The Development & Evolution of Prefabricated Mass Timber Façades

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… or aside from mass timber:

"How to De-risk New & Innovative Façade Systems"

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MOISTURE RISK MANAGEMENT STRATEGIES FOR MASS TIMBER BUILDINGS

A guide for designers, construction professionals, and building developers

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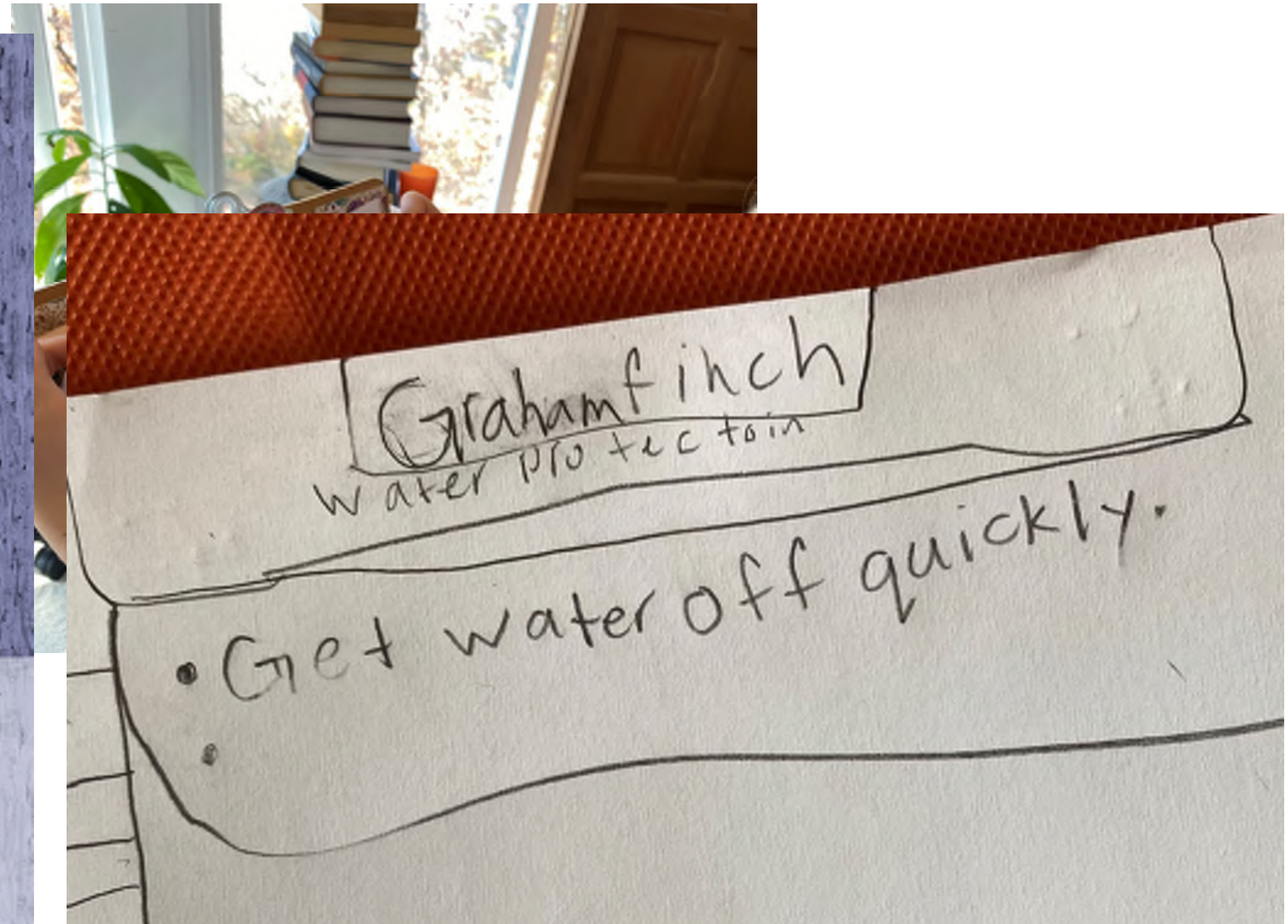
NOVEMBER 2021 | V2



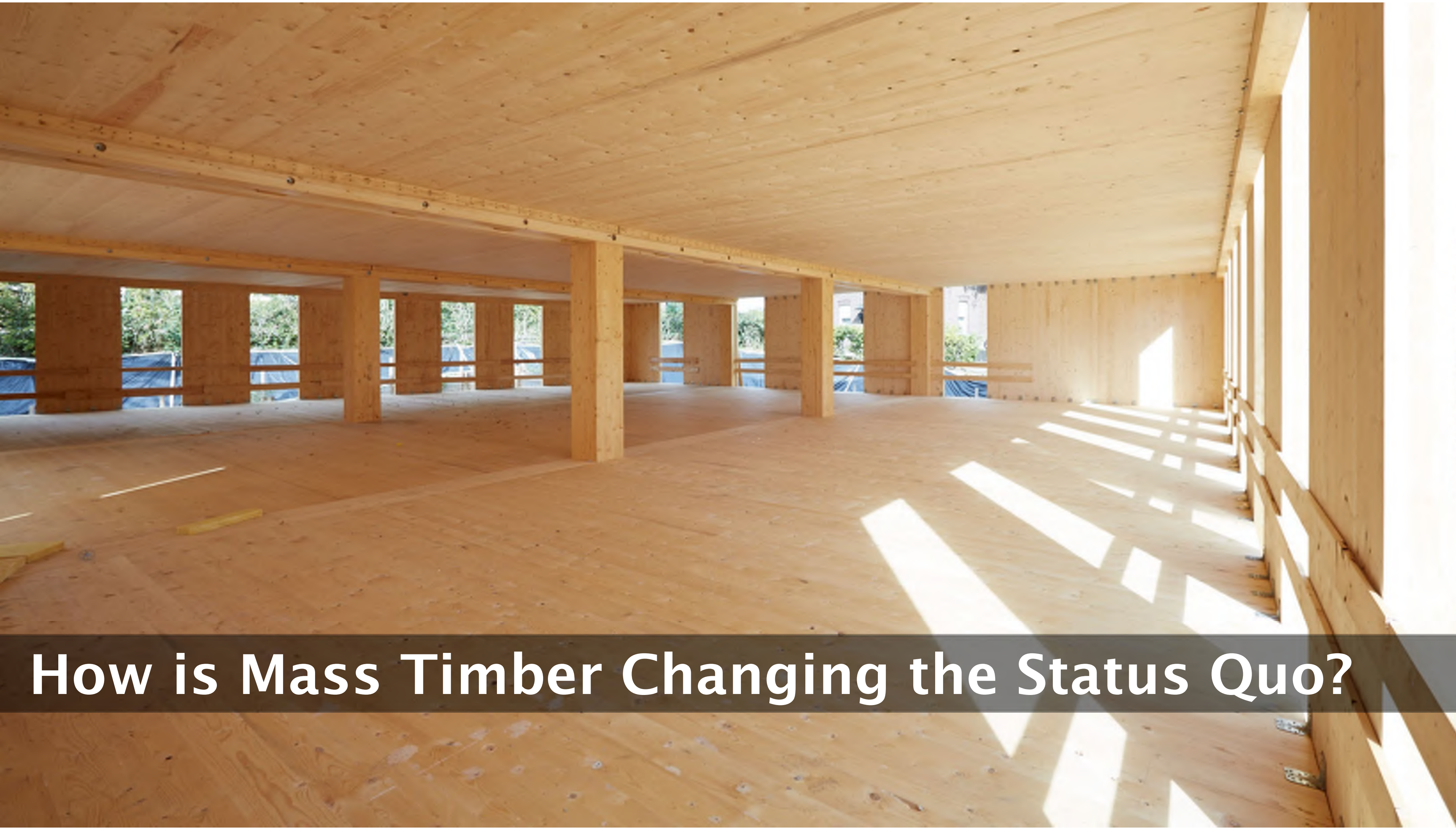
High-rise Facades

Traditionally: Concrete, Steel & Glass

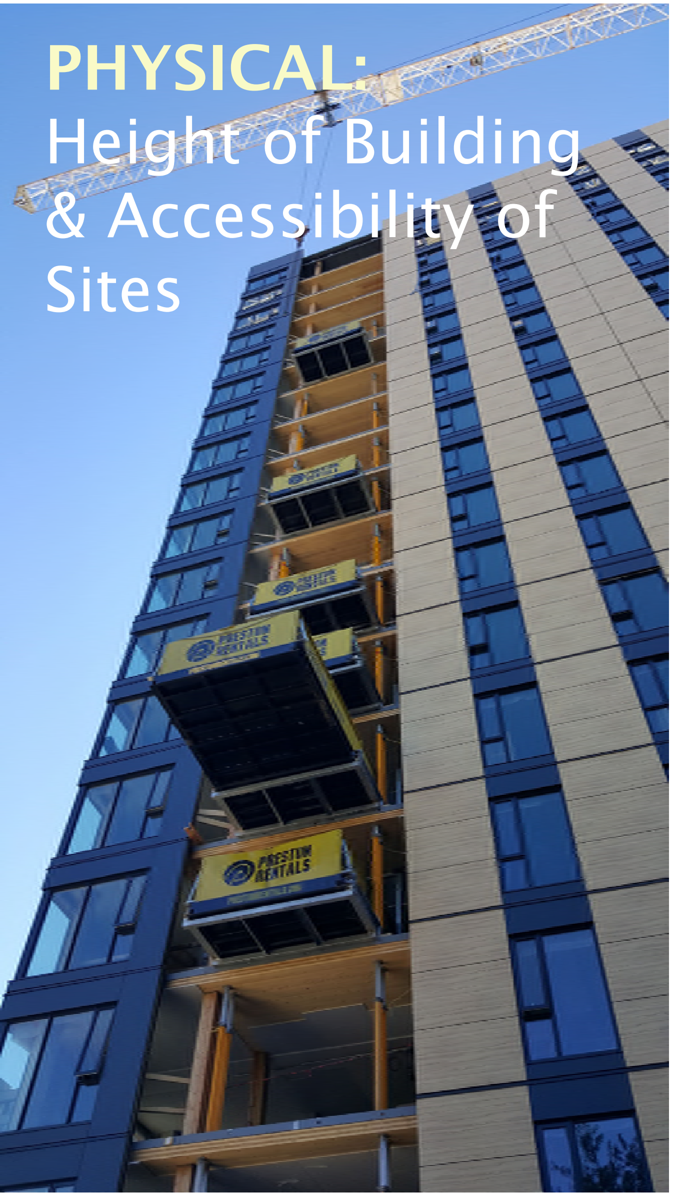
Site Built & Prefabricated

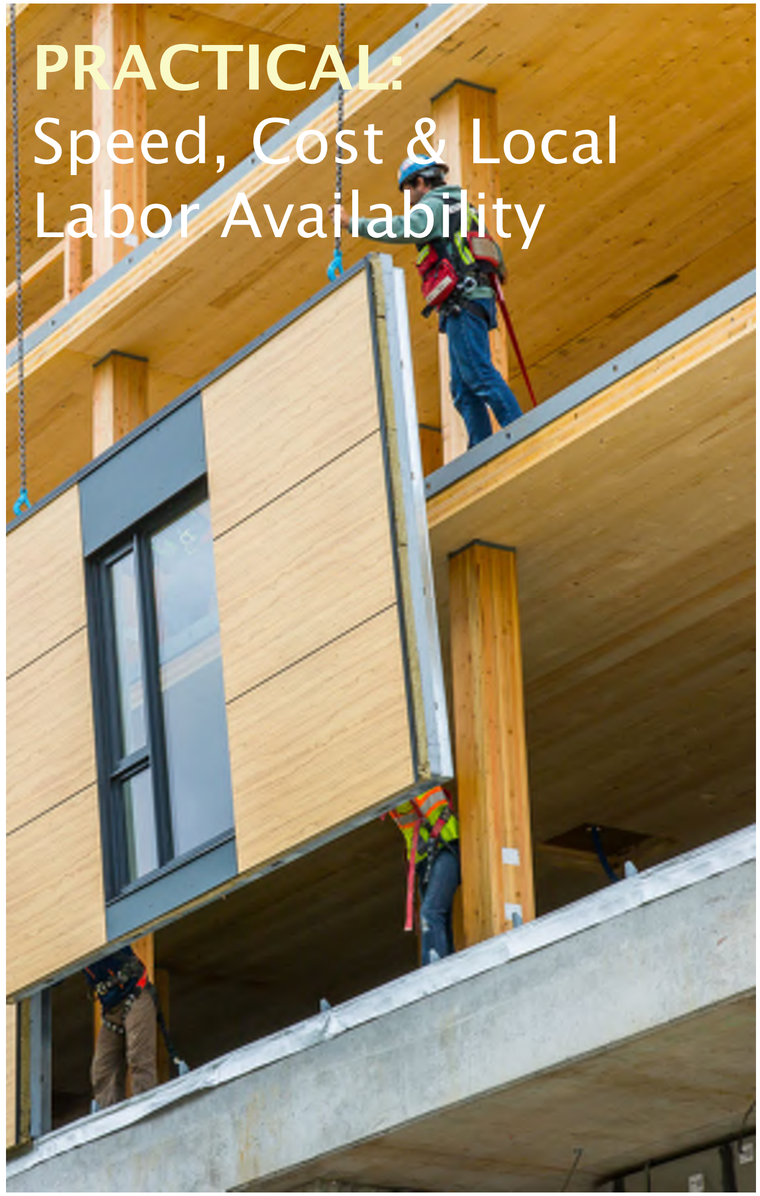


Prefabrication is not New

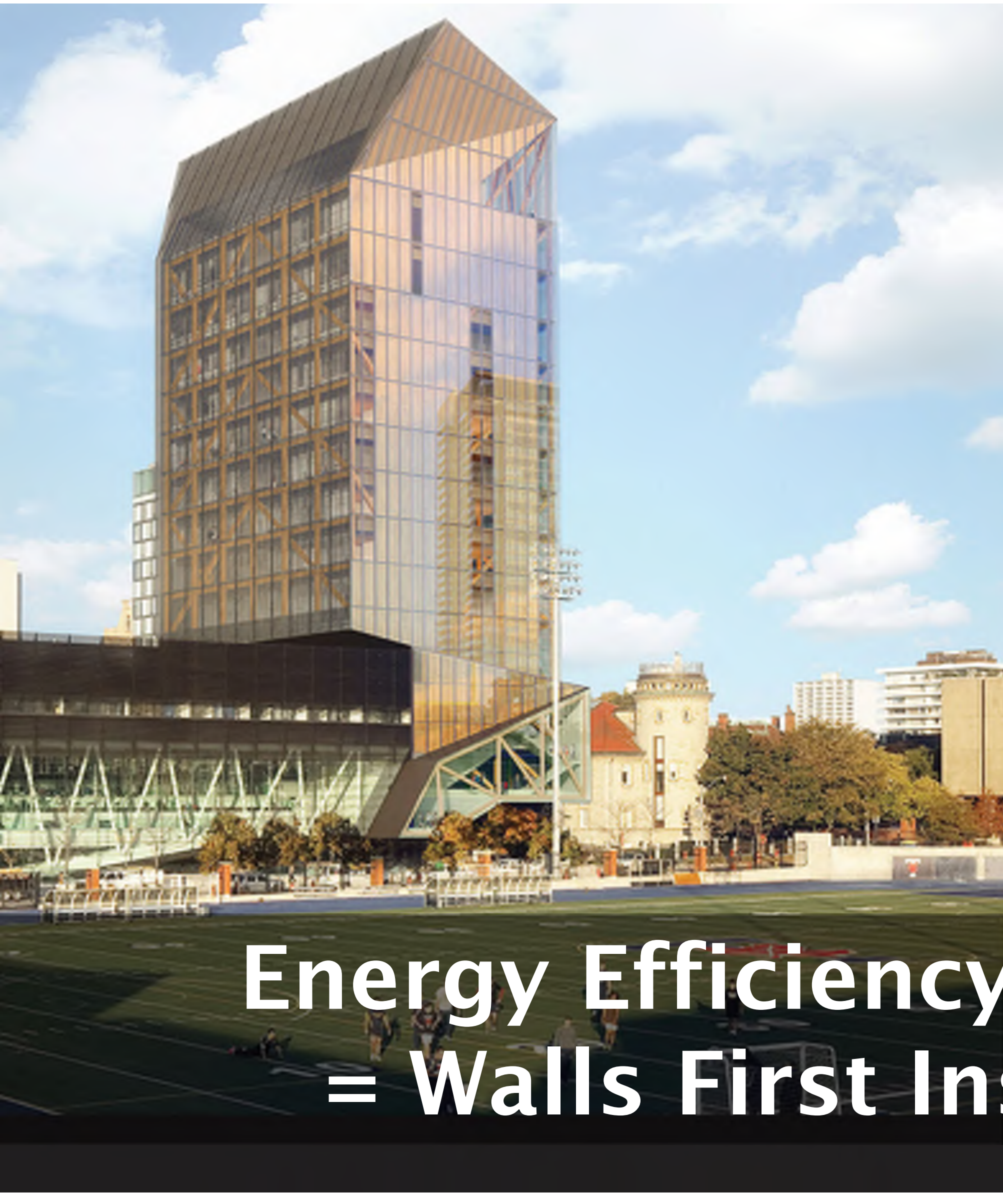

How is Mass Timber Changing the Status Quo?

A Confluence of Drivers Leading to Next Generation Prefabricated Façade Systems for High-rise Buildings


PHYSICAL:
Height of Building & Accessibility of Sites

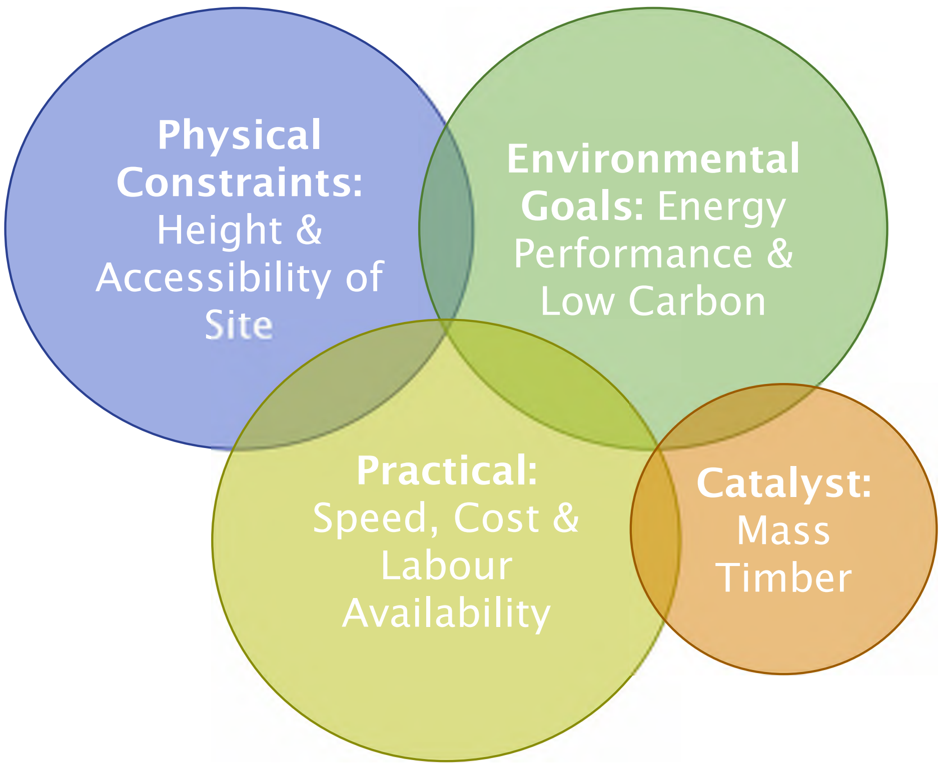

PRACTICAL:
Speed, Cost & Local Labor Availability


ENVIRONMENTAL:
Energy Efficiency (PH/NZ) & Low Carbon



Energy Efficiency Impacts on Façade = Walls First Instead of Windows

Pre-fabricated Facades for High-rises & Mass Timber



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Mass Timber as the Catalyst

Steel Framed Prefabricated Facade


Steel Framed Prefabricated Facade

Glazed Systems

High-rise

=

Site-Built vs. Prefabricated Façades

(market, design and speed dependent)

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High-rise
+
Passive House
=
Site-Built vs. Prefabricated Façades

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High-rise

+

Passive House

+

Mass Timber Structure

=

Prefabricated Façades

High-rise

+

Passive House

+

Mass Timber Structure

+

Low Carbon Goals

=

Prefabricated Wood-based Façades

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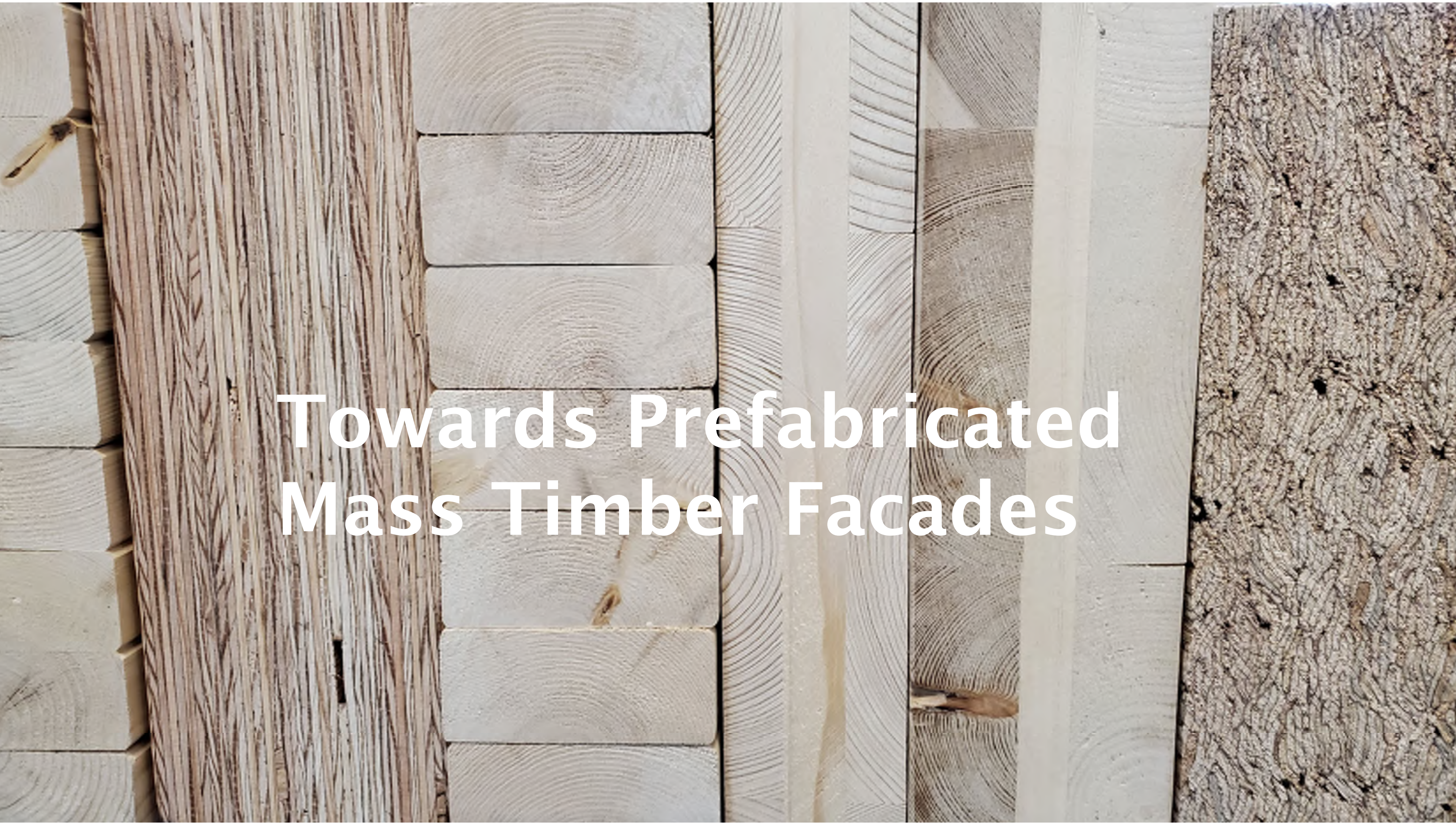
Towards Prefabricated Mass Timber Facades




