NEWBuildS Workshop “The Checker Building: a 2-storey conceptual wood building”
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Checker building: Building Envelope Design

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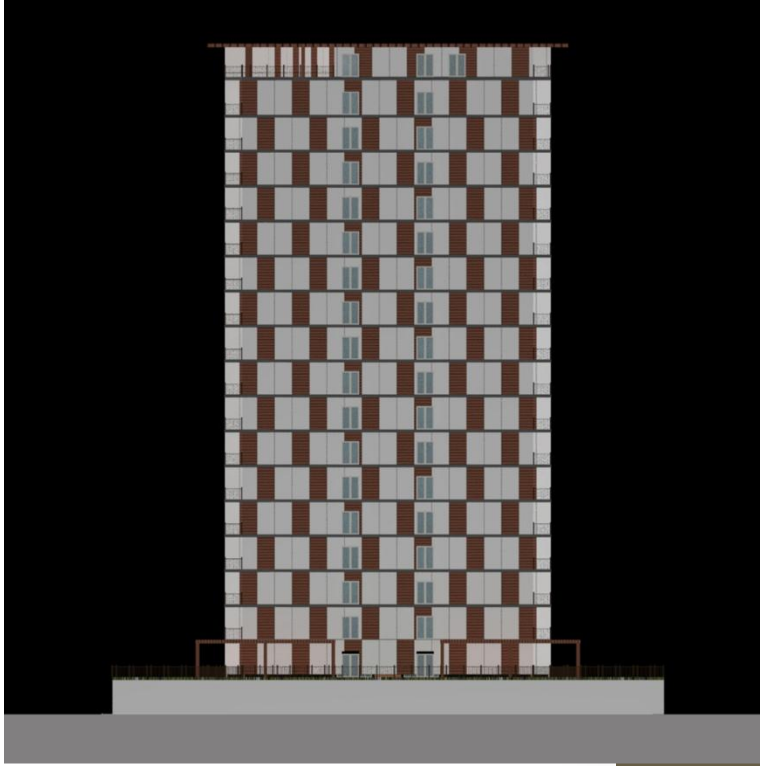
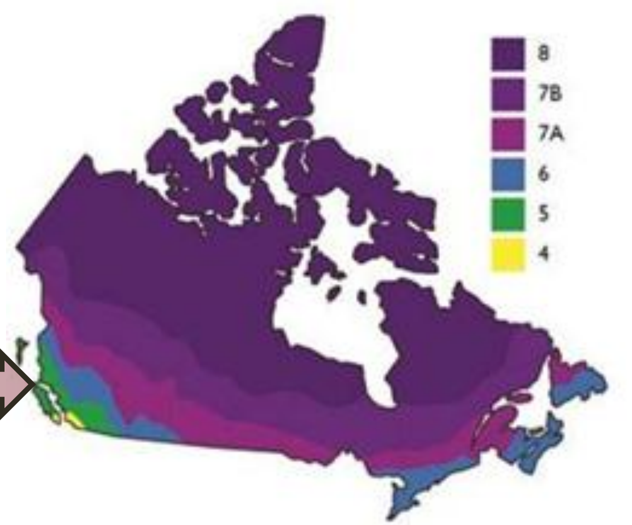
Background

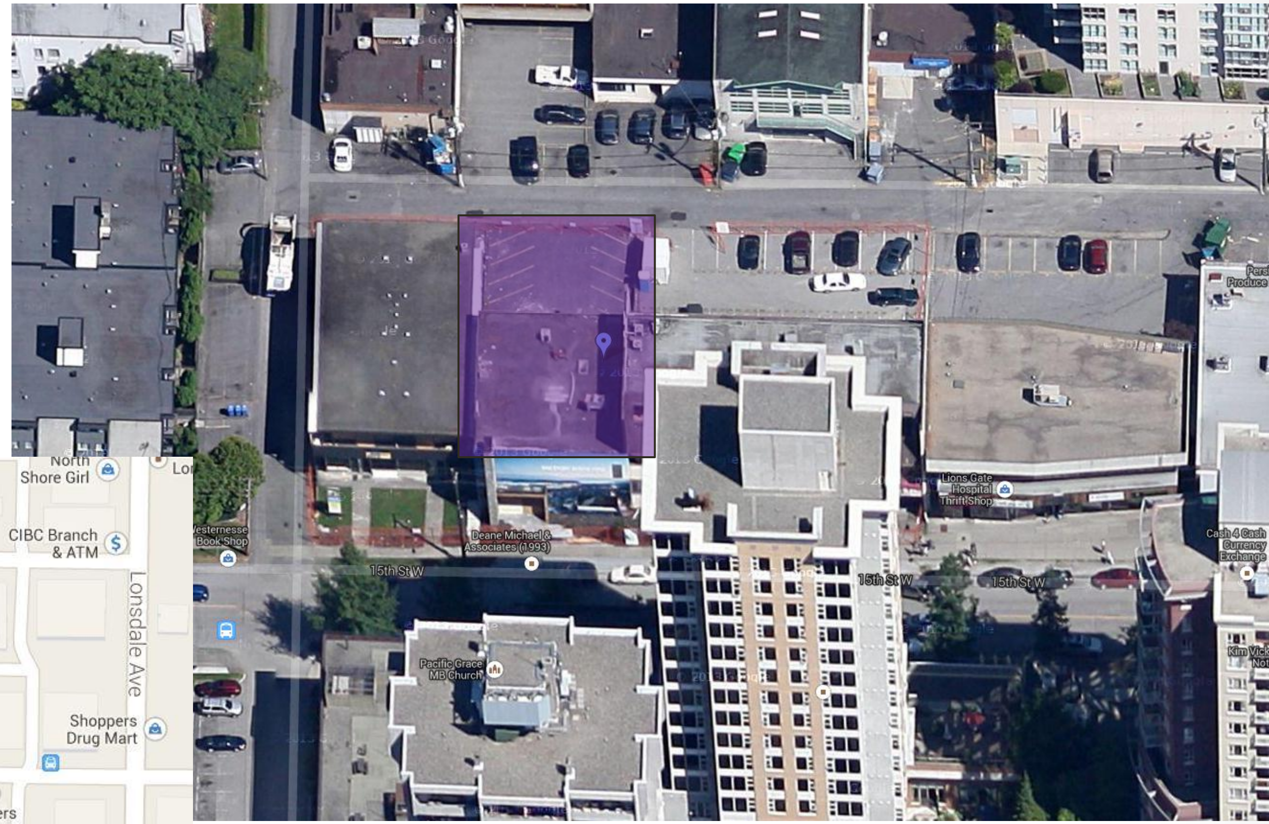
- Size
  - 20 stories tall (~60 m high)
- Hybrid construction
  - Concrete podium (1st floor)
  - Wood construction (19 floors)
- Location
  - Challenging - high rain load

