Optimizing Steel and CLT for Seismic Performance

Solomon Tesfamariam
Professor, University of British Columbia

CTBUH 2022
Steel-Timber Conference

Optimizing Steel and CLT for Seismic Performance

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Principal's Research Chair in the Resilient and Sustainable Built Environment (Tier 1)

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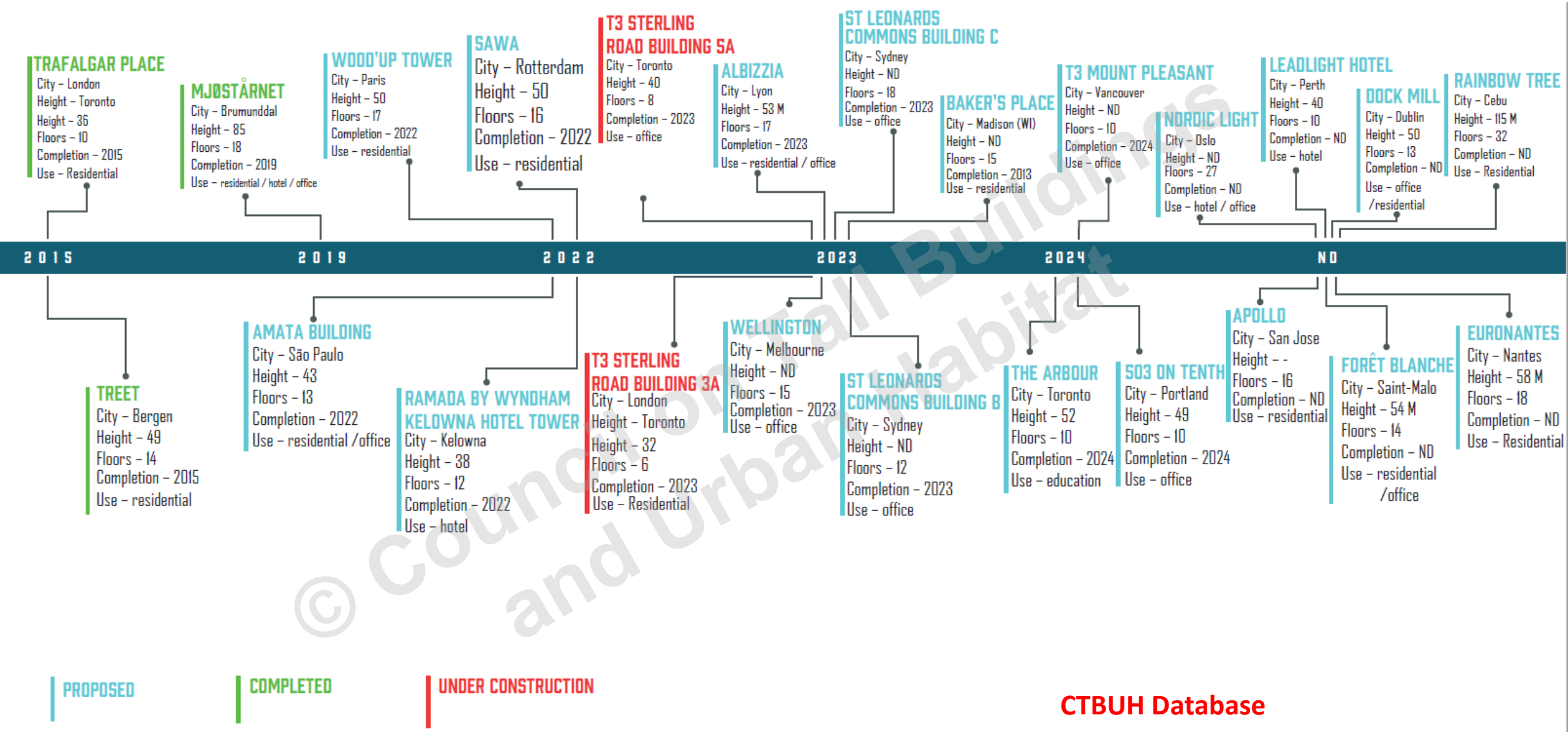
CTBUH 2022 Steel-Timber Hybrid Buildings Conference
23–24 May 2022 | Chicago

Motivation



CTBUH Database

FPInnovations' CLT Handbook

- State-of-the-art peer-reviewed technical source for designers that facilitates use of CLT as alternative solution (2013)

- Second edition (2019)

Origine, Quebec City (13 Stories, completed 2017)

https://www.thinkwood.com/our-projects/origine-tallest-wood-building-in-eastern-north-america

Brock Commons, UBC Vancouver (18 Stories, completed 2017)

https://www.thinkwood.com/our-projects/brock-commons-tallwood-house

Steel MRF – CLT Infills

FORCE BASED DESIGN GUIDELINE FOR TIMBER-STEEL HYBRID STRUCTURES:
STEEL MOMENT RESISTING FRAMES WITH CLT INFILL WALLS

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ACADEMIC COLLABORATOR
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Forestry Innovation Investment

