Building Enclosure Commissioning

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Program Outline

Defining the Enclosure
Building Science Concepts
Façade Design
State of the Practice
  • Energy Usage
  • BECx
  • Enclosure Testing
Tomorrow’s Trends
Environmental Separation

Building enclosures are designed to separate interior from exterior.

Understanding the Environment
Owner’s Project Requirements

Leaks
Leaks

Air Quality / Health
Sustainability Status
Sustainability Drivers

Environmental
- Energy Efficiency
- Rising Energy Costs

Social

Regulatory
- Design Changes
- Life Safety
- Code Updates

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2007:
US Army Corps of Engineers

Air barrier material air permeance not to exceed 0.004 cfm/ft² at 0.3 in. wg (1.57 psf) (0.02 L/s·m² @ 75 Pa)

Whole building’s air leakage rate must not exceed 1.25 L/s·m² @ 75 Pa (0.25 cfm/ft² at 1.57 psf) when tested according to ASTM E779

2011/2012:
Baseline Standards:
- IBC 2012
- IECC 2012
- ANSI/ASHRAE/IES 90.1 – 2010

Enhancement Standards:
- IGCC Version 2.0 – 2012
- LEED 2012 – Public Version 2
- ASHRAE 189.1 – Public Review
What is an Air Barrier?

Materials with air permeability ≤0.004 cfm/ft²

Compliant Materials

- Plywood ≥ 3/8 in. thick
- Oriented Strand Board ≥ 3/8 in. thick
- Extruded Insulation Board ≥ 1/2 in. thick
- Foil-back Insulation Board ≥ 1/2 in. thick
- Closed-cell spray foam (min. density of 1.5 pcf and thickness ≥ 1-1/2 in.)
- Open-cell spray foam with density 0.4-1.5 pcf and thickness ≥ 4-1/2 in.
- Exterior or interior gypsum board ≥ 1/2 in.
- Cement board ≥ 1/2 in.
- Built-up roofing membrane
- Mod-bit roofing membrane
- Fully-adhered single-ply roofing membrane
- Portland cement/sand parge or gypsum plaster ≥ 3/8 in. thick
- Cast-in-place or precast concrete
- Fully grouted concrete block masonry
- Sheet steel or aluminum
Stucco: Air Vs. Flashing Requirements

Considered air barrier per C402.4.1.2.2

Must be flashed per 1405.4 IBC 2012

Weeps in assembly compromise air performance of assembly

Vapor Control Layer

Vapor Retarders per IBC 2012:

- Class I or II vapor retarders provided on interior side of frame wall in Zones 5-8 and Marine 4
- Class III permitted conditionally
Building enclosures are designed to control multiple loadings.

**Control layers include:**
1. Water control layer
2. Air control layer
3. Vapor control layer
4. Thermal control layer

**Modes of Bulk Water Transport**
Moisture Transport

4x8 GWB Interior at 70 F 40% RH

2/3 Pint via Diffusion

Vapor diffusion - 2/3 pint of water per heating season

Air leakage (1/2 inch hole) - 50 pints of water per heating season

50 Pints via Air Flow

Enclosure Design

Typical Wall Section

Formulas

\[ Q = U_{md} \left( T_{md} - T_{wall} \right) \]

Bi = \frac{U_{md}}{R_{md}}

\[ T_{md} = \frac{P_d + \Phi_{md} R_{md}}{R_{md}} \]

\[ P_d = 6.11 x 10^5 \left( \frac{273 + T_{md}}{273 + T_d} \right)^{5.26} \]

\[ \Phi_{md} = \frac{P_d}{P_e} \]

\[ P_e = 6.11 x 10^5 \]
Enclosure Design

Brick veneer/stone veneer

Drained cavity

Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass

Membrane or trowel-on or spray applied vapor barrier (Class I vapor retarder), air barrier and drainage plane (impermeable)

Concrete block

Metal channel or wood furring

Gypsum board

Latex paint or vapor semi-permeable textured wall finish
Enclosure Design

Conceptual Assemblies

Cavity wall
- Masonry
- Metal panels
- Drained EIFS/Stucco

Source: NBS www.wbdg.org
Conceptual Assemblies

Cavity wall
- Masonry
- Metal panels
- Drained EIFS/Stucco

Barrier wall
- Barrier metal wall panels
- Barrier EIFS/Stucco

Source: NIBS www.wbdg.org

Conceptual Assemblies

Cavity wall
- Masonry
- Metal panels
- Drained EIFS/Stucco

Mass wall

Source: NIBS www.wbdg.org
Common Elements

- Cladding
- Insulation
- Air Barrier
- Substrates

Sources: NBS www.wbdg.org; nexusfocus.com; www.greenbuildingadvisor.com; www.wbdg.org; www.huggettbetten.com

