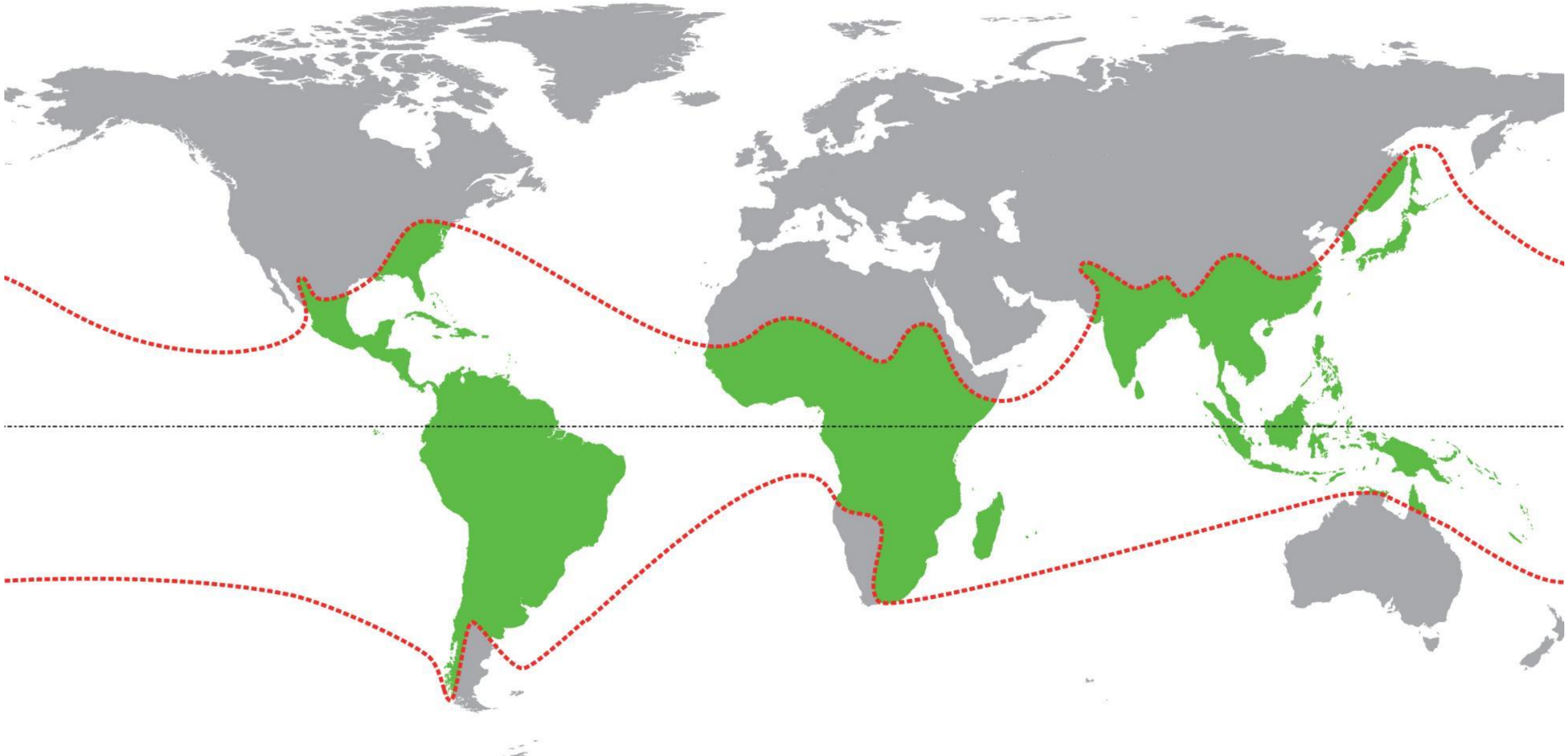
Finite resources

	production (mio. t)	reserves (mio. t)	R-T-P ratio (years)
bauxite	159	25'000	157
lead	3.15	67	21
iron ore	1'340	160'000	119
copper	14.6	470	32
nickel	1.4	62	44
zinc	9.4	220	23
tin	0.26	6.1	23

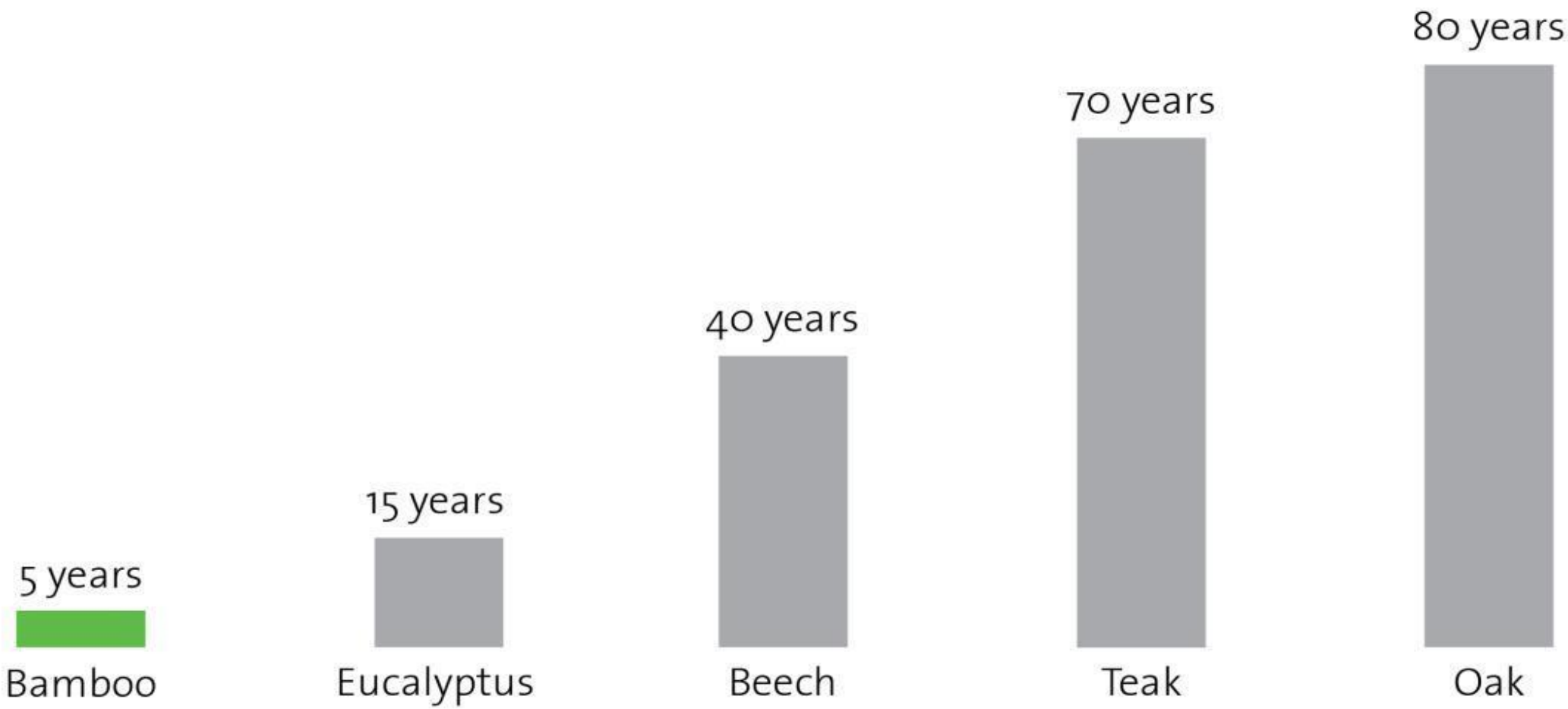
Construction activity is a major user of the world's **non-renewable resources**.