FPInnovations

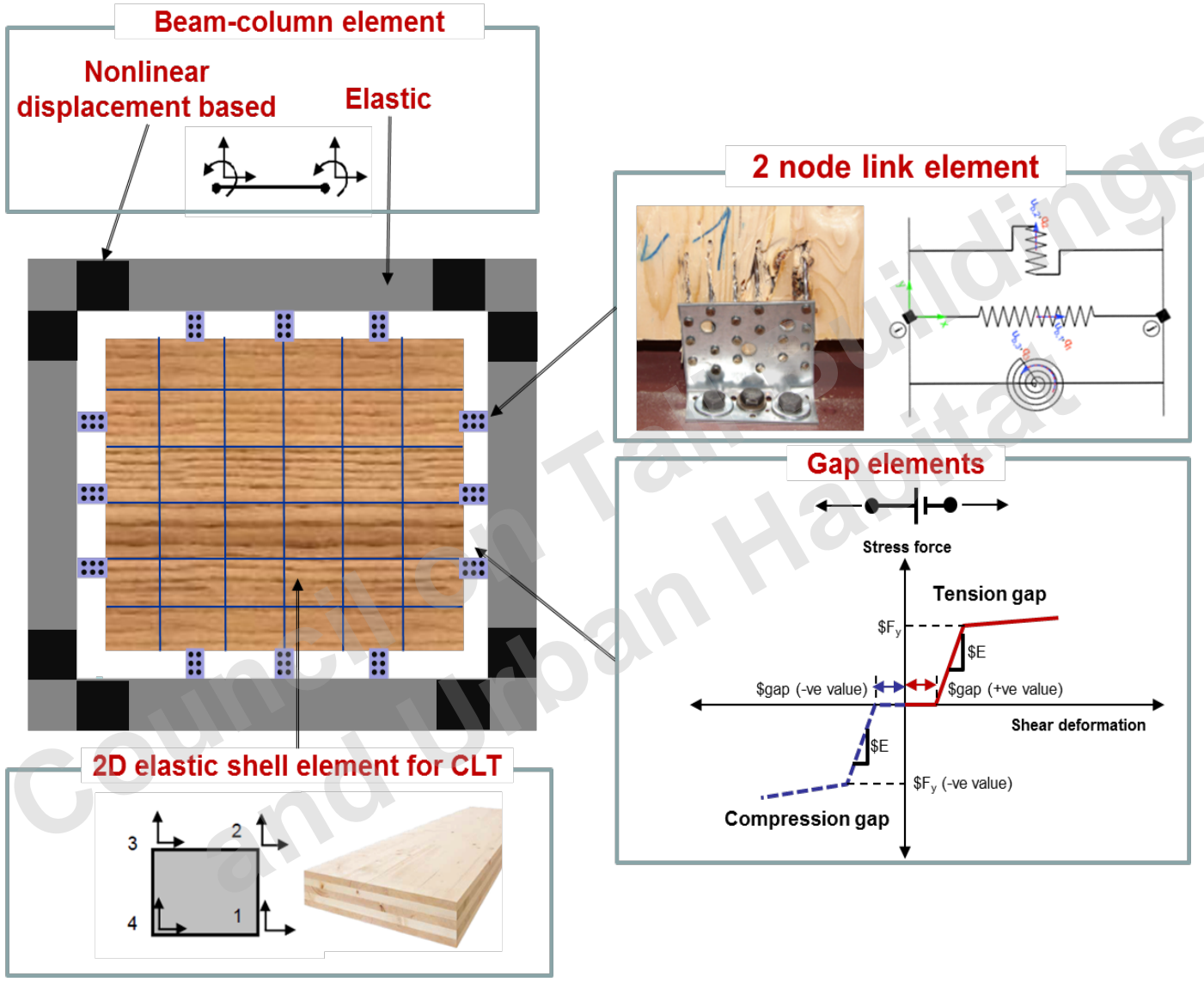
NSERC CRSNG

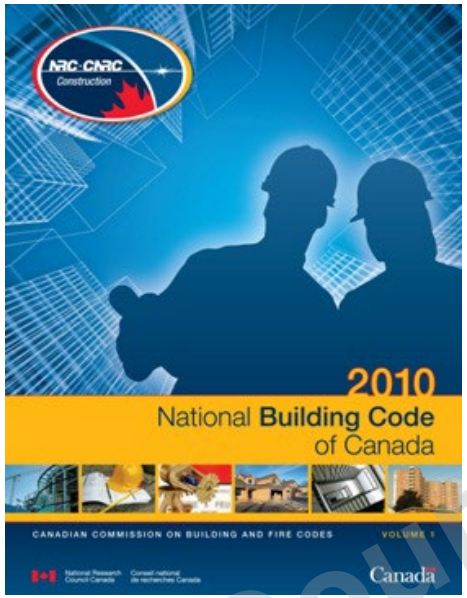
NEWBuildS

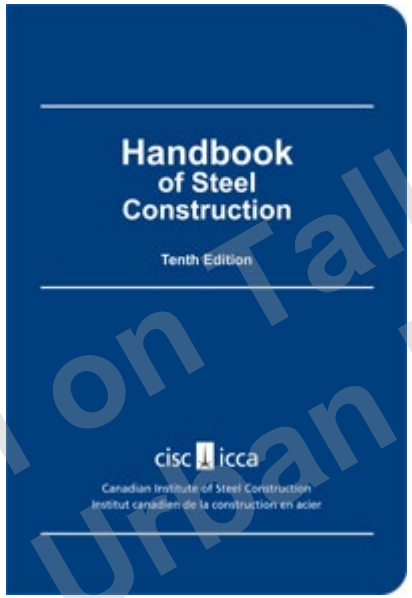
UBC

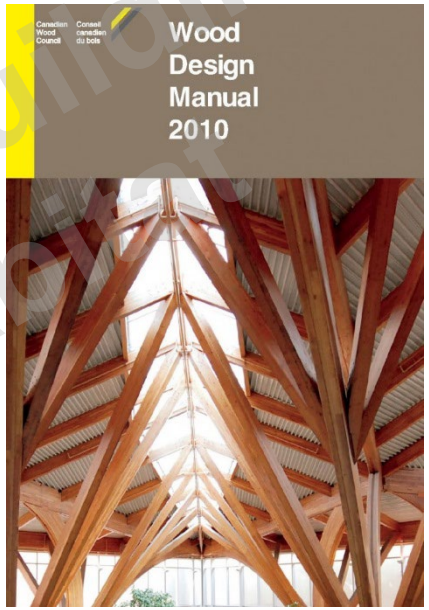
December 2015

https://dx.doi.org/10.14288/1.0223405



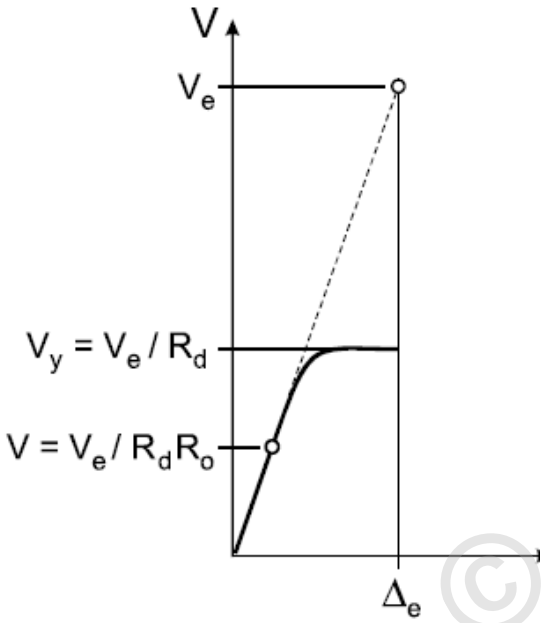






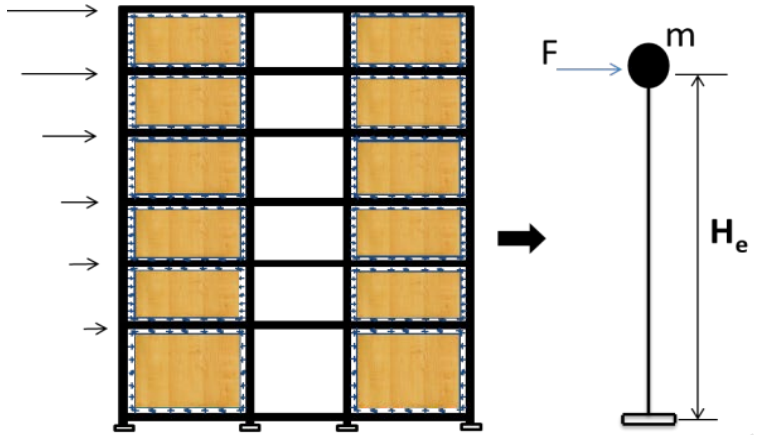
Validation for $R_d = 4$

$$V = \frac{S(T_a) M_v I_e W}{R_d R_o}$$

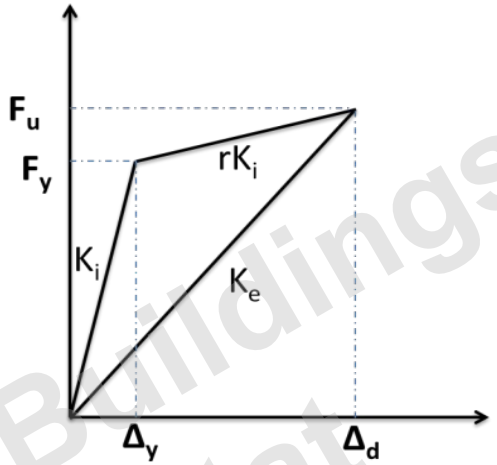


Force Based Design
(Carla's MASc thesis)

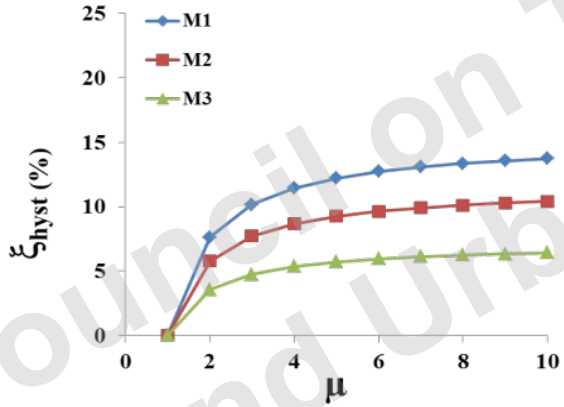
performance group	Hybrid Building Configuration		Calculated R_o and $ACMR$				Evaluation	
Low-rise	No. of storey	Infilled bays	R_o	S_{CT}	S_{MT}	$ACMR$	FEMA P695 requirement	Pass/fail
	3	1	3.54	3.05	0.39	7.8	1.88	Pass
Average			**3.54**			**7.8**	**2.61**	Pass
Mid-rise	6	1	2.82	3.49	0.21	17.1	1.88	Pass
Average			**2.82**			**17.1**	**2.61**	Pass
High-rise	9	1	2.46	2.96	0.14	21.14	1.88	Pass
Average			**2.46**			**21.14**	**2.61**	Pass



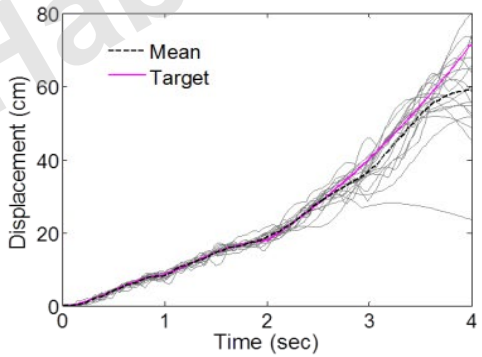
a) SDOF representation



b) Effective stiffness



c) EVD vs. ductility

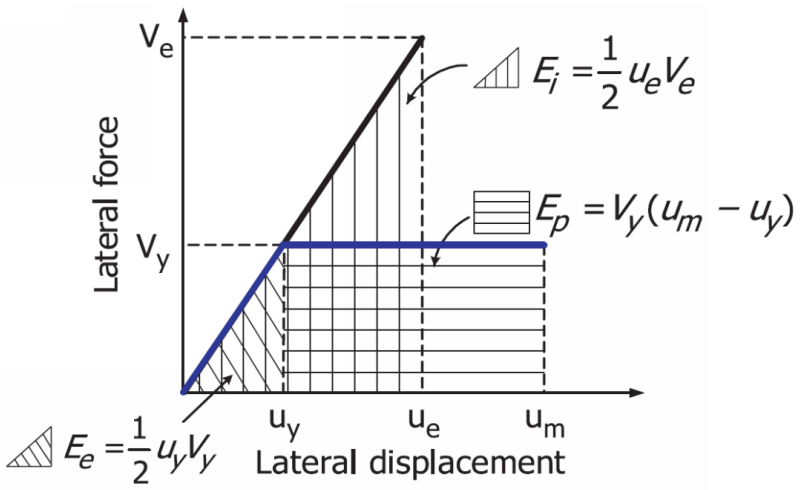


d) Design displacement spectra

Displacement Based Design

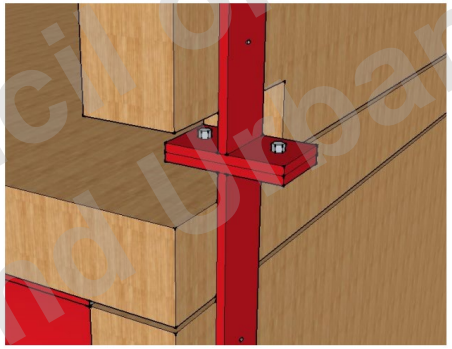
(Matiyas's MASc thesis)

