BECx & Building Airtightness

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Principal

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The Building Enclosure

• 2007 study: out of 17,000 construction defect claims, 69% result of moisture related defects in building enclosure systems (July 2008 ASHRAE Journal).

• $9 BILLION ANNUALLY in North America repairing & litigating damages from moisture intrusion (ASTM)
BECx Reference Guidelines & Standards

WK26027 - New Practice for Enclosure Commissioning

337 Pages!

“not a one-size-fits-all ‘how to’ document on avoiding leaky envelopes”
Primary Enclosure Components Targeted in a BECx Program

- **Moisture Barrier** – Ability to control exterior moisture sources.
- **Air Barrier** – Ability to control air leakage via infiltration or exfiltration.
- **Vapor Barrier** – Ability to control interior moisture loads and vapor drive.
- **Thermal Barrier** – Ability to control thermal envelope performance.
The BECx Pie

- Pre-Design
- Design
- Pre-Construction
- Construction
- Performance Testing
- Occupancy
- Pre-Design
- Construction
- Performance Testing
- Occupancy

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Functional Performance Testing

• Fenestration Testing
  – ASTM E1105 / E783 Water and Air Testing
  – AAMA 501.2 Water Leakage Testing
• Air Barrier Testing
  – ASTM E779 Whole Building Air Leakage (Quantitative)
  – ASTM E1186 Air Leakage Site Detection (Qualitative)
• Thermal Barrier Testing
  – ASTM C1060 or C1153 Infrared Thermography
• Other
  – Roof Uplift (FM Global 1-52)
  – ASTM D5957 Flood Testing
  – ASTM D4541 Adhesion Testing
Fenestration / Moisture Barrier Testing

• ASTM E1105: Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls and Doors by Uniform or Cyclic Static Air Pressure Difference
Fenestration / Moisture Barrier Testing

- AAMA 501.2 Testing: Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Slope Glazing Systems
- Implement field testing regimen throughout construction process (example: 25%, 50%, 75% and 100%)
Field Assembly Air Tightness Testing

- ASTM E783: Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
Field Thermal Performance Testing

- ASTM C1060: Standard Practice for Thermographic Inspection of Insulation Installation in Envelope Cavities of Frame Buildings
Other Specialty Envelope Testing
Whole Building Air Tightness Testing

- ASTM E779: Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
Air Tightness Testing Diagnostics

Cost / Budget for BECx

• NIBS GL3: “Level of effort influenced by such factors as owner’s preferred level of building quality, level of risk the owner will accept, building size/type/complexity. Thus it is difficult to develop general estimates…”

• “Guidance”: 0.3% to 1% of Construction
Fort Carson, CO Dining Facility

- 26,000 SF - LEED Gold
- Scope
  - SD and DD Development/Charettes
  - Hygrothermal analysis of roof
  - Technical review of BE systems in CDs
  - Mock-up & in-situ curtain wall/storefront air and water testing
  - Fenestration installation sequencing consultation
  - On-site quality assurance observations and reporting
  - Whole building air barrier testing
- Construction Cost: $14,300,000
- BECx Fee: $61,750 (0.43%)
Solera Apartments in Denver, CO

- 12-Story mixed-use
- LEED Gold

Scope
- Design Development Consultation
- Technical review of BE systems in CDs
- Pre-construction training
- Mock-up air leakage and water penetration testing
- On-site quality assurance observations and reporting

- Construction Cost: $22,000,000
- BECx Fee: $85,500 (0.38%)
Fort Hood, TX Replacement Hospital

- 947,000 SF Medical Center
- LEED Silver (targeted)
- Scope
  - Review of hygrothermal analysis
  - Technical review of BE systems and meetings in SD, DD And CD’s (20, 35, 65 & 100%)
  - Submittals/shop drawings review
  - Pre-Construction Conferences
  - Mock-up & in-situ air leakage and water penetration testing
  - Construction checklists & training seminar
  - On-site quality assurance observations and reporting
  - Whole-building air barrier testing
- Construction Cost: $534,000,000
- BECx Fee: $386,900 (0.07%)
Why Air Barriers?