IS THERE AN ALTERNATIVE?

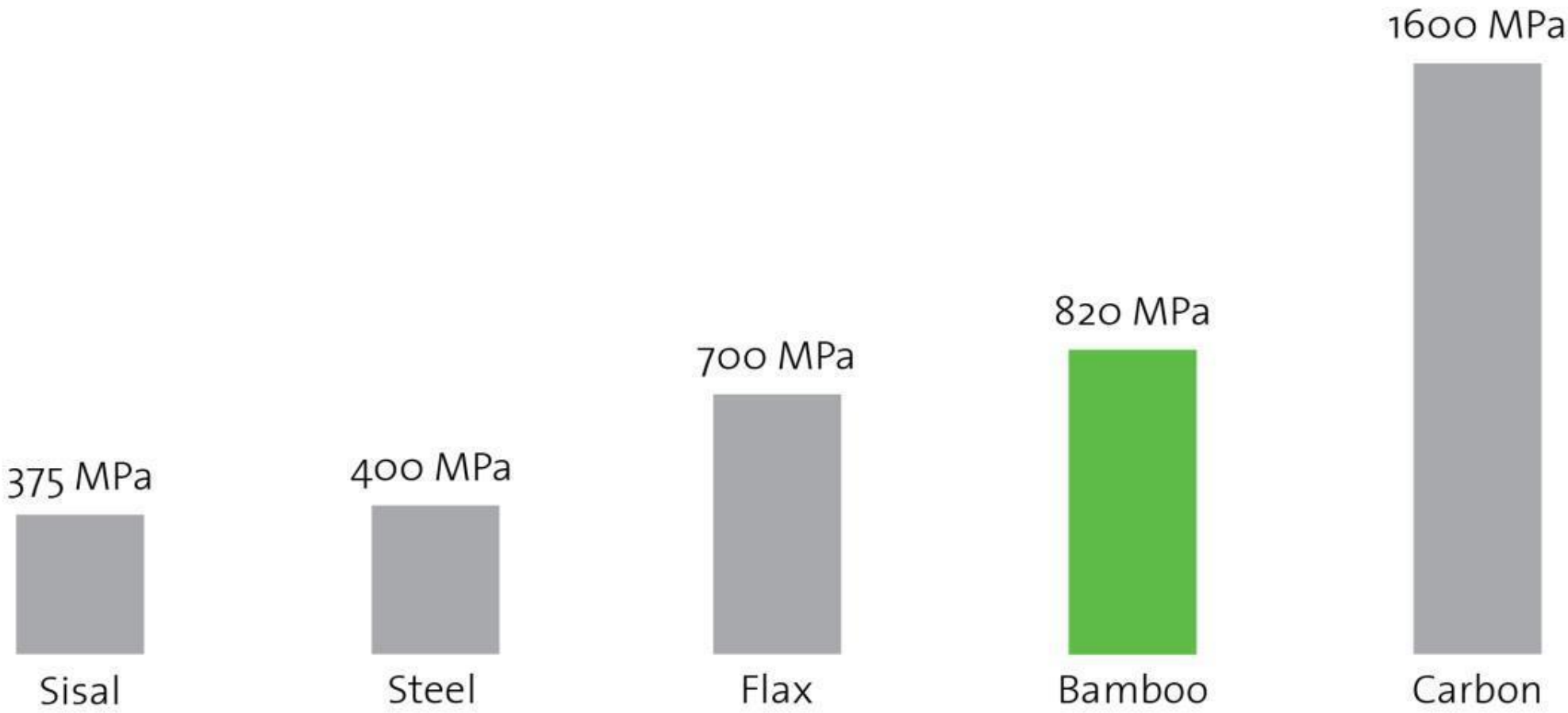
Availability



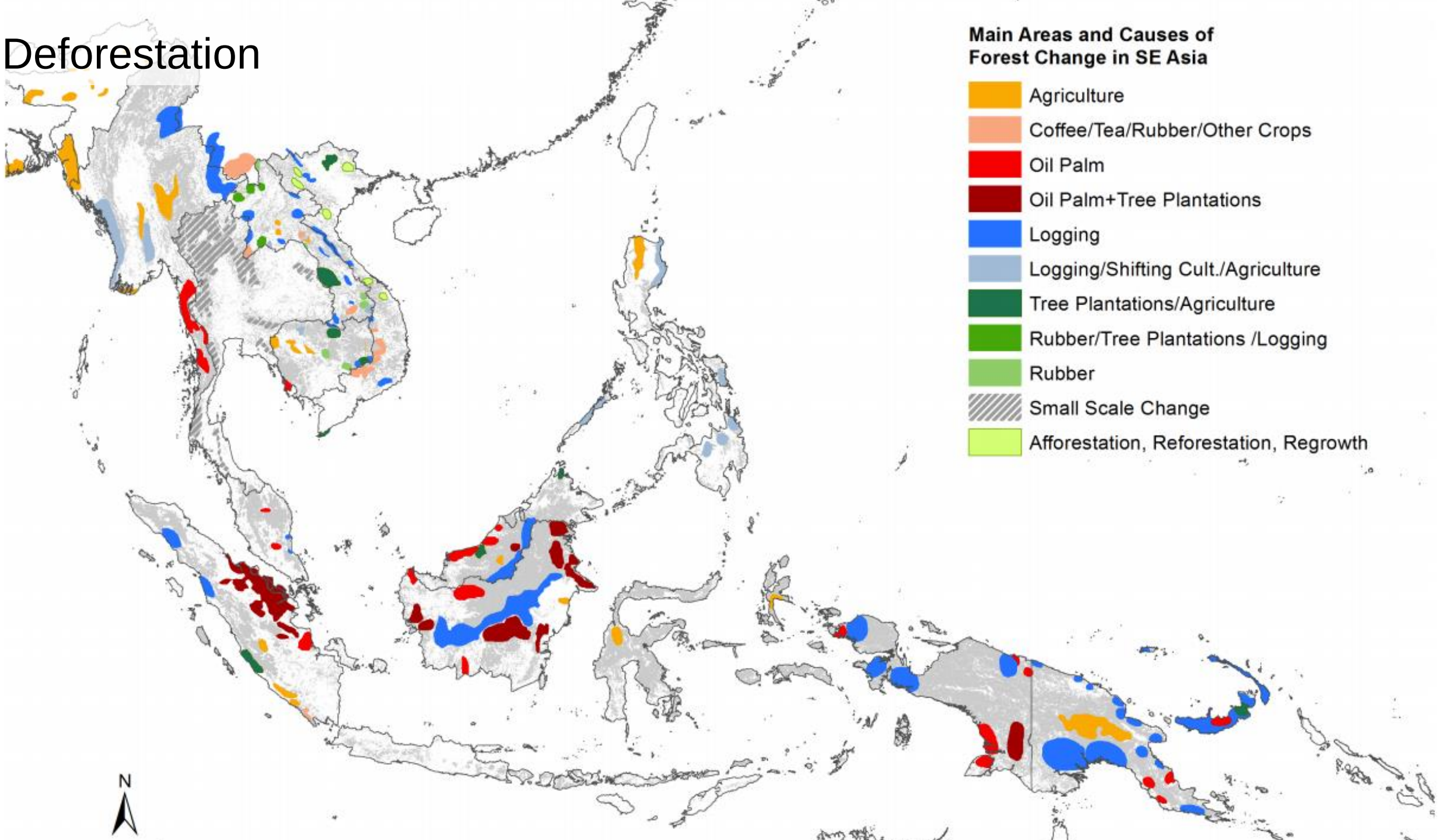
Highly Renewable



High Strength



Deforestation



Fibrous bamboo strips


NALGENE

Class	Wall thickness (MPa)	Measured tensile strength (MPa)	Measured MOR (MPa)
Class 1	6 to 7	281	209
	7 to 8	295	207
	8 to 9	285	198
Class 2	6 to 7	260	172
	7 to 8	298	180
	8 to 9	292	162
	9 to 10	280	190
	10 to 11	294	161
Class 3	6 to 7	288	172
	7 to 8	290	168
	8 to 9	285	158
	9 to 10	287	160
	10 to 11	301	168
Class 4	6 to 7	324	166
	7 to 8	320	159
	9 to 10	326	155
Class 5	8 to 9	340	159
	9 to 10	318	153
	10 to 11	303	149
	11 to 12	268	150
Class 6	10 to 11	310	165
	11 to 12	282	162
	12 to 13	263	160
	14 to 15	247	151
Class 7	11 to 12	244	138
	12 to 13	224	127
	16 to 17	203	125
	19 to 20	193	121

Dendrocalamus asper
Indonesia

The highest tensile strength of raw bamboo measured is 340MPa.

The lowest tensile strength of raw bamboo measured is 193MPa.

The highest MOR of raw bamboo measured is 209MPa.

The lowest MOR of raw bamboo measured is 121MPa.

$$MOR = -0.78D + 250$$
$$E_f = -33D + 14300$$
$$E_t = -3620t + 25300$$
$$E_t = 18500SD + 6870$$
$$E_t = 33600SD + 70.4D + 13080$$
$$E_t = 27200SD + 95.1D - 364.6t - 7180$$
$$CS = -0.36D + 96.7$$
$$CS = -0.22D - 1.30t + 92.8$$
$$CS = -0.18D - 1.12t + 21SD + 71$$
$$TS = -8.5t + 363$$
$$SD = -0.002D - 0.009t + 1.075$$

Statistical modeling

