schaefer | emersion DESIGN

The Bigger Picture | Insight from America’s First CLT Hotel

Doug Steimle, PE – Adam Luginbill, RA, LEED AP, NCARB

Rebuild 10-12-2023

1450° C

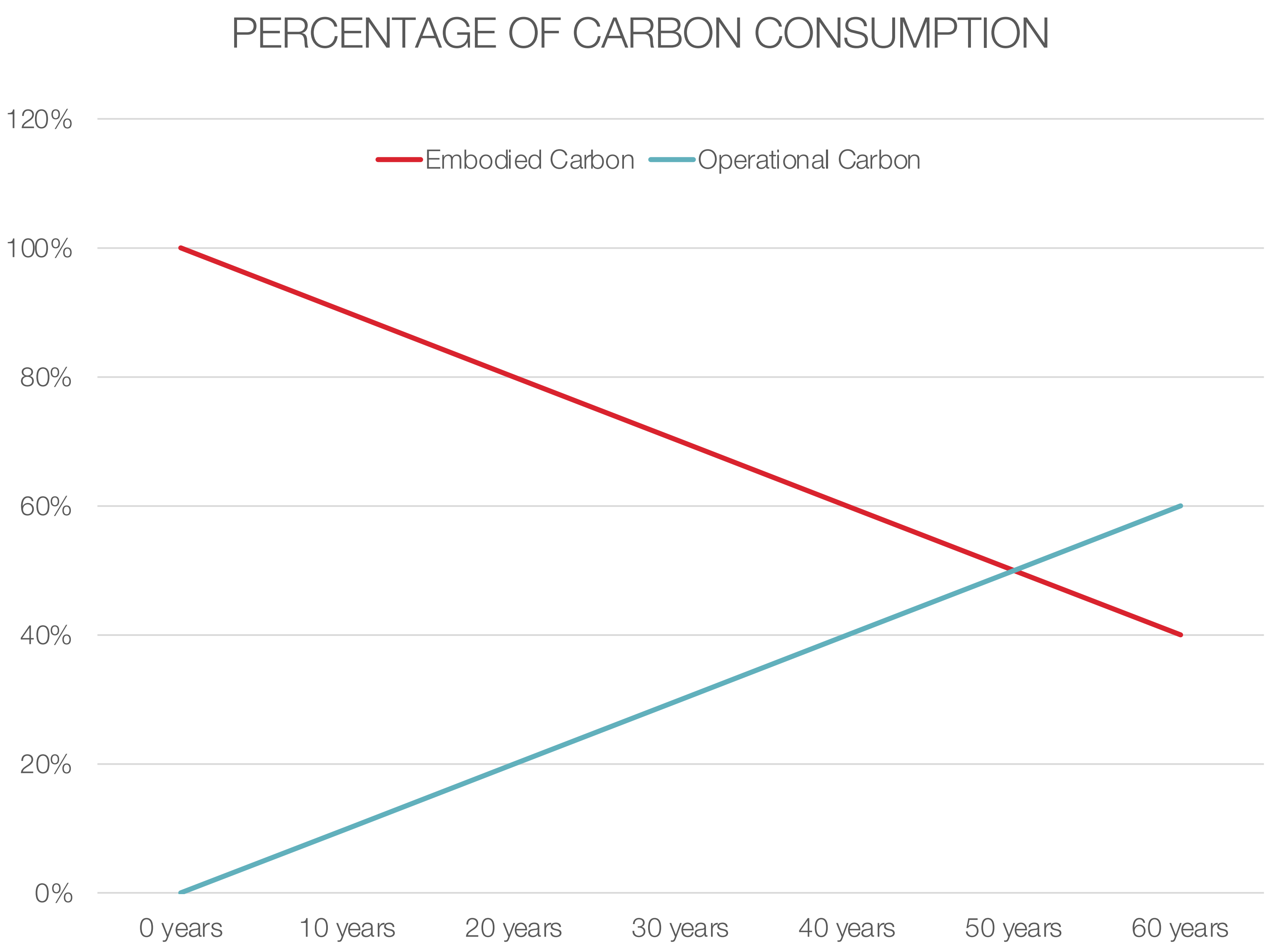
Alfred T. Palmer, Public domain, via Wikimedia Commons

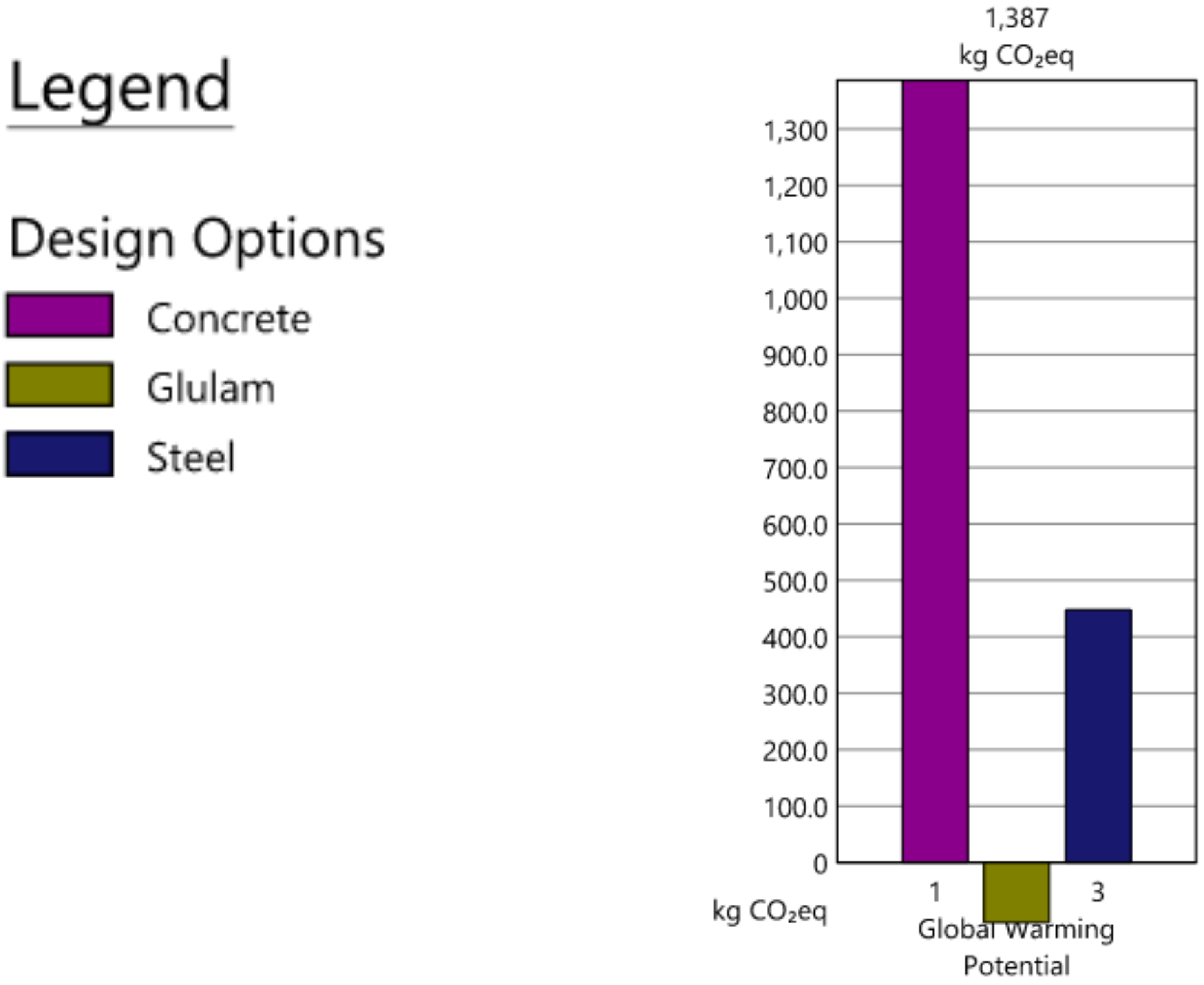
ACCORDING TO ARCHITECTURE 2030, TOTAL ANNUAL GLOBAL C02 EMISSIONS INCLUDE:

BUILDING OPERATIONS: 27%

CEMENT, IRON/STEEL, AND ALUMINUM PRODUCTION: 15%

Embodied carbon is today





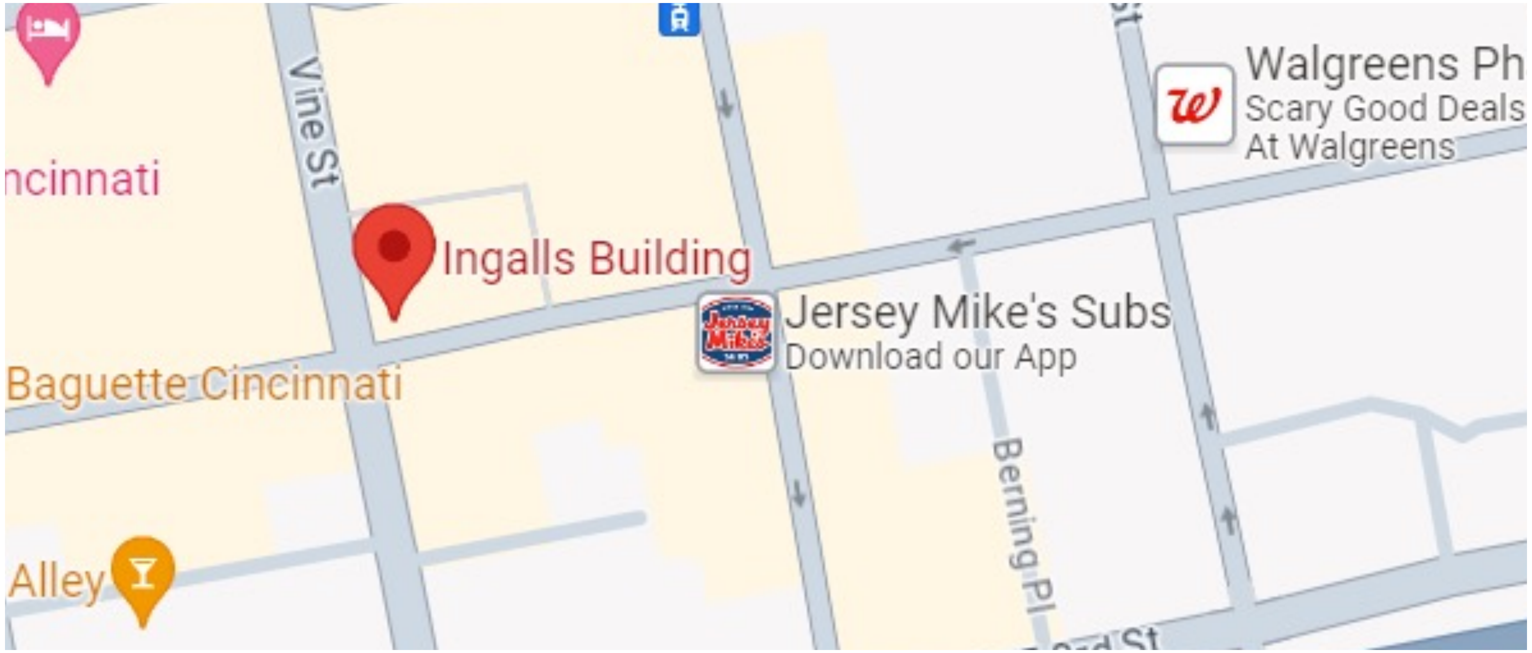
Legend
Design Options
Concrete
Glulam
Steel
1,387
kg CO₂eq
1,300
1,200
1,100
1,000
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0
kg CO₂eq
1
3
Global Warming
Potential