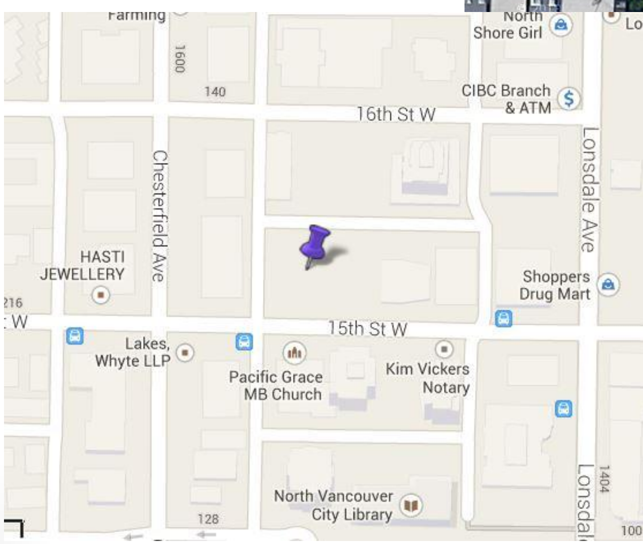


North Vancouver



Background


Deane Michael & Associates (1993)
15th St W
Lions Gate Hospital Thrift Shop
Pacific Grace MB Church
Kim Vickers Notary
Cash 4 Cash Currency Exchange


North Shore Girl
CIBC Branch & ATM
16th St W
140
1600
Chesterfield Ave
Lonsdale Ave
HASTI JEWELLERY
Shoppers Drug Mart
15th St W
Lakes, Whyte LLP
Pacific Grace MB Church
Kim Vickers Notary
North Vancouver City Library
128
1404
100

Objectives

- To analyze the structural, fire and **building envelope** performance of a tall wood building based on tools and technical data arising from the research and outreach programs of NEWBuildS and FPInnovations
- Specific to building envelope
  - ✓ Review of Ch. 6-Building Envelope Design: Technical guide for the design and construction of Tall wood buildings in Canada
  - ✓ Design for durability, energy efficiency and cost-effectiveness
  - ✓ Meet/exceed building code requirements

Method

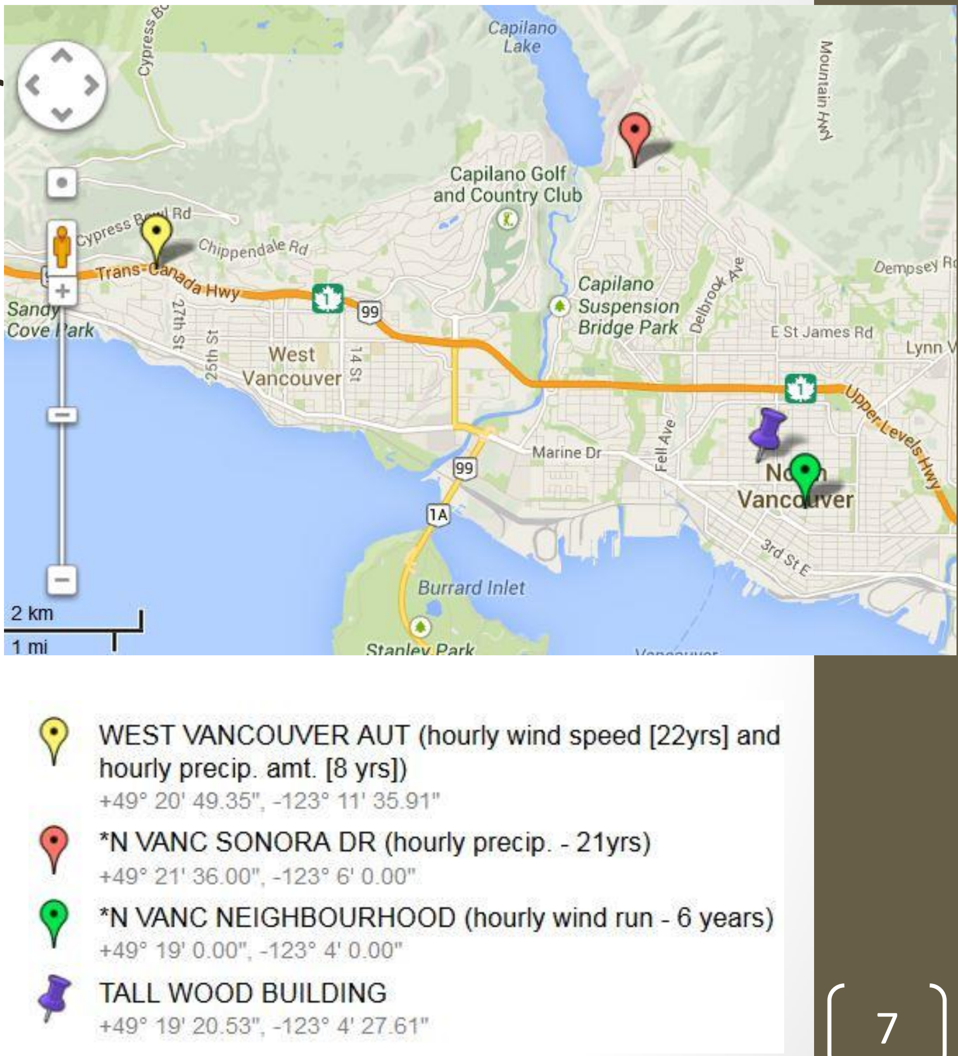
- Building science principles & best practices
  - Chapter 6-Building Envelope Design: Technical guide for the design and construction of Tall wood buildings in Canada
- Important design considerations
  - Durability
  - Energy efficiency
  - Constructability
  - Maintenance
  - Fire & acoustics

Durability

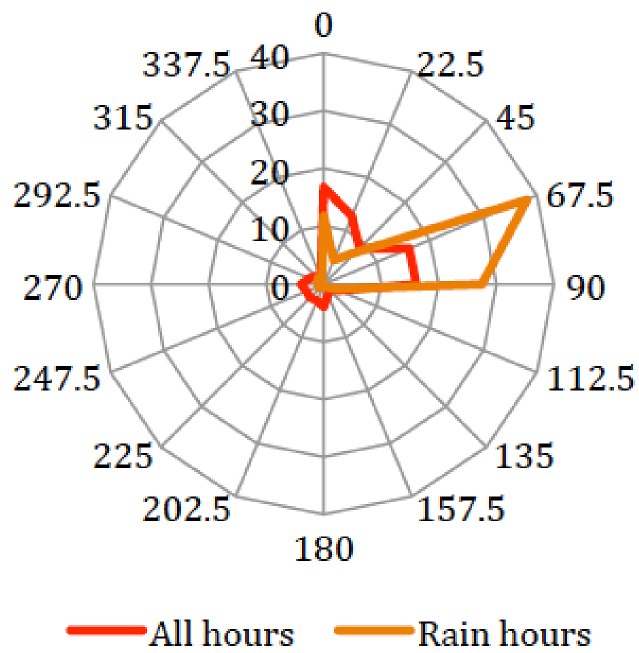
- Prevent excessive moisture accumulation and allow wood to dry
- Design considerations
  - ✓ Wind-driven rain load
  - ✓ Rain screen wall assemblies for drainage, pressure moderation & ventilation
  - ✓ Vapour permeable membranes/finishes to allow drying
  - ✓ Continuous air barrier to control air flow
  - ✓ Exterior insulation to avoid vapour/air exfiltration condensation
  - ✓ Durable cladding materials
- Hygrothermal simulations: parametric analyses

