Case Study:
Active Vapor Mitigation System Design for a Complex Industrial Building Renovation

Application of Multiple Active Depressurization Technologies (ADT) in the Renovation of a Historical Landmark Building

2nd Annual RE3 Conference
Philadelphia, Pennsylvania

January 29, 2014
Part 1: Project Background
Project Background

Building Layout

KEY

- Garage (slab on grade)
- Crawlspace (earthen)
- Basement
- Partially Excavated

Building Area = 253,000 ft²

Property = 3.94 Acres

Base Drawing by NTH
Project Background
Building Layout

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Conceptual Representation, not to scale

- Garage
- Floor 4...
- Floor 3
- Floor 2
- Floor 1

- Garage (Future Gymnasium)
- Sandy Fill 1–4 ft.

- West Basement

- Native Silt and Clay
Aerial View
Former Michigan Bell Building, Detroit, MI
Project Background
Contaminants of Concern

- **VOCs – Detected Below Building:**
  - Not all of below exceeded “generic” sub-slab residential soil gas screening levels:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Highest Soil Gas Conc. Detected (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,1-DCA</td>
<td>8,800</td>
</tr>
<tr>
<td>1,1-DCE</td>
<td>5,500</td>
</tr>
<tr>
<td>cis-1,2-DCE</td>
<td>640</td>
</tr>
<tr>
<td>TCE</td>
<td>99</td>
</tr>
<tr>
<td>Benzene</td>
<td>260</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>160</td>
</tr>
<tr>
<td>1,2,4-TMB</td>
<td>1,400</td>
</tr>
<tr>
<td>1,3,5-TMB</td>
<td>440</td>
</tr>
</tbody>
</table>

- However, not fully delineated due to access and water issues.
Criteria and Risk
Federal and State Requirements

• **More Stringent:**
  – Barriers integrated with active depressurization?
    • EPA guidance (current) suggests active often enough
    • Some State guidance recommended both
    • Required by HUD and MSHDA

• **Client Owner Risk Objectives:**
  – Future Property Use
  – Long Term Liability

• **Health:** FCM (Fetal Cardiac Malformation)
  – Short Term Exposure - TCE 2 μg/m³
    • NHDES recommends relocation even with a short term exposure risk
- Bell Building, Stairwell, 2009. Preservation was required by historic commission.
Challenges and Unknowns
Designing a “Presumptive Remedy”

- **Unknown VOCs Concentrations:**
  - Water/access prevented full characterization

- **Silty Clay Soils:**
  - Below basements, depressurization influence issues

- **Various Sub-Slab Features:**
  - Grade beams, voids, or variable permeability fill
  - Utility Penetrations

- **Groundwater and Surface Water Infiltration:**
  - Active Sumps/Drains
...Possible vapor intrusion points?
### Part 3: Demonstrating Vapor Control
Overcoming Building Envelope Effects

<table>
<thead>
<tr>
<th>EPA 1993 Radon Guidance</th>
<th>Target Sub-Slab Vacuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Maintain “any measurable value” (all season)</td>
<td>above 0.001 in. H₂O</td>
</tr>
<tr>
<td>• In cold weather while appliances running (heating systems)</td>
<td>0.015 in. H₂O</td>
</tr>
<tr>
<td>• In mild weather while appliances running (cooling systems)</td>
<td>0.01-0.02 in. H₂O.</td>
</tr>
<tr>
<td>• Cold weather no appliances</td>
<td>0.025 -0.035 in. H₂O</td>
</tr>
</tbody>
</table>

EPA 2008 VI Guidance: 4 to 10 Pascals (Pa) or 0.016 to 0.04 in H₂O
Sub-Slab Depressurization Considerations

Weather, Ventilation, and Architects

- **Stack Effect – What is it?**
  - Significant in tall buildings
    - Stairwells, elevator shafts, etc.
  - Air Pressure/Temperature/Humidity
  - Winter “stack effect” can result in LOWER (neg.) pressure lower levels
  - Architects control this with HVAC and entry vestibules, etc.
  - Drives potential for VI and affects design
Got Stack Effects?
I think this qualifies

Winter Stack Effect
On a cold day with heat on:

- NEGATIVE Pres.
- -0.05 to -0.06 in. H₂O
  ΔP on ground floor

Summer Stack Effect
On a hot day with air cond. on:

- POSITIVE Pres.
- +0.01 to +0.02 in. H₂O
  ΔP on ground floor
Demonstrating Effectiveness
Need Year Round Vapor Control

- **Seasonal Variations:**
  - Highest vapor conc. in winter typically (Jan-Mar) (EPA 2012)

  
  - Affected by:
    - HVAC trends / Ventilation
    - Building Envelope-Specific
    - Barometric pressure swings

  
  - Affected by source
    - Deeper source can result in greater seasonal fluctuations (EPA 2012)
    - Groundwater fluctuations

  
  Typical residential building exchange rates:
  0.18 to 1.26 Air Changes Per Hour (ACH)

  Commercial/Industrial vary widely depending on use and area:
  0.3 to 4.1 ACH

  (EPA 2011)
• Design for a cold, windy day....