The Wood Facade Aesthetic Argument

The Wood Facade Aesthetic Argument

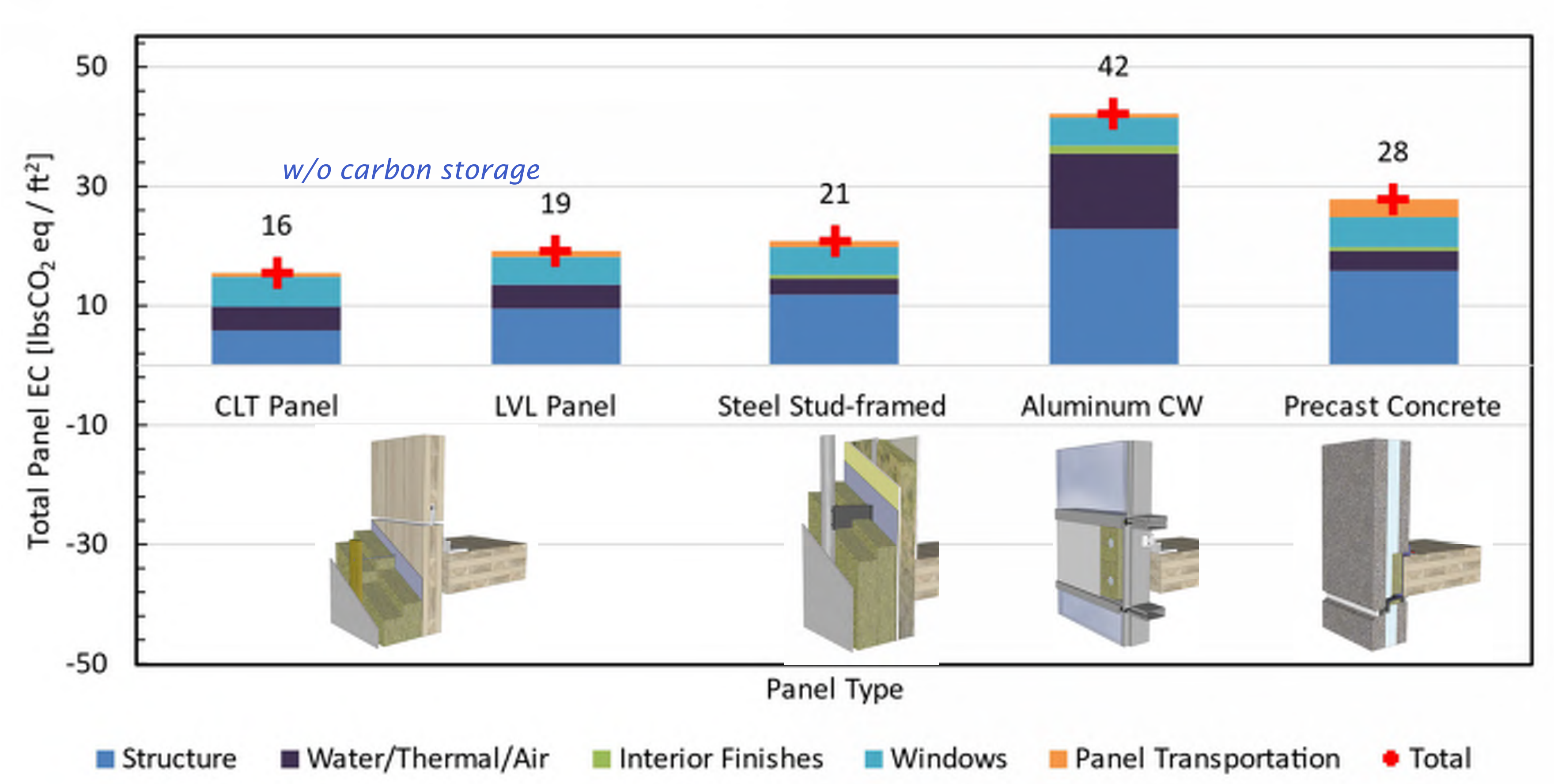
The Carbon Argument for Mass Timber Facades

- → **Operating** Carbon
  - → Carbon equivalent emitted as part of operation and maintenance
  - → Reduced with *energy efficiency measures (ie NZ/PH)*
- → **Embodied** Carbon
  - → Cumulative equivalent emitted carbon from acquisition, manufacture, transport, and installation of material
  - → Reduced with *low carbon* or *carbon sequestering* materials (ie wood)

- → **Trend** – In jurisdictions with low carbon energy grids and energy efficient building standards – embodied carbon is becoming increasingly scrutinized

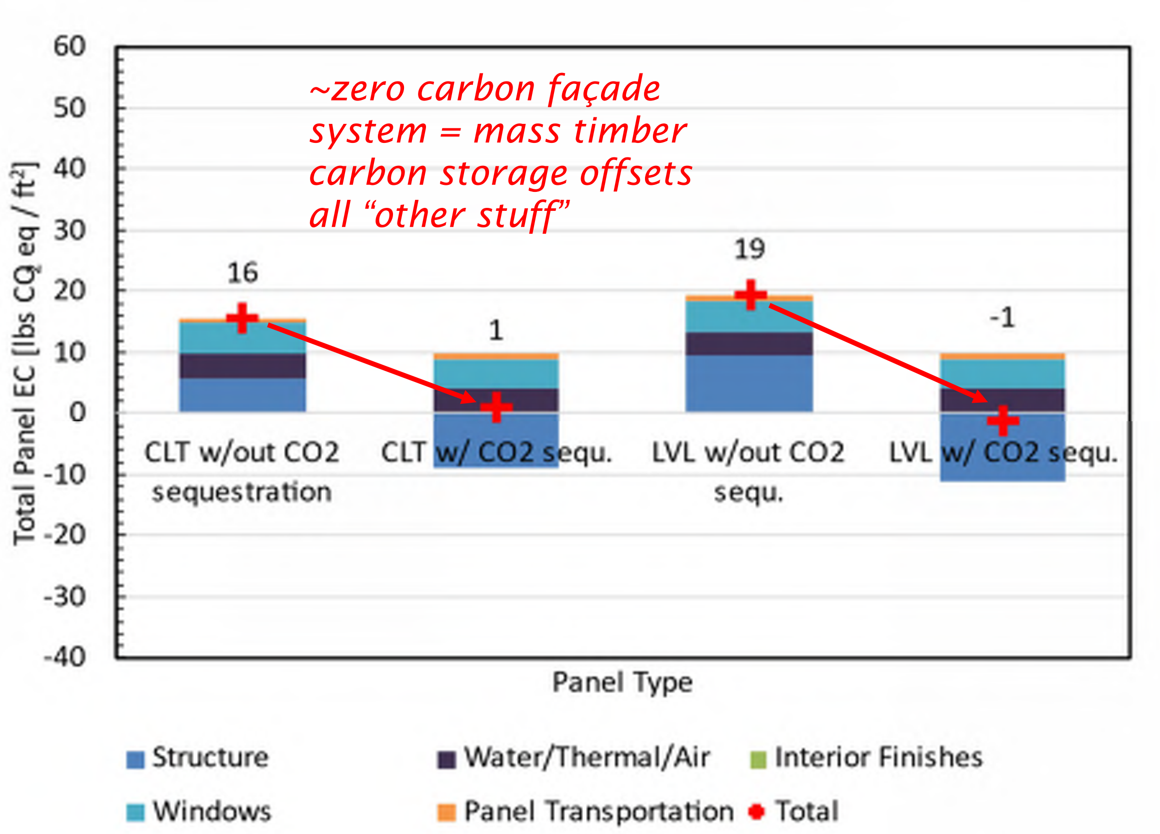
Embodied Carbon Benefits of Mass Timber Facades

Embodied Carbon Comparison (A1-A4 regionally produced) for Large Format Façade Panels with Windows with Structure comparison for: Mass Timber (CLT and LVL/MPP, Steel Frame, Aluminum Frame w/ IMP and Pre-cast Concrete



Zero Carbon Potential of Mass Timber Facades

Embodied Carbon Comparison (A1-A4) for Mass Timber:
- *without CO_2 sequestration due to end-of-life negation*
- *with CO_2 sequestration to understand "short" term benefits*

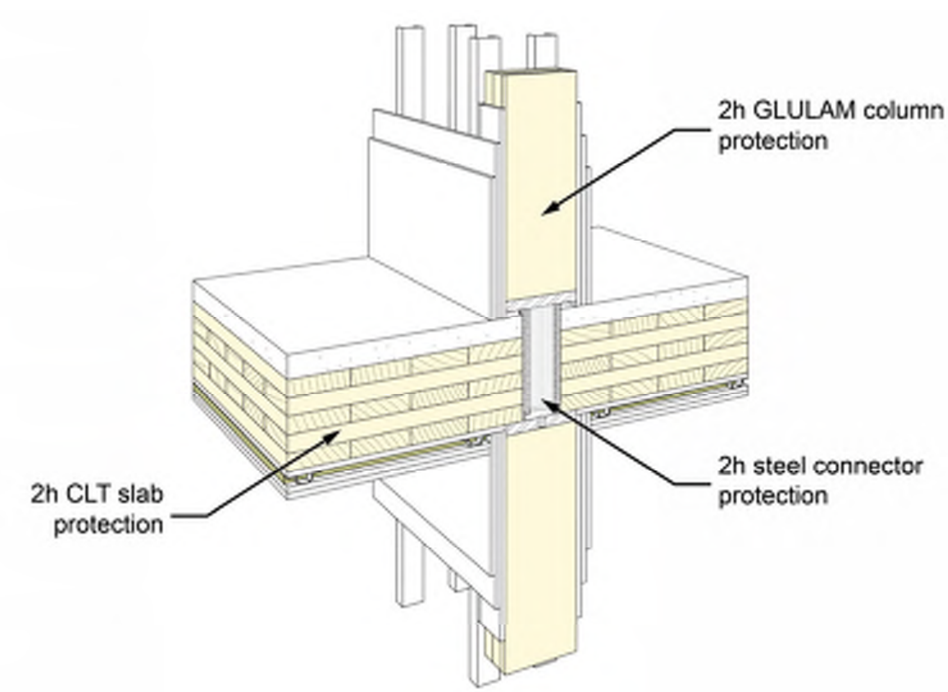


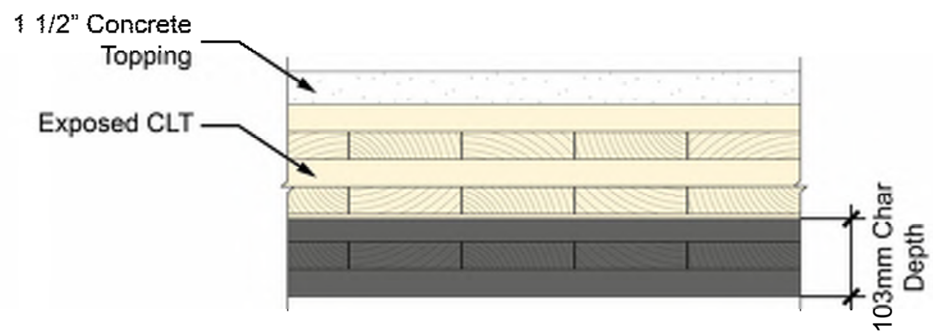
What will happen to our mass timber buildings in 50 years?

For now, value in "flattening the curve" of CO_2 emissions.

Wood can sequester carbon until we can solve the climate crisis

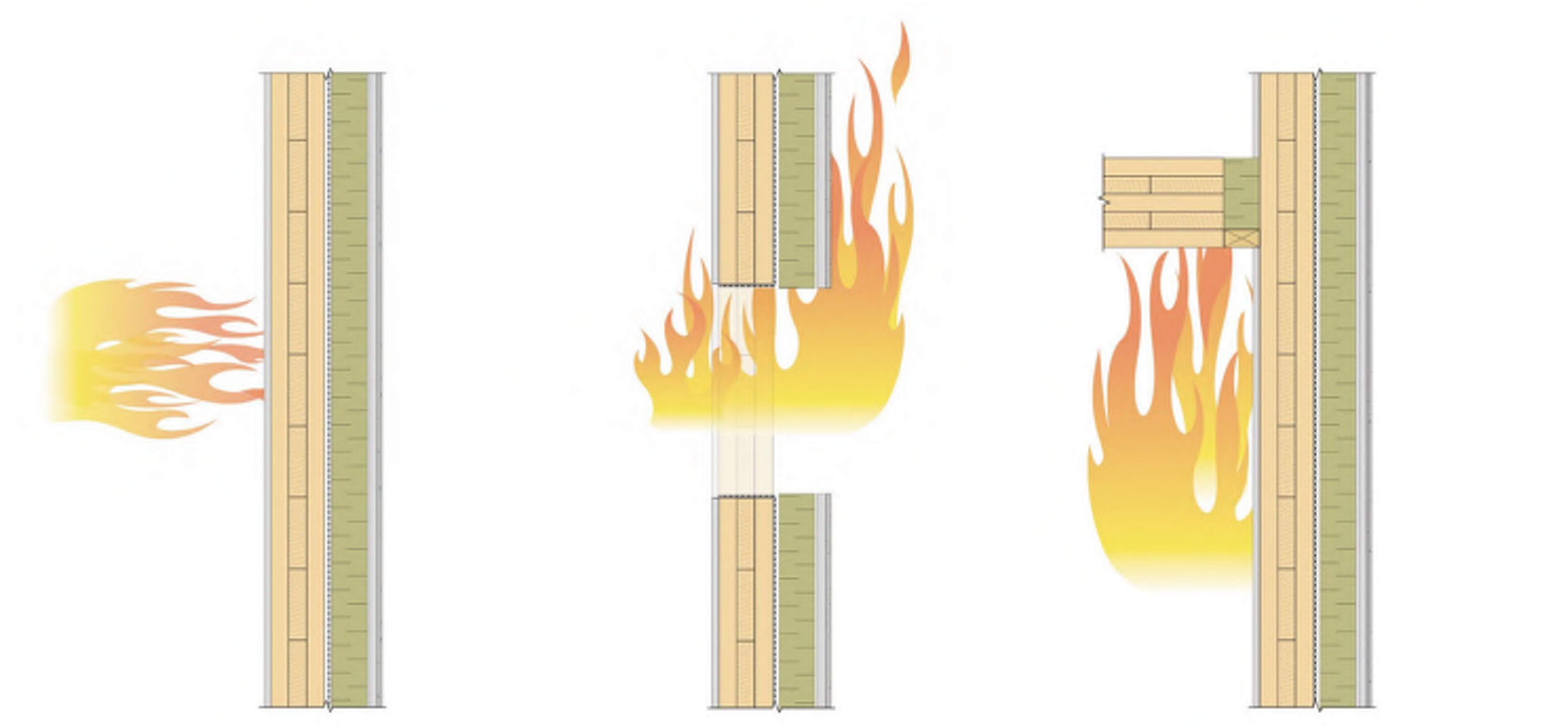
Tall Wood Fire Protection = Encapsulation and/or Char



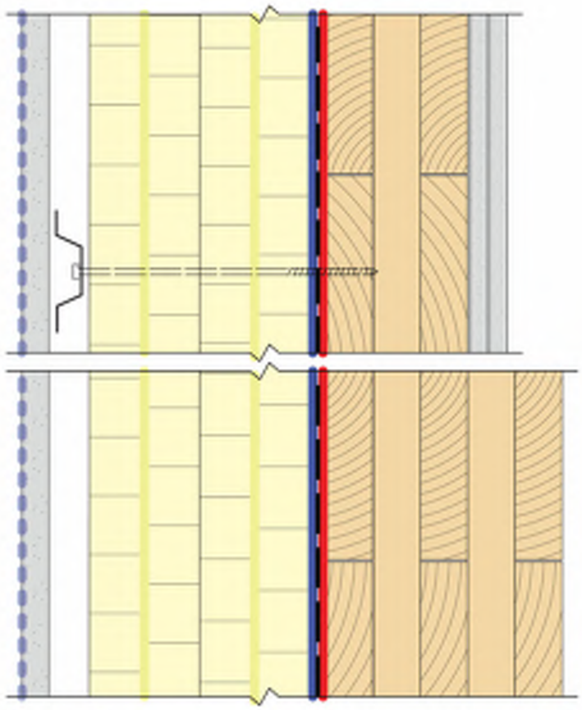


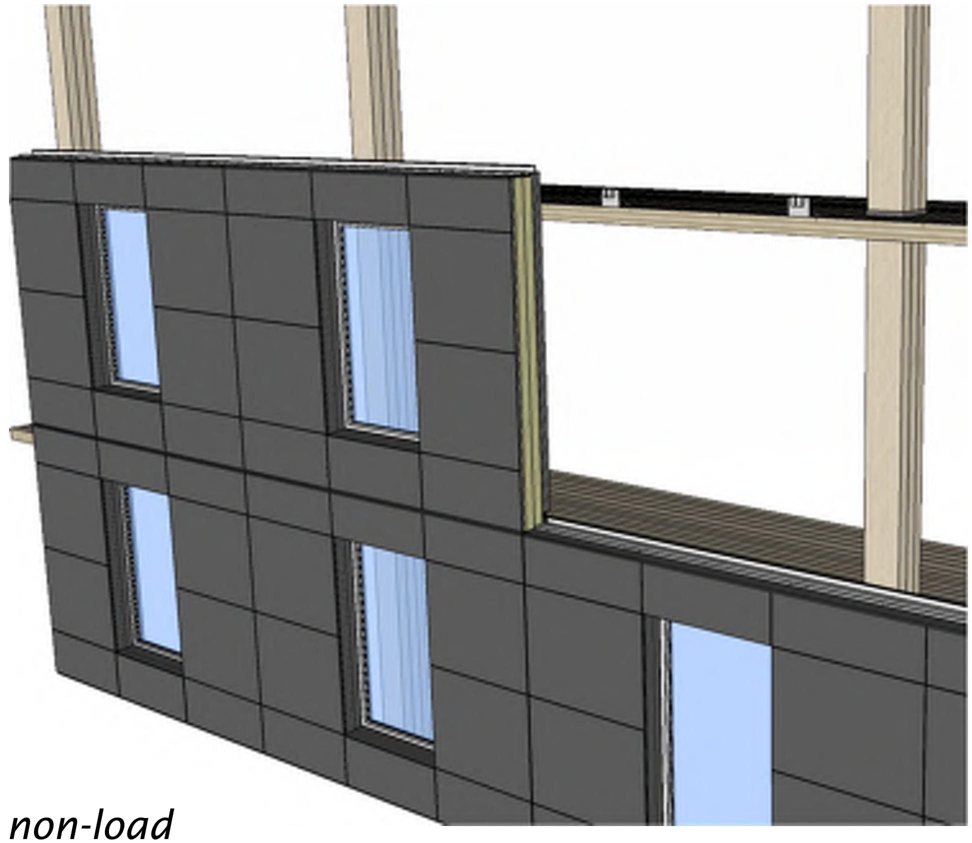
Exposed CLT - with 103mm char provides 120min FRR
(0.8mm/min x 120min + 7mm) per CSA 086 Annex B

Tall Wood Facades - Fire Resistance, Exterior Fire Spread & Firestopping Performance



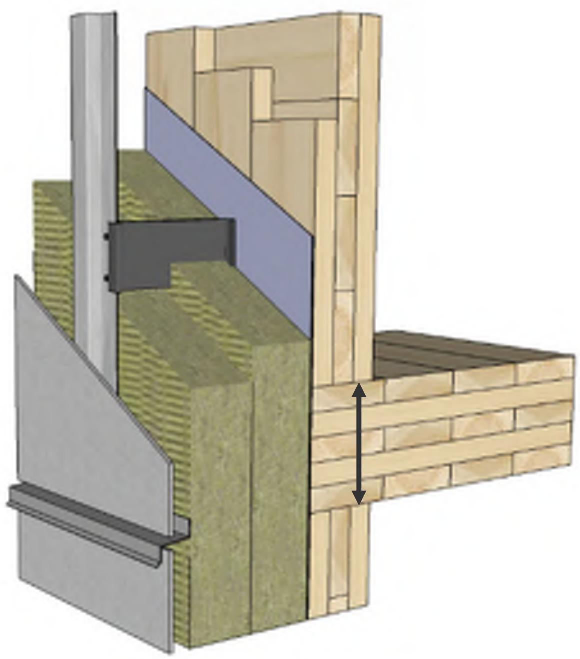
Tall Wood Façade Fire Protection



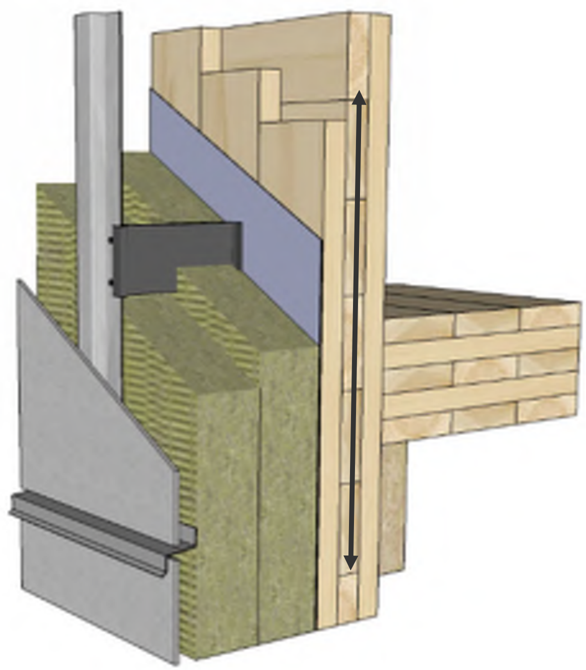


Generally 1 hr fire ratings required for non-load bearing walls and 2hr ratings for load bearing walls

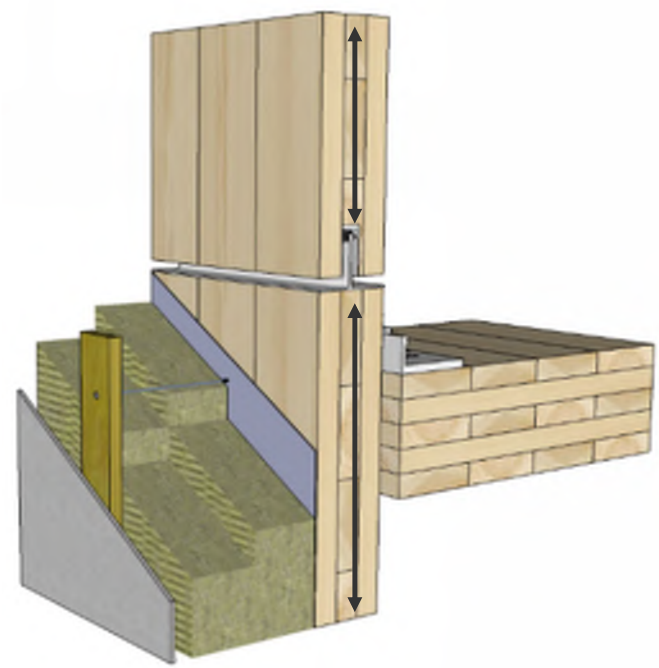
Tall Wood Façade & Building Movement Considerations



