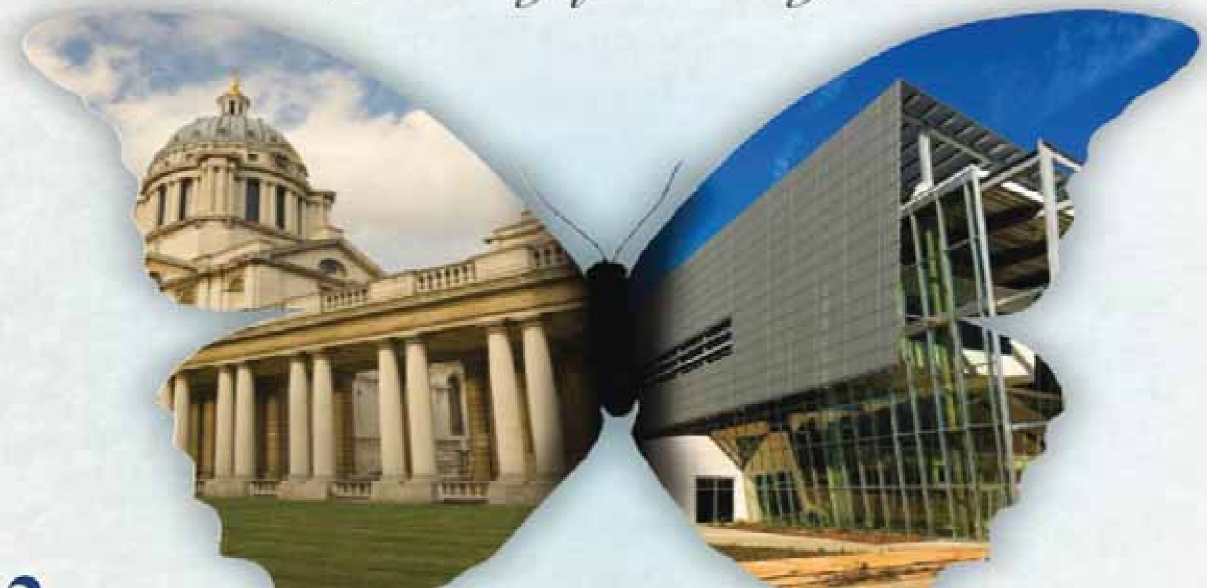
ASSOCIATION OF
Texas College & University Facilities
PROFESSIONALS

Managing Metamorphosis,
Building for Change



Session: 100102

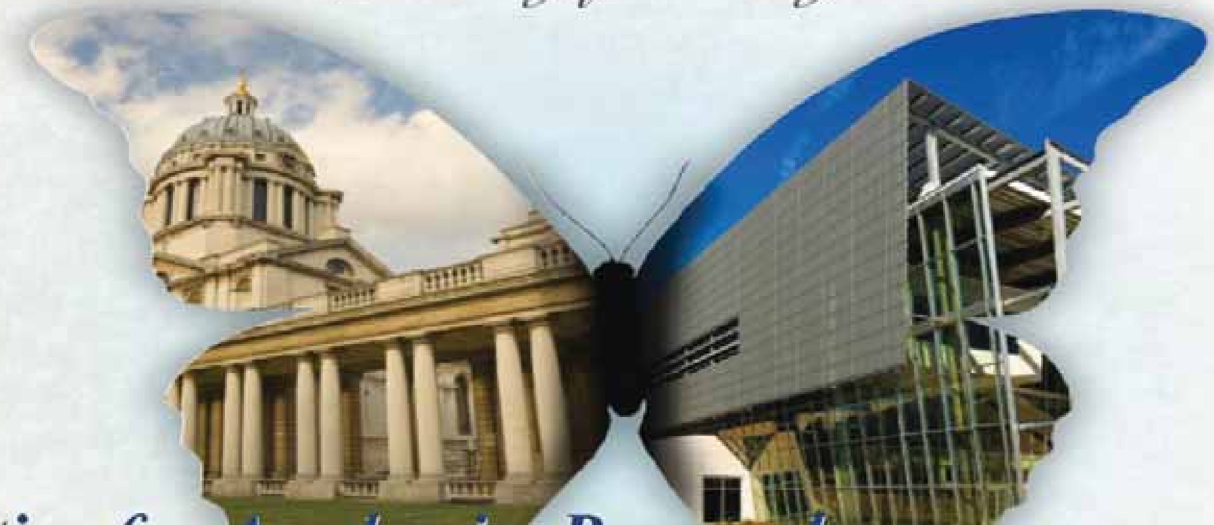
Date: Wednesday, October 1, 2014

Time: 1:00 pm – 3:00 pm

CONTINUING EDUCATION AIA

ASSOCIATION OF Texas College & University Facilities PROFESSIONALS

Managing Metamorphosis, Building for Change



Acoustics for Academic, Research, Healthcare & Residential Design

Presented by:

- **Guillermo Ramos, Director CIP Construction Services, UT Southwestern Medical Center**
- **Jack B. Evans, PE, Principal, JEAcoustics**
- **Chad N. Himmel, PE, Associate, JEAcoustics**

CONTINUING EDUCATION AIA

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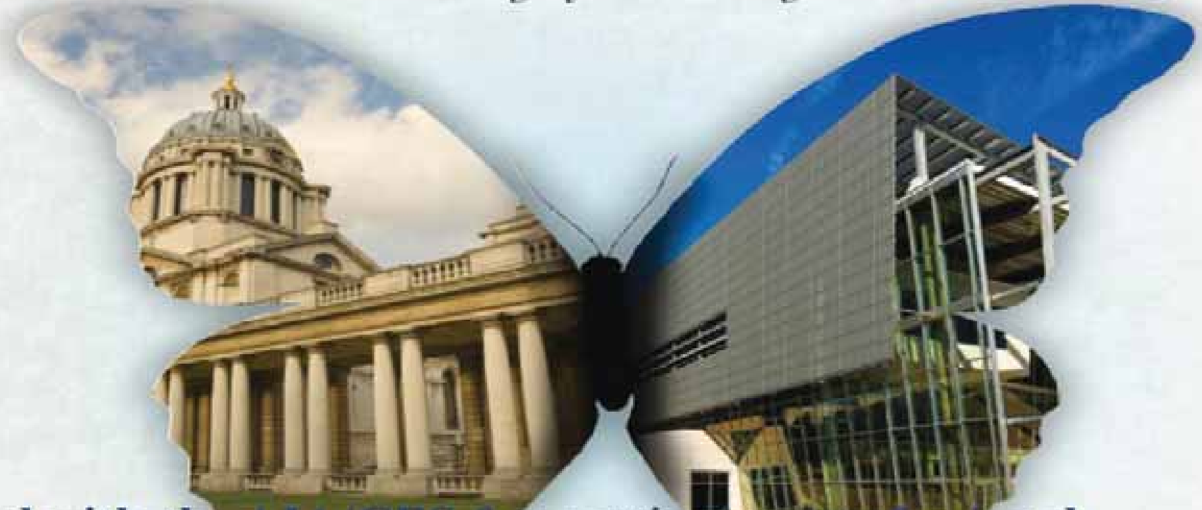

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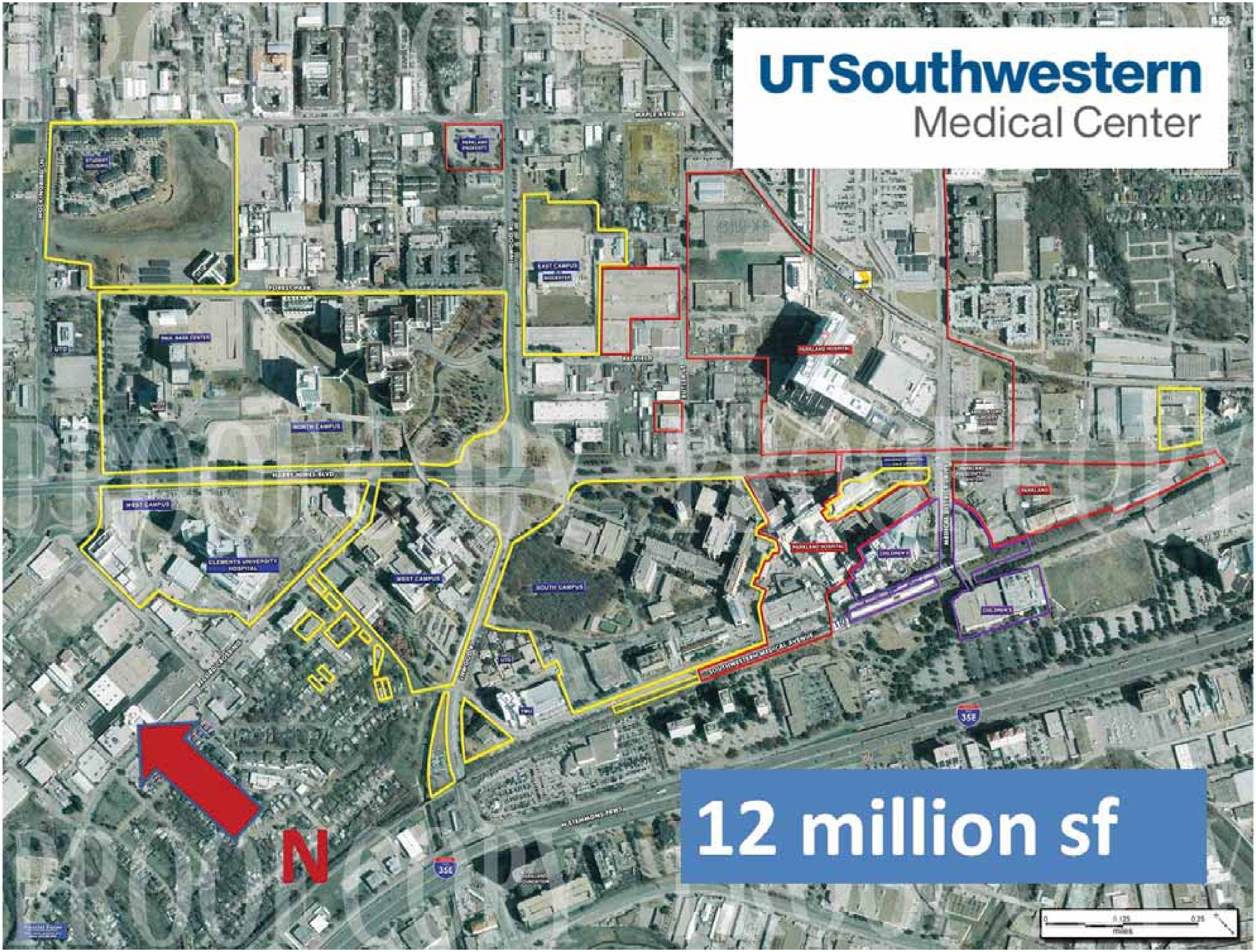
CONTINUING EDUCATION AIA

UT Southwestern
Medical Center

- **Established: 1942**
- **Nobel Prices Earned: 6**
- **National Academy of Sciences Members: 21**
- **Square Feet: 12 million**


UTSouthwestern
Medical Center
N
12 million sf

UTSouthwestern
Medical Center

Facilities Design & Construction
Capital & Renovation Program

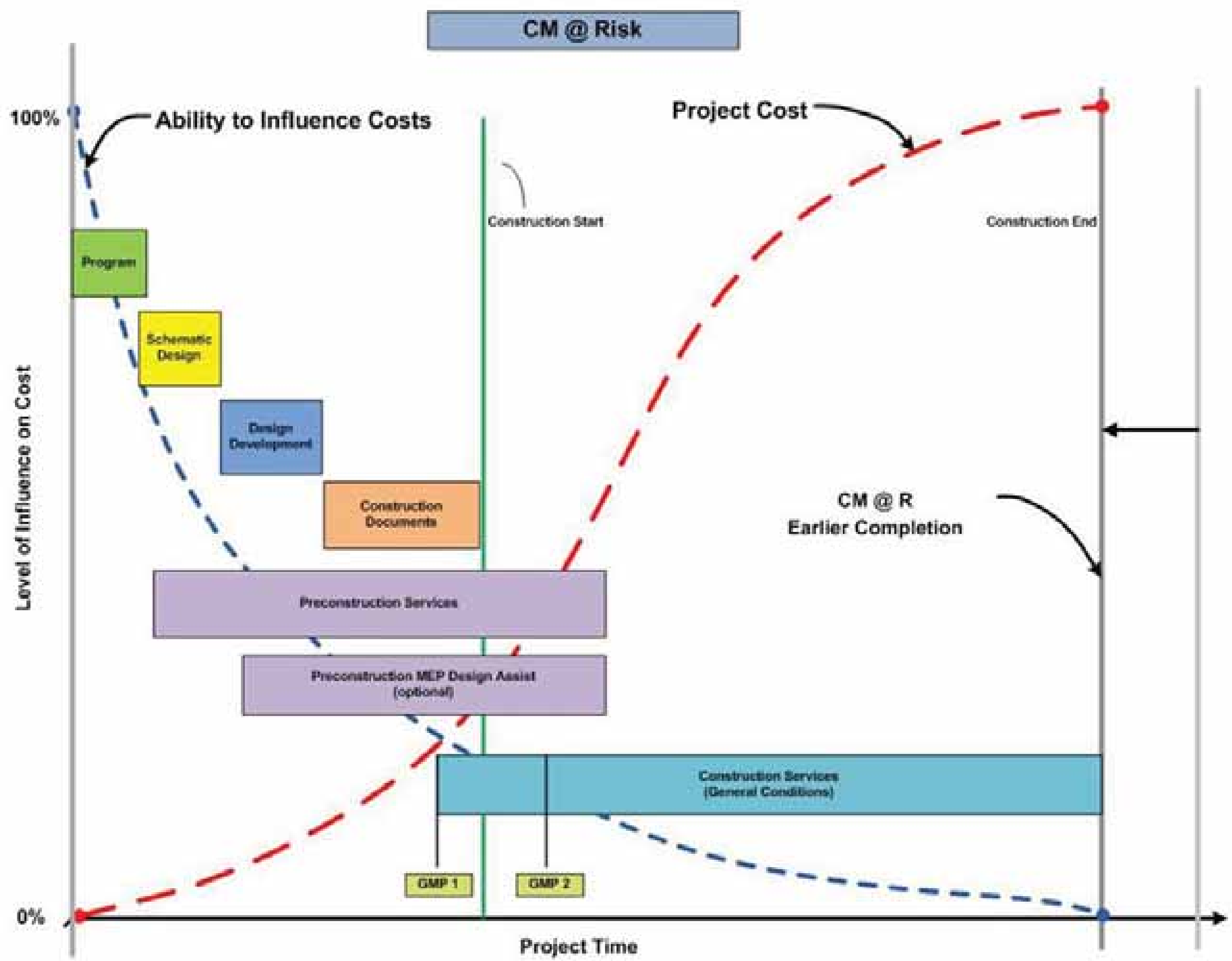
- 2007- 2010: $ 230 Million
- 2010-2014: $ 1 Billion +
- 2014-2018: $ 260 Million
- Ongoing Annual Renovations: $ 25 Million

UTSouthwestern
Medical Center

Facilities Design & Construction
Project Types

- Hospital
- Outpatient Clinics
- Academic Offices
- Academic Teaching Facilities
- Dry & Wet Labs
- Animal Lab Facilities
- Infrastructure Upgrades

Ability to Make Changes



UT Southwestern Medical Center

Facilities Design & Construction Proactive Planning Approach

- Peer/Cx Review
  - MEP Cx
  - Building Envelope Cx
  - Plans Coordination Review Consultant
  - BIM Consultant
  - Wind Consultant
  - Acoustical Consultant


March 2011


• $ 800 M
• 34 acres.
• 13 Floors
• 1,191,003 sf
• 460 beds (102 intensive care beds & 358 medical/surgical beds).
• 46,765 MMB).
October 2014

Atrium

Lobby

Cafeteria

Cafeteria

Patient Room

Patient Corridor

ITEMS OF DISCUSSION:

1. M. Hoffmeyer provided a summary of items requiring immediate consideration and recommendations from JEAcoustics (JEA). The list includes the following:

    a. Slab isolation and vibration reduction requirements for the fourth and fifth floor mechanical areas: RTKL noted that an isolation slab and other vibration attenuation provisions have been discussed by the Project Team and require further definition.

    b. Vibration isolation requirements for first floor imaging area: RTKL noted that this level has been designed as a structural floor and is not a slab on grade. The structural Design should be reviewed to verify that adequate stiffness has been included.

    c. STC rating requirements for the building's exterior wall system

    d. Identification of the sources of and mitigation for noise transmission from the Thermal Energy Plant to the hospital

    e. Atrium space noise levels

    f. Dining room and kitchen noise levels: JEA noted that ceiling and wall absorption treatments are more effective than utilizing soft flooring materials such as carpet.

    g. Noise levels on the patient room floors: RTKL noted that personal paging devices would be utilized in lieu of an overhead PA system. JEA recommended that soft wheels (tires) be provided for carts and equipment. Penetrations through walls will require special acoustical treatment.

2. RTKL requested that JEA provide feedback regarding items 1a-g by late-August 2010.


Hockey puck isolation pads

UT Southwestern
Medical Center

Acoustics for Academic, Research & Medical-Healthcare Facilities Design & Construction

- Guillermo Ramos, Director CIP Construction Services, UT Southwestern Medical Center
- Jack B. Evans, PE, Principal, JEAcoustics
- Chad N. Himmel, PE, Associate, JEAcoustics

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Acoustics for Academic, Research & Medical-Healthcare Design

- College and university facility acoustics for speech intelligibility, speech privacy, freedom from intrusive noise and prevention of annoyance and fatigue.
- Incorporate standards in programs of requirements (POR) and project bases of design (BoD).
- Design criteria and objective performance standards are presented for academic, research, medical-healthcare and for residential facilities.
- Common problems, characteristics of sensitive installations, and unique situations are presented.
- Gain a basic understanding of effective noise and vibration control measures for design and construction.

Acoustics for Academic, Research & Medical-Healthcare Design

Attendees will learn:

- Facility design standards for building acoustics and vibration performance can improve quality, value and relevance of capital improvements, and can increase users' comfort and confidence.
- New acoustics standards that have recently been developed by international institutions (such as the ICC & FGI) or by USGBC (LEED), which can help shape facility design standards.
- New/revised FGI 2014 Acoustical Criteria for healthcare facilities have implications for university facilities.
- Terms and methods to understand and determine how typical student housing designs measure up to current IBC and ICC standards for multifamily residential uses.
- Demolition and Construction for new facilities can affect the operations and occupants in existing facilities.

Introduction of Appropriate Criteria in Design

- Program of Requirements (PoR): Owner
- Basis of Design (BoD): A/E Design Team
- Supplement or Amend Standard Criteria for Specialized Facilities: Consultants
- Construction phase noise and vibration impacts on existing facilities: PM, CM, GC

Design Phase Implementation of Acoustical, Noise & Vibration Designs

- Adoption / Integration in Architect and Engineer (A/E) Design Documents
- Manufacturers' Acoustical, Noise or Vibration Data for Design
- Value Engineering Evaluations, Issues and Dispositions
- Demolition & Construction Phase noise and vibration mitigation for existing facilities

Construction Phase & Commissioning

- Submittal Reviews
- Requests for Information
- Manufacturer Qualification
- Product Validation
- Product Substitution
- Facility Acoustical Performance Validation (Post-Construction, Initial Occupancy)

Primary acoustical disciplines in building design and construction

- Room Acoustics
- Sound Isolation/Privacy
- Structural Vibration
- Mechanical Noise & Vibration
- Environmental Noise
- Related: “Low-Voltage Systems”

Acoustical Criteria and Guidelines for Architectural Design

Agenda:

- Architectural Acoustics Disciplines
  - Room Acoustics – Reverberation & Reflections
  - Sound Isolation – Privacy & Intrusive Noise
- Structural Vibration
- Building Systems Noise & Vibration
  - Mechanical, Electrical, Plumbing, Elevator Systems
  - Vibration Isolation
- Environmental Noise
- Occupational/Workplace Noise

Architectural Acoustics

- **Room Acoustics**: reverberation and reflections
- **Privacy / Sound Isolation**: containment of sound, freedom from intrusive noise
- **Audio Systems**: Speech Reinforcement, Sound Masking, A/V audio, (data, comm, IT)
- **Structural Vibration**: feelable (floor) vibration, radiated airborne sound due to structure borne surface vibration

Architectural Acoustics Criteria

- **Room Acoustics**:
  - Reverberation Decay Time (RT60) time in seconds for 60 dB decrease
- **Privacy / Sound Isolation**:
  - STC (lab), ASTC or NIC (field measurement),
  - CAC (ceiling)
  - Outdoor-Indoor Transmission Class (OITC)
  - Impact (floor-ceiling assy.) (IIC)
  - Speech Intelligibility Index (SII), Speech Privacy Class (SPC), or STI (field measurement)

Structural Vibration & Criteria

- **Structural Vibration**:
  - Ground borne vibration / foundation
  - Girder, beam & floor slab
  - Partition, ceiling & lightweight structures
- **Structural Vibration Criteria**:
  - Generic Floor Vibration Criteria (VC)
  - Manufacturer's environmental/installation vibration criteria

Building Systems Noise & Vibration

- **Bldg. Systems Noise**:
  - Central plant, cooling tower, ACCU
  - HVAC, mechanical, electrical, elevator, etc.

