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

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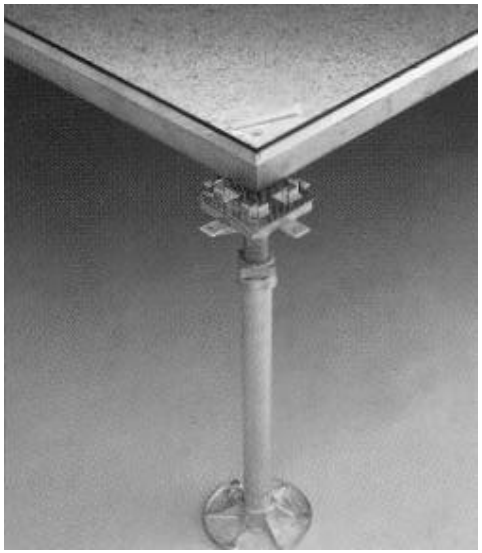
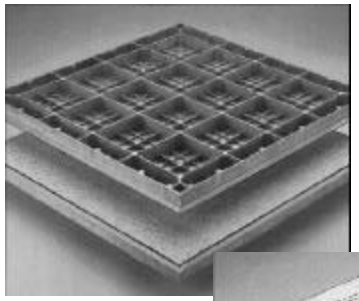
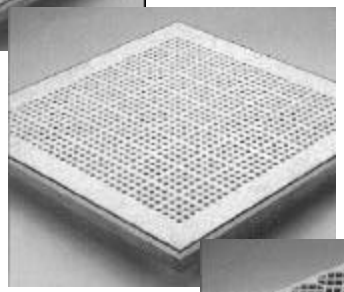
Components of Access Flooring



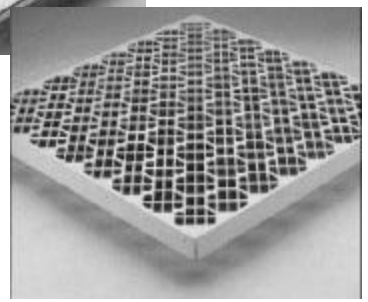
Typical Pedestal and Tile



Top and Bottom of Solid Tile



Perforated Tile



Grating

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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

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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

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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

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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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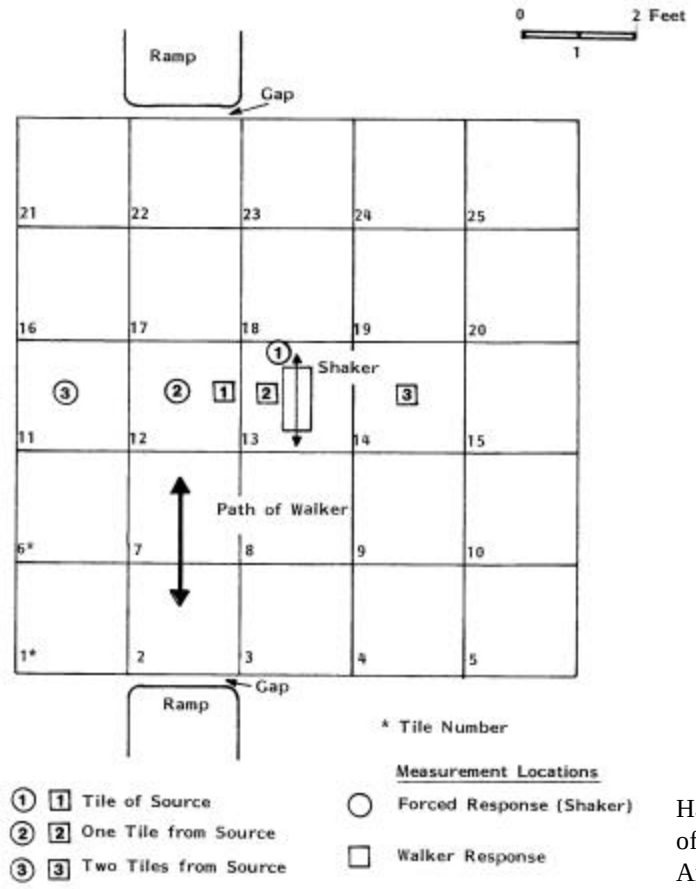
Laboratory Test Floor – 10’ x 10’