Low-rise only due to shrinkage of wood



Low to mid-rise, or taller where exterior load bearing walls



Non-load bearing exterior wall applications – i.e. most tall buildings

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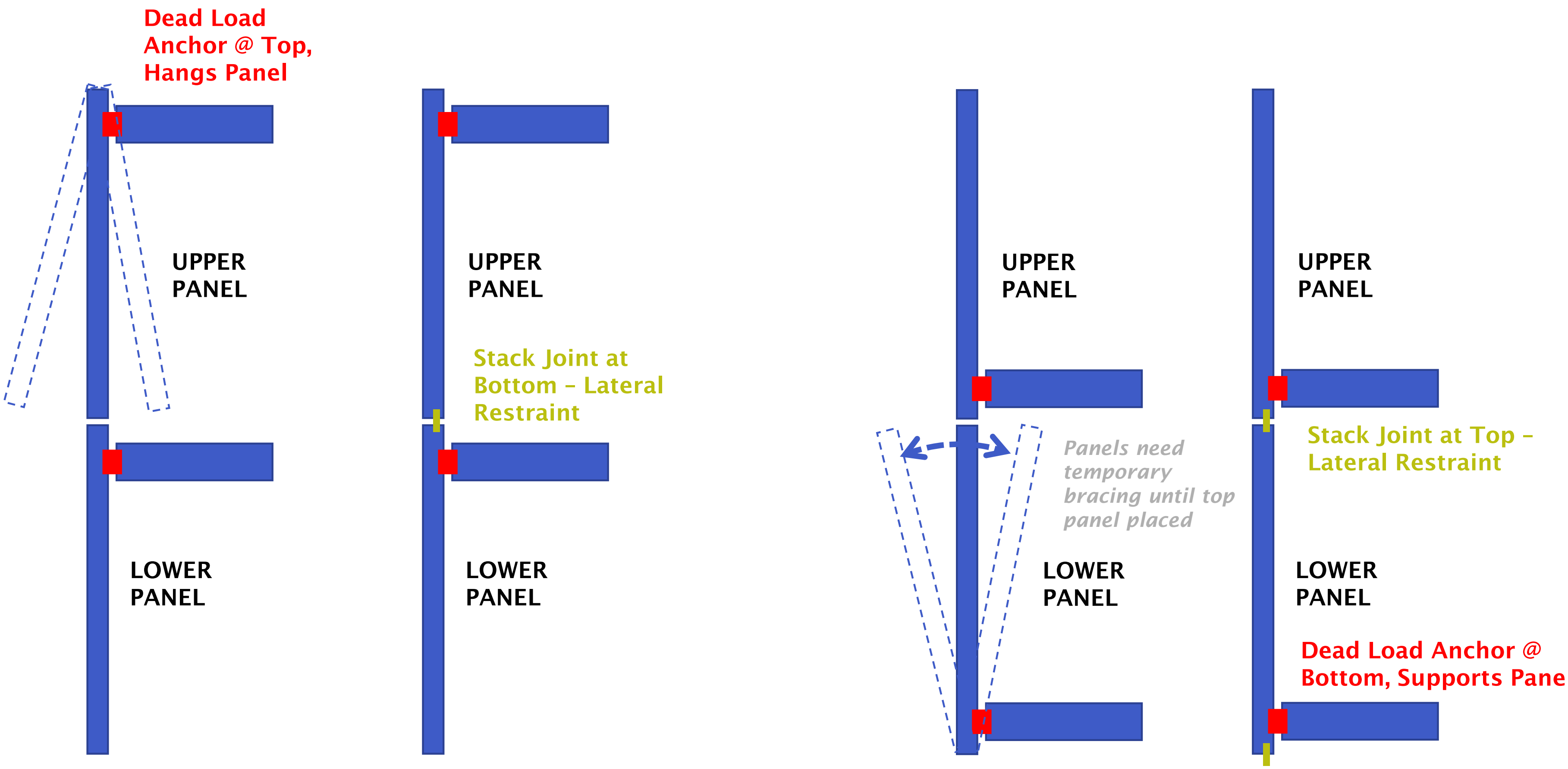
Hanging Non-Load Bearing Facades



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Façade Technical Performance Criteria

- → *Don't break and/or fall off!*
  - → Imposed structural loads: wind, seismic, building movement, thermal movement, possibly blast and impact resistance
- → *Don't leak!*
  - → Wind driven rain, air leakage (rate)
- → *Don't Sweat!*
  - → Condensation resistance, thermal performance
- → *Don't Burn!*
  - → Fire performance, combustibility
- → *Look Good!*
- → *Sound Good!*
- → Addressed by a combination of engineering, physical testing, & installed experience

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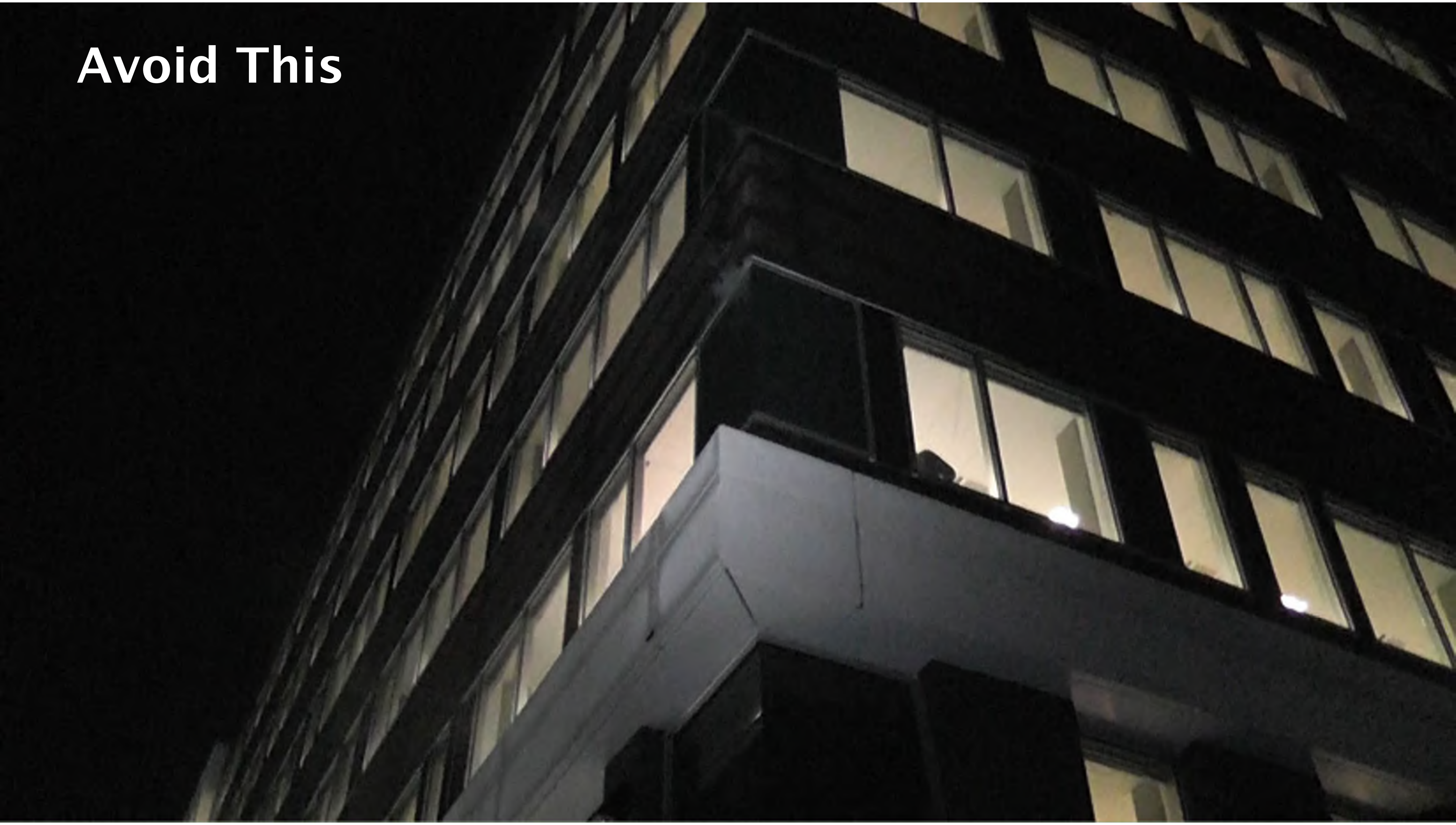
Avoid This!

Avoid This

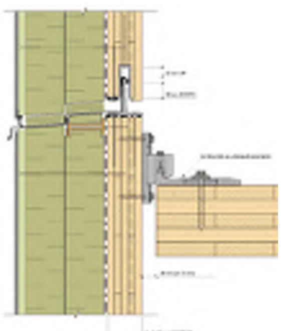



Avoid This

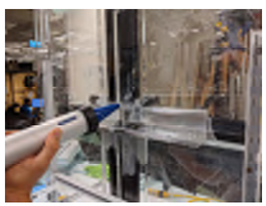

Avoid This

De-risking New Prefabricated Façade Systems

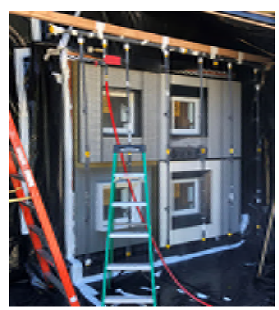
New façade system idea!



Design, engineering & prototyping



Small scale bench tests & detail iterations



Performance mockups, testing, engineering review & design tweaks

Early (small) real projects, feedback and iterations

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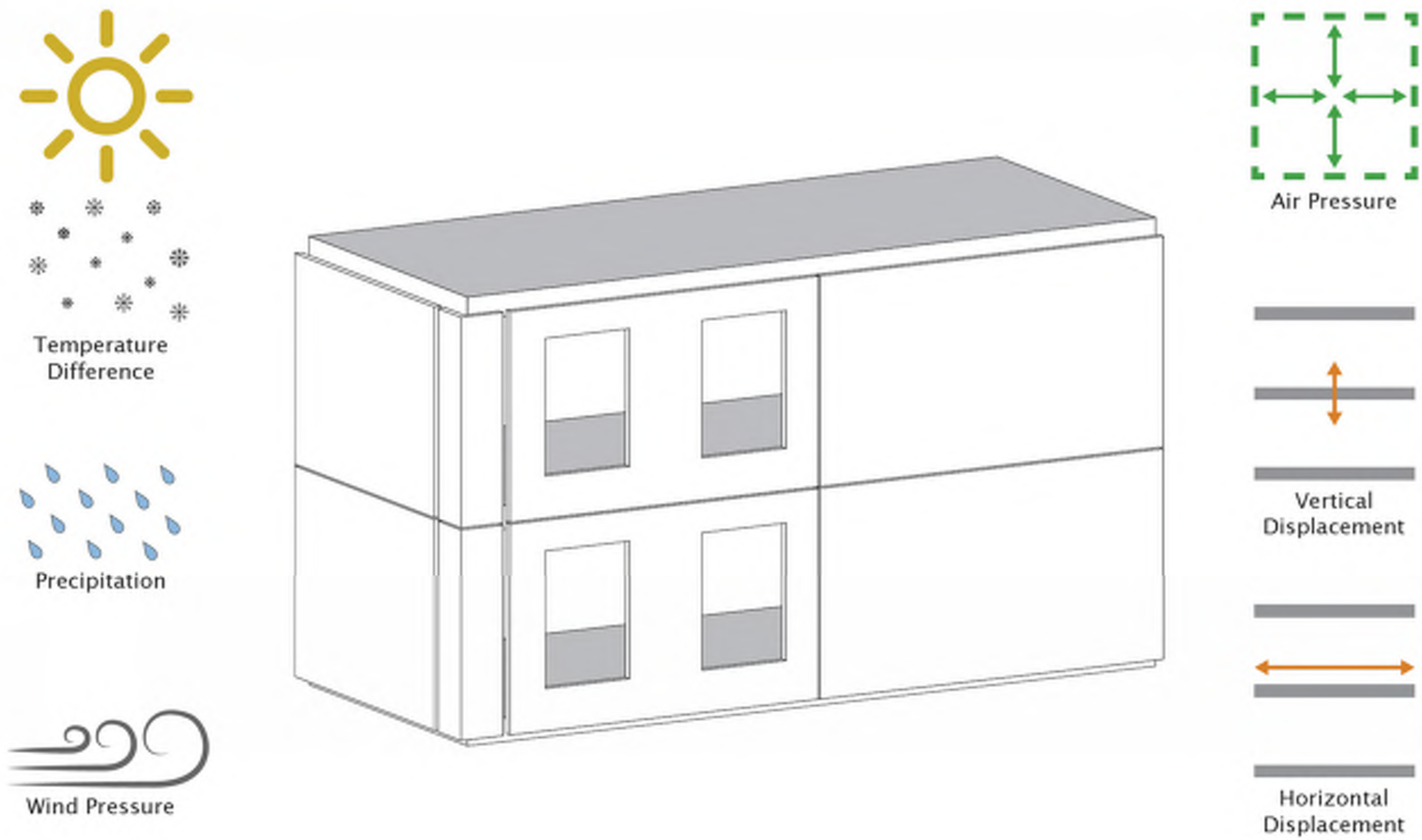
Façade Performance Mockup (PMU)



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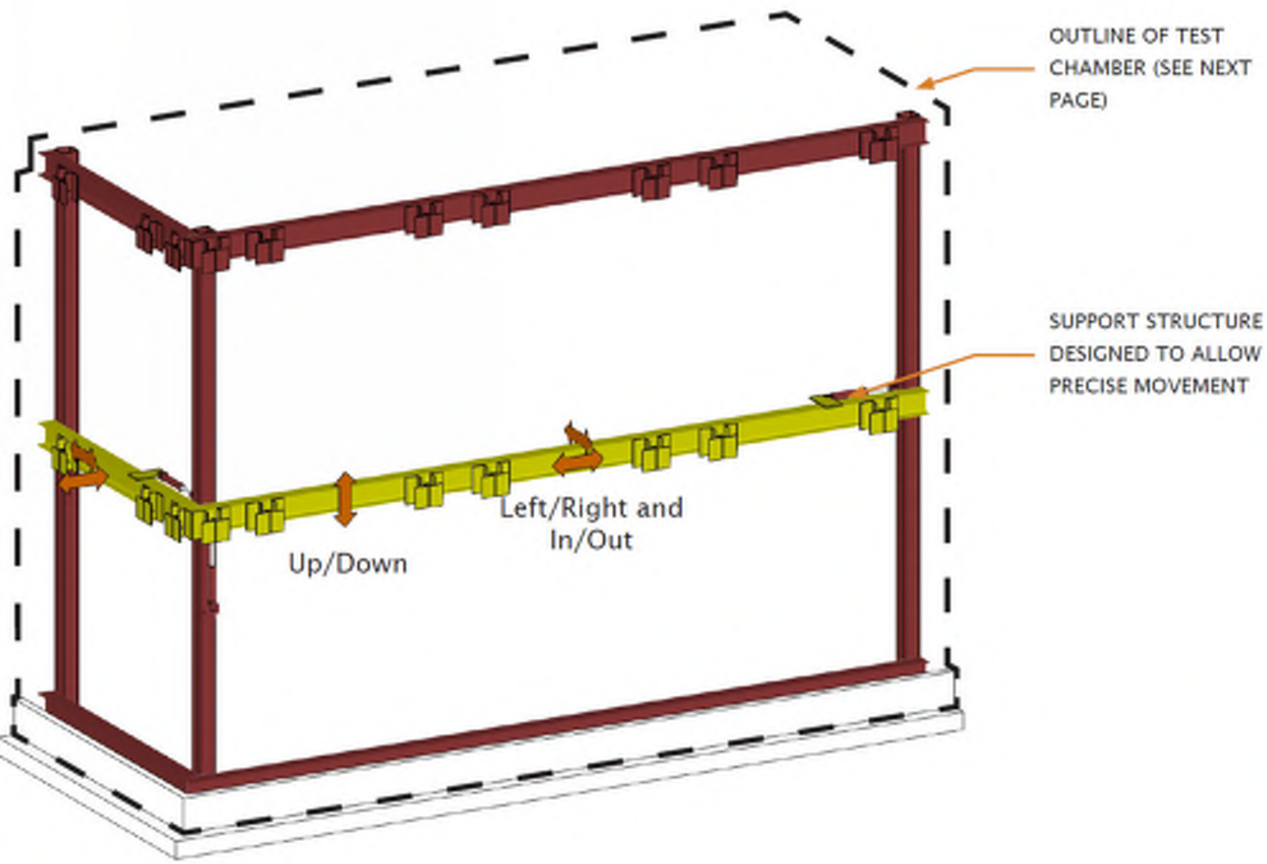
PMU Support Structure



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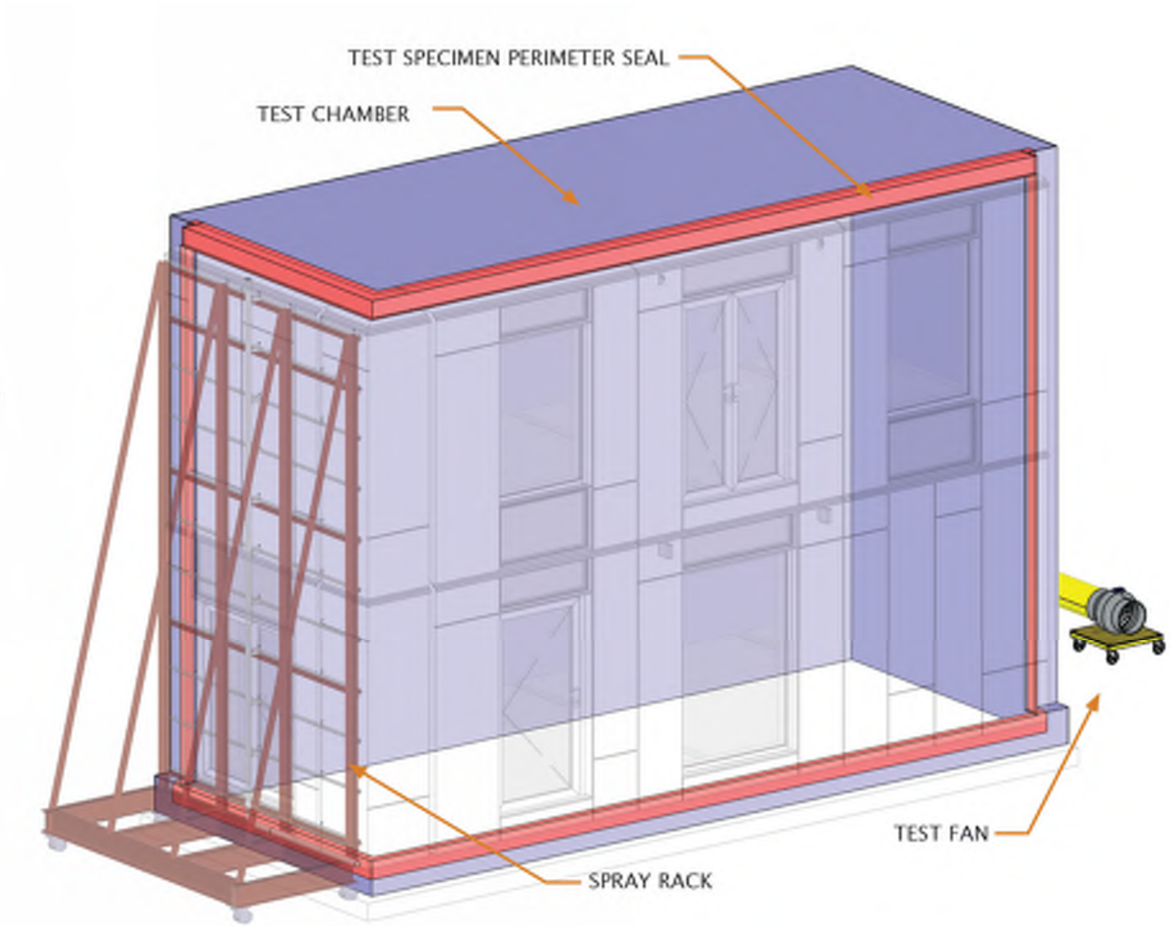
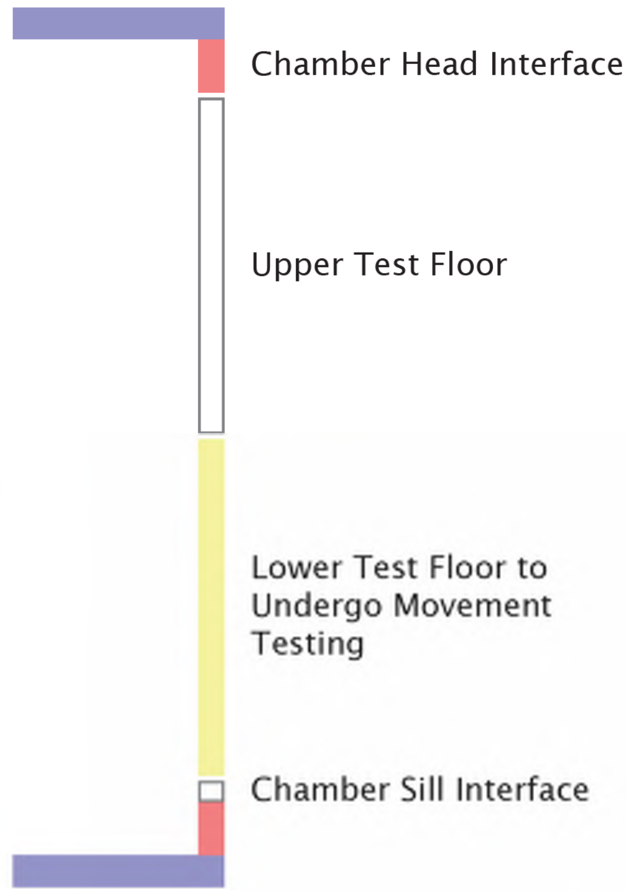
PMU Testing





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Typical PMU Test Procedure

Construct & Pre-Load

1. Air Leakage Rate
2. Static Pressure Water Penetration
3. Dynamic Pressure Water Penetration
4. Structural Wind Load (Design Pressure)
5. *Repeat Air & Water Leakage*
6. Vertical Inter-Storey Displacement (Design Movement)
7. *Repeat Air and Water Leakage*
8. Elastic Lateral Inter-Storey Drift Displacement
9. *Repeat Air and Water Leakage*
10. Thermal Cycling and Condensation Resistance
11. *Repeat Air and Water Leakage*
12. Structural Wind Load (Proof Loading, 150% Design pressure)
13. Inelastic Lateral Inter-Storey Drift Displacement

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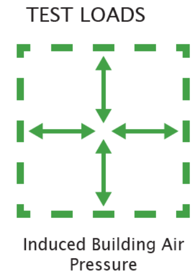
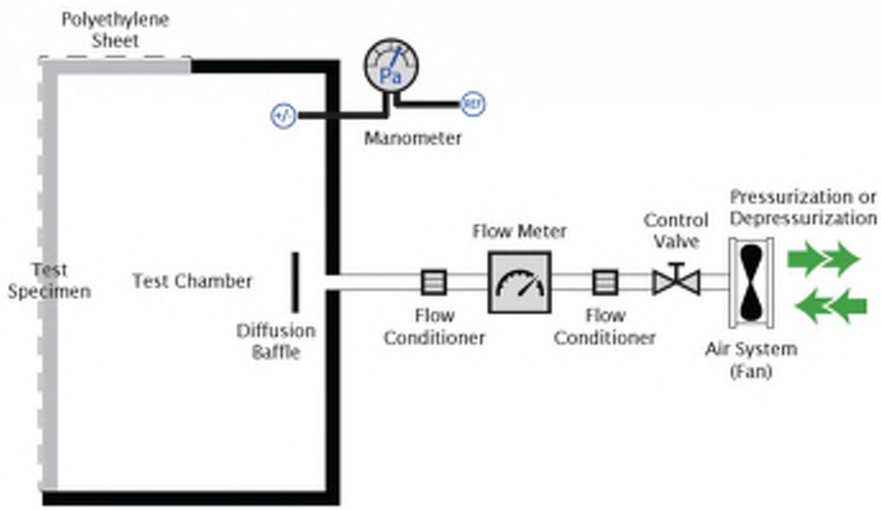
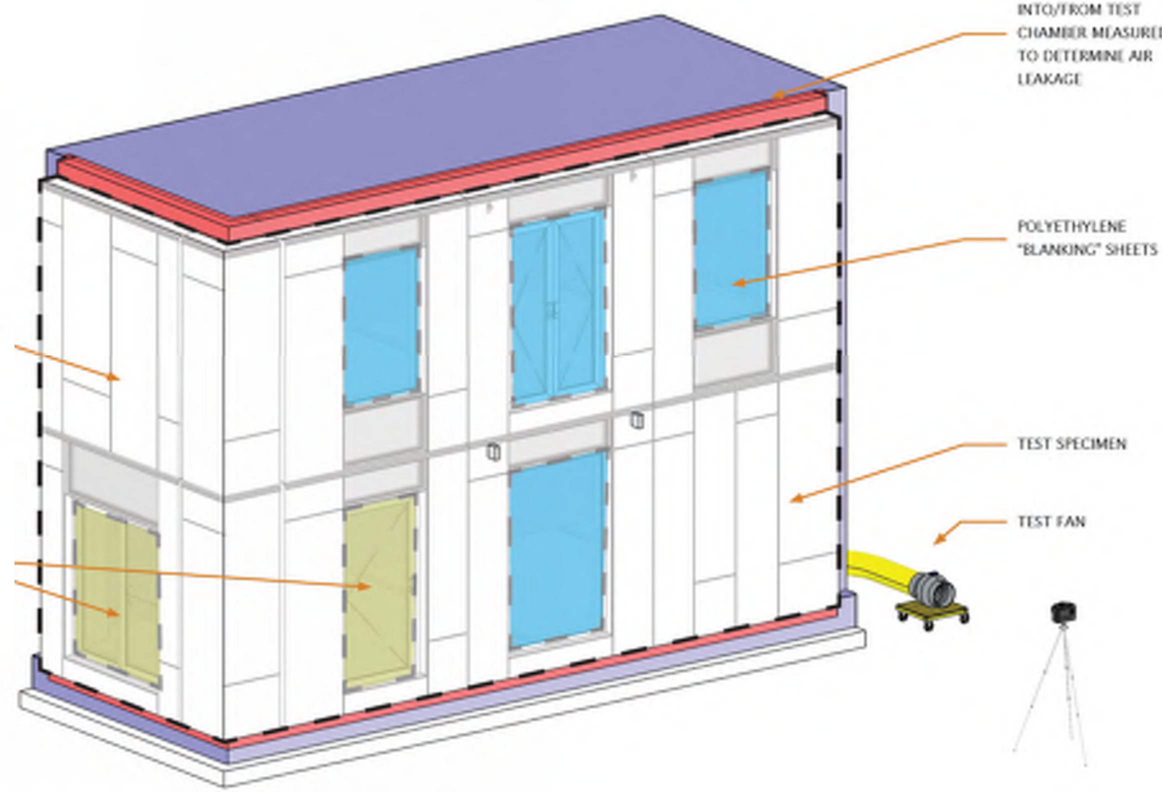
Air Leakage / Infiltration Rate