- **Bldg. Systems Vibration Isolation**:
  - Equipment, piping, conduit, duct & ancillary

Building Systems Noise & Vibration Criteria

- **Continuous Bldg. System Background Noise***
  - Room Criteria (RC)
  - Noise Criteria (NC)
  - Noise Rating (NR, Europe)

  *Ambient noise spectrum in unoccupied space due to building systems only; HVAC, electrical, etc., exclusive of occupant and user-installed equipment noise

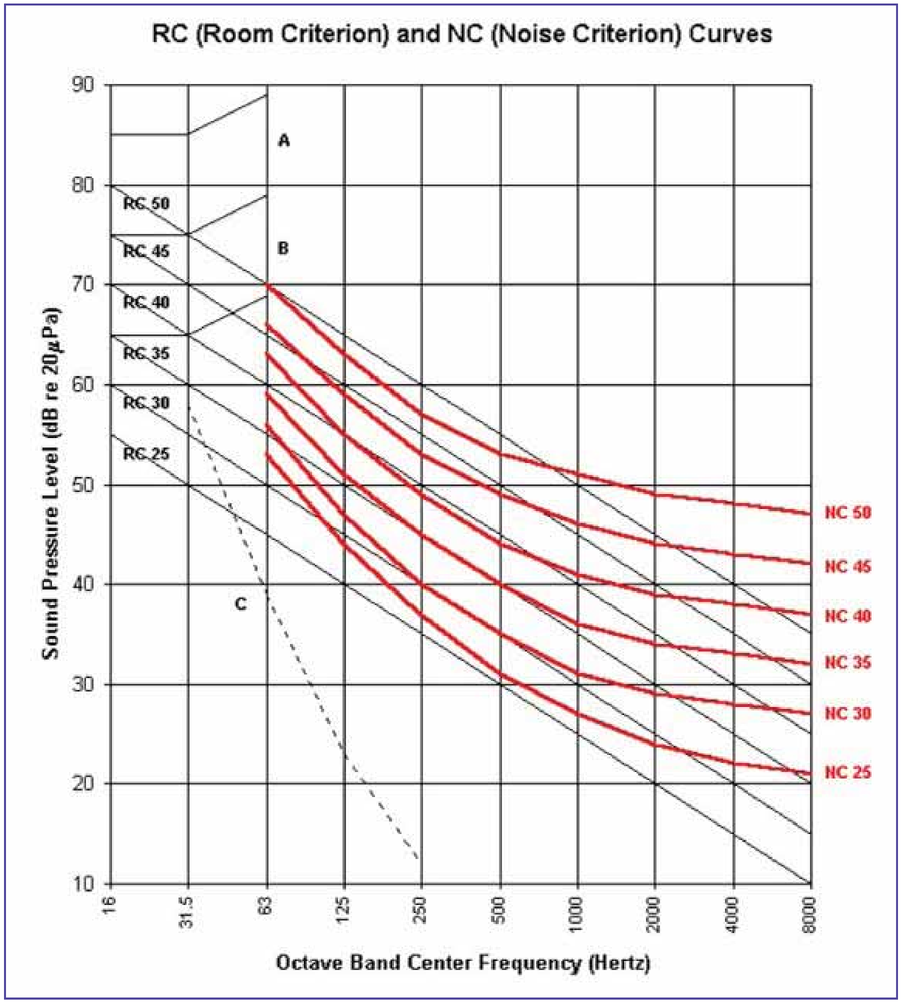
Building Systems Criteria & Ratings

Noise Criteria (NC) vs. Room Criteria (RC)

- Allowable noise level in each octave; graduated families of spectrum curves for neutral sound with limited tonality
- RC includes Low Frequency Limits
- *Criteria are for Continuous Noise in Unoccupied Space*

Building Systems

- HVAC Background Noise; spectrum level
- Electrical and Lighting Background
- Radiated noise ratings in octaves (NC)
- Radiated overall weighted level ratings (dBA)



Environmental Noise

- **Noise Crossing Property Boundaries**:
  - Sound source emissions on building site or
  - Intrusive sound sources entering building site
- **Noise Entering Building From Site**:
  - Sound source emissions on building site
  - Building roof mounted equipment
  - Building noise from louvers, openings
- **Outside to Inside Transmission Loss**:
  - Sound intrusion through building shell

Environmental Noise Criteria

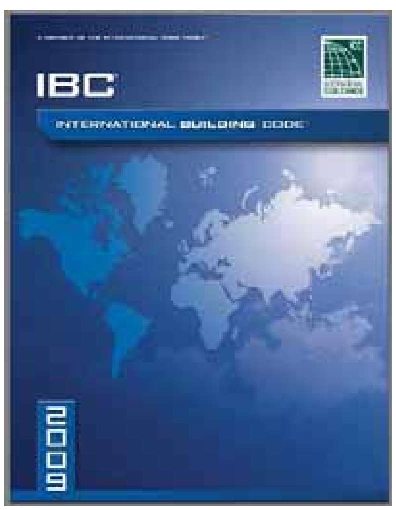
- **A-weighted**: single-number descriptor for overall noise level with A-weighting
- **Day-Night Level (Ldn)**: annualized time-weighted average with night penalty
- **Equivalent Level (Leq)**: integrated average over measurement time
- **Sound Pressure Level (Lp)**: instantaneous or simple level for transient or continuous sound

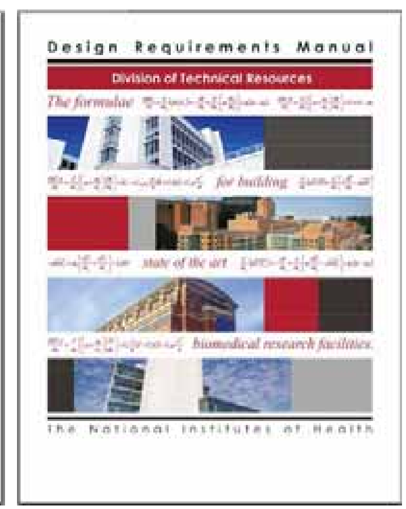
Occupational / Workplace Noise

- Noise related to hearing conservation, health & stress
- This is where those familiar 85 dBA and 90 dBA numbers come from…
  - OSHA 1910 - 90 dBA TWA over 8 hours, based on monitoring trigger at 85 dBA TWA
  - Exposure: time-weighted average dBA
    - 5 dBA increase allowed for one-half reduction of time
    - 5 dBA decrease allowed for each doubling of time
- Not generally relevant to architectural acoustics, unless industrial or high-noise facility
- ***Will not be covered in this seminar***.

Institutional Criteria for Acoustics, Noise and/or Vibration

- FGI, LEED/USGBC, ASHRAE, NIH
- Codes: IBC, ICC, others
- Owners' Design Criteria and Guidelines



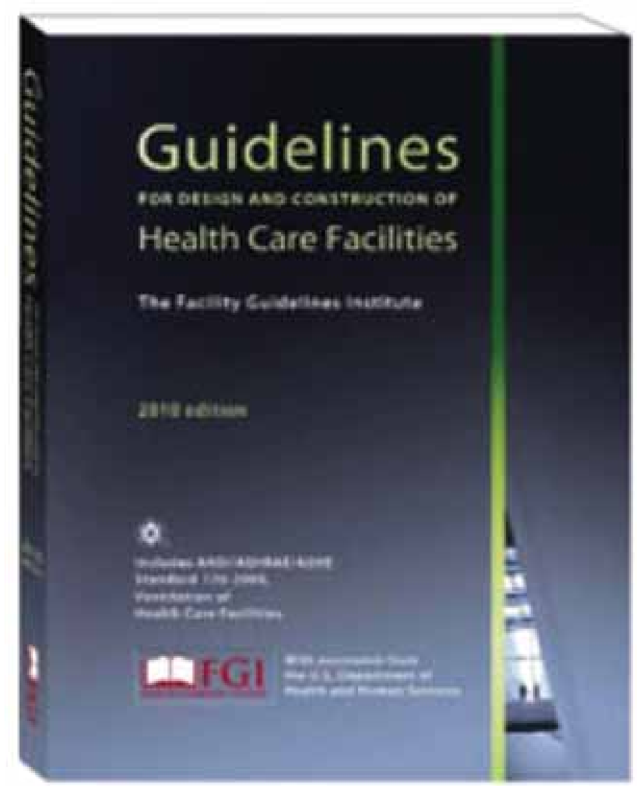


FGI: Why Does it Matter?

- Recognized and Accepted Standards
- Code in 42 States and Cited in 60 Countries
- Only Comprehensive Acoustical Criteria and Sole Reference for ICC, LEED HC, etc.
- HCAHPS' lowest scoring area is "Quiet"
- 4 year – Continual Improvement Program Health Guidelines Revision Committee

Acoustical Criteria

FGI Guidelines for Design & Construction of Health Care Facilities, 2010

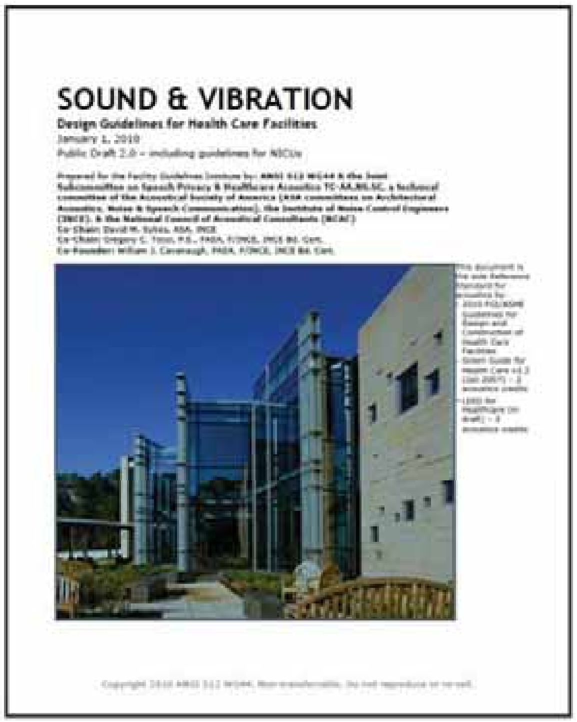


FGI Guide	Acoustical Criteria Categories
Exterior Noise Table A1.2-a	Exterior shell STC 35-50 based on exterior site noise exposure category, outdoor day-night average level (Ldn)
Acoustical Finishes Table 1.2-1	Design Room noise reduction coefficient (NRC) based on room/function type
Room Noise Table 1.2-2	Permissible continuous building systems background noise criteria (RC, NC, dBA)
Sound Isolation Table 1.2-3	Permissible room-to-room composite sound transmission class rating (STCc)
Speech Privacy Table 1.2-4	Closed Plan and Open Plan: separate ratings for normal, confidential and secure (AI, PI, STI or SII)
Alarm, Call & Paging Table 2.1-4	Locations and Criteria for audibility, intelligibility and minimal annoyance and masking
Floor Vibration Table 1.2-5	Patient, Operating, Procedure rooms: ISO Operating Theatre (4000 μ-in/sec) Administrative and public circulation: ISO Daytime (8000 μ-in/sec)

Acoustical Criteria

Sound & Vibration for Health Care Facilities, V 2.0, Including New Guidelines for NICUs

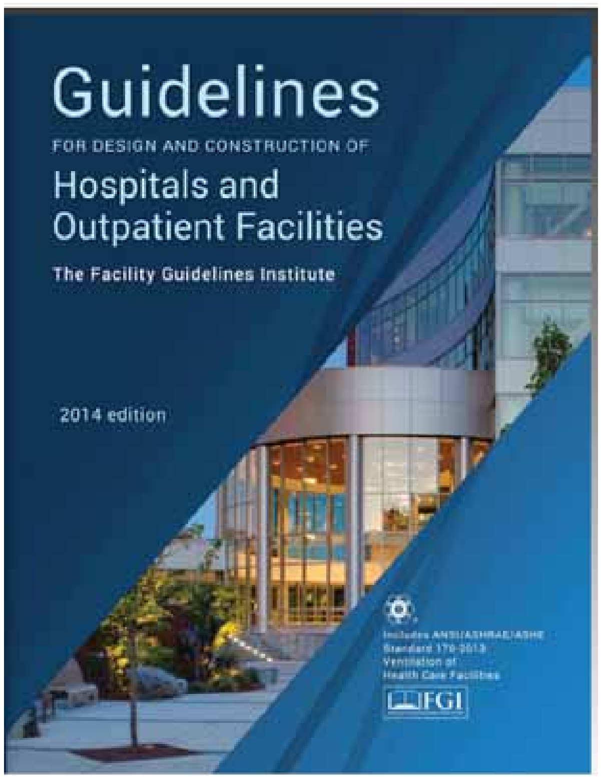
V 3.0 to be released 4Q14 – 1Q15



FGI 2010	Sound & Vibration V 2.0
Table A1.2-a	Table 1.3-1: "Categorization of Hospital Sites by Exterior Ambient Sound"
Table 1.2-1	Table 2.3-1 "Recommended Design Room Sound Absorption Coefficients"
Table 1.2-2	Table 3.3-1 "Recommended Criteria for Noise in Interior Spaces"
Table 1.2-3	Table 4.3-1 "Recommended Sound Isolation Performance Between Enclosed Rooms"
Table 1.2-4	Table 4.4-1 "Speech Privacy for Enclosed Rooms" & Table 4.4 "Speech Privacy Goals for Open-Plan Spaces"
Table A2.1-a	"Adapted from Evans JB, Philbin MK, Facility and Operations Planning for Quiet Hospital Nurseries" (Page 58)
Table 1.2-5	Table 6.3.2-1 "Recommended Limits on Footfall Vibration in Hospitals"

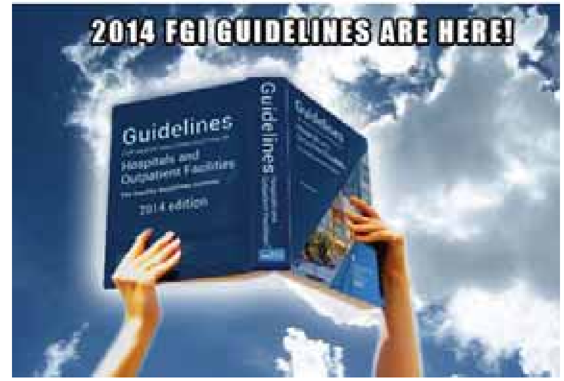
Acoustical Criteria

FGI Guidelines for Design & Construction of Health Care Facilities, *2014 in Two Volumes*



FGI Guide	Acoustical Criteria Categories, 2014
Exterior Noise Table 1.2-3	Exterior shell OITC 35-50 based on exterior site noise exposure category, outdoor day-night average level (Ldn)
Acoustical Finishes Table 1.2-4	Design Room noise reduction coefficient (NRC) based on room/function type
Room Noise Table 1.2-5	Permissible continuous building systems background noise criteria (RC, NC, dBA)
Sound Isolation Table 1.2-6	Permissible room-to-room composite sound transmission class rating (STCc)
Speech Privacy Table 1.2-7	Closed Plan and Open Plan: separate ratings for normal, confidential and secure (AI, PI, SPC or SII)
Alarm, Call & Paging Table 2.1-4	Locations and Criteria for audibility, intelligibility and minimal annoyance and masking
Floor Vibration Table 1.2-8	Patient, Operating, Procedure rooms: ISO Operating Theatre (4000 μ-in/sec) Administrative and public circulation: (8000 μ-in/sec) Patient (6000 μ-in/sec)

Acoustical Criteria



FGI Guidelines for Design & Construction of Health Care Facilities, 2014 Edition Changes & Additions

Site Exterior Noise, Tbls 1.2-3, 1.2-b: Categorization of Health Care Facility Sites
- Shell Composite OITC (OITCc) in Lieu of STC

Acoustic Finishes, Tbl 1.2-4: Minimum Design Room Sound Absorption Coefficients
- Add “Medication Safety Zone” and “Operating Room” (Appendix)

Room Noise Levels, Tbl 1.2-5: (only) Maximum noise criteria due to building systems
- Add: “Medical Safety Zones,” “NICU Sleep Areas” & “NICU Staff & Family Areas”
- Change to “Private Offices, exam rooms” in lieu of “Offices…”

Sound Isolation, Tbl 1.2-6: Minimum Sound Isolation (STCc)
- Footnote 2 now allows +/- 2, based on testing method accuracy and repeatability

Speech Privacy, Tbl 1.2-7: Speech Privacy Rating Methods
- Introduce “SPC” in lieu of “STI” – Keep “PI,” “AI” and “SII”
- Reorder Secure / Confidential / Normal and rating value modifications

Building Vibrations, Tbl 1.2-8: Footfall Impact Vibration Peak Velocity (micro inches/sec)
- Change “Patient Rooms and other Patient Areas” 6000 mips in lieu of 4000 mips

Acoustical Criteria

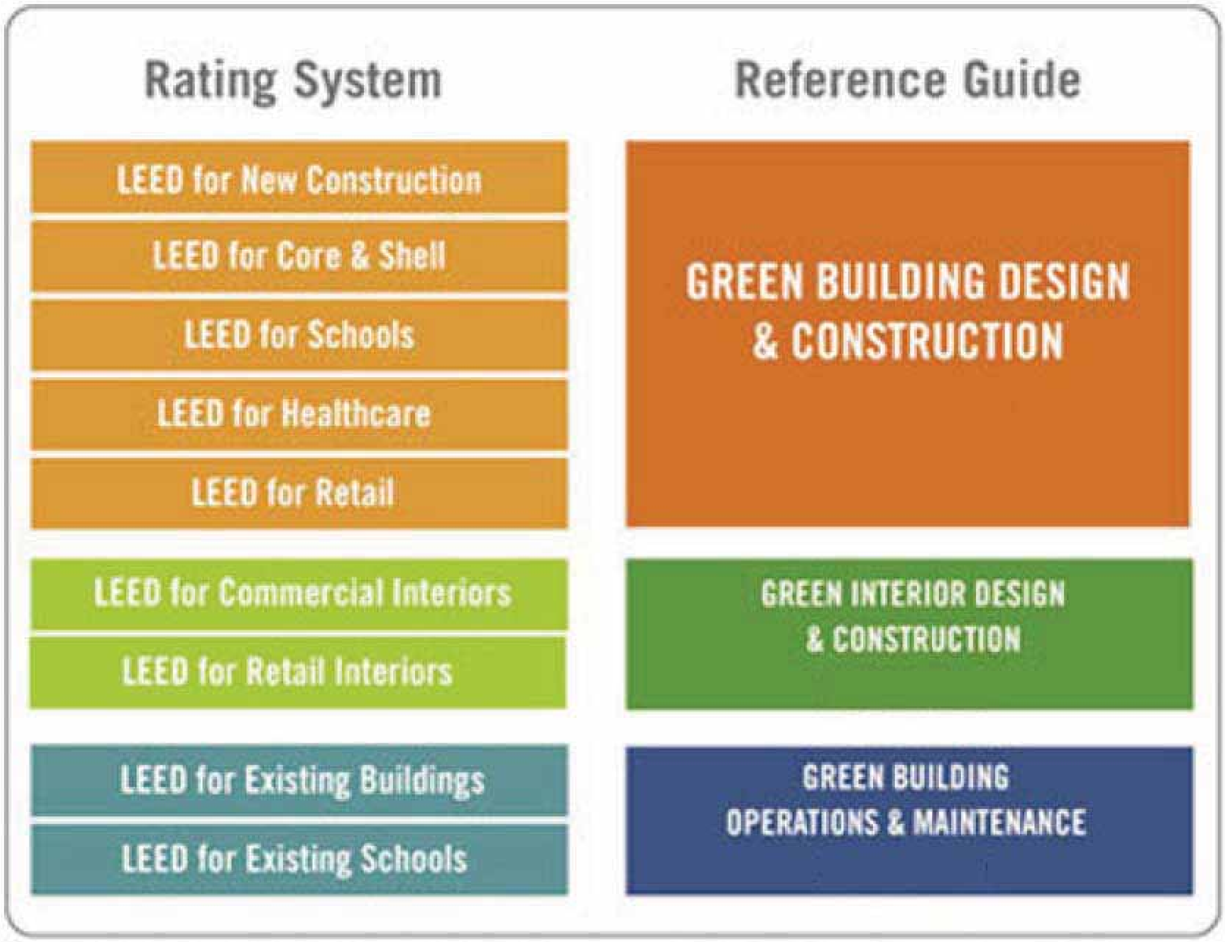
HEALTH INSURANCE PORTABILITY AND ACCOUNTABILITY ACT (HIPAA)

- HHS issued an interim final rule to strengthen enforcement and increase penalties for violations of HIPAA, effective November 30, 2009.
- The American Recovery and Reinvestment Act of 2009 (ARRA) included the Health Information Technology for Economic and Clinical Health (HITECH)
- Public Law 104-191, enforced by U.S. Dept. of Health and Human Services (HHS) & the U.S. Dept. of Justice (DOJ).
- **Section 13410(d) increased maximum penalties to $1.5 million for each violation.**
- Acoustical privacy requirements are now subject to such enforcement.
- Refer to FGI "Acoustical Guidelines," for assistance with design implementation of HIPAA requirements.

Health Insurance Portability and Accountability Act (HIPAA)

- Speech privacy is a function of multiple variables, chief among them being background noise and distance between source and receiver.
- Articulation Index (AI) and Speech Intelligibility Index (SII) are functions based on the relationship between decreasing speech intelligibility and increasing speech privacy.
  - Example AI < 0.05, or less than 5% of syllables being intelligible, is considered confidential, whereas AI ≤ 0.15 is considered acceptable or normal privacy for open offices.
  - SII is similar, but expressed in percentiles, i.e. 39% is confidential and 75% is normal privacy.
- Refer to the new FGI “Acoustical Guidelines,” for assistance with design implementation of HIPAA requirements.

Acoustics and Sustainability
Leadership in Energy & Environmental Design (LEED*)



** Leeds is a city in W. Yorkshire, UK*

LEED for Schools – Acoustical Criteria

LEED for Schools	IEQ 9: Enhanced Acoustical Performance
Exterior Noise	Design Building Shell to meet STC in ANSI S12.600-2002, except windows which must meet STC-35
Sound Isolation	Classroom & Core Learning Space Partitions meet STC in ANSI S12.60-2002
Room Noise Levels	Permissible continuous building systems background noise criteria in Classroom and Core Learning Spaces $\leq$ 40 dBA (also ref: ASHRAE Applications, 2007)
Design considerations include reducing noise from exterior to interior spaces, between spaces within the building, and within the classroom space. External to internal noise transmission can be reduced by orienting classrooms away from external noise sources and using thick and/or massive materials in walls and roofs. Windows should be well-sealed and have adequate air gaps between sheets of glass. See IEQ Prerequisite 3: Minimum Acoustical Performance for more potential technologies and strategies.	

