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Design Guide 30: Sound Isolation and Noise Control in Steel Buildings

November 13, 2018

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Course Description

Design Guide 30: Sound Isolation and Noise Control in Steel Buildings
November 13, 2018

Many have the perception that acoustics qualities of steel structures are not as robust as those of other major building materials. This presentation will shed light on the superior acoustical qualities of steel structures that can be achieved, as described in AISC Design Guide 30. Practical design applications will be incorporated including discussions on floor/ceiling and wall assemblies. Both engineers and architects will find this presentation immediately applicable to their projects.

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Learning Objectives

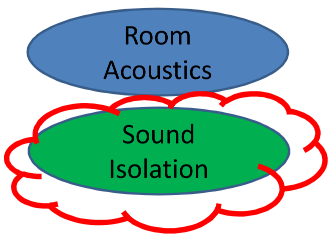
- Select acoustical design criteria through observation of source sound levels, noise sensitivities, and adjacencies.
- Describe building code sound isolation requirements, industry guidelines and design standards that apply to practical acoustical design in steel buildings.
- Identify and prioritize paths of sound transmission.
- Explain how sound-isolating constructions in steel-framed structures achieve applicable performance criteria.

Design Guide 30: Sound Isolation and Noise Control in Steel Buildings

Benjamin Markham
Director, Architectural Acoustics
Acentech
Cambridge, MA

Introduction

- Introduction to Sound / Acoustics
- Architectural Acoustics is four things:



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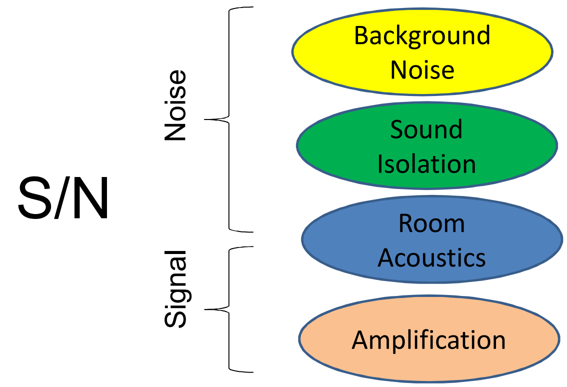
Introduction



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A Road Map to Good Sound Isolation Design

1. How Sensitive is your Room?
2. How Loud is the Source?
3. Codes, Standards, and Derived Criteria
4. Identify the Paths
5. Design Sound-Isolating Constructions

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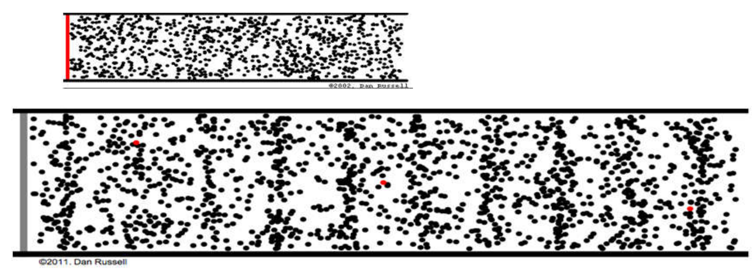
Introduction to Sound

Sound is **vibration** through an **elastic medium.**



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A Few Properties of Sound

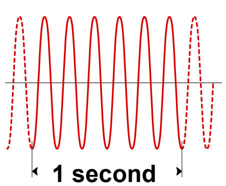
- Amplitude
- Frequency
- Propagation
- Speed
- Diffraction and other wave-behavior

Amplitude

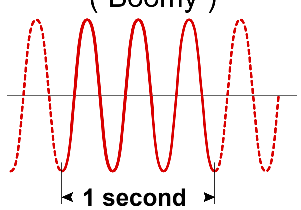
- Sound pressure and sound power
- Scale is ~ 13 orders of magnitude
- Decibel (dB) is a ***log ratio***
  - Unitless
  - Manageable scale (roughly 0 to 130 dB)
  - Better matches perception (loudness)
  - “pressure level” and “power level”

Frequency

High Frequency (“Hissy”)