(ASTM E283 @ 300 Pa & other measurement points)







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Air Leakage Diagnostics

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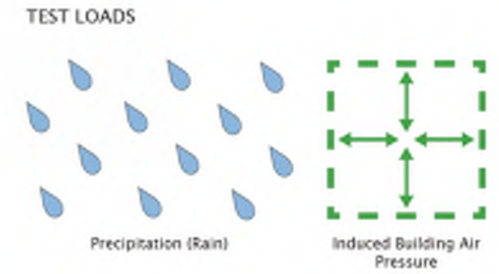
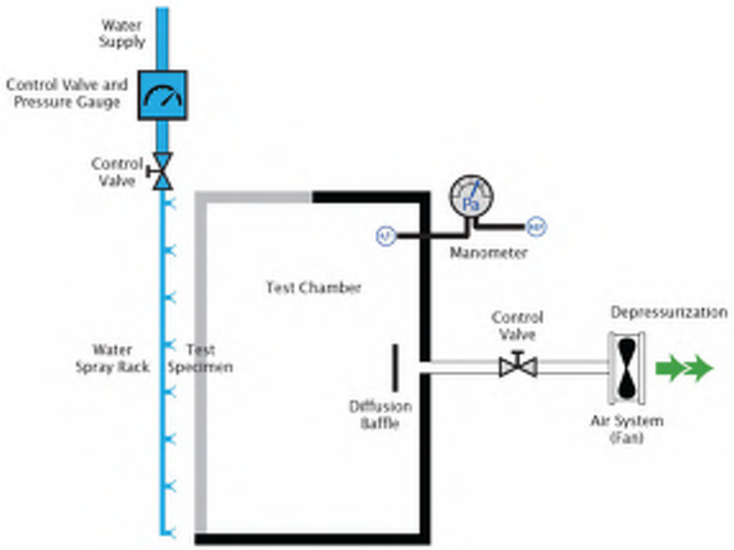
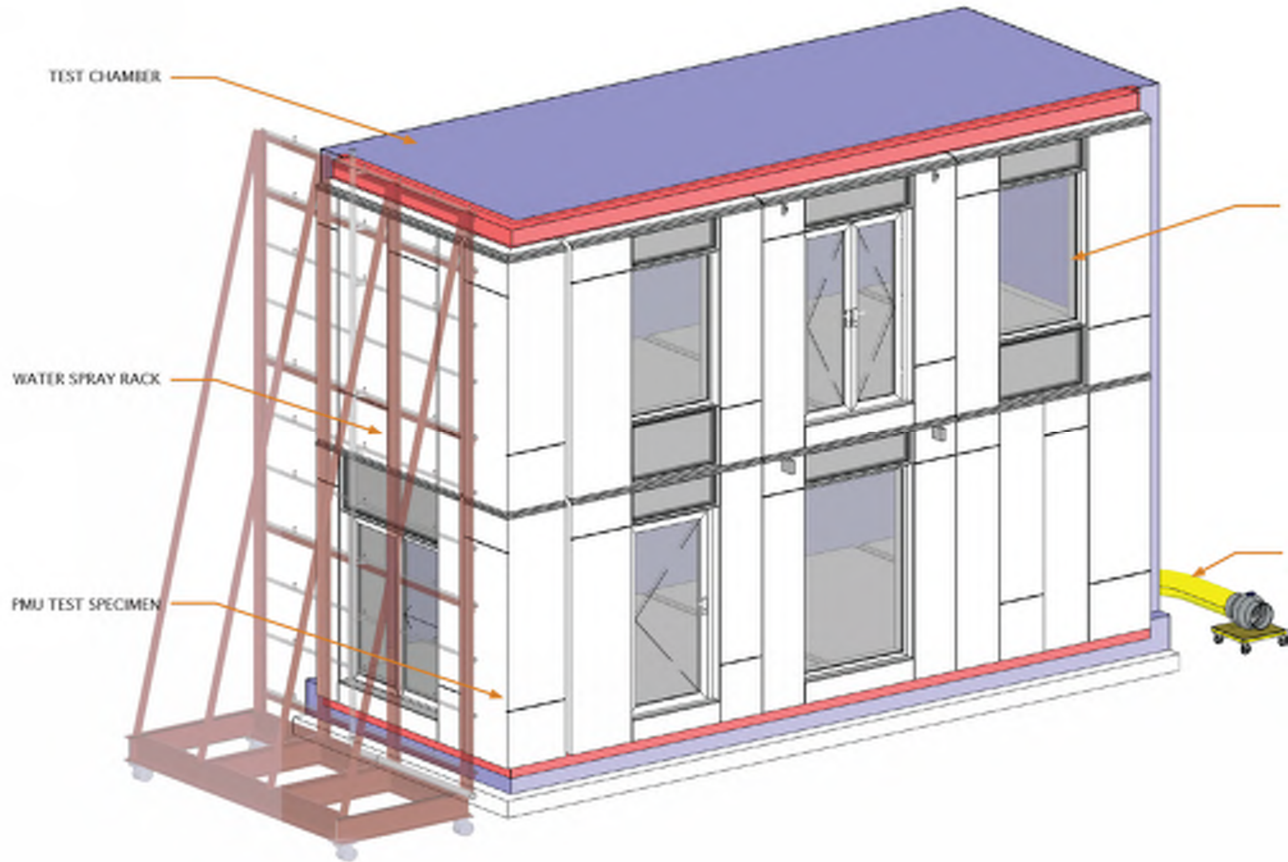
Static Pressure Water Penetration

(ASTM E331 @ design driving rain test pressure, 720 Pa max)

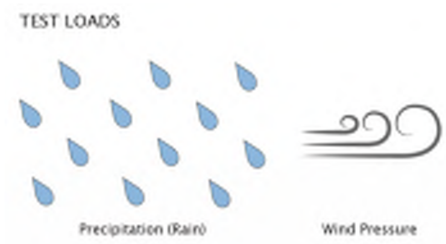


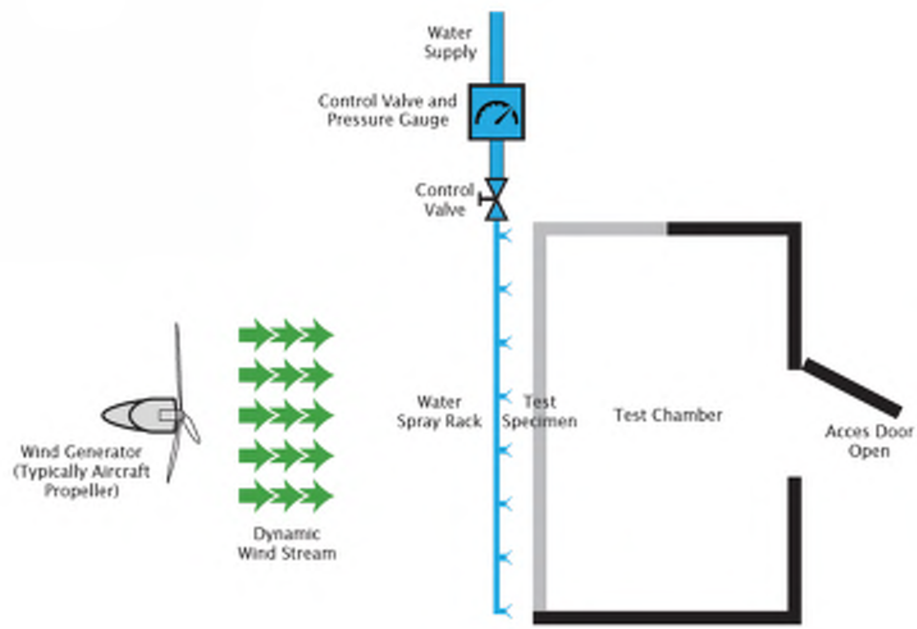


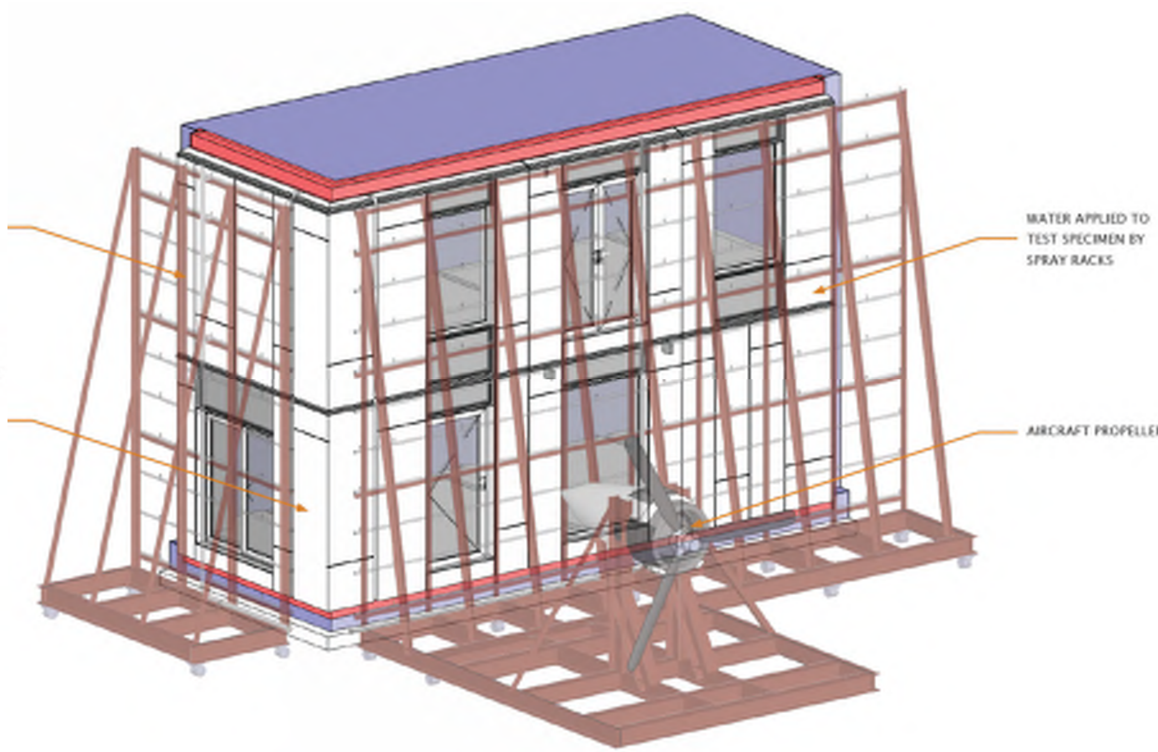


Dynamic Pressure Water Penetration

(AAMA 501.1 @ design driving rain wind speed/pressure)







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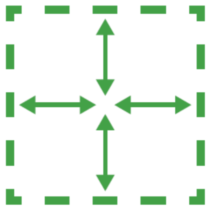
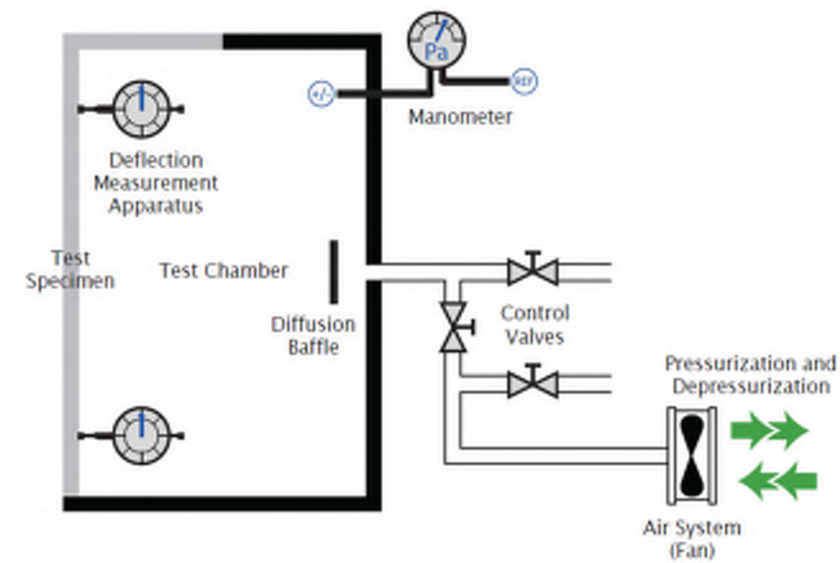
Structural Wind Loading

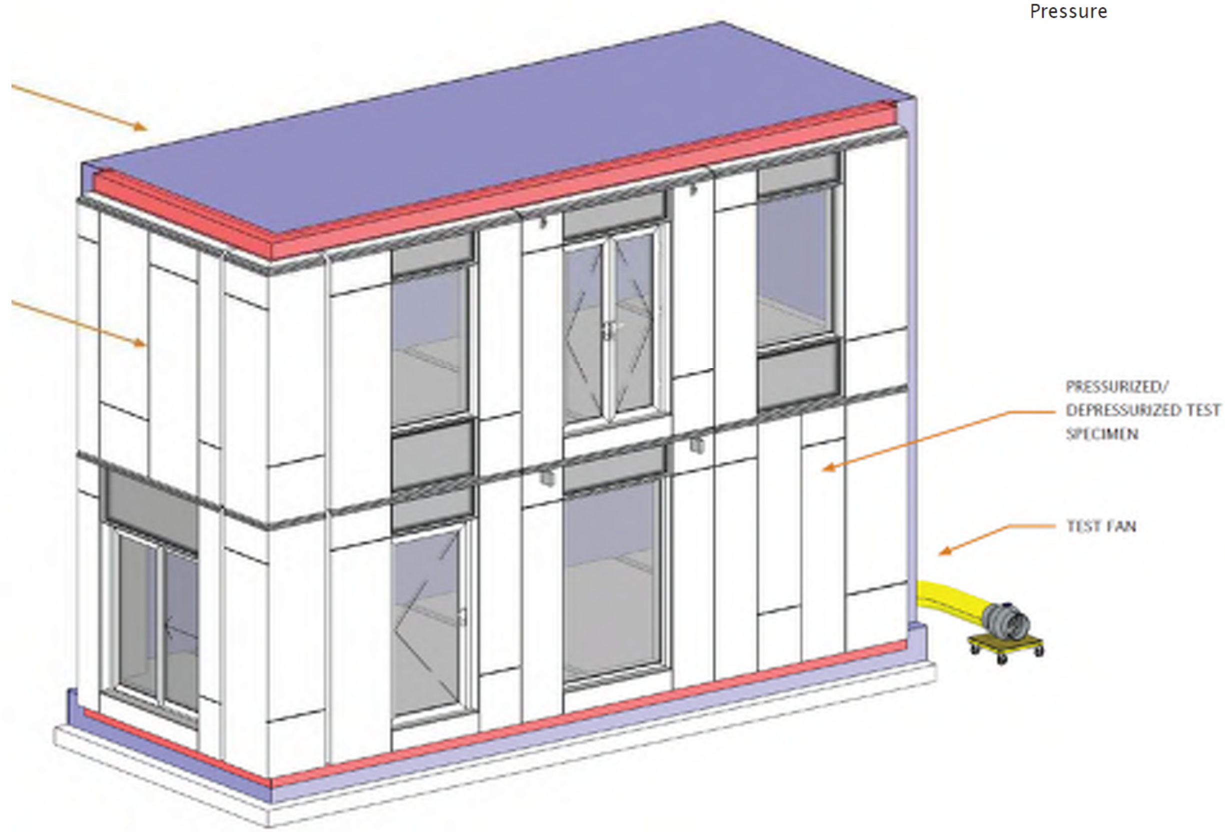
(ASTM E330 @ design wind speed/pressure)

TEST LOADS



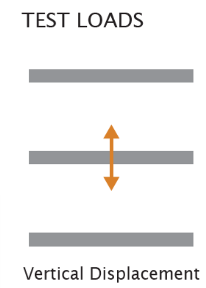
Induced Building Air Pressure

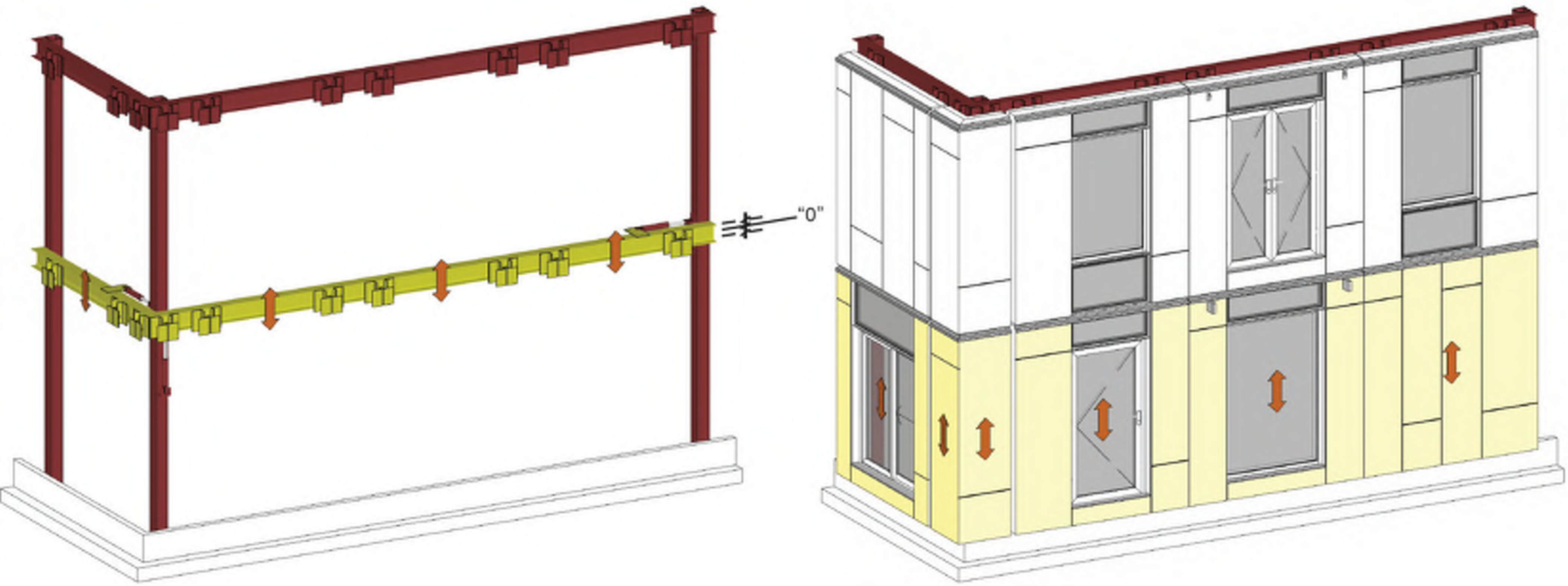




Vertical Inter-Storey Displacement

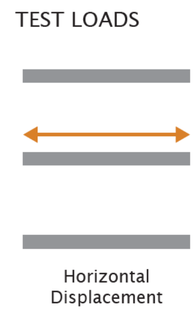
(AAM 501.7 @ design vertical displacement - e.g., due to live load, structure movement, creep, seismic, wind)

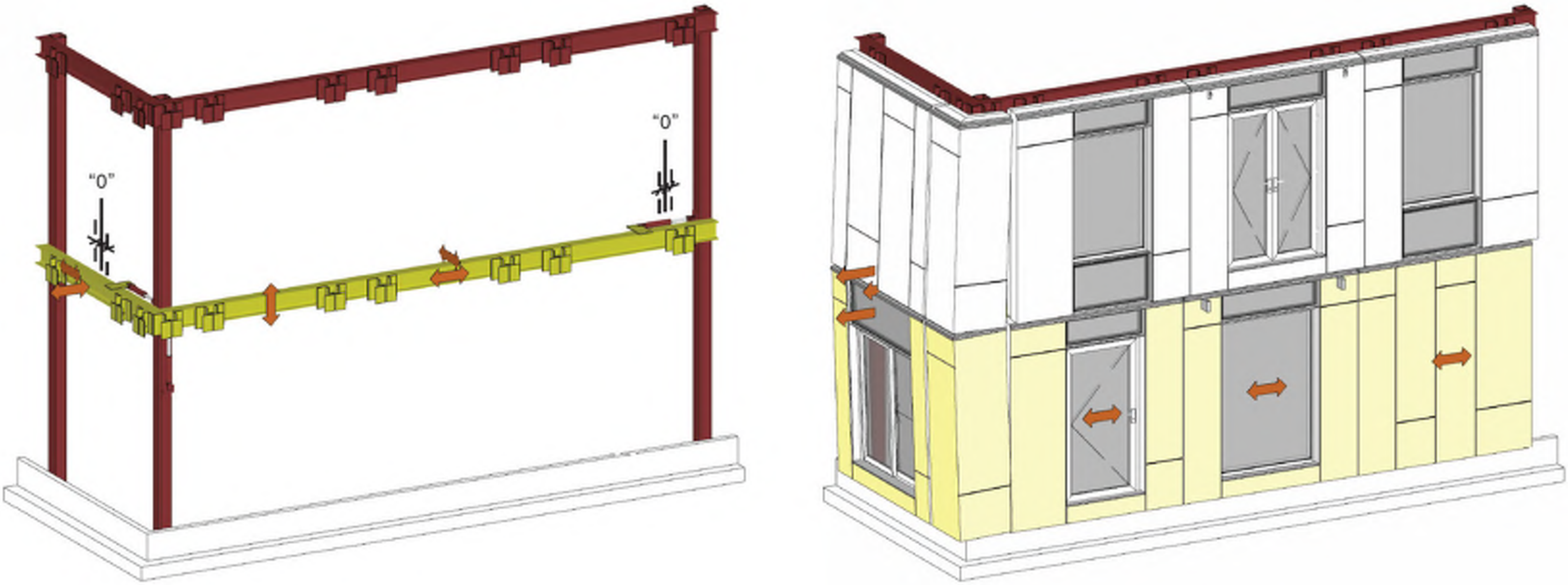




Elastic Lateral Inter-Storey Displacement

(AAM 501.4 @ design horizontal movement caused by seismic event or significant wind event on structure causing inter-storey drift