LEED for Schools – Acoustical Criteria

Specific acoustical criteria for Indoor Environmental Quality

- LEED for Schools
  - IEQ Credit 9, 1 point, Enhanced Acoustical Performance, reference ANSI S12-60.
- LEED for Healthcare.
  - Two IEQ credits, reference HIPAA and FGI Guidelines,
  - 1 point for Speech Privacy and
  - 1 point for Acoustical Finishes & Details and Environmental Noise.
- Innovation in Design category (ID) possible for all LEED rating systems (other facility types).

LEED for Healthcare

- **LEED HC 2009 relies on:**
- Facility Guidelines Institute (FGI) "Guidelines for Design and Construction of Healthcare Facilities," 2010 [1],
- "Sound & Vibration for Health Care Facilities, V2.0," 2010 [2], the "reference standard" document from ANSI S12 WG44,
- The FGI criteria and guidelines are adopted as code in many states of the US and in several other countries. In other states, FGI is a design standard implemented at the discretion of the owner and/or architect [3].

[1] The Facility Guidelines Institute, ASHE, Chicago (2010) http://www.fgiguidelines.org

[2] *Sound & Vibration, V2.0,* ANSI S12 WG44, The Joint ASA/INCE/NCAC Subcommittee on Healthcare Acoustics & Speech Privacy, Cambridge, MA (2010)

[3] D. Sykes, "Speech Privacy: the 2009-10 LEED, AIA & ASHE criteria for healthcare facilities," *Proc. Of InterNoise 2009, Ottawa, CA* (pdf 278), International Institute of Noise Control Engineering (2009)

LEED for Healthcare Acoustical Requirements

Sound isolation & speech privacy

- **Option 1:** One point for achieving three sets of goals for representative adjacencies:
  - **Sound Isolation.** Calculate composite STC (STCc) ratings for entry partitions at corridors and document STC ratings of demising partitions.
  - **Speech Privacy.** Calculate using a choice of descriptor (PI, AI, STI or SII), or the simple calculation method of STCc + dBA = at least 75.
  - **Room Noise.** Calculate background noise using choice of descriptor (NC, RC(N), or dBA). *ASHRAE 2007, Ch. 47, Sound and Vibration Control, is a supplemental reference.*

LEED FGI and ASHRAE Criteria

Option 1 - Sound isolation & speech privacy

- **Sound Isolation**. FGI Table 1.2-3, “Design Criteria for Minimum Sound Insulation Performance between Enclosed Rooms.” [4].
  - Demising partition between Patient Rms.: STC-45,
  - Patient Rm. to Public Demising Partition: STC-50,
  - Patient Rm. corridor partition with entry STCc-35.
- **Speech Privacy**. FGI Table 1.2-4, “Design Criteria for Speech Privacy for Enclosed Rooms and Open-Plan Spaces.” [5].
  - Normal speech privacy: PI $\geq$ 85%, AI $\leq$ 0.15, STI $\leq$ 0.19, SII $\leq$ 0.20.
  - (PI is minimum value, but AI, STI and SII are maximum values).
- **Room Noise**. FGI Table 1.2-2, “Minimum-Maximum Design Criteria for Noise in Interior Spaces.” [6].
  - Patient Room: NC/RC(N) 30-40, 35-45 dBA
  - Corridors, Public: NC/RC(N) 35-45, 40-50 dBA

[4, 5, 6] *Guidelines for Design and Construction of Health Care Facilities*, pages 35-36, FGI (2010)

LEED for Healthcare Acoustical Requirements

Acoustical finishes & exterior noise

- Option 2: *Available only after achieving Option 1*
  - one additional point for achieving two sets of goals:
  - **Acoustical Finishes**. Calculate reverberation decay time, RT60 in seconds.
  - **Site Exterior Noise**. Calculate STCc for exterior shell using combination of exterior wall, window, etc. Requirements vary with exterior sound levels.

LEED FGI and ASHRAE Criteria

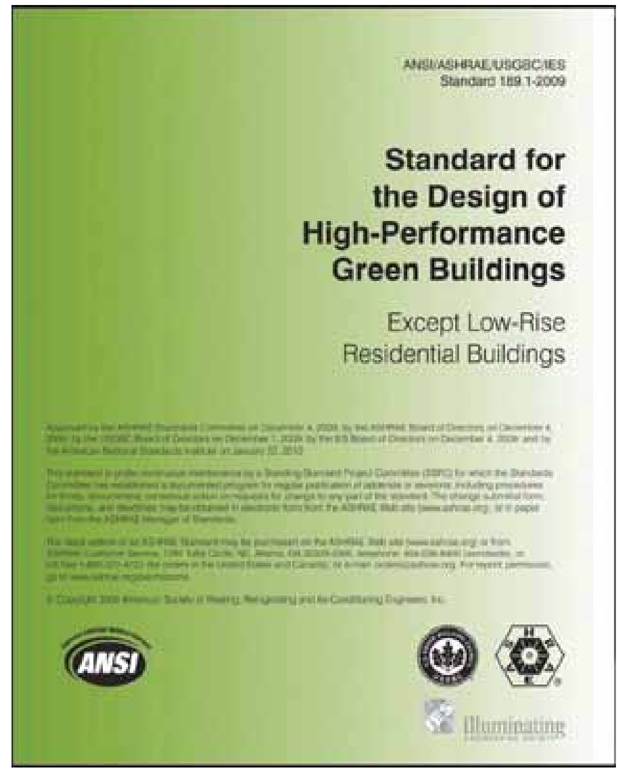
Option 2 - Acoustical finishes & exterior noise

- **Acoustical Finishes**. FGI Table 1.2-1, “Design Room Sound Absorption Coefficients” [7].
  - Private patient room, NRC 0.15, “average room.”
- **Site Exterior Noise**. FGI Table A1.2-a, “Categorization of Health Care Facility Sites by Exterior Ambient Sound” [8].
  - minimal, moderate, significant or extreme categories based on day-night average (Ldn) or maximum hourly L01 (dBA) and distances to major noise sources.

[7, 8] *Guidelines for Design and Construction of Health Care Facilities*, pages 35, 37, The Facility Guidelines Institute, ASHE, Chicago (2010).

Acoustics and Sustainability
ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings

- Standard 189.1 applies to:
  - new buildings and their systems
  - new portions of buildings and
  - new systems in existing buildings,
  - Exception: residential spaces of 3 stories or less.
- Standard 189.1 Intended to exceed (earlier) Std. 90.1
  - Std 90.1:minimum energy efficiency and design.
  - Std 189.1: siting, design and construction characteristics for high-performance or green buildings
- Specific requirements for indoor environmental quality:
  - environmental tobacco smoke control,
  - outdoor air delivery monitoring,
  - thermal comfort,
  - low-emitting materials
  - day lighting
  - ***acoustical control***



ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings

- Section 8.3.3 Acoustic Control covers exterior and interior sound:
  - a) Outdoor-Indoor Transmission Class (OITC), ASTM E1332,
  - b) Sound Transmission Class (STC), ASTM E90 and E413.
- Section 8.4.2 Materials
  - limits emissions or VOC contents for many building materials including
    - adhesives and sealants,
    - ceiling and wall systems,
    - references to acoustical sealants, wall insulation, ceiling panels, etc.

ASHRAE 189.1 Standard for the Performance of High-Performance Green Buildings

Std. 189.1	8.3.3 Acoustical Control
Exterior Sound	Design Building Envelope to meet Outdoor-Indoor Transmission Loss (OITC) $\geq$ 40 or Composite STC (STCc) $\geq$ 50. Fenestration (windows) OITC or STC $\geq$ 30
Interior Sound – Wall & Floor-Ceiling Assemblies	Dwelling Units: STCc $\geq$ 50 Hotels, Motels, Nursing Homes and Healthcare Patient Rooms: STCc $\geq$ 45 Classrooms at Toilets/Showers, STCc $\geq$ 53 Classrooms at Music, Cafeteria, Gym/Pool, Mechanical Rooms, STCc $\geq$ 60
Reference Standards	OITL according to ASTM E1332 STC according to ASTEM E90 & E413

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, ANSI/ASA S12.60-2010 (R2009)

- The U.S. Access Board partnered with Acoustical Society of America (ASA) on development of a classroom acoustics standard
  - Based on reducing educational barriers for children.
  - Young students adversely affected by lower levels of background noise and reverberation, due to less developed hearing systems and smaller vocabulary.
  - Students with hearing impairments or with different home language than the teaching language also risk educational difficulties.
- Acoustical Performance Criteria, Design Requirements and Guidelines for Schools S12.60-2010 / Part 1, Permanent Bldgs.
- S12.60-2009 / Part 2, Portable classrooms
- For K-12, but useful acoustical guide for higher ed.

Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, ANSI/ASA S12.60-2002 (R2009)

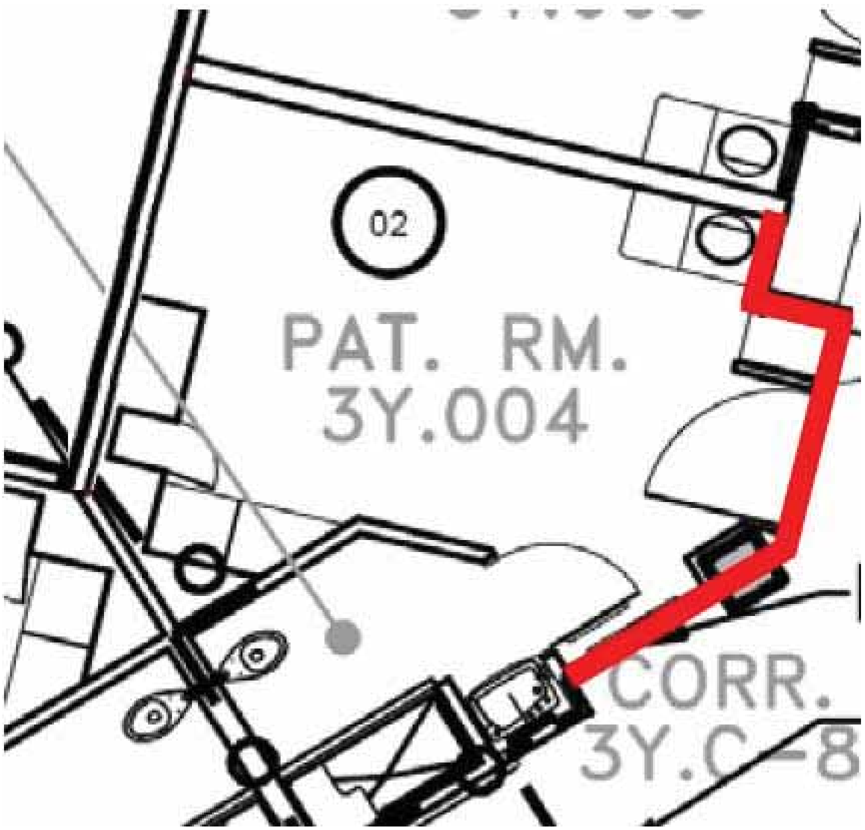
- Voluntary standard, unless referenced by code, local ordinance or regulation. School systems may also require compliance.
- The Classroom Acoustics standard provides criteria for
  - reverberation decay time
  - continuous building systems noise,
  - sound transmission from adjacent interior spaces and
  - intrusive exterior environmental noise.
- 15 dB signal-to-noise ratio (SNR) for instructor speech
- Apply to all new classroom and learning space facility design and construction, and also to renovations when practical.
- ASA companion manuals assist with classroom acoustical design;
  - Vol. 1 Design Manual and
  - Vol. 2 Key Acoustical Issues in Learning.

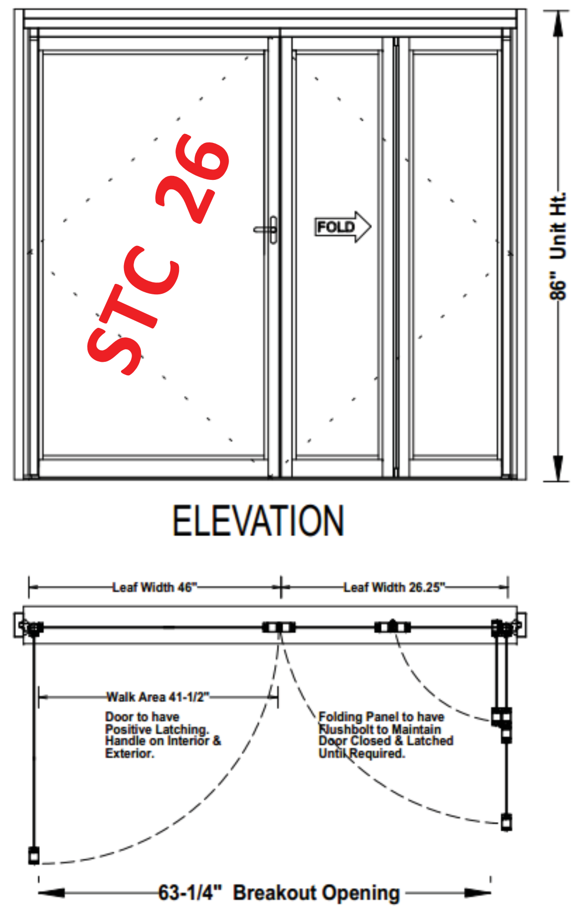
Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, ANSI/ASA S12.60-2002 (R2009)

S12.60-2002	Core Learning Space Requirements
Background 1Hr Noise and Reverberation	< 283 m^3 : 35 dBA, RT60 - 0.6 sec < 566 m^3 : 35 dBA, RT60 - 0.7 sec > 566 m^3 : 40 dBA (see Std. Annex C)
If noisiest 1-hour period is dominated by transportation noise, increase maximum limits by 5 dB	
Sound Isolation	Core Learning : Adjacent, STC 50 Common Use, Toilet, Bath, STC 53 Conference, Office Corridor, STC 45 Music, Mechanical, Cafeteria, STC 60 Classroom Doors, STC 30 Music Room Doors, STC 40
Open-plan classrooms do not meet sound isolation requirements of this standard	
Impact Insulation	Floor-Ceiling above, IIC 50 w/out carpet Gym, Dance or High-Impact, IIC 65-70 (new not recommended above classrooms)

Some Case Studies in Acoustics for Academic, Research, Healthcare & Housing Projects

FGI and LEED HC Point No. 1





sliding doors or "breakout doors" with unsealed gaps do not achieve STCc 35

FGI and LEED for Healthcare

Point No. 1

Feasibility

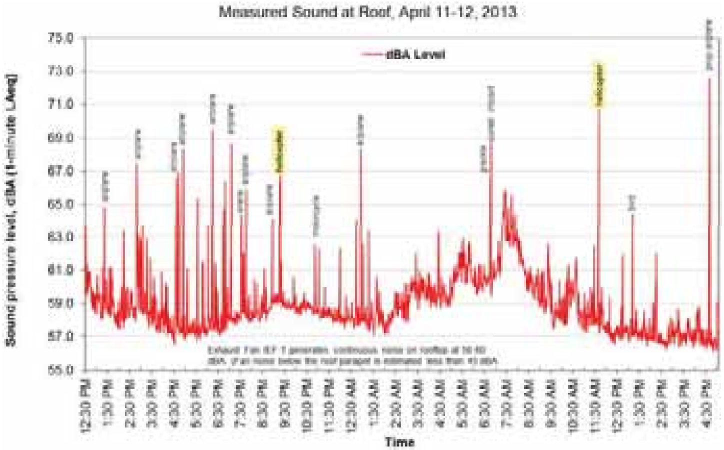
- Plan for preliminary calculations and review to determine whether it is worth pursuing points in acoustics for LEED.

Point 1 – interior STC ratings and HVAC noise

- Door seals & frames are often challenging, especially sliding.
- Watch out for HVAC return air paths for noise and privacy.
- **Tip**: Include walls above the ceiling plenum for STCc.
- **Tip**: Include distance loss in "long" rooms and tie in with T60.
- **Tip**: Request exception in CIR* for patient room sliding doors and poorly sealed double doors at protected inner corridors.

*credit interpretation request

FGI and LEED HC Point No. 2



The site's distance from highway, airport or railroad can indicate general site categorization, or

Measurements can be done with calculation to indicate the ambient noise level and category.

Ambient Sound (Ldn)	Categorization of Site by Exterior Ambient Sound	Exterior Shell Composite STCc
< 65	Minimal	35
65-70	Moderate	40
70-75	Significant	45
>75	Extreme	50

FGI and LEED for Healthcare

Point No. 2

Point 2 – exterior STC ratings and T60 (reverberation)

- Can be more challenging than Point 1.
- Implement absorptive finishes that fit with hospital function.
- Upgrade specs for exterior glazing as needed to fit budget.
- Tip: Include walls at exterior toilet rooms, floor slabs and above ceiling plenum, millwork on exterior walls.
- Tip: Include distance loss in “long” rooms & tie that in with T60 needs.

FGI and LEED HC Point No. 2

Patient Room 2Y.023

Universal Patient Room Level 2

Outdoor-Indoor STCc

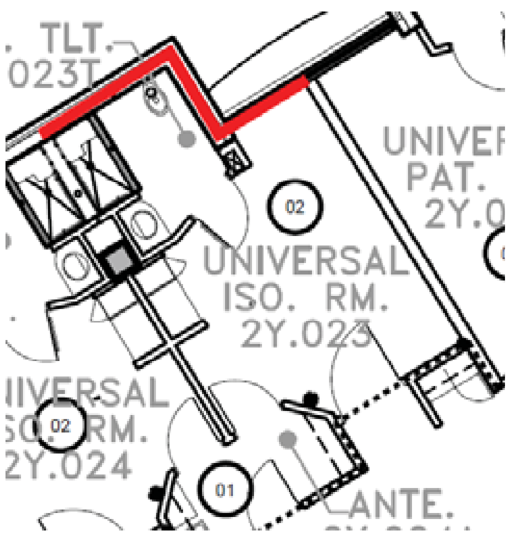
		Frequency (Hz) 63	125	250	500	1000	2000	4000	8000
1. Outdoor 64 Ldn	64 dBA	70	66	62	59	60	56	52	42

2. Composite Partition NR, Lp source:

$Lp_1 - Lp_2 = TL - 10Log(Sw/4) - 10log(1/Sw + 4(1-\alpha)/S\alpha)$

	Area	63	125	250	500	1000	2000	4000	8000			
	33	16	22	20	30	37	34	38	40	GL1/4_AIR1/2_GL1/4 Curtain Wall	STC 32	Vision glass
	15	22	30	26	35	38	35	42	45	Spandrel (insulated)	STC 36	Spandreal glass
	133	25	30	42	59	64	65	68	68	Wall with ext masonry along toilet	STC 54	Toilet Wall
TL		21	27	27	37	43	40	45	47	Composite Partition TL		
α_2		0.10	0.12	0.14	0.15	0.20	0.20	0.20	0.20	receive room absorption		
				Room2 >>	Sw	L	W	H	S			
STCc =	39				181	15'	10'	9'	750			
									>>			