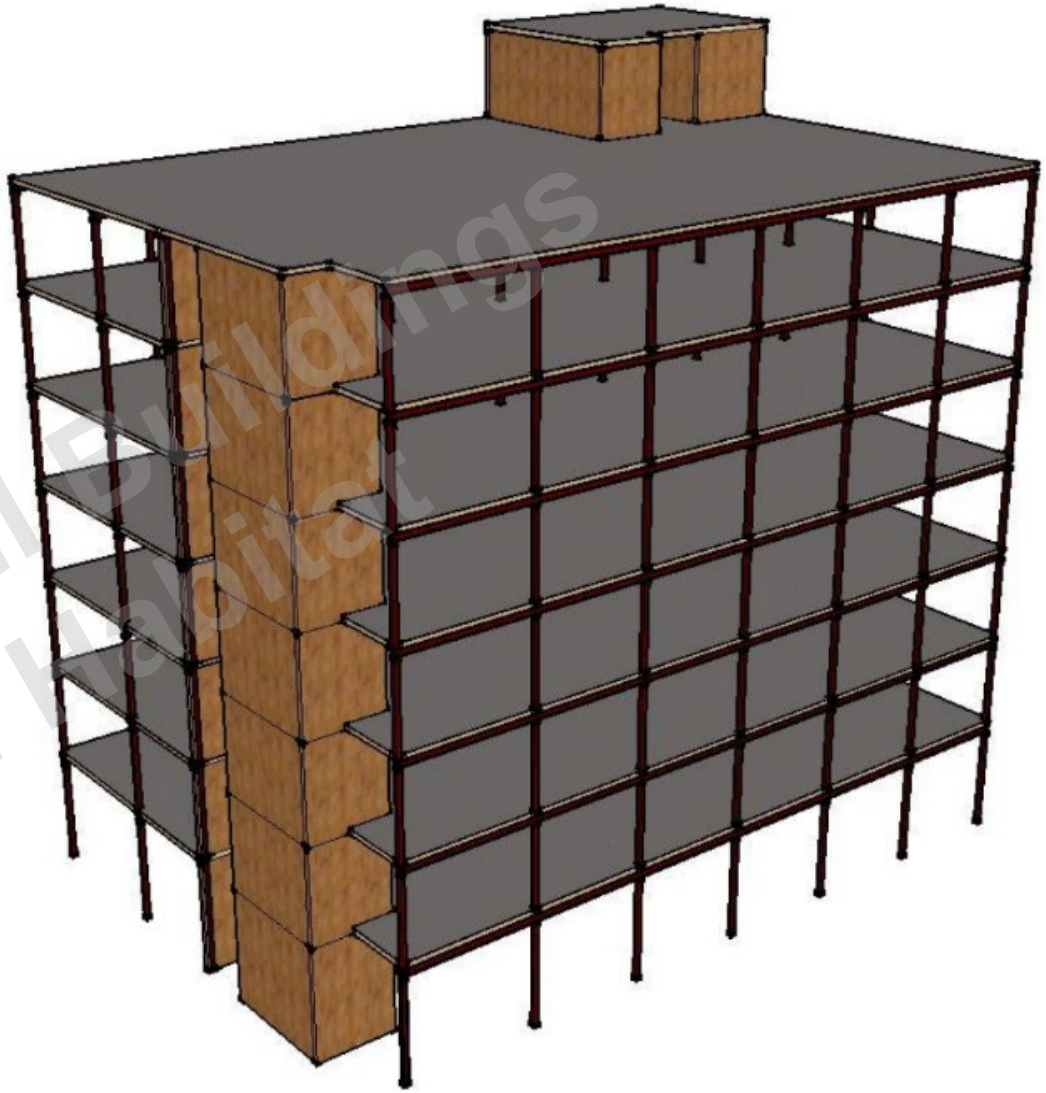
$$E_k + E_d + E_s + E_h = E_i$$



Energy Based Design

(Caleb's MASc thesis)





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Coupled CLT Shear Walls – Replaceable Steel Link

Design of Tall-Coupled-Wall Timber Building: Energy Dissipating Coupling Beams

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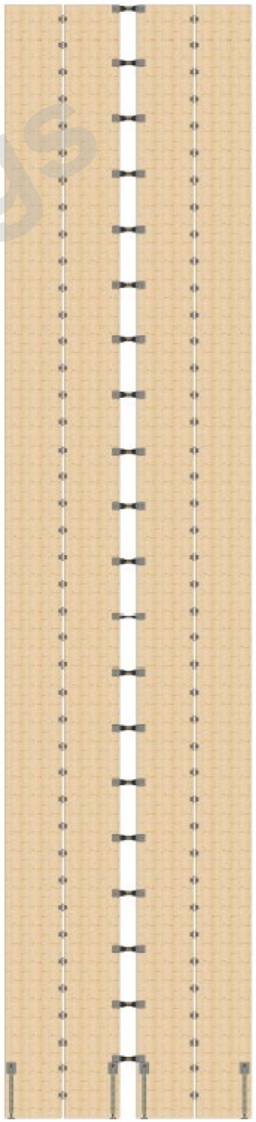
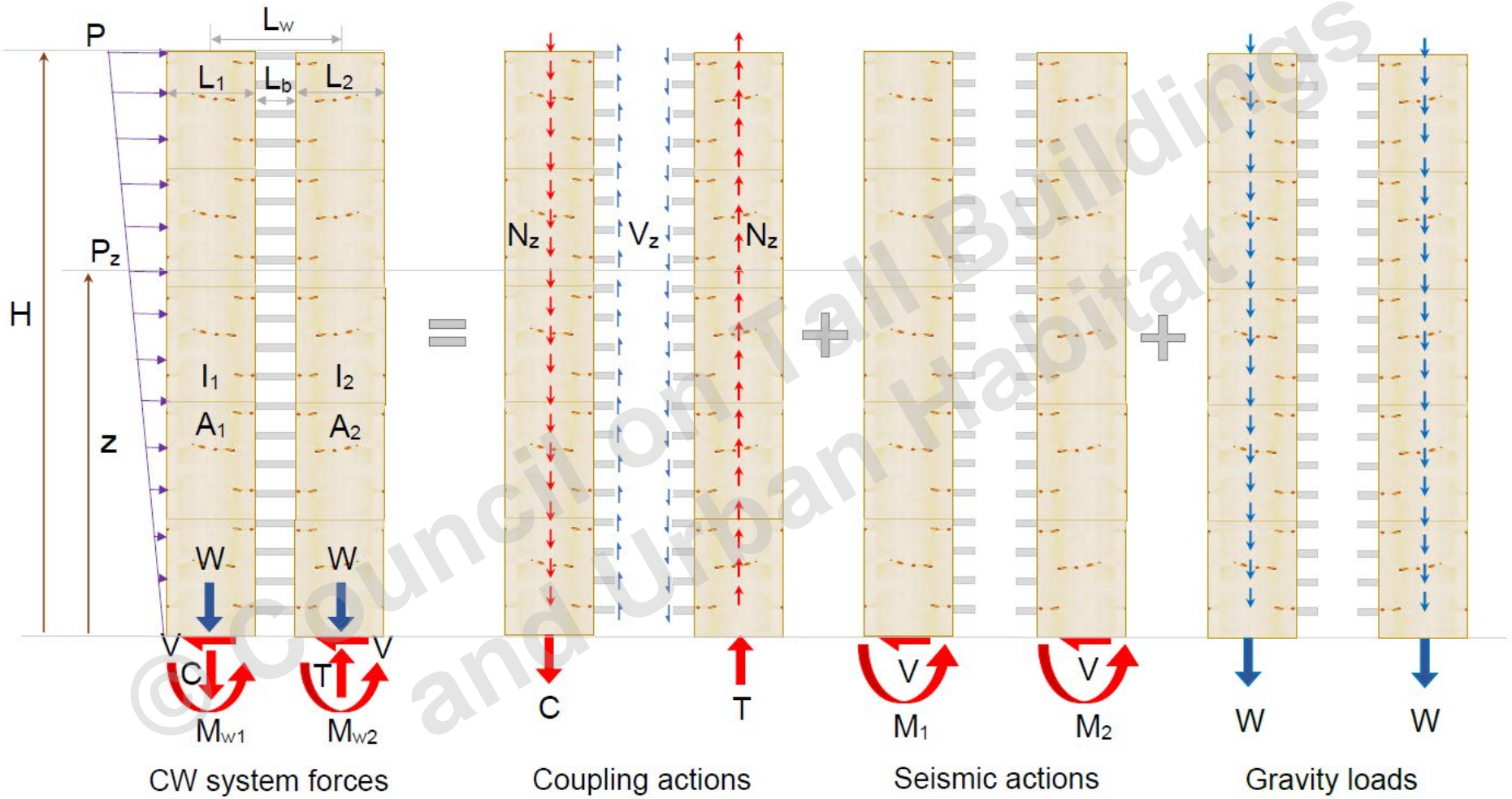
December 2021