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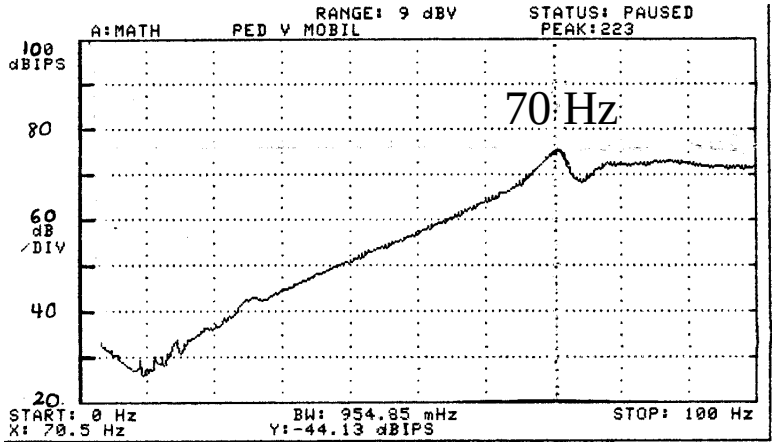
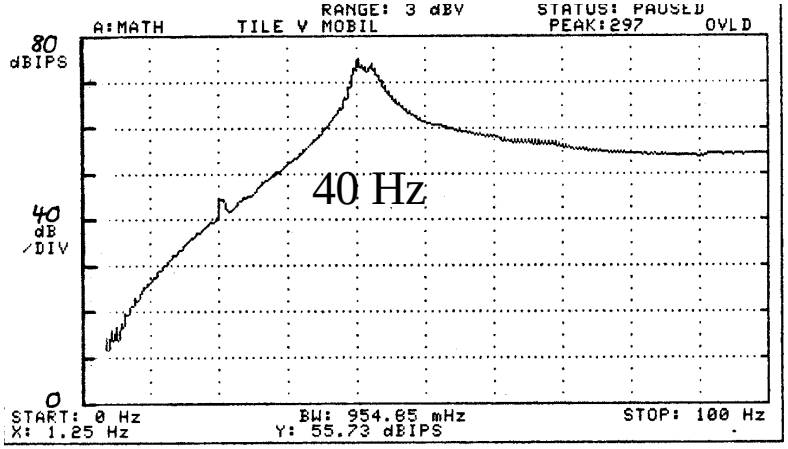
Vertical Mobility



Pedestal Mobility

Tile Mobility



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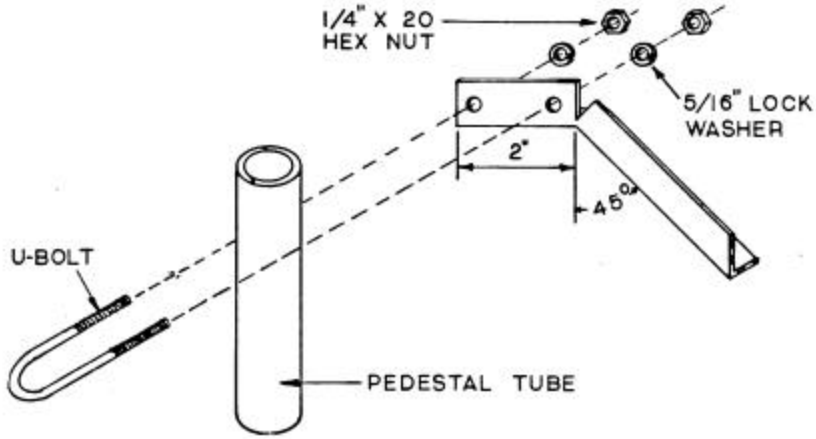
Horizontal Bracing Schemes

