Designing & Constructing High Performance Envelope for Schools

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Agenda

- Integrative Process Design and Early Performance Modeling
- Performance Modeling implementation in School Projects
- Envelope Commissioning Process
- Identifying Risk in Envelope Design
What is Integrated/Integrative Design Process?

As it relates to green building, an integrated process is a method used for the design and operations of sustainable built environments. What it boils down to is getting everyone who will be involved in the project, from the design phase to construction to the actual day-to-day operations, together right from the start to collaborate. (USGBC)
What is Integrated/Integrative Design Process?

An Integrated Design Process (IDP) involves a holistic approach to high performance building design and construction. It relies upon every member of the project team sharing a vision of sustainability, and working collaboratively to implement sustainability goals. (NRC- Canada)
Integrative Design Process vs Building System Design

- Mechanical
  - Mechanical system efficiency
  - Mechanical system type

- Lighting
  - Lighting power density
  - Skylight-to-roof ratio
  - Window-to-wall ratio
  - Electrical lighting system

- Envelope
  - Orientation study
  - Shading strategy
  - Envelope construction assembly
  - Massing study
  - Finite element analysis

- Pre-design
- Schematic design
- Design development
- Construction document
Integrative Design Process vs Building System Design

- Mechanical
- Lighting
- Envelope

- Lighting power density
- Skylight-to-roof ratio
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Integrative Design Process vs Building System Design

- **Mechanical**
  - Lighting power density
  - Skylight-to-roof ratio
  - Window-to-wall ratio

- **Lighting**
  - Orientation study
  - Shading strategy
  - Envelope construction assembly
  - Massing study
  - Shading strategy
  - Finite element analysis

- **Envelope**
  - Commissioning
  - Pre-design
  - Schematic design
  - Design development
  - Construction document
Building Commissioning Authority

The **Commissioning Authority** or **Commissioning Agent (CxA)** is generally contracted directly to the building owner as a third-party independent representative to ensure unbiased performance of the CxA.
Plan for Commissioning

The work shall commence with the Design phase and including Schematic Design, Design Development and Construction Documents.
Building Commissioning Flow Chart
Energy Modeling & Integrative Design Process

- LEED BD+C: New Construction, LEED v4 – Integrative Process
LEED v4 – Integrative Design Process
LEED v4 – Integrative Design Process

• Perform a preliminary “simple box” energy modeling analysis
• Perform a preliminary water budget analysis
Our Three Core Values

“Simple Box” Energy Modeling

Implementations

• Building and site program
• Building form and geometry
• Building envelope and façade treatments on different orientations
• Elimination and/or significant downsizing of building systems
• Other systems
Energy Simulation Aided Design for Buildings except Low-Rise Residential Buildings (2nd Draft)
ASHRAE 209p

Compliance

- Section 6 (Climate analysis, software and energy modeler requirements)
- Section 6.3 Modeling Cycle #3 – Load Reduction Modeling, and
- At least one of the following sections:
  a. Section 6.1 Modeling Cycle #1 – Simple Box Modeling
  b. Section 6.2 Modeling Cycle #2 – Conceptual Design Modeling
  c. Section 6.4 Modeling Cycle #4 – HVAC System Selection Modeling
  d. Section 6.5 Modeling Cycle #5 – Design Refinement
  e. Section 6.6 Modeling Cycle #6 – Design Integration and Optimization
  f. Section 6.7 Modeling Cycle #7 – Energy-Simulation-Aided Value Engineering
Implementation
Simple Box Modeling

1. "BAR" 1 STORY scheme
   - ground access
   - low operational costs
   - no need for stairs and elevator
   - larger building footprint needed all around site

2. "BAR" 2 STORY scheme
   - ground access only from 1st floor
   - needs stairs and elevator
   - stacking minimizes building footprint

3. "L-COURTYARD" 1 STORY scheme
   - creates courtyard for outdoor learning activities
   - creates shaded outdoor areas
   - no need for stairs and elevator

4. "L-COURTYARD" 2 STORY scheme
   - creates courtyard for outdoor learning activities
   - creates shaded outdoor areas
   - needs stairs and elevator