“When the end of the world comes, I want to be in Cincinnati because it’s always twenty years behind the times.” (Mark Twain)

From Life magazine, Aug. 9, 1883

Where is the first concrete high-rise in the world?

Where is the first concrete high-rise in the world?



Cincinnati

Credit: wikipedia

Where is the first concrete high-rise in the world?

Cincinnati

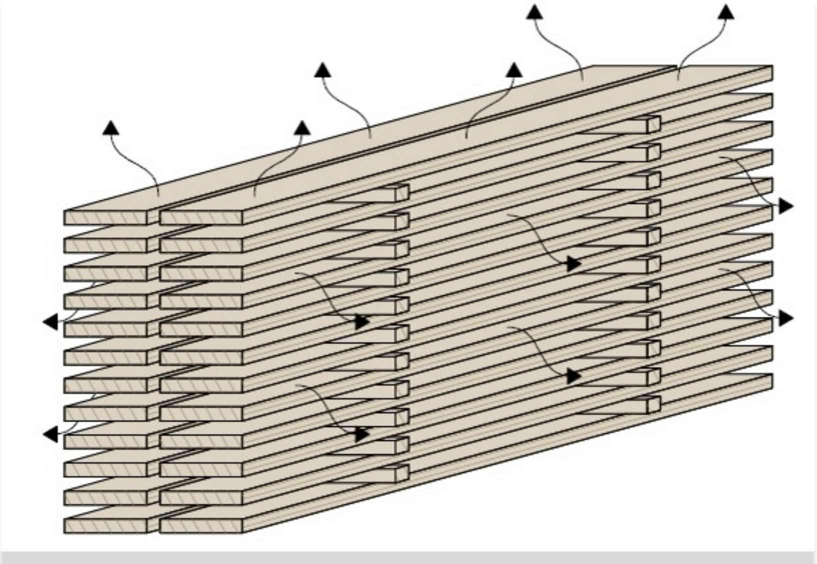
learning objectives

- Consider potential applications of CLT based on its structural characteristics, including strength + shrinkage properties
- Determine how CLT impacted the Redstone Arsenal project with regard to schedule, site + labor constraints, and building performance objectives
- Discuss lessons learned during the design + construction processes and considerations for future projects
- Review the Life Cycle Analysis on the Cincinnati Public Radio project

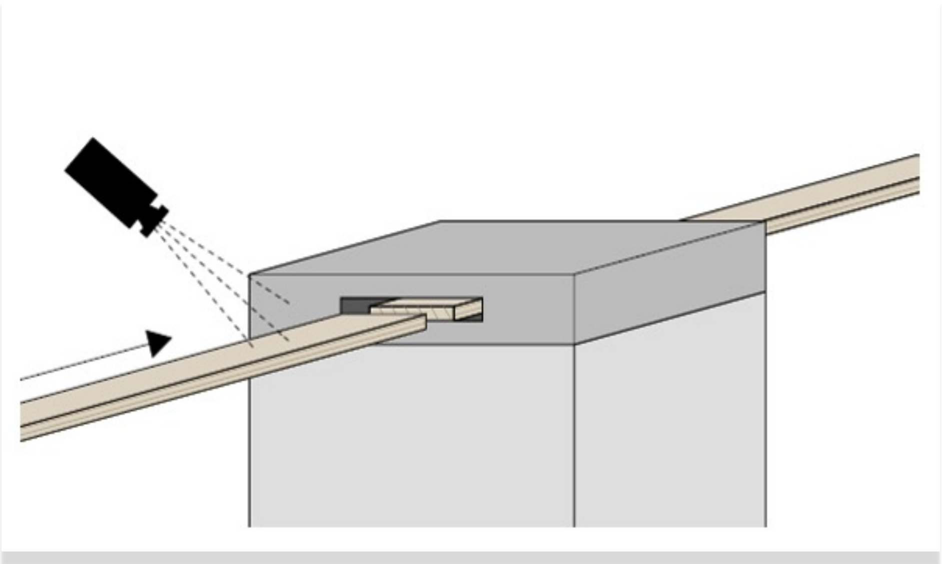
CLT basics

CLT basics | steps 1 + 2

> Kiln drying
  12% +/- 3%

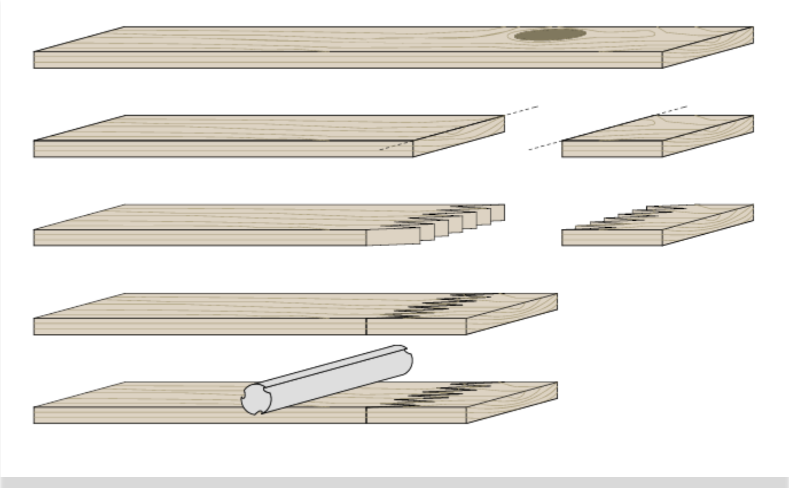


> Grading
  Visual or MSR

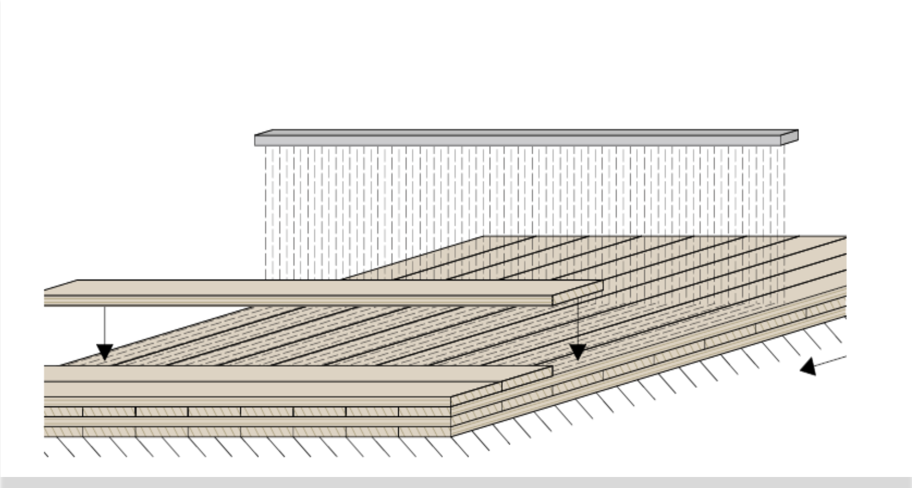


CLT basics | steps 3 + 4

> Strength optimization
> Finger-jointing
> Planing / sanding

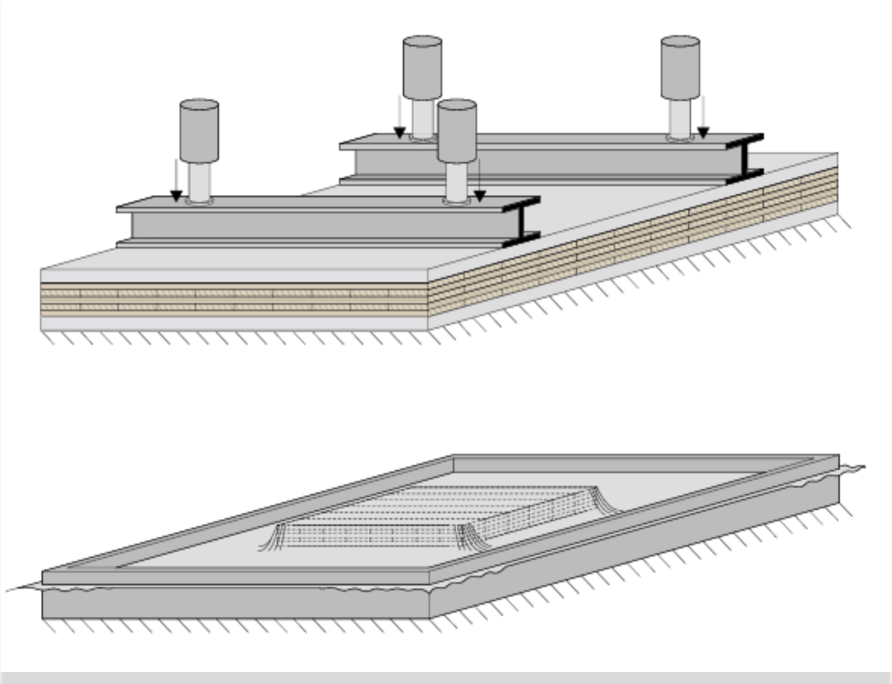


> Pressure rack loading
> Glue application (PUR/MUF)