• Energy conservation
  – Reduce heating and cooling loads
  – EPACT 2005 / EISA 2007
    • 30% reduction over ASHRAE 90.1-2004 by 2012
    • Net zero by 2030 (Executive Order 13514)

• Mechanical System Sizing/Operation
  – Designing / Modeling Infiltration Loads

• Moisture and mold control
  – Water vapor transport via air movement
  – Very costly to remediate
  – Politically volatile

• Pollutant transport (IAQ)
  – Example: TEMF facilities - Fumes

• Microclimate Conditioning
Historic Performance of Commercial Buildings

- Air leakage reported in cfm/ft$^2_{envelope}$
- 1998 and 2005 NIST Studies show commercial buildings are very leaky
  - Average of multiple studies of commercial buildings between 0.7 to 2.5 cfm/ft$^2$
- ASHRAE Fundamentals Ratings:
  - “Tight”: 0.1
  - “Average”: 0.3
  - “Leaky”: 0.5
Existing Army Barracks Constructed without Air Tightness Requirement – Test Results

Ft Meyer UEPH tested Feb06

- Tested by ERDC/CERL
- Measured leakage rate was 0.57 CFM/sqft envelope area @ 75 Pa

Ft Bragg UEPH tested May 06

- Tested by ERDC/CERL
- Measured leakage rate un-renovated was 0.56 CFM/sqft envelope area @ 75 Pa
- Measured leakage rate for renovated was 0.77 CFM/sqft
Un-Renovated VOLAR at Ft Polk – Sep06

Individual soldier rooms measured average tightness: 0.75 cfm/ft²
How About a New LEED® Platinum Building
**LEED® Platinum Test Results**

<table>
<thead>
<tr>
<th>Description</th>
<th>Air Leakage (cfm/ft² at 75-Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurization (Whole Building)</td>
<td>0.64</td>
</tr>
<tr>
<td>Depressurization (Whole Building)</td>
<td>0.57</td>
</tr>
<tr>
<td>Average</td>
<td>0.61</td>
</tr>
<tr>
<td>Pressurization (Excluding Carpentry and Workshop)</td>
<td>0.64</td>
</tr>
<tr>
<td>Depressurization (Excluding Carpentry and Workshop)</td>
<td>0.57</td>
</tr>
<tr>
<td>Average</td>
<td>0.61</td>
</tr>
</tbody>
</table>

1. Soffit conditions, where the metal panel soffit meets the metal wall panels
2. Soffit conditions, where the metal panel soffit meets the storefront entrance assemblies
3. Eave conditions
4. Top of the foundation
5. Rake wall conditions
6. South elevation sunshade vertical penetrations through the metal panel soffit
7. Transition between storefront assemblies and stone veneer
8. Interior corner transition between storefront assembly and a metal wall panel
9. Interior corner transition between stone veneer and storefront assembly
10. Overhead doors
11. Exterior doors
12. Interior corner of the stone veneer, beneath a south elevation stone windowsill
13. Lighting fixture, fire alarm strobe and exterior duplex outlet penetrations
Percent Annual Energy Savings due to improved building air tightness (Modeling results from Annex 46)

<table>
<thead>
<tr>
<th>Source</th>
<th>Leakage Rate at 0.3 in w.g. (75 Pa) cfm/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.0</td>
</tr>
<tr>
<td>ASHRAE Std 189.1 requirement for air sealing</td>
<td>0.40</td>
</tr>
<tr>
<td>Current Army requirement for air sealing</td>
<td>0.25</td>
</tr>
<tr>
<td>Proposed requirement for air sealing</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Example of Just One Success Story

Envelope = 371,099 sf
Allowable Leakage = 92,775 cfm (@ 75-Pa)
BRAC Dorm Air Leakage Testing

(x4)
# BRAC – FSH METC Student Dormitory Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depressurization</strong></td>
<td>Air exhausted from building (28,788 CFM)</td>
<td>0.078 Pass</td>
</tr>
<tr>
<td><strong>Pressurization</strong></td>
<td>Air supplied to building (25,016 CFM)</td>
<td>0.067 Pass</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>26,092 CFM</td>
<td>0.073 Pass</td>
</tr>
</tbody>
</table>

Equivalent Leakage Area = 19.1 to 21.9 s.f. (371,099 s.f. envelope)
What about that Ft. Polk, LA VOLAR Barracks – 2010 Renovation Project?

USACE actually reduced 0.25 requirement to 0.30 because this was one of the 1st renovation projects with the whole building requirement
# Ft. Polk, LA
## Volar Barracks Renovation Results

### RESULTS FROM BASELINE TEST AT BLDG 1150

<table>
<thead>
<tr>
<th>BUILDING</th>
<th>REQUIREMENT (cfm/ft² at 75-Pa)</th>
<th>ACTUAL TESTED (cfm/ft² at 75-Pa)</th>
<th>% BETTER THAN REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1150</td>
<td>0.30</td>
<td>0.10</td>
<td>67%</td>
</tr>
</tbody>
</table>