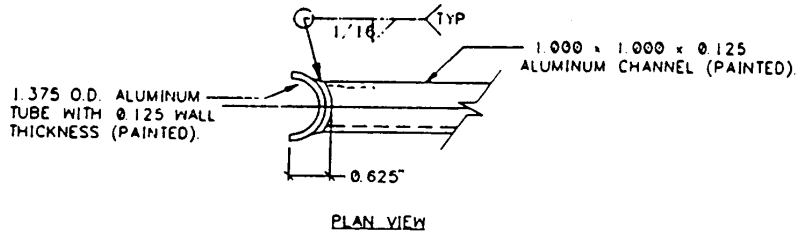


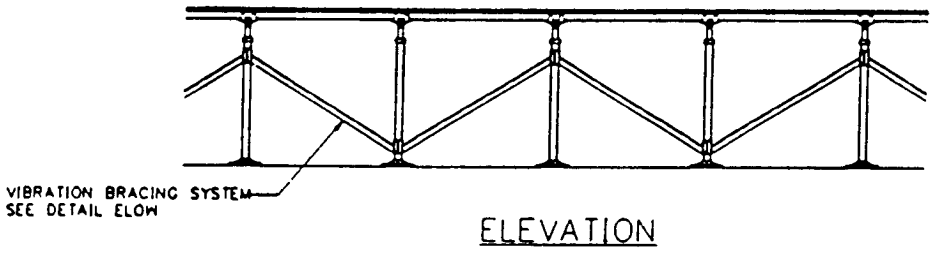
Seismic Brace

Eccentric Load Path

"Dynamic" Bracing

In-Line Load Path





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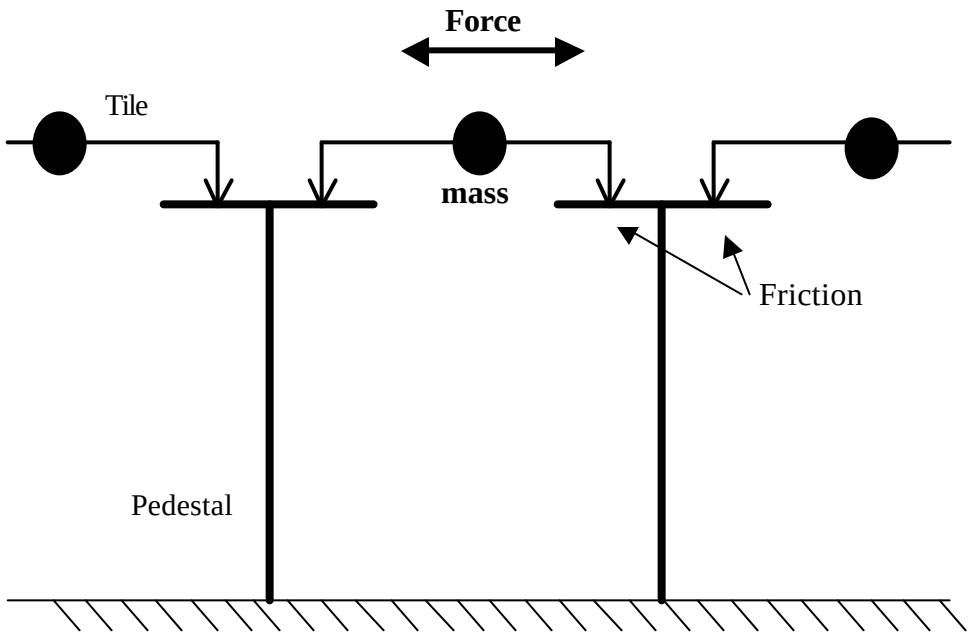
Idealized Horizontal Model