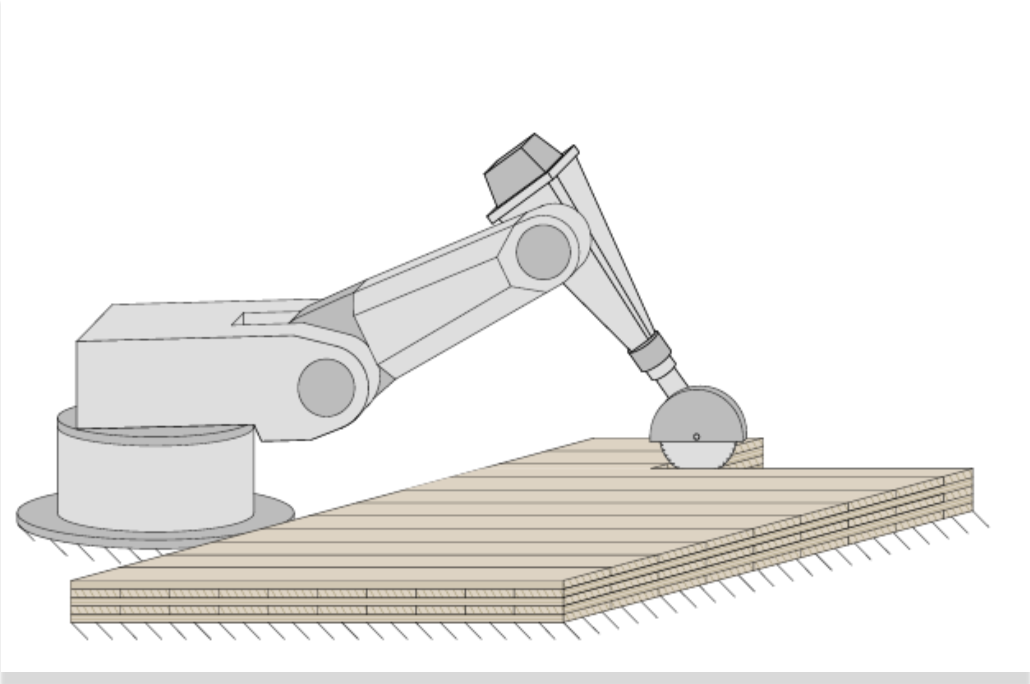


CLT basics | steps 5 + 6

- Pressure application
- Hydraulic / vacuum



- CNC / robot
- Cut to final size



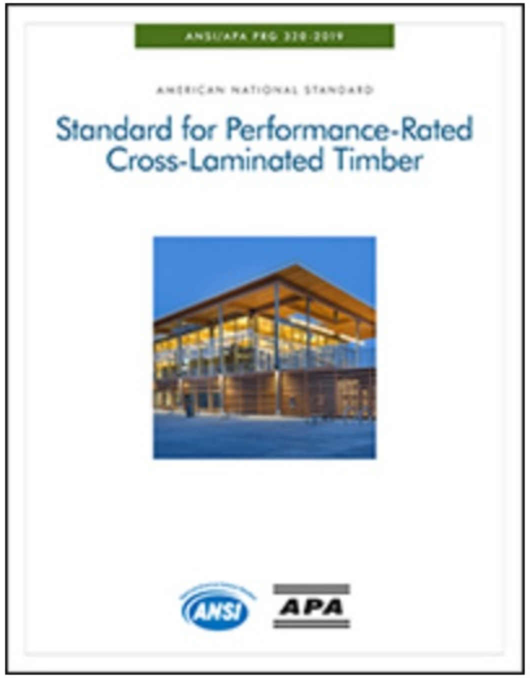
CLT basics

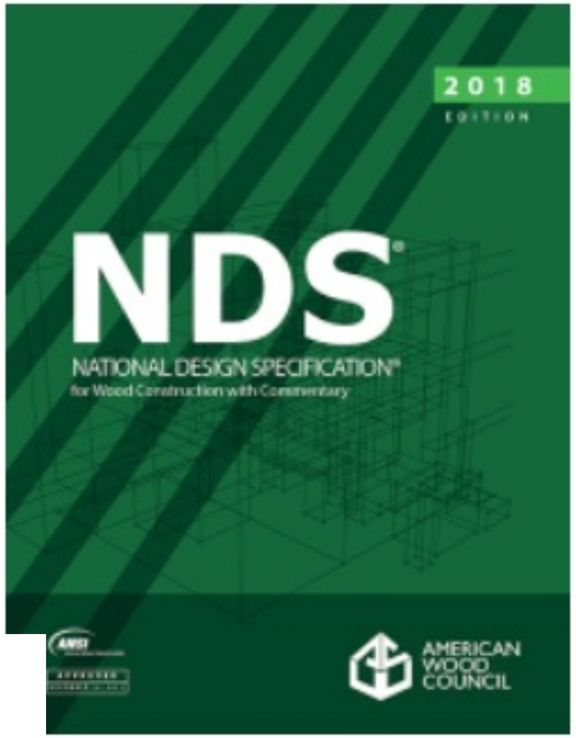
Design Resources:

ANSI/APA PRG-320 | Standard for Performance-Related Cross Laminated Timber

CLT Handbook

2018 NDS | Chapter 10

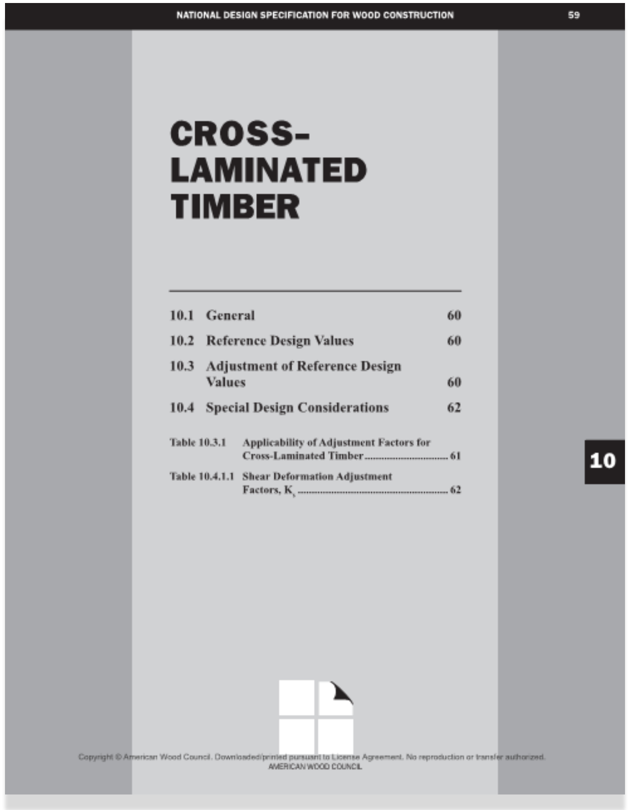




CLT basics

Design Resources:

2018 NDS | Chapter 10



NATIONAL DESIGN SPECIFICATION FOR WOOD CONSTRUCTION 59

CROSS-LAMINATED TIMBER

10.1	General	60
10.2	Reference Design Values	60
10.3	Adjustment of Reference Design Values	60
10.4	Special Design Considerations	62
Table 10.3.1	Applicability of Adjustment Factors for Cross-Laminated Timber	61
Table 10.4.1.1	Shear Deformation Adjustment Factors, K_s	62

10

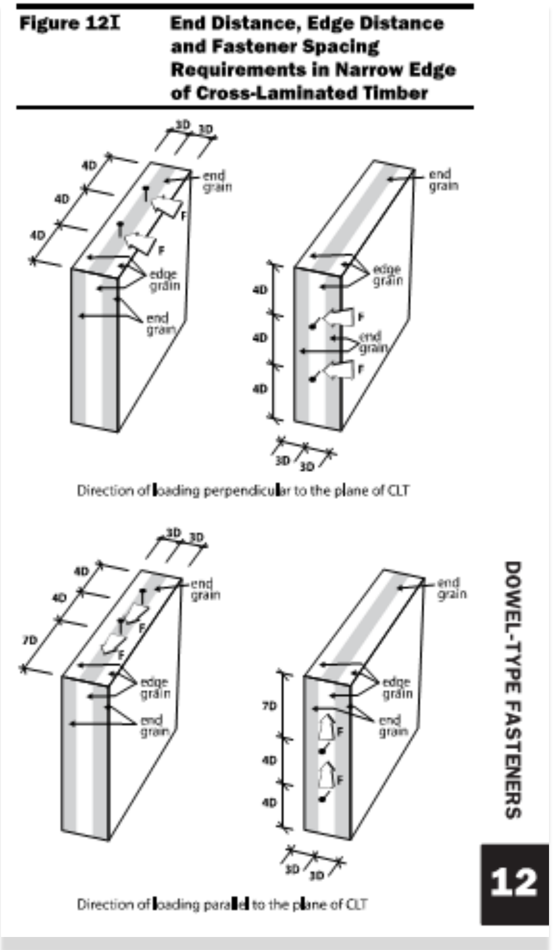


TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANEa

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION											TYPE OF CONSTRUCTION	TYPE OF CONSTRUCTION
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
		A	B	A	B	A	B	A	B	C	HT	A	B
A, B, E, F, M, S, U	NSb	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
H-1, H-2, H-3, H-5	NSc, d	UL	160	65	55	65	55	120	90	65	65	50	40
	S												
H-4	NSc, d	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	140	100	85	85	70	60
I-1 Condition 1, I-3	NSd, e	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	180	120	85	85	70	60
I-1 Condition 2, I-2	NSd, e, f	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85									
I-4	NSd, g	UL	160	65	55	65	55	65	65	65	65	50	40
	S	UL	180	85	75	85	75	270	180	85	85	70	60
Rh	NSd	UL	160	65	55	65	55	65	65	65	65	50	40
	S13D	60	60	60	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	270	180	85	85	70	60