Wind driven rain load analysis

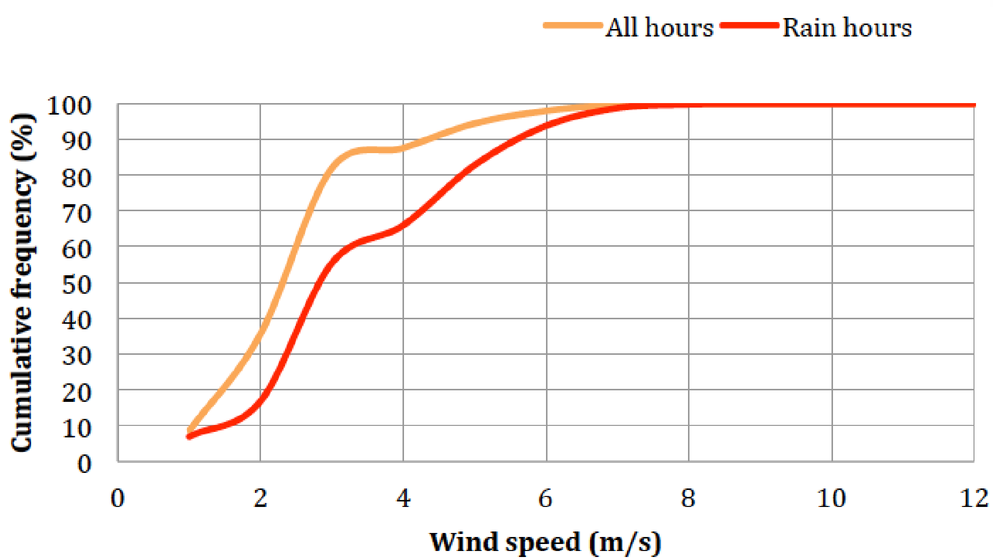
- 16 years of available data for wind speed, wind direction and rain
  - ✓ East & North orientation – higher wind-driven rain loads
  - ✓ Avg. rainfall intensity = 2.14mm/hr
  - ✓ Annual rainfall amount=1800mm



Wind driven rain load analysis



Prevailing wind direction for the proposed building site



Frequency distribution of mean wind speeds for the proposed building site

Wind driven rain load analysis

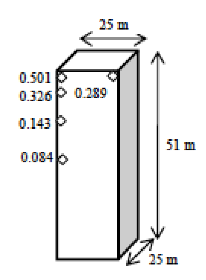
60m	Airfield Annual Index (l/m^2)	Wall Surfaces (l/m^2)	30m	Airfield Annual Index (l/m^2)	Wall Surfaces (l/m^2)	10m	Airfield Annual Index (l/m^2)	Wall Surfaces (l/m^2)
N	667.1	200.1	N	561.0	67.3	N	426.3	51.2
NE	1733.3	520.0	NE	1457.5	174.9	NE	1107.5	132.9
E	1824.2	547.3	E	1534.0	184.1	E	1165.6	139.9
SE	884.8	265.4	SE	744.0	89.3	SE	565.3	67.8
S	31.7	9.5	S	26.6	3.2	S	20.2	2.4
SW	15.9	4.8	SW	13.4	1.6	SW	10.2	1.2
W	31.0	9.3	W	26.1	3.1	W	19.8	2.4
NW	66.2	19.8	NW	55.6	6.7	NW	42.3	5.1

ISO 15927-3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data

Air field WDR: $$I_A = \frac{2}{9} \frac{\sum U * R_h^{8/9} \cos(D-\theta)}{N}$$

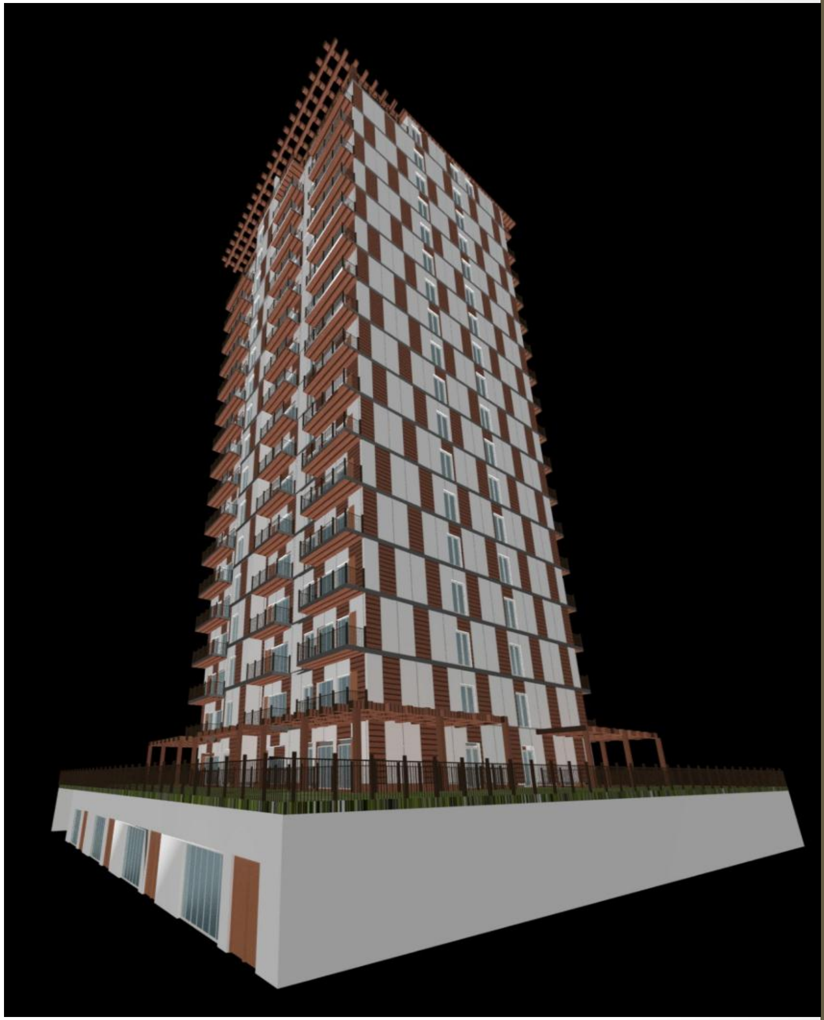
Wall surface WDR: $$I_{WA} = I_A C_R C_T O W$$