Fluid-Applied

- Asphalt
- Acrylic
- STPE
- Silicone

Spray
Trowel
Roller
Self-Adhered Sheet

May include:
• Rubberized asphalt
• Cross-laminated HDPE film
• Polypropylene
• Other polymers

Other

• Board
• Spray polyurethane foam
• Insulated metal wall panels
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Building Science Concepts

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State of the Practice
  • Energy Usage
  • BECx
  • Enclosure Testing

Tomorrow’s Trends

Successful Design

• Achieve environment separation
• Meet durability/sustainability
• Fulfills desired use
• Simple
• Redundant
• Constructible
Successful Design

• Achieve environment separation
• Meet durability/sustainability requirements
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Energy Conservation

Solar Heat Gain  U-Factor  Air Leakage

Energy Usage Index (EUI) – expressed in BTU/sf
Energy Conservation

Solar Heat Gain

SHGC
Transmittance
Reflectance
Absorptance
Emittance

Energy Conservation

Window:Wall
Energy Conservation

Thermal Discontinuities

Energy Modeling & BECx

<table>
<thead>
<tr>
<th>Assembly 10</th>
<th>R&lt;sub&gt;10&lt;/sub&gt;</th>
<th>R&lt;sub&gt;11&lt;/sub&gt;</th>
<th>0.000</th>
<th>0.000</th>
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<tr>
<td>(Nominal)</td>
<td>R-value</td>
<td>R-value</td>
<td>R-value</td>
<td>R-value</td>
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<tr>
<td>-----------</td>
<td>----------</td>
<td>----------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Two base assemblies:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r = roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w = wall (Detail 11)</td>
<td></td>
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</table>

Transmittance / Resistance without Anomaly:

U<sub>wr</sub> | R<sub>wr</sub> | U<sub>wr</sub> | R<sub>wr</sub>

Surface Temperature Index:

T<sub>i</sub> = exterior temperature
T<sub>i</sub> = interior temperature

Linear Transmittance:

Y = Incremental increase in transmittance per linear length of parapet

Nominal (1D) vs. Assembly Performance Indicators

Base Assembly – Wall

<table>
<thead>
<tr>
<th>Wall Exterior</th>
<th>R&lt;sub&gt;10&lt;/sub&gt;</th>
<th>R&lt;sub&gt;11&lt;/sub&gt;</th>
<th>R&lt;sub&gt;20&lt;/sub&gt;</th>
<th>U&lt;sub&gt;20&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>Insulation 10</td>
<td>ft&lt;sup&gt;2&lt;/sup&gt;·hr·F / Btu</td>
<td>ft&lt;sup&gt;2&lt;/sup&gt;·hr·F / Btu</td>
<td>(m&lt;sup&gt;2&lt;/sup&gt;·K / W)</td>
<td>(W/m&lt;sup&gt;2&lt;/sup&gt;·K)</td>
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<tr>
<td>R-5 (0.88)</td>
<td>19.2 (3.38)</td>
<td>13.40 (2.36)</td>
<td>0.075 (0.42)</td>
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<tr>
<td>R-10 (1.76)</td>
<td>24.2 (4.26)</td>
<td>16.28 (2.87)</td>
<td>0.061 (0.35)</td>
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</tr>
<tr>
<td>R-15 (2.64)</td>
<td>29.2 (5.14)</td>
<td>18.49 (3.25)</td>
<td>0.054 (0.31)</td>
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<tr>
<td>R-20 (3.52)</td>
<td>34.2 (6.00)</td>
<td>20.90 (3.61)</td>
<td>0.049 (0.28)</td>
<td></td>
</tr>
<tr>
<td>R-25 (4.40)</td>
<td>39.2 (6.90)</td>
<td>22.14 (3.90)</td>
<td>0.045 (0.26)</td>
<td></td>
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Base Assembly – Roof