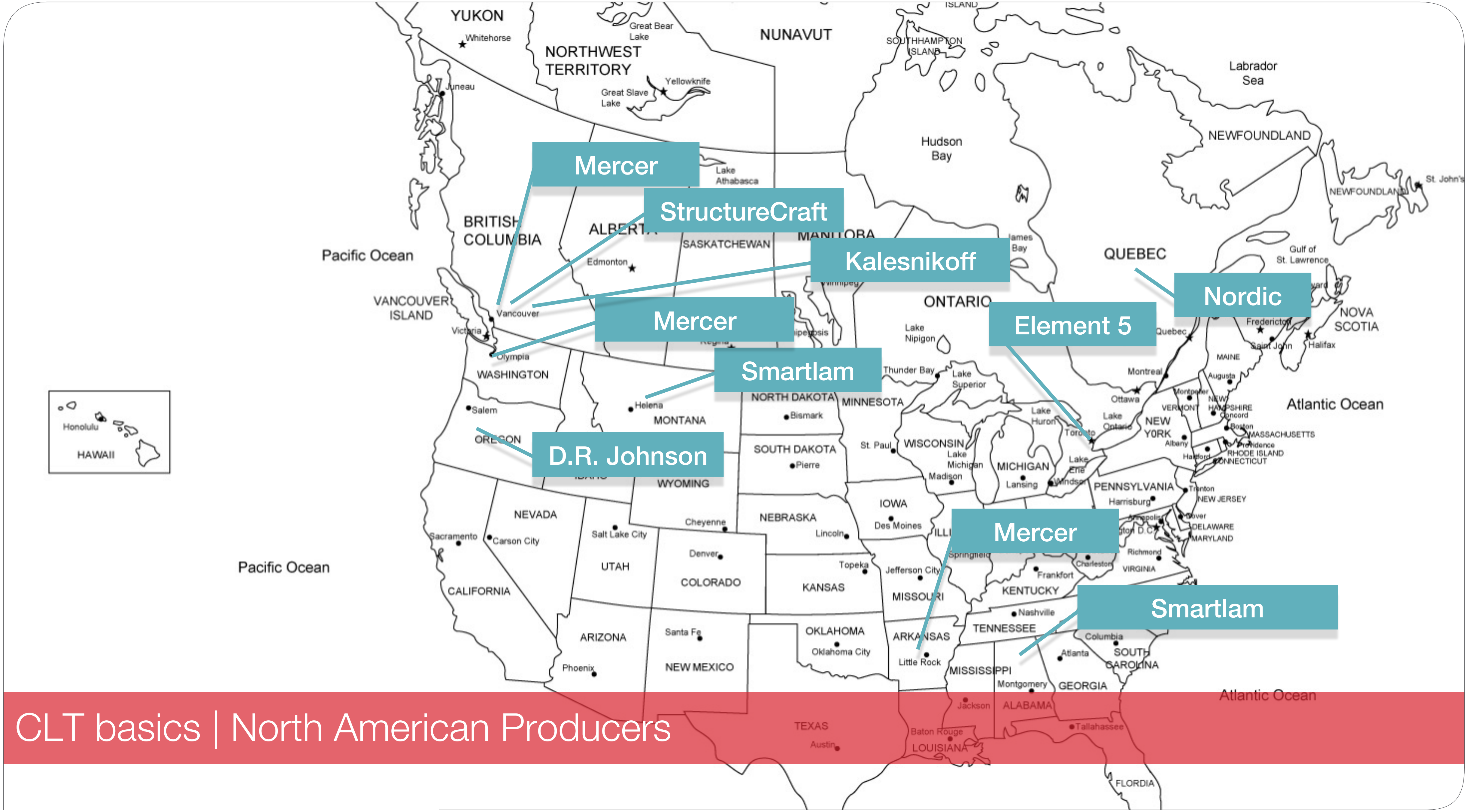
For SI: 1 foot = 304.8 mm.

UL = Unlimited; NS = Buildings not equipped throughout with an automatic sprinkler system; S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1; S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2; S13D = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.3.

TABLE 504.4
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANEa, b

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION										TYPE OF CONSTRUCTION	TYPE OF CONSTRUCTION	TYPE OF CONSTRUCTION
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE IV	TYPE IV	TYPE IV	TYPE V	
		A	B	A	B	A	B	A	B	C	HT	A	B
R-1 h	NSd	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4									4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
R-2h	NSd	UL	11	4	4	4	4	4	4	4	4	3	2
	S13R	4	4	4								4	3
	S	UL	12	5	5	5	5	18	12	8	5	4	3
R-3h	NSd	UL	11	4	4	4	4	4	4	4	4	3	3
	S13D	4	4									3	3
	S13R	4	4									4	4
	S	UL	12	5	5	5	5	18	12	5	5	4	4
R-4h	NSd	UL	11	4	4	4	4	4	4	4	4	3	2
	S13D	4	4									3	2
	S13R	4	4									4	3
	S	UL	12	5	5	5	5	18	12	5	5	4	3
S-1	NS	UL	11	4	2	3	2	4	4	4	4	3	1
	S	UL	12	5	3	4	3	10	7	5	5	4	2
S-2	NS	UL	11	5	3	4	3	4	4	4	4	4	2
	S	UL	12	6	4	5	4	12	8	5	5	5	3
U	NS	UL	5	4	2	3	2	4	4	4	4	2	1
	S	UL	6	5	3	4	3	9	6	5	5	3	2

CLT basics | North American Producers



CLT basics | north american producers

> Mercer

- Maximum panel size 10ft x 40ft (BC)
- Maximum panel size 10ft x 60ft (Ark)

> Nordic

- Maximum panel size 8ft x 64ft

> D.R. Johnson

- Maximum panel size 10ft x 24ft
- Working to increase maximum panel size

> Mercer

- Maximum panel size 10ft 6in x 41ft 4in
- Working to increase to 10ft x 50ft

> StructureCraft

- Maximum panel size 8ft x 64ft

> Others – New Facilities popping up all around + European Suppliers as well

CLT basics | strength

TABLE A1

ASD REFERENCE DESIGN VALUES[a] FOR LAMINATIONS USED IN BASIC CLT GRADES

CLT Grade	Laminations Used in Major Strength Direction						
	F_b (psi)	E [(b)] (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	F_b (psi)
E1	1,950	1.7	1,375	1,800	135	45	500
E2	1,650	1.5	1,020	1,700	180	60	525
E3	1,200	1.2	600	1,400	110	35	350
E4	1,950	1.7	1,375	1,800	175	55	450
E5	1,650	1.5	1,020	1,700	150	50	500
V1	900	1.6	575	1,350	180	60	525
V1(N)	850	1.6	500	1,400	180	60	475
V2	875	1.4	450	1,150	135	45	500
V3	750	1.4	450	1,250	175	55	450
V4	775	1.1	350	1,000	135	45	450
V5	850	1.3	525	1,300	150	50	500
S1	2,250	1.5	1,500	1,950	130	40	2,250
S2	1,900	1.3	1,300	1,650	150	50	1,900
S3	1,750	1.3	1,200	1,500	115	35	1,750

For SI: 1 psi = 0.006895 MPa

a. The ASD reference design values for laminations in the basic CLT grades made of visually graded lumbe limit the lamination sizes used, the ASD reference design values for laminations in basic CLT grades are r adjustment factors when calculating the ASD reference design properties for basic CLT grades provided i

b. The tabulated E values are published E for lumber and flatwise (plank) apparent E for SCL.

CLT basics | strength

Wall

CrossLam® Wall Panel Load Table (Axial Loading Only)				
Panel d (in)	SLT3	SLT5	SLT7	SLT9
	3.90	6.66	9.42	12.18
L (ft)	**Pr (lbs/ft)**			
6	31062	51778	71115	90263
8	26993	50462	70352	89724
10	21381	48275	69224	88968
12	16393	44782	67581	87938
14	12688	39887	65209	86551
16	10021	34344	61864	84689
18		29124	57440	82206
20		24667	52187	78947
22		21005	46663	74823
24		18028	41385	69917
26		15603	36626	64514
28			32464	58993
30			28871	53670

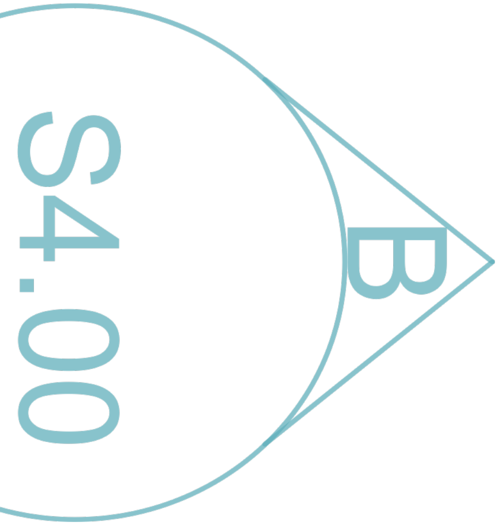
CLT basics | strength

P

Concentric end loads
Allowable uniform load P (lbf)

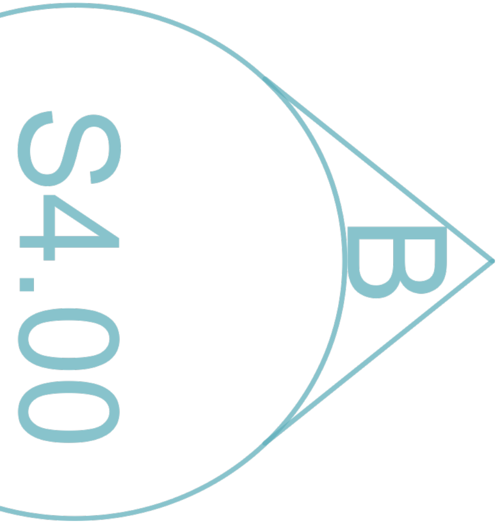
L (ft)	Major strength direction Layup Combinaison 78-3s	105-3s	131-5s	175-5s
6	29 730	49 150	59 300	83 490
7	24 930	44 990	56 780	82 020
8	20 720	40 130	53 370	80 090
9	17 270	35 200	49 140	77 600
10	14 510	30 640	44 420	74 440
12		23 260	35 250	66 170
14		17 960	27 810	56 520
16			22 190	47 360
18			17 980	39 590
20			14 790	33 270

POLL QUESTION



Both wood and concrete shrink…
which material shrinks more?

