Vibrations of Raised Access Floors

Hal Amick, Michael Gendreau and Colin G. Gordon

Colin Gordon & Associates

Presented at the First Pan-American/Iberian Meeting on Acoustics; 144th Meeting of the Acoustical Society of America, 2-6 December 2002, Cancun, Mexico
What is Raised Access Flooring?

- Raised Access Flooring (RAF) is a flooring system used in laboratories, cleanrooms, computer rooms, and offices.
- Walking surface consists of 24” x 24” (600mm x 600mm) metal tiles.
- Various surfaces available, may be perforated
- Tiles are supported on network of pedestals

Components of Access Flooring

Typical Pedestal and Tile

Top and Bottom of Solid Tile

Perforated Tile

Grating

Why is Access Flooring Used?

• Allows for piping, ducting, and wiring to run beneath the floor. Reduces clutter.
• Allows through-the-floor air flow and provides underfloor plenum path for return
• Modular
• Removable, easily reconfigured

Vibration Characteristics of RAF

- Generally a more severe vibration environment
- Chief concern is vibration from people walking
- Vertical – Generally governed by vertical performance of floor beneath it; doesn’t propagate far
- Horizontal – Governed by horizontal dynamic characteristics of floor system; can be severe; can propagate a great distance

Nature of Study

• Combines the results of many studies over a dozen years, involving laboratory and in-situ experiments, as well as finite element modeling
• Both swept-sine and walker excitation
• Three papers in preparation
  – Basic properties and response to sinusoidal loading
  – Response to impulsive loading, including walkers
  – Methods to improve performance
• This presentation focuses on the first, with a little discussion of response to walkers

Test Configurations
(for this presentation)

• Laboratory
  – 10’ x 10’ (~ 3m x 3m) stand-alone floor
  – Several bracing configurations
  – Swept sinusoidal and walker excitation

• In-situ
  – Large extent of floor in cleanroom under construction
  – Swept sinusoidal excitation

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Society of America, 2-6 December 2002, Cancun, Mexico
Laboratory Test Floor – 10’ x 10’
Vertical Mobility

Pedestal Mobility

Tile Mobility

Horizontal Bracing Schemes

Seismic Brace  
Eccentric Load Path

“Dynamic” Bracing  
In-Line Load Path

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System Horizontal Mobility

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# Basic Properties of Test Floor

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Resonance Frequency (Hz)</th>
<th>Damping Ratio (%)</th>
<th>Total Stiffness (x10^6 N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Floor</td>
<td>12.3</td>
<td>23</td>
<td>1.0</td>
</tr>
<tr>
<td>Corner Bolting Only</td>
<td>22.8</td>
<td>4</td>
<td>6.4</td>
</tr>
<tr>
<td>Bolted &amp; Braced</td>
<td>47.8</td>
<td>8</td>
<td>11.5 – 26.3</td>
</tr>
</tbody>
</table>

Horizontal Response to Walker

Unbolted and Unbraced
(Seismic Bracing Only)

Bolted and Unbraced
(Seismic Bracing Only)

Bolted and Braced
(Dynamic Bracing)

## Horizontal Response to Walker

<table>
<thead>
<tr>
<th>Configuration</th>
<th>$f_{max}$, Hz</th>
<th>Peak-Hold, $\mu$m/s</th>
<th>Linear Avg., $\mu$m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>@ 2 Hz</td>
<td>@ $f_{max}$</td>
</tr>
<tr>
<td>Basic Floor</td>
<td>16.5</td>
<td>112</td>
<td>199</td>
</tr>
<tr>
<td>Corner Bolting Only</td>
<td>22.5</td>
<td>112</td>
<td>705</td>
</tr>
<tr>
<td>Bolted and Braced</td>
<td>54</td>
<td>22</td>
<td>79</td>
</tr>
</tbody>
</table>

In-situ Floor

- Floor components similar to those of lab test floor, same height
- Large, “ballroom style” cleanroom
- No walls, equipment, etc.
- Exciter placed near center of open area
- Examined drive point properties, propagation away from exciter
- Studied coupled motion perpendicular to force

Drive Point Response

## Basic Properties

### All Floors in Study

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<th>Configuration</th>
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<th>Total Stiffness (x10^6 N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-situ</td>
<td>Basic Floor</td>
<td>35.5</td>
<td>12</td>
<td>18.0</td>
</tr>
<tr>
<td>5x5</td>
<td>Basic Floor</td>
<td>12.3</td>
<td>23</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Corner Bolting Only</td>
<td>22.8</td>
<td>4</td>
<td>6.4</td>
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</tbody>
</table>


Propagation
(\textit{along line perpendicular to force -- Path A})

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Propagation

(along line of force – Path B)

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Effect of Floor’s Extent

- Resonance frequency increases w.r.t. plain floor
- Damping increases
- Gradient improves
- Stiffness increases
  - More tiles activate more pedestals
  - Edge effect?
  - “Tighter”?  

A Few Thoughts on Remediation

• Generally involves stiffening
• Stiffening is more effective with bolting
• Stiffening schemes …
  – Stiffeners beneath walker paths
  – Stiffeners beneath equipment
  – Creation of “islands” using isolation breaks

Conclusions

• Access floors are …
  • highly nonlinear
  • softer in horizontal direction

• Bracing, corner bolting and extent affect …
  • Damping and stiffness
  • Amplitude
  • Propagation

• Local stiffening reduces amplitude

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