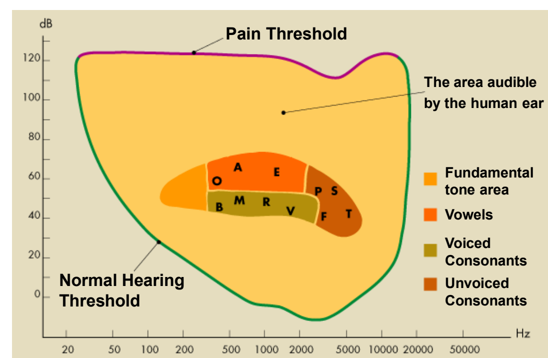


Low Frequency (“Boomy”)



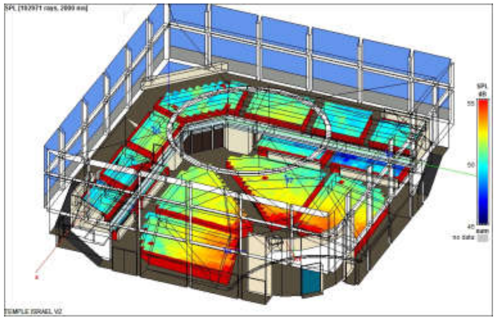
$$\text{Frequency (Hz)} = \frac{\text{cycles}}{\text{second}}$$

Normal Hearing

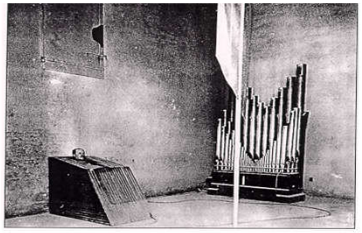


Courtesy: Ecophon

Room Acoustics



Wallace Clement Sabine Discovered a Formula for Reverberation Time



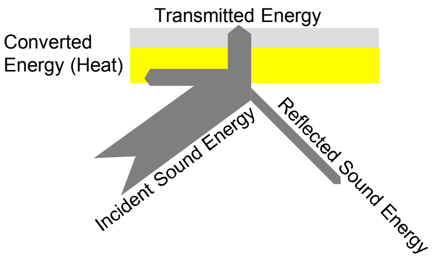
$$\text{Reverberation Time} = k * \frac{\text{Volume}}{\text{Absorption}}$$

Natatorium – 6 Second RT

- 6 second RT without treatment
- 1.7 second RT with an absorptive ceiling

What is Sound Absorption?

The ratio between energy not reflected and incident energy for a sound wave hitting a surface



Graphic, courtesy: Ecophon

Coefficient of Absorption, α

0 0.05 — 0.3 — 0.55 — 0.95 **1**

little absorbing — very absorbing

Material	Coefficient of Absorption
Brick, concrete block, glass	0.05
Carpet combined pile and foam	0.30
Heavy velour	0.55
Glass wool (fiberglass)	0.95

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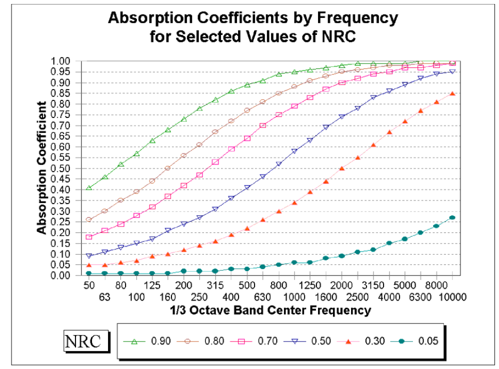
Absorption Versus Frequency



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Noise Reduction Coefficient

$$NRC = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4}$$

…rounded to the nearest 0.05.

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Sabins

$$a = \sum S_n \alpha_n$$

$$\bar{\alpha} = \frac{\sum S_n \alpha_n}{S_{total}}$$

Where:
S = surface area
α = absorption coefficient
a = absorption (sabins)

All rooms have surfaces.
All surfaces have α.
∴ All rooms have sabins.