POLL QUESTION



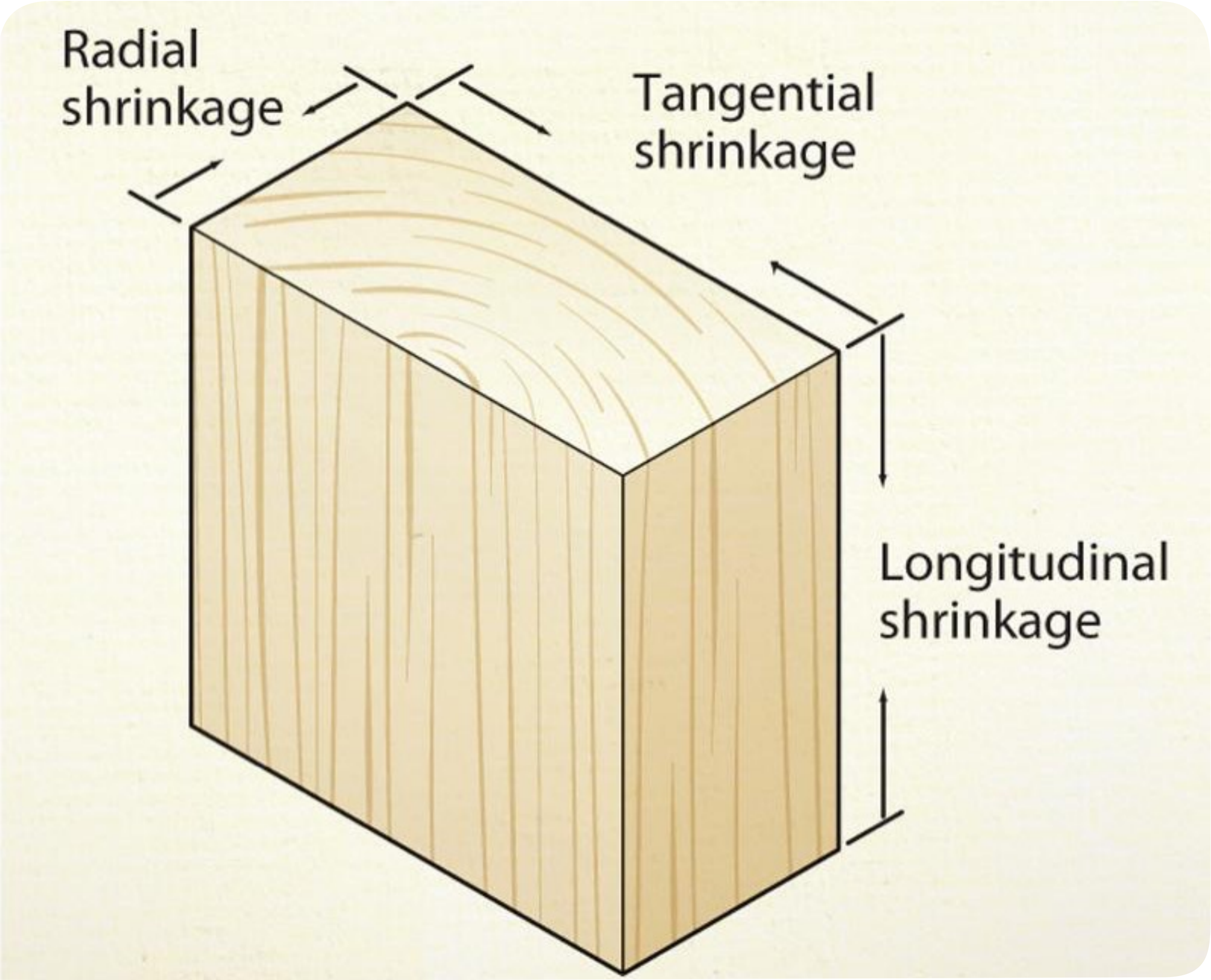
Both wood and concrete shrink…
which material shrinks more?

It depends!

CLT basics | shrinkage

Amount of Shrinkage for 30% Change in MC	
Radial	4-5%
Tangential	7-8%
Longitudinal	0.1-0.2%

> 40 times less shrinkage in longitudinal direction than the average radial/tangential direction



CLT basics | shrinkage

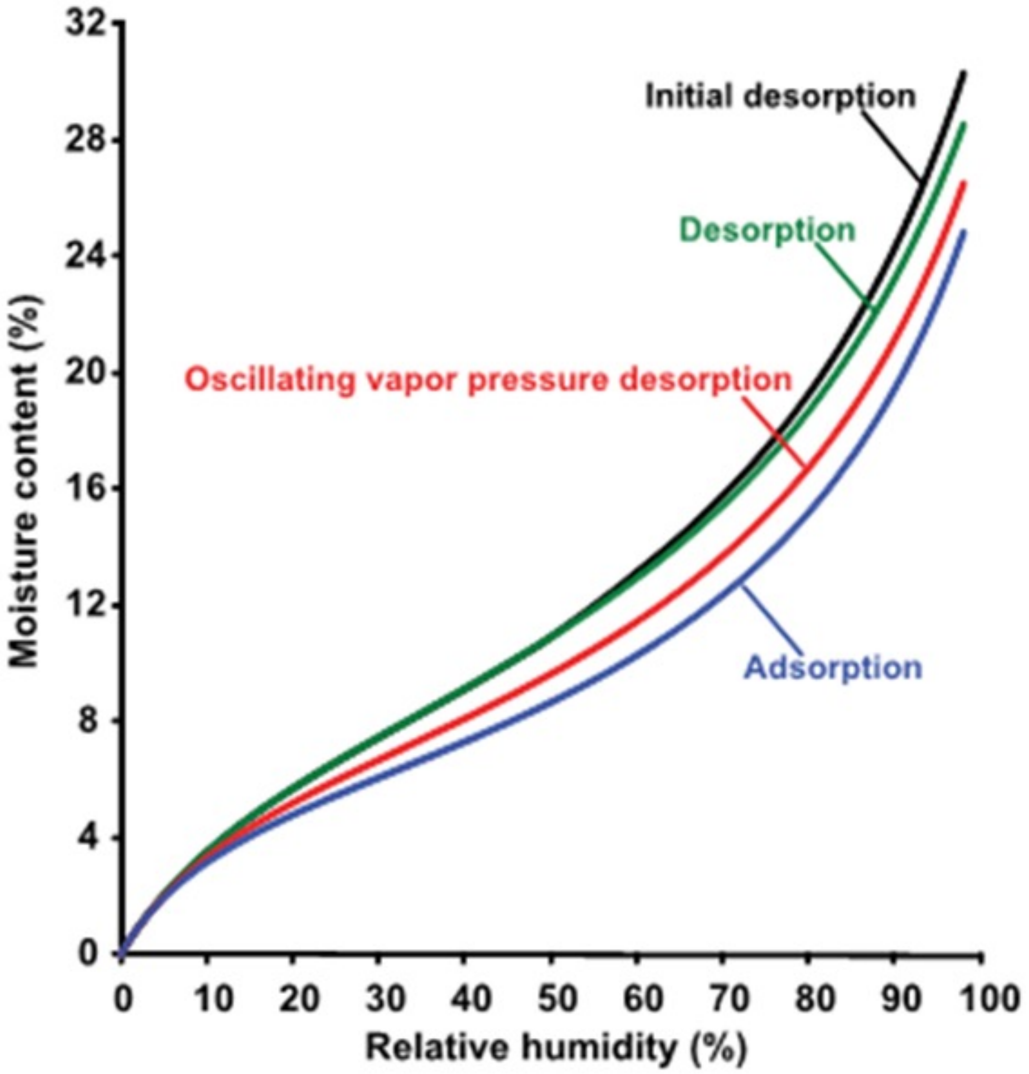
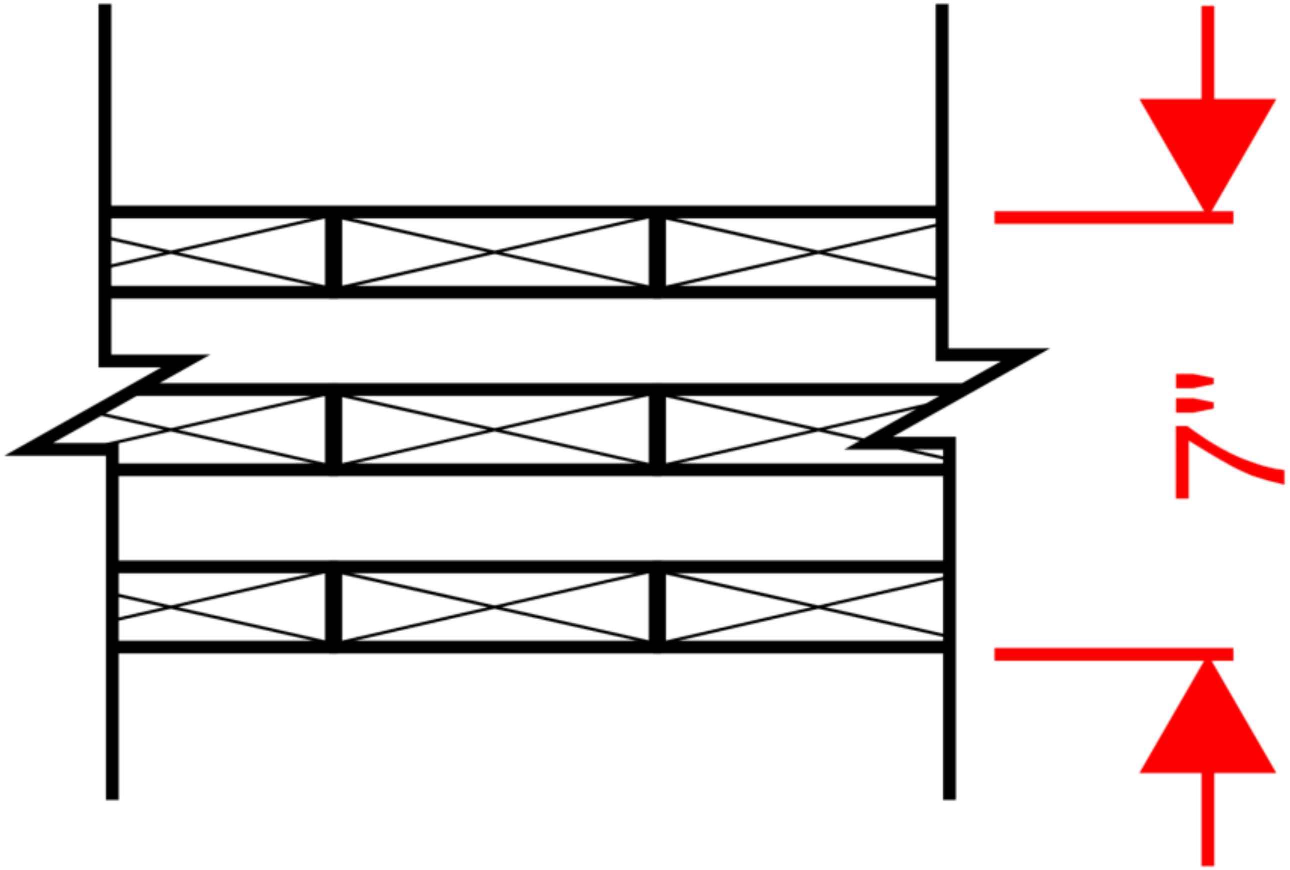