C_R=1.0, CT=1.0, O=0.6, W=0.5

Field measurements	BS1804 (1992)
	0.5 for the top 2.5 m 0.2 for remainder

Wind-driven rain load

- Deflection
  - ✓ Roof overhang consideration
  - ✓ Balcony projection
- Hygrothermal performance evaluation
  - ✓ Climatic loads for simulations



(M. N. Adi)

Durability

- Importance of continuous air barrier
  - ✓ Stronger wind pressure, higher stack effect
  - ✓ Energy, rain penetration, condensation, sound, & fire
  - ✓ A rigid air barrier approach or adhered/liquid vapour permeable membrane applied to a rigid substrate is preferred

Energy Requirements

- Minimum Effective Assembly R-value
  - Prescriptive Path - NECB 2011

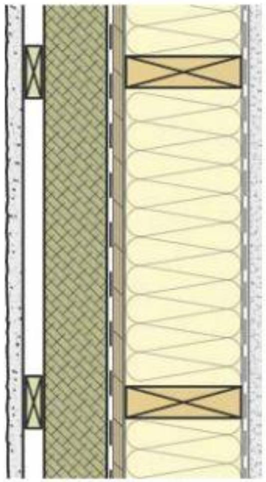
	Wood-frame, above grade wall	Wood-frame roof – insulation entirely above deck
	RSI	RSI
Present Meets minimum NECB requirements	3.2	4.4
Future* 25% above present minimum requirements	4.0	5.5

* The minimum requirements at a future date would be likely closer to the high-performance requirements of today

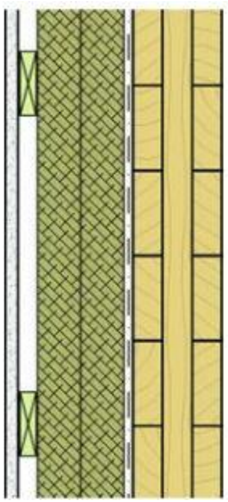
- Fenestration to wall ratio: 40%
- Overall thermal transmittance: 2.4 $W/m^2 K$
  ✓ double IGU low-e coating, Argon, thermally broken frame, warm spacer

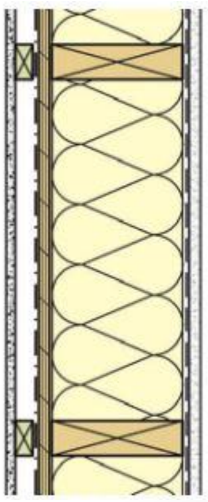
Wall Design

- ❑ Split-insulated stud wall



- ❑ Alternative assemblies considered
  - ✓ Exterior insulated CLT
    - ❑ Non-loading bearing perimeter
  - ✓ Simple stud wall
    - ❑ Thermal bridging
    - ❑ Deeping cavity framing required

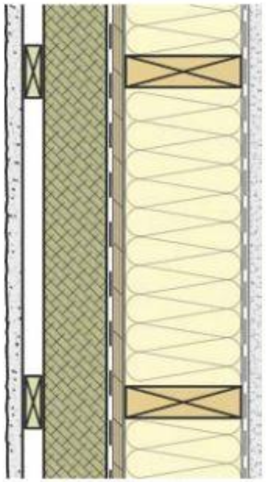




(Technical guide for tall wood building design)

Wall Design

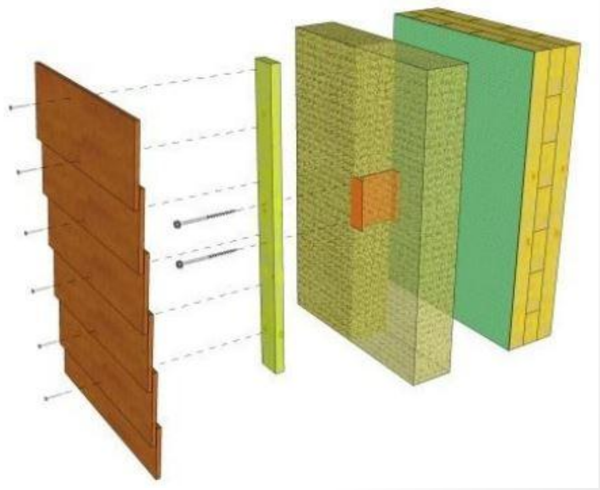
- Split Insulated
  - ✓25% framing factor is assumed
  - ✓R-value: 4.8 Km^2/W
  - ✓Thickness: 250 mm



- Exterior-to-Interior
  - ✓Cladding (fiber cement, 12mm & wood cladding 20mm)
  - ✓Vertical strapping
  - ✓Air cavity, 20mm
  - ✓Semi-rigid mineral wool insulation (50mm)
  - ✓Vapour permeable self-adhered Weather Resistive Barrier
  - ✓Exterior gypsum board/plywood, 13 mm
  - ✓Mineral wool batt Insulation, 140 mm
  - ✓Polythylene vapour barrier
  - ✓Interior gypsum board, 12.5mm

