Weaving Large-Scale PH Envelope Design, Detailing + BECx into a Cohesive Approach

MARCH 1ST, 2019
About MH

- Multi-disciplinary employee-owned engineering firm founded in 1946
  - BUILDING SCIENCE
  - Building Envelope Consulting and Façade Engineering
  - Sustainability: ZEB, PH, LEED, Living Building
  - Mission critical MEP Engineering
  - Civil and Structural Engineering
- Strong focus on resilience, contributing to social wellbeing and economic prosperity of communities we serve
- 22 offices. 2000+ employees

Pacific Northwest Locations
- Vancouver BC
- Victoria BC
- Seattle
- Portland
- SF Bay Area
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DEVELOPMENT IN PASSIVE HOUSE

- Trend towards larger projects more complexity
- Window wall, curtain wall, noncombustible construction
- Increasing adoption and reference to PH in step codes/reach codes and net zero, carbon neutral
- Need: BEFORE adoption reaches tipping point gear up for large scale excellence with strong focus on resilience via sound building science
**MORE THAN THICKER WALLS AND EXTRA INSULATION**

**All Stakeholders to Recognize:**

- The impact of thermal bridging at every junction between building components
- Deviation from conventional practice is required, but it is in everyone’s best interest to minimize disruption and build on local practice
- Success will come from a **holistic** viewpoint to design specifications and project requirements
- More effort will be required, by everyone, until new norms are established

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Design Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Protection</td>
<td>Insulation type</td>
</tr>
<tr>
<td>Structural Support</td>
<td>Cladding type</td>
</tr>
<tr>
<td>Environmental Separation</td>
<td>Glazing type</td>
</tr>
<tr>
<td>Durability</td>
<td>Cladding attachment</td>
</tr>
<tr>
<td>Constructability</td>
<td>Window detailing</td>
</tr>
<tr>
<td></td>
<td>Insulation placement</td>
</tr>
</tbody>
</table>
**RESILIENCE: STRIVE TO A HIGHER STANDARD**

**Areas for Improvement**

- Address any gaps between architectural scope and PH consultant scope wrt to envelope
  - Thermal
  - Air
  - Vapor
  - Water
- Involve more expert Building Science Engineers in PH Community + projects
RESILIENCE: STRIVE TO A HIGHER STANDARD

Improvement Goals
• Improve envelope design process from a building science perspective
• Improve understanding and modeling of component performance (3D)
RESILIENCE: STRIVE TO A HIGHER STANDARD

 Improvement Goals

• Improve rigor of plan and spec review wrt air, vapor and water control
• Improve integration of BECx process into projects and provide guidelines and resources for larger PH buildings
Low TEDI (PH) Guide

Includes

- Methodologies for determining thermal transmittance & HRV efficiency
- Whole building energy balance parameters
- Paths to PH levels of performance for CZ’s 4-7
- Software tools
- Design and construction of low energy buildings and TB free details including those for non-combustible building envelopes
Figure 1: Clear Wall Precast Sandwich Panel Wall Assembly

Table 1: Clear Field Joint Linear and R-value and Connector Point Transmission and Vertical Joint Linear Transmission for Precast Concrete Sandwich Panels

<table>
<thead>
<tr>
<th>Wall Insulation R-value / inch</th>
<th>Connector - Face</th>
<th>Connector - Face</th>
<th>Connector - face</th>
<th>Vertical Joint Linear Transmission</th>
<th>Thermal Bridge Free?</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CG</td>
<td>0.022</td>
<td>Yes</td>
<td>0.0028</td>
<td>Yes</td>
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<tr>
<td>6</td>
<td>CG</td>
<td>0.024</td>
<td>Yes</td>
<td>0.0028</td>
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<tr>
<td>7</td>
<td>CG</td>
<td>0.024</td>
<td>Yes</td>
<td>0.0028</td>
<td>Yes</td>
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</tbody>
</table>

Figure 2: Core Detail

Table 2: Exterior Corner Linear Transmittance for Proposed Wall Assembly

<table>
<thead>
<tr>
<th>Wall Insulation R-value / inch</th>
<th>Exterior Corner Linear Transmission</th>
<th>Thermal Bridge Free?</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.022</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>0.022</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>0.022</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 3: Base of wall at Foundation Detail