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Alphabet Soup of Acoustics

Room Acoustics and Materials

- NRC: Noise Reduction Coefficient (of a material)
- RT: Reverberation Time
- GWB: Gypsum wallboard
- LVP: Luxury vinyl plank (flooring)

Sound Isolation and Noise Control

- NC: Noise Criteria
- dBA: A-weighted decibels
- TL: Transmission Loss
- STC: Sound Transmission Class
- NIC: Noise Isolation Class
- IIC: Impact Insulation Class
- NR: Noise Reduction

Effects of Absorption

$$RT = \frac{0.049V}{a}$$

- Time it takes an impulse to decay 60 dB
- *V* is volume in ft^3
- *a* is absorption in sabins
- Affects speech intelligibility and music
- Range: 0.2 to 6+ seconds

$$NR = 10\log\frac{a_2}{a_1}$$

- Reduction in level, for a given source, by increasing *a*
- a_1 is absorption “before”
- a_2 is absorption “after”
- Range: 0 to 5 dB (usually)

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Mechanical Systems Noise Control


Quiet Background Sound

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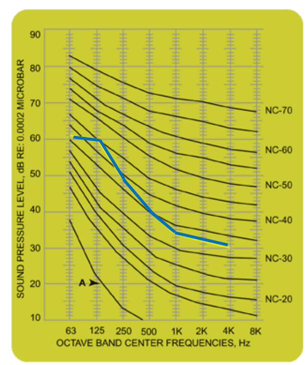
Background Noise Goals



TYPICAL PROJECT NOISE GOALS	
Pro Recording Studios:	Threshold
Concert Halls:	Threshold
Professional Theaters:	NC–15–20
High School Auditoria:	NC–20–25
High-end Board Rooms:	NC–25
Classrooms:	NC–30
Typical Offices:	NC–35–40
Lobbies:	NC–45

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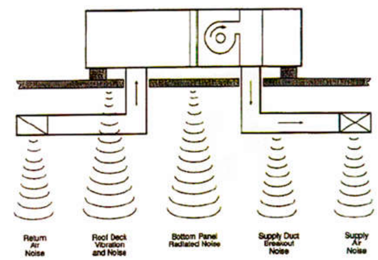
Background Sound – HVAC Systems

Noise Generators		Noise Control Solutions
High Airflow Velocities	→	Large Ducts
Fan Noise	→	Quiet Machines & Sound Attenuators
Vibrating Equipment	→	Vibration Isolation

Mechanical Systems: An Example

Equipment Location: Rooftop

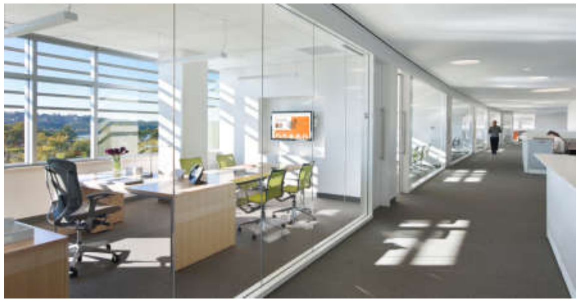


Transient Sound Level Criteria

From Design Guide 30, Table 4.2: Criteria for Transient Sounds

Room Usage	Transient to Background Noise Difference (NC points or dB)
Critical listening (music performance, sound editing, etc.) and confidential speech	-10
Teaching, learning, studying	-5 to 0
Sleeping, residential activity	-5 to 0
Office work, research	-5 to +5
Circulation, waiting, support function	+5 to +10

Privacy: S/N in Reverse



Dassault Systemes HQ: © Acentech

Source Levels (examples from Ch. 6)

Sound source	Sound Pressure Level (dBA)
Normal speech	56 dBA
Cocktail party	75 to 85 dBA
Music (*fortissimo*)	90 to 95 dBA
Diesel locomotive from 100 feet	90 dBA
Truck driving 55 mph, from 50 feet	80 dBA
Footsteps on an IIC 45 floor/ceiling	55 dBA in the room below
Chiller with rotary-screw compressor	90 dBA
Chiller with reciprocating compressor	97 to 103 dBA

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Example criteria calculation

- Aircraft flyover produces
- 80 dB at 500 Hz, at
- New academic lab building

Table 4-3. Example Calculations of Sound Isolation Requirement (500 Hz)

	Classroom	Research Lab
Steady-state criterion from Table 4-1	30 dB	45 dB
Plus transient criterion from Table 4-2	–5 dB	+5 dB
Equals criterion for intruding sound level	25 dB	50 dB
Source level	80 dB	80 dB
Minus criterion for intruding sound level	25 dB	50 dB
Equals sound isolation requirement	55 dB	30 dB