THE UNIVERSITY OF BRITISH COLUMBIA

FACULTY OF APPLIED SCIENCE, SCHOOL OF ENGINEERING



https://dx.doi.org/10.14288/1.0403817



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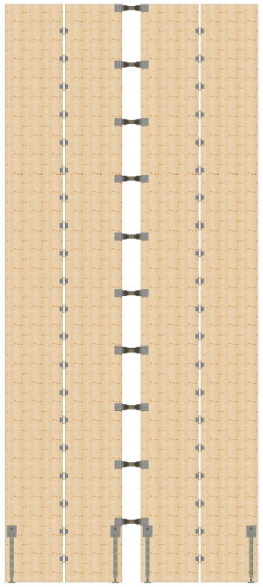
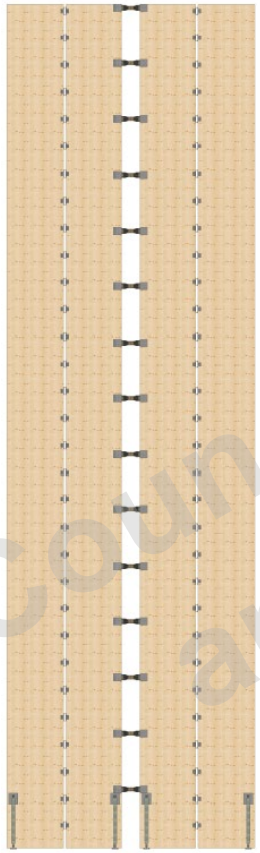
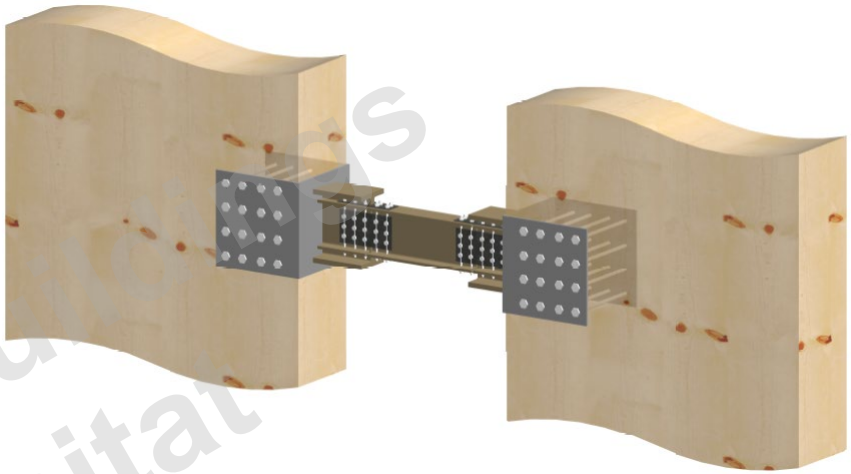
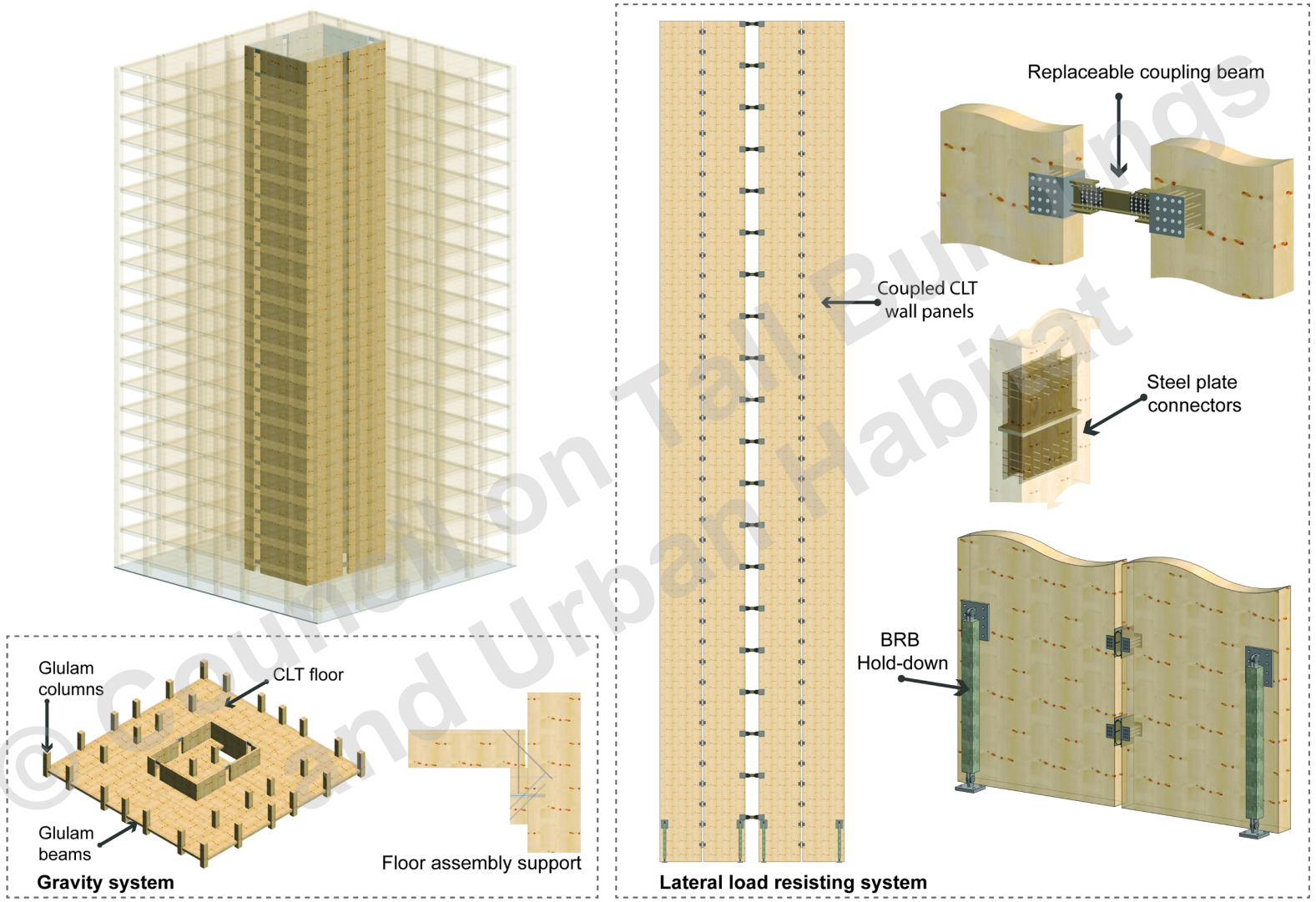






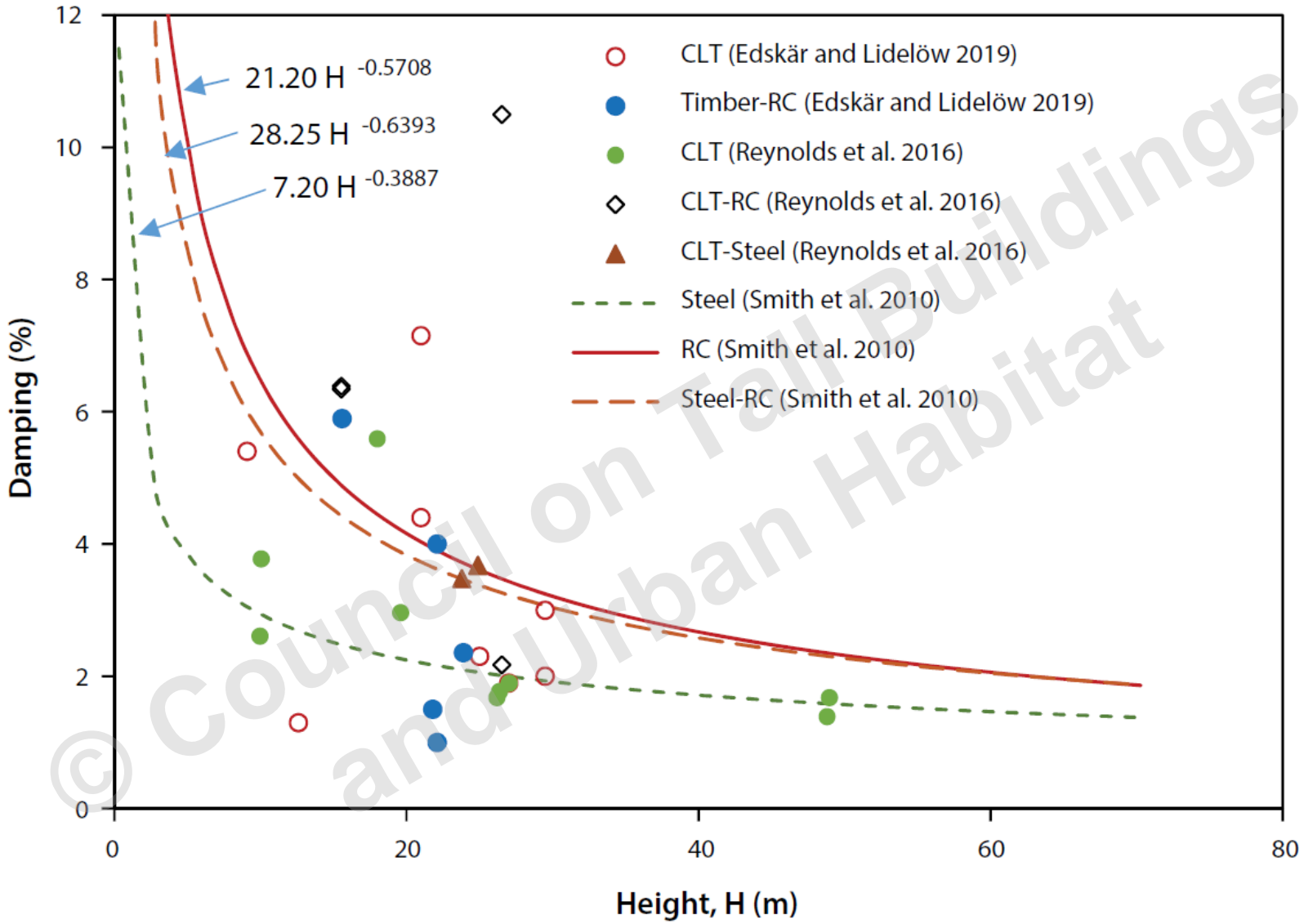


Tall Timber Buildings: Innovative Building Design and Damping Considerations

Solomon Tesfamariam

40 | Structural Engineering CTBUH Journal | 2022 Issue I

"The most important sources of intrinsic damping for tall buildings are soil structure interaction (SSI) and structural behavior."