Table 3: Base of Wall at Foundation Detail Linear Transmittance

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Wall Insulation R-value / inch</th>
<th>Foundation Heat Loss of Slab on Grade per Sq. Ft.</th>
<th>Foundation Perimeter Heat Loss</th>
<th>Wall to Foundation Linear Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Insulation</td>
<td>5</td>
<td>1.10 (1.90)</td>
<td>-0.455 (0.787)</td>
<td>0.002 (0.005)</td>
</tr>
<tr>
<td>Insulation above slab</td>
<td>6</td>
<td>-0.454 (0.786)</td>
<td>0.034 (0.006)</td>
<td></td>
</tr>
<tr>
<td>R-Q Insulation</td>
<td>7</td>
<td>-0.454 (0.785)</td>
<td>0.004 (0.007)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Punch Window Detail

Table 4: Window Installation Linear Transmittance

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Wall Insulation R-value / inch</th>
<th>Frame U-factor</th>
<th>Edge of Glass U-factor</th>
<th>Insulated Linear Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75&quot; Spray Foam</td>
<td>5</td>
<td>0.016 (0.020)</td>
<td>0.017 (0.020)</td>
<td>0.006 (0.009)</td>
</tr>
<tr>
<td>0.75&quot; Spray Foam</td>
<td>6</td>
<td>0.017 (0.020)</td>
<td>0.017 (0.020)</td>
<td>0.006 (0.009)</td>
</tr>
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<td>7</td>
<td>0.017 (0.020)</td>
<td>0.017 (0.020)</td>
<td>0.006 (0.009)</td>
</tr>
<tr>
<td>0.75&quot; Insulation</td>
<td>8</td>
<td>0.017 (0.020)</td>
<td>0.017 (0.020)</td>
<td>0.006 (0.009)</td>
</tr>
</tbody>
</table>
Refining Passive House Detail Design

MARCH 1ST, 2019
ENVELOPE CONTINUITY

The assembly of components that separates the interior and the exterior environment.
**Envelope Continuity**

The assembly of components that separates the interior and the exterior environment.
CONTROL LAYERS OR BARRIERS

A. Water Barrier (most important)
B. Air Barrier
C. Thermal Barrier
D. Vapor Retarder
Control Layers or Barriers

- **Water Barrier**
  - Rain Shedding Surface
    - Lapping of element
    - Drips directing water off walls
    - How does water run off horizontal elements
  - Internal moisture barrier
    - Drain path to outside
    - Lapping of elements
    - Venting of cavities

- **Air barrier**
  - Continuous
  - Structurally supported
  - Provision for relative movement
CONTROL LAYERS OR BARRIERS

- Thermal Barrier (Insulation)
  - Continuity/thermal bridges
  - Keeping interior surfaces above dew point
  - Outside of structure if possible

- Vapor Barrier (Humidity Control)
  - On warm side of insulation
CONTINUITY: AIR BARRIER

- Should be planned from beginning of design
- Air tightness goals established early
- Draw line of air barrier on drawing
- Critical to schedule
CONTINUITY: AIR BARRIER

- Region: Cold/Moderate rainfall
- New Construction
- Topics
  - Continuity of Air Barrier
  - Vapor Permeability of insulation
  - Rainscreen & Drying Potential
  - Durability of materials (ie, OSB vs Plywood)
Vapor Permeability: Insulation Panel

<table>
<thead>
<tr>
<th>Wall Detail</th>
<th>Wall Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>Prefinished HardiePanel® Smooth Vertical Siding (Color Two)</td>
</tr>
<tr>
<td></td>
<td>3/8” min. thick furring strips @ 16” o.c.</td>
</tr>
<tr>
<td></td>
<td>Tyvek CommercialWrap D’</td>
</tr>
<tr>
<td></td>
<td>3” GAF ThermaCal® Wall Exterior Wall Insulation Panels</td>
</tr>
<tr>
<td></td>
<td>7/16” ext. OSB sheathing per struct.; Caulk &amp; tape seams.</td>
</tr>
<tr>
<td></td>
<td>2x6 Wood Studs @ 16” o.c.</td>
</tr>
<tr>
<td></td>
<td>Blown-In fiberglass insulation. (R-20 min.)</td>
</tr>
<tr>
<td></td>
<td>5/8” Type ‘X’ GWB</td>
</tr>
</tbody>
</table>

Credit: Passive House Institute, 2015
Vapor Permeability: Insulation Panel
Air Barrier Diagram: Penetrations
Air Barrier Diagram: Penetrations