### RESULTS FROM PHASE I BUILDING TESTING

<table>
<thead>
<tr>
<th>BUILDING</th>
<th>REQUIREMENT (cfm/ft² at 75-Pa)</th>
<th>ACTUAL TESTED (cfm/ft² at 75-Pa)</th>
<th>% BETTER THAN REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1150</td>
<td>0.30</td>
<td>0.09</td>
<td>70%</td>
</tr>
<tr>
<td>1154</td>
<td>0.30</td>
<td>0.13</td>
<td>57%</td>
</tr>
<tr>
<td>1156</td>
<td>0.30</td>
<td>0.10</td>
<td>67%</td>
</tr>
<tr>
<td>1346</td>
<td>0.30</td>
<td>0.13</td>
<td>57%</td>
</tr>
<tr>
<td>1348</td>
<td>0.30</td>
<td>0.15</td>
<td>50%</td>
</tr>
</tbody>
</table>
Air Barrier Material Type and Design Approaches: What Works?
Air Barrier Performance Realized with USACE M&V Requirement (160+ Buildings Tested by Pie)

0.18 CFM/SF for the 160+ buildings tested by Pie is a 28% betterment than the USACE requirement and a 55% betterment than ASHRAE 189.1-2009.
AIR LEAKAGE RATE COMPARISON

Note: LO & HI Values are for Buildings with ABT Requirement
Design and Site Consultation Effect

Design and site consultation results in an 56% overall betterment than the USACE requirement.
Separate Air Barrier Plan with Limits & Square Footage Provided by Designer
Expert Review of Air Barrier Limits and Critical Detailing
(Both for Design Build & Bid Build)
Diagnostic Results: Infrared & Smoke
Diagnostic Results: Infrared & Smoke
Failure to Plan, is a Plan to ...
Other Added Benefits of Whole Building or Area Air Tightness

- Air tightness testing and retrofit applications for reasons other than energy efficiency or condensation development control. What about airborne contaminant levels, pollutants (IAQ), clean rooms, smoke zones, infectious control, micro climates, sound, etc.?
Existing Building Retro-Commissioning
Poudre School District 2011 Testing
## PSD Tabulated ABT Results

<table>
<thead>
<tr>
<th>School</th>
<th>Building Envelope (ft²)</th>
<th>Floor Gross SF</th>
<th>Q₇₅/SF_BldgEnv (cfm/ft²)</th>
<th>Q₇₅ (cfm/ft²)</th>
<th>EqLA (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boltz MS</td>
<td>259,893</td>
<td>109,504</td>
<td>0.20</td>
<td>51,979</td>
<td>39.6</td>
</tr>
<tr>
<td>Webber MS</td>
<td>286,490</td>
<td>120,238</td>
<td>0.32</td>
<td>91,677</td>
<td>69.9</td>
</tr>
<tr>
<td>Shepardson ES</td>
<td>121,187</td>
<td>49,856</td>
<td>0.27</td>
<td>32,720</td>
<td>24.9</td>
</tr>
<tr>
<td>Taveli ES</td>
<td>147,081</td>
<td>62,754</td>
<td>0.33</td>
<td>48,537</td>
<td>37.0</td>
</tr>
<tr>
<td>Rocky Mountain HS</td>
<td>654,871</td>
<td>291,310</td>
<td>0.18</td>
<td>117,877</td>
<td>89.8</td>
</tr>
<tr>
<td>Poudre HS</td>
<td>549,234</td>
<td>228,743</td>
<td>0.21</td>
<td>112,593</td>
<td>85.8</td>
</tr>
<tr>
<td>Johnson ES</td>
<td>135,782</td>
<td>55,496</td>
<td>0.29</td>
<td>39,377</td>
<td>30.0</td>
</tr>
<tr>
<td>Eyestone ES</td>
<td>136,992</td>
<td>64,992</td>
<td>0.17</td>
<td>23,289</td>
<td>17.7</td>
</tr>
<tr>
<td>Fort Collins HS</td>
<td>321,757</td>
<td>250,000</td>
<td>0.35</td>
<td>112,615</td>
<td>85.8</td>
</tr>
</tbody>
</table>
Low Slope Roof to Wall Interfaces
Steep Slope Roof to Wall Interfaces
Expansion Joints & Dissimilar Interfaces

AIR LEAKAGE PATHWAY

EXTERIOR

INTERIOR

AIR LEAKAGE OBSERVED

OBSERVE FOR SEALANT

EXTERIOR

INTERIOR

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Beam Pockets
Doors & Operable/Fixed Windows
Soffits & Mansard Roofs
Roof Transitions/Rise Wall Expansion Joints
Clerestory Assemblies & Skylights
PSD 2011 Air Leakage Testing Results
Thermal Discontinuities
Thank You!

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