Coupled CLT Shear Walls – Outrigger Beams

Resilient Tall Timber Building Design: Damped-Outrigger System

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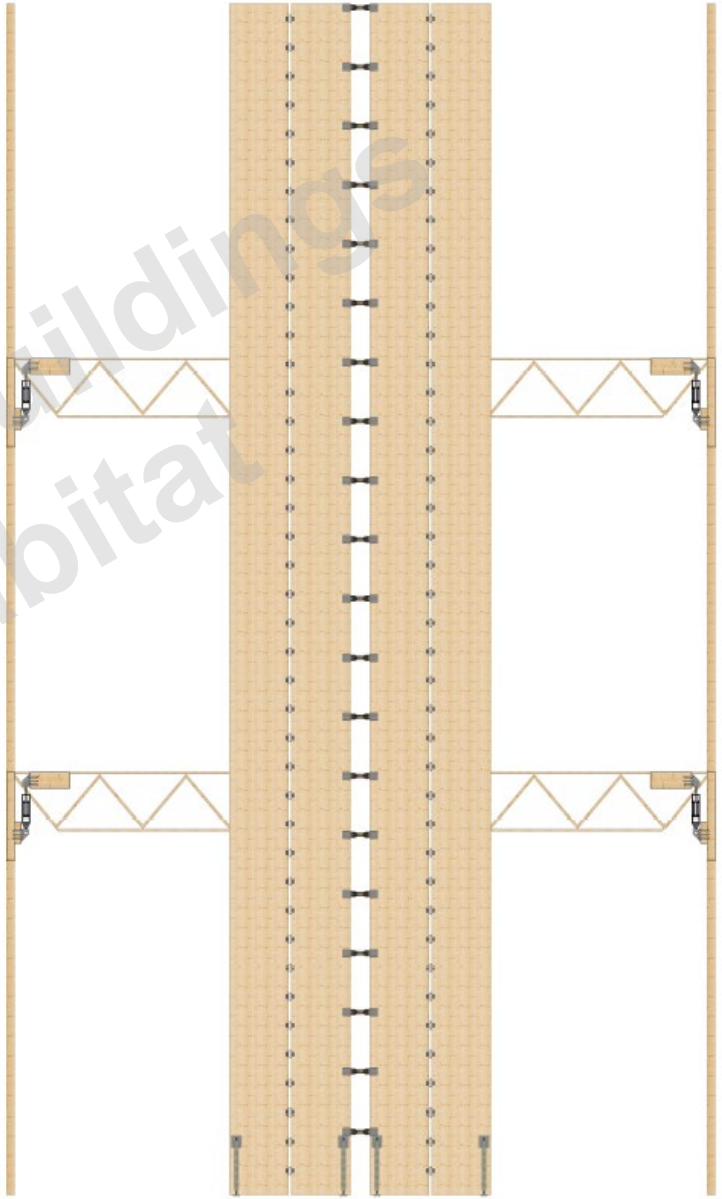
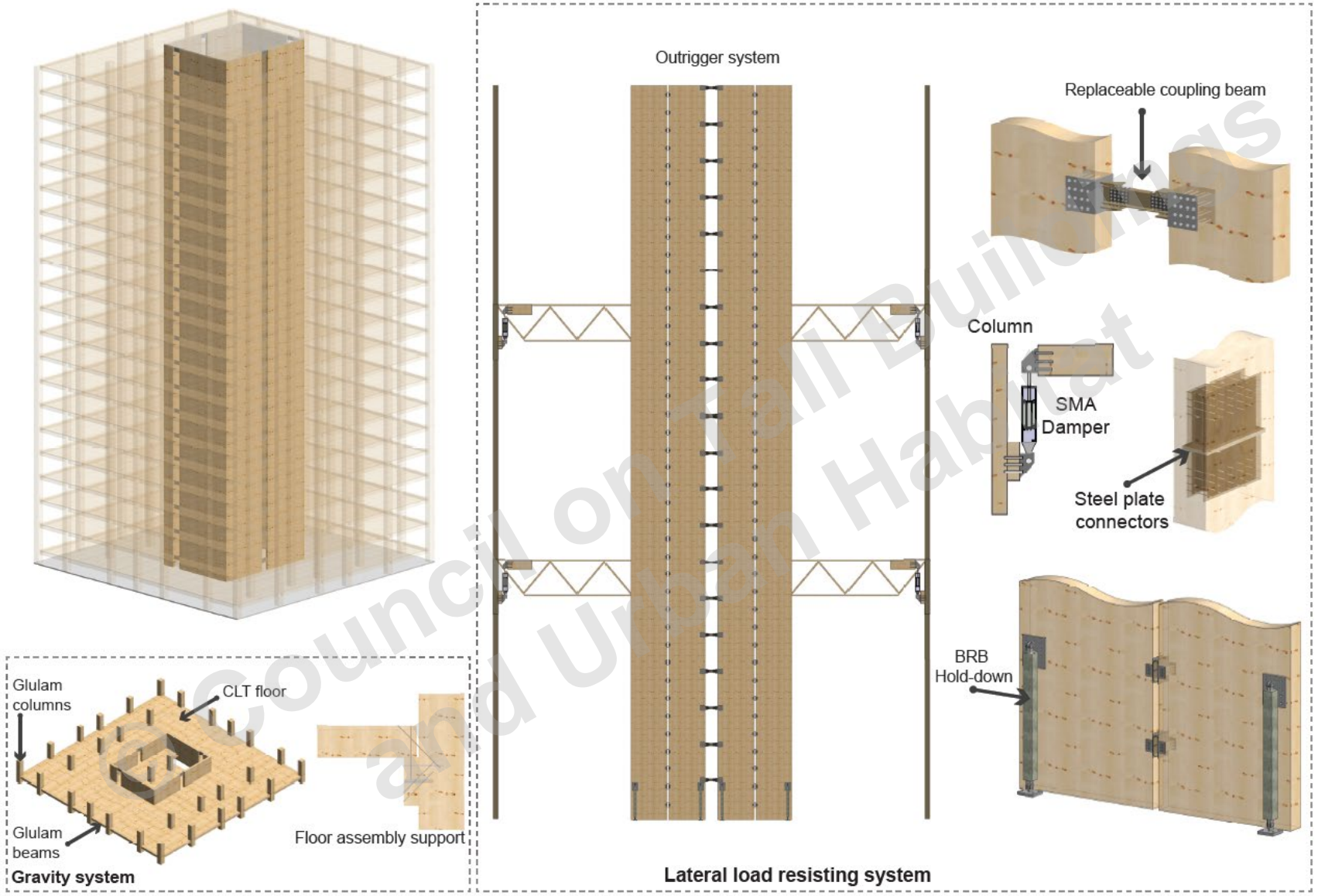
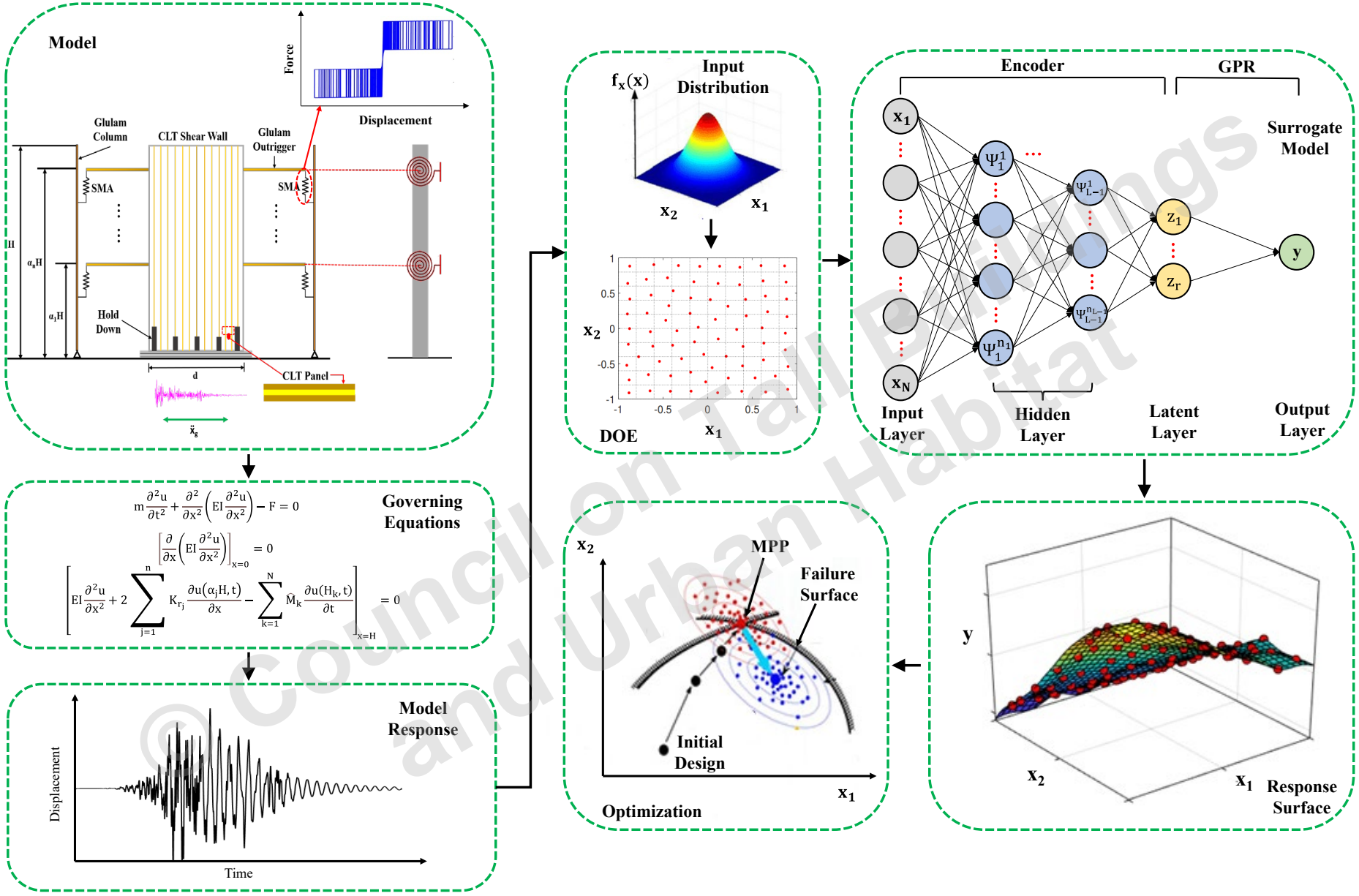
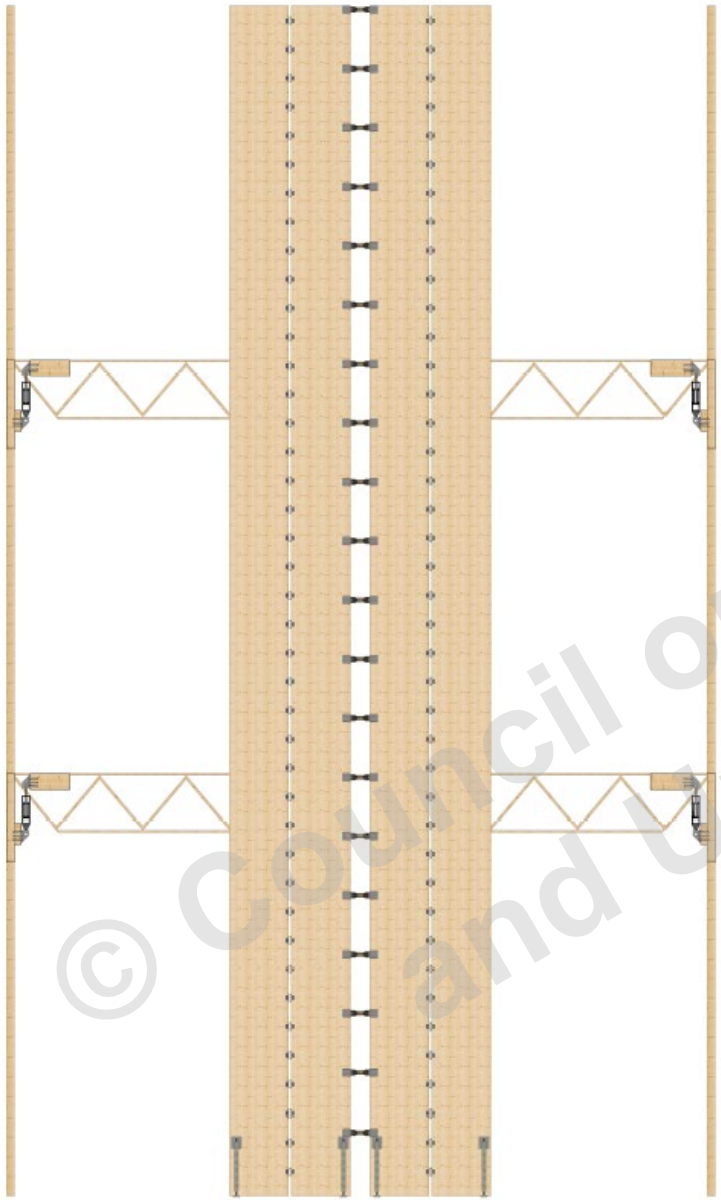