Credit: https://www.vulcanheat.com/
Air Barrier Diagram: Penetrations

- Mechanically attached vs. fully-adhered membrane
- Penetrations in assembly
- Terminations
- Anchors through assembly
Air Barrier Diagram: Enclosed Cavities

- Region: Cold/Moderate rainfall
- New Construction
- Topics
  - Condensation Risk
  - Air Leakage into Parapet
  - Venting Cold Cavity
Air Barrier: Solid Sheet Goods

- Gyp Sheathing + tape/liquid
- OSB + tape/liquid
- Plywood + tape/liquid
- Rigid Insulation (ship-lapped + tape)
  - XPS
  - Foil-Faced
Air Barrier: WRB Materials
Air Barrier: Fluid Applied
Rain Penetration Control

4-Ds to Rain Control
- Deflection
- Drainage
- Drying
- Durability

Redundancy is important to success
Continuity: Moisture Barrier

- NE United States
- Retrofit of existing masonry building
- Topics
  - Sill pan transition to WRB
  - Back dam
  - Continuous interior seal
  - Joint between end dam and back dams
  - Verify WRB (moisture barrier)
Continuity: Moisture Barrier

- NE United States
- Retrofit of existing masonry building

Topics
- Clarity of role of barriers
- Barriers may diverge
- Tie-in with adjacent glazing assemblies
FENESTRATION: WINDOW INTEGRATION

- New Construction
- Topics
  - Deflect moisture away
  - Drain moisture out of the assembly
FENESTRATION: WINDOW INTEGRATION

- Region: Cold/Moderate rainfall
- New Construction
- Topics
  - Call Out Seal at Transitions in assembly
  - Utilize Products as Intended
Penetrations in Insulation Panel
Penetrations in Insulation Panel

[Diagram showing details of penetrations in an insulation panel]

Credit: Passive House Institute, 2015
Penetrations in Insulation Panel
Penetrations in Insulation Panel
Building Envelope Commissioning for PH

March 1, 2019
THE COMMISSIONING PROCESS

“The Commissioning Process is a quality-focused process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.”


Simply

Set goals, check goals, meet goals
BECx Process

Step 2
Owner’s Project Requirements

STEP 1
Appoint Commissioning Authority (MH proposal stage)

STEP 2

Pre-Design - Design

STEP 3
Review Basis of Design

STEP 4
Develop Commissioning Plan

STEP 5
Develop Commissioning Specifications

STEP 6
Review Construction Documents

Construction

STEP 7
Review Contractor Submittals

STEP 8
Installation and Performance Verification

STEP 9
Review Building Operation and Maintenance Manuals

STEP 10
Building Operator Training

STEP 11
Final Commissioning Report

STEP 12
Post Occupancy Activities

Occupancy
**MEP** testing typically towards the end of construction, when MEP systems near complete.

Enclosure ‘Performance Mock-up Testing’ can occur as early as during later CD phase or in very early construction phase.

Enclosure construction often complete much earlier in construction phase (than MEP systems installation)

Field testing of installed enclosure systems typically much earlier than MEP testing.

Seasonal testing for enclosure typical only IF automated systems included and control linked to M+E operation and performance.
Certification Criteria

The PHIUS+ Certification process for multifamily projects includes energy modeling and design consulting performed by a Certified Passive House Consultant (CPHC) to demonstrate compliance with PHIUS program energy performance metrics, as well as on-site verification of all critical project energy features by a Certified PHIUS+ Rater or Multifamily Verifier.
BUILDING ENVELOPE: PERFORMANCE FUNCTIONS

- Control heat flow;
- Control air flow;
- Control water vapour flow;
- Control rain penetration;
- Control light, solar and other radiation;
- Control noise;
- Control fire;
- Provide strength and rigidity;
- Be durable AND RESILIENT;
- Be aesthetically pleasing;
- Be economical.

- Use low impact materials;
- Health impacts;
- Contribute ecologically;
- Power generation;
- End of life considerations;
- Social uses (ex. Green roof).

CANADIAN BUILDING DIGEST

CBD-48. Requirements for Exterior Walls
Originally published December 1963
M.B. Hutchison
Owner’s vision = Team’s vision?
OWNER’S PROJECT REQUIREMENTS
COMPARE & CONTRAST EXAMPLES

OPR sample 1

Envelope

1. Owner’s Vision

Describe the owner's vision for the building exterior enclosure as it relates to such issues as the building's function, orientation, compatibility with existing building(s), integrated enclosure systems (such as active facades), image and aesthetic appeal, energy efficiency, maintenance and renewal expectations, and durability. Detail any non-mandatory standards or Code of Practice or Guidelines that are to be adhered to.