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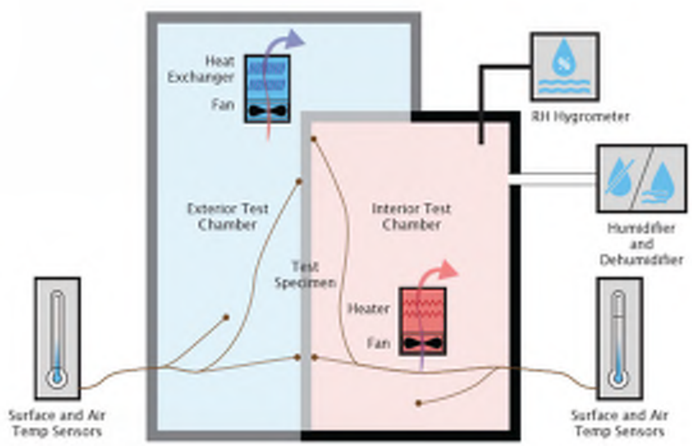
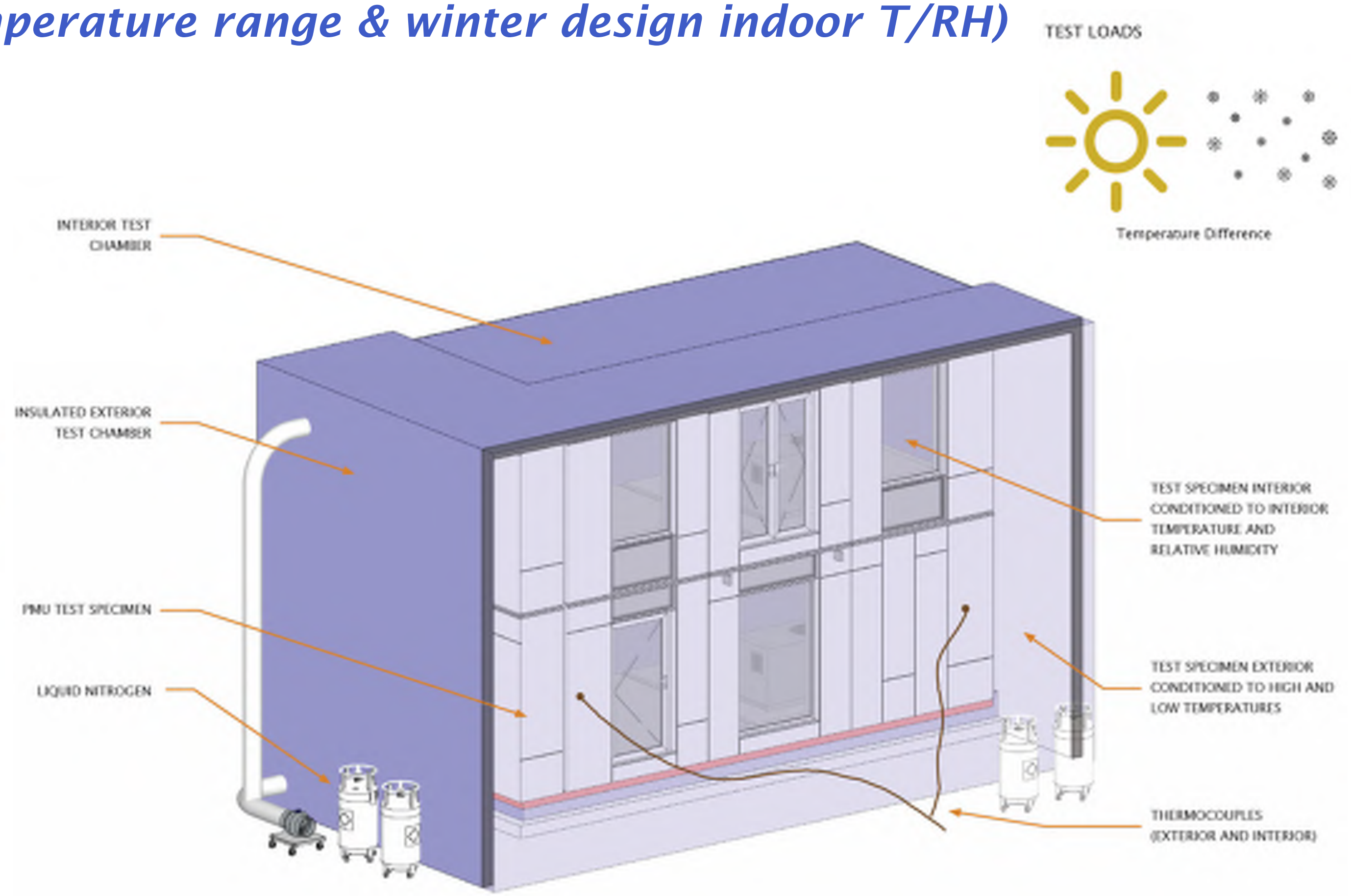
Thermal Cycling and Condensation Resistance

(AAMA 501.5 @ design temperature range & winter design indoor T/RH)





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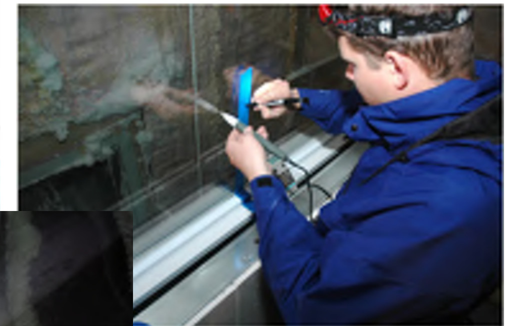
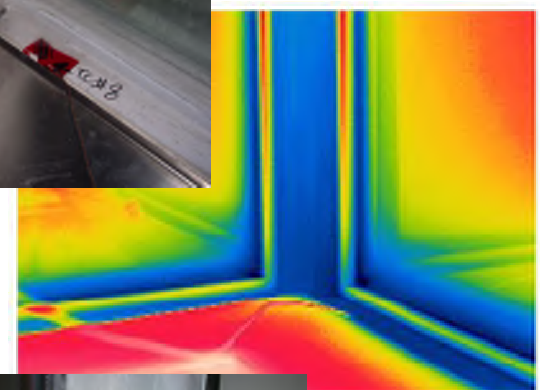
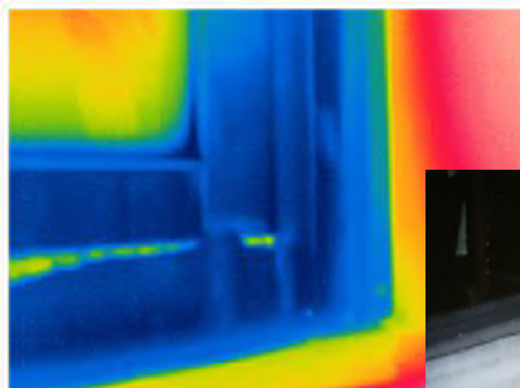
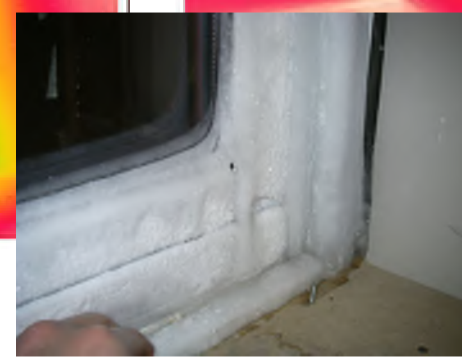
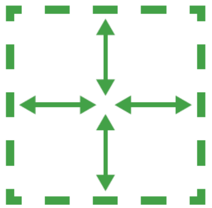


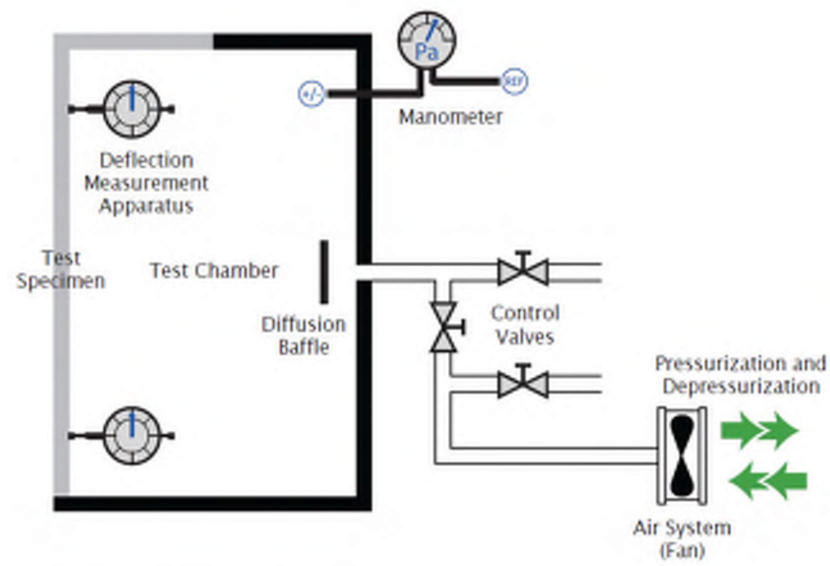




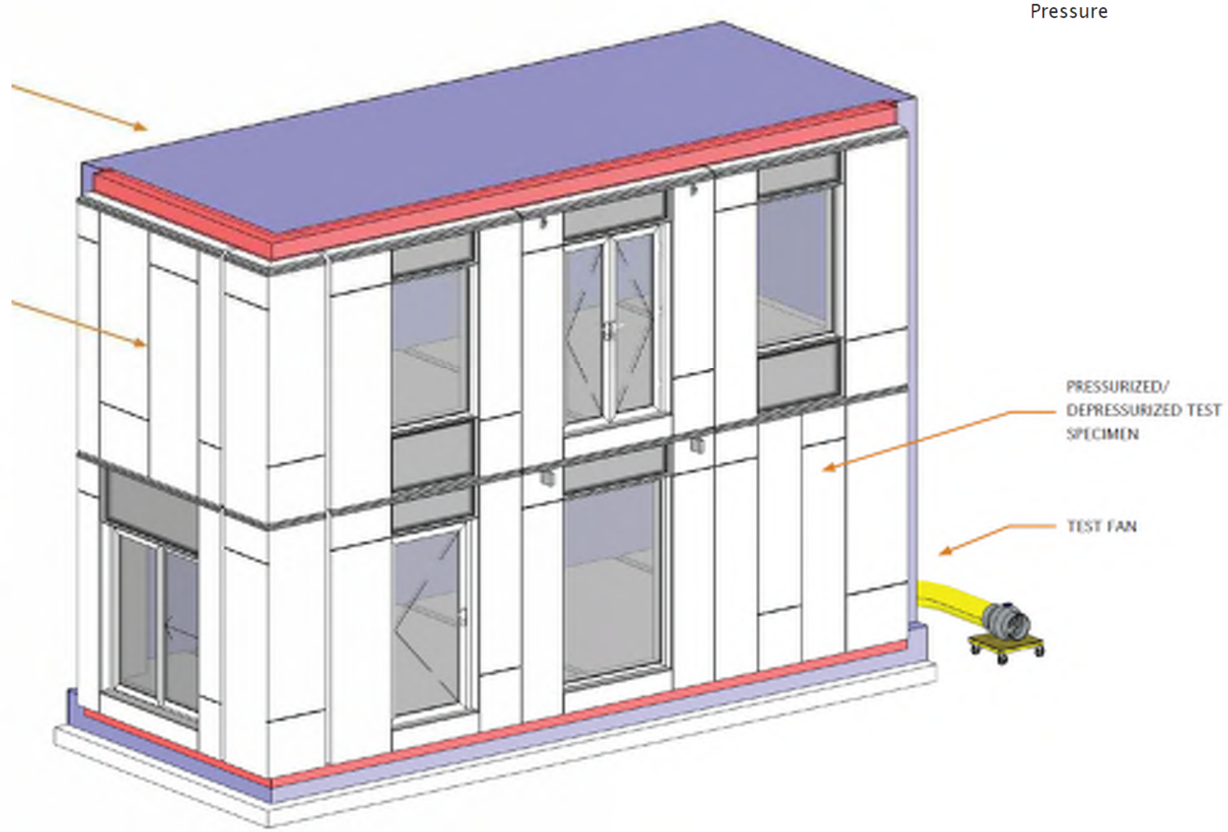
Structural Proof Wind Loading

(ASTM E330 @ 150% design wind speed/pressure)

TEST LOADS







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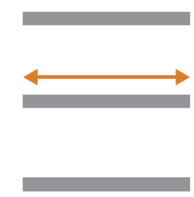
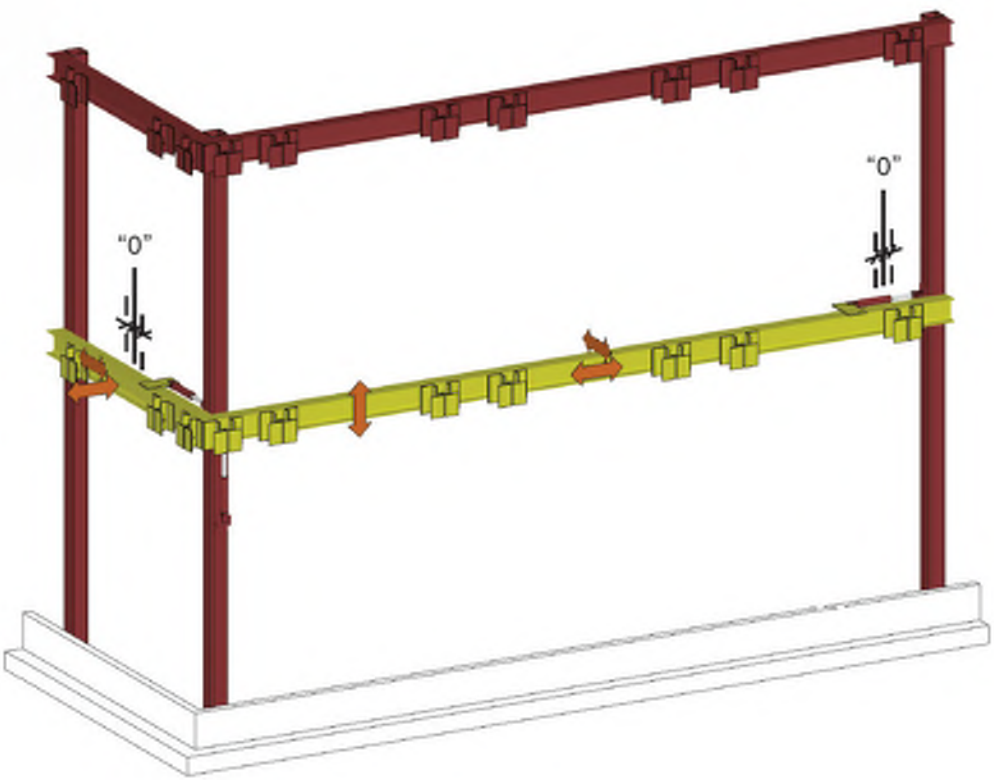
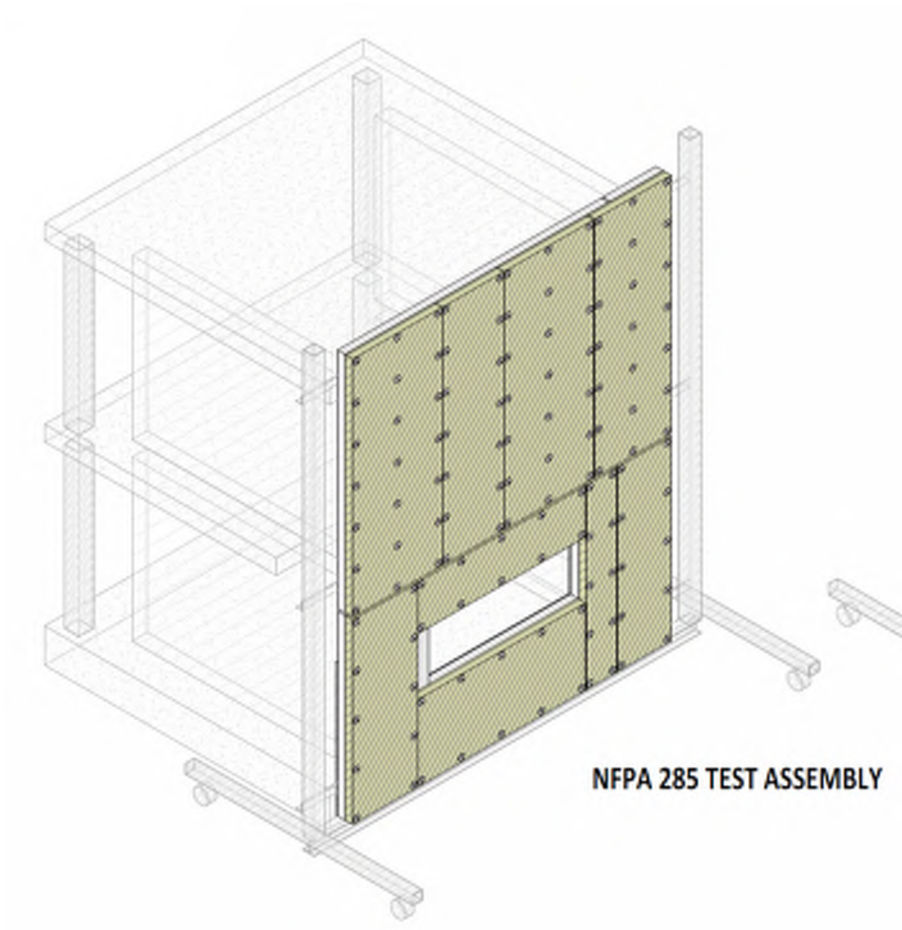
Inelastic Lateral Inter-Storey Displacement

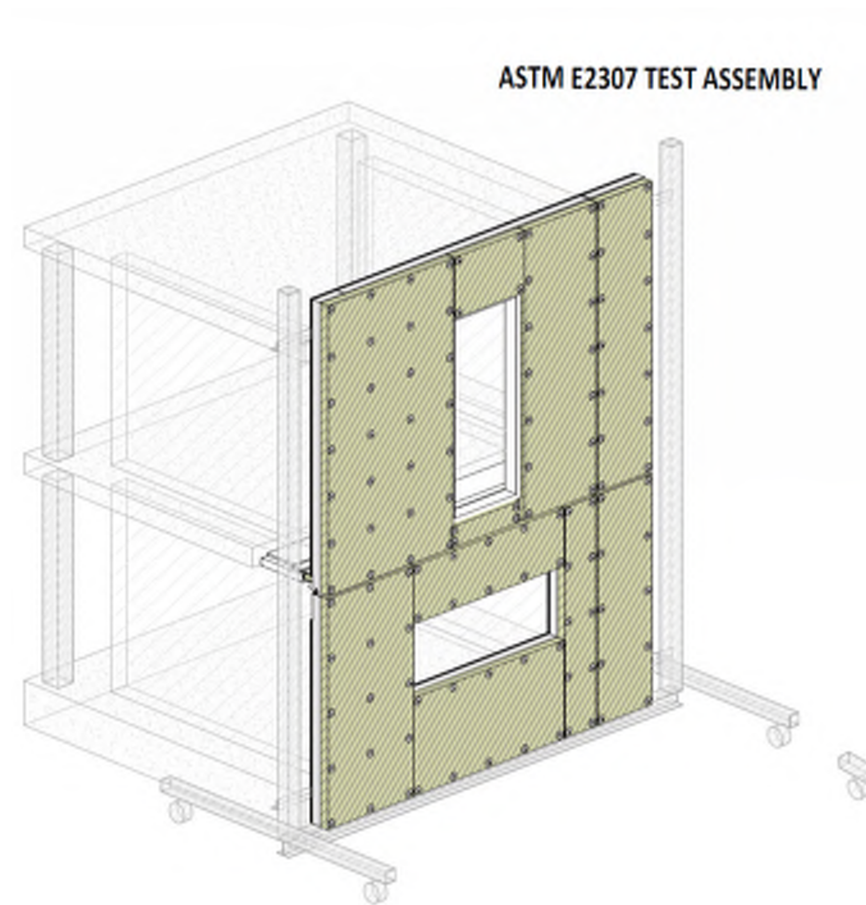
(AAM 501.4 @ design horizontal movement caused by significant seismic event on structure causing inter-storey drift





Fire Testing





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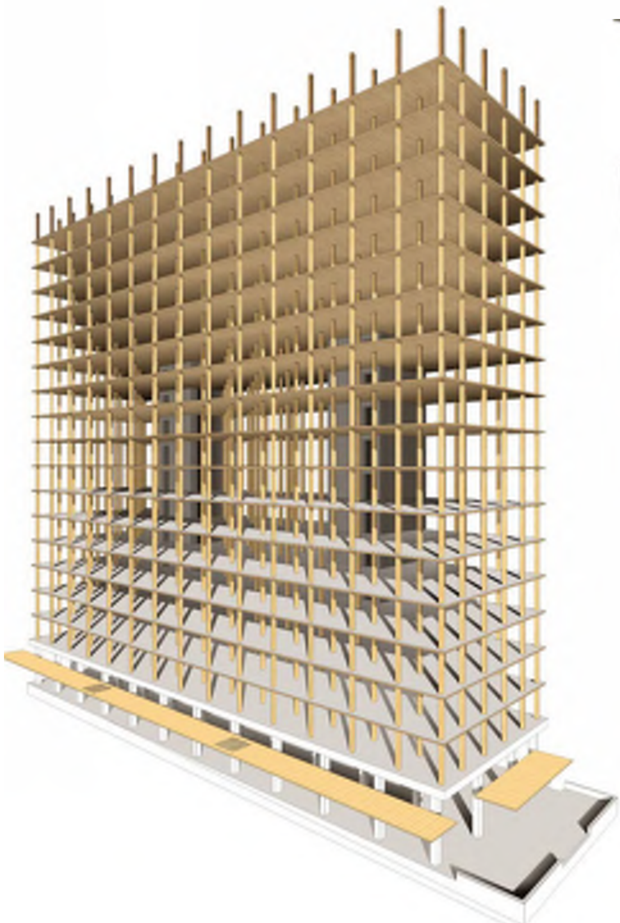
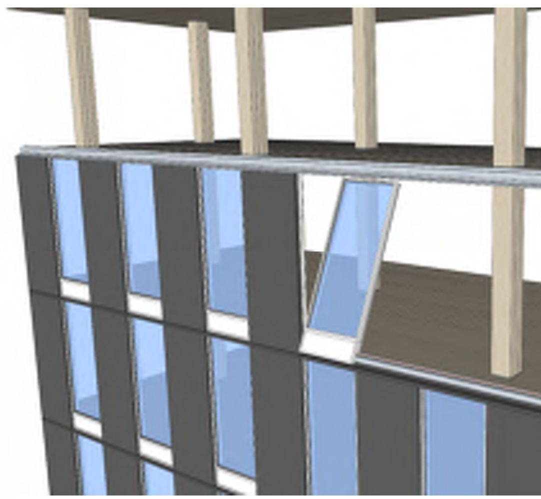
Additional Security & Safety Testing

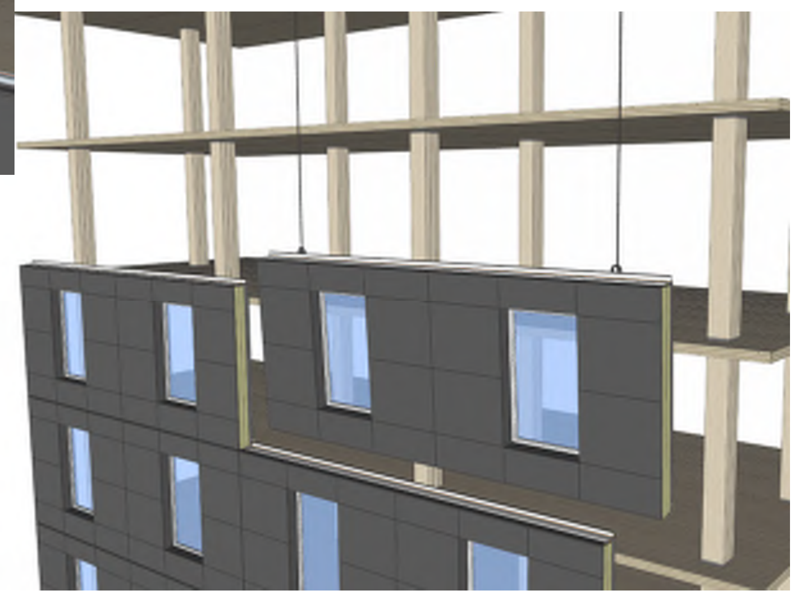
Blast resistance, hurricane/wind blown debris resistance, security & impact resistance