	63	125	250	500	1000	2000	4000	8000
>>	-17	-24	-25	-35	-42	-40	-44	-46

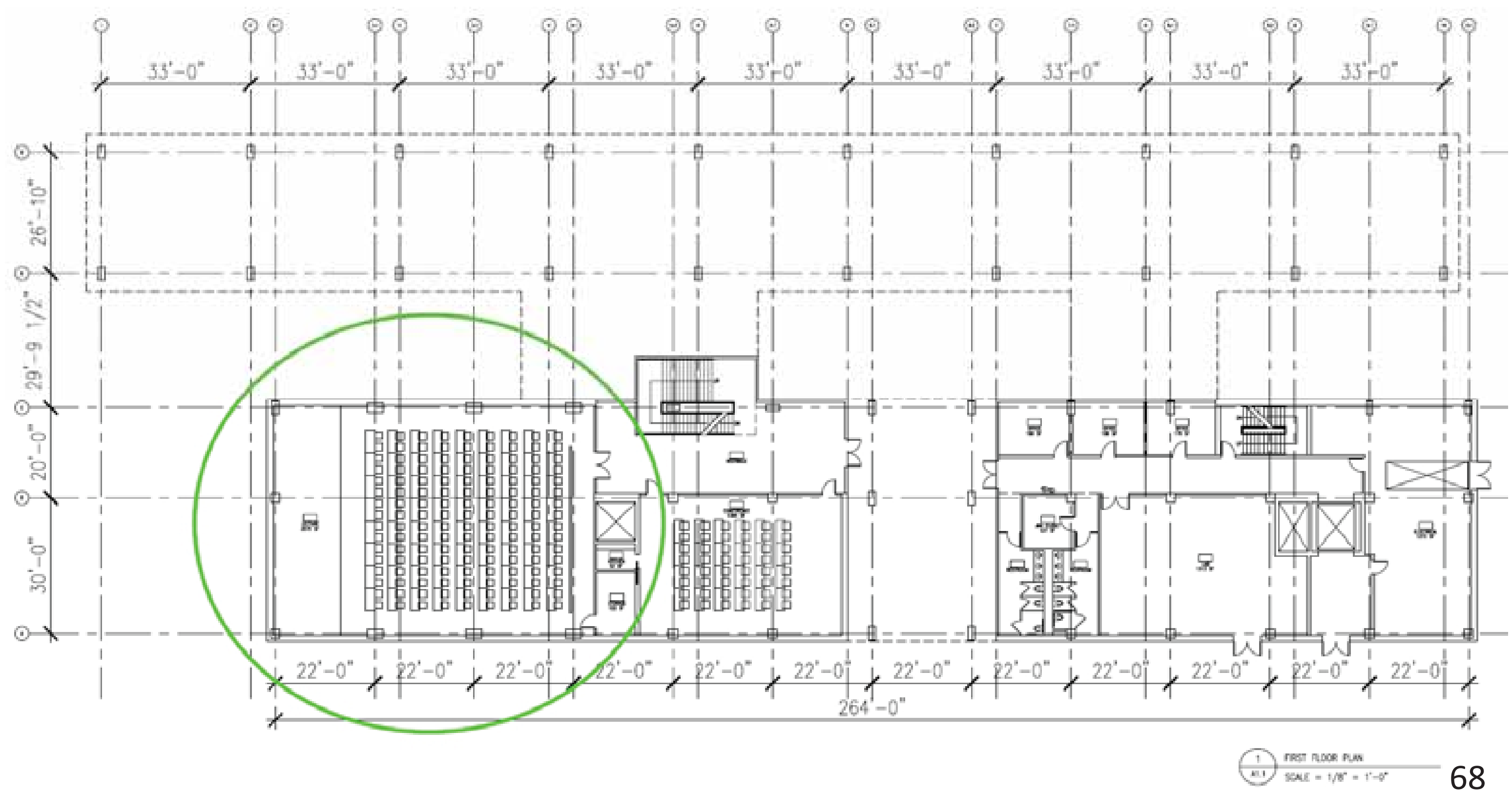


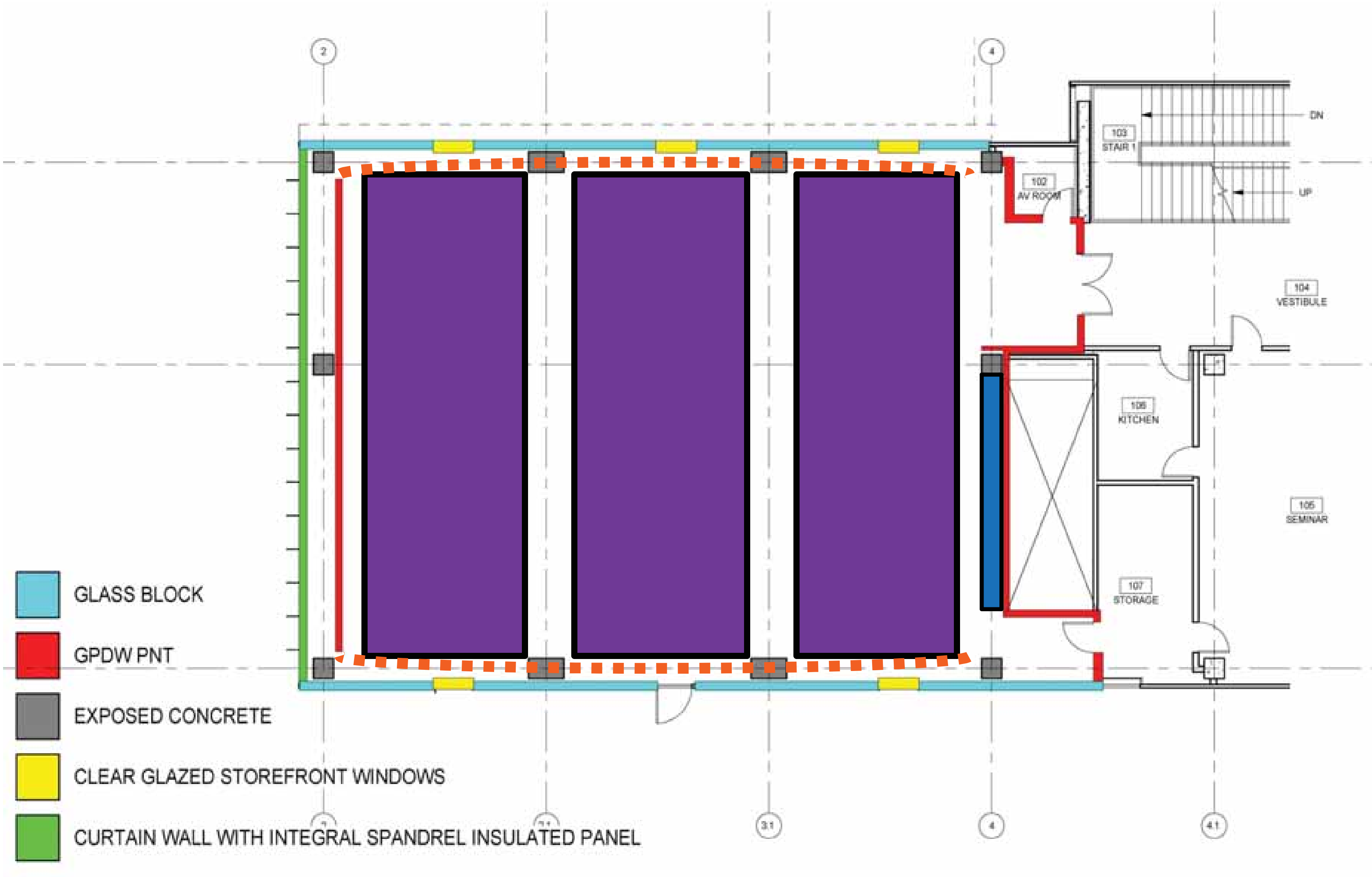
Case Study
Lecture Hall at Rice University’s Brockman Hall for Physics

- Brockman Hall: ~110 ksf facility, LEED Gold certified.
- Laboratories to support work in atomic, molecular and optical physics; biophysics; condensed matter physics; nanoengineering and photonics.
- Ground level seminar classroom and main lecture hall.
- Student-Centered Active Learning at Rice (or "SCAL@R") features students in small discussion groups instead of the traditional seating in a large lecture hall, with the aim of improving student interest and retention of material.

Main Objectives

- Design to achieve LEED credit, 1 pt (2009-NC, Innovation in Design)
- Assure room's acoustics properly support learning environment

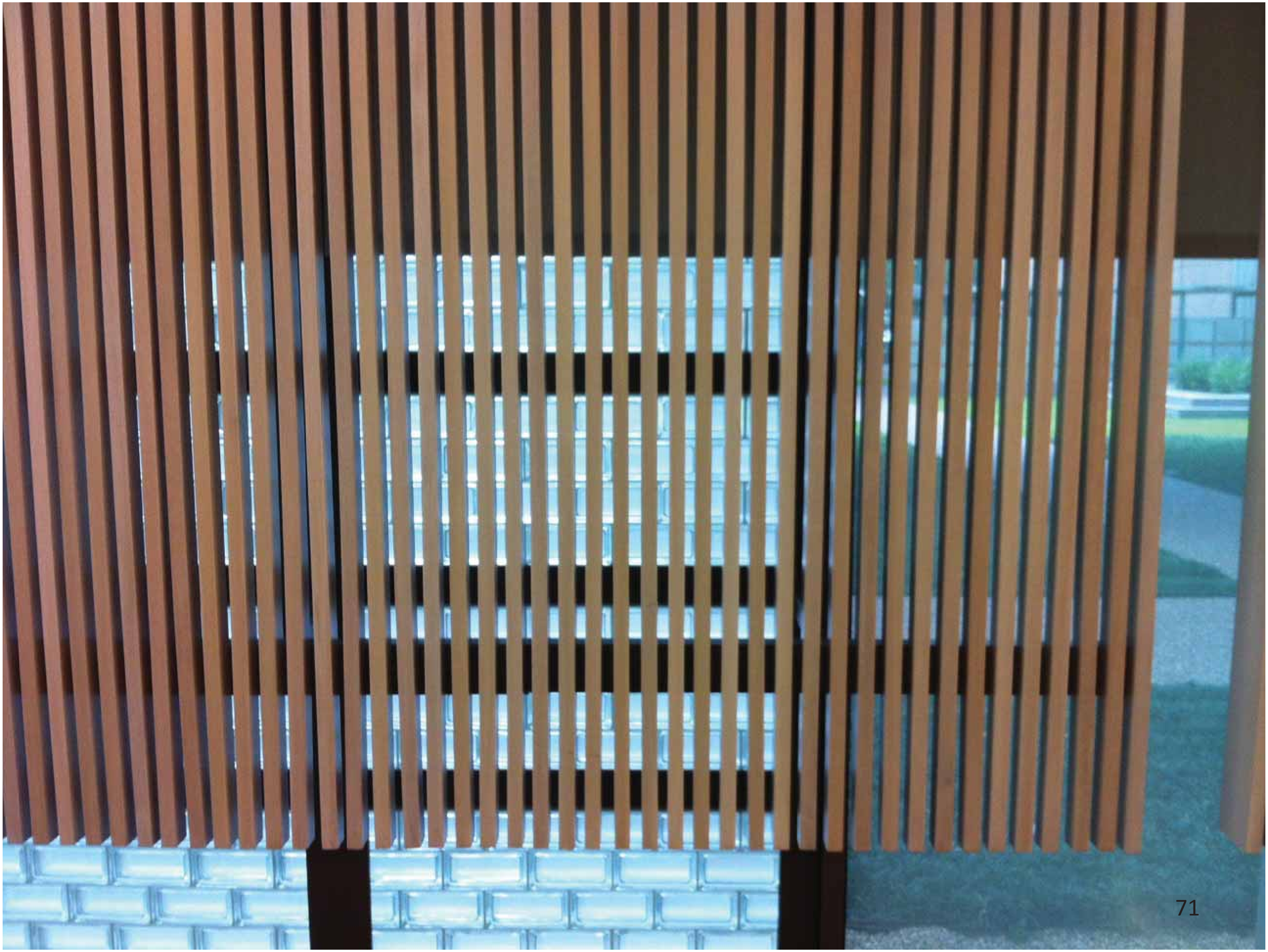




Absorptive rear wall; acoustical panels controls reflections.

Diffusive side walls; wood lattices control reflections and allow daylight.

Absorptive ceiling; acoustical plaster controls reverberation.




LEED for Schools (v.3 2009) referenced ANSI/ASA S12.60-2010/Part 1

"Design guidelines for controlling reverberation in classrooms and other learning spaces"

Table 1 — Limits on A- and C-weighted sound levels of background noise and reverberation times in unoccupied furnished learning spaces

Learning space [a)]	Greatest one-hour average A- and C-weighted sound level of exterior-source background noise [b), f)] (dB)	Greatest one-hour average A- and C-weighted sound level of interior-source background noise [c), f)] (dB)	Maximum permitted reverberation times for sound pressure levels in octave bands with midband frequencies of 500, 1000, and 2000 Hz (s)
Core learning space with enclosed volume ≤ 283 m^3 (≤ 10 000 ft^3)	35 / 55	35 / 55	0.6 s [e)]
Core learning space with enclosed volume > 283 m^3 and ≤ 566 m^3 (> 10 000 ft^3 and ≤ 20 000 ft^3)	35 / 55	35 / 55	0.7 s
Core learning spaces with enclosed volumes > 566 m^3 (> 20 000 ft^3) and all ancillary learning spaces	40 / 60 [d)]	40 / 60 [d)]	No requirement

a) See 3.1.1.1 and 3.1.1.2 for definitions of core and ancillary learning spaces.

b) The greatest one-hour average A- and C-weighted interior-source and the greatest one-hour average A- and C-weighted exterior-source background noise levels are evaluated independently and will normally occur at different locations in the room and at different times of day.

c) See 5.2.2 for other limits on interior-source background noise level.

d) See 5.2.3 for limits in corridors adjacent to classrooms.

e) See 5.3.2 for requirement that core learning spaces ≤ 283 m^3 (≤ 10 000 ft^3) shall be readily adaptable to allow reduction in reverberation time to 0.3 s.

f) The design location shall be at a height of 1 m above the floor and no closer than 1 m from a wall, window, or fixed object such as HVAC equipment or supply or return opening. See A.1.3 for measurement location.

Annex C states for larger room volumes, "reverberation times usually are greater than in small classrooms, with values of 0.7 s to 1.1 s in occupied rooms not uncommon.

NRC-CNRC Construction Technology Update No. 51
"Acoustical Design of Rooms for Speech" by J.S. Bradley

Table 1. Maximum ambient noise levels and optimum reverberation times (RT) for good speech intelligibility

Example Situations	Maximum noise		RT
	dBA	NC	
Primary school classroom Boardroom for elderly adults	30	23	0.5
Law court	30	23	0.5
High school classroom General meeting room	35	28	0.7
Large lecture hall theatre	30	23	0.7

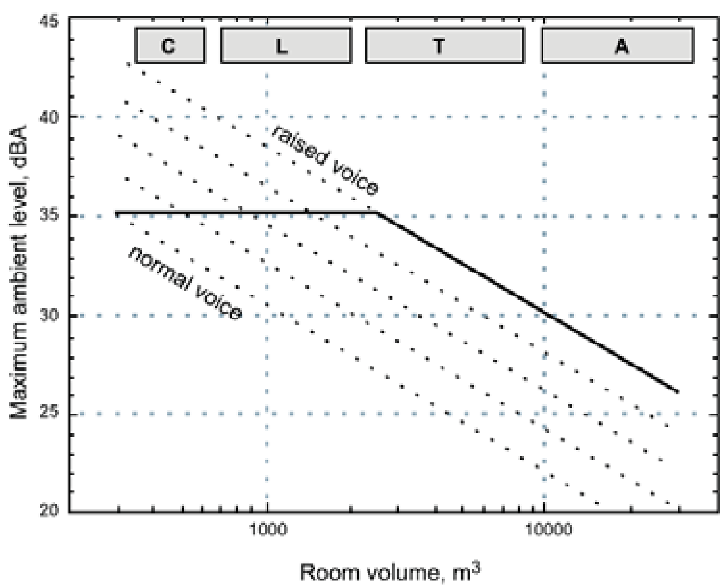


Figure 2. Maximum ambient noise level goals (solid line) (C=classrooms, L=lecture halls, T=theatres, A=large auditoriums)

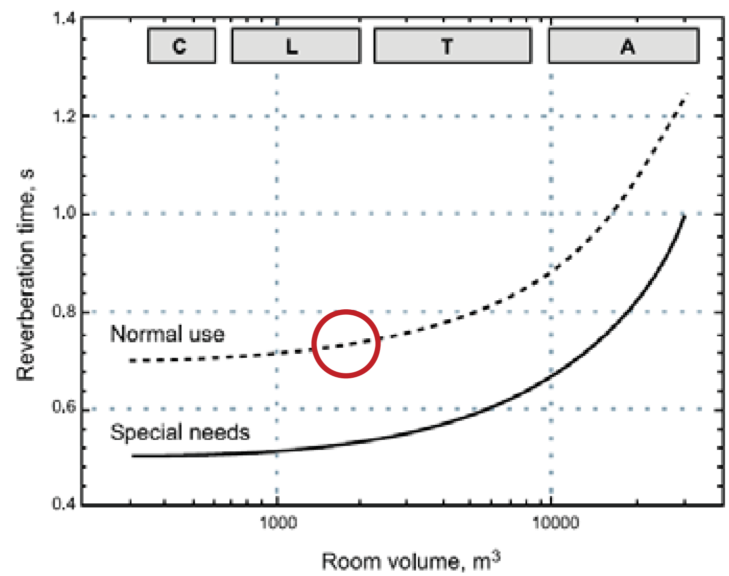
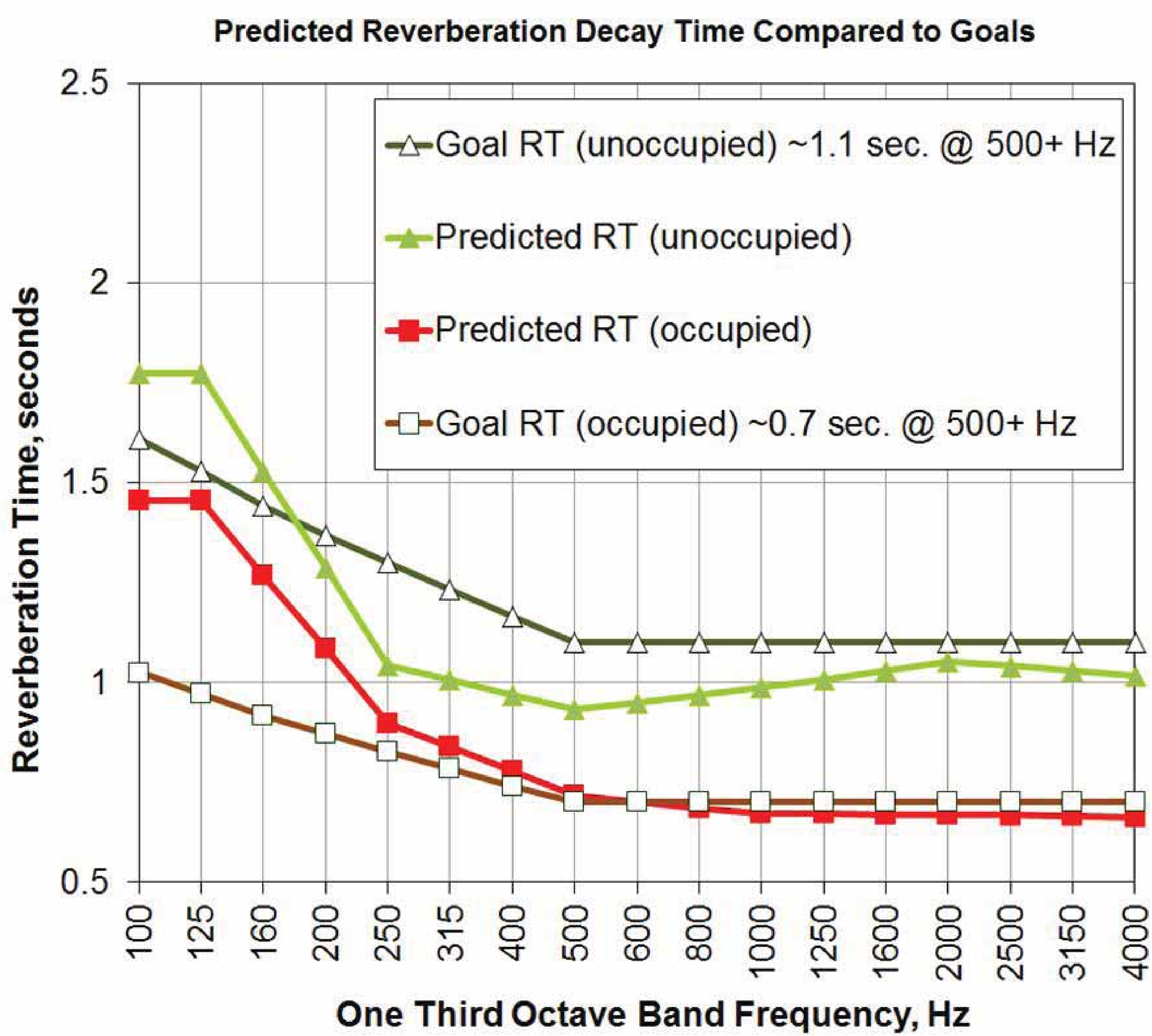
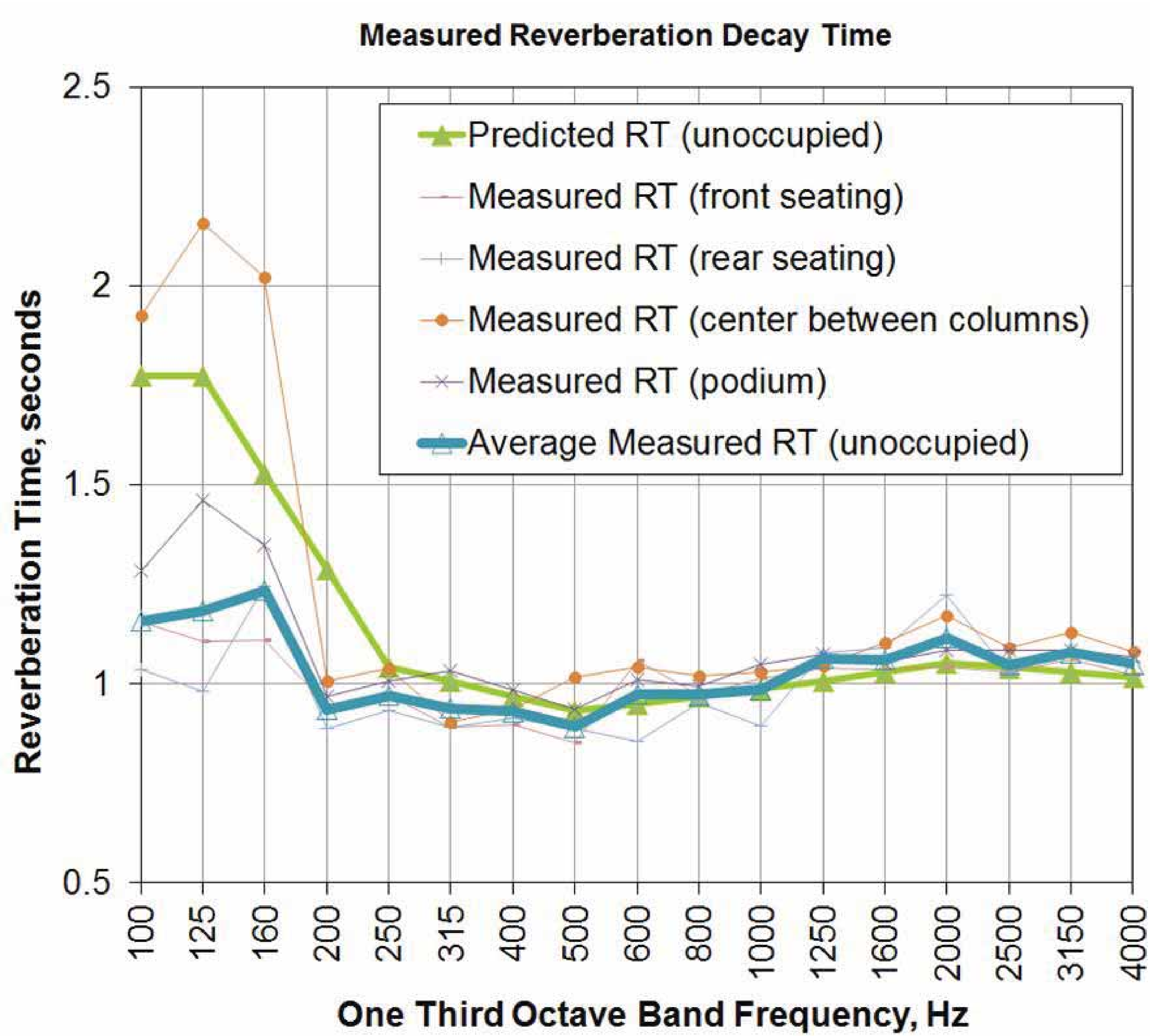
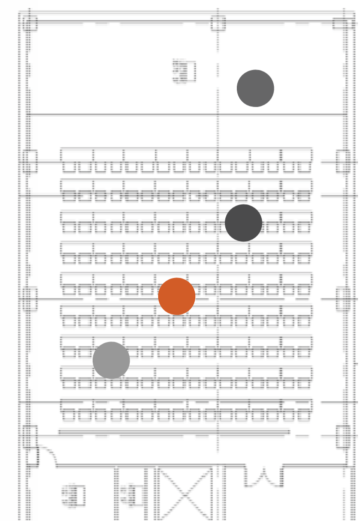