https://dx.doi.org/10.14288/1.0403816

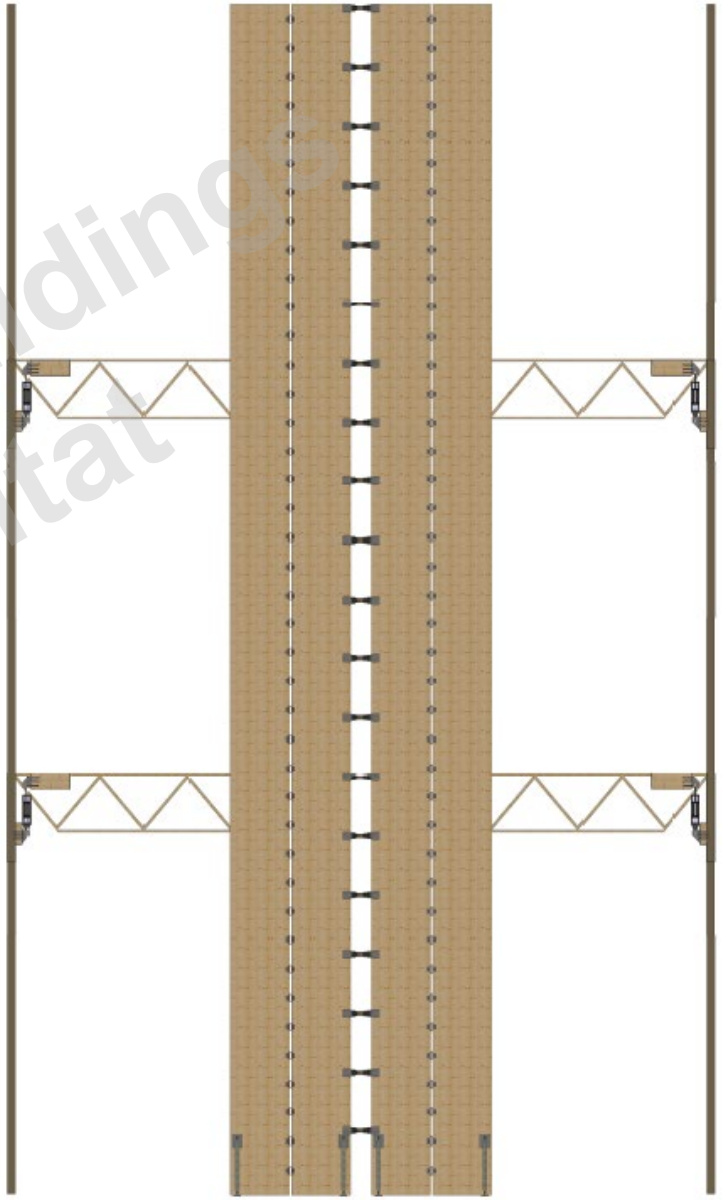




Glulam Columns



Steel Columns



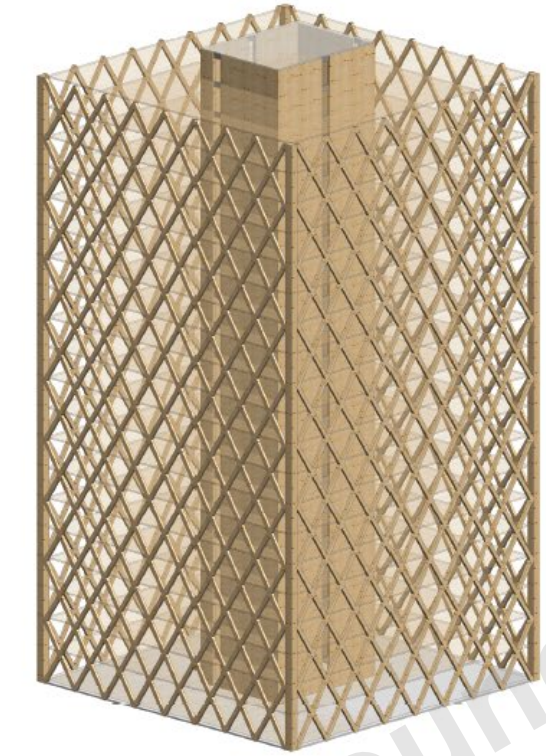
Coupled CLT Shear Walls – Steel Diagrid Skeleton