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Sound Isolation Codes and Standards (Ch 5)

Building Type	Reference
Offices	GSA *P-100* – NIC requirements
Multifamily housing	HUD: STC and IIC ICC Guideline: NNIC and NISR IBC and other codes: STC and IIC
Schools	ANSI S12.60: STC requirements
Healthcare	FGI Guidelines: STC requirements
Courts	GSA Courts Design Guide: NIC
"Green" Buildings	ASHRAE, IgCC, LEED, and others

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Sound Isolation Metrics

Airborne Sound Isolation		Impact Sound Isolation	
Laboratory	**Field**	**Laboratory**	**Field**
STC	ASTC, NIC, NNIC	IIC	AIIC, ISR, NISR

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Rating system - STC

- Transmission Loss varies with frequency
- Sound Transmission Class (STC) is a single-number rating (like NC, dBA)
  - Simple
  - Misses things (i.e. not good for low-freq music, diesel trucks, etc.)
- On a decibel scale. 0 to 80+
  - Δ of 1 = insignificant
  - Δ of 5 to 10 = significant

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Sound Isolation

- Outdoor-to-outdoor
  - Highway barriers
  - Outdoor music venues
- Outdoor-to-indoor
  - Envelope construction
    - Curtainwall design
    - Fenestration
- Indoor-to-indoor

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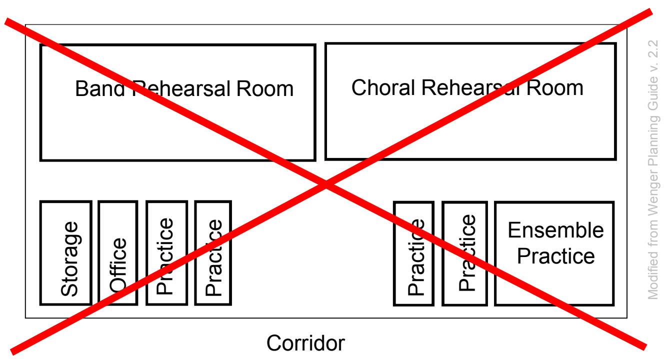
Sound Isolation: Space Planning



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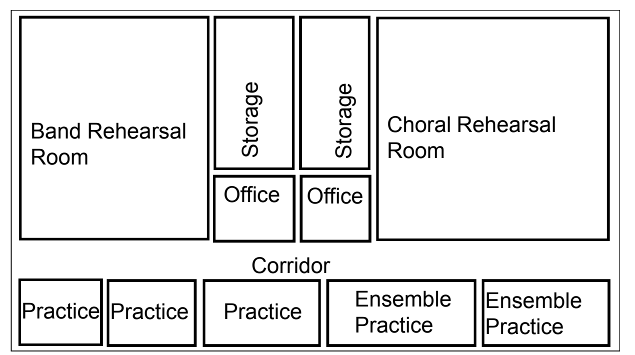
Space Planning



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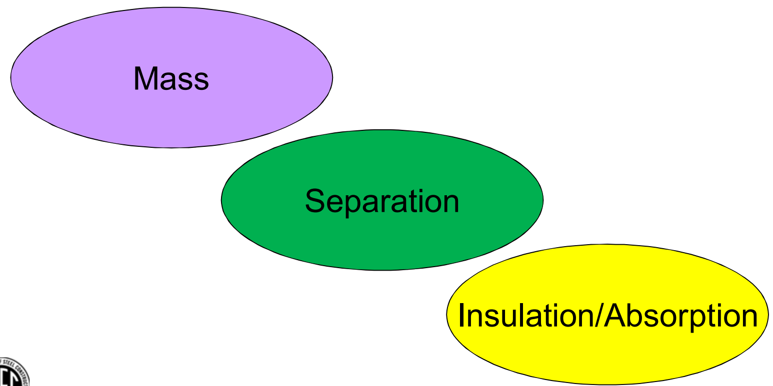
Three tools



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Mass law

- *For a given frequency:*
  - TL increases ~5 to 6 dB/doubling of mass
- *For a given mass:*
  - TL increases ~5 to 6 dB/octave
- Mass law ideal for *limp* monolithic homogeneous structures