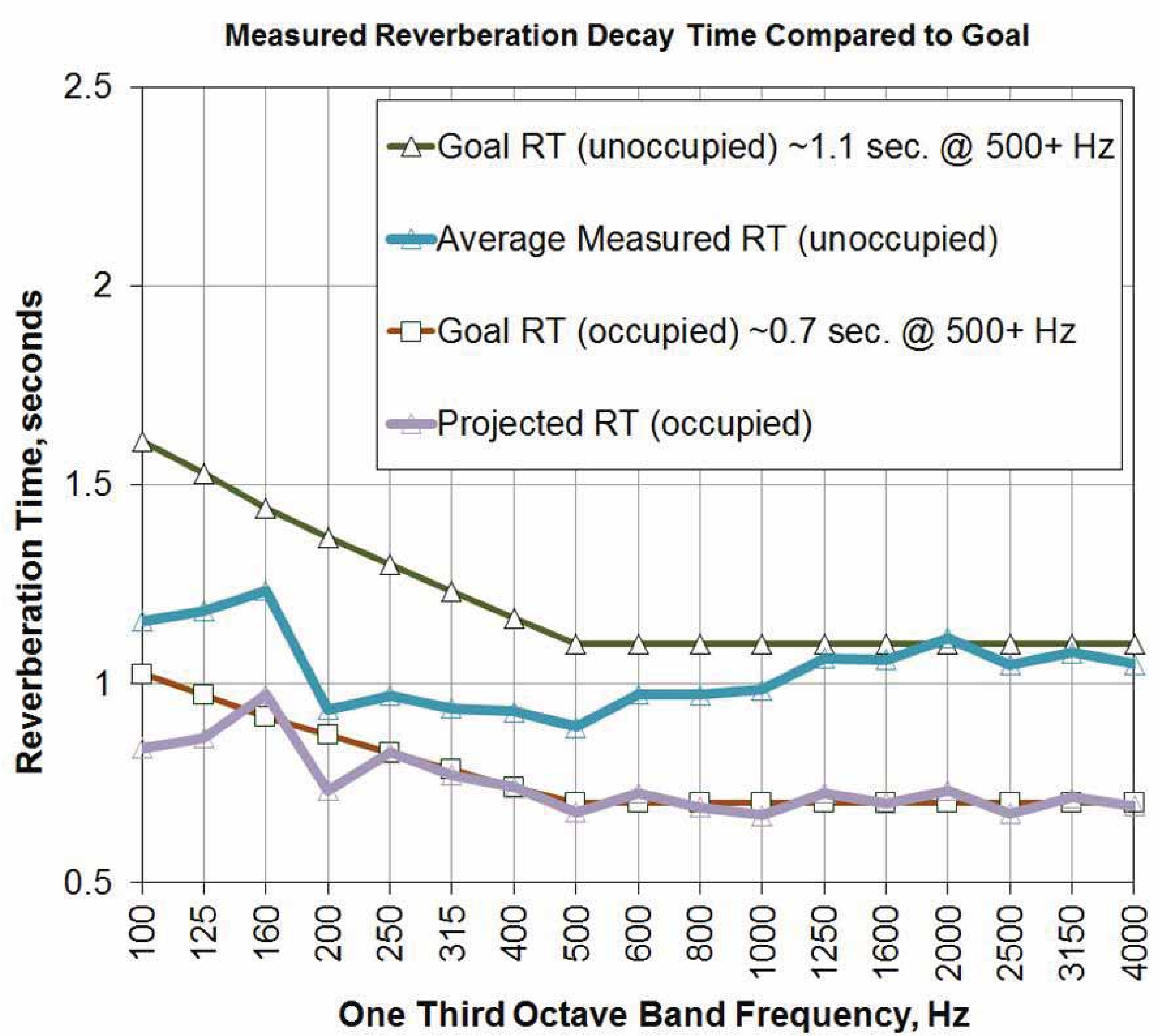
Figure 3. Mid-frequency (500 to 2k Hz) reverberation time design goals (C=classrooms, L=lecture halls, T=theatres, A=large auditoriums)



Predicted Reverberation Decay Time Compared to Goals
Goal RT (unoccupied) ~1.1 sec. @ 500+ Hz
Predicted RT (unoccupied)
Predicted RT (occupied)
Goal RT (occupied) ~0.7 sec. @ 500+ Hz
Reverberation Time, seconds
2.5
2
1.5
1
0.5
100
125
160
200
250
315
400
500
600
800
1000
1250
1600
2000
2500
3150
4000
One Third Octave Band Frequency, Hz


Measured Reverberation Decay Time
Reverberation Time, seconds
2.5
2
1.5
1
0.5
Predicted RT (unoccupied)
Measured RT (front seating)
Measured RT (rear seating)
Measured RT (center between columns)
Measured RT (podium)
Average Measured RT (unoccupied)
100
125
160
200
250
315
400
500
600
800
1000
1250
1600
2000
2500
3150
4000
One Third Octave Band Frequency, Hz




Measured Reverberation Decay Time Compared to Goal
Goal RT (unoccupied) ~1.1 sec. @ 500+ Hz
Average Measured RT (unoccupied)
Goal RT (occupied) ~0.7 sec. @ 500+ Hz
Projected RT (occupied)
Reverberation Time, seconds
2.5
2
1.5
1
0.5
100
125
160
200
250
315
400
500
600
800
1000
1250
1600
2000
2500
3150
4000
One Third Octave Band Frequency, Hz

Case Studies: high plume exhaust fans

Air and fume dilution bells

In-line mixed flow fans and motors

Mixing plenum and bypass air inlets

Roof mounted high plume dilution exhaust fans

Case Studies: high plume exhaust fans


Case A: Forensic Sciences – 3 stories


Case B: Biomedical Research – 12 stories

Case Studies: high plume exhaust fans

Case A: Forensic Sciences – 3 stories

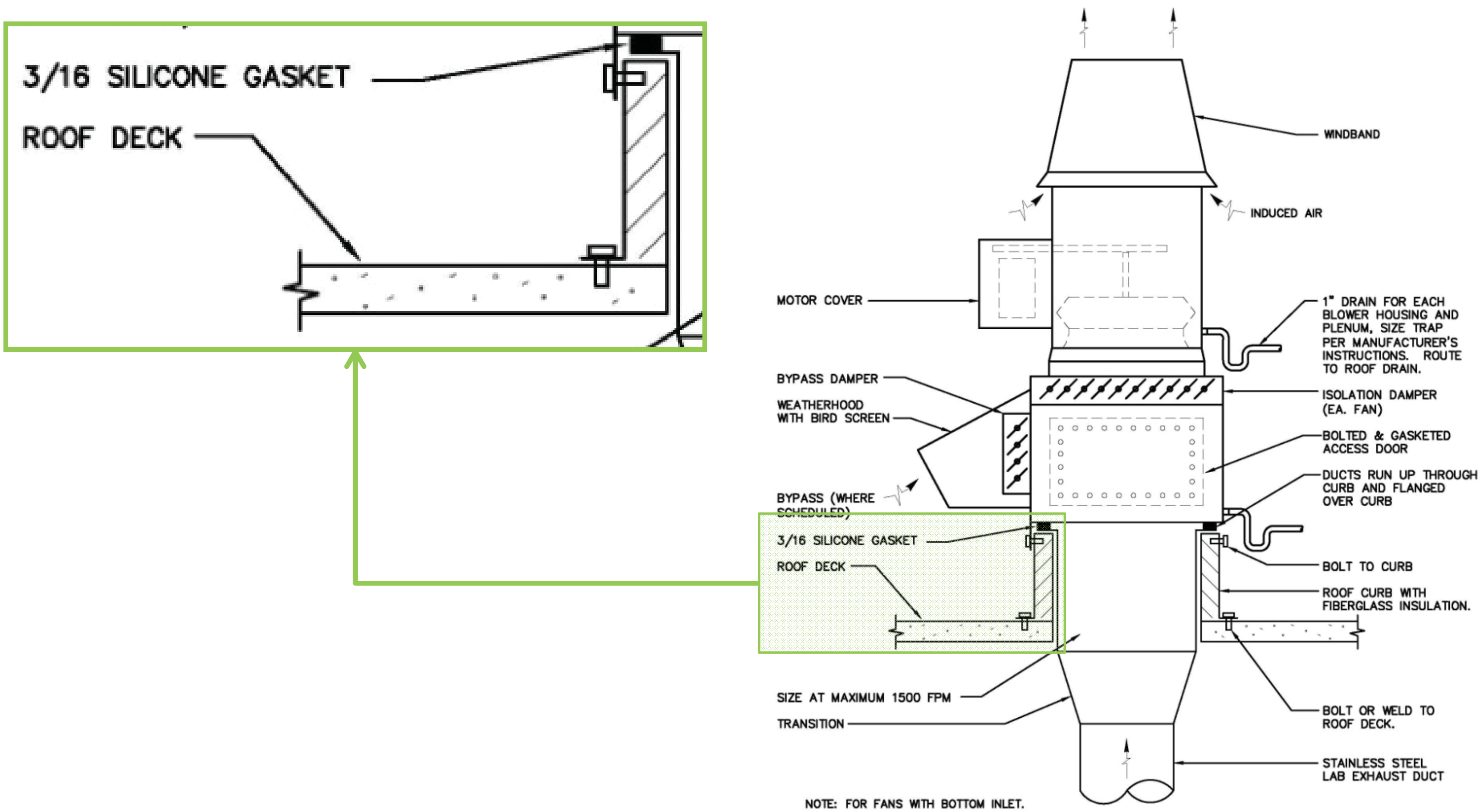
Case B: Biomedical Research – 12 stories

Case Studies: high plume exhaust fans

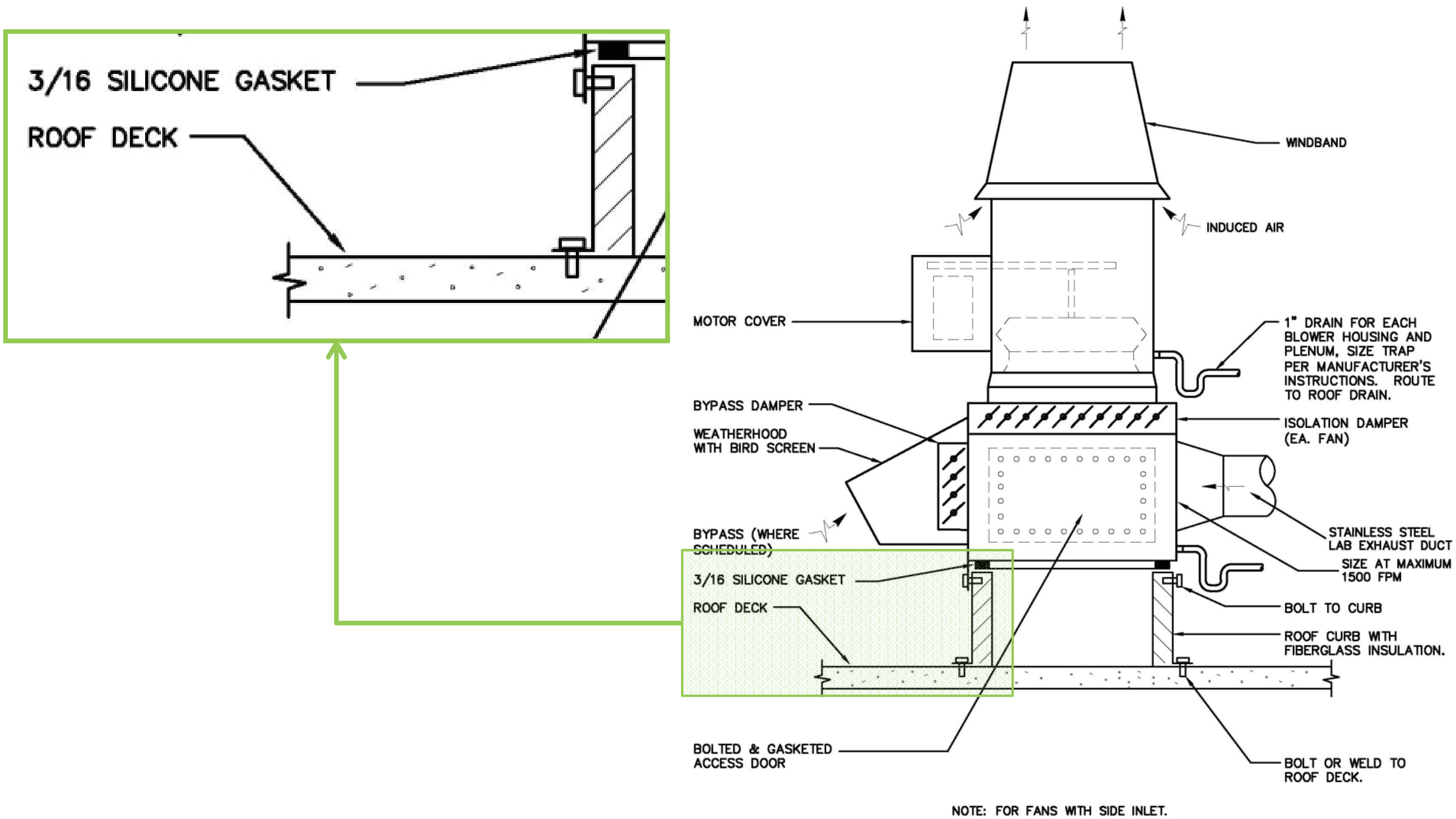
Both case studies:

- Similar pan-joist concrete floor structures
- Similar floor vibration design goals of VC-A 50 μm/s for microbalances and microscopes
- Fan sizes at 15, 20, 40, and 50 hp.
- Flow volume of ~10,000 to 20,000 cfm.

Case A: photo of high plume exhaust fans on the roof with bottom inlet



Case A: roof installation detail of non-isolated fan and bottom-inlet mixing plenum on curb

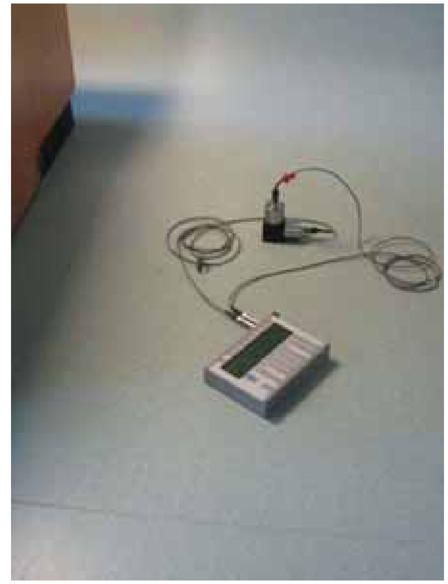
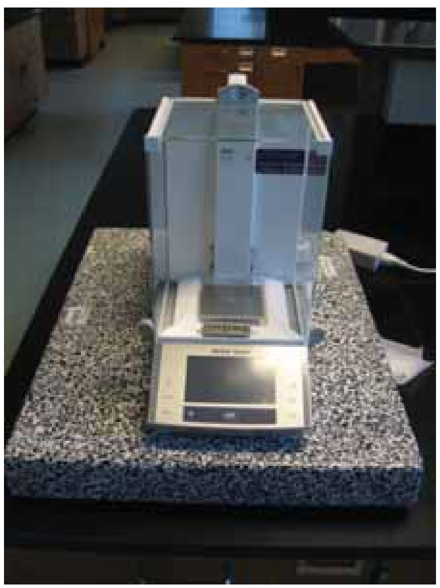


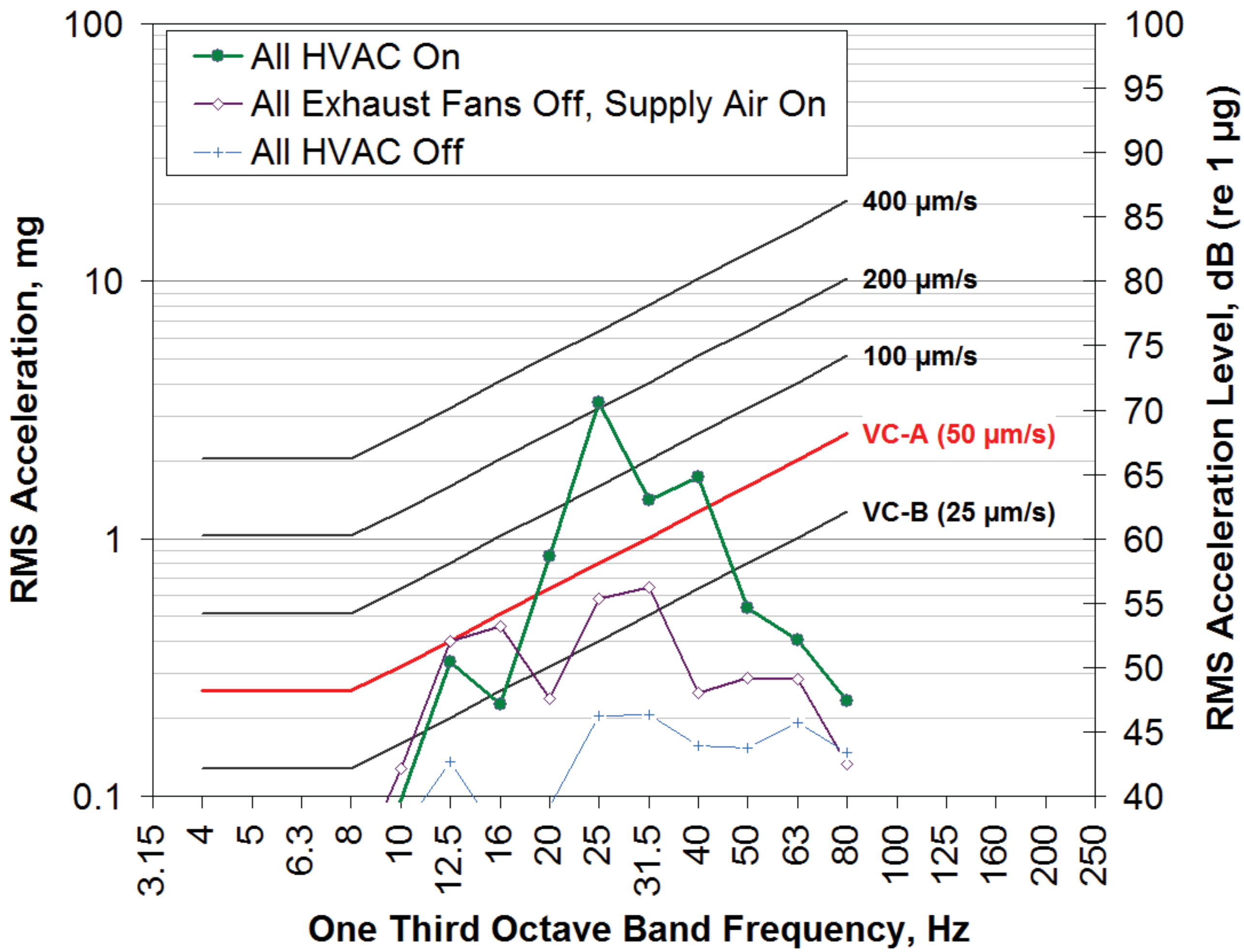
Case B: roof installation detail of non-isolated fan and side-inlet mixing plenum on curb

Case B: photo of exhaust fans on the roof with side inlet ducts

Standard Vibration Isolation for High Plume Fans

- Fan manufacturers typically recommend that the fan plenum be mounted on a 1.5" wide strip of 1/4" neoprene or silicon pad or gasket. No further vibration isolation is required or recommended! **Why? Stability concerns? Flex ducts failing?**
- Claims are made that fans are balanced to below 0.013 mm, with measurements on the roof base as low as 0.003 mm in the vertical direction. **Not really possible, we have learned.**
- Claims have been made that at the fan frequency of 1170 RPM, the standard vibration pad (with 0.1" static deflection) will have an efficiency well over 90%. **Not true… Maybe 80%. Anyway we tend to get flanking around the isolation pad.**