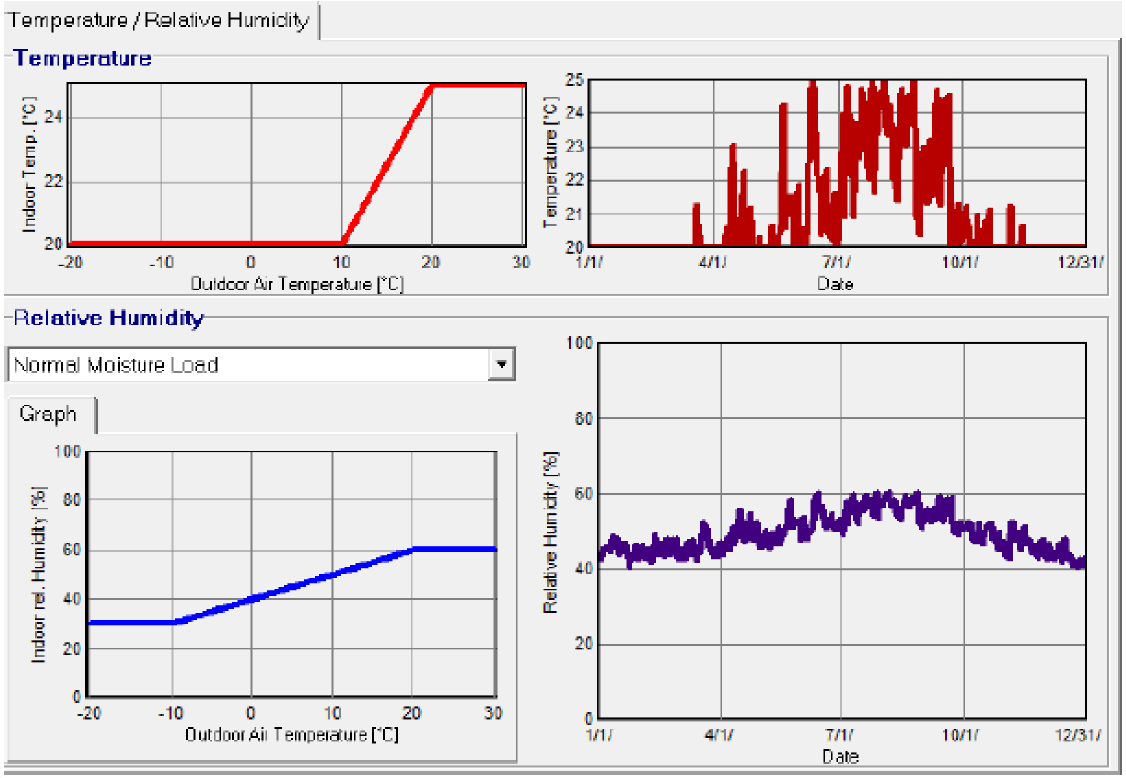
Cladding

- ❑ Non-combustible
  - ✓ Fibre cement board (SWISSPEARL)
- ❑ Combustible
  - ✓ Western Red Cedar Engineered Wood Panels (Silva, 20mm)
    - ❑ Limited to 30%
    - ❑ Horizontal spandrels preferred
    - ❑ Maintenance concerns
- ❑ Ventilated air cavity: compartmentalization
- ❑ Attachment strategy
  - ✓ Thermal spacers
  - ✓ Joints to allow vertical and horizontal movement due to
    - Thermal & moisture expansion/contraction
    - Structural movement due to loads
    - Initial irreversable dimension change



Hygrothermal performance evaluation of proposed wall assembly

- ❑ Exterior weather data:
  - ✓ Hourly wind speed, wind direction, rainfall intensity, T, RH, solar radiation for year 1999
- ❑ Indoor climate:
  - ✓ standard EN15026(2007)

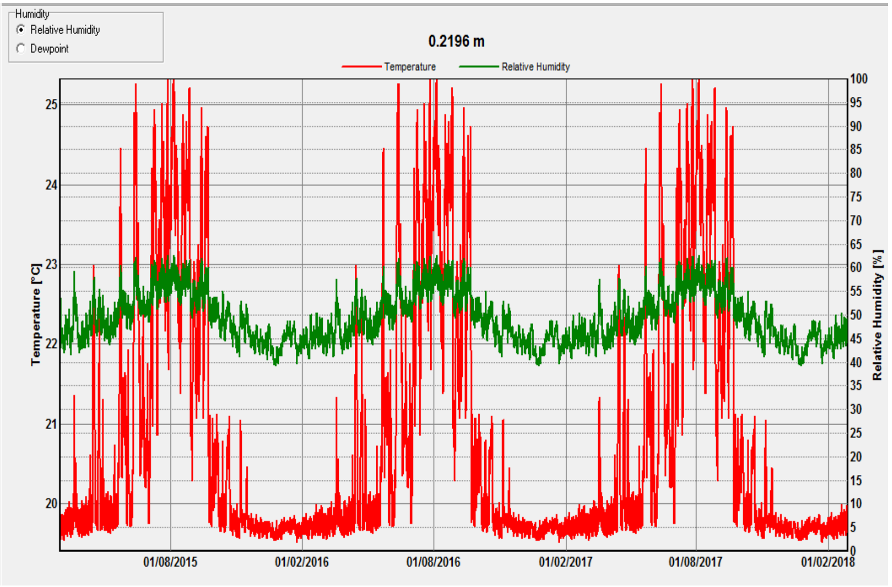


Parameters Investigation

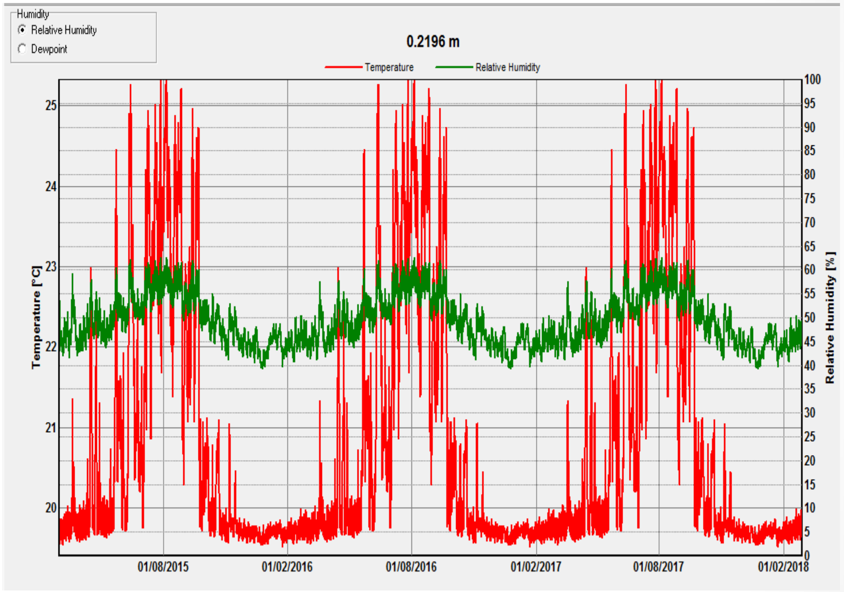
Orientation	N, E, S
Wall assemblies	With/without poly
	Plywood/Exterior grade gypsum board sheathing
	Western red cedar wood siding/fiber cement panel cladding
	Permeable WRB+mineral wool insulation (with a combined permeance of 975 ng/Pa.s.m^2)
	Permeable WRB+EPS insulation (with a combined permeance of 64.4 ng/Pa.s.m^2)
	Impermeable WRB+mineral wool insulation (with a combined permeance of 1.6 ng/Pa s m^2)
Cavity ventilation	0, 10, 50, 100 and 200 ACH
Moisture load	Vapour diffusion only
	Air leakage (1.5L/m^2·s) into the stud cavity
	1% rain leakage deposited onto the WRB/directly to sheathing
Water absorption coefficients of cladding	Default value: 0.001 kg/m^2.$s^{0.5}$
	Half value: 0.0005 kg/m^2.$s^{0.5}$
Driving rain coefficient R2	Default value, R2=0.2
	Half value, R2=0.1
	Double value, R2=0.4

Hygrothermal simulations

- Effect of polyethylene as vapour barrier
  - ✓ Solar-driven inward vapour diffusion induced condensation?