Wood Façade Developments & Evolution to Date

UBC Tall Wood – First Steps Towards Prefabricated Mass Timber Facades







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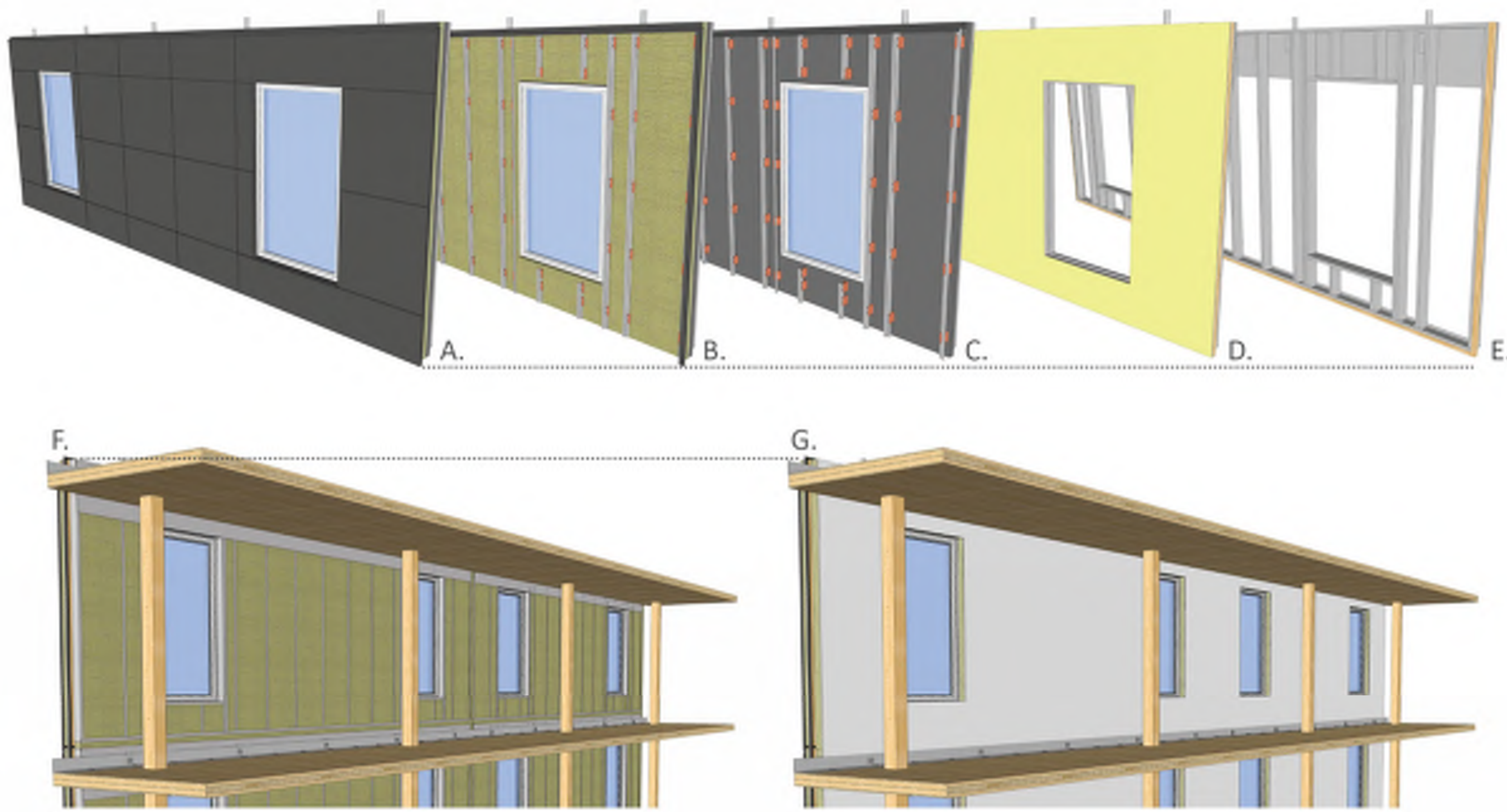
Prefabricated Facade System Competition

Prefabricated wood, steel, & concrete façade systems all prototyped, built and judged

Steel Frame Prefabricated Façade for Tall Wood



Exterior Envelope Layers

A. Wood fibre laminated panels + punched windows

B. Stone-wool insulation

C. Liquid-applied membrane

D. Weather-proof drywall

E. Steel studs

Interior Envelope Layers

F. Batt insulation + vapour barrier

G. Drywall

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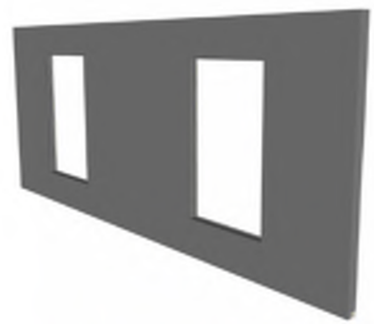
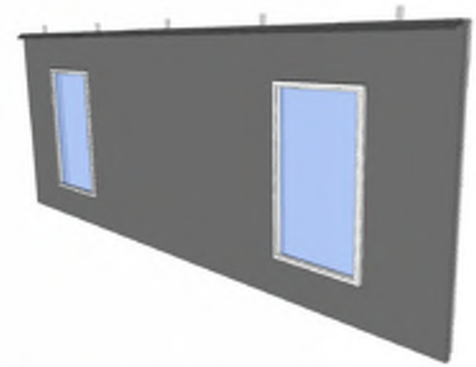
Alternate Mass Timber Prefabricated Façade Option

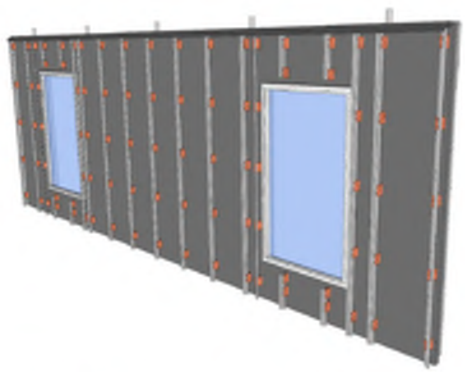
1 Mass timber back-up wall structure. 3 or 5-ply CLT.



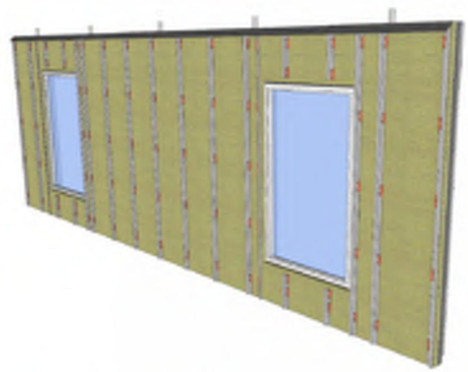
2 Vapour permeable and WRB. Multiple products available but self-adhered membrane recommended for ease of install.



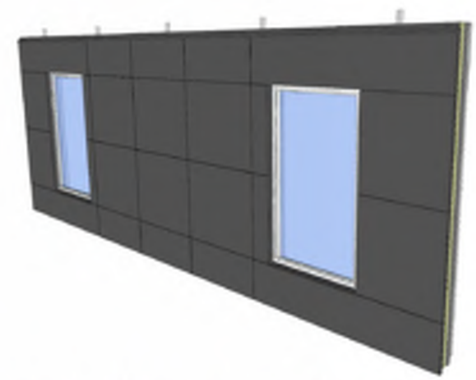
3 Punched windows installed to specifications. Step is omitted if curtain or window walls are specified.



4 Thermal clip and rail cladding attachment. Cheaper option to install hat tracks or Z-girts pinned through insulation with long screws. Cladding is to include an exterior air gap for rainscreen cavity.



5 Exterior mineral insulation of required thickness.



6 WSS. Cladding of choice must be durable as it experiences frequent wetting and drying cycles. Flashing detail is critical where panels join.

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Façade Performance Mockup (PMU) Testing






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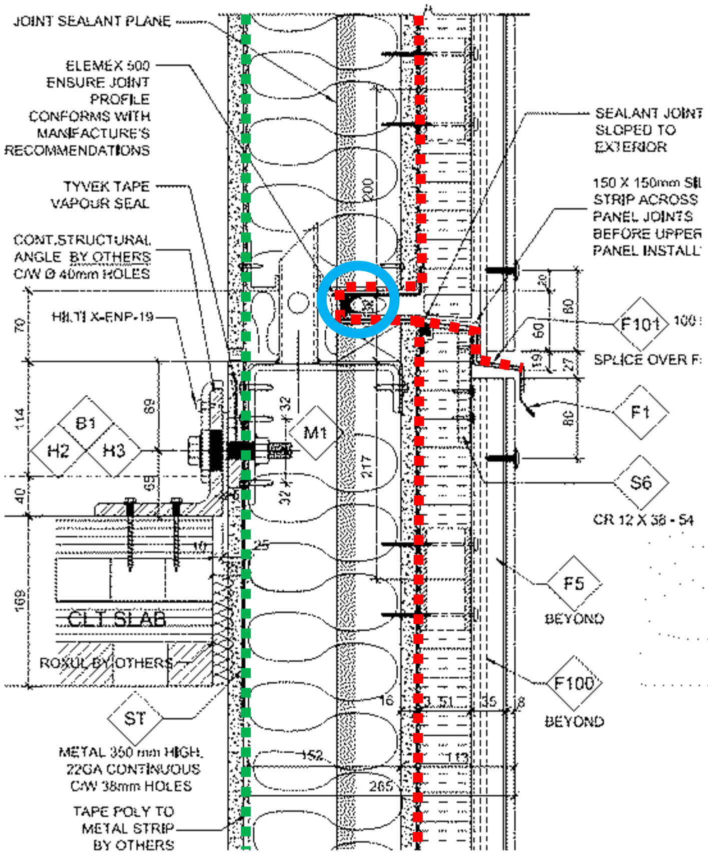
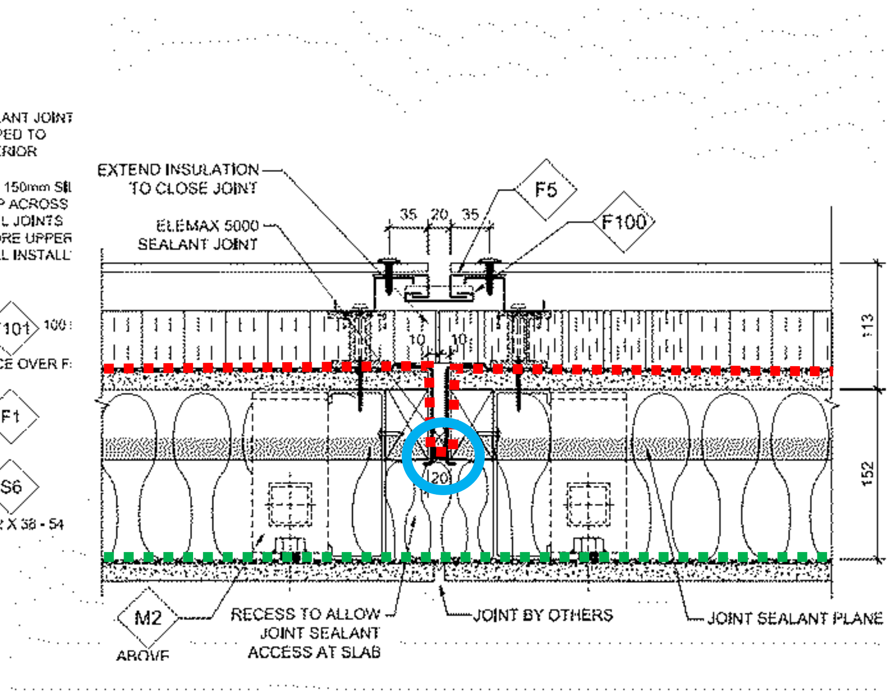
Site Installation – at Pace with Structure – 2 floors/week

The Wet Seal – Water and Air Control from Inside



Horizontal Section at Floor Slab



Vertical Section at Panel Joint

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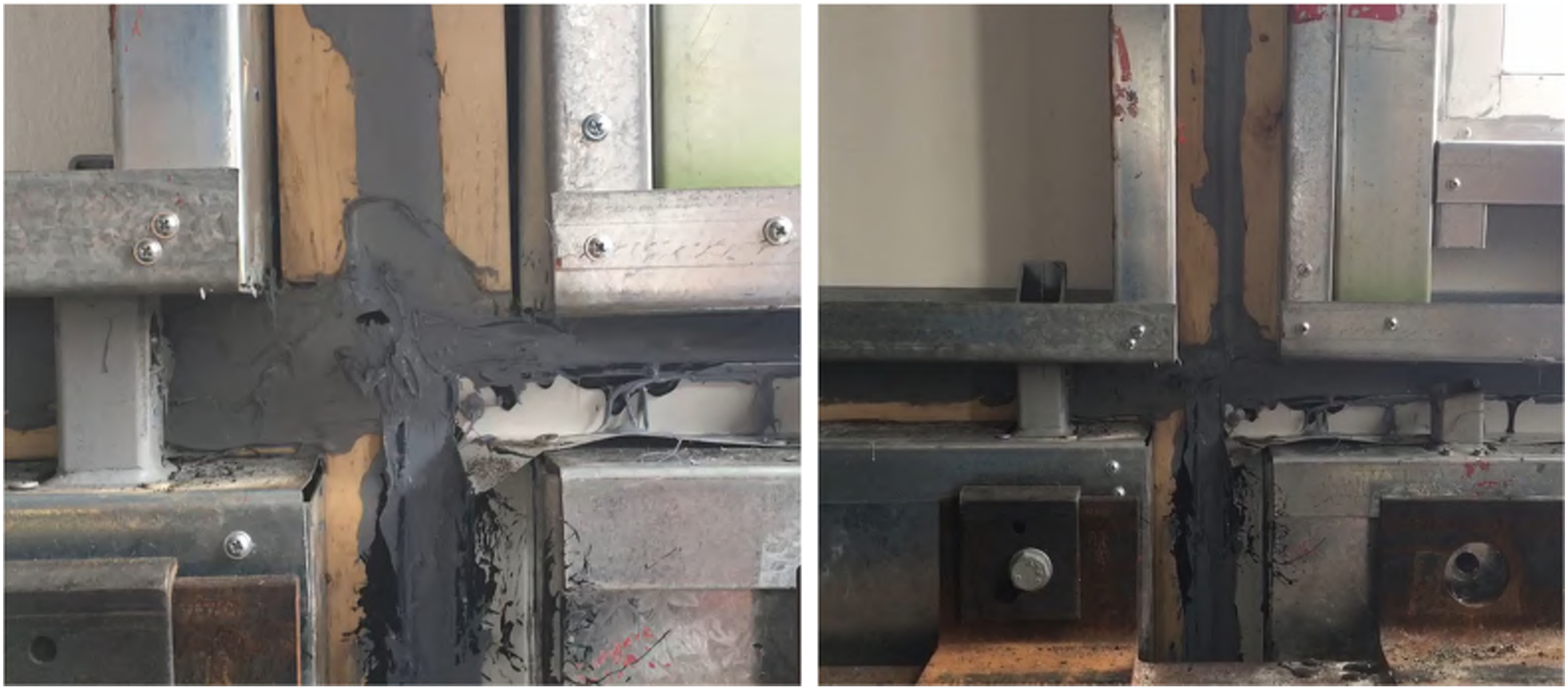
Structural Silicone Elastic Drift Movement



Field Commissioning

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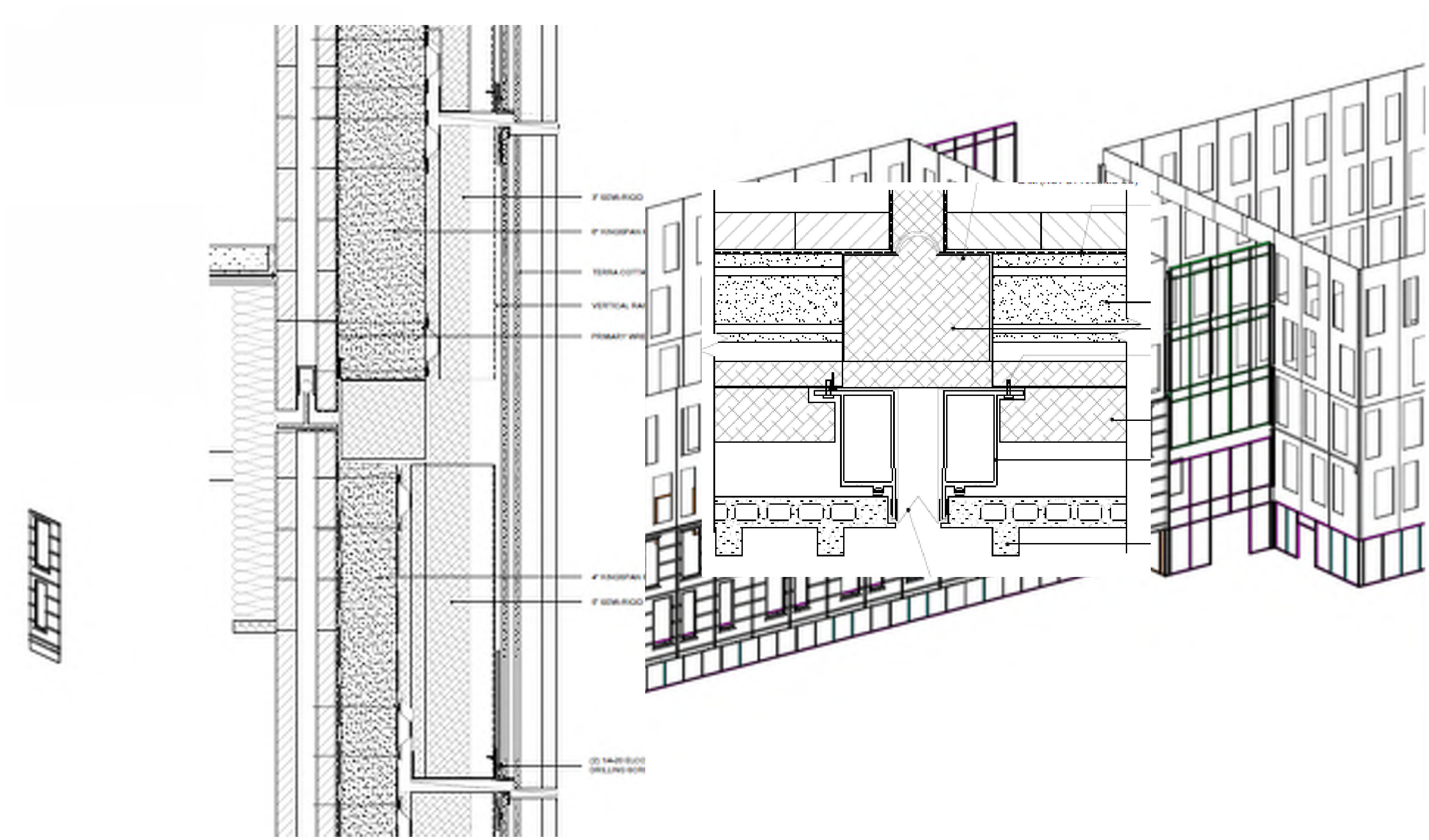
First Generation Panelized Mass Timber Facade



Net Zero Performance Goal, Passive House Building Enclosure & Airtightness Goals


Mass Timber Structure

Prefabricated CLT Façade Panels to Cladding Supports


Very Flexible Air & Water Seals


Structural Connection

Site Panel Installation & Window Installation

Site Joint Sealing

The Very Flexible Wet Seal


Structural Brackets
(2 Storey Hung Panels, Gravity Mid, Wind Top, Wind Bottom)

The PMU…

- Typical vertical joint
- Typical horizontal joint
- Typical corner joint
- Typical 4-way joint
- Window installation

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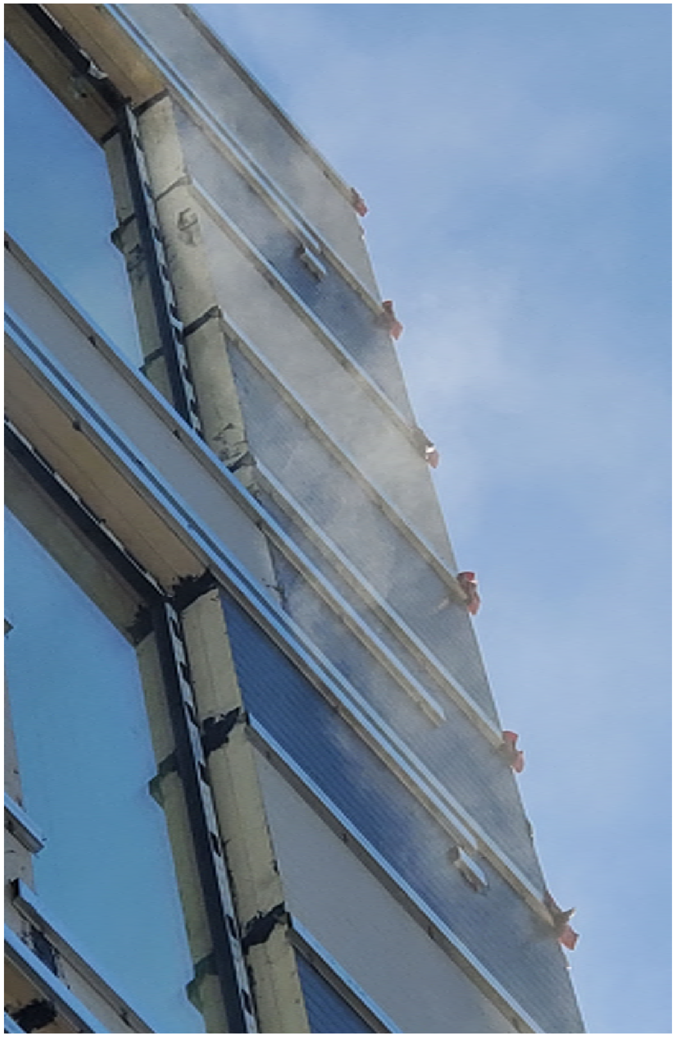
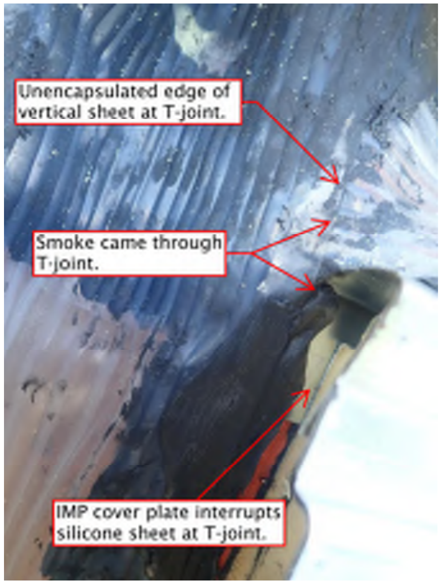
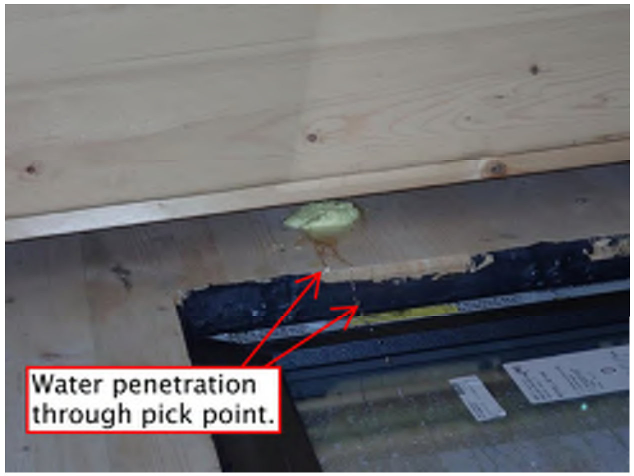
The Site PMU