5. "U-COURTYARD" 1 STORY scheme
   - creates centralized courtyard for outdoor learning activities
   - allows even daylighting and cross ventilation
   - exterior circulation is subtracted from building footprint
   - ground access

6. "U-COURTYARD" 2 STORY scheme
   - creates centralized courtyard for outdoor learning activities
   - stacking minimizes building footprint
   - allows daylighting and cross ventilation
   - creates shaded areas that may be beneficial during hot school days
   - exterior circulation is subtracted from building footprint
   - needs stairs and elevator

Source: HMC Architects
IMPLEMENTATION

Simple Box Modeling

Source: HMC Architects

- "TERRACED BAR" 1 CORRIDOR scheme
  - creates outdoor patio/balcony for outdoor learning activities on 2nd floor
  - stacking minimizes building footprint
  - exterior circulation with ventilation and daylighting
  - terracing breaks down building mass / scale
  - needs stairs and elevator

- "L-COURTYARD" 1 CORRIDOR scheme
  - ground access to courtyard only on 1st floor
  - stacking minimizes building footprint
  - exterior circulation with ventilation and daylighting

- "U-COURTYARD" 1 CORRIDOR scheme
  - creates centralized courtyard for outdoor learning activities
  - allows even daylighting and cross ventilation
  - exterior circulation
  - ground access

- "TERRACED BAR" 2 CORRIDOR scheme
  - stacking minimizes building footprint
  - terracing breaks down building mass / scale
  - terracing allows multiple balconies for outdoor learning activities
  - ground access only from 1st floor
  - needs stairs and elevator

- "L-COURTYARD" 2 CORRIDOR scheme
  - ground access to courtyard
  - doubled classroom count
  - increased building footprint
  - interior circulation needs HVAC and light
  - no need for stairs and elevator

- "U-COURTYARD" 2 CORRIDOR scheme
  - creates centralized courtyard for outdoor learning activities only on 1st floor
  - creates shaded areas
  - minimizes building footprint
  - large building mass / scale
  - needs stairs and elevator
  - interior circulation needs HVAC and light
Simple Box Modeling

Legend:
Utility 60%/year **
[Utility Bill/year/ft]** **
**The numbers are based on the early conceptual energy modeling results. The actual building energy usage may vary.

Source: HMC Architects
Double Loaded Corridor

$/sf

10%  20%  30%  40%
Double Loaded Corridor

$/sf

- 0.4
- 0.45
- 0.5
- 0.55
- 0.6
- 0.65
- 0.7
- 0.75
- 0.8

10% 20% 30% 40%
WWR Recommendations

Single Loaded Corridor

Double Loaded Corridor

ASHRAE 90.1 2016 APP. G BASELINE WWR FOR SCHOOL (22%)
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

A. BASELINE – 40% WWR
B. OPTION 1 – 25% WWR – INT AND EXT LIGHTSHELVES
C. OPTION 2 – 25% WWR – EXT LIGHTSHELVES
D. OPTION 3 – 25% WWR – INT LIGHTSHELVES
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

Daylight Potential

A. BASELINE – 40% WWR

B. OPTION 1
25% WWR INT AND EXT LIGHTSHELVES

C. OPTION 1
25% WWR EXT LIGHTSHELVES

C. OPTION 1
25% WWR INT LIGHTSHELVES

73.59%
UDI 100 – 2000 (LUX)

83.19%
UDI 100 – 2000 (LUX)

82.50%
UDI 100 – 2000 (LUX)

81.69%
UDI 100 – 2000 (LUX)
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom
Daylight Potential

A. BASELINE – 40% WWR

73.59%
UDI 100 – 2000 (LUX)

B. OPTION 1
25% WWR INT AND EXT LIGHTSHELVES

83.19%
UDI 100 – 2000 (LUX)

C. OPTION 1
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C. OPTION 1
25% WWR INT LIGHTSHELVES

81.69%
UDI 100 – 2000 (LUX)
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

Glare Potential

A. BASELINE – 40% WWR

22.88
UDI
>=2000 (LUX)

B. OPTION 1
25% WWR INT AND
EXT LIGHTSHELVES

8.26%
UDI
>=2000 (LUX)

C. OPTION 1
25% WWR EXT
LIGHTSHELVES

9.60%
UDI
>=2000 (LUX)