<table>
<thead>
<tr>
<th>R&lt;sub&gt;10&lt;/sub&gt;</th>
<th>R&lt;sub&gt;11&lt;/sub&gt;</th>
<th>U&lt;sub&gt;20&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft&lt;sup&gt;2&lt;/sup&gt;·hr·F / Btu</td>
<td>ft&lt;sup&gt;2&lt;/sup&gt;·hr·F / Btu</td>
<td>(W/m&lt;sup&gt;2&lt;/sup&gt;·K)</td>
</tr>
<tr>
<td>R-21.2 (3.74)</td>
<td>21.0 (3.69)</td>
<td>0.048 (0.27)</td>
</tr>
</tbody>
</table>

Reference ASHRAE 1365 -RP
Whole building air test results (ASTM E779) are expressed as air flow through the wall, roof, and floor, not just the facade.
Case Study

Diagnostic investigation

• Occupants had difficulty regulating the temperature
• Windows and wall areas were cold concurrent with outside temp
• High heating costs reported by the owner

Blower Door Testing:

Building air leakage rate @ 75PA
0.50 cfm/ft² (Positive)
0.61 cfm/ft² (Negative)

Diagnostic Evaluation:

• A significant amount of the air leakage occurs into the inter-story air plenums
• Air leakage around the windows and through the window systems
• Air leakage through the wall penetrations
Achieve Exceptional Energy Savings

Building Envelope Commissioning

Over the years DFCM has learned the immense value of having high performing building envelopes. Quality systems that perform as designed provide value to the building and its occupants for decades.

In an effort to quantify the value of this program, DFCM conducted an analysis utilizing a sophisticated energy modeling process to determine annual energy cost savings ranging from 4% to 32%, with a majority of buildings experiencing savings in the 10% to 15% range.

- John Burningham, Energy Development Director

DFCM’s Case for Rigorous BECx

Modeled Yearly Energy Cost Saved (%) = [(0.8-0.1)/0.8] x 100
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Forced Entry Resistance
Discipline Specific Cx

- Electrical
- Plumbing
- Life Safety
- Mechanical
- Security
- Whole Building Commissioning
- Building Envelope

Sub-Discipline Specific Cx

- BECx
  - Thermal
  - Structural
  - Solar
  - Safety
  - Systems
  - Durability
  - Fire
  - Acoustics
  - Blast
  - Water / Air
  - Testing
  - Calibration
  - Mock-up
  - IAQ
  - Roofing
  - Glazing
  - Façade
  - Waterproofing
  - Material Properties
Functional Performance Testing

Typical Failures:

Concrete cracks
Z-girt fasteners
Brick ties

Functional Performance Testing

Typical Failures:

Curtain wall gaskets
Perimeter seal
Functional Performance Testing

Typical Failures:

- Stem wall connection
- Mullion intersection

Functional Performance Testing

Typical Failures:

- Unsealed holes
- Roof-to-wall interface
Functional Performance Testing

Performance Requirements

• Building Enclosure Functional Performance Testing Specification Section
• This Section shall supersede other Sections where contradictions occur

Design Phase

FPT Specification:

SECTION 019117
BUILDING ENCLOSURE FUNCTIONAL PERFORMANCE TESTING REQUIREMENTS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. This section includes the functional performance testing requirements for the Building Enclosure systems. Refer to Section 019115 for Building Enclosure Commissioning Requirements

1.02 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section. Divisions 03, 04, 07, 08 and 09 Specification Sections also apply to this section. Where conflicts arise regarding building enclosure testing, this Section shall supersede other Sections where contradictions occur.

1.03 TESTING AGENCY

A. The Owner will retain a Building Enclosure Testing Agent (BETA), which may be the same entity as the Building Enclosure Commissioning Agent (BECA). In such cases, the BECA
Design Phase

Design Reviews:

Head Detail

AIR / WATER BARRIER
BRICK
EXTERIOR GYP SHEATHING
FLASHING
WEEPS
24" OC
SHEET METAL FLASHING
PAINT ANGLE TO MATCH COLOR OF BRICK
BACKER ROD & SEALANT
ALUMINUM GLAZED CURTAINWALL

5"
Typical Interface Concerns

Parapet Cap
Extended Curtain Wall

Soffits
Mechanical Equipment

Typical Interface Concerns

Penetrations
**Wall to Foundation**

**Pre-Construction Phase**

- Review the BECx process and purpose
- Review plans and specifications
- Review of shop drawings
- Construction schedule and sequencing
- Material selections and compatibility
- Field observation report process
- Functional performance testing
Pre-Construction Phase