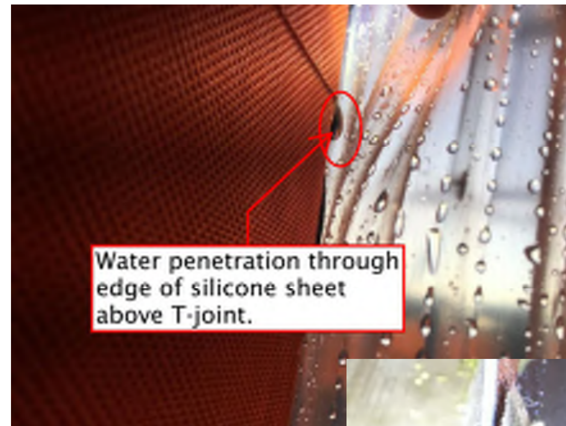
Air Leakage Testing – Qualitative Results

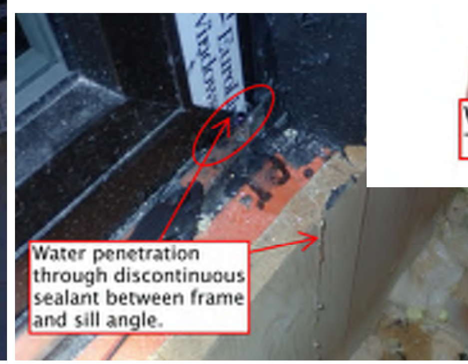




Water Penetration Testing







What to Do? Inspect All Seals, Repair and Verify Fixes

100% Joint QA/QC Works!.. But Need to be Simpler

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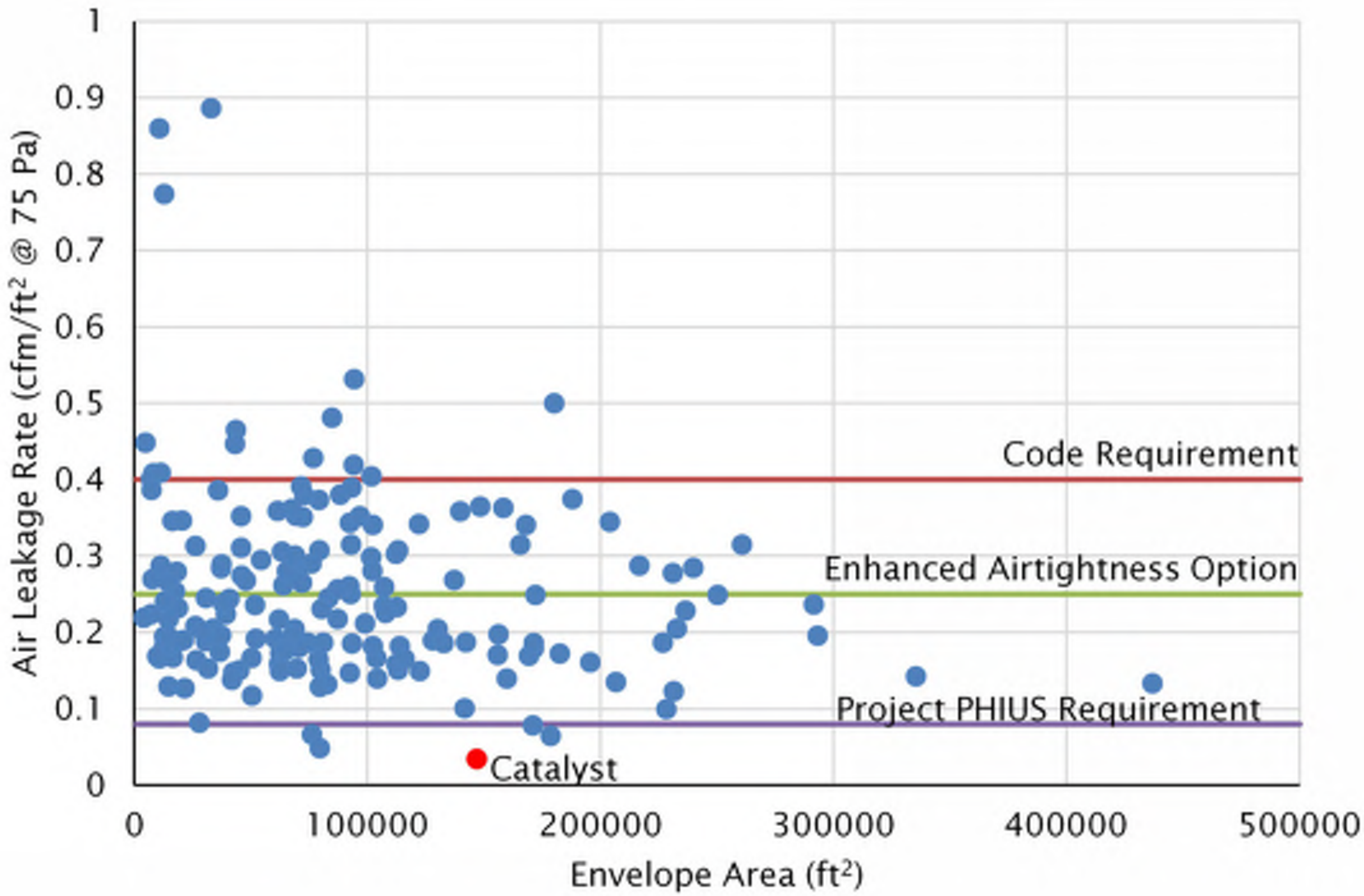
Airtightness Success:
0.034 cfm/ft^2@75 Pa < 0.08 PHIUS target



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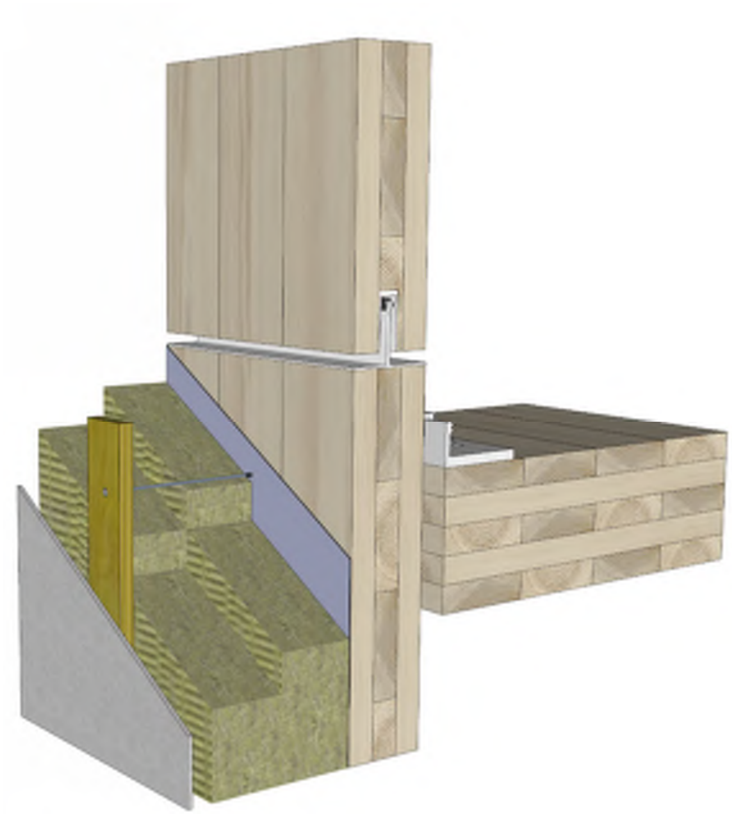
The "Not So Hot" Wood Veneer Curtainwall Side-Track & PMU Lessons

Continuing to Tinker



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The Next Catalyst for Prefab Mass Timber Facades

Perkins&Will

DELTA GROUP

Façade Design and Prototype Competition

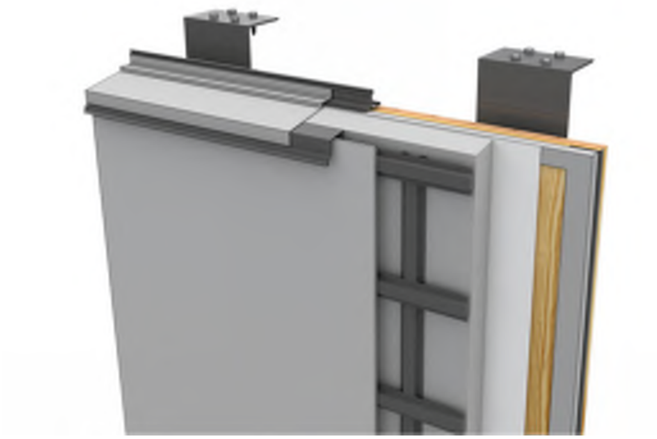
- Created to get ahead of the need for a low carbon, low energy, wood-based façades for mass timber buildings
- Approached over 40 companies across Canada and the US
  - Included façade contractors, existing façade system manufacturers (steel, curtainwall, concrete, wood, window), mass timber producers, wood prefabricators, modular builders, new startups in sector
- 1 partial, 5 complete/viable product entries received and narrowed down to a top 3 based on competition criteria
  - Top 3 each contracted to produce small scale mock-up
  - Top team contracted for performance mockup

Key Design Parameters

- →Wood as primary structural element, exposed if possible where allowed*
- →Entirely prefabricated w/ exceptions*
- →Flexibility in design concept and pairing of punched windows, large balcony doors, adjoining curtainwall, roof decks etc.
- →Suitable for high-rise buildings in high seismic regions
- →Meet stringent fire code requirements for tall wood buildings through design and later testing

Key Design Parameters

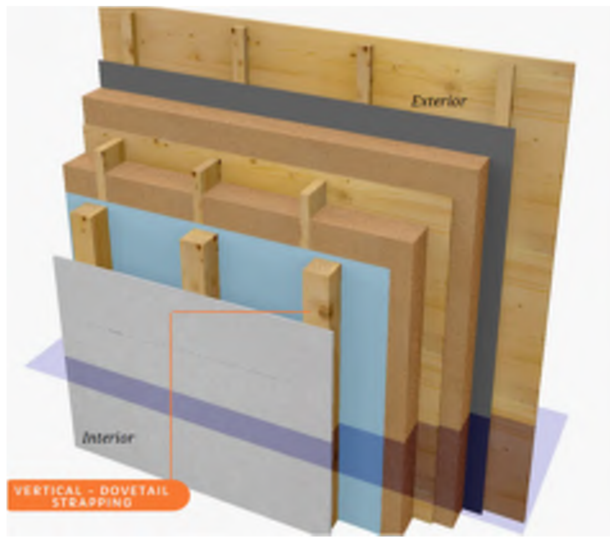
- Thermally efficient and suitable for Passive House projects
  - ~R-40 walls, R-6+ windows
  - Minimal bridging at balconies and other penetrations (<10% reduction in performance)
  - Extremely airtight
- Cost effective, competitive vs. other systems of similar performance
- Durable, high-rise water tightness
- Low embodied carbon, sustainably harvested wood
- Socially equitable manufacturing

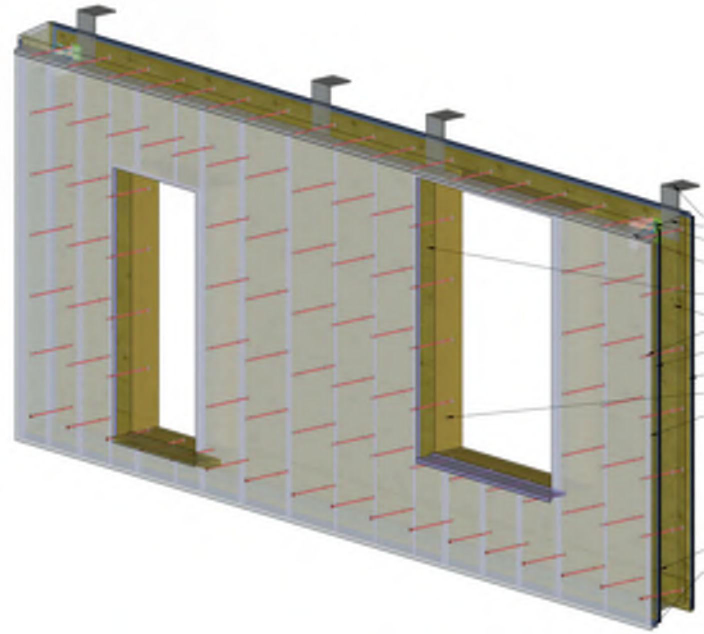


Scoring & 6 Entries

- Use of Wood
- Acceptance by Building Code
- Acceptance by Fire Code
- Design Flexibility
- Aesthetics
- Durability
- Acoustics
- Thermal Performance
- Constructability
- Sustainable Wood
- Social Equity
- Cost
- Manufacturing Experience
- Engineering Experience
- Façade Systems Experience
- Overall Submittal

