Summary and Analysis of Large Building Air Leakage Testing for the U.S. Department of Defense.

J. Lee Durston, BCRA Building Science
Matthew Heron, PE, Pie Consulting and Engineering
Why Air Barriers and Why Now?

- Energy Conservation Measure
  - First Costs/Construction
  - Operational Costs

- Building Envelope Durability
  - H - Heat Barrier
  - A - Air Barrier
  - $M_L$ - Moisture Liquid
  - $M_V$ - Moisture Vapor
Energy
Durability
Benefits of an air-tightness standard:

- Reduced building heating and cooling costs
- Reduced building enclosure moisture problems
- Improved indoor air quality
- Improved acoustical isolation
- Isolates the indoor environment
- Sustainable, durable buildings
<table>
<thead>
<tr>
<th>Country</th>
<th>Standard/Category</th>
<th>Ventilation Rate</th>
<th>Energy Efficiency</th>
<th>CFM/ft² [L/s⋅m²²] at 75Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>TS-1 Commercial Best Practice</td>
<td>5 m³/h/m² at 50 Pa</td>
<td></td>
<td>0.36/1.82</td>
</tr>
<tr>
<td>US</td>
<td>LEED</td>
<td>1.25 in² EfLA @ 4 Pa / 100 ft²</td>
<td></td>
<td>0.30/1.52</td>
</tr>
<tr>
<td>US</td>
<td>ASHRAE 90.1 Average</td>
<td></td>
<td></td>
<td>0.30/1.52</td>
</tr>
<tr>
<td><strong>US Army standard is 0.25 cfm/ ft² at 75Pa</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.25/1.27</td>
</tr>
<tr>
<td>UK</td>
<td>TS-1 Commercial Tight</td>
<td>2 m³/h/m² at 50 Pa</td>
<td></td>
<td>0.14/0.71</td>
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<tr>
<td>CAN</td>
<td>R-2000</td>
<td>1 in² EqLA @10 Pa /100 ft²</td>
<td></td>
<td>0.13/0.66</td>
</tr>
<tr>
<td>US</td>
<td>ASHRAE 90.1 Tight</td>
<td></td>
<td></td>
<td>0.10/0.51</td>
</tr>
</tbody>
</table>

For a 4 story building, 120 x 110 ft, n=0.65
Requirements for an Air Barrier System

1) It must be continuous, with all joints made tight.

2) The materials shall have an air permeability not to exceed 0.004 cfm/sf under a pressure differential of 0.3 in. of water. (Or 0.02 L/s/m² @ 75 Pa)

3) It shall be capable of withstanding positive and negative combined design, wind, fan and stack pressures on the envelope without damage or displacement, and shall transfer the load to the structure. It shall not displace adjacent materials under full load.
Requirements for an Air barrier System

4) It shall be durable or maintainable

5) The air barrier shall be joined in an airtight and flexible manner to the air barrier of adjacent systems, allowing for the relative movement of systems due to thermal and moisture variations and creep. Connections shall be made between:
   a) Foundations and walls
   b) Walls and windows or doors
   c) Different wall systems
   d) Wall and roof
   e) Walls, floor and roof across construction, control and expansion joints
   f) Walls, floor and roof and utility, pipe and penetrations
Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25 cfm/ft² at a pressure differential of 0.3” w.g. (75 Pa) in accordance with ASTM E-779 (2003) and E-1827-96 (2002).

(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1 deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997).
Assessment and Testing Protocol
Multi-Phased Holistic Approach

- Design
- Construction
- Testing

Continuous Air Barrier
What We Have Learned

CASE STUDIES
Case Study - Detroit Arsenal Bldg. 270
Detroit Arsenal Bldg. 270
# Target Air Leakage

<table>
<thead>
<tr>
<th>USACE</th>
<th>cfm/sf@75Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFP requirement</td>
<td>.25cfm/sf @75PA</td>
</tr>
<tr>
<td>Detroit Arsenal Bldg. 270</td>
<td>Envelope SF 144,622</td>
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<tr>
<td>Allowable leakage rate</td>
<td>36155.5 cfm</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th></th>
<th>Depressurize</th>
<th>Pressurize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.168</td>
<td>0.161</td>
</tr>
<tr>
<td></td>
<td>24,330 cfm/75</td>
<td>23,235 cfm/75</td>
</tr>
</tbody>
</table>

**Average** = 0.16

- Data correlation > 99%
Whole Building Test
Case Study 5-5 ADA COF JBLM, WA
Extents of Air Barrier
Extents of Air Barrier
Construction
Construction
## Target Air Leakage