Figure 4–2. Moisture content–relative humidity relationship for wood under adsorption and various desorption conditions.

CLT basics | vertical shrinkage



0.06”
shrinkage

CLT basics | horizontal shrinkage

>CLT: ¼" over 100-feet

>Concrete: 5/8" over 100 ft

>Takeaway | CLT shrinks less than concrete

CLT basics | shrinkage

CLT basics | shrinkage

CLT basics | shrinkage calculation at Redstone

	Cumulative Shrinkage (inches)
Top of First Floor Wall	0.03
Top of Second Floor	0.05
Top of Second Floor Wall	0.08
Top of Third Floor	0.11
Top of Third Floor Wall	0.13
Top of Fourth Floor	0.16
Top of Fourth Floor Wall	0.19
Top of Roof	0.20

candlewood suites at redstone arsenal

the team

owner	Rest Easy LLC c/o Lend Lease US Public Partnerships
design/build contractor	Lend Lease US Public Partnerships
architect/MEP/civil/fire	Leidos Engineering
structural engineer	**Schaefer** Nordic
CLT supplier	Nordic

why mass timber

- Acoustics
- Building performance
- Speed of construction
- Dimensionally stable
- Extends construction season

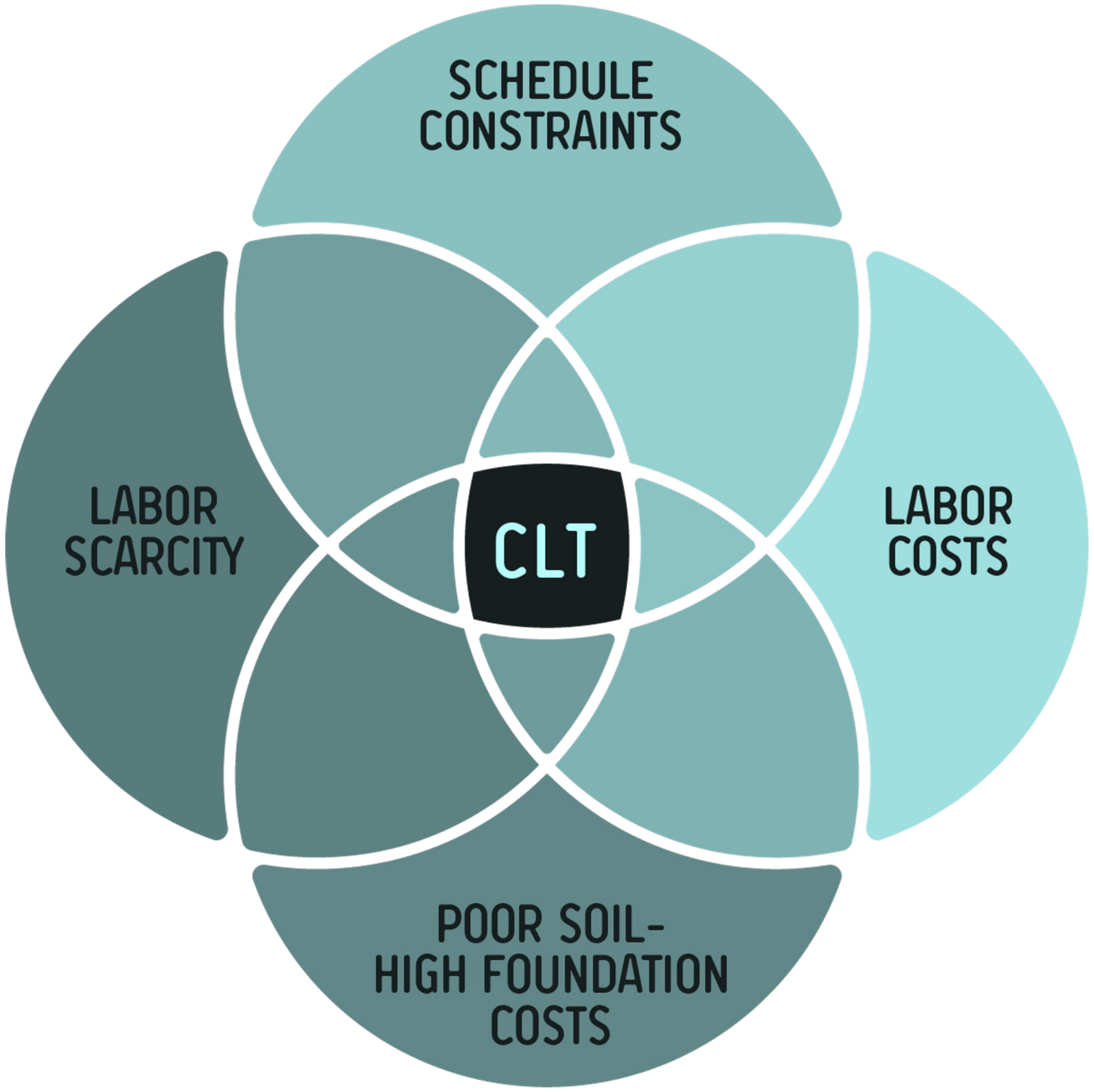
- Less labor
- Light weight
- Less foundations
- Lighter cranes
- Highly mechanized production-accurate

why mass timber

- Reduce onsite inventory
- Reduce pilferage
- Clean, safe worksite
- Conventional tools + connectors
- Carpenters
- Reduced high risk work
- No formwork
- Reduced site impact
- Renewable Resource
- Increase Forestry Demand

market sector strategies

- > The sweet spot
- > CLT should be strongly considered when a project experiences 3/4 of these conditions



the CLT optimal spectrum

residential | hospitality

1-5 stories
wood stick frame
metal stud frame

residential | office | hospitality

6-10 stories
CLT

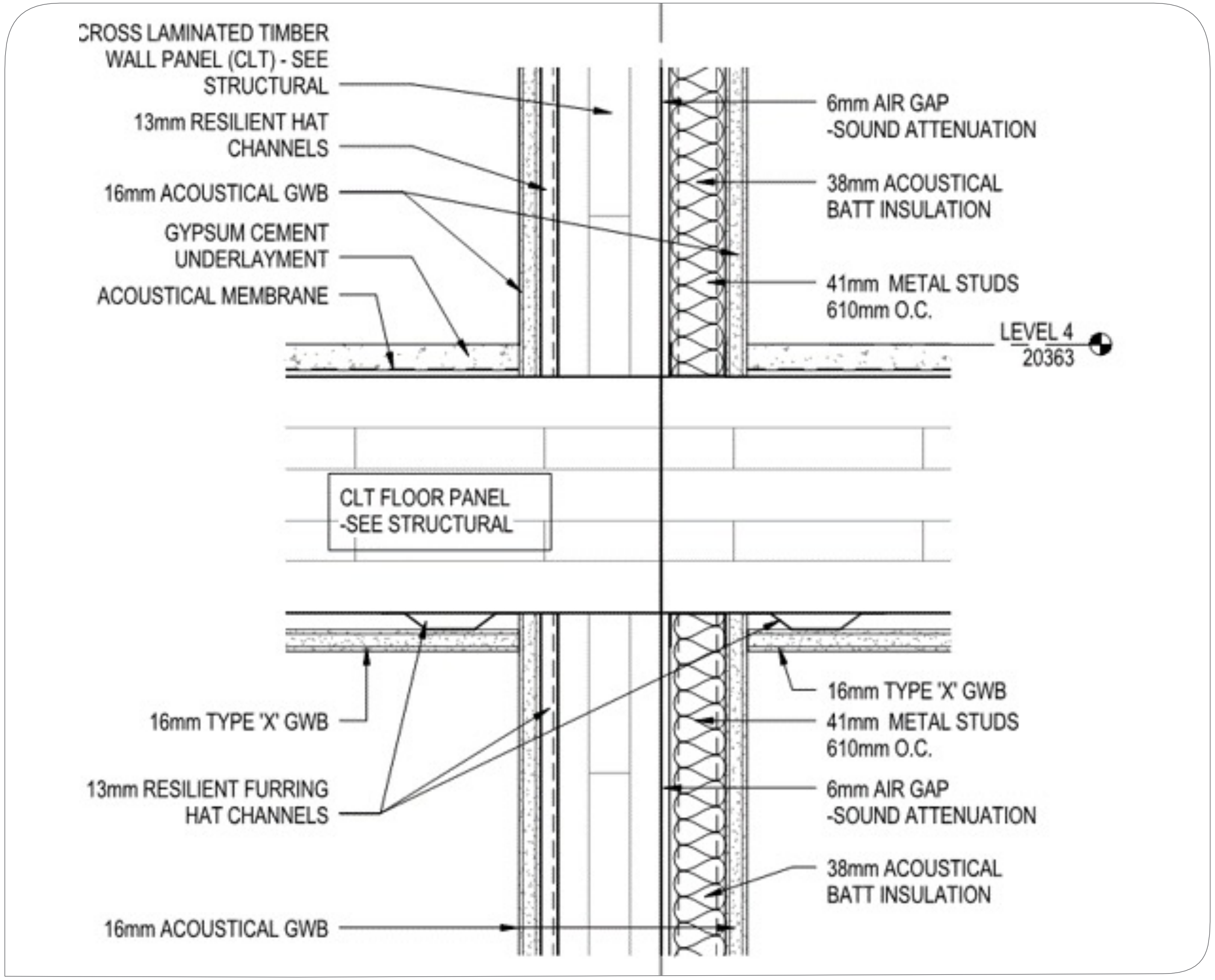
residential | office

10+ stories
concrete | steel

*When all development, design + construction costs are aggregated, the schedule savings achieved through CLT with other speed + value-added solutions can be cost competitive in 1-5 stories construction