Value of Mockups:

• Verify the performance of the systems
• Set construction standards
• Establish sequencing of work
• Verify material selection
Pre-Construction Phase

Types of Site Mock-ups:

- Freestanding fully enclosed
- Freestanding partially enclosed
- In-situ

Pre-Construction Phase

Other Pre-Construction Items:

- RFI, ASI, PR
- Change order
- Substitution request
- Value engineering
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Functional Performance Testing

ASTM E783
  • Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
  • Quantitative Air Infiltration Test
Functional Performance Testing

ASTM E1186, Practice 4.2.1

- Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems - Building Depressurization (or Pressurization) with Infrared Scanning Techniques
- Qualitative Air Infiltration/Exfiltration Test

Functional Performance Testing

ASTM E1186, Practice 4.2.6

- Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems - Chamber Pressurization or Depressurization in Conjunction With Smoke Tracers
- Qualitative Air Infiltration/Exfiltration Test
Functional Performance Testing

ASTM E1186, Practice 4.2.6

Functional Performance Testing

ASTM E1186, Practice 4.2.7

- Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems - Chamber Depressurization in Conjunction With Leak Detection Liquid
- Qualitative Air Infiltration/Exfiltration Test
Functional Performance Testing

ASTM E1186, Practice 4.2.7
Quantitative Field Air Testing
Functional Performance Testing

**ASTM E779 (Whole Building Air Test)**

- Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
- Quantitative Whole Building Air Leakage Test

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**Functional Performance Testing**

**ASTM E1105**

- Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference
- Water Penetration Test
AAMA 501.1

- Standard Test Method for Water Penetration of Windows, Curtain Walls, and Doors using Dynamic Pressure
- Water Penetration Test
**Functional Performance Testing**

**AAMA 501.2**
- Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems
- Water Penetration Test

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**Functional Performance Testing**

**ASTM D4541**
- Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
- Quantitative Adhesion Test
Surface Preparation
Field Observations

Typical Observations:

- Thin air/vapor barrier
- Missed fasteners
Field Observations

Typical Observations:

Insufficient spray foam

Unsealed electrical box

Field Observations

Typical Observations:

Air/Vapor Barrier

Unsealed holes

Holes in flashing
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Geographical Expansion

• The recognition of building enclosure commissioning has expanded beyond US
• International labor force
• Increase in foreign fabrication/materials
Primary Air and Water Seal

Sealant

Primary Air and Water Seal

Silicone Sheet
Primary Air and Water Seal

Silicone Sheet

Case Study – New York

• Built in 1940’s
• 14 stories, 460,000 sf
• Concrete encased steel frame
• Client is upgrading building to change use from manf. to education
• Client looking to greatly increase energy performance
• Minor facade repairs
Case Study – New York

- Existing BECx starts with an investigation
- Mock-ups were key to verifying repair scope
- New windows, insulation, air barrier, roof, existing cladding to remain
- Air leakage performance increase by 10x

Case Study 3 – New Jersey

Project Location
Case Study 3 – New Jersey

Glass Fabrication
Case Study 3 – New Jersey
Case Study 3 – New Jersey
### Case Study 3 – New Jersey

#### ATI OBSERVATION REPORT

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Observation</th>
<th>Action</th>
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<tbody>
<tr>
<td>5/10</td>
<td>Apartment</td>
<td>Electrical</td>
<td>Repaired</td>
</tr>
<tr>
<td>6/20</td>
<td>Commercial</td>
<td>Plumbing</td>
<td>Replacement</td>
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</table>

#### Table

<table>
<thead>
<tr>
<th>Issue</th>
<th>Recommendation</th>
<th>Action</th>
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</thead>
<tbody>
<tr>
<td>Electrical issues</td>
<td>Install new wiring</td>
<td>Completed</td>
</tr>
<tr>
<td>Plumbing leaks</td>
<td>Replace pipes</td>
<td>In progress</td>
</tr>
</tbody>
</table>

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Energy Modeling & BECx

Trends:

• Model accuracy is increasing
• Model comparison with actual performance is increasing
• Most projects have modeling requirements
• Modeling is dictating some design decisions

Consulting/Design QA

Revit Model
Consulting/Design QA

Building Envelope Details Set

Intertek
Building Better Together

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