North orientation: RH at the interface of cavity insulation and polyethylene film(poly with rain leakage)



South orientation: RH at the interface of cavity insulation and polyethylene film(poly without rain leakage)

Hygrothermal simulations

- Effect of polyethylene as vapour barrier
  - ✓ Vapour diffusion control in winter time

Maximum MC(%) in plywood sheathing with permeable WRB and mineral wool exterior insulation

	Vapour diffusion only		Air leakage		Rain leakage			
					1% on WRB		1% on plywood (200ACH) w/poly	
	w/poly	w/o poly	w/poly	w/o poly	w/poly	w/o poly	w/poly	w/o poly
N	10.6	14.3	12.1	14.0	10.7	14.3	36.4	38.3
E	10.2	13.6	10.4	13.4	10.2	13.6	102.1	100.0
S	9.6	12.3	10.8	12.3	9.8	12.4	9.8	12.5

Maximum MC(%) in plywood sheathing with impermeable WRB and mineral wool exterior insulation

	Vapour diffusion only		Air leakage		Rain leakage, 1% on plywood	
	w/poly	w/o poly	w/poly	w/o poly	w/poly	w/o poly
N	13.8	17.2	10.0	16.6	117.0	71.3
E	13.8	16.6	9.7	16.0	121.3	116.0
S	13.8	14.9	9.3	14.5	33.0	15.5

Hygrothermal simulation

- Effect of cavity ventilation: wood siding & plywood sheathing

Maximum MC(%) in the wood siding and plywood sheathing in the proposed wall assembly under different cavity ventilation rates

	MC in wood siding with rain leakage on the wood siding					MC in plywood sheathing with 1% rain leakage on plywood with poly				
	0	10	50	100	200	0	10	50	100	200
N	94.3	45.7	27.1	26.6	25.7	115.9	42.5	37.8	36.4	36.4
E	74.3	48.6	29.3	27.1	27.1	120.2	117.0	110.6	106.4	102.1
S	17.7	12.0	12.6	12.0	12.0	10.9	9.4	9.6	9.8	9.8

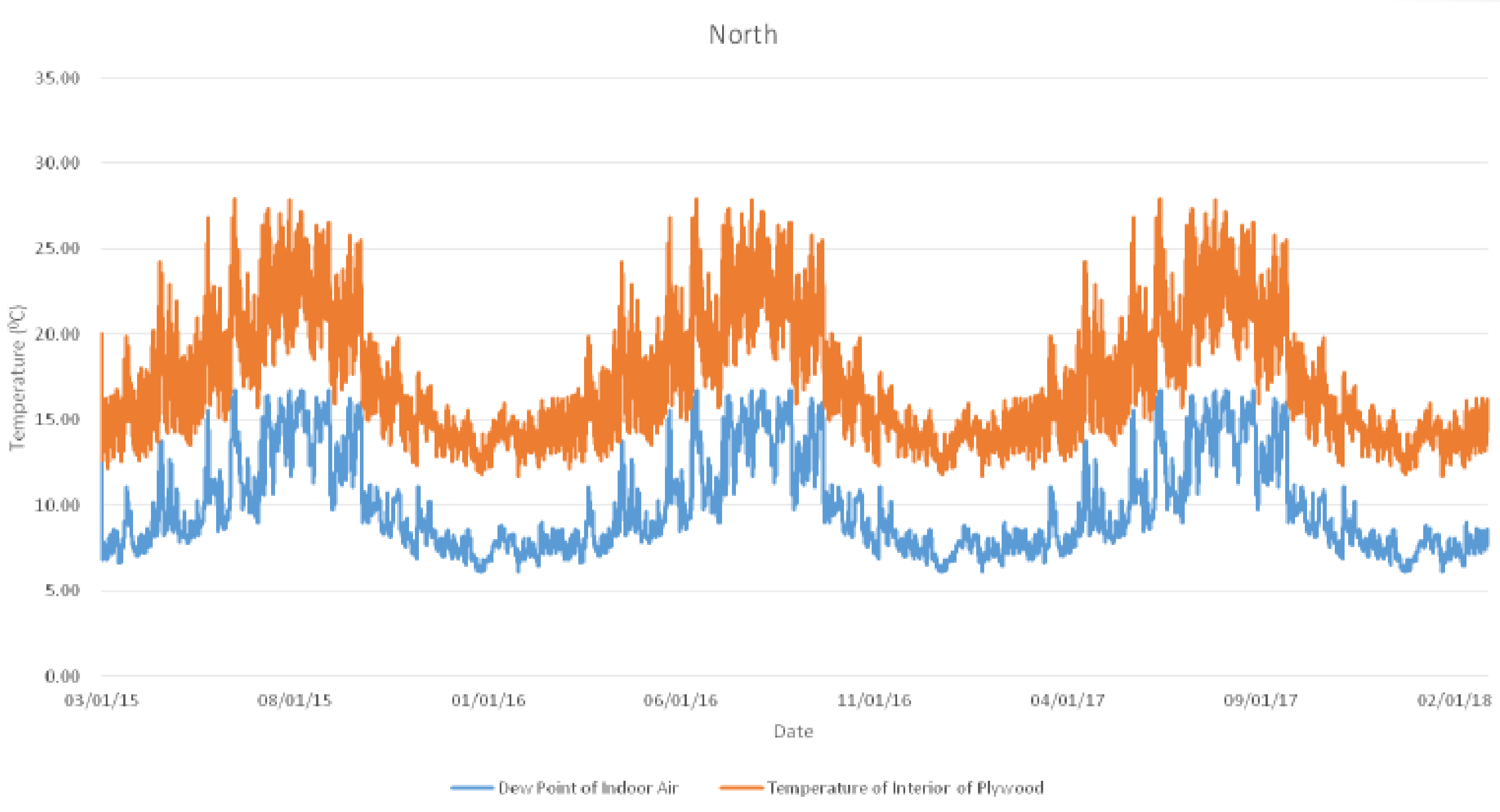
The drying effect of cavity ventilation

✓is more significant for North than for East and South facades

✓becomes insignificant when ventilation rate is higher than 50 ACH

Hygrothermal simulations

- Effect of air leakage



Condensation risk check at the interior surface of plywood for the north orientation

Hygrothermal simulations

❑ Effect of air leakage

Maximum MC(%) in plywood sheathing with permeable WRB and mineral wool exterior insulation

	Vapour diffusion only		Air leakage	
	w/poly	w/o poly	w/poly	w/o poly
N	10.6	14.3	12.1	14.0
E	10.2	13.6	10.4	13.4
S	9.6	12.3	10.8	12.3