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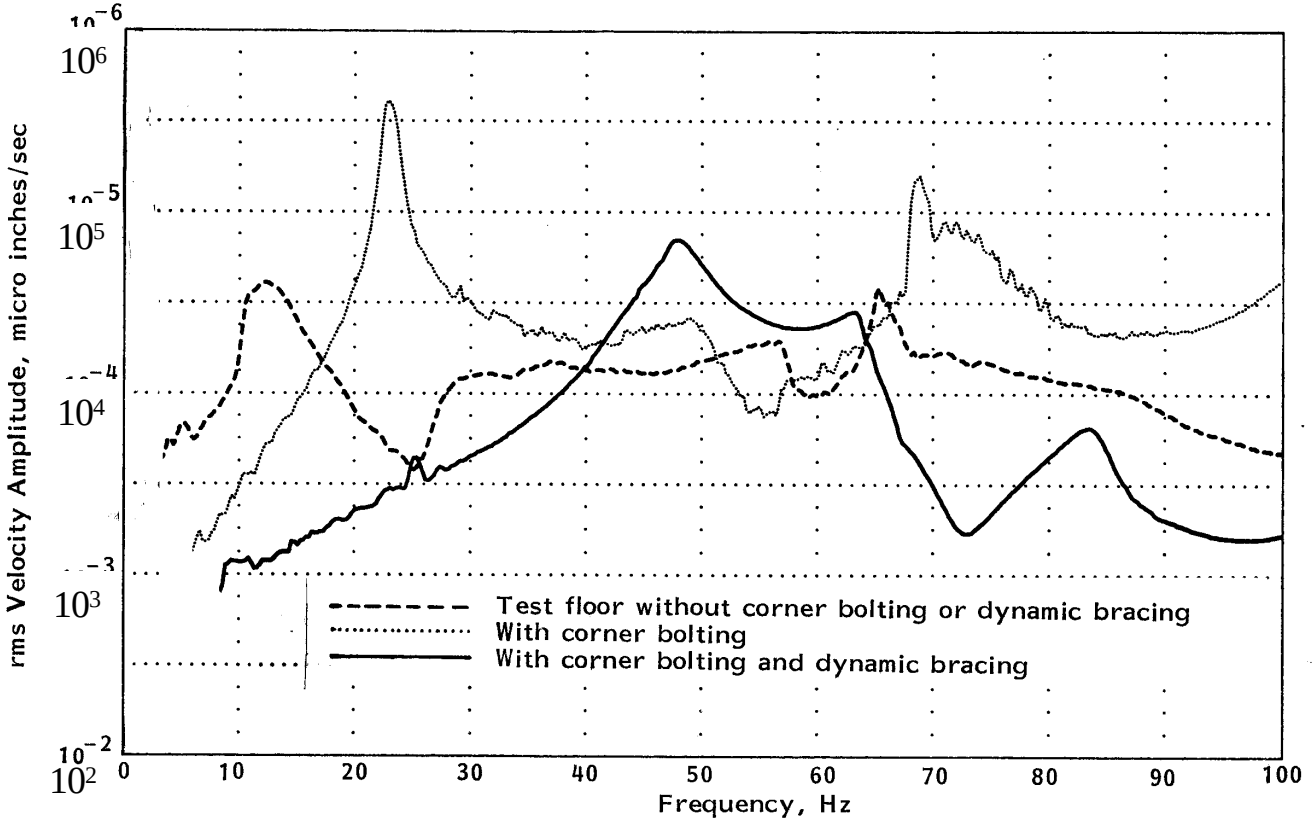
System Horizontal Mobility



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Basic Properties of Test Floor

Configuration	Resonance Frequency (Hz)	Damping Ratio (%)	Total Stiffness ($x10^6$ N/m)
Basic Floor	12.3	23	1.0
Corner Bolting Only	22.8	4	6.4
Bolted & Braced	47.8	8	11.5 – 26.3

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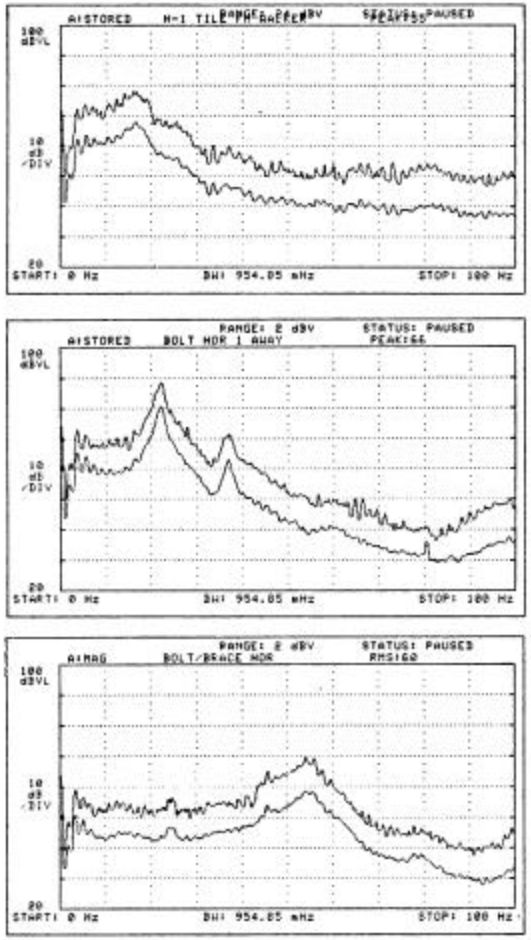
Horizontal Response to Walker