C. OPTION 1
25% WWR INT
LIGHTSHELVES

10.51%
UDI
>=2000 (LUX)
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

Glare Potential

A. BASELINE – 40% WWR

B. OPTION 1
25% WWR INT AND EXT LIGHTSHELVES

C. OPTION 1
25% WWR EXT LIGHTSHELVES

C. OPTION 1
25% WWR INT LIGHTSHELVES

<table>
<thead>
<tr>
<th>UDI</th>
<th>&gt;=2000 (LUX)</th>
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</thead>
<tbody>
<tr>
<td>22.88</td>
<td></td>
</tr>
<tr>
<td>8.26%</td>
<td></td>
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<tr>
<td>9.60%</td>
<td></td>
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<tr>
<td>10.51%</td>
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</tbody>
</table>
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

**Energy Modeling**

- **Baseline**
  - Roof U Value: 0.039
  - Wall U Value: 0.084
  - Slab on Grade: 0.73
  - U Value fenestration: 0.4
  - SHGC: 0.25
  - WWR: 40%
  - Misc Power: 1.5 W/sf
  - LPD: 1.24 W/sf
  - Package DX

- **Option 1**
  - Roof U Value: 0.028 (R-35 c.i)
  - Wall U Value: 0.054 (R-21 batt+R-9c.i)
  - Slab on Grade: 0.73
  - U Value fenestration: 0.4
  - SHGC: 0.25
  - WWR: 25%
  - Misc Power: 0.7 W/sf
  - LPD: 0.7 W/sf
  - VRF + DOAS

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Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom

Energy Modeling

Option 1

Baseline

40% LESS ENERGY USAGE
18% LESS COOLING PEAK LOAD
16% LESS HEATING PEAK LOAD
35% LESS AIRFLOW
Coupling Daylight Modeling & Energy Modeling for Typical Floor Classroom Energy Modeling

Option 1: 15.9 kBtu/sf.yr

Baseline: 26.7 kBtu/sf.yr

NET ZERO READY EUI TARGET PER ASHRAE (INCLUDING EXT. LIGHTING AND DHW – 30% ADD ENERGY USAGE)

40% LESS ENERGY USAGE

18% LESS COOLING PEAK LOAD

16% LESS HEATING PEAK LOAD

35% LESS AIRFLOW
PV REQUIREMENT TO BE NET ZERO SCHOOLS: 30623 SQFT (26.5% OF ROOFING AREA) OR 575 kW System; ESTIMATE COST = $1.5 Million

NET ZERO READY EUI TARGET PER ASHRAE

Original Design
Improve Window Assembly
Improve Roof Assembly
Optimize Building Orientation
Reduce Plug Loads
Shading
Reduce Elevator Usage
Reduce Clg VAV min
Improve chiller efficiency
Supply Air Reset Temperature Increase
Economizers
Add Energy Recovery
Reduce Interior Lighting Power Densities
Reduce/Eliminate Summer Use
High Performance VAV
Add Heat Recovery to Chillers

Base Utilities (Ext. Lighting, Kitchen, Hot Water, Elev.)
Misc. Plug Load
HVAC
Int Lighting

Additional strategies to reduce base utilities more (EnergyStar Kitchen Equipment, Proper Zoning and Scheduling for Ext. Lighting, Using low flow or waterless for plumbing fixtures)

ELEMENTARY SCHOOL PROJECT IN HOUSTON (DESIGNED IN 2015)
Energy Use vs PV Production per Square Foot (kBtu/sf)

PV PRODUCTION
100% ROOFING COVERAGE

PV PRODUCTION
75% ROOFING COVERAGE

PV PRODUCTION
50% ROOFING COVERAGE
BECx – Design Stage
Integrative Design Process vs Building System Design

- **mechanical**
- **lighting**
- **envelope**
- **commissioning**

- lighting power density
- skylight-to-roof ratio
- window-to-wall ratio

- orientation study
- shading strategy
- envelope construction assembly

- massing study
- finite element analysis

- pre-design
- schematic design
- design development
- construction document
What’s Building Envelope

- Sun
  - Heat Gain
- Rain
  - Water Penetration
- Wind
  - Air Infiltration
- Moisture
  - Vapor Diffusion
Program Validation – Early Design Stage