Maximum MC(%) in plywood sheathing with impermeable WRB and mineral wool exterior insulation

	Vapour diffusion only		Air leakage	
	w/poly	w/o poly	w/poly	w/o poly
N	13.8	17.2	10.0	16.6
E	13.8	16.6	9.7	16.0
S	13.8	14.9	9.3	14.5

1.5 L/m^{2}s under 75Pa air leakage assumed

Hygrothermal simulations

Effect of rain leakage

Maximum MC(%) in plywood sheathing with permeable WRB and mineral wool exterior insulation

	Vapour diffusion only		Rain leakage			
	w/poly	w/o poly	1% on WRB		1% on plywood (200ACH) w/poly	
			w/poly	w/o poly	w/poly	w/o poly
N	10.6	14.3	10.7	14.3	36.4	38.3
E	10.2	13.6	10.2	13.6	102.1	100.0
S	9.6	12.3	9.8	12.4	9.8	12.5

- ✓ 1% rain leakage deposited on the WRB: no noticeable increase
- ✓ 1% rain leakage deposited on plywood: much higher in East and North
- ✓ Poly does not have impact when rain leakage present

Hygrothermal simulations

- Effect of wind-driven rain exposure and cladding water absorption coefficients

Maximum MC (%) in the wood siding with respect to driving rain coefficients and water absorption coefficients

A-value	**Western red cedar, A=0.001 $kg/m^2.s^{0.5}$**			**Western red cedar, A=0.0005 $kg/m^2.s^{0.5}$**		
R2	default	half	double	default	half	double
N	25.7	22.8	27.0	18.8	17.7	20.0
E	26.0	24.3	27.4	18.8	17.1	20.0
S	12.0	11.7	12.0	11.4	11.4	11.5

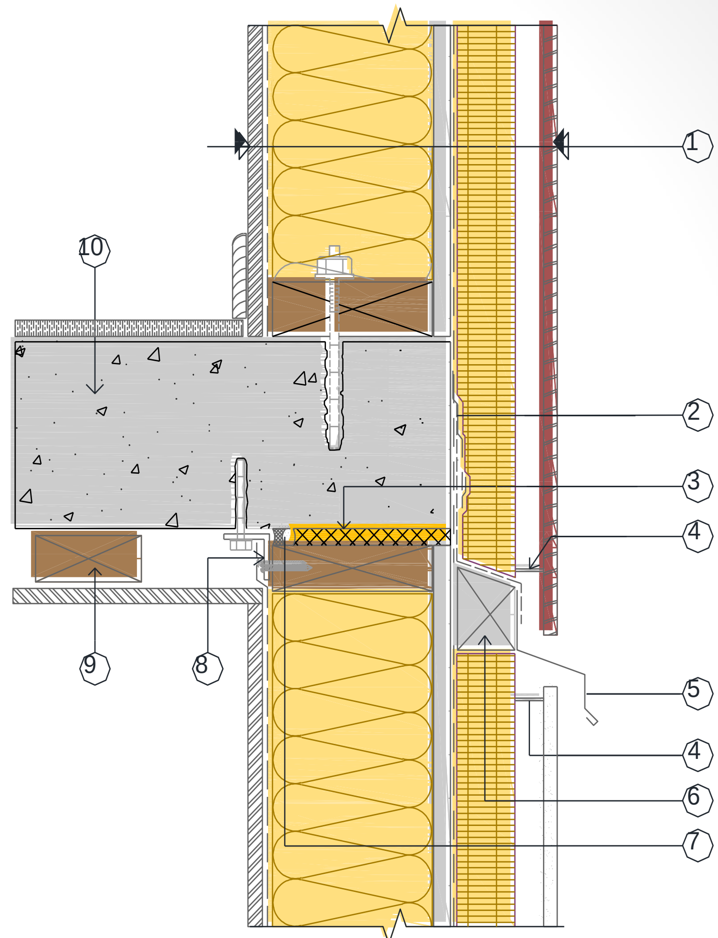
- ✓ The effect of rain exposure and water absorption is minimal for South orientation
- ✓ The influence of water absorption coefficient is more significant than the driving rain coefficient for the north and east orientation

Hygrothermal simulations

- The proposed wall assembly can manage the moisture loads from vapour diffusion, air leakage and rain leakage passing through the first line of defense, i.e. cladding
- The East and North façade have the higher risks with rain leakage passing through the WRB due to higher amount of wind-driven rain and lower solar radiation on the North façade
- A permeable exterior insulation and WRB with an interior vapour retarder is recommended to allow incidental rain water leaked to the sheathing to dry to outside since there is little drying potential towards indoor during the winter time
- A permeable protection coating that reduces the water absorption but does not inhibit drying of the wood siding should be applied to the wood siding
- The building form and details such as overhangs, balcony projections is recommended to reduce the amount of wind-driven rain exposure on East and North façade
- Quality construction to avoid any rain leakage passing through WRB is critical.

Wall/floor connection

- Control of heat flow
  - ✓ Minimizing thermal bridge
- Control of air flow
  - ✓ Continuous & structurally supported air barrier
- Control of rain penetration
  - ✓ Rain screen
  - ✓ WRB
  - ✓ Cross-cavity flashing
  - ✓ Ventilated air space
- Drying
  - ✓ ventilated air space
  - ✓ Vapour permeable WRB
  - ✓ Permeable insulation
- Control of condensation
  - ✓ Exterior insulation
  - ✓ Vapour barrier
  - ✓ Continuous air barrier
- Control of movement
  - ✓ Level of initial MC
  - ✓ Joints
  - ✓ Sufficient spacing