Class	Wall thickness (MPa)	Measured tensile strength (MPa)	Measured MOR (MPa)	Estimated tensile strength (MPa)	Estimated MOR (MPa)
Class 1	6 to 7	281	209	**268 to 291**	**200 to 219**
	7 to 8	295	207	**290 to 298**	**201 to 217**
	8 to 9	285	198	**276 to 289**	**276 to 289**
Class 2	6 to 7	260	172	**255 to 268**	**166 to 180**
	7 to 8	298	180	**291 to 301**	**175 to 189**
	8 to 9	292	162	**289 to 295**	**155 to 170**
	9 to 10	280	190	**277 to 283**	**184 to 197**
	10 to 11	294	161	**291 to 300**	**155 to 170**
Class 3	6 to 7	288	172	**282 to 294**	**166 to 178**
	7 to 8	290	168	**284 to 296**	**161 to 174**
	8 to 9	285	158	**281 to 288**	**150 to 166**
	9 to 10	287	160	**285 to 291**	**155 to 170**
	10 to 11	301	168	**296 to 306**	**164 to 176**
Class 4	6 to 7	324	166	**318 to 329**	**162 to 175**
	7 to 8	320	159	**315 to 324**	**151 to 167**
	9 to 10	326	155	**323 to 329**	**151 to 157**
Class 5	8 to 9	340	159	**333 to 347**	**152 to 166**
	9 to 10	318	153	**310 to 327**	**148 to 157**
	10 to 11	303	149	**299 to 310**	**141 to 156**
	11 to 12	268	150	**260 to 276**	**145 to 155**
Class 6	10 to 11	310	165	**304 to 315**	**160 to 170**
	11 to 12	282	162	**277 to 288**	**155 to 168**
	12 to 13	263	160	**255 to 269**	**155 to 167**
	14 to 15	247	151	**241 to 254**	**145 to 157**
Class 7	11 to 12	244	138	**240 to 248**	**130 to 144**
	12 to 13	224	127	**218 to 230**	**120 to 133**
	16 to 17	203	125	**192 to 216**	**120 to 130**
	19 to 20	193	121	**186 to 199**	**119 to 127**