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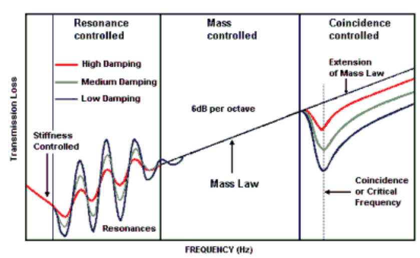
Mass law

- TL is a low-frequency problem
- Varies with:

1. Internal stiffness
2. Internal resonance
3. Angle of incidence



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Separation

- Need to beat mass law
- Stop those molecules from bumping into each other
- De-couple mass layers
- Steel Buildings: **WHERE IT'S AT**

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Absorption / Insulation

- Insulation inside the cavity
- Related to NR ($NR = 10\log\frac{a_2}{a_1}$)
- Like a very small room – fill it with fuzz
- Eliminates reverberance/resonance inside the cavity, and
- Damps the movement of the skins

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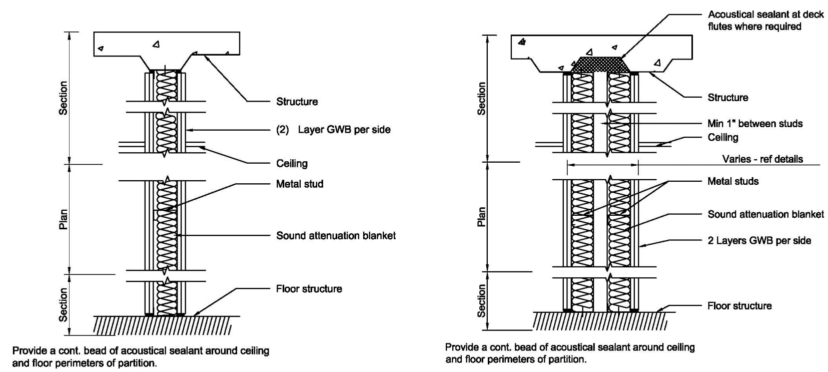
Sound Isolating Constructions



STC 52 STC 64

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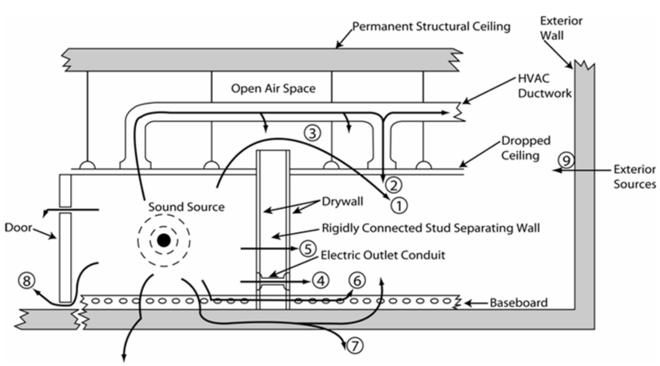
Sound Isolation – Flanking Paths



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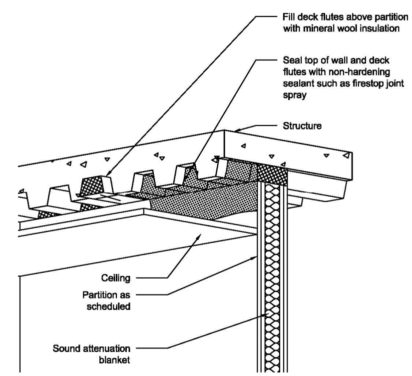
Eliminate gaps



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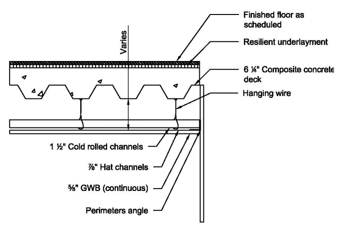
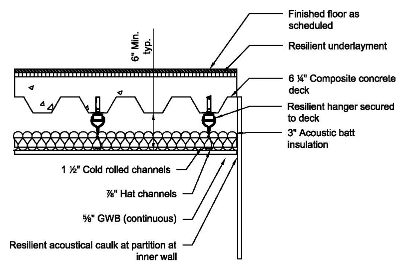
Floor/Ceiling Assemblies