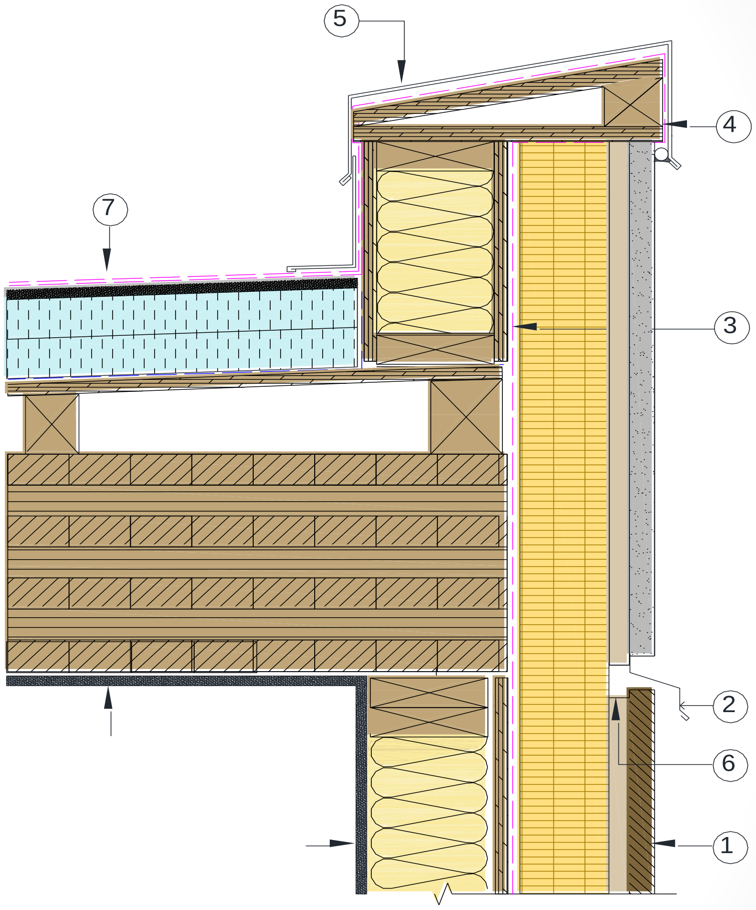
LEGEND

1. Wall Assembly
   - Cladding (Top: Engineered wood; Below: Fibre cement panel)
   - 20 mm Ventilated air space & wood strapping
   - 50.8 mm (2") Semi-rigid mineral wool insulation
   - Vapour permeable sheathing membrane
   - 13 mm Plywood Sheathing
   - Wood framing 38X140mm (2X6)
   - 140 mm Mineral wool batt insulation
   - Polyethylene
   - 12.5mm Gypsum board
2. Vapour permeable sheathing membrane lapped over & taped to membrane flashing
3. Movement allowance joint
4. Insect screen
5. Pre-finished metal flashing
6. Shear block
7. Backer rod & sealant
8. Slotted metal attachment clip
9. Wood furring
10. Concrete structural slab

(adapted from “Technical guide for tall wood building design”)

Roof Design (option 1)

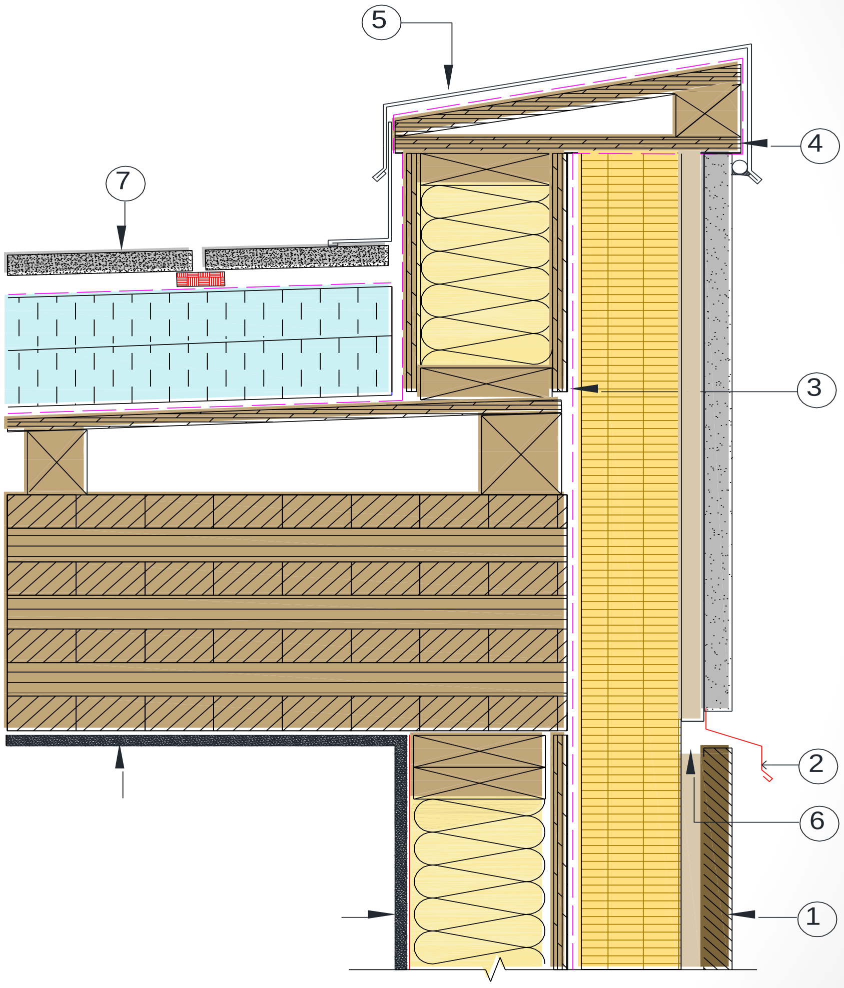
- Deck
  - ✓ 7 ply CLT, flat roof (2% slope)
  - ✓ Spaces between CLT
    - Room for ventilation
    - Facilitate drainage
- Conventional Roof Assembly
  - ✓ Roof membrane
  - ✓ Protection board
  - ✓ Roofing insulation
  - ✓ Adhered or torch on membrane (air/vapour barrier)
  - ✓ Build-up structure for ventilation/slope
  - ✓ 7-ply CLT roof deck
  - ✓ Ceiling finish



adapted from “Technical guide for tall wood building design”

Roof Design (Opt. 2)

- Inverted Protected Roof Assembly
  - ✓ Concrete pavers or gravel
  - ✓ Filter fabric
  - ✓ XPS insulation
  - ✓ Roof membrane (waterproofing, air barrier/vapour barrier)
  - ✓ Built-up wood structure (slope to drain)
  - ✓ 7-ply CLT roof deck
  - ✓ Ceiling finish



adapted from “Technical guide for tall wood building design”

Maintenance

- Important for the longevity of building envelope
  - ✓ Select durable and low-maintenance materials
  - ✓ Wood component: preservative treatment or naturally durable species
- Design consideration
  - ✓ Anticipated failure modes
    - Compatibility of materials
    - Appropriate joints design
  - ✓ Access for repair/replacement
- Regular inspection/proper maintenance plan

Conclusions/final thoughts

- Durable, energy efficient and cost-effective building envelopes for tall wood buildings possible
- Challenges
  - ✓ Higher risks of moisture damages
    - Greater exposure to wind, rain and stack effect
  - ✓ Higher quality of design, construction, and maintenance required
  - ✓ More robust/tolerant building envelope systems required
- Established best practices
  - ✓ Comprehensive guide
- Valuable experience for HQP
  - ✓ Real-word experience/challenges
  - ✓ Interaction with professionals & other HQPs

Collaborators and Acknowledgements

Collaborators

- Mr. Robert Drew, Perkins+Will
- Dr. Mohamed N. Adi, University of Alberta
- Dr. Jieying Wang, FP Innovations

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