Unbolted and Unbraced

(Seismic Bracing Only)

Bolted and Unbraced

(Seismic Bracing Only)

Bolted and Braced

(Dynamic Bracing)

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Horizontal Response to Walker

Configuration	f_{max}, Hz	Peak-Hold, μm/s		Linear Avg., μm/s	
		@ 2 Hz	@ f_{max}	@ 2 Hz	@ f_{max}
Basic Floor	16.5	112	199	63	63
Corner Bolting Only	22.5	112	705	44	250
Bolted and Braced	54	22	79	9	20

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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

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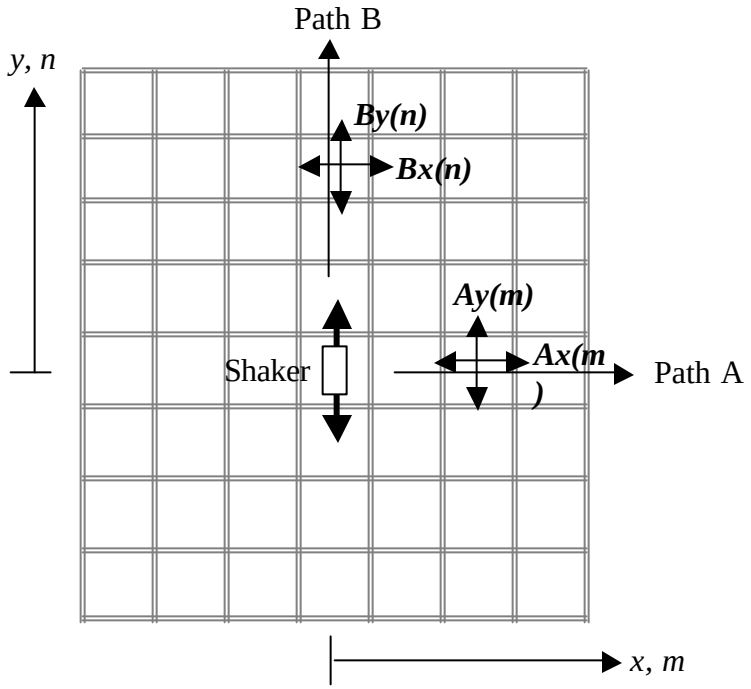
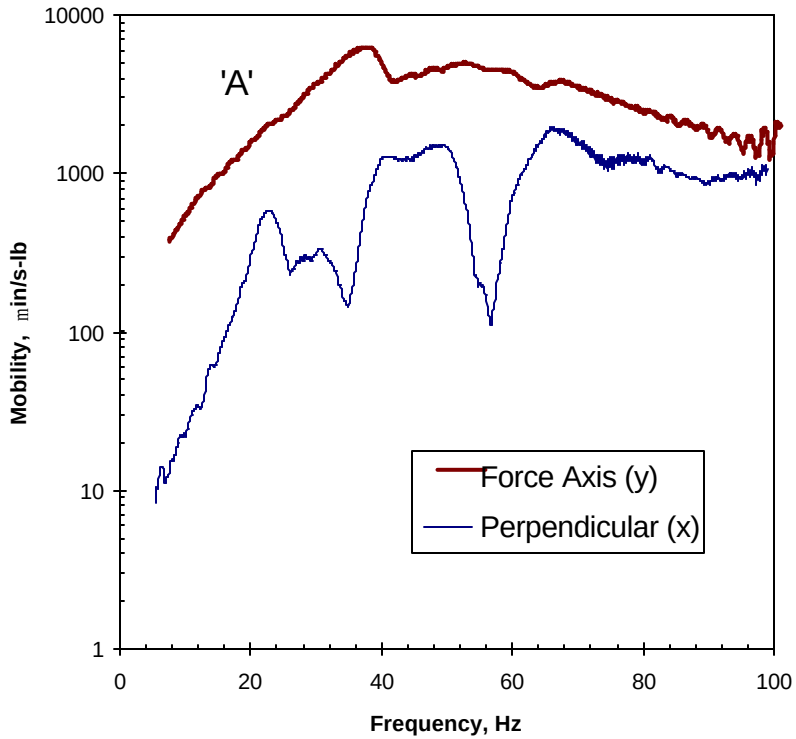
Drive Point Response