why CLT
acoustics

- Quiet construction site
- Higher measured STC than anticipated



shear wall holdowns | sill detail

stair shafts

stair shafts

second floor framing


second floor framing

second floor installation

second floor installation

wood stairs – view from below

stair shaft installation

preinstalled screws | platform construction

roof + parapet installation

exterior

exterior

takeaways

PAL Portfolio	Typical New PAL Hotel (actual*)	Redstone Arsenal (actual)	Difference
gross sq ft	54,891	62,688	+14%
average number of employees	18 (peak 26)	10 (peak 11)	-43%
structural duration (days)	123	78	-37%
structural man hours	14,735	8,203	-44%
structural production rate/day (sq ft)	460 sq ft/day	803 sq ft/day	+75%
overall schedule	15 months	12 months	-20%

takeaways

> Economic

- 37% faster than traditional metal stud construction
- Cost neutral to metal stud framing on military installations

> Environmental

- 31% more energy efficient than previous PAD new hotels of similar size per current energy model
- 1,656 tons carbon sequestered (1m3 of timber = 1 ton CO2)

> Social

- Unemployed veterans upskilled in construction trades
- Eliminated exposure to falls for workers from elevated heights

where to next?

> What is most important to the owner/end user?

- Initial cost
- Operating cost
- Efficiency
- Speed
- Long-term durability
- Acoustics
- Sustainability

where to next?

buffalo harbor center | buffalo, new york

where to next?

michigan state university
STEM teaching, learning
+ interdisciplinary
research facility

where to next?

michigan state university STEM teaching, learning + interdisciplinary research facility

where to next?

90 arboretum | newington, new hampshire

where to next?

princeton university art museum | princeton, new jersey

Photos Credit Adjaye Associates

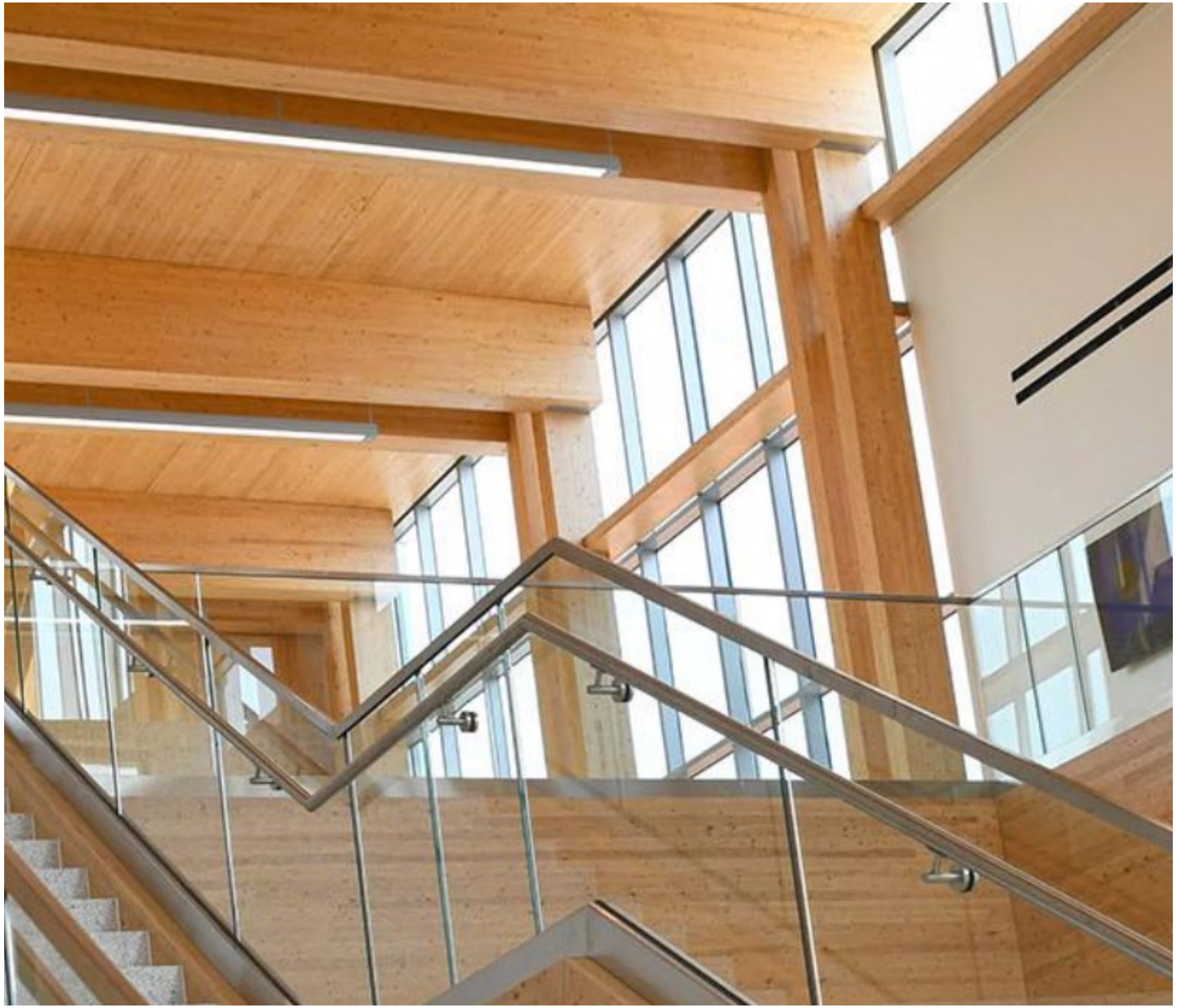
where to next?

brown university | providence, rhode island

Photos Credit Shawmut

where to next?

san jacinto college | texas



where to next?

university of pennsylvania | philadelphia, pennsylvania

Photos Credit Lake Flato Architecture

where to next?

salvagnini | hamilton, ohio

where to next?

salvagnini |
hamilton, ohio

where to next?
salvagnini |
hamilton, ohio

where to next?

salvagnini |
hamilton, ohio

where to next?

salvagnini |
hamilton, ohio

where to next?

cincinnati public radio | cincinnati, ohio

CPR – Mass Timber and LEED Gold

view from evanston park

Site

eMERSION DESIGN
② ALSO, EXPRESSED SUSTAINABILITY
= FOCUS ON SHARED FUTURE
(GREEN ROOF, SOLAR, MASS TIMBER)
① GROUND PLANE LIFTED UP ON FOREST
GRID = CPR
ROOTED-NESS IN CINCI

view from dana & realistic

Stair and shear wall

Gathering/performance space

Performance studio


Heading to broadcast studios

On-air studio

Offices

view to lobby

view of entry – SE corner

LCA Phases

Majority of Emissions

Product Phase	Construction Phase	Use and Maintenance Phase	End-of-Life Phase
Raw material and transportation; Manufacturing	Transportation to site; Installation	Use and maintenance; Repair and refurbishment; Operational energy and water	Deconstruction and demolition; Transportation; Processing and disposal