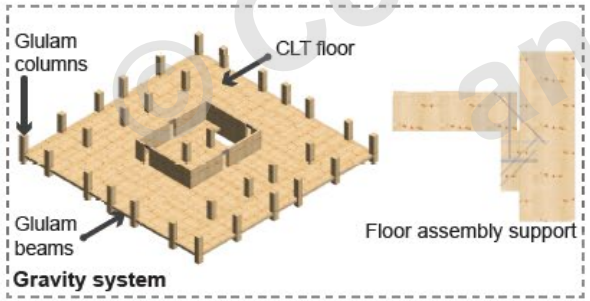
5 stories

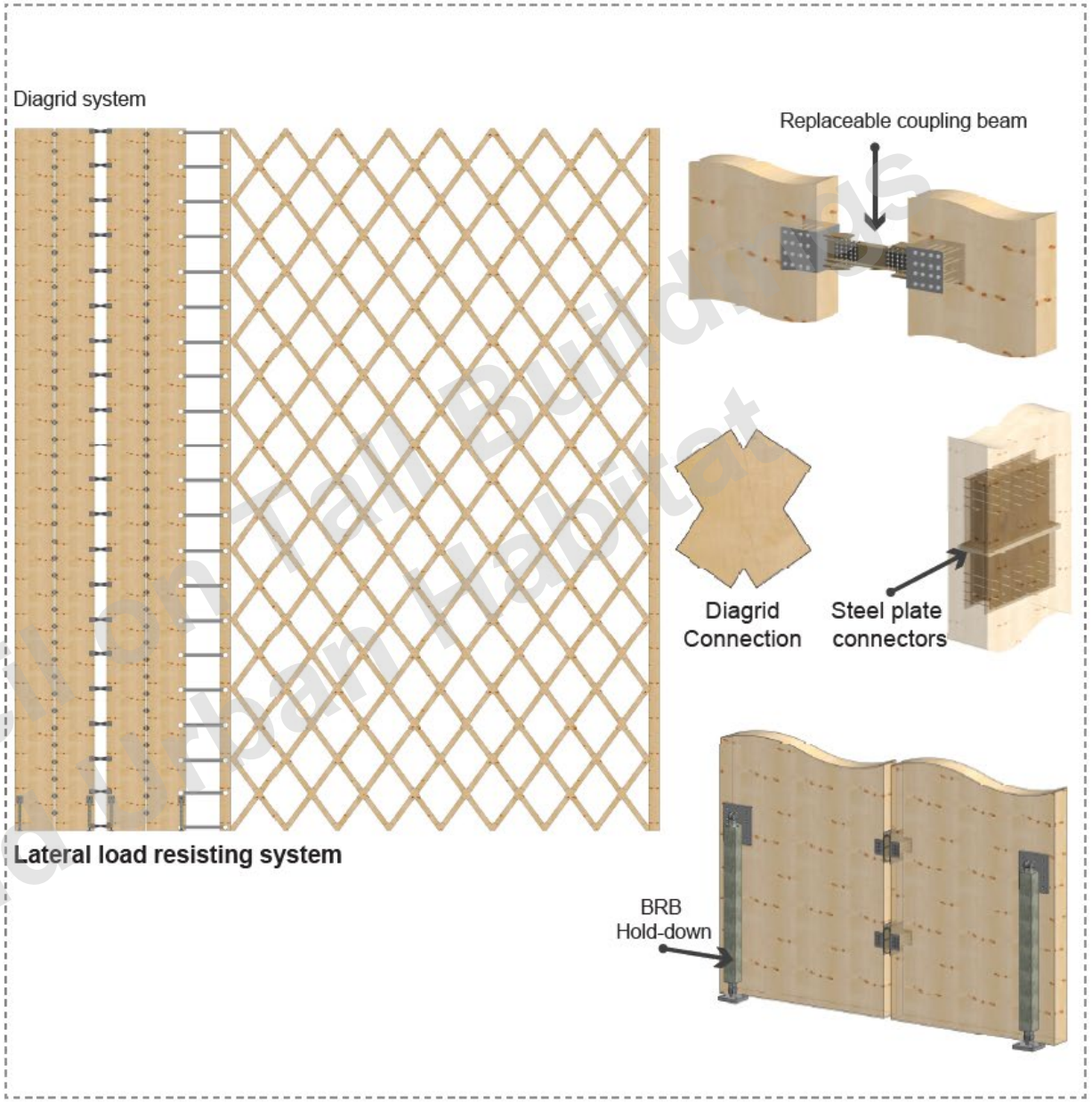
10 stories

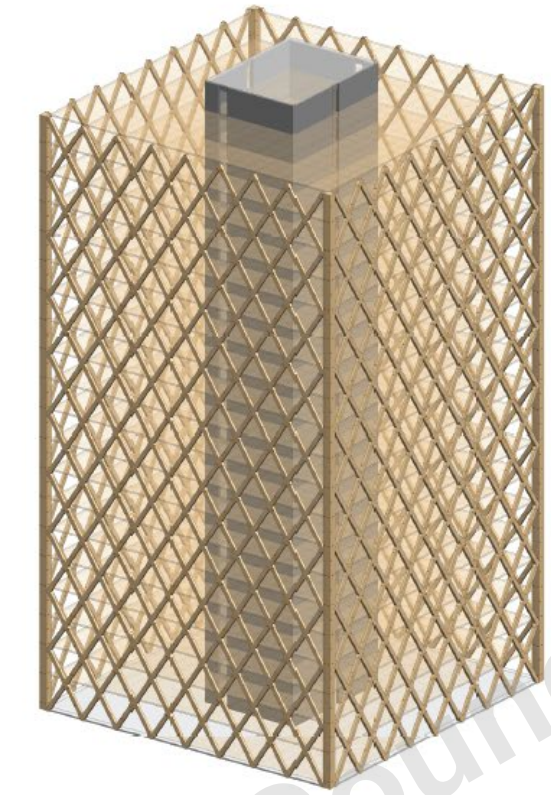
15 stories

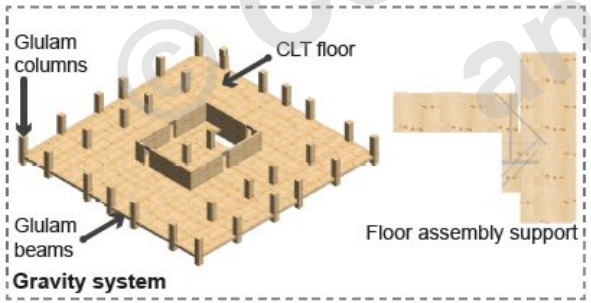
20 stories

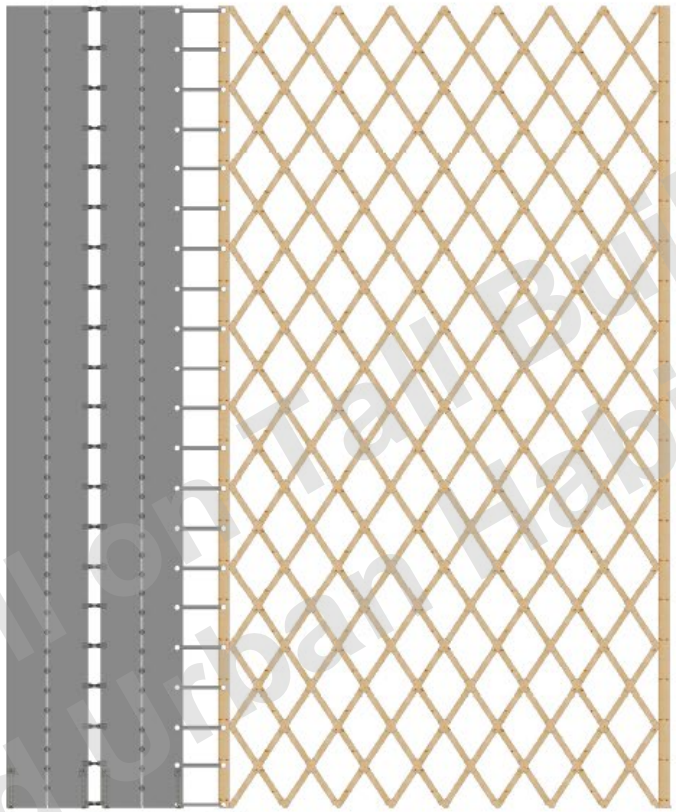


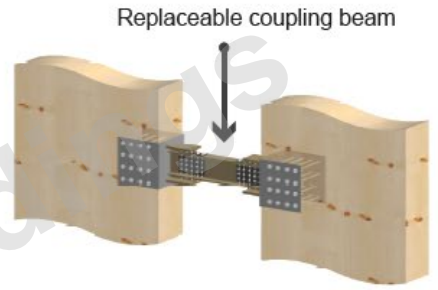


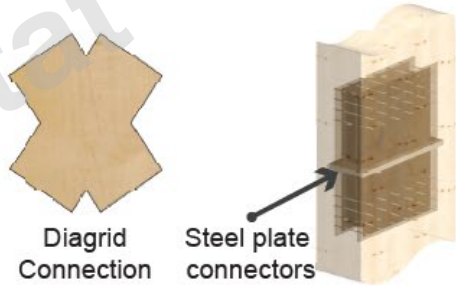


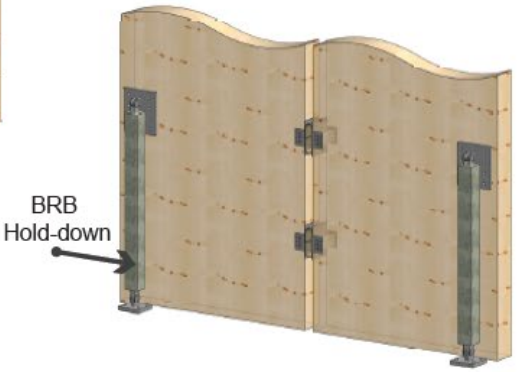


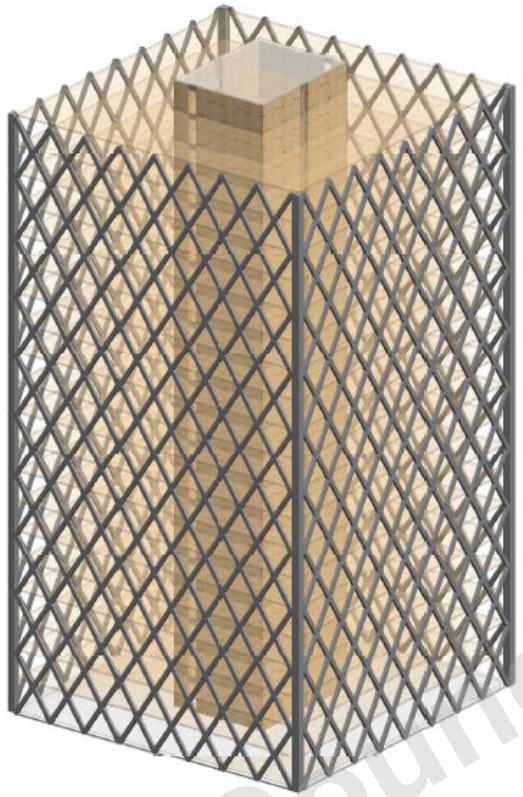


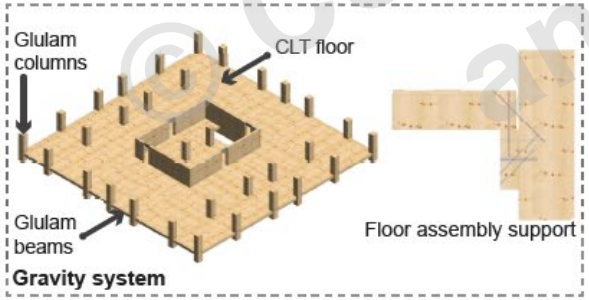


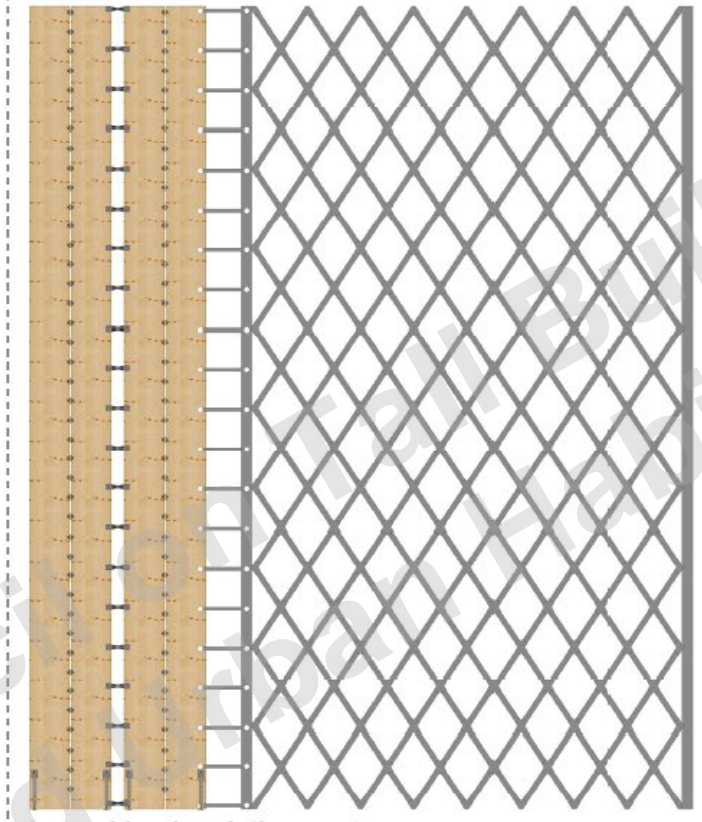