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Basic Properties
All Floors in Study

Floor	Configuration	Resonance Frequency (Hz)	Damping Ratio (%)	Total Stiffness ($x10^6$ N/m)
In-situ	Basic Floor	35.5	12	18.0
5x5	Basic Floor	12.3	23	1.0
	Corner Bolting Only	22.8	4	6.4
	Bolted & Braced	47.8	8	11.5 – 26.3

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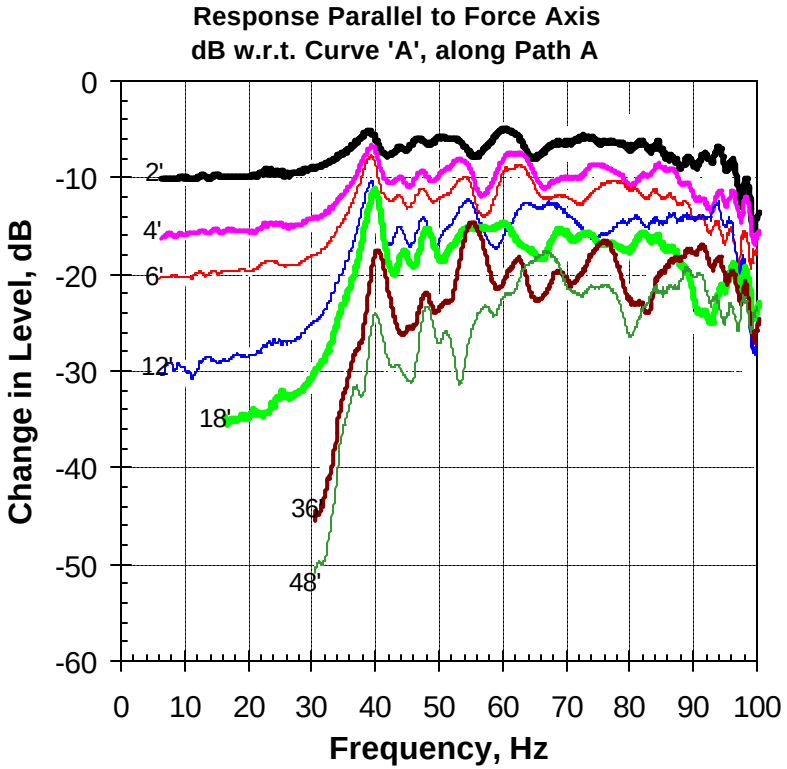
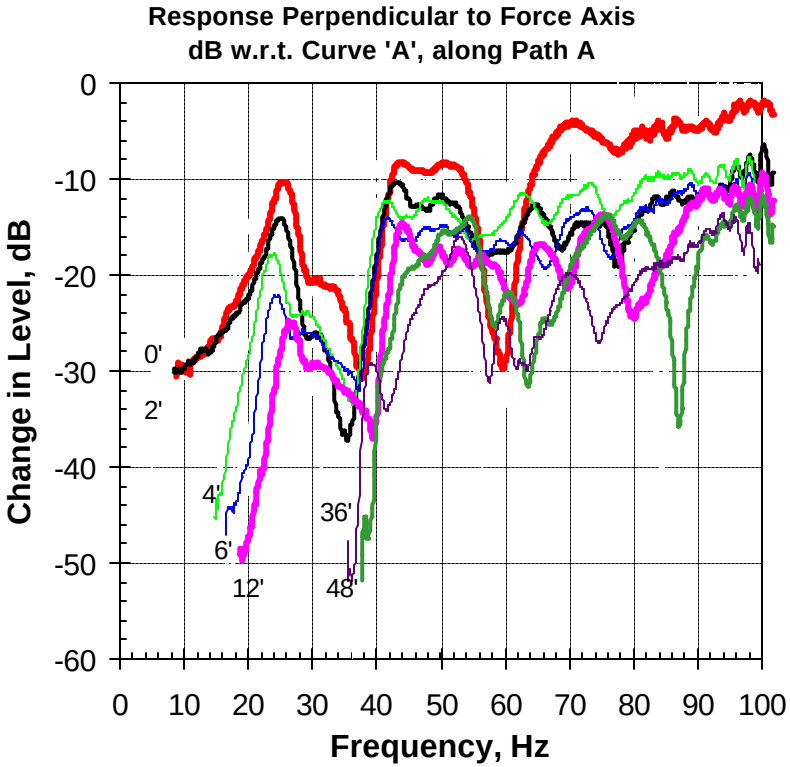
Propagation

