Using an Aerosol Sealant to Reduce Multifamily Envelope Leakage

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Project Team & Funding

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  • Kirk Kolehma and Megan Hoye

• UC Davis Western Cooling Efficiency Center
  • Curtis Harrington
  • Mark Modera and Jose Garcia

• The Energy Conservatory
CEE - What We Do

- Energy Program Design & Delivery
- Lending Center
- Public Policy
- Education and Outreach
- Engineering Services
- Research
Benefits:

• Reduced air infiltration energy costs
• Reduced odor transfer & improved IAQ
• Improved comfort from reduced drafts
• Reduced noise transmission (neighbors and outside)
• Improved envelope durability
• Reduced stack effect
Envelope Sealing Challenges:

- **Existing buildings.** No/difficult/costly access to distributed air leaks. 10% to 30% reduction is challenging.

- **New Construction.** Single family approaches only recently starting to carry over to multifamily buildings. How can we do this more effectively for both exterior leakage and compartmentalization?
Envelope Tightness Requirements:

  - SF and 1 to 3 story MF: **3.0 ACH50**
  - 4+ story MF: **0.4 cfm75/sf**

- 4+ story MF: typically met by either Materials (0.004 cfm75/sf) or Assemblies (0.04 cfm75/sf) prescriptive options.

- **Green Communities (MHFA).** EPA ENERGY STAR for multifamily high rise = **0.3 cfm50/sf** (4 – 8 ACH50)

- **LEED.**
  - Prerequisite. 1-3 story: **3.0 ACH50**; 4-8 story: **0.3 cfm50/sf**; 9+ story: continuous air barrier.
  - Secondhand smoke. 9+ story prerequisite & credits
Envelope Aerosol Sealing

- Pressurize apartment
- Spray air sealing fog
- Sealant particles build up on gaps as they flow through the leaks

Similar to process used for aerosol duct sealing
How does it do that?

No, really?
(animation video here)

Sealant is a synthetic acrylic – typically rolled or sprayed on for monolithic, elastomeric exterior air barrier. Diluted for aerosol application.

Sealant is low VOC: GREEN Guard Gold Certified for use in California school and health care facilities.
• **Aerosol Benefits:**
  
  • Automatically finds and seals leaks
  • Very effective at sealing small, diffuse leaks
  • Continuous update of leakage during sealing
  • Reliably meet air tightness requirements
  • Potential savings for avoided conventional air sealing (?)
Study Objectives:

Demonstrate sealing capability and evaluate commercialization

- Refine sealing technique – measure leakage and noise transmission reduction & identify sealing locations
- How to incorporate into sealing strategy – preseal “large” leaks and protect horizontal surfaces as necessary
- Time estimates
- Model energy savings and effect on ventilation

1. Sealed 18 units in 3 new construction buildings

2. Sealed 9 units in 3 existing buildings
Aerosol Sealing Process: All In One Visit

1. Walk thru to identify pre-sealing & protection requirements *(prior to sealing visit?)*
2. Pre-seal large gaps & temporary sealing as necessary
3. Site work prep – cover horizontal surfaces
4. Set up sealing equipment
5. Perform sealing
6. Remove coverings
7. Clean surfaces (if necessary)
8. Post-sealing air leakage test
9. Air leakage test when unit finished?
Site Work Prep: pre-seal wide gaps

Sprinkler head

Plumbing penetration
Site Work Prep: pre-seal wide gaps

Range electric line

Low-voltage wiring
Site Work Prep: pre-seal wide gaps

AC Line set

Duct – narrow enough to leave?
**Site Work Prep: pre-seal wide gaps**

<table>
<thead>
<tr>
<th>Construction</th>
<th>Plumbing</th>
<th>Electrical</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor wall connection</td>
<td>Showerhead penetration</td>
<td>Range plug</td>
<td>Line sets for HVAC</td>
</tr>
<tr>
<td>Sprinkler penetration</td>
<td>Sink penetrations</td>
<td>Electric baseboards</td>
<td>Vent duct penetrations</td>
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<tr>
<td></td>
<td>Waste line penetrations</td>
<td>Low voltage wiring</td>
<td>Fresh air duct penetration</td>
</tr>
<tr>
<td>Clothes washer connections</td>
<td>Additional wiring</td>
<td></td>
<td>Combustion and exhaust air</td>
</tr>
<tr>
<td></td>
<td>penetrations</td>
<td></td>
<td>penetrations</td>
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<tr>
<td>Toilet water connection</td>
<td></td>
<td>PTAC wall penetration</td>
<td></td>
</tr>
<tr>
<td>Kitchen water connection</td>
<td></td>
<td>Gas line penetrations</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(range, HVAC, laundry)</td>
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</tbody>
</table>

