energies

MDPI

Supplementary Material

A Life-Cycle Approach to Investigate the Potential of Novel Biobased Construction Materials toward a Circular Built Environment

Naomi Keena [1,2,*], Marco Raugei [3,4], Mae-ling Lokko [2], Mohamed Aly Etman [2], Vicki Achnani [2], Barbara K. Reck [5] and Anna Dyson [2]

[1] Peter Guo-hua Fu School of Architecture, Faculty of Engineering, McGill University, Montreal, QC H3A 0C2, Canada
[2] Yale Center for Ecosystems in Architecture (Yale CEA), Yale School of Architecture, New Haven, CT 06511, USA
[3] School of Engineering, Computing and Mathematics, Oxford Brookes University, Wheatley, Oxford OX33 1HX, UK
[4] Center for Life Cycle Assessment, Columbia University, New York, NY 10027, USA
[5] Center for Industrial Ecology, Yale School of the Environment, New Haven, CT 06511, USA
* Correspondence: naomi.keena@mcgill.ca

Supplementary Material contains:

Complete Bills of Materials (BOMs) for four considered wall assemblies (Table S1 - S4)_

R-value calculations for four considered wall assemblies (Tables S5 – S8)

Table S1. Bill of Materials information for Traditional Timber Frame Wall Assembly

Item Name	Material	Density (kg/m3)	Thickness (m)	Area (m2)	Volume (m3)	Mass (kg)
Timber Siding Boards	Western Red Cedar	370.000	0.020	1.000	0.020	7.400
Wood battens (25mm x 38mm)*	Sawn Softwood	510.000	0.038	0.025	0.001	0.485
Continuous Foam Insulation*	Rockwool	160.000	0.050	1.000	0.050	8.000
OSB*	Engineered wood panel	680.000	0.019	1.000	0.019	12.920
Timber studs (2x4" or 89mm x 38mm) *	Sawn Softwood	510.000	0.038	0.025	0.001	0.485
Insulation*	Rockwool	160.000	0.050	1.000	0.050	8.000
Dry Wall	Gypsum board	600.000	0.013	1.000	0.013	7.800

* Potential for re-use at EoL

Table S2. Bill of Materials information for CLT Wall Assembly

Item Name	Material	Density (kg/m3)	Thickness (m)	Area (m2)	Volume (m3)	Mass (kg)
Siding	Western Red Cedar	370.000	0.020	1.000	0.020	7.400
Timber battens (25mm x 38mm)*	Sawn Softwood	510.000	0.038	0.025	0.001	0.485
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	925.000	0.001	1.000	0.001	0.463
Plywood Sheathing*	Southern Yellow Pine Ply	650.000	0.010	1.000	0.010	6.500
Interior finish + insulation (solid)*	Solid Wood CLT Black Spruce panel+wood fiber insulation	500.000	0.055	1.000	0.055	27.500
Insulation*	wood fiber insulation	160	0.100	1.000	0.100	16.000

* Potential for re-use at EoL

Table S3. Bill of Materials information for Bamboo Wall Assembly

Item Name	Material	Density (kg/m3)	Thickness (m)	Area (m2)	Volume (m3)	Mass (kg)
Bamboo Siding Board	Bamboo siding	1150	0.018	1.000	0.018	20.7
Split Bamboo Batten (25mm x 38mm)*	Split Bamboo batten	1100	0.038	0.025	0.001	1.0
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	925	0.001	1.000	0.001	0.5
Bamboo laminated Panel*	Compressed Bamboo panel	700	0.020	1.000	0.020	14.0
Laminate Bamboo beam(2x4" or 89mm x 38mm)*	Compressed Split Bamboo beams	1050	0.038	0.178	0.007	7.1
Insulation*	Loose cellulose fiber insulation	160	0.050	1.000	0.050	8.0
Bamboo laminated Panel*	Compressed Bamboo panel	700	0.020	1.000	0.020	14.0