Case A: initial lab floor vibration under microbalance bench locations

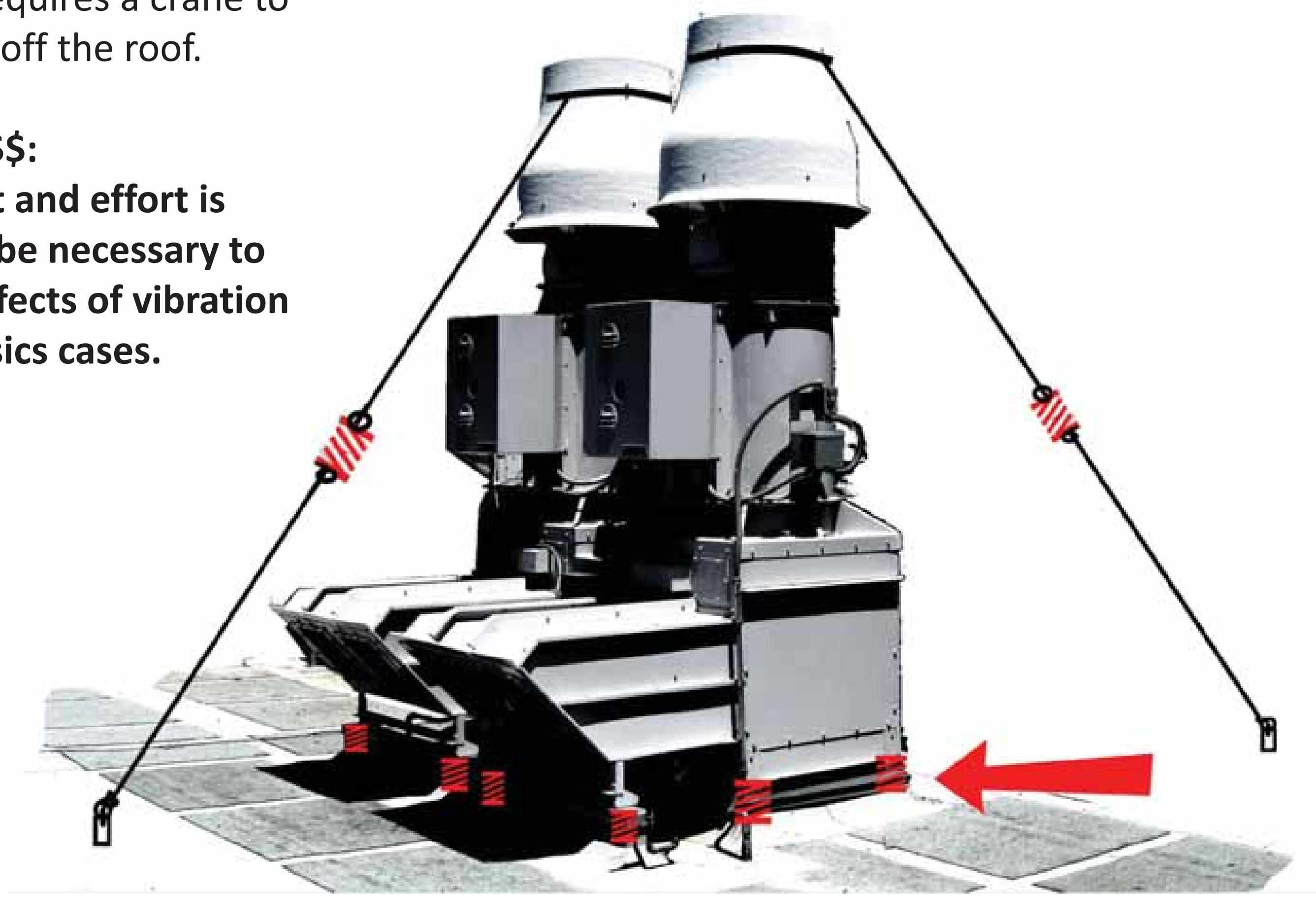
Fan and Motor Balancing & Rebalance

- In Case A, equipment was rebalanced to ISO 1940-1* Balance **Grade G 2.5** (2.5 mm/s velocity) rather than the standard **Grade G 6.3** (6.3 mm/s velocity). Vibration measurements were redone after rebalancing. Building vibration was **reduced by 8-10 decibels** in many locations on the top floor.
- In Case B, the owner determined balancing to Grade G 2.5 was not practical. Rebalancing to **Grade 6.3 was done, with efforts to approach Grade 2.5**. Building vibration was **reduced by 3-12** dB in some locations, but was **not reduced at all in many other locations**.
- In both cases, equipment vibration would be expected to creep to higher levels over time as fans or motors would eventually become less balanced as a result of normal operation. More permanent solutions were desired.

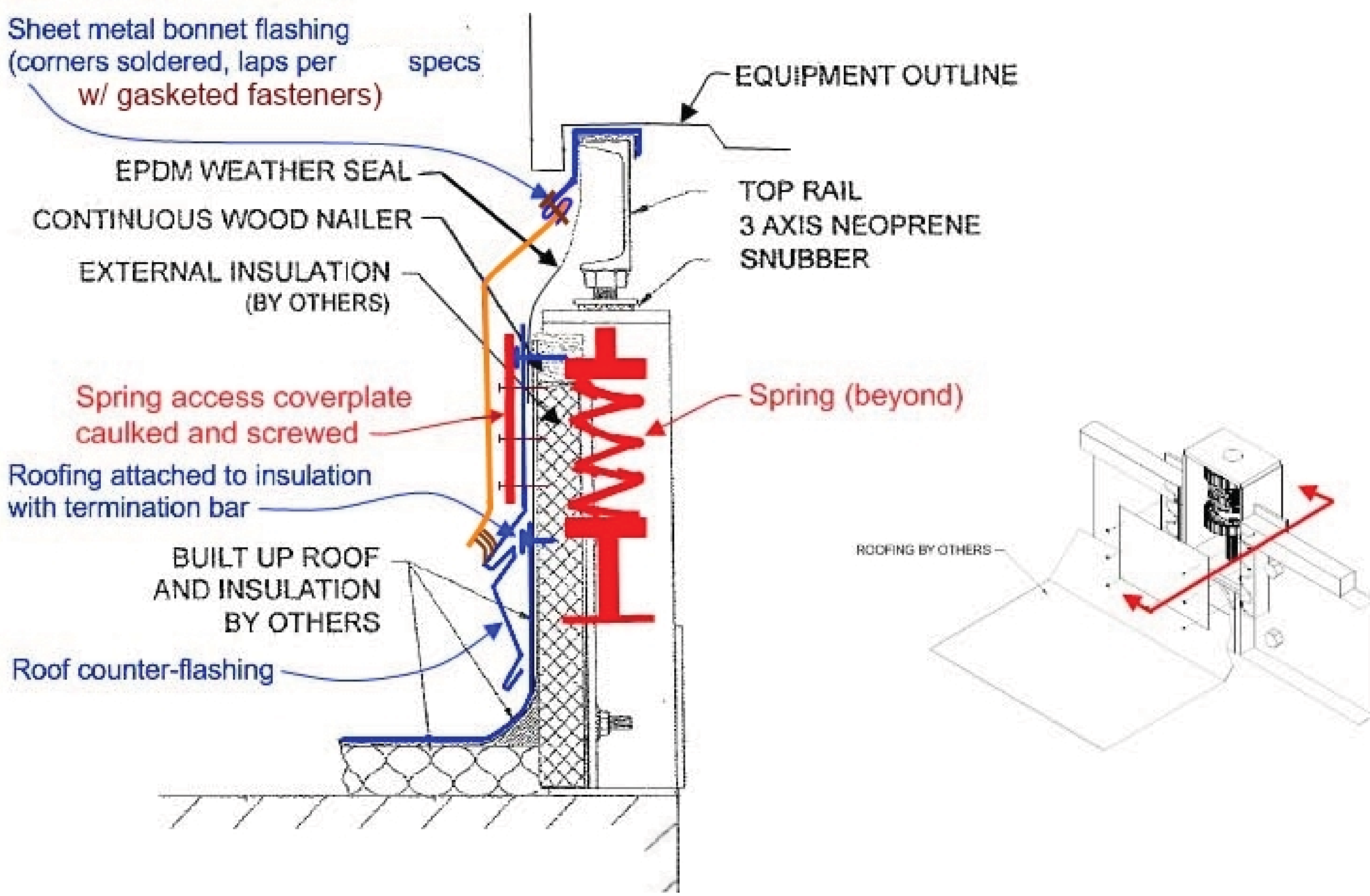
* ISO 1940-1:2003(E) Mechanical vibration - Balance quality requirements for rotors in a constant (rigid) state.

Adding springs requires a crane to lift the fans off the roof.

$$$:
The high cost and effort is determined to be necessary to avoid adverse effects of vibration on forensics cases.

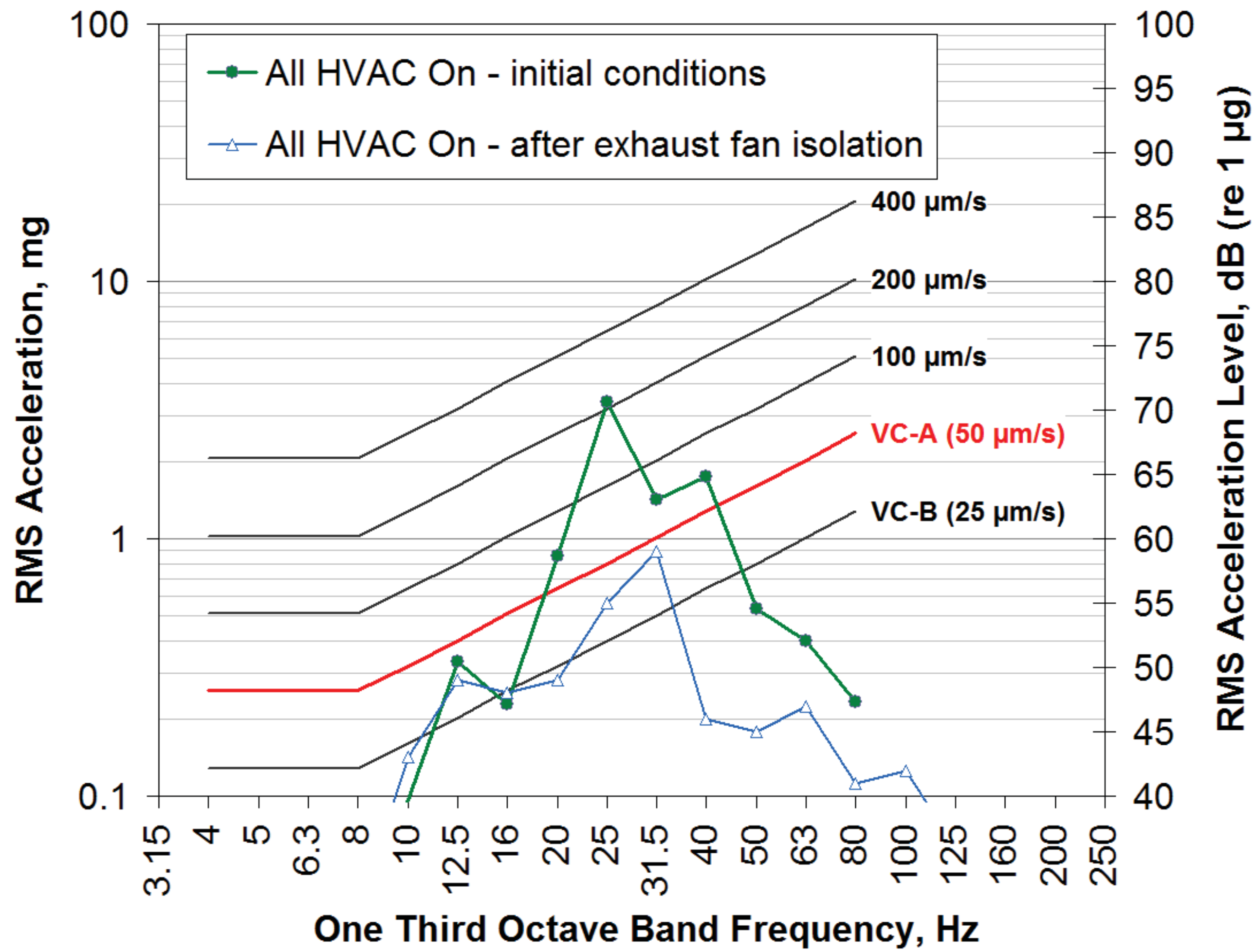


Case A: proposed retrofit of spring isolators at roof curb and guy wires



Case A: Section detail of spring curb, showing flashing and seals for water protection

Case A: photos after installation (Note: the new guy wires and flashing)



Case A: floor vibration under microbalance bench locations before and after fan isolation

Table 1 – Case A: floor vibration results before and after fan isolation.

(See **KEY**, below)			Vibration dB above or below VC-A (50 µm/sec) criterion at floor slab locations					
			After fan isolation			Previous conditions*		
Room	Tag	Change (Lmax)		Maximum transient (Lmax)	Average continuous (Leq)		Maximum transient (Lmax)	Average continuous (Leq)
L3021	3-1F	-3	● (green)	-1	-10	● (blue)	2	-6
L3021	3-2F	-6	● (green)	-1	-6	● (red)	5	2
L3022	3-3F1	-2	● (green)	-5	-14	● (green)	-3	-8
L3043	3-7F1	+2	● (blue)	3	-4	● (blue)	1	-5

KEY

● (green)	Green: vibration achieves criteria (acceptable)
● (blue)	Blue: vibration marginally achieves criteria (acceptable)
● (red)	Red: vibration exceeds criteria (unacceptable)

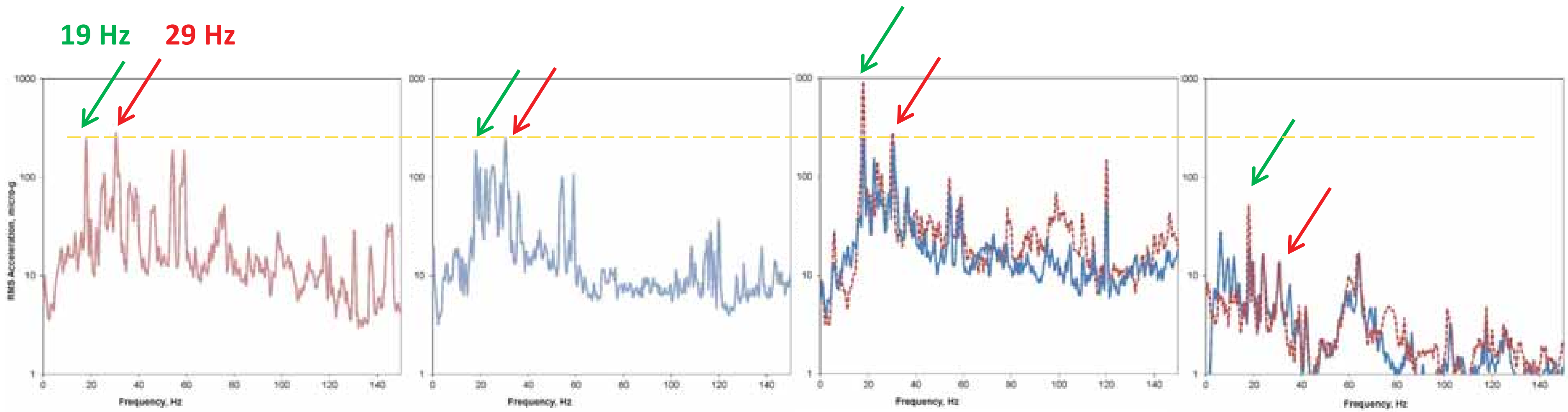
Table 2 – Case A: casework surface vibration results before and after fan isolation.

(See **KEY**, above)			Vibration dB above or below microbalance 2 mg criterion at bench locations					
			After fan isolation			Previous conditions*		
Room	Tag	Change (Lmax)		Maximum transient (Lmax)	Average continuous (Leq)		Maximum transient (Lmax)	Average continuous (Leq)
L3021	3-1C1	-7	● (green)	-2	-11	● (red)	5	0
L3021	3-1C2	-10	● (green)	-6	-10	● (red)	4	-2
L3021	3-1C3	-25	● (green)	-11	-15	● (red)	14	7
L3021	3-1C4	-13	● (green)	-16	-21	● (green)	-3	-6
L3021	3-1C5	-8	● (green)	-6	-13	● (blue)	2	-3
L3021	3-2C1	-10	● (green)	0	-4	● (red)	10	5
L3021	3-2C2	-11	● (green)	-10	-17	● (red)	1	0
L3022	3-3C1	-12	● (green)	-17	-23	● (green)	-5	-7
L3022	3-3C2	-11	● (green)	-13	-16	● (green)	-2	-3
L3022	3-3C3	-7	● (green)	-14	-19	● (green)	-7	-9
L3043	3-7C1	-3	● (green)	-5	-11	● (red)	2	0
L3043	3-7C2	+2	● (green)	-4	-10	● (green)	-6	-13
L3043	3-7C3	-5	● (green)	-9	-13	● (green)	-4	-8
L3043	3-7C4	-21	● (green)	-8	-15	● (red)	13	5

*After the fan equipment was rebalanced to Balance Grade 2.5.

No Retrofit Vibration Isolation

- In Case B, vibration affected all floors, but not all locations.
- It was not practical to install vibration isolation beneath existing fans.
- Instead, lab users on levels 1-12 of the building would purchase vibration isolation tables and pedestals for sensitive instruments as needed.



Level 12 Offices | Level 9 Research | Level 5 Research | Level 1 Electron microscopes

Conclusions: high plume exhaust fans

- Passive vibration isolation measures can be implemented for buildings that require low-level vibration environments (less than VC-A (50 µm/s rms)).
- Care is also needed to address potential flanking paths related to connected ducts, electrical conduits, wind restraints, seismic restraints, and moisture protection seals and flashing.
- Even with isolated fan and motor assemblies, areas at unsupported mid-bay locations away from beams and columns might show higher vibration than VC-A, and vulnerable areas like that should be recognized in lab layouts and facility design.
- Ground level slab-on-grade foundations would still be a more appropriate location for installations of **very** sensitive lab equipment, such as high-magnification and electron microscopes.

Housing Facilities

Topics

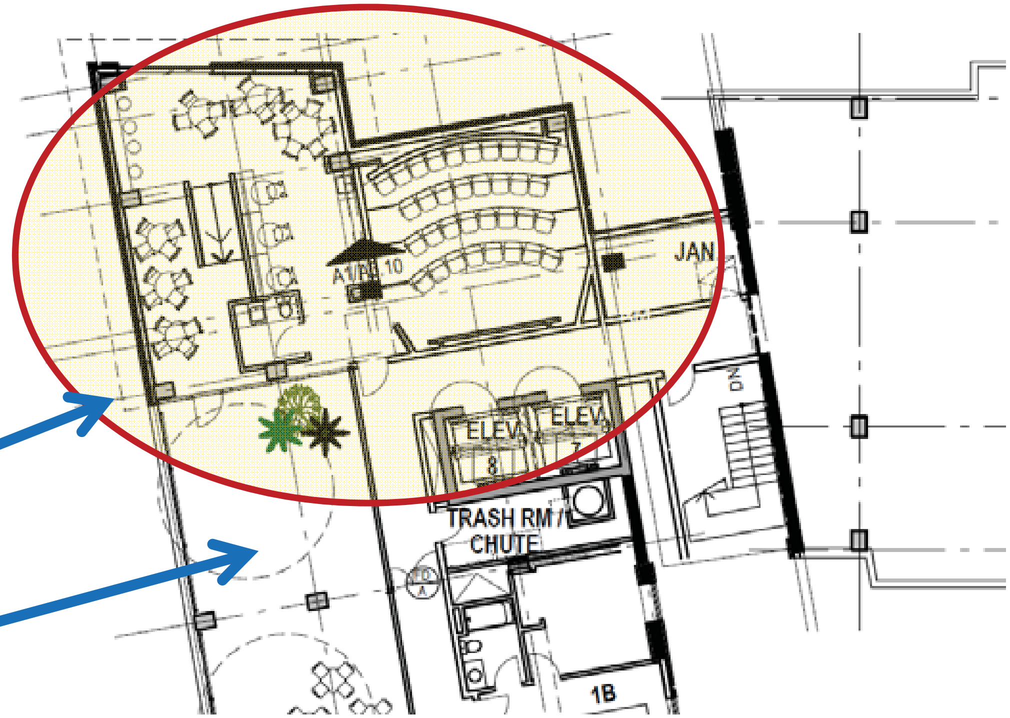
1. Density – issues for housing project planning
2. IBC & ICC – minimum code and other goals
3. STC – airborne sound and partitions
4. IIC – impact noise and floor types
   - Concrete floor structures
   - Wood floor structures
5. OITC – outdoor to indoor noise transmission
6. Mechanical equipment & parking

Density and noise

- **Infill / Campus** – tough sites near noisy transportation or entertainment use.
  - **Highways, airports, railroads, commuter rail or bus transit stations**
  - **Entertainment districts, parks plazas**
  - **Hospitals with helipads, industrial uses, rail yards**
  - Mostly these projects raise concerns for the building shell design and selection of windows, exterior doors, roof, and could also affect site/building layout, possibly ground borne vibration concerns.

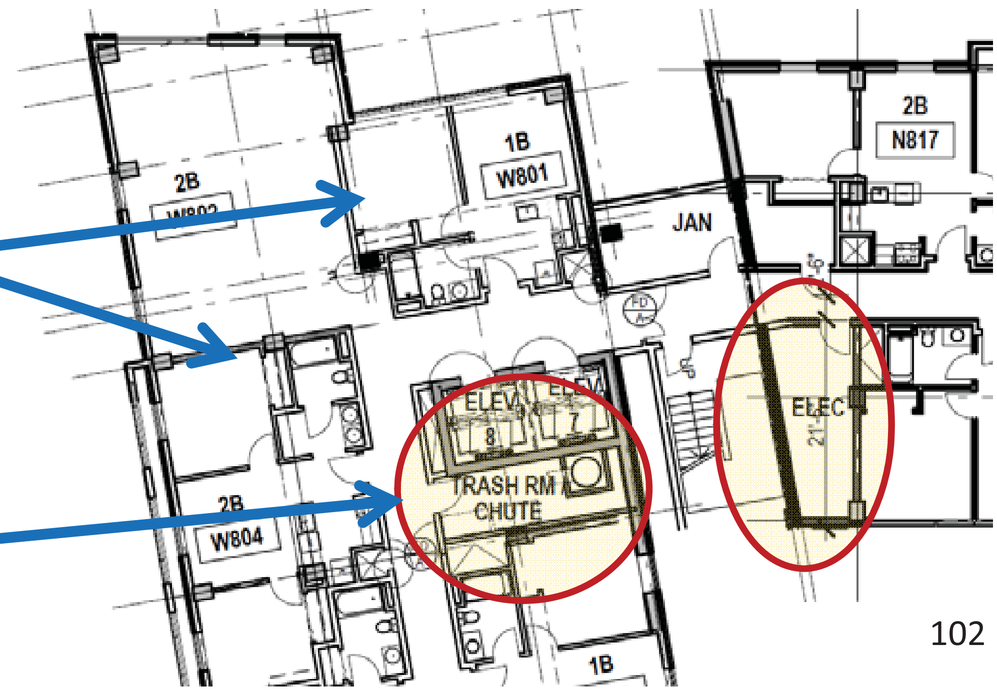
- **Mixed use / Amenities** – on-site adjacencies with noisy amenities or retail use.
  - **Fitness, game room, pool deck, roof terrace, parking garage**
  - **Student Union Retail, cafe, restaurant, kitchen, cinema, laundry**
  - **Mechanical equipment, electrical transformers, elevators, pumps**
  - These projects raise concerns for the interior floor ceilings and wall types and interior vibration impacts, but also often include concerns for the building shell (windows) near noisy outdoor uses.