STC 60
IIC 50 to 60

STC 64 to 69
IIC 60 to 65

Compare to concrete:

6" CIP Concrete Slab		8" CIP Concrete Slab	
STC 55	IIC 50 to 60	STC 58	IIC 50 to 65+

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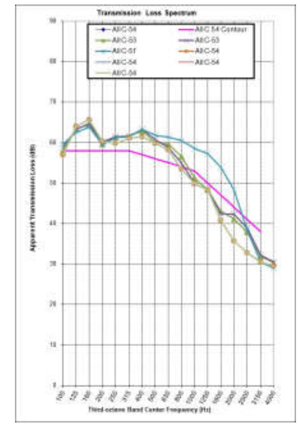
Concrete, no ceiling

- 8" P-T Slab
- No Ceiling
- LVP with integral impact sound isolation material (1mm to 2.5mm)
- N=8
- AIIC values from 51 to 54



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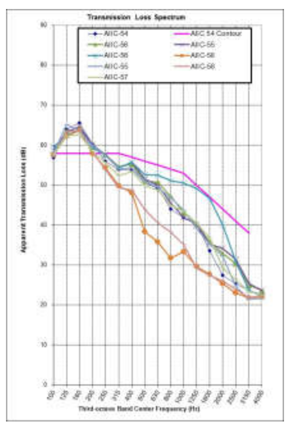
Concrete, with Ceiling; Same Floors

- 8" P-T Slab
- Wire-hung GWB ceiling, 3" batt
- LVP with integral impact sound isolation material (1mm to 2.5mm)
- N=8
- AIIC values from 54 to 57



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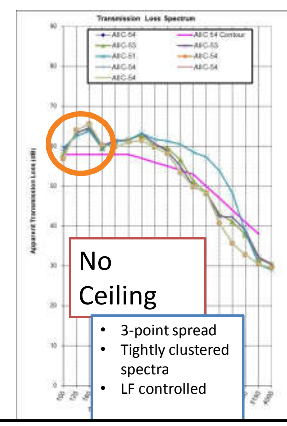
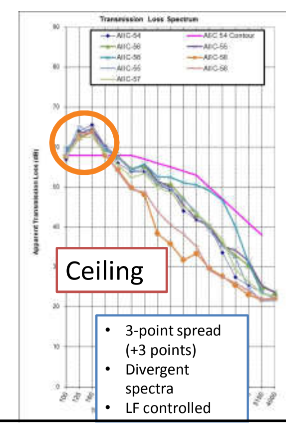
Concrete Comparison



No Ceiling

- 3-point spread
- Tightly clustered spectra
- LF controlled



Ceiling

- 3-point spread (+3 points)
- Divergent spectra
- LF controlled

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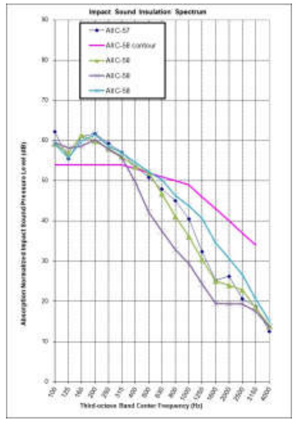
Steel



- 6-1/4" Total Slab Depth (TSD) Composite Slab
- LW Concrete on Metal Deck
- 1 layer GWB on resilient clips, batt insulation
- LVP with integral sound mat (1mm to 2.5mm)
- N=4
- AIIC-58

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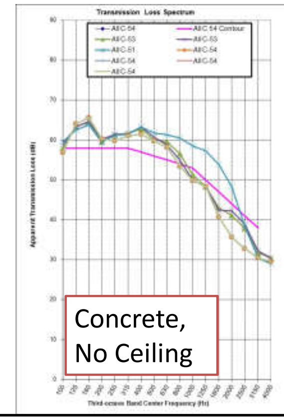
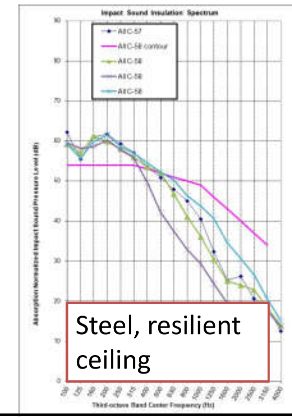
Concrete versus Steel