• Owner’s Project Requirements (OPR) and Basis of Design (BOD)
  – Critical to establish the scope and budget for the building enclosure commissioning activities during the pre-design phase
  – Both the ASTM standard for building enclosure commissioning and the current LEED requirements include two levels of building enclosure commissioning: fundamental commissioning and enhanced commissioning
Performance Reviews

- Performance Modeling Reviews
- Drawing Reviews
- Specifications Reviews
- Pre-installation meeting
- Mockup Testing
- Site Visits
- Field Reports
- Documentations
Performance Validation

• Verifying Performance Values During Design:

  • Energy Usage
  • Heat Gain / Loss
  • Wind Impact
  • Thermal Comfort
  • Daylighting
  • Glare & Reflectivity
  • Condensation / Mold Growth Index
Simulations on Building Envelope

- Purposes:
  - Energy Comparison
  - Risk Identification
  - Optimization
  - Cost Analysis
Energy Efficient Glazing

- Energy Analysis:
  - Orientation
  - Daylighting
  - Window Wall Ratio
  - Shading Control
  - Window Types

Which Is The Best Window Glass?
Mold Growth

- ASHRAE 160-2016 (Criteria for Moisture-Control Design Analysis in Buildings)
  - Bad if Mold Growth Index is over 3
Vapor “Barrier”?
Vapor Retarder – Class 1
Review the building envelope related Construction Documents and Installer's submittals to become familiar with the systems selected and approved by the Architect.
Specifications Review

- The BECx specification should clarify the field testing and shall be included in the Project Manual, Section 1, in coordination with specifications addressing:
  - Contractor Quality Assurance
  - Moisture Prevention Procedures during Construction
  - Building Enclosure Performance Requirements (inclusive of the Air Barrier)
  - Testing and Inspection Services
  - Project specific Substitution Request Form for building enclosure components.

BUILDING ENVELOPE SPECIFICATION REVIEW COMMENTS

SECTION 034500 – PRECAST ARCHITECTURAL CONCRETE
1. General – BES recommends referencing the installation of dual lines of sealant along the pre-cast panel joints. Reference Specification section 079200.

SECTION 042000 – UNIT MASONRY & SECTION 042200 – CONCRETE UNIT MASONRY
1. General – BES recommends referencing the weather barrier specification in order to ensure the weather barrier and associated flashing materials are single sourced.

SECTION 053123 – STEEL ROOF DECKING
1. General – Verify that performance requirements are coordinated with associated FM letter in order to ensure uplift performance as required by specified uplift performance criteria.

SECTION 061053 – ROUGH CARPENTRY
1. General: Use FM 1-49 reference for the attachment of roof-related wood blocking. If project is FM Global insured, adherence to this standard may be required. For wood blocking or nailers at roof conditions, comply with the requirements of FM Global Bulletin 1-49 for fastening these elements to the building, including the methodology, gauges, thicknesses, and frequency of attachment.
BECx – Construction Stage
Mock-up

• Verification of Details
• Coordination of Trades
• Identification of Conflicts
• Confirmation of Acceptable Workmanship
• Observation of Performance Testing
• Evaluation of Visual Appearance
Laboratory Mock-up Tests

- Verifying Performance Values before Construction:
  - Static Air Infiltration Test (ASTM E283)
  - Static Water Test (ASTM E331)
  - Dynamic Water Test (AAMA 501.1-83)
  - Uniform Load Test (ASTM E330)
  - Static Water Test (ASTM E331)
  - Thermal Cycle (AAMA 501.5)
  - Thermal Resistance Test (AAMA 1503)
Field Mock-up Tests

• Verifying Performance Values during Construction:
  – Waterproofing (Below Grade)
  – Enclosure Cladding (Above Grade)
  – Roofing
  – Penetrations – Wall/Roof
# Field Observations and Reports

- **Site Visits and Reports**

<table>
<thead>
<tr>
<th>Item 1.4</th>
<th>System Observed: Roof - Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion: BES observed the isolated locations.</td>
<td></td>
</tr>
</tbody>
</table>

Additionally, access to the roof was noted.