Density and noise



movie / game room

roof terrace



living units below game and terrace

utilities

Design for density and noise

- Discuss with the owner & team to establish the budget and expectations. **Some things are just not possible to do successfully unless you have more money to spend on special construction**.

- ICC and IBC focus on separation of dwelling units, but do not address how to deal with off-site noise sources or challenging adjacencies with amenities or mechanical systems. **We have other guidelines by HUD/FHA, ASHRAE, WHO, LEED, etc., or you can do independent evaluations.**

International Building Code

SECTION 1207

SOUND TRANSMISSION

- **1207.1 Scope** – Applies to common interior walls, partitions and floor/ceiling assemblies between adjacent dwelling units or between dwelling units and adjacent public areas.

- **1207.2 Air-borne sound** – walls and floor/ceiling assemblies
  - **Sound transmission class (STC) not less than 50**
  - **FSTC 45 if field tested**
  - Penetrations or openings sealed, lined, insulated or otherwise treated.
  - Dwelling unit entrance doors shall be tight fitting to the frame and sill.

- **1207.3 Structure-borne sound** – floor/ceiling assemblies
  - **Impact insulation class (IIC) not less than 50**
  - **FIIC 45 if field tested**

International Code Council

ICC G2-2010

Guidelines for Acoustics

- **Scope** – addresses the acoustical performance of walls and floor/ceiling assemblies used to separate occupied spaces in multiple-family dwellings, and for certain commercial and health care settings such as closed offices, courtrooms and examination rooms for which acoustical privacy is necessary or expected.

- **Air-borne sound** – walls and floor/ceiling assemblies
  - **Sound transmission class (STC) not less than 55 acceptable; 60 preferred**
  - **NNIC (FSTC) 52 minimum if field tested; 57 preferred**

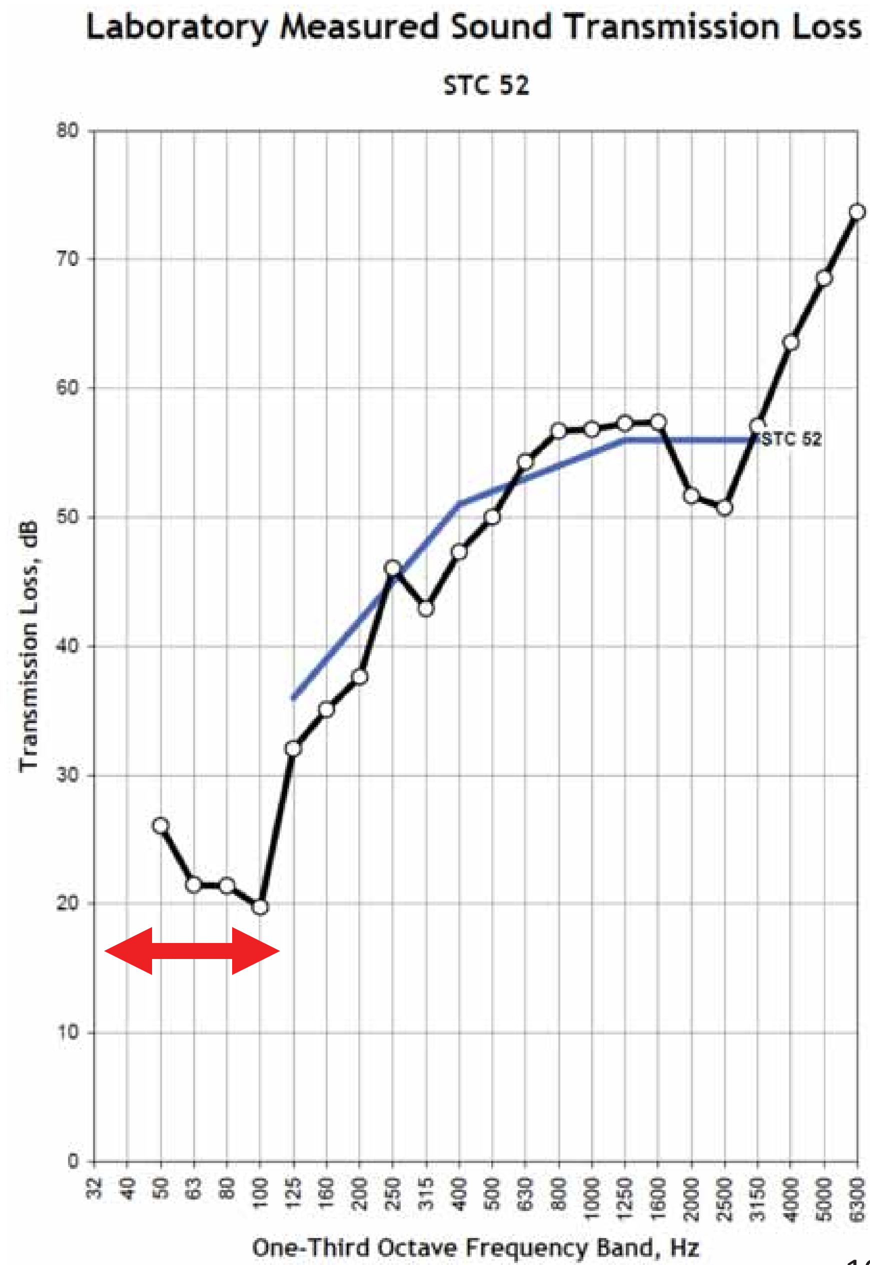
- **Structure-borne sound** – floor/ceiling assemblies
  - **Impact insulation class (IIC) not less than 55 acceptable; 60 preferred**
  - **NISR (FIIC) 52 minimum if field tested; 57 preferred**

Various criteria for low-cost apartments or dorms up to luxury units or condos

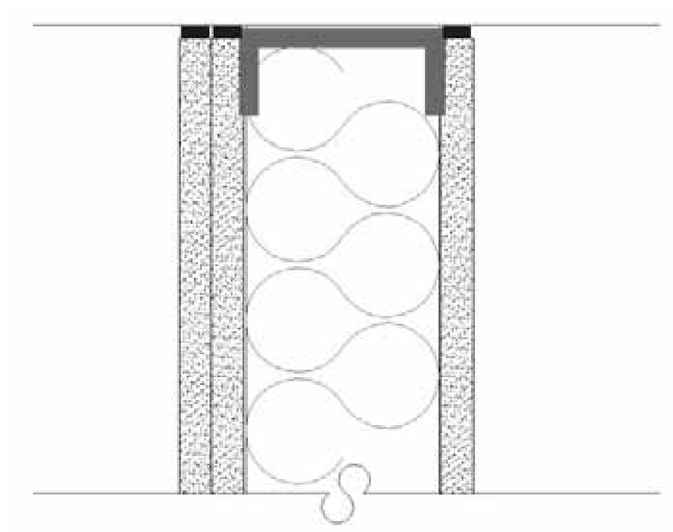
Class of Building	**STC**	**IIC**
Code Minimum (IBC)	50	50
Guideline (ICC) Class B "acceptable"	55	55
Minimum Quality / **Apartments**	**55**	**55**
Guideline (ICC) Class A "preferred"	60	60
Medium Quality / **Normal Condos**	**60**	**65**
High Quality / **High Quality Condos**	**65**	**75** ??

STC Rating

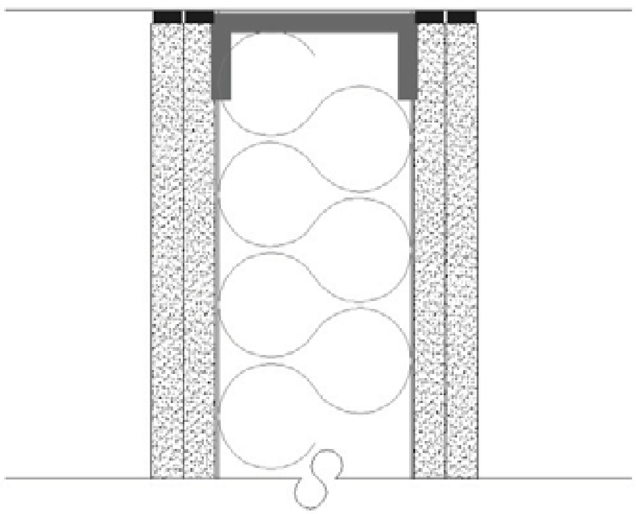
- STC rating is determined by performance measured between 125 Hz and 4000 Hz
- Low frequencies below 125 Hz are ignored in STC ratings, but can still have an impact on residential sound isolation quality
- **Music, TV, games, mechanical noise**



Barely achieving STC 50



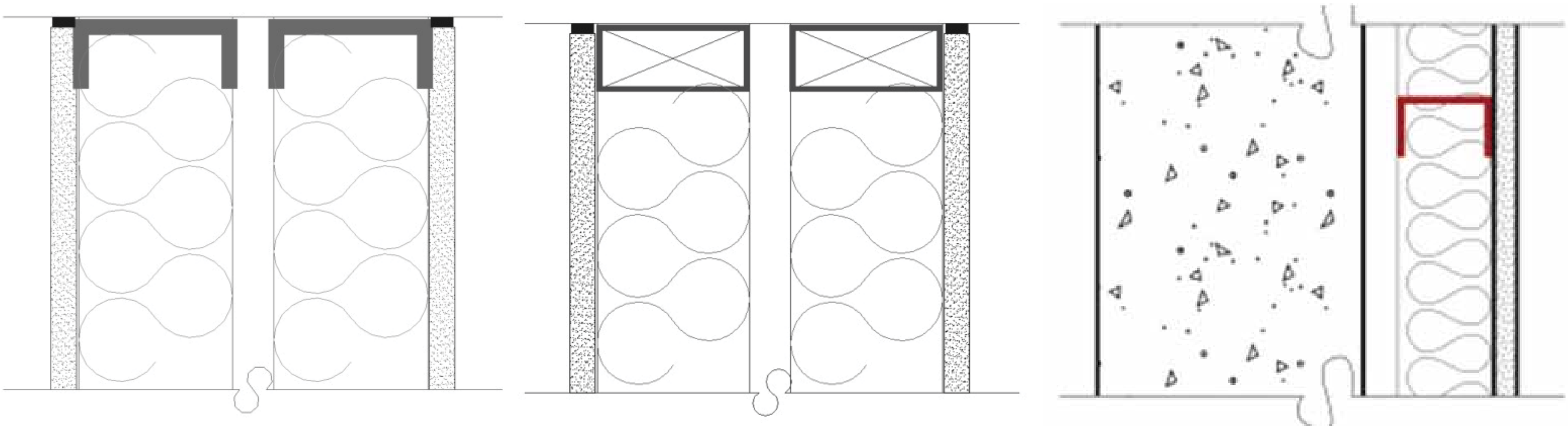
STC 44-54



STC 48-58

25-gauge metal studs
Light, flexible metal studs provide better noise isolation than structural studs or wood studs

Easily achieving STC 55+



STC 53-59

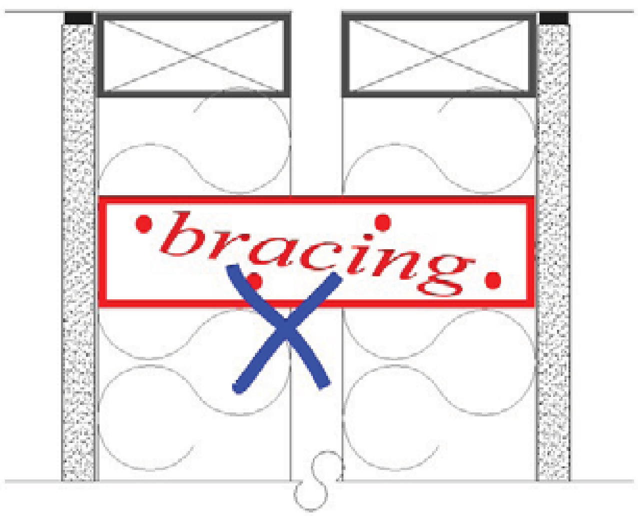
Nominal 1-inch air gap

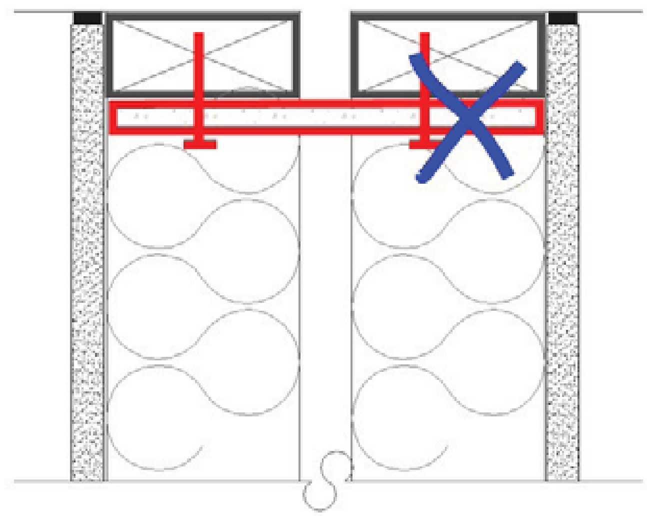
- The gap provides good structural decoupling regardless of stud type
- The deep cavity provides good low frequency sound isolation
- Additional layers of drywall can be added to achieve STC 60-65+

Systems that can affect field performance of partitions

- Structural bracing
- Fire safe and draft stop methods
- Plumbing systems
- HVAC, vents, exhaust, dryer vents
- Electrical and cable penetrations
- Unsealed drywall gaps (not caulked)

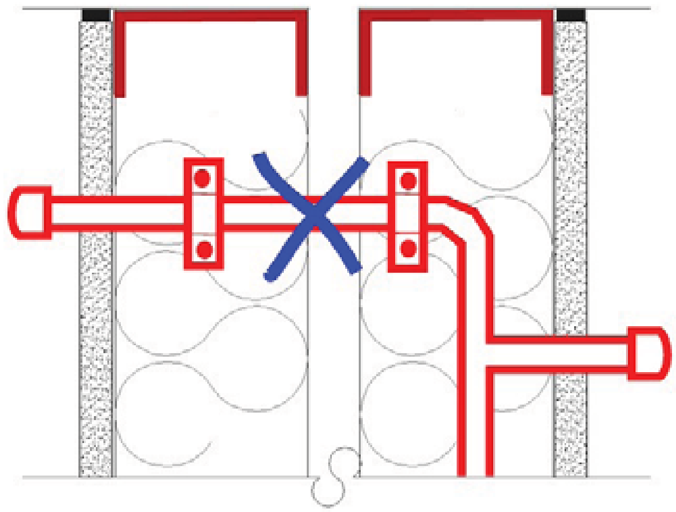
Avoid bridging and bracing

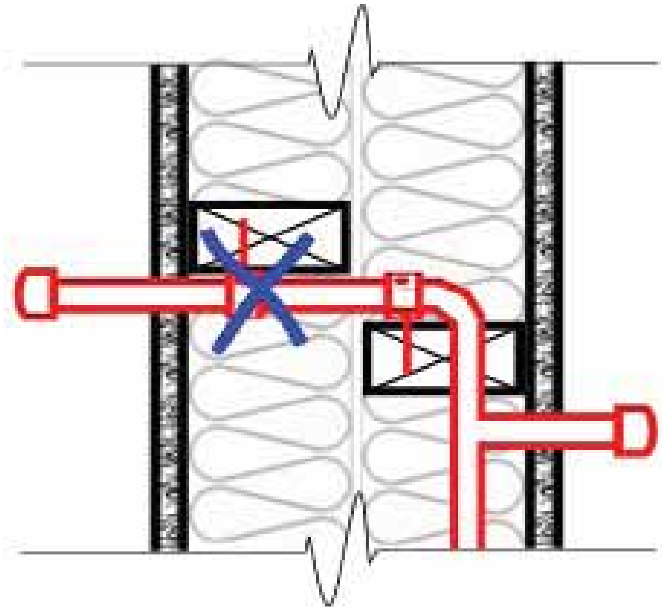




- **Bracing and rigid draft stop methods can reduce sound isolation by -5 or more STC points.**
- **Use flexible draft stop: mineral wool, resilient fire caulk/putty**
- **If bracing is required for structural, use alternative methods or resilient braces that do not compromise isolation.**

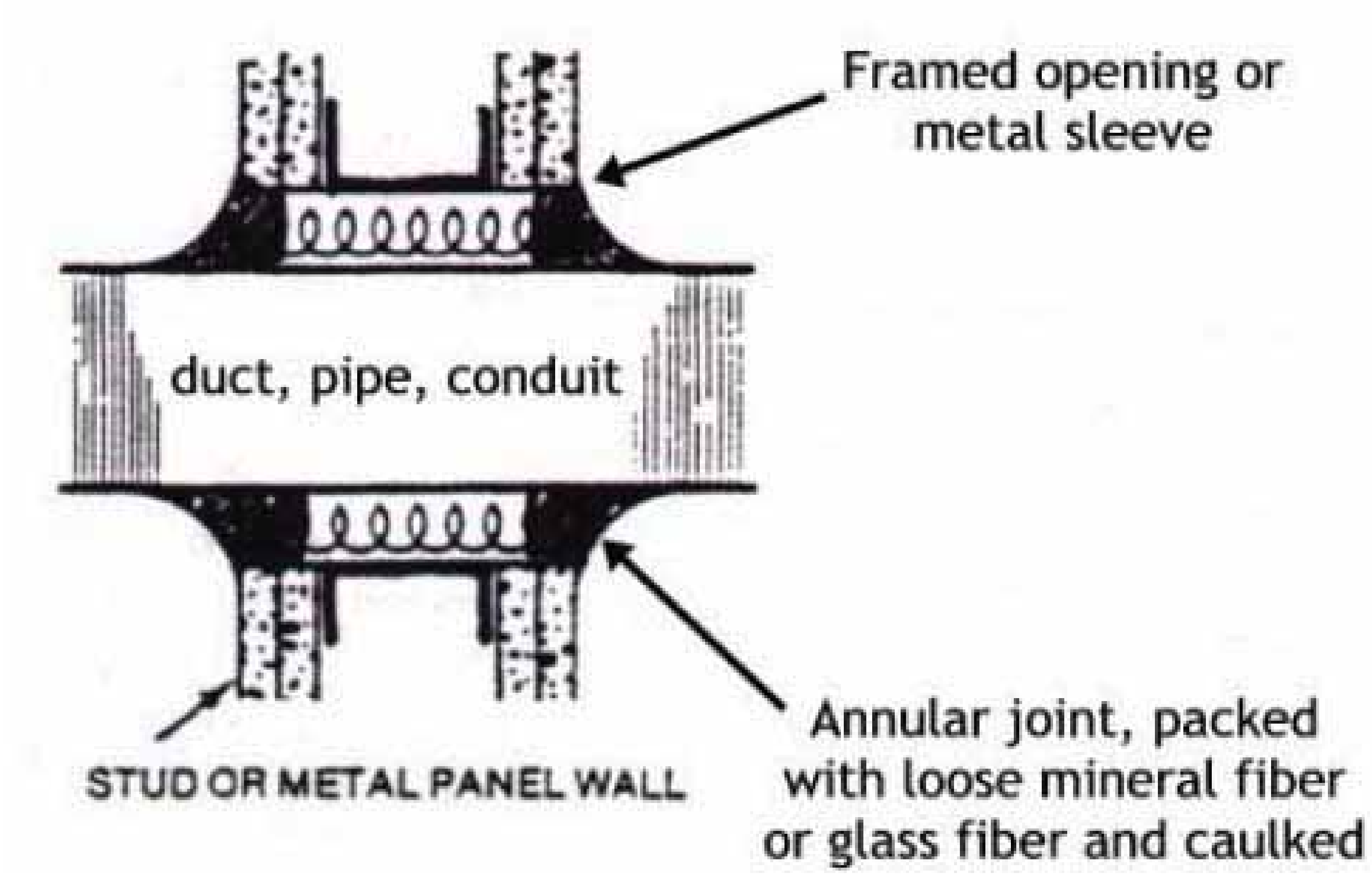
Provide separate plumbing runs





- Shared supply and wastewater lines can bridge isolated walls and can transmit plumbing noise between units.
- If plumbing must be shared, provide isolated piping mounts and design to reduce valve, flush, and wastewater noise.