Estimated parameters

Production Process

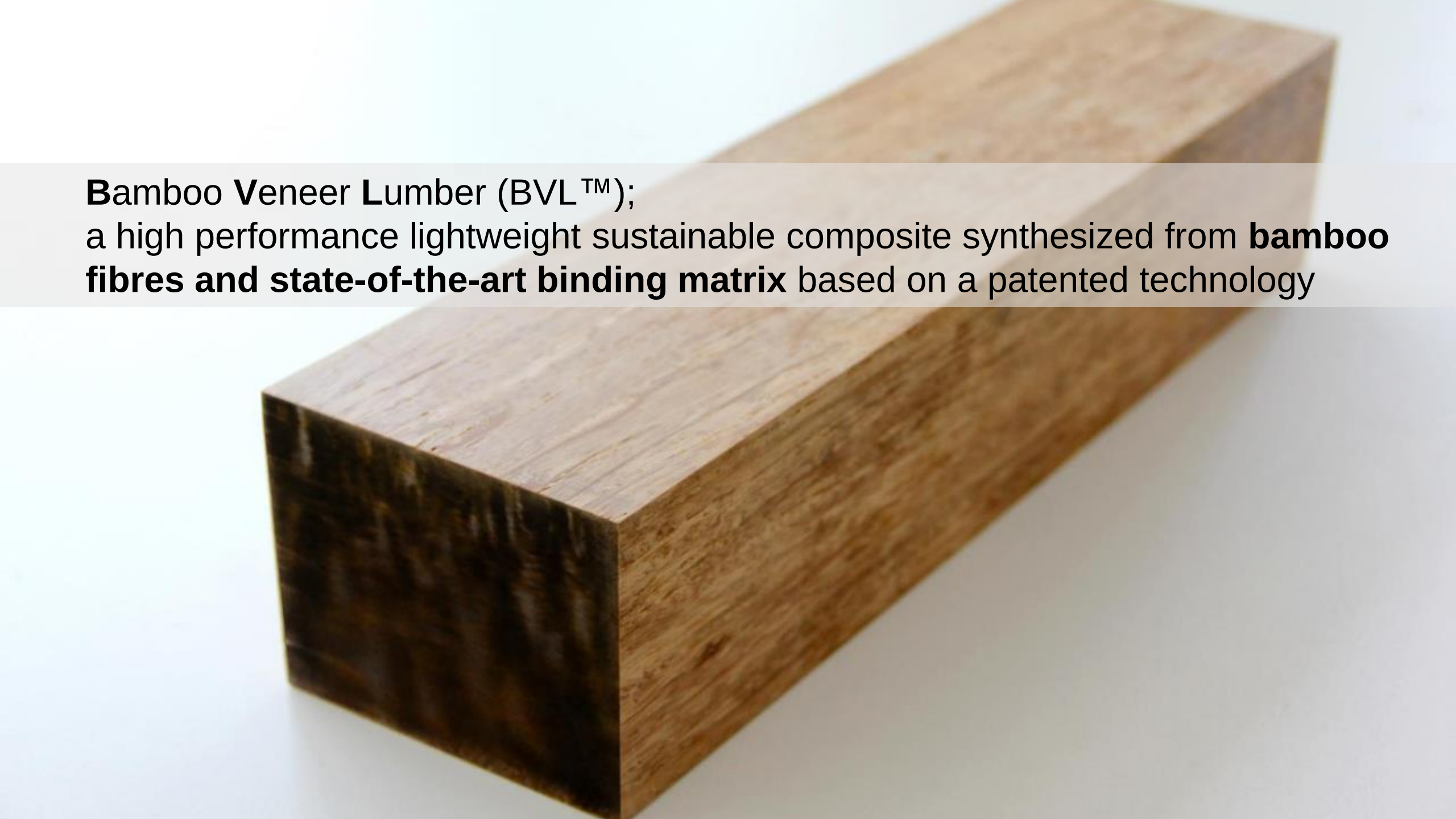
Unique processing

State of the art formulation

Rigorous testing

Patent US20180371755A1

US, China, EU and Singapore



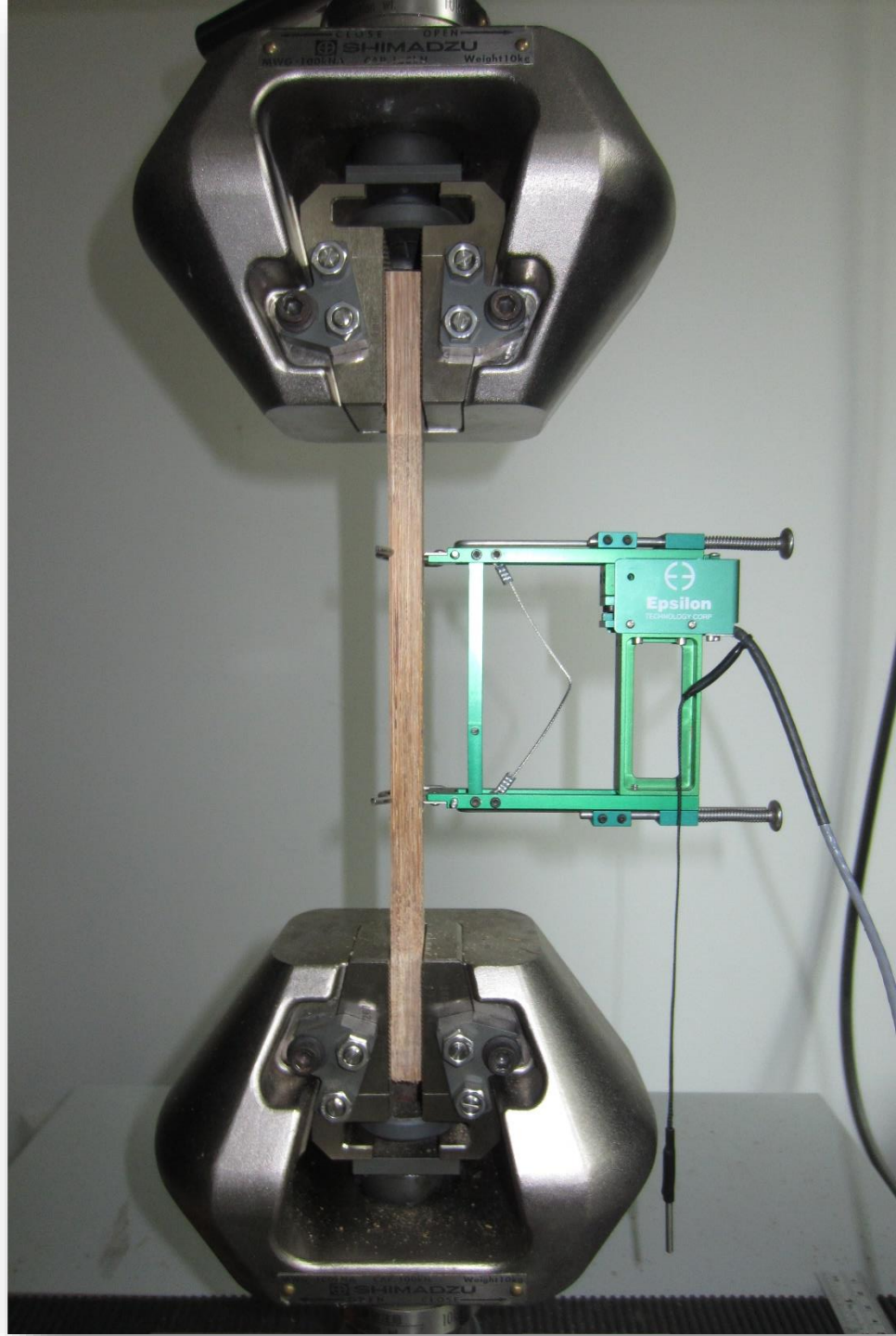
Bamboo **V**eneer **L**umber (BVL™);
a high performance lightweight sustainable composite synthesized from **bamboo fibres and state-of-the-art binding matrix** based on a patented technology

Tensile Tests

Shimadzu AG-IC 100 kN
ASTM D3039-08
for polymer matrix composite materials
strain rate: 1 mm/min

Ave. Tensile strength f_t = 270 MPa

Ave. Young's Modulus = 30 GPa

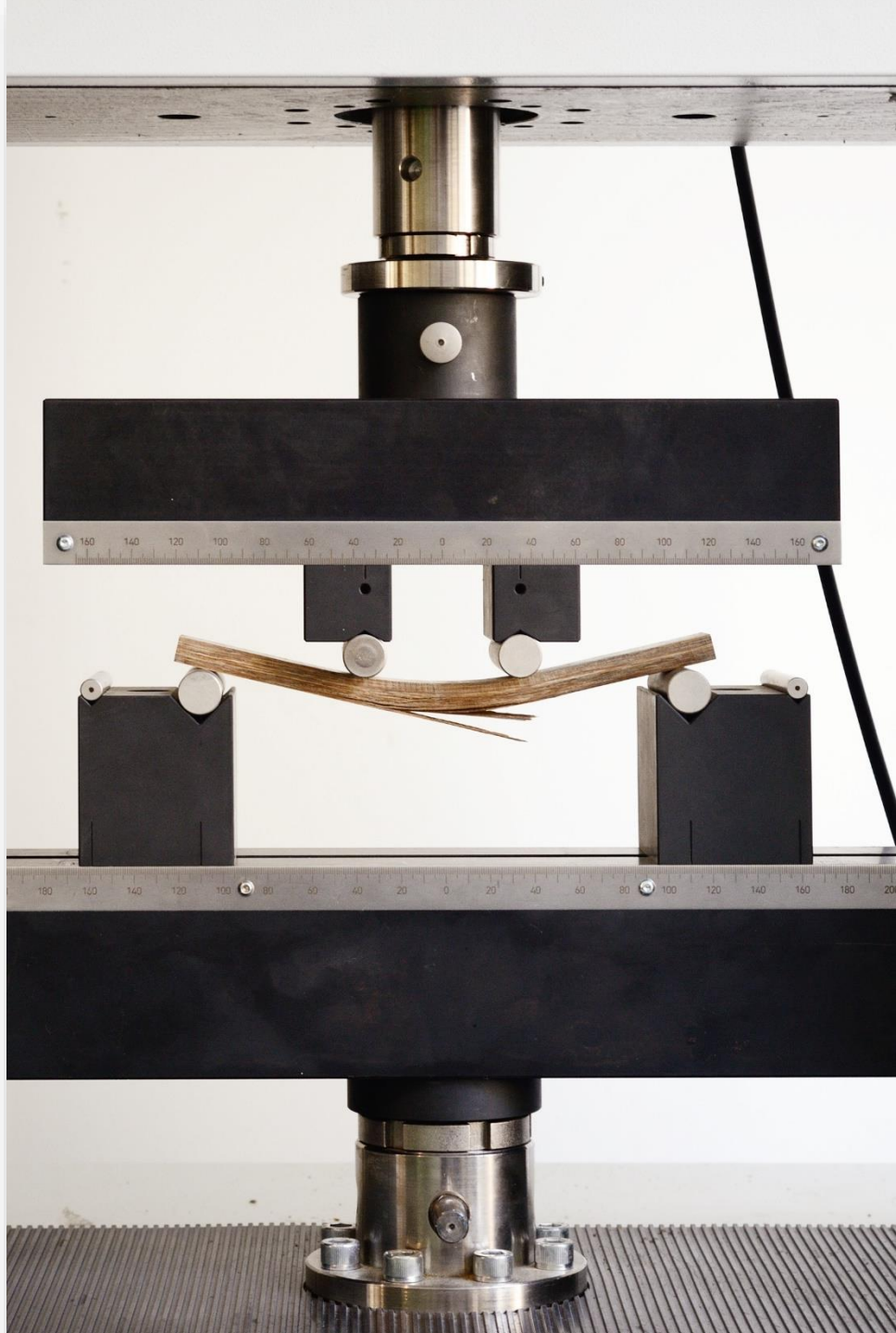


Flexural Tests

Shimadzu AG-IC 100 kN
ASTM D7264-15
for polymer matrix composite materials
Four-point-bending

Ave. Flexural strength f_m = 250 MPa

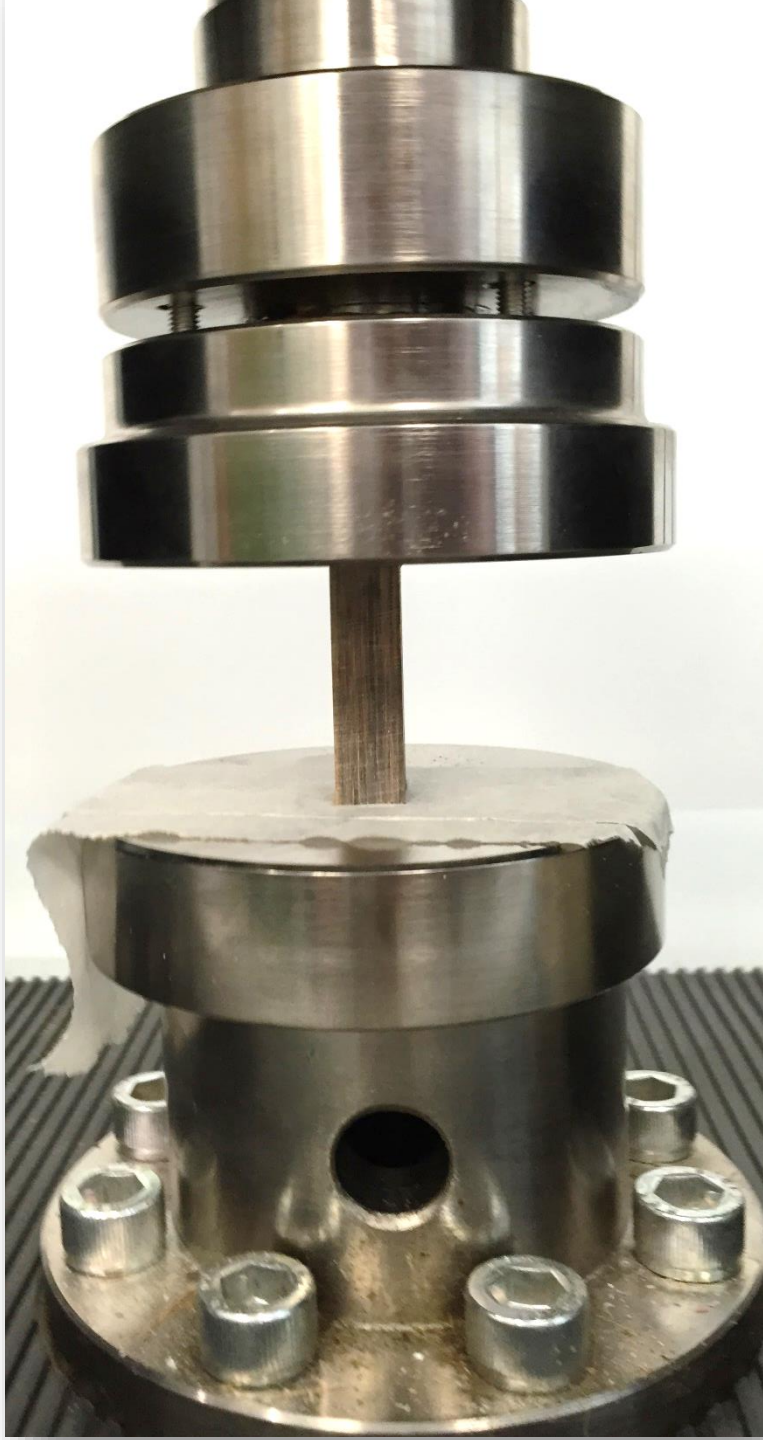
Ave. Flexural Modulus = 28 GPa



Compression Tests along fiber direction

Shimadzu AG-IC 100 kN
ASTM D6641-14
for polymer matrix composite materials

Ave. Compressive strength f_c = 145 MPa



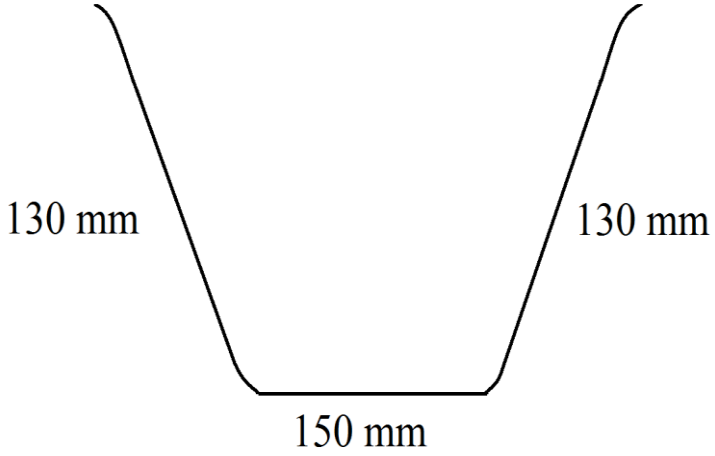
BVL™ Properties

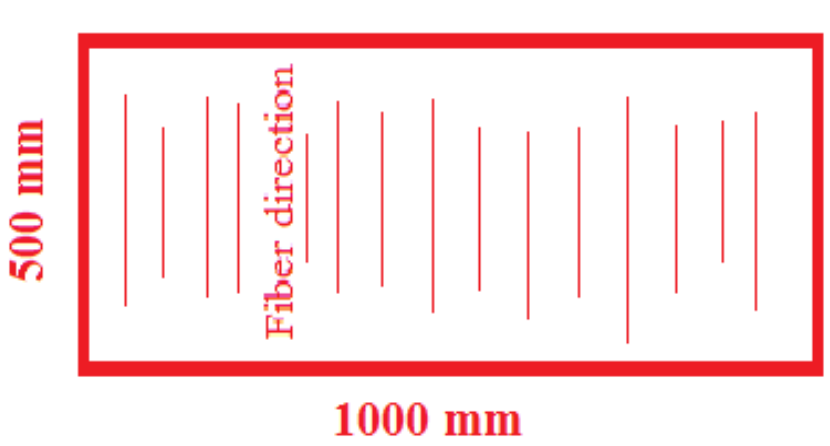
	BVL™	Steel S275	Glulam
Tensile Strength (MPa)	200 to 300	275 to 410	6 to 15
Bending Strength (MPa)	150 to 250	220 to 350	13 to 24
Compressive Strength (MPa)	90 to 150	250 to 350	3 to 6
Elastic Modulus (MPa)	20,000 to 35,000	190,000 to 220,000	8000 to 12000
Density (Kg/m3)	1.10 to 1.30	7.2 to 7.9	0.5 to 0.8

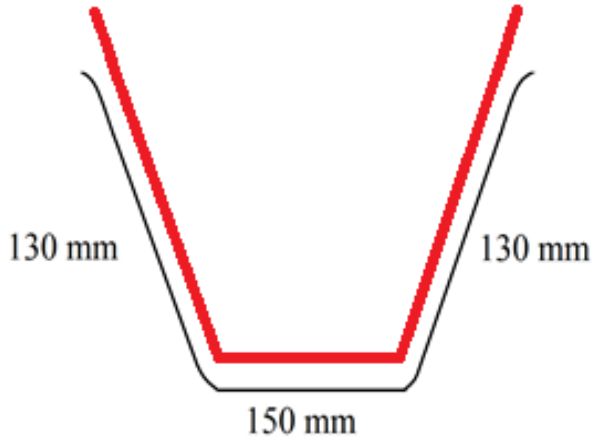
Applications

BVL™ Reinforcement for Concrete

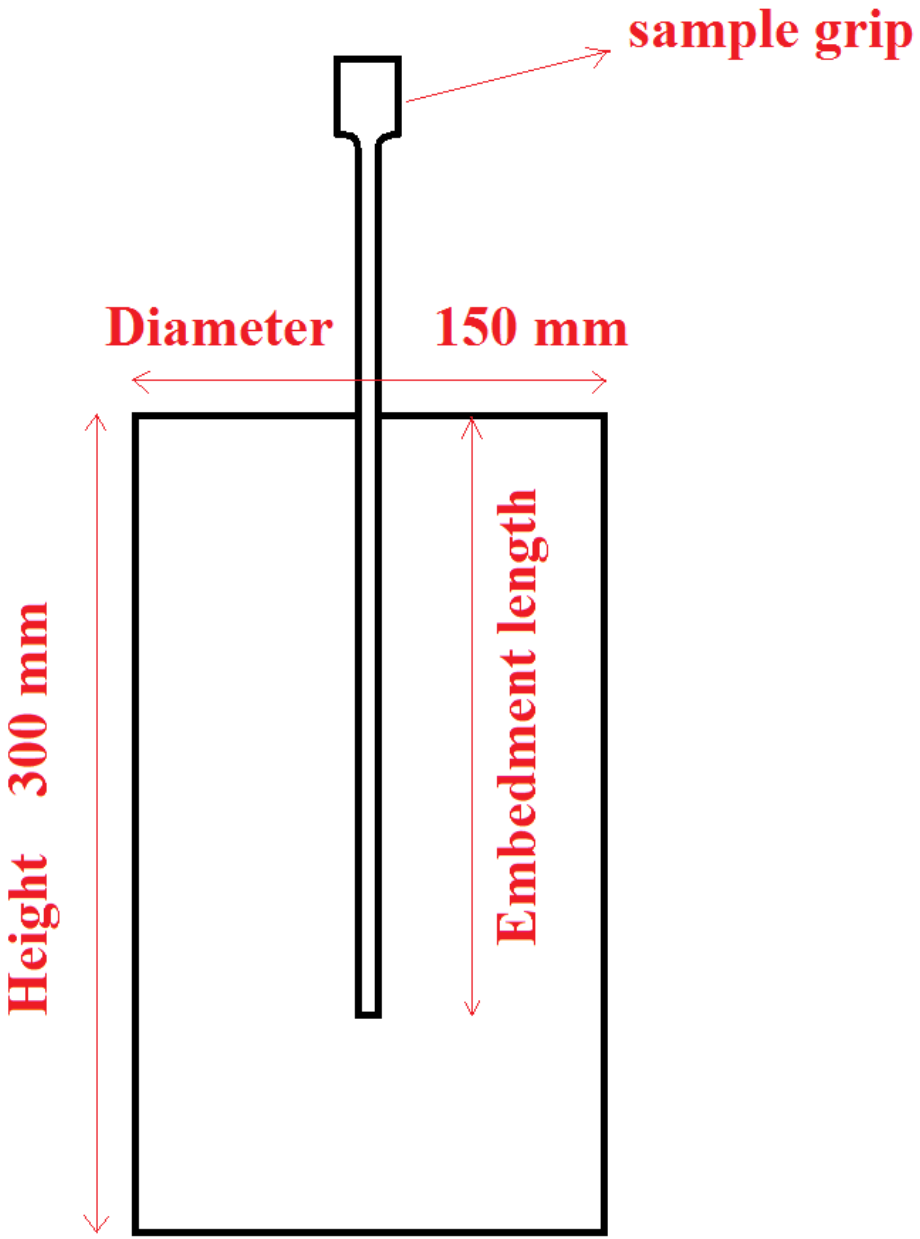
Production of BVC stirrups

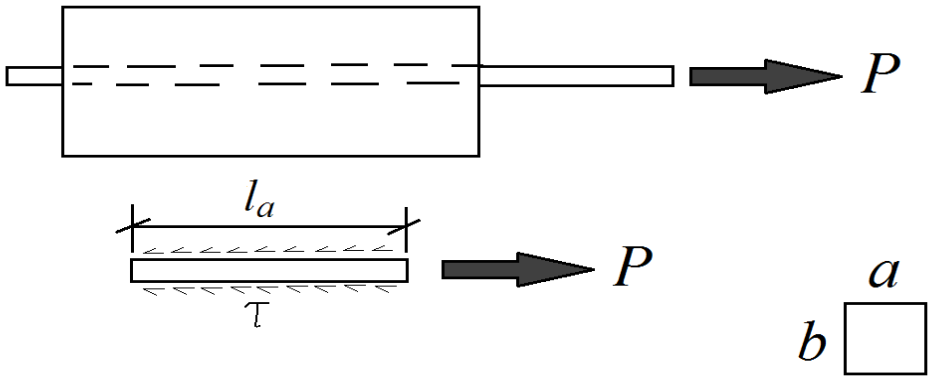






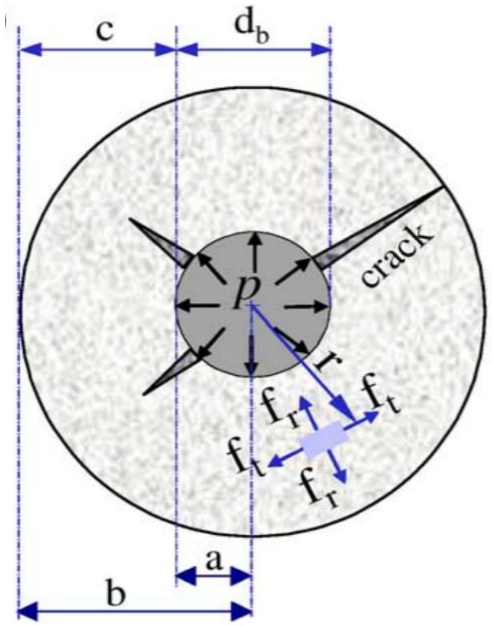
Pull-out tests






SHIMADZU
Epsilon


2
Tokyo Sokki Kenkyujo Co., Ltd.
STOP
START



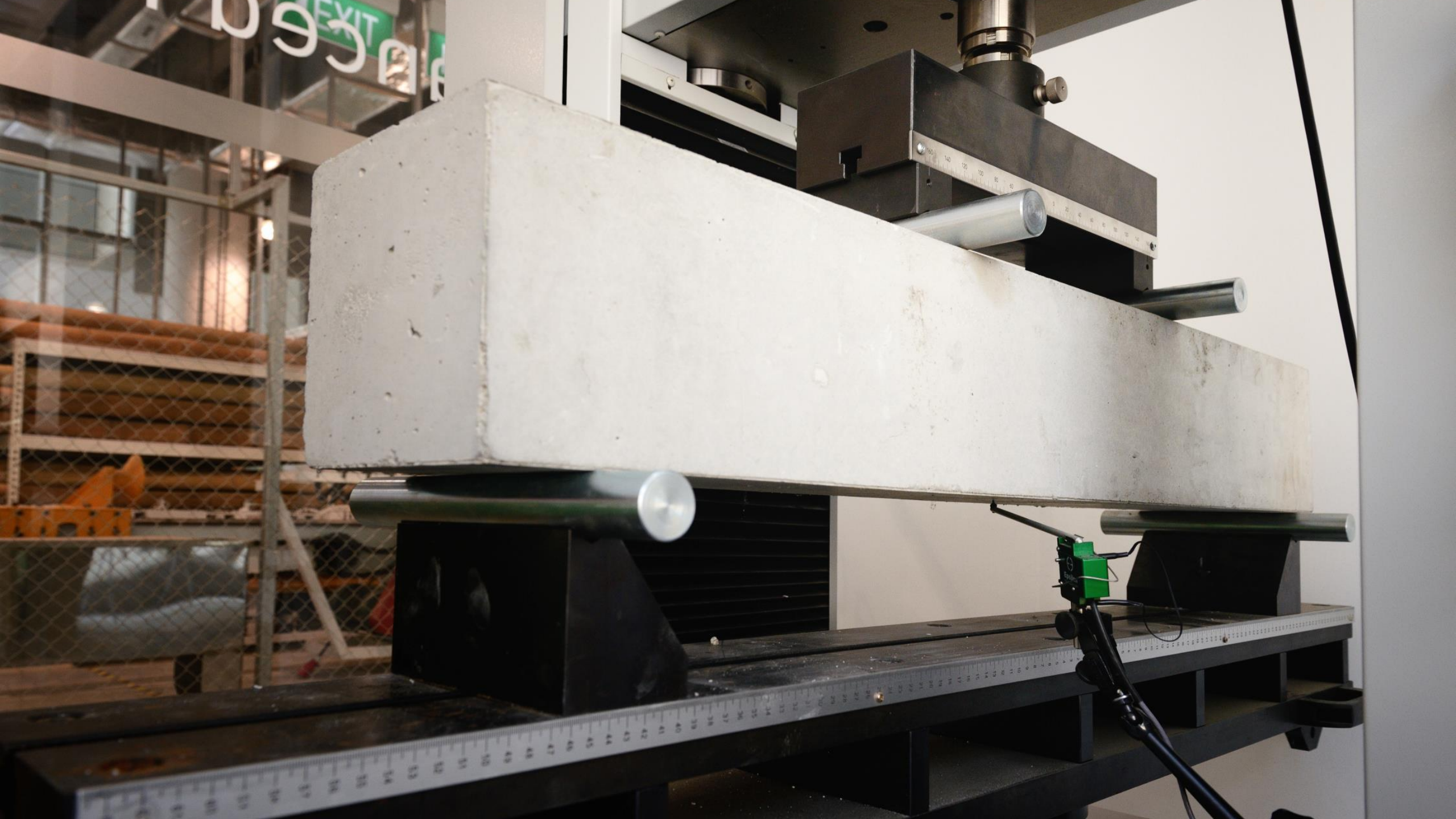
$$P = \frac{(\alpha_{fT} - \alpha_c)Tn_{fT}E_c}{n_{fT}(\beta + \upsilon_c) + (1 - \upsilon_{fT})}$$

$$\beta = \frac{(b^2+a^2)}{(b^2-a^2)}$$

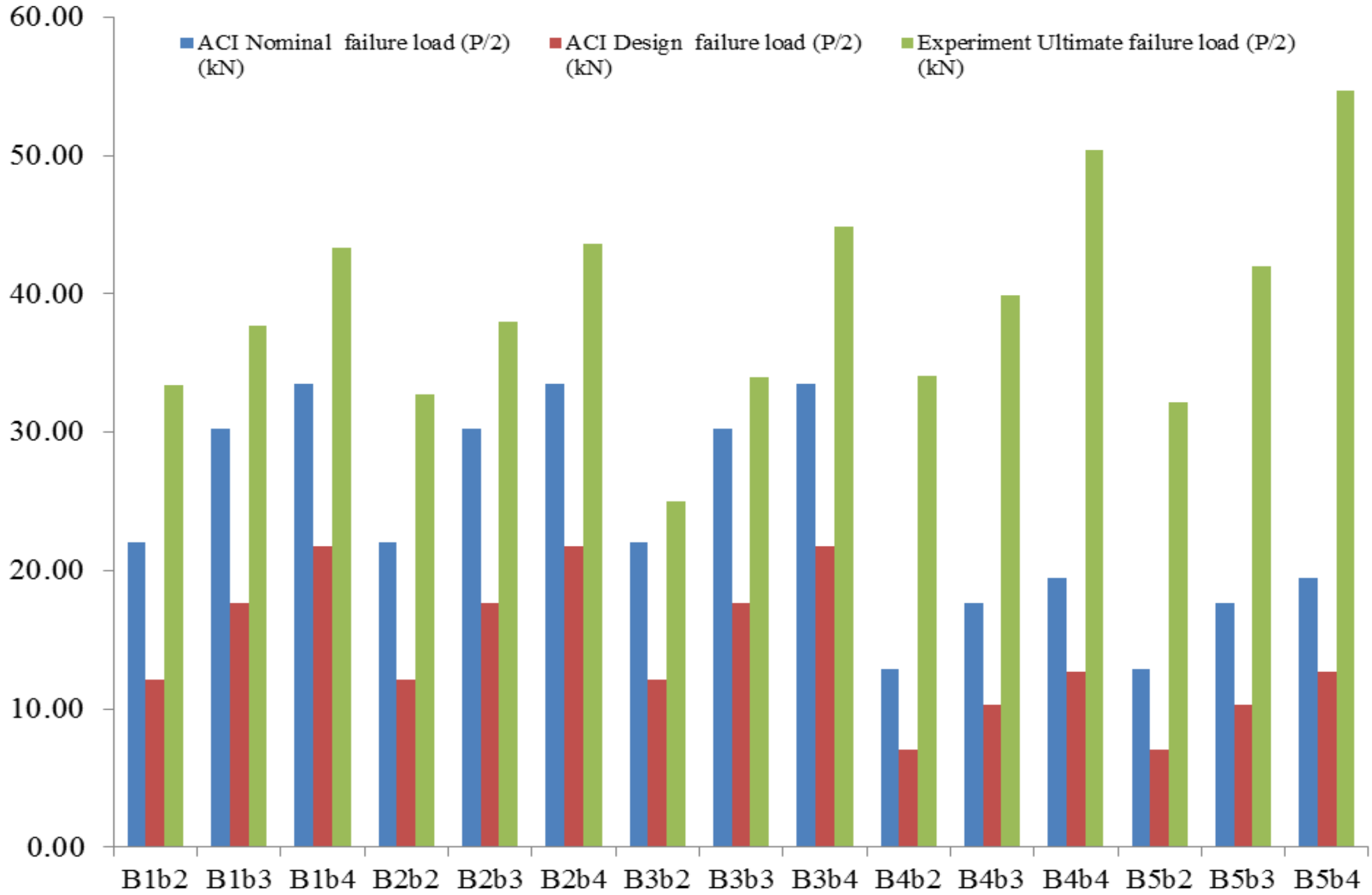
$$\sigma_{tmax} = \beta P$$

Estimation of thermal stresses

	Sample	Maximum temperature difference (T), °C	Radial pressure (P), MPa	β	Maximum tangential stress (σ), MPa
Cylinder	1	22	3.68	1.01	3.72
	2	27	4.51	1.01	4.56
	3	26	4.35	1.01	4.39
	4	24	4.01	1.01	4.06
	5	26	4.35	1.01	4.39
Beam	6	25	4.18	1.01	4.23
	7	25	4.18	1.01	4.23
	8	28	4.68	1.01	4.73
	9	23	3.84	1.01	3.89
	10	22	3.68	1.01	3.72


EXIT


27/01/14


60.00
50.00
40.00
30.00
20.00
10.00
0.00
ACI Nominal failure load (P/2) (kN)
ACI Design failure load (P/2) (kN)
Experiment Ultimate failure load (P/2) (kN)
B1b2
B1b3
B1b4
B2b2
B2b3
B2b4
B3b2
B3b3
B3b4
B4b2
B4b3
B4b4
B5b2
B5b3
B5b4

2030 Agenda for Sustainable Development

Creating sustainable value chains using local resources by creating jobs and employing people

Bamboo as :

- Clean source of charcoal
- For biomass for electricity

Engineered Bamboo for affordable housing solutions

green sustainable alternative to steel, concrete and glass

a great alternative to cement, steel and even timber as a natural carbon sink to fight climate change

Bamboo forest and plantation can help to restore degraded land and Help to balance the ecosystem in the nature

Thank you

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