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<tr>
<td><strong>RFP requirement</strong></td>
<td><strong>.25cfm/sf @75PA</strong></td>
</tr>
<tr>
<td><strong>5-5 COF Admin Office Area</strong></td>
<td><strong>Envelope SF 51,352</strong></td>
</tr>
<tr>
<td><strong>Allowable leakage rate</strong></td>
<td><strong>12,838 cfm</strong></td>
</tr>
<tr>
<td><strong>5-5 ADA COF Mezzanine Office</strong></td>
<td><strong>Envelope SF 4,887</strong></td>
</tr>
<tr>
<td><strong>Allowable leakage rate</strong></td>
<td><strong>1222 cfm</strong></td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Admin Area</th>
<th>Mezzanine Offices</th>
</tr>
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<tbody>
<tr>
<td>0.063</td>
<td>0.209</td>
</tr>
<tr>
<td>3,260 cfm/75</td>
<td>1,020 cfm/75</td>
</tr>
</tbody>
</table>
Proportion of Operational Leaks

10,000 sf of envelope area
Allowable leakage = 2,500 cfm @ 75 Pa

1,000 sf of envelope area
Allowable leakage = 250 cfm @ 75 Pa

150 cfm @ 75 Pa
Leakage Rate vs. Building Size

![Graph showing leakage rate vs. building size. The x-axis represents Building Envelope (BE) Area in square feet, ranging from 0 to 400,000. The y-axis represents Air Leakage in cfm/ft², ranging from 0.00 to 1.40. The data points are scattered across the graph, with a trend line indicating a decrease in leakage rate as the Building Envelope area increases. The graph also includes a horizontal line at an Air Leakage rate of 0.60.]
Case Study – Brigade Battalion HQ
# Project Overview

- Tilt-up Concrete Panels
- Single-Ply TPO Membrane
- 3rd Party Peer Reviews (60% and 95%)

## Review Comments

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>SHEET NO. / SPEC. SECTION</th>
<th>REVIEW COMMENTS</th>
</tr>
</thead>
</table>
| 1        | AIR BARRIER GENERAL       | BFP Section 01.10.00, Item 5.5.2. states, “Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.”
|          |                           | Pie recommends adding an additional sheet to the Architectural Drawings including both plan and section views that clearly depict the extents of the air barrier and specific materials that are intended to be the air barrier systems. This will likely include multiple wall sections and plans due to the varying geometry of the BBHQ building.
|          |                           | In addition, Pie recommends that the designer provide total envelope square footage for extent of the air barrier to be tested on this plan sheet. |

| 2        | 07 26 20                  | Air and Vapor Barrier Specification:
|          |                           | The most common wall assembly consists of pre-cast concrete panels, which in themselves qualify as an air barrier (i.e. no additional material is needed). In a few instances, traditional steel and gypsum framed walls exist which are called out to be covered by a fluid-applied air barrier.
|          |                           | Pie takes no exception to the proposed air barrier materials listed in Item 2.1 WP-3, but does take exception to the materials in WP-4 and WP-5 if used as the primary wall air barrier.
|          |                           | The current air barrier materials in WP-4 and WP-5 are vapor impermeable. Vapor impermeable air and moisture barriers are not recommended to be placed on the outside of the insulation (i.e. cold side) in a heating climate. In heating climates, the predominant vapor drive is from the interior of the building, thus a vapor barrier on the cold side of the insulation increases the risk of condensation development. It should also be noted that if in foamed wall assembly callouts, a vapor barrier is indicated behind the interior drywall already, which is inappropriate. |
Project Overview - Construction
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## Target Air Leakage

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<td>RFP requirement</td>
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<td>.25cfm/sf @75PA</td>
</tr>
<tr>
<td>BBHQ</td>
<td>Envelope SF 172,572</td>
<td>43,143 cfm</td>
</tr>
<tr>
<td>Allowable leakage rate</td>
<td></td>
<td></td>
</tr>
</tbody>
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<tbody>
<tr>
<td>0.039</td>
<td></td>
<td>0.045</td>
</tr>
<tr>
<td>6,735 cfm/75</td>
<td></td>
<td>8,006 cfm/75</td>
</tr>
</tbody>
</table>

Average = 0.04

- Data correlation > 99%
Range (standard deviation) w/ no expert consultation
TEMFs are challenging
0.25 CFM/SF & 0.15 CFM/SF
Averages, expert consultation vs. no consultation

Range (standard deviation) w/ no consultation

Concrete is an excellent air barrier

0.25 CFM/SF & 0.15 CFM/SF
Average & range, w/ no consultation

0.25 CFM/SF & 0.15 CFM/SF
Air Leakage for Different Roof/Ceiling Air Barrier Systems

- Blanket Insulation DOES NOT WORK
- 0.25 CFM/SF & 0.15 CFM/SF
- Average & range, w/ no consultation
Others W/ Commercial Air Barrier Requirements

- GSA P100 (0.4 CFM/SF@75Pa)
- ASHRAE 90.1 – 2010
  - Compliance through materials or assemblies (no testing)
  - Climate Zones 1 – 3 exempt
- IECC 2012
  - Compliance through materials, assemblies, OR testing
  - Testing Option: 0.40 CFM/SF@75Pa
- City of Fort Collins – Completely modeled from USACE program
- Seattle / Washington
Question & Answer

Matt Heron, PE
Pie Consulting & Engineering

Lee Durston, BS, CBST
BCRA Building Science