1 to 2 hours/unit
Site Work Prep: temporary sealing

- Exhaust fan ducts
- Combustion vents
- Exterior doors
- Plumbing penetrations
- Fill traps or cover waste line openings
- Shower handles
Site Work Prep: cover horizontal finished surfaces

Ideal: drywall mud/tape no other finishes (bare floor better)

Not ideal: ready for occupancy
Site Work Prep: cover horizontal finished surfaces
Site Work Prep: cover horizontal finished surfaces

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<th>Construction</th>
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<th>Electrical</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finished floors</td>
<td>Tub or shower surrounds and floors</td>
<td>Ceiling Fans</td>
<td>Top surface of baseboard heating</td>
</tr>
<tr>
<td>Window sills</td>
<td>Toilets, sinks, other bathroom pieces</td>
<td>Light switches</td>
<td></td>
</tr>
<tr>
<td>Window meeting rail and muntins</td>
<td>Plumbing fixtures</td>
<td>Light fixtures</td>
<td></td>
</tr>
<tr>
<td>Door tops and hardware</td>
<td>Sprinkler heads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top surface of baseboards, trims,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>molding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal surfaces of cabinets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and built-ins</td>
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</tbody>
</table>

Temporary seals & covers: 3 to 7 hours/unit
Site Work:

Set-up, Seal & Breakdown
- Blower door and nozzles
- 100Pa pressurization
- ~ 90% RH maintained
- Open windows & purge
  6 to 7 person-hours/unit

Remove Covers & Pack-up
- Care to not disturb seals
- Minimal clean-up
  1.5 to 3.5 hours
Site Work Prep: how long does it take?

14 to 22 hours: researchers still learning
Site Work Prep: reduce time

Opportunities to reduce labor time

- Pre-sealing: new construction – GC or sub completes
- Unit preparation: select time during construction when
  - Minimum horizontal surfaces to protect
  - Leaks are accessible
  - Seals will be durable
- Sealing time: new generation of more portable equipment is being developed & stop when no longer cost effective
- Breakdown/clean-up: minimize surfaces to cover and better positioning of spray nozzles
Sealed Penetrations

Plumbing Penetrations
Sealed Penetrations

Sprinkler Head

Kitchen exhaust fan
Sealed Penetrations

Electrical Boxes
Site Work Prep: black light photos

Electrical Boxes

Floor/wall Joint
Site Work Prep: black light photos

- Recessed Light
- Sprinkler Head
Leakage Reduced Over Injection Period

New construction
Floor area: 900 to 1,300sf

ACH50 pre: 2.0 – 2.9, post: 0.2 – 0.7; 71% to 94% reduction
Sealing Rate

The graph illustrates the sealing rate over time from the start of injection, with various lines representing different data sets labeled from 204 to 211. The x-axis represents time from the start of injection in hours and minutes, while the y-axis shows the sealing rate in cfm/50 min. A question mark is noted in the graph indicating a possible stop time. The data for each run is color-coded for easy differentiation.
Leakage Reduced Over Injection Period

New construction
Floor area: 350 to 420sf
Sealed 4 in one day

ACH50 pre: 7.1 – 8.4, post: 0.9 – 1.4; 82% to 89% reduction
Leakage Results: 18 New Construction Units

Average leakage: pre = 3.9 ACH50, post = 0.7 ACH50
54% to 95% below code requirement, average = 77%
Leakage Results: 9 Existing Units

Average leakage: pre = 14.6 ACH50, post = 4.8 ACH50
6 of 9 within 15% of new construction code requirement
Model

- **EnergyPlus**

  - **Ventilation model:** Airflow network
    - Calculates inter-zone flows
    - Accounts for wind and stack effects

  - **HVAC Equipment:**
    - Based on MN multifamily building stock
      - Heating provided by baseboard radiant heaters
      - Cooling provided by window air conditioners
Model – Ventilation Method

- Four ventilation strategies investigated
  - Exhaust only
  - Exhaust with some supply
  - Balanced
  - No ventilation

- Individual unit exhaust fans and balanced ventilators
Model – Leakage

Envelope leakage (total):