**Wind Effects**
Windward Side of Building:

POSITIVE Pres.
+0.02 to +0.03 in. H₂O
Difference (typically upper floors have maximum ΔP)

**Barometric Pressure Effects**
Often Ignored as Insignificant:

Swing of +/- 1 in. Hg.
(1.2 feet H₂O !)

20-75% transmission efficiency to sub-slab/soils

**Relation to Sub-Slab:**
Often see a positive pressure below the slab during sub-slab vacuum monitoring (before SSD activation)

This is often stack effect and the potential driver for vapor intrusion

- People Walking Up Hill In a Snow Storm
Building Pressurization
Viable Technique?

• **Mechanical Ventilation**
  - Intake / Relief Blowers cause pressure differential
  - **Summer**: Zero to Positive Pressure (+0.05 to +0.10 in. H₂O)
  - **Winter**: Zero to Negative Pressure (-0.02 to -0.10 in. H₂O)
  - Building “tightness” controls ability to pressurize/depressurize

• **If Excessive ΔP:**
  - Doors hard to open, “whistling” air exiting building windows/doors
  - Impedes air flow/temp. control in high pressure areas
  - Air infiltration / exfiltration, drafts
  - Affects HVAC loads/operation costs

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Ideal Building Pressurization for the Architect:
Slight negative during winter and slight positive during summer.....
Not good for our purposes.
Architects vs. Engineers
Can’t we just get along?

PICNIC OF AN ARCHITECT

PICNIC OF AN ENGINEER
Part 4: Design Approach

• **Compartmentalized Areas:**
  – Identified Major Structural Features:
    • Crawlspace
    • Slab on Grade (varying void space below)
    • Basement (water infiltration concerns)
  – Other Special Features:
    • Partially unexcavated crawlspace (void below floor)
    • Smoke stack, elevator shafts, stairwells (contribute to stack effects)
    • Sumps, drains (floor/footer), utility penetrations, equipment
    • Basement Walls
    • Garage and loading docks

• **Requires Multiple Technologies and Verification:**
  – Unknowns (voids, grade beams, trenches)
  – Pilot and Post-Construction Verification
Selecting Technologies
Providing Performance Verification

- **Active Depressurization:**
  - Sub-slab vacuum distribution
    - Overcome stack effects, HVAC, etc.

- **Ventilation (when depressurization not suitable):**
  - Areas in contact with groundwater
  - Diffusion a concern due to potentially elevated sub-slab concentrations?

- **Demonstrate Effectiveness:**
  - SVE testing principles required for existing construction (pilot)

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**New Construction:** A 200 scfm fan is suggested as being able to create a 0.02 in H2O vacuum over a 4,000 ft² area within the crushed stone if slab leakage is not excessive (NAVFAC, 2011).

One suction point per 5,000 ft² (NAVFAC, 2011)
Part 5:
Design In Practice
Sub-Membrane Depressurization (SMD) Crawlspace and Unexcavated Areas

**Challenges:**

- Considered ventilation via air exchanges (HVAC load issues)
- Some areas not accessible (partially unexcavated areas)
- Leakage points (concrete columns)
Sub-Slab Depressurization Design
Garages / Slabs on Grade

- **Challenges:**
  - Soils vary from sand to silty clay with voids (high leakage)
  - Loading docks not accessible (SMD)
  - Leakage points (utilities, etc.)
  - Garage negative pressure per code

- **Design Parameters:**
  - Agency proposed 0.10 in H$_2$O vacuum requirement
    - Typical SVE ROI design parameter
  - Negotiated 0.075 in. H$_2$O (still higher than most guidance)
    - Verification: Add more extraction points / flow as needed to achieve vacuum distribution
Garages required ventilation for automobile exhaust
Sub-Slab Depressurization
First Floor – Before and After

Ground Level Showing Piping
Slab on Slab Ventilation Design

Basements

• **Challenges:**
  - Soils silty clay
  - Perched water in contact with basement / sumps
  - Sub-Slab Depressurization not viable

• **Design Parameters:**
  - Ventilation design
  - Air inlet points
  - Membrane, venting layer, and new slab
  - Integrated drains

Drawings by NTH
Cupolex and Polyurea Technologies

**Venting Layer:**
- Original design was for gravel venting layer
- Cupolex was coming into market
  - Provides open venting layer

**Membrane:**
- Polyurea Coating
  - More flexible and durable than epoxy
  - Developed for marine applications (deep sea oil platforms, tunnel coatings, secondary containment, etc.)
  - Primer coat (urethane) and thick polyurea coatings (80 mil)
  - Low permeation rates (comparable to other liquid-applied membranes)
  - Spray over geotextile backing
• **Maintained Functioning Drains:**
  - Equipment Leaks / Pipe Breaks above
  - Perched Water below
Summary
Former Michigan Bell Building, Detroit, MI

• **Renovation:**
  – Funding received
  – Building renovated between 2011-2013
  – Residents moving in as of 2012

• **Design:**
  – Presumptive Remedy Approach – must work under all conditions
  – Guidance available, but historical buildings often too complex
  – SVE Design Concepts
Thank You! Questions?

Let your fingers do the walking….contact us!

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