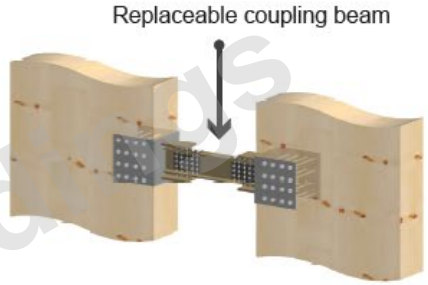


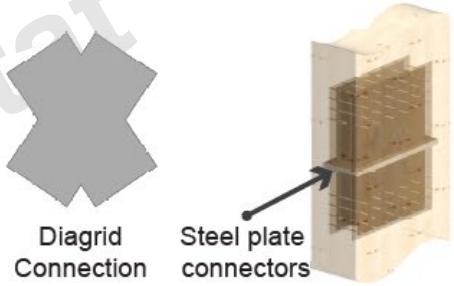


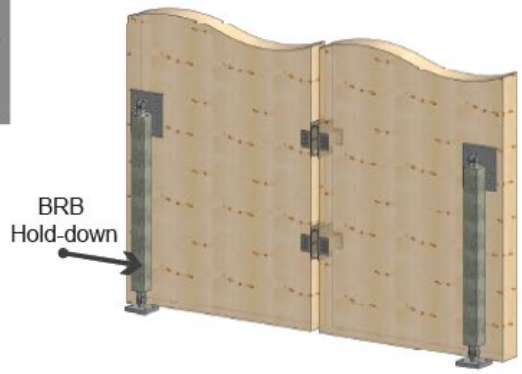




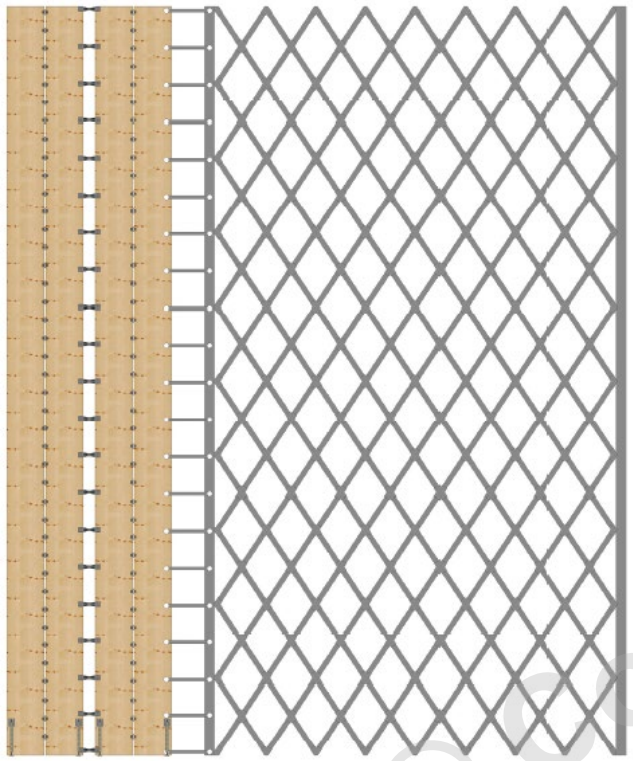




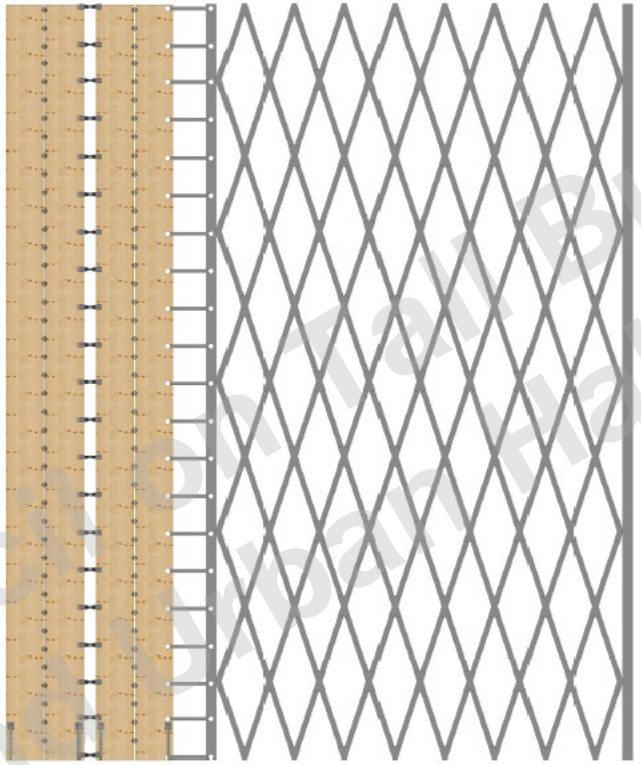




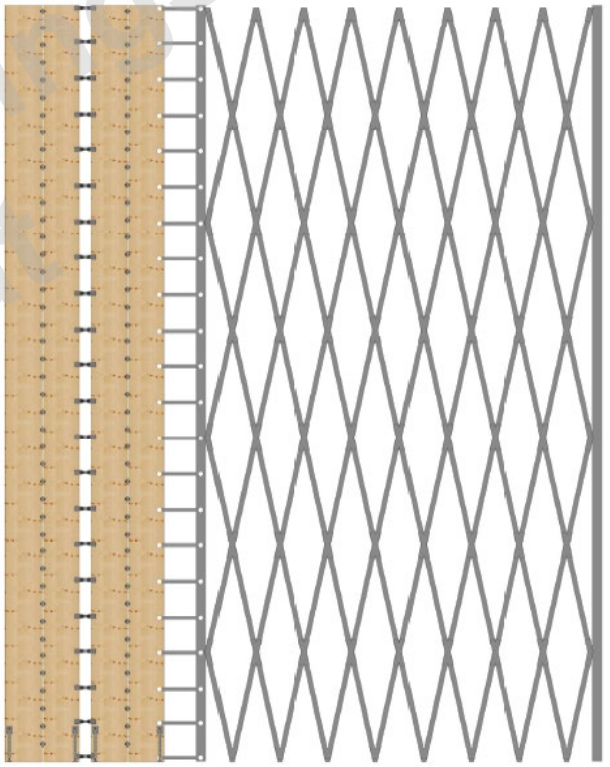
Topology optimization



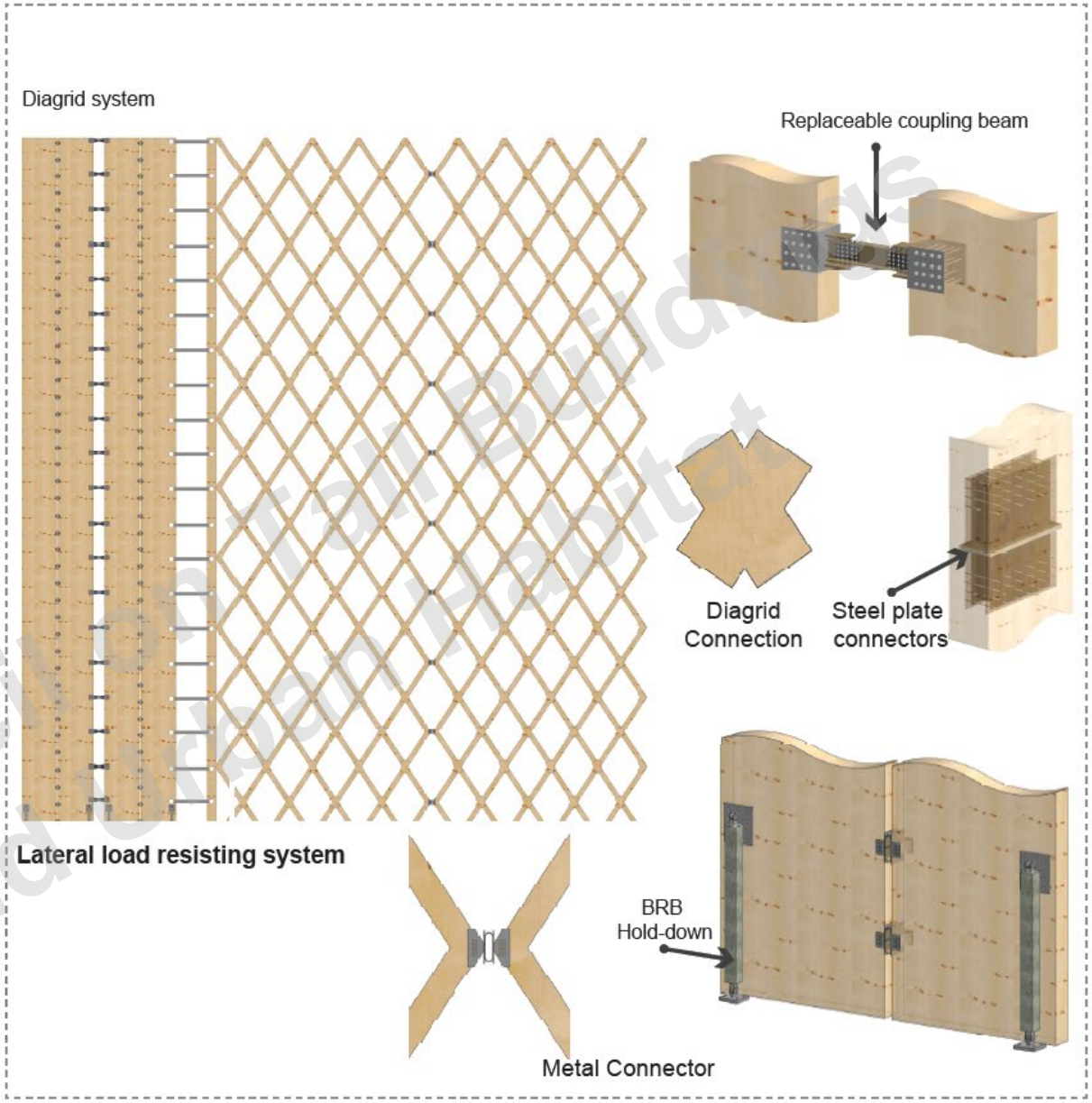
2-story



4-story



6-story



“There’s a way to do it better—find it.”

Thomas Edison

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