• Existing Building
  • Leaky: 9.5 ACH50 (existing data)
  • Sealed: 3 ACH50 (MN code)

• New Building
  • Compliant: 3 ACH50 (MN code)
  • Tight: 0.6 ACH50 (Passive House)

<table>
<thead>
<tr>
<th>ACH50</th>
<th>Exterior</th>
<th>Interior</th>
<th>Floor/Ceiling</th>
<th>Door</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5</td>
<td>43%</td>
<td>34%</td>
<td>13%</td>
<td>9%</td>
</tr>
<tr>
<td>3</td>
<td>47%</td>
<td>18%</td>
<td>5%</td>
<td>29%</td>
</tr>
<tr>
<td>0.6</td>
<td>47%</td>
<td>18%</td>
<td>5%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Table 1: Leakage distribution used in models
Results – Ventilation Flows

Annual building average fresh airflow per unit

- 9.5 ACH50
- 3 ACH50
- 0.6 ACH50

Vent Fan Flow
MN Code Req’t

0.6 ACH50 – 96 cfm50; depressurization???

0.35ach (MN code)
Results – Interior Flows

Average Flow from Adjoining Apartment (CFM)

- Exhaust Only
- Exhaust & Some Supply
- Balanced
- No Vent

- 9.5 ACH50
- 3 ACH50
- 0.6 ACH50
Results – Summary Table

- Impact of sealing air leaks in apartment buildings in Minneapolis

<table>
<thead>
<tr>
<th></th>
<th>New Buildings 80% reduction</th>
<th>Existing Buildings 68% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Savings (therms/year)</td>
<td>60 - 75</td>
<td>40 - 200</td>
</tr>
<tr>
<td>Heating Savings ($/year)</td>
<td>$33 - $44</td>
<td>$23 - $120</td>
</tr>
</tbody>
</table>

Exterior leakage reduced from 3.0 ACH50 to 0.6 ACH50

Low savings: Total leakage reduced from 9.5 ACH50 to 3 ACH50

Little or negative impact on cooling energy

New construction: balanced ventilation
Existing buildings: exhaust only typically acceptable
Air Sealing at Lower Cost?

Aerosol
• Prep
• Sealing process
• Simultaneous air leakage testing ensures results

Vs.

Manual air sealing
i.e. caulking/foaming/tapes
• Architectural specification
• Labor
• Air leakage test

=> Uncertain results
Conclusions

• Not a solution for large air leak gaps > 5/8”

• When aerosol envelope sealing can be used
  • New construction
  • Rehab
  • Change in occupancy (higher cost)

• New construction
  • 81% reduction & 77% below code
  • Reduce to below code w/o excessive QC
  • Comply with code reliably

• Existing units
  • 68% reduction & 6 of 9 comply with new code (3 ACH50)
  • Heating savings= 40 - 200 therms/yr (Minnesota)
  • 85% reduction in flows from adjacent units

• Balanced ventilation is crucial for new construction, exhaust or supply OK for existing

• Can you eliminate some “conventional” sealing? If not, too costly?
Ongoing Work

Large Building Sealing with Department of Defense
- UC Davis WCEC project with Aeroseal
- Sealing existing commercial buildings on military bases
- Lab testing of seal strength and durability

Aeroseal AeroBarrier Commercialization
- Announced at 2017 RESNET conference
- Currently has limited commercial service
- Developing partnership network in 2018
Aerosol Sealing in New Construction
THANK you!

Dave Bohac
dbohac@mncee.org
Key Issues:
• Previous Building America projects showed 60% to 95% improvements in envelope tightness.
• Sealing typically applied after drywall in place. No experience with ability to replace current sealing methods.

Approach:
• Iterative approach with multiple builders – when & what to eliminate
• Assess current sealing methods for a MN & CA builder and develop two approaches for each
• Net cost and tightness will be evaluated against standard methods
• Process repeated with second set of houses for first builders and a set of houses for additional builders.
Progress and Accomplishments

Lessons Learned (Builder Kickoff Meeting):

- Builders interested in sealing after mechanical penetrations/before insulation and drywall
- Eliminate 4 ml poly interior and use low perm paint for interior vapor retarder?
- Seal ducts from outside > in?
  - Ductwork exposed to interior
  - Plug duct boots & create opening to outside; protect furnace
- Change rim joist spray foam approach?
- Likely to need help working with code officials to approve some changes