<table>
<thead>
<tr>
<th>Item 2.1</th>
<th>System Observed: Weather Barrier - Self-Adhesive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion: BES conducted a site observation of the exterior gypsum board. The joints were in heavy foot traffic areas.</td>
<td></td>
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</tbody>
</table>

**Overall View of Building**

**Overview of the Building**

**Exterior Windows**

<table>
<thead>
<tr>
<th>Item 3.5</th>
<th>System Observed: Joint Sealsants - Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion: Voids were noted in select fenestration, were exposed and not yet flashed (see arrow).</td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions:** Voids in the roof.

**Action Items:**

1.4A: Repair voids
1.4B: Provide repair

- **Conclusions:** N/A

**Action Items:**

3.5A: Verify that flashing at penumbral manufacturers installation instructions

<table>
<thead>
<tr>
<th>Item 6.1</th>
<th>System Observed: Walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade/Subcontractor: Drywall</td>
<td></td>
</tr>
<tr>
<td>Discussion: BES conducted a site observation of the exterior gypsum sheathing substrate, self-adhesive membrane, damp proofing, masonry wall installation, as well as fenestration system at the exterior of the building.</td>
<td></td>
</tr>
</tbody>
</table>

**Partial view of the South elevation**

**Building corner view of Southwest Elevation**

**Partial view of the West elevation**

**Partial view of the North elevation**

**Conclusions:** N/A

**Action Items:**

<table>
<thead>
<tr>
<th>Responsible Party:</th>
</tr>
</thead>
</table>
Field Observations and Testing

• Chamber Water Test (ASTM E1105)

Item 13.4
System Observes: Chamber Water Testing

Discussion: Test Specimens 1: CCL commenced testing at 8:53am CST.

Conclusions: BES observed and confirmed with CCL that the testing pressure was 1.54H* across the test specimen. Action Items:

12.4A None

Item 13.8
System Observes: Chamber Water Testing

Discussion: Test Specimens 2: CCL commenced testing at 8:53am CST.

Conclusions: BES observed and confirmed with CCL that the testing pressure was 1.54H* across the test specimen. Action Items:

13.4A None

Item 13.11
System Observes: Chamber Water Testing

Discussion: Test Specimens 2: CCL commenced water testing at 11:30am CST.

Conclusions: At 50 seconds into testing, water intrusion was observed at the lower left perimeter. At 4 minutes into the test cycle, water intrusion and pooling was observed on the left side of the center vertical inside corner mullion. At 4 minutes 30 seconds, water intrusion and pooling was observed on the right side of the center vertical inside corner mullion. The test was stopped at 5 minutes due to the amount of water infiltration. CCL removed the testing chamber to review the source of the water intr

Action Items:

13.11A Retest window assembly following the repairs to verify the repairs are sufficient to meet the specified system performance. Responsible Party: Harmon

13.11B Review curtain wall system and sealant installation. Provide photographic documentation of the cause of the water intrusion. Harmon

13.11C Repair/replace the unitized window assembly and/or joint sealant in accordance with the manufacturer’s installation instructions. Harmon
Pre-Design Phase:
- A written plan is prepared. This defines roles, responsibilities, activities and expectations.

Design Phase:
- Peer review of the building envelope during design
- Building enclosure commissioning authority performs periodic reviews which ensure the owner’s standards are met.

Plans and Specifications:
- Details for the interfacing building enclosure materials, performance requirements, responsibility for QA/QC
BECx Summary – Construction Phases

• Pre-Construction Phase:
  • Building enclosure commissioning authority serves as a second reviewer for RFI, addenda, and bids related to the building enclosure.
  • Prequalification of contractors, materials, and specialty subcontractors.

• Construction Phase:
  • Building enclosure commissioning authority acts as a second reviewer for building enclosure submittals, field testing of mock ups, and shop drawings.
  • Perform periodic site visits during the construction of the building enclosure, testing, and documentation of the building envelope sequential installation.
Conclusion

- Integrative Process Design is crucial to drive high performance envelope design
- Performance Modeling implementation can determine envelope parameters such as massing, WWR, and assemblies
- Building Envelope Commissioning is dynamic and it should be integrated from the design phase
- Building Performance Modeling can enhance the Holistic Approach during various design stages
Questions?

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