Seal penetrations

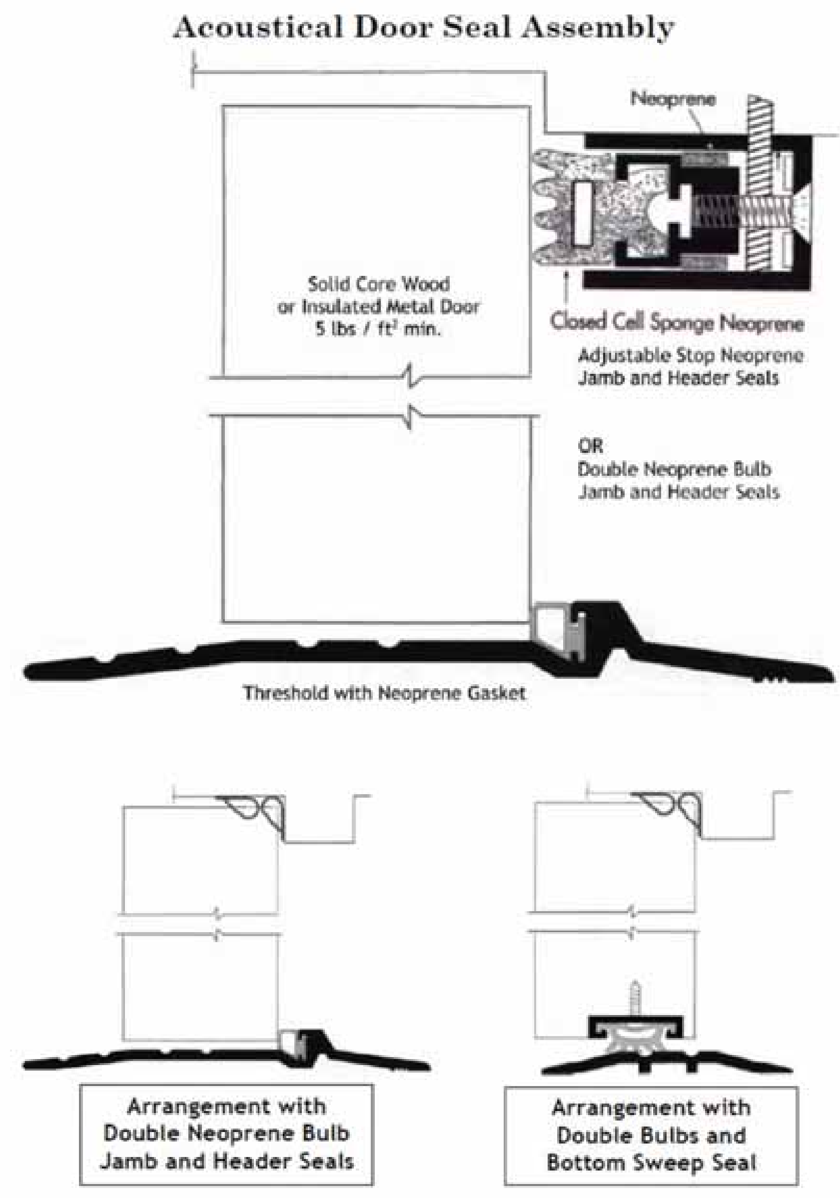


- **IBC requires seals**
- **Acoustical caulk: low modulus (resiliency) and neutral cure (tackiness)**

IBC mentions dwelling ENTRY doors at corridors but is not specific.

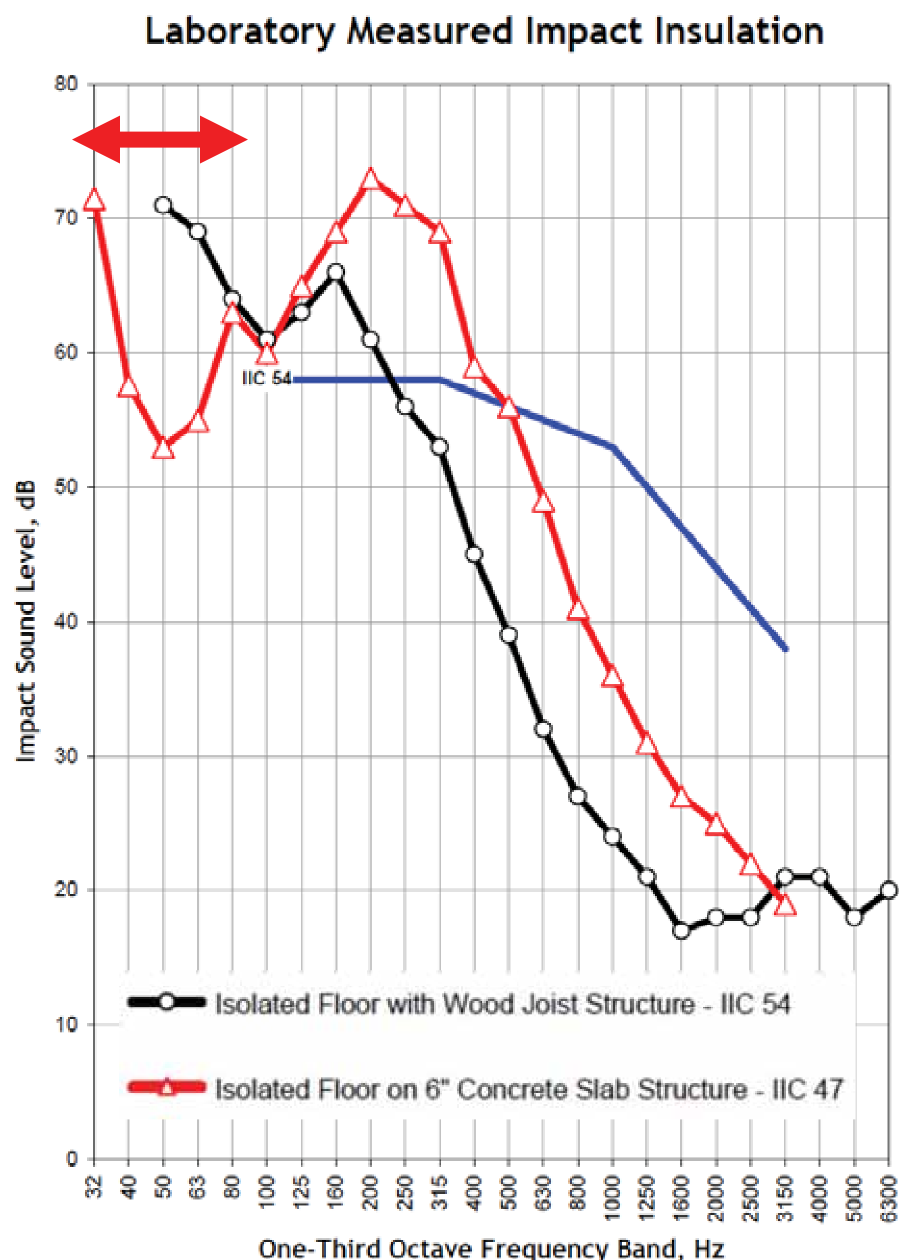
Also, IBC does not address challenging adjacencies to amenities or mixed uses.

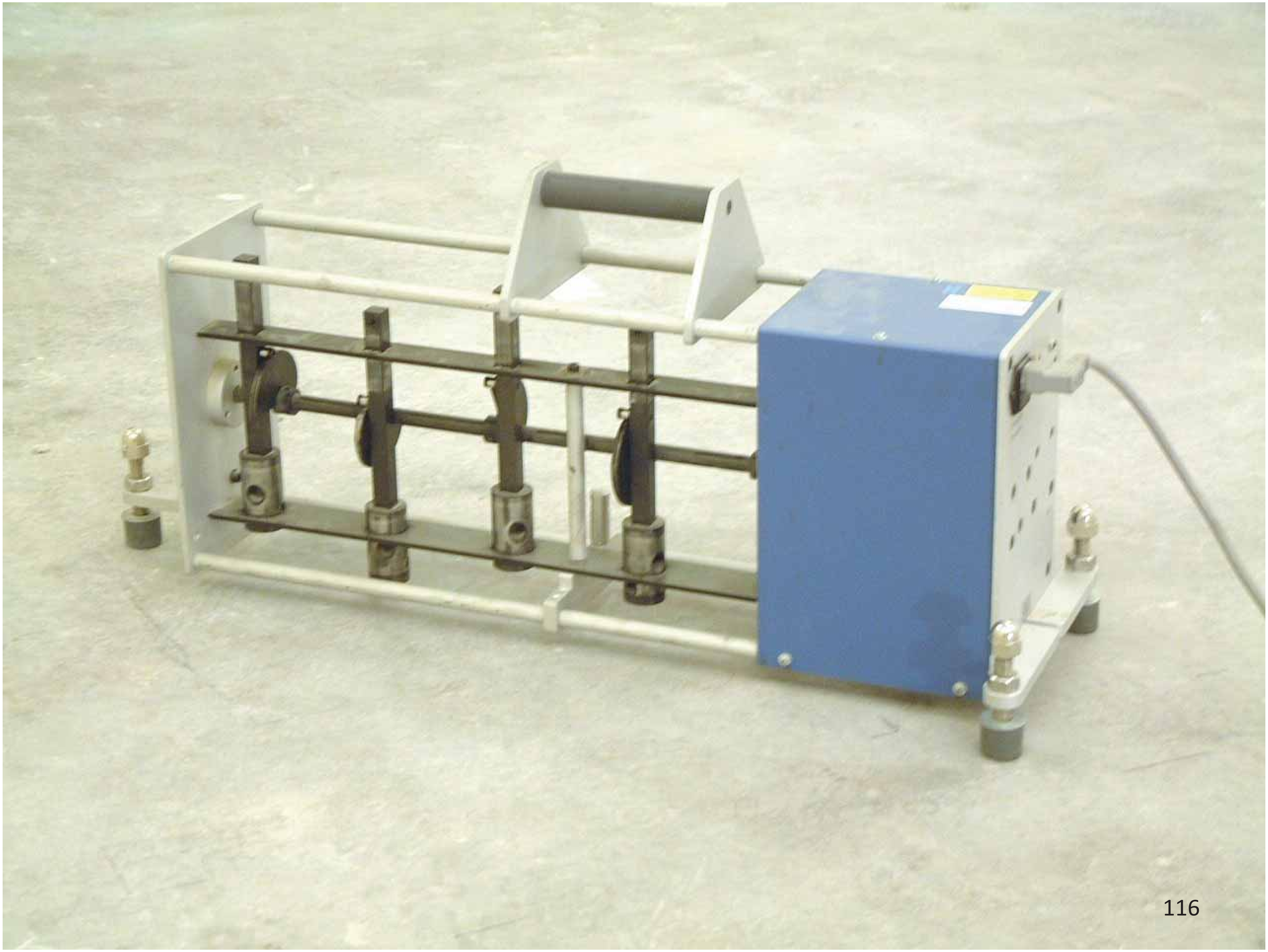
Selecting the right door seals is always a compromise among cost, looks, ease of use, and sound isolation.

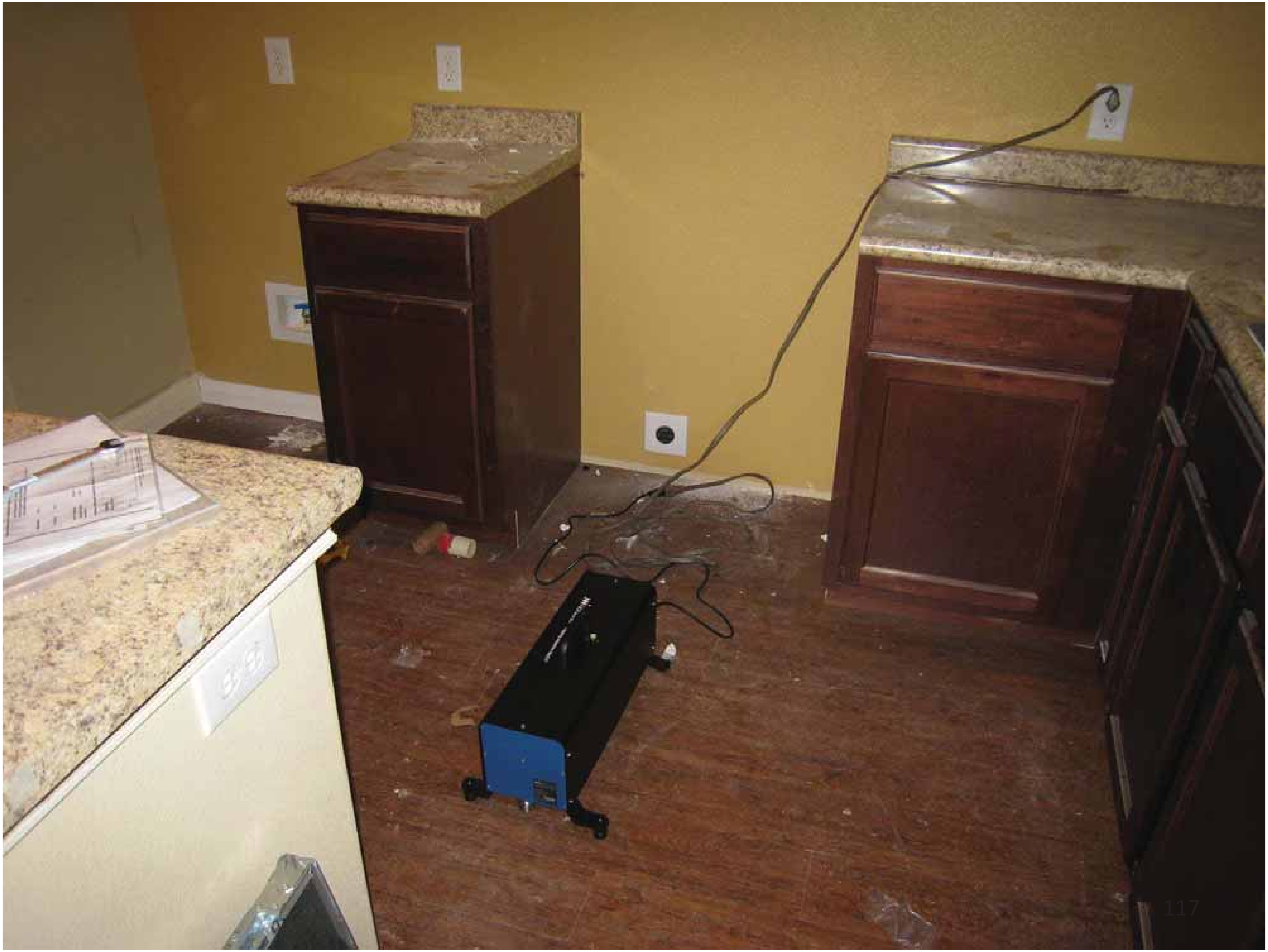


IIC Rating

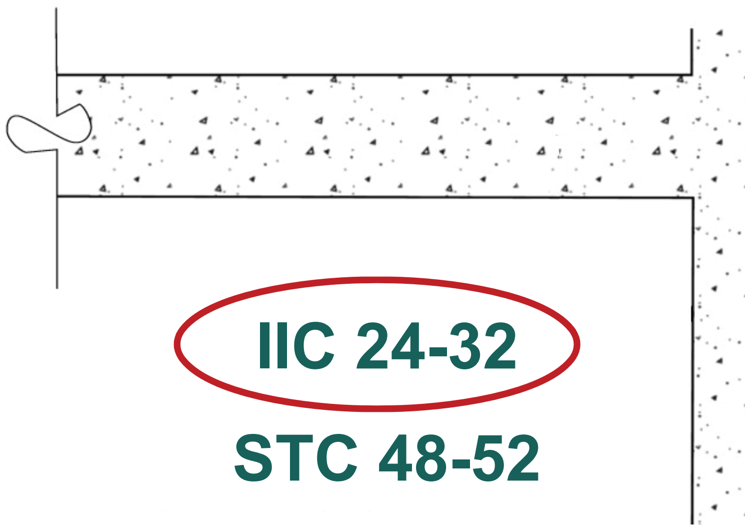
- IIC rating is determined by performance measured between 100 Hz and 3150 Hz
- Low frequencies below 100 Hz are ignored in IIC ratings, but can still have an impact on residential sound isolation quality
- Heavy footfall
- Structural floor resonance 4 – 30 Hz







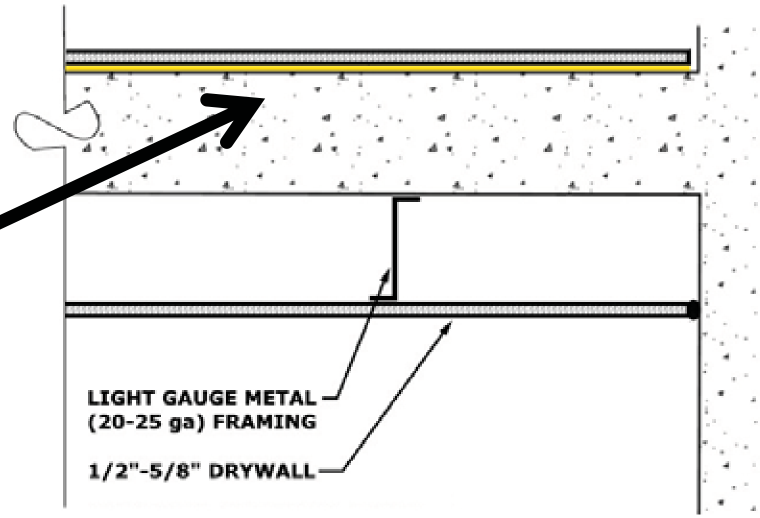
Bare concrete slabs



IIC 70-80
with carpet finish

- **With bare slab or hard floor and no ceiling, IIC is not even close to IBC.**
- **Flanking paths and low and high frequency weaknesses.**

Isolating noise control floor underlayment sheet system

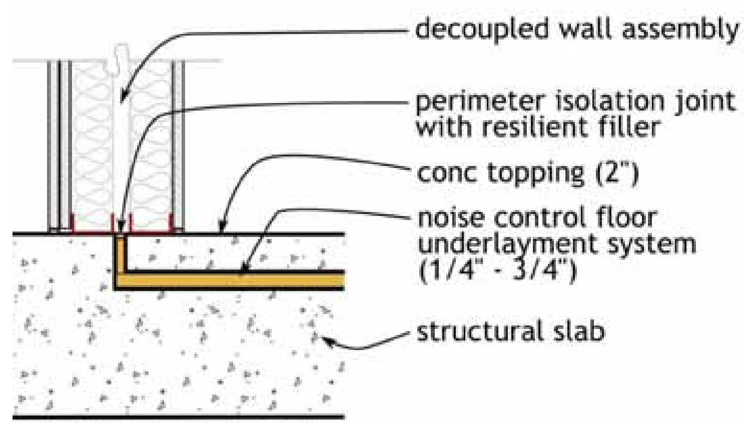


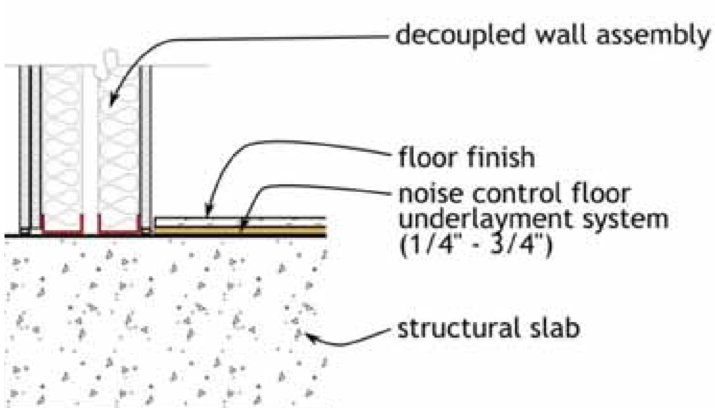
Use resilient underlayment to reduce noise transmission down to spaces below.
Underlayment sheet does not effectively reduce noise transmission coming up from below.

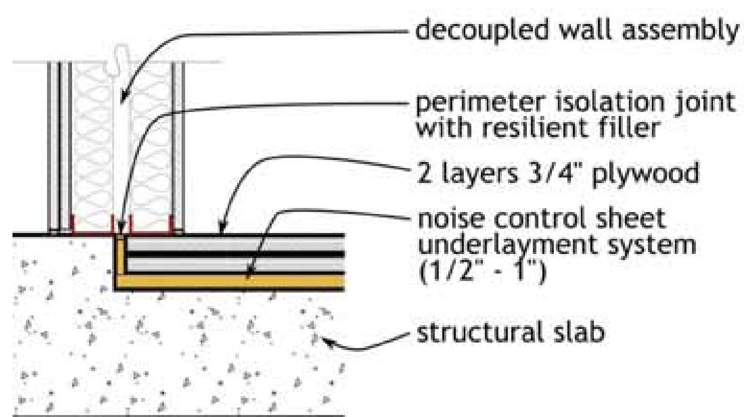
Resilient underlayment sheets thinner than 1/4" (5mm) tend to transmit mid-low frequency impact noise.

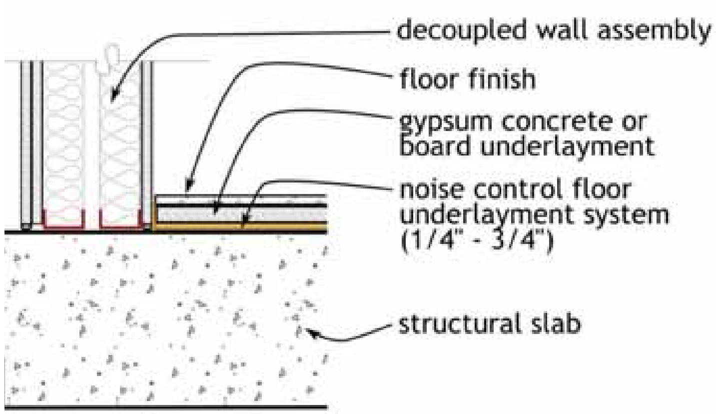
Use sheet at least 1/4" thick.

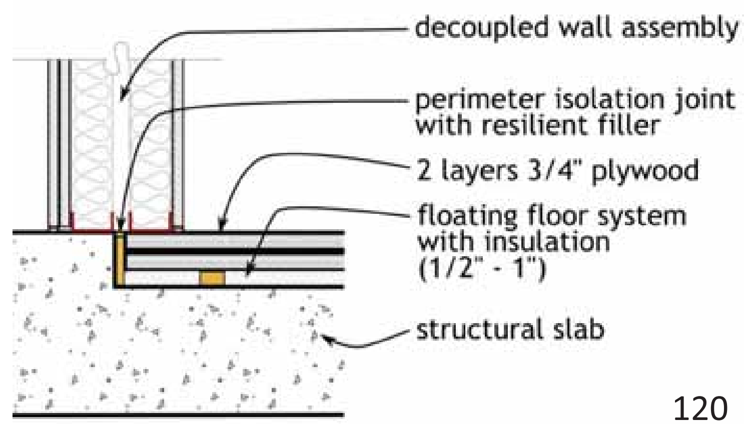
Do more for mixed use.