- Building envelope to be high performance

2. Roof

Describe any specific requirements or manufactured products such as accessible roof areas, reflective or light coloured roofs, "vegetated roof", standard or extended warranties, roof anchors, swing stage tracks or datum arms, or exclusions such as "no products by Manufacturer 'A'" and life expectancy.

- Meet Durability service life requirements of 50 years.

3. Opaque Wall

Describe any specific requirements or manufactured products such as "brick veneer façade", number of cladding types, or exclusions such as "no curtain wall" and life expectancy. (Discuss major maintenance activities such as re-caulking, or renewal dates such as full cladding replacement, that might affect owner decisions).

- Meet Durability service life requirements of 50 years.

OPR sample 2

Envelope

1. Owner’s Vision

Per the Owner’s Design Guidelines for Educational Facilities. The building envelope and its components shall be based on the following criteria.

- High Performance Building
- Asneas 90.1
- Building Aesthetics
- Building Design Service Life: 75 years
- Quality Daylighting
- Initial Cost
- Maintenance and Life Cycle Cost
- Material Availability
- Environmental Friendly Materials:
- Low VOC content,
- Recycle content,
- Minimal Urea Formaldehyde
- No HCF or CFC

2. Roof

2.1 Roof – Air, Vapor, Thermal

- Average R value = 30 (R6.28) using Minimum R 20
- Roofing principles shall be in keeping with good roofing practices as outlined by the National Roofing Contractors Association.
- No pressure treated wood to be used on roofs.

2.2 Roof – Sustainability

- Green roofs may be considered upon Owner’s approval and written approval.
- Materials shall include their performance characteristics for solar reflectance and emissivity. LEED Sustainable Sites credit 7.2 is not required.
- Granulated membrane cap sheet color: White
- Environmentally Friendly materials (low VOC content, recycle content, minimal urea formaldehyde).
- Metal roofing: SRI > 78 for 75% of surface and comply with Energy Star.

2.3 Roof – Warranty

- Workmanship 5 years.
CX PROCESS TIMELINE COMPARISON

What + When typically differs between MEPCx and BECx - For Example:

**MEP Cx**
- Design
- Enclosure Construction
- Construction
- MEP Construction
- Occupancy

**BE Cx**
- Design
- Mock-up Testing
- Construction
- MEP Construction
- Occupancy

**Enclosure 'Performance Mock-up Testing'**
- Can occur as early as during later CD phase or in very early construction phase.

**MEP testing**
- Typically towards the end of construction, when MEP systems near complete.

**Enclosure construction**
- Often complete much earlier in construction phase (than MEP systems installation).

**Field testing of installed enclosure systems**
- Typically much earlier than MEP testing.

**Seasonal testing for enclosure**
- Typical only if automated systems included and control linked to M+E operation and performance.
# Quality Control - Commissioning

## Building Envelope

**PHIUS+ On-site Quality Control**

The Rater/Verifier is responsible for verifying all items on this worksheet for projects with multiple buildings that differ in their envelope configurations, please create a duplicate worksheet for each building in the project.

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Rater Verified</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Take as many exterior photos as needed to appropriately depict all building elevations and significant architectural features of building for documentation folder.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Take pictures of surrounding site on all sides of building.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Take representative pictures of all unique insulated assemblies and window/door installations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Perform thorough IR scan of entire building from interior and exterior, including all dwelling units and common spaces, and document representative photos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>If insulated, describe passive shading. Include photos in documentation folder.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rater Notes:**

6.1 Drawings check - describe any significant variations in construction from the construction drawings and specifications (insulation, window sizes, window performance, fixed shading etc.)

**Rater Notes:**

6.2 Insulation R-value: All insulation R-values match those listed on architectural plans. If not, please describe in notes section below.

**Rater Notes:**

7. All insulated assemblies have achieved a RESNET Grade I cavity insulation level, or alternatively Gill with continuous insulation.

**Rater Notes:**

8. Framing inspection: Framing matches architectural plans. If not, please describe in notes section below.
TRYING TIMES ARE TIMES FOR TRYING
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