ANALYSIS TOOL: TALLY

LEED MATERIAL RESOURCE CREDIT: BUILDING LIFE-CYCLE IMPACT REDUCTION

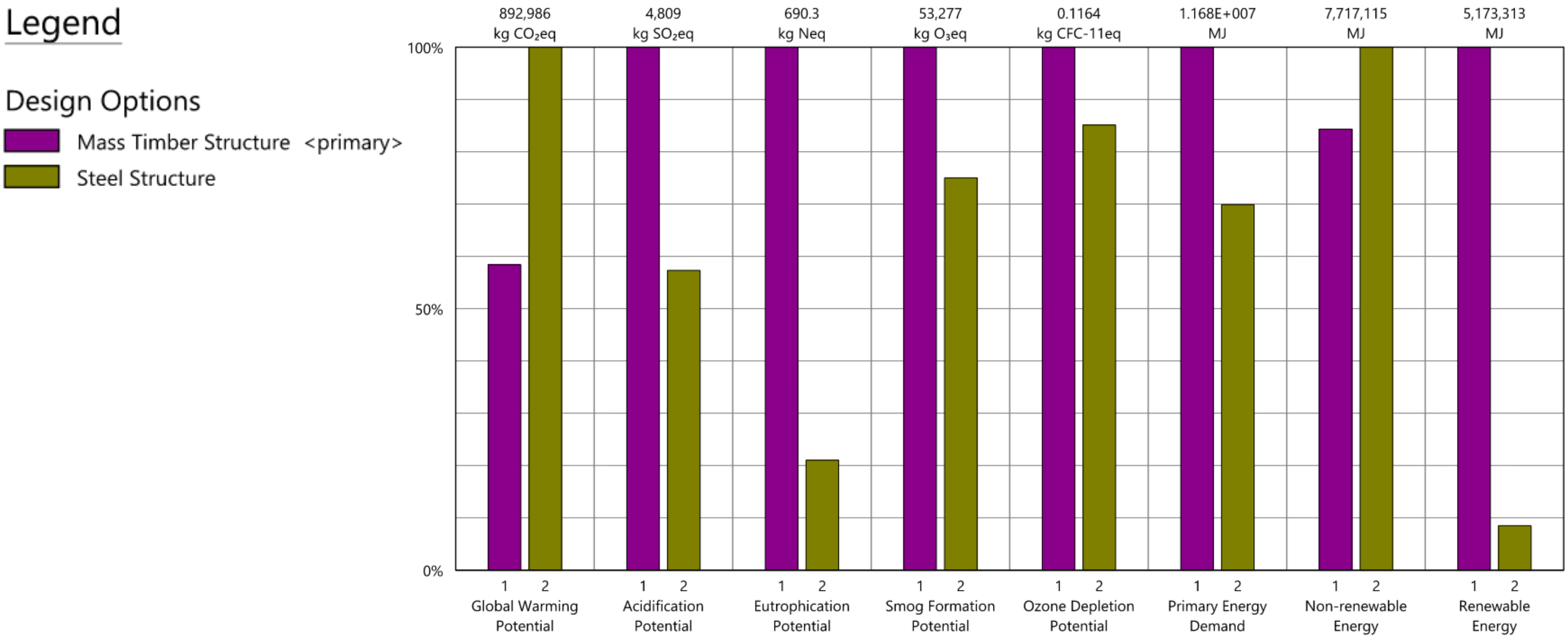
FSC WOOD

Environmental Product Declaration (EPD)

From Nordic Lam EPD for 1 cubic meter of glulam wood

Carbon Balance	Kg of CO2 equivalent
Forest Carbon Uptake	-741.36
Life-cycle GHG emissions	100.38
Unaccounted biogenic carbon emissions in GWP reporting	26.70
Net GWP	-614.27

Tally Results



Legend

Net value (impacts + credits)

Design Options

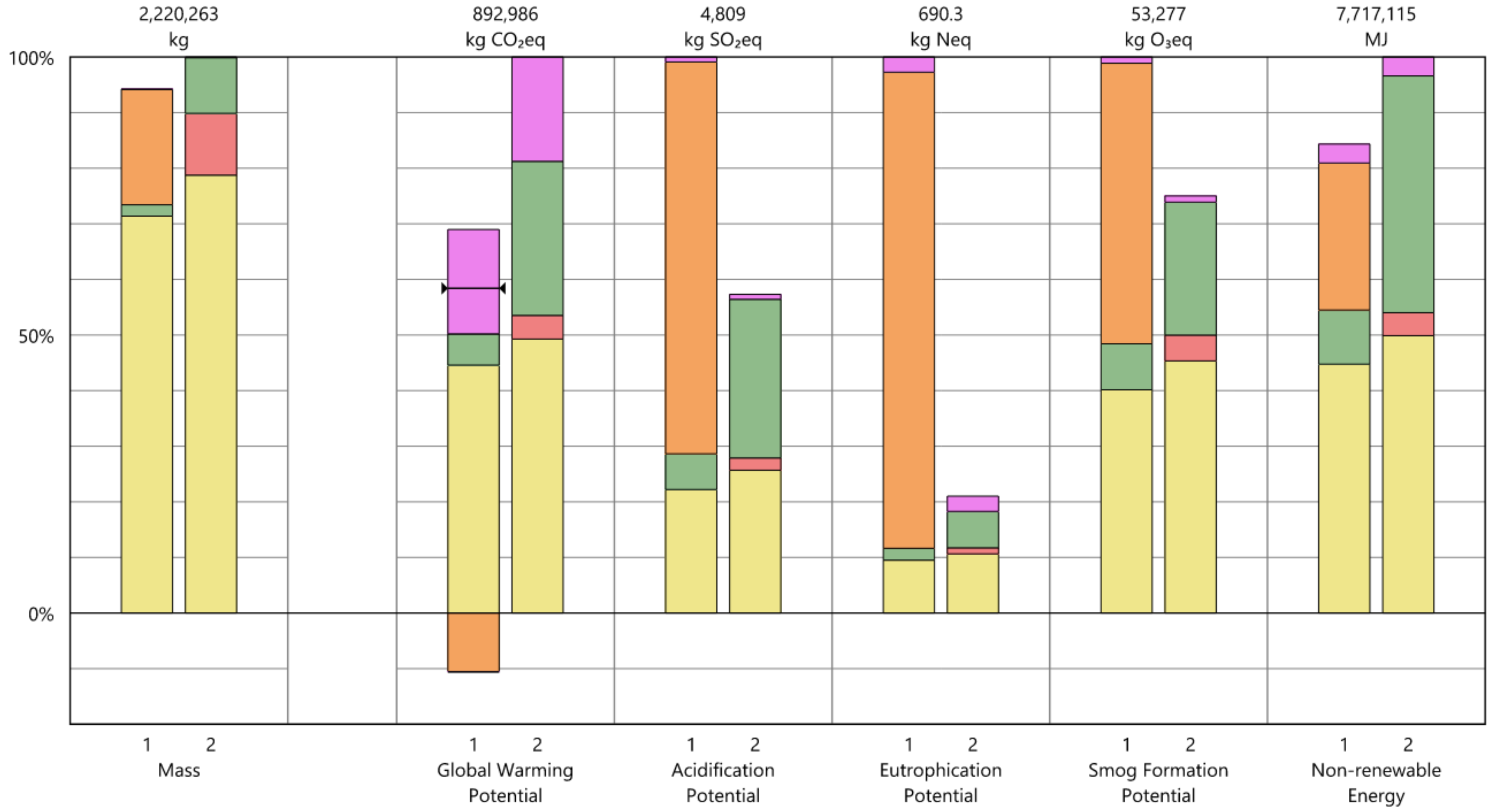
Option 1 - Mass Timber Structure <primary>

Option 2 - Steel Structure

Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 06 - Wood/Plastics/Composites
- 07 - Thermal and Moisture Protection

Results per Division



Legend

Net value (impacts + credits)

Design Options

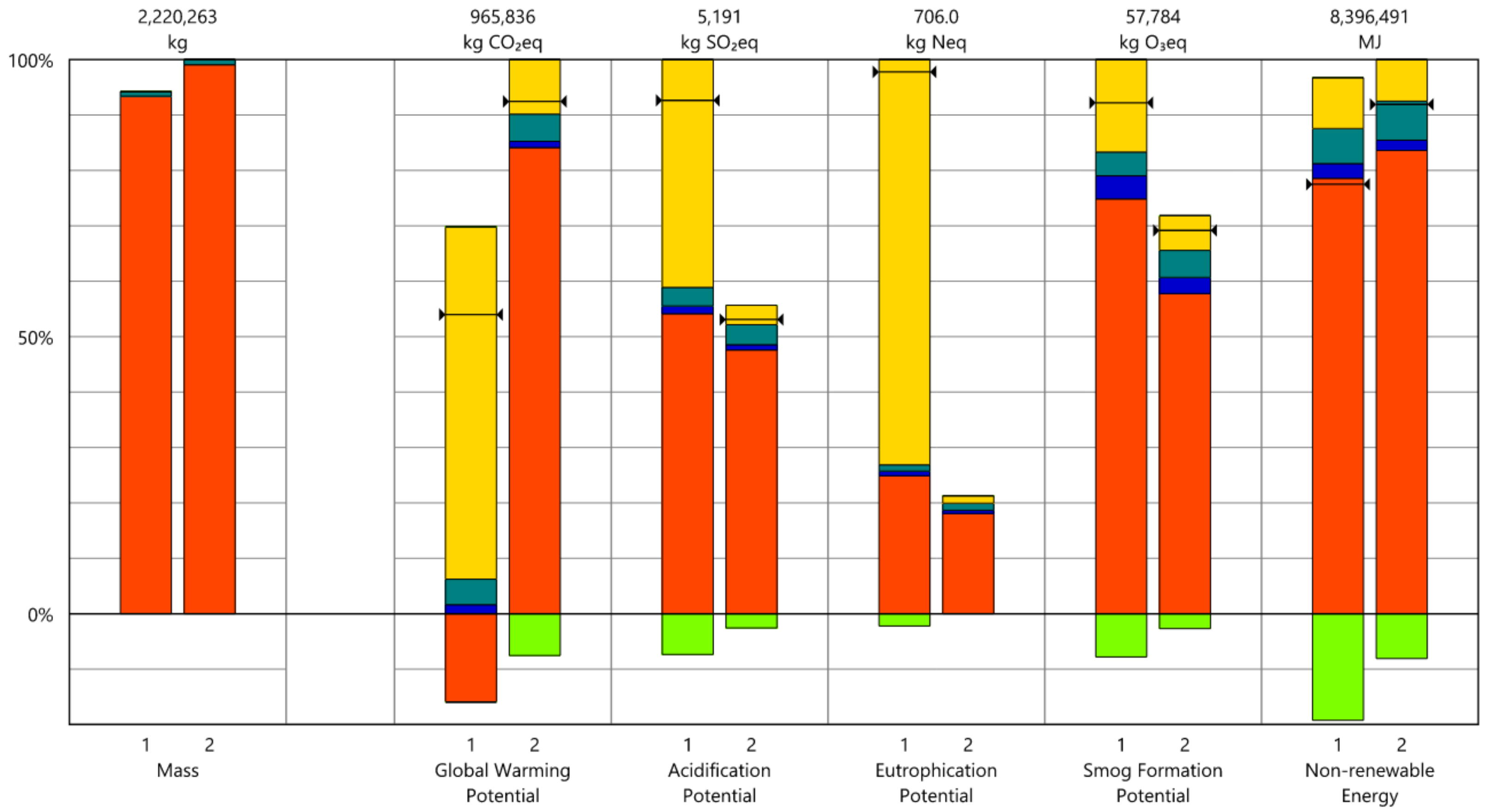
Option 1 - Mass Timber Structure <primary>

Option 2 - Steel Structure

Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]

Results per Life Cycle Stage



view from evanston park

schaefer

emersion DESIGN

questions?

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