(along line perpendicular to force – Path A)





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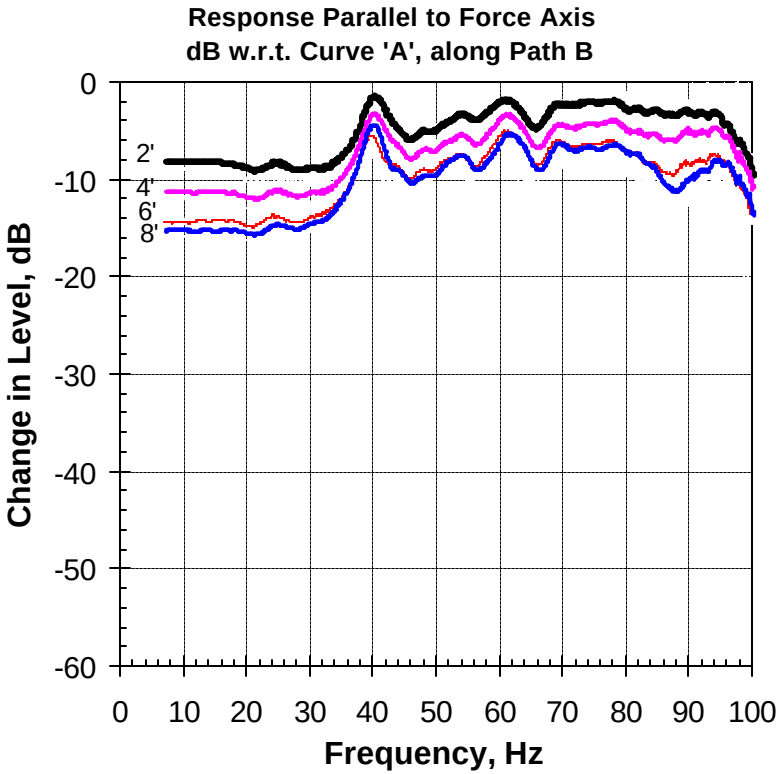
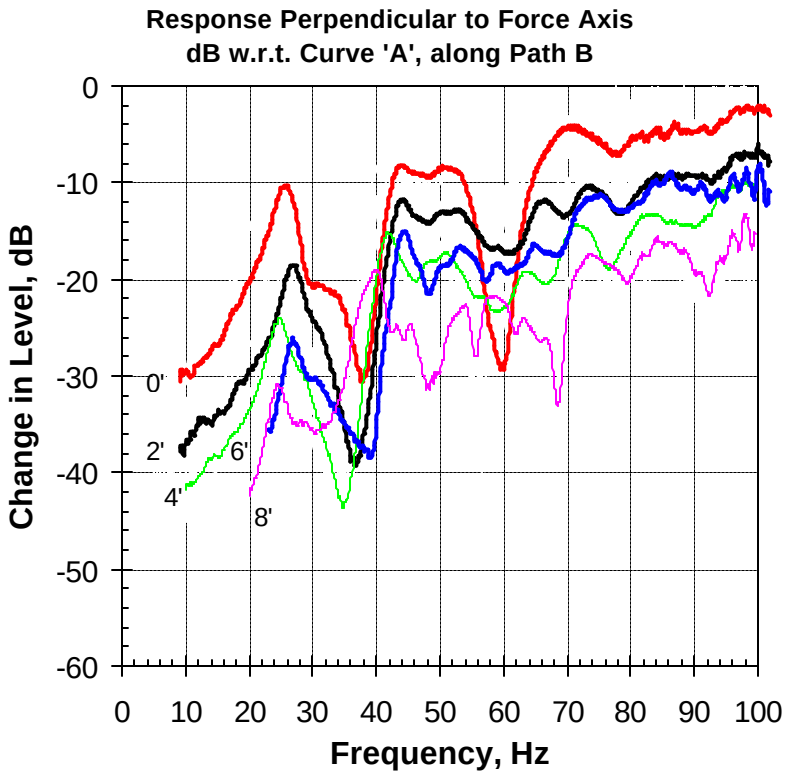
Propagation

(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"?

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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

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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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