The 6 Entries



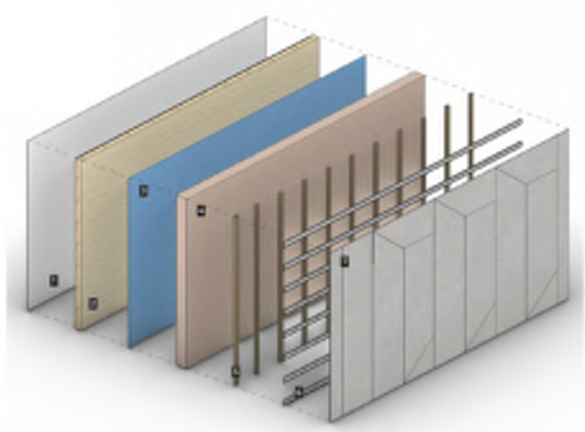


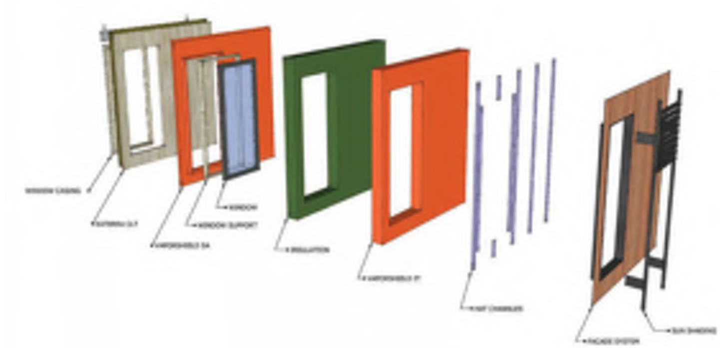
MANASC ISAAC

TREE CONSTRUCTION

F3 Timber Technologies

The 6 Entries





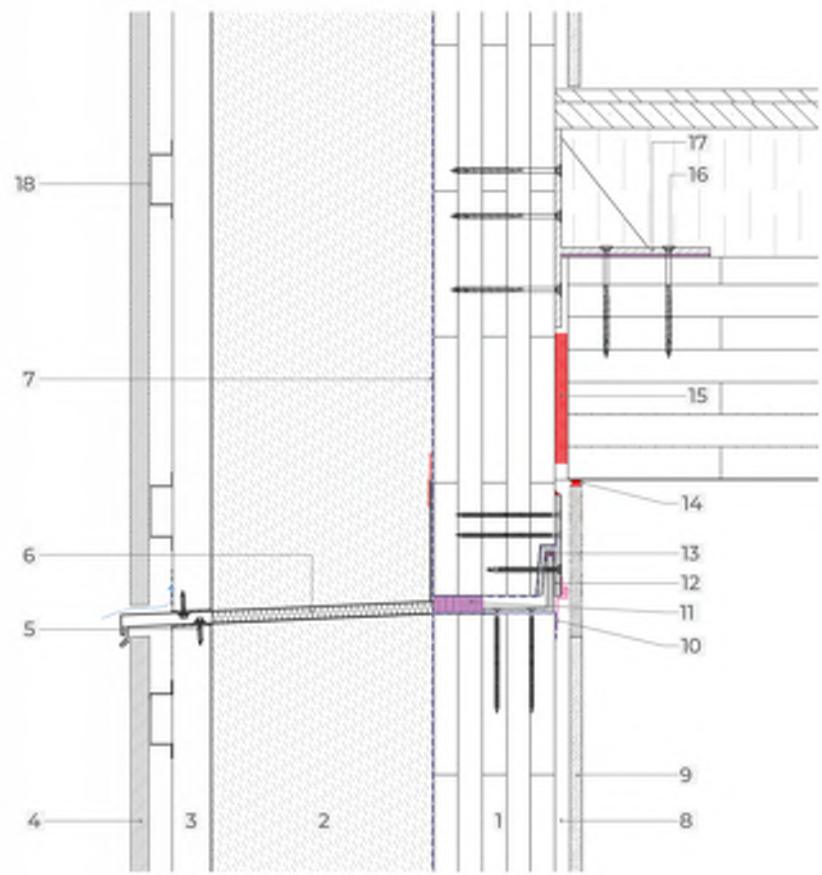
ELEMENT5
MASS TIMBER STRUCTURES

KATERRA

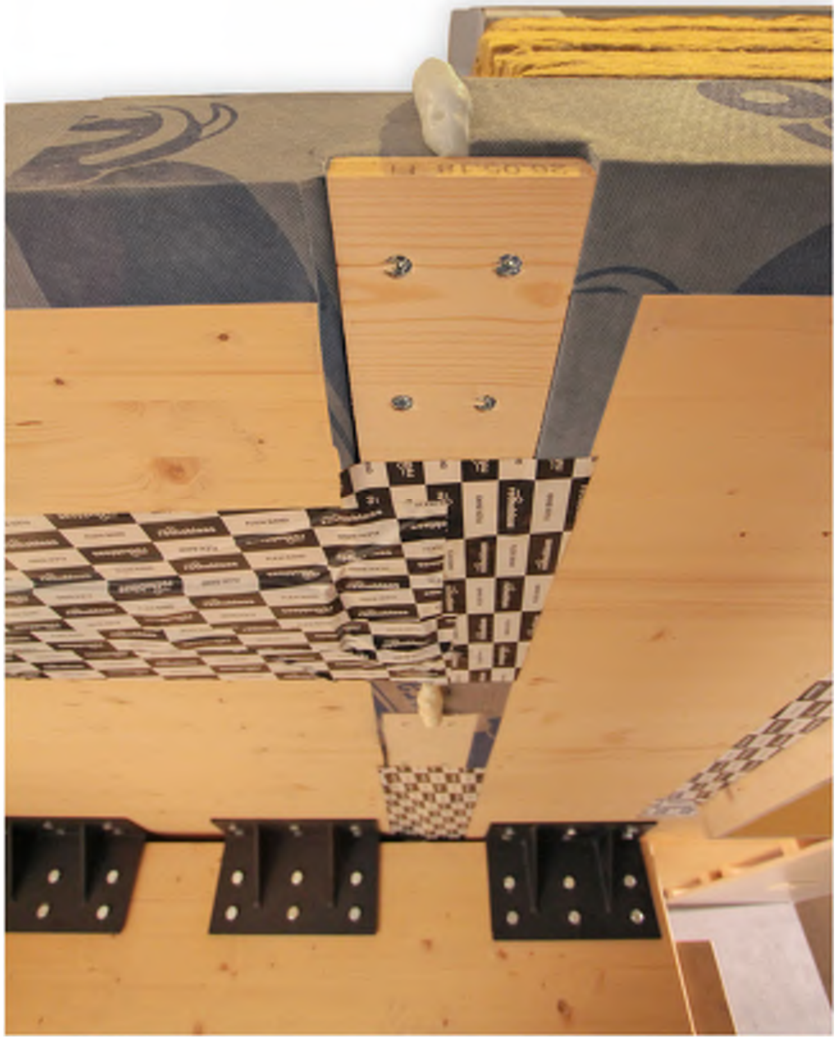
SIDE WALK LABS

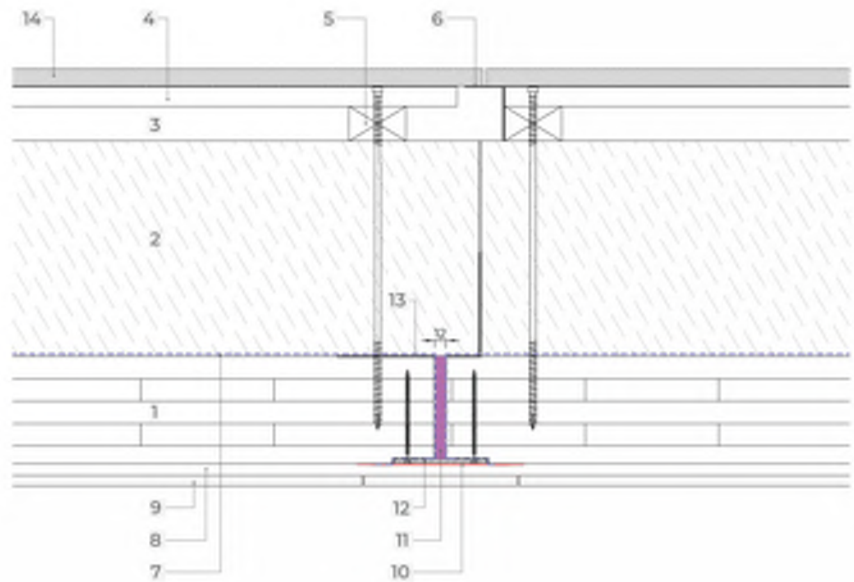
The Top 3

ELEMENT5
MASS TIMBER STRUCTURES



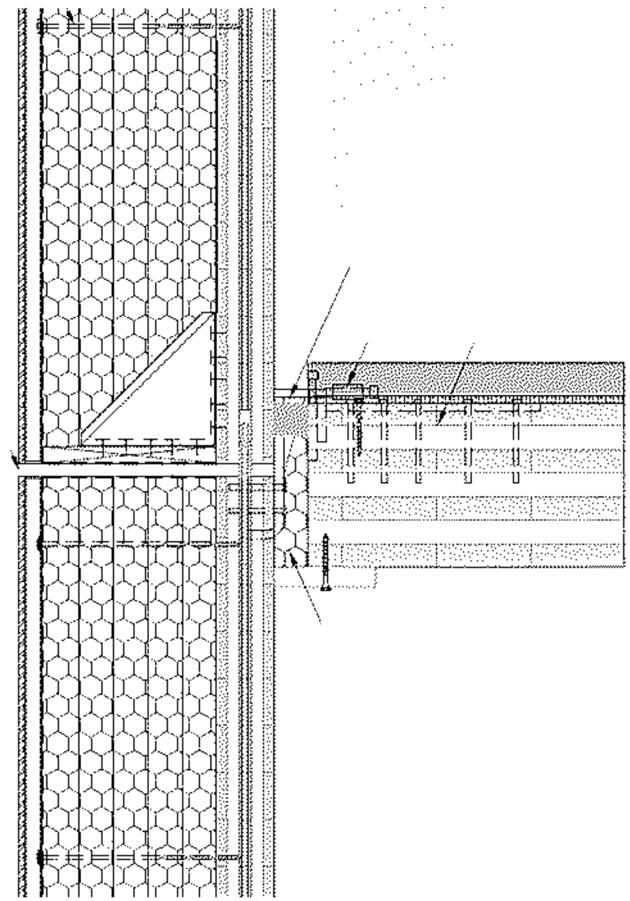
ELEMENT5
MASS TIMBER STRUCTURES



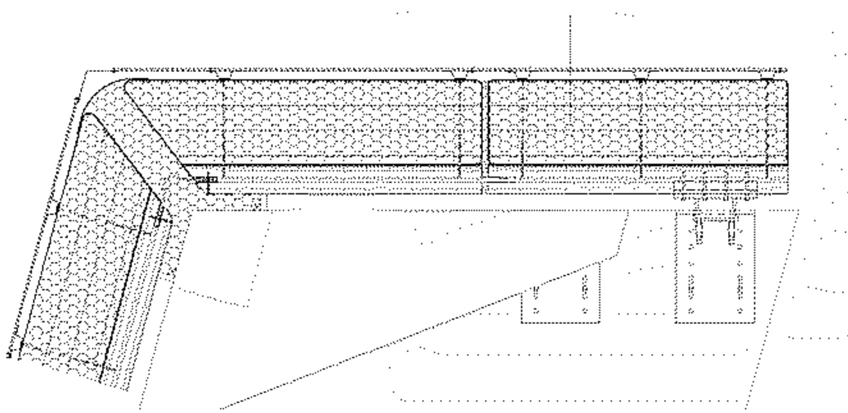


ELEMENT5
MASS TIMBER STRUCTURES

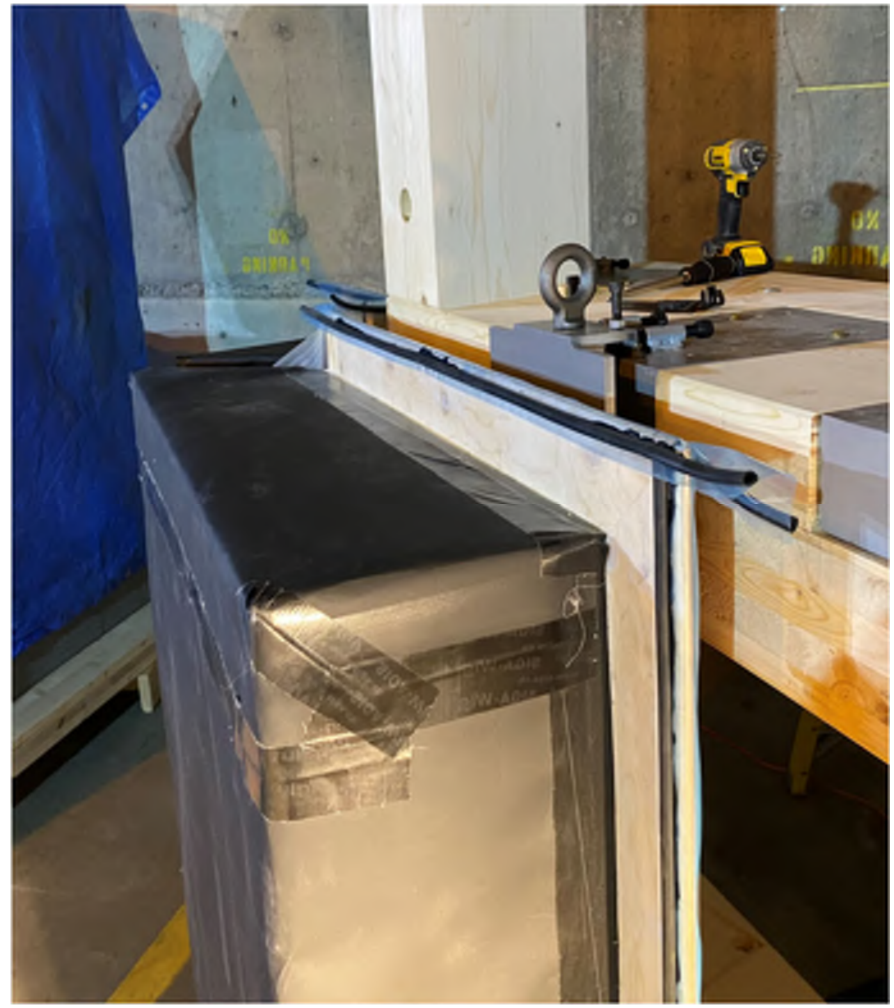
Katerra



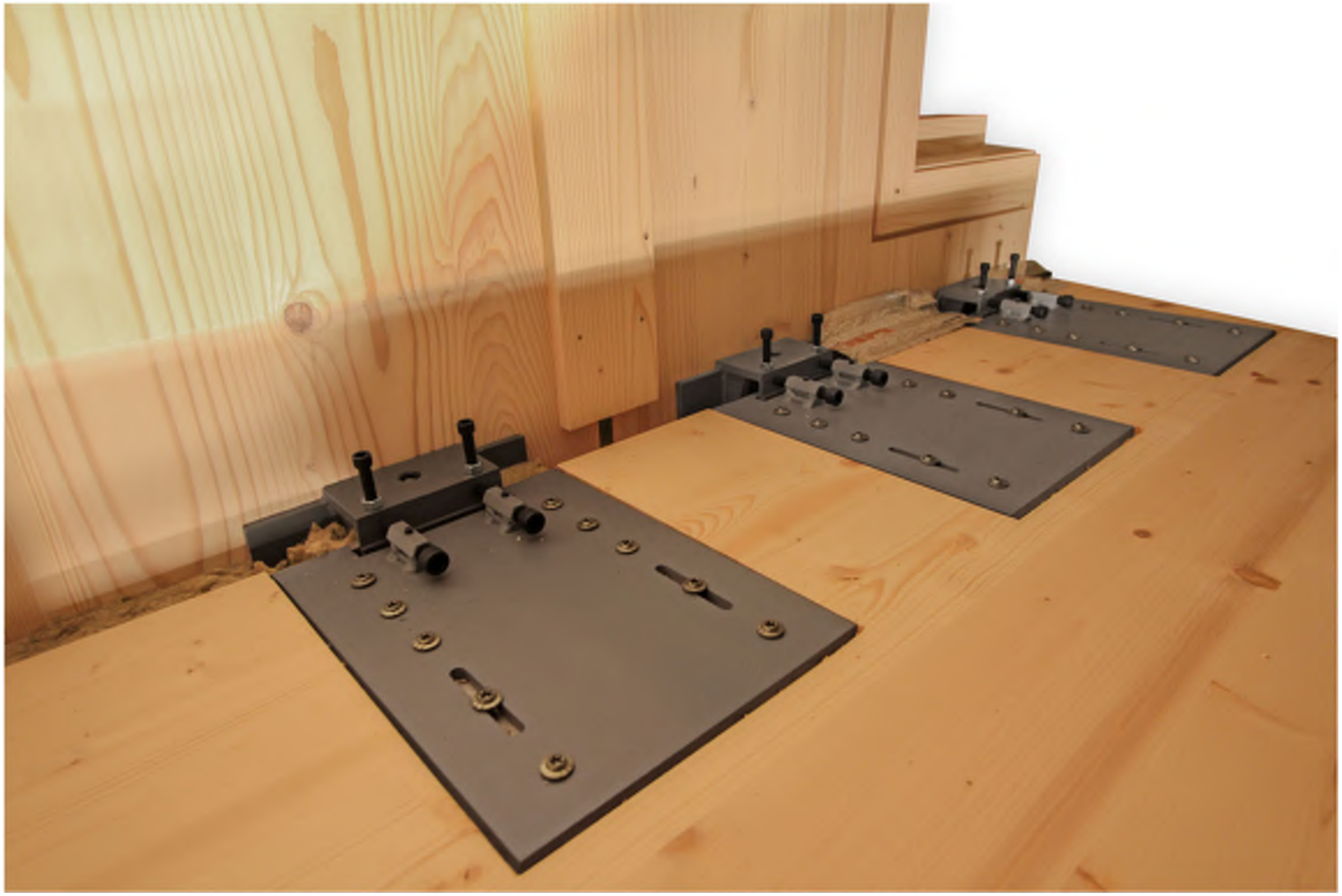
KATERRA



PLAN VIEW



KATERRA



FPInnovations

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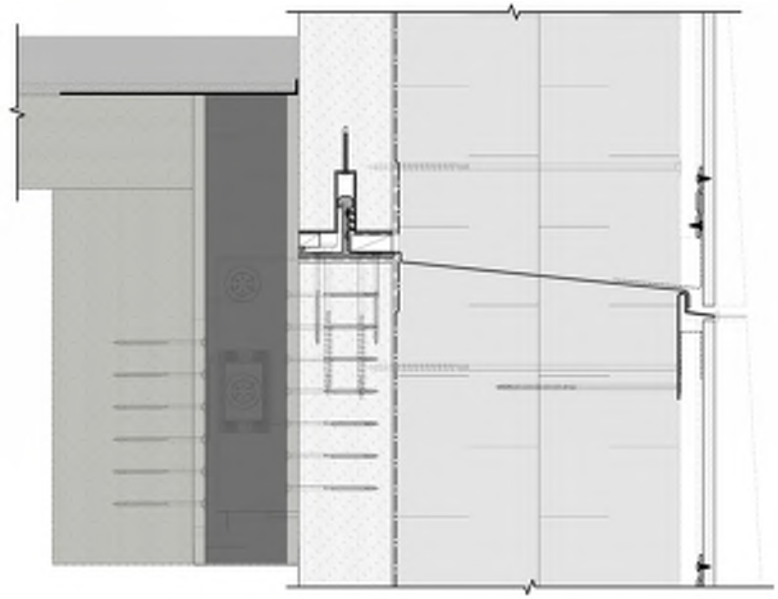
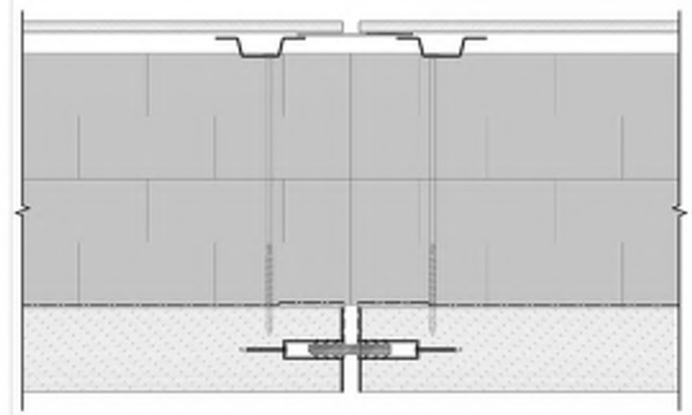
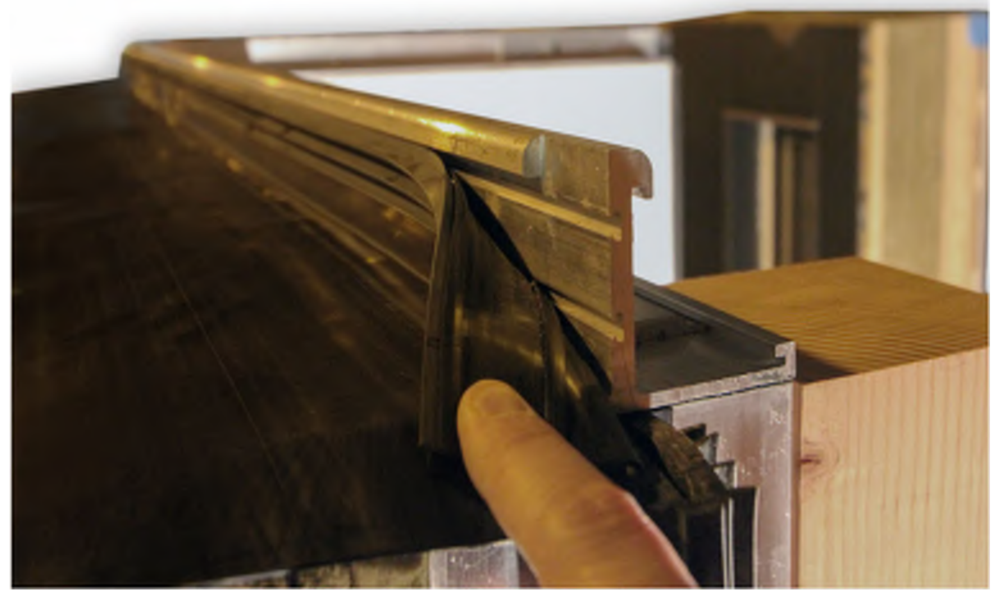
Sidewalk Labs





SIDE WALK LABS



A Lot of Similarities in Approach & Fabrication

Same: Wood Structure, Dry Joints, AB/WRB on Wood, MW Insulation, Cladding Support, Rainscreen Cladding

Trial PMU Assembly & Acoustic Testing

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Full Scale PMU Assembly

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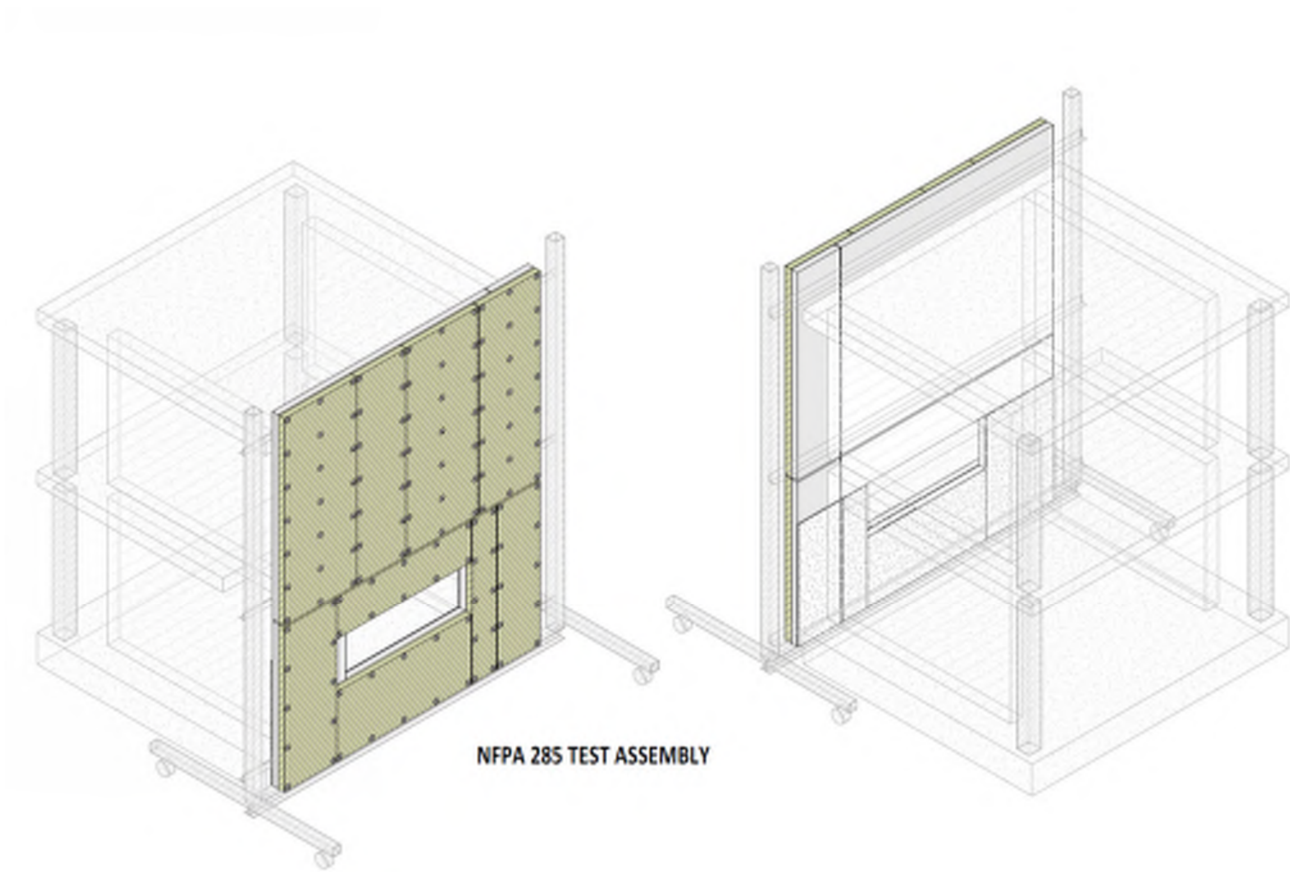
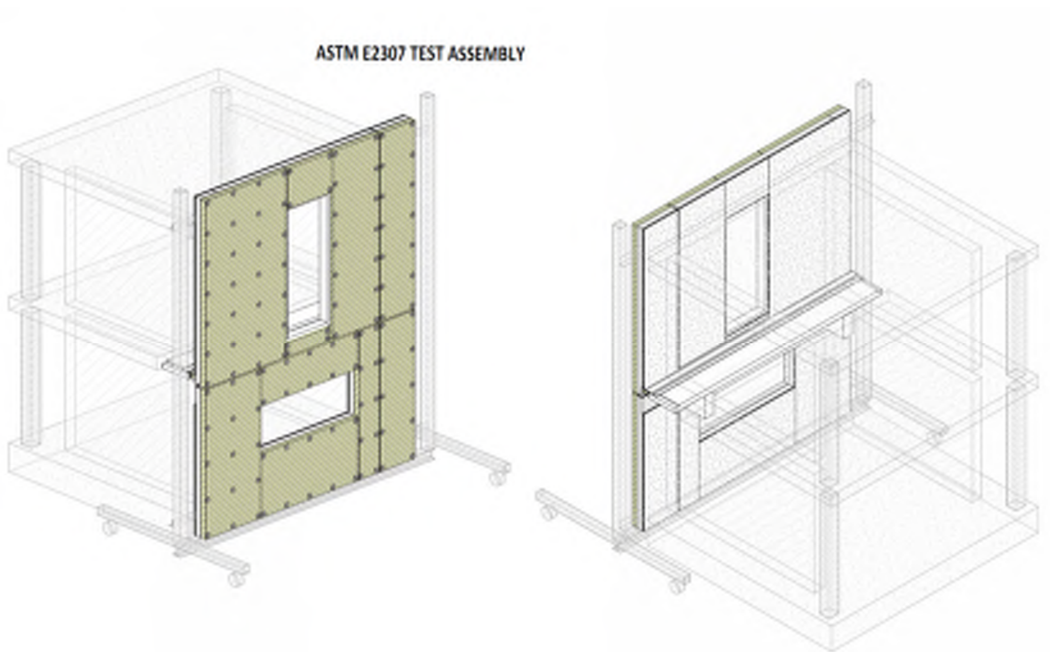
PMU Testing

Fire Testing (NFPA 285 - Facade)



Pass! Wood & WRB didn't even know there was a fire

Fire Testing (ASTM E2307 – Slab Edge Smoke/Fire)



Pass!, 2 & 3 hour floor slab edge to wood
façade smoke seal/fire protection options

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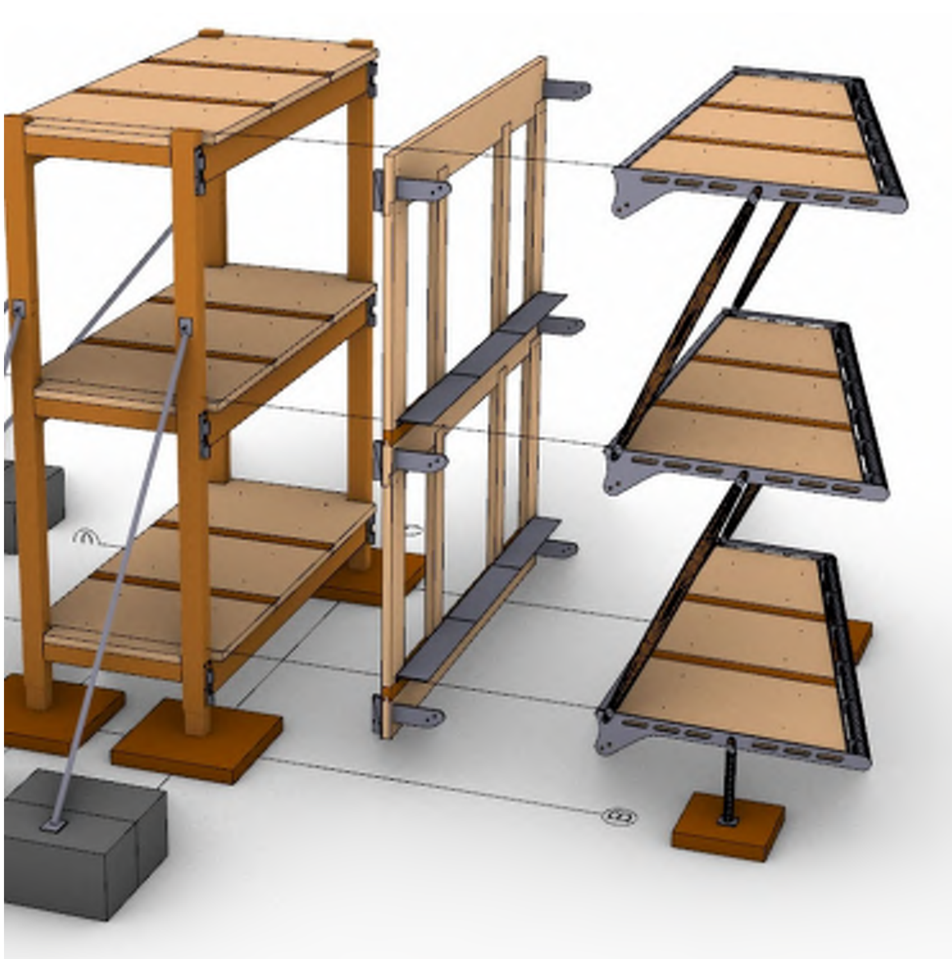
Parallel Work – Prefabricated MT/Steel Balconies



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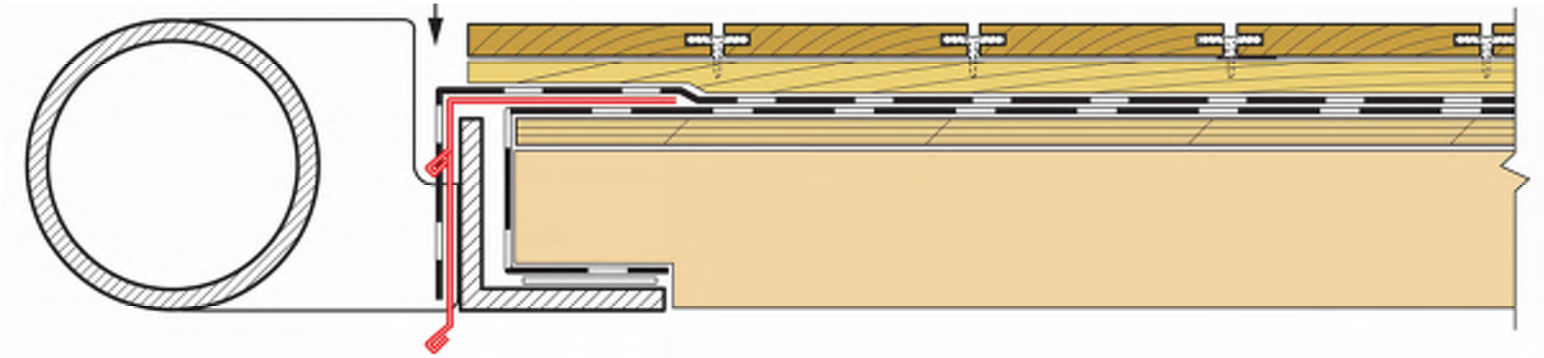

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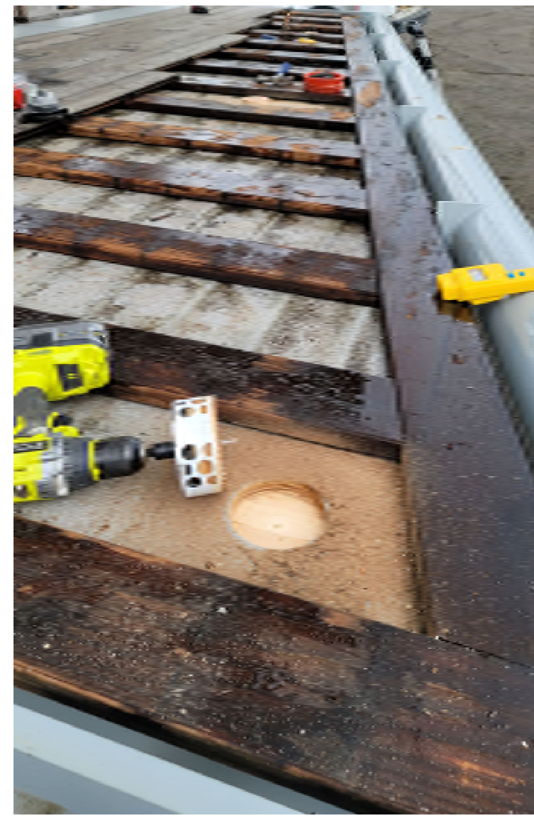


Intelligent
City

The Growing Market for Mass Timber Facades

- → Tall mass timber buildings need prefabricated façade systems for speed & moisture and fire protection during construction
- → Systems need to be more thermally efficient to meet more stringent energy codes – typically means more opaque wall than glazed area
- → Mass timber systems (3 so far) have all demonstrated ability to meet the demanding needs of high-rises in high seismic zones
- → Cost so far is comparable to cold-form steel framed and a bit less than aluminum (the wood structure is a relatively cheap component of the system)
- → Mass timber systems can be carbon neutral as wood sequestration can offset other materials (insulation, cladding, finishes, structural connections etc.)

Discussion + Questions

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