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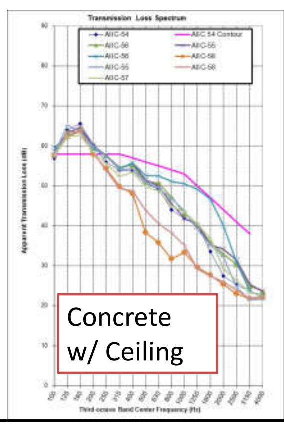
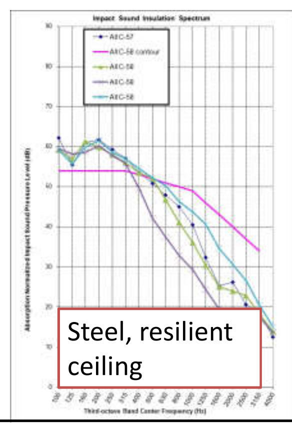
Concrete versus Steel





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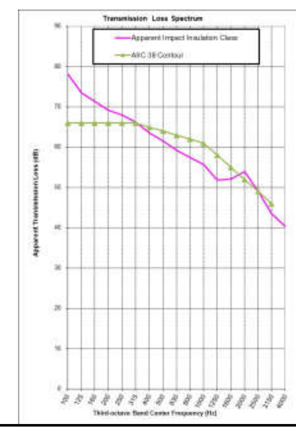
Wood – Open-Web Truss

- Wood floor nailed through fiberboard "underlayment" to subfloor
- 12" OW Truss
- 1 layer GWB on 2-legged "resilient channels", compromised
- Batt insulation
- AIIC 38
- Subject of lawsuit



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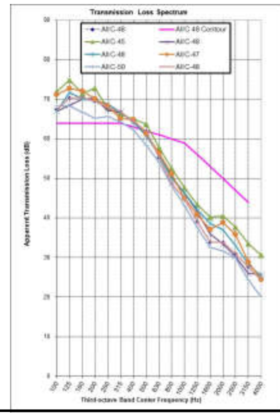
Wood – Open-Web Truss

- LVP on 1-1/2" Gypsum Concrete
- ¼" resilient mat
- 18" open-web truss
- Batt insulation
- 1 layer GWB on resilient channels
- AIIC 45 to 50 (n=9)
- (No lawsuits)



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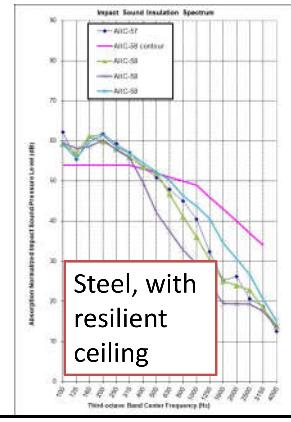
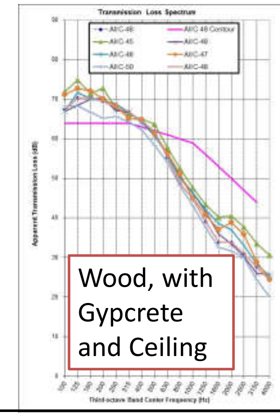
Steel vs Wood





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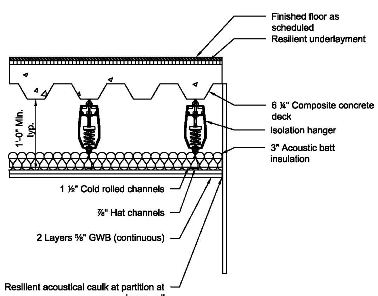
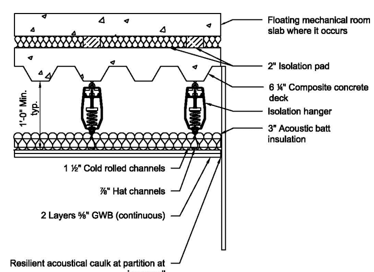
Floor/Ceiling Assemblies



STC 70+
IIC 65 to 70



STC 75 to 80
IIC 70 to 75

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Example: EMPAC

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EMPAC: Springs for Floated Floors

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EMPAC: Springs for Floated Floors

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EMPAC: Springs for Floated Floors

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