* Potential for re-use at EoL

Table S4. Bill of Materials information for Coconut Wall Assembly

Item Name	Material	Density (kg/m3)	Thickness (m)	Area (m2)	Volume (m3)	Mass (kg)
Raffia Stem panels	Raffia stems	750	0.020	1.000	0.020	15.000
Coconut Fiber bundle / Thatch proxy	Coconut fiber	900	0.025	1.000	0.025	22.500
Split Bamboo Batten (25mm x 38mm)*	Bamboo Split	1100	0.038	0.025	0.001	1.100
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	925	0.001	1.000	0.001	0.463
Plywood Sheathing*	Southern Yellow Pine Ply	650	0.010	1.000	0.010	6.500
Bamboo Laminate plates (2x4" or 89mm x 38mm)*	High Density Split bamboo laminate beam	1050	0.038	0.178	0.007	7.102
Insulation	Loose coconut mat fiber insulation	160	0.050	1.000	0.050	8.000
Interior finish*	Coconut coir compressed boards	1300	0.005	1.000	0.005	6.500

* Potential for re-use at EoL

Table S5. R-Value Calculation Traditional Timber Frame Wall Assembly

Item Name	Material	Layer Thickness (m)	Conductivity (W/m.K)	Resistance (m^2.K/ W)
Outside Thermal Resistance				0.04
Timber Siding Boards	Western Red Cedar	0.020	0.130	0.15
Wood battens (25mm x 38mm)	Sawn Softwood	0.038	0.14	0.27
Continuous Foam Insulation	Rockwool	0.050	0.034	1.47
OSB	Engineered wood panel	0.019	0.13	0.15
Timber studs (2x4" or 89mm x 38mm)	Sawn Softwood	0.038	0.14	0.27
Insulation	Rockwool	0.050	0.034	1.47
Dry Wall	Gypsum board	0.013	0.17	0.08
Inside Thermal Resistance				0.13
Total thermal resistance (RSI)				**4.03**
R-value				**23**

Table S6. R-Value Calculation CLT Wall Assembly

Item Name	Material	Layer Thickness (m)	Conductivity (W/m.K)	Resistance (m^2.K/ W)
Outside Thermal Resistance				0.04
Siding Boards	Western Red Cedar	0.020	0.130	0.15
Wood battens (25mm x 38mm)	Sawn Softwood	0.038	0.14	0.27
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	0.001	0.17	0.003
Plywood Sheathing	Southern Yellow Pine Ply	0.010	0.16	0.063
Wood fiber insulation (x2)		0.100	0.035	2.86
Interior finish	Solid Wood CLT Black Spruce panel	0.055	0.12	0.458
Dry Wall	Gypsum board	0.013	0.17	0.08
Inside Thermal Resistance				0.13
Total thermal resistance (RSI)				**4.00**
R-value				**23**

Table S7. R-Value Calculation Bamboo Wall Assembly

Item Name	**Material**	**Layer Thickness (m)**	**Conductivity (W/m.K)**	**Resistance (m^2.K/ W)**
Outside Thermal Resistance				0.04
Siding Boards	Bamboo	0.018	0.125	0.14
Split battens (25mm x 38mm)	Bamboo	0.038	0.14	0.27
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	0.001	0.17	0.003
Bamboo laminated panel	Compressed Bamboo	0.020	0.125	0.16
Laminate Bamboo beam (2x4" or 89mm x 38mm)	Compressed Split Bamboo beams Spruce panel	0.038	0.14	0.27
Insulation	Loose cellulose fiber insulation	0.050	0.038	1.32
Bamboo laminated panel	Compressed Bamboo	0.020	0.125	0.16
Inside Thermal Resistance				0.13
Total thermal resistance (RSI)				**2.5**
R-value				**14**

Table S8. R-Value Calculation Coconut Wall Assembly

Item Name	**Material**	**Layer Thickness (m)**	**Conductivity (W/m.K)**	**Resistance (m^2.K/ W)**
Outside Thermal Resistance				0.04
Coconut Fiber bundle (Thatch)	Coconut fiber	0.025	0.04	0.63
Split battens (25mm x 38mm)	Bamboo	0.038	0.14	0.27
Vapor control & airtight membrane	High Density Polyethylene Plastic (HDPE)	0.001	0.17	0.003
Plywood Sheathing	Southern Yellow Pine Ply	0.010	0.13	0.08
Bamboo Laminate plates (2x4" or 89mm x 38mm)	High Density Split bamboo laminate beam	0.038	0.14	0.27
Insulation	Loose coconut mat fiber insulation	0.050	0.04	1.25
Interior finish	Coconut coir compressed boards	0.005	0.36	0.01
Inside Thermal Resistance				0.13
Total thermal resistance (RSI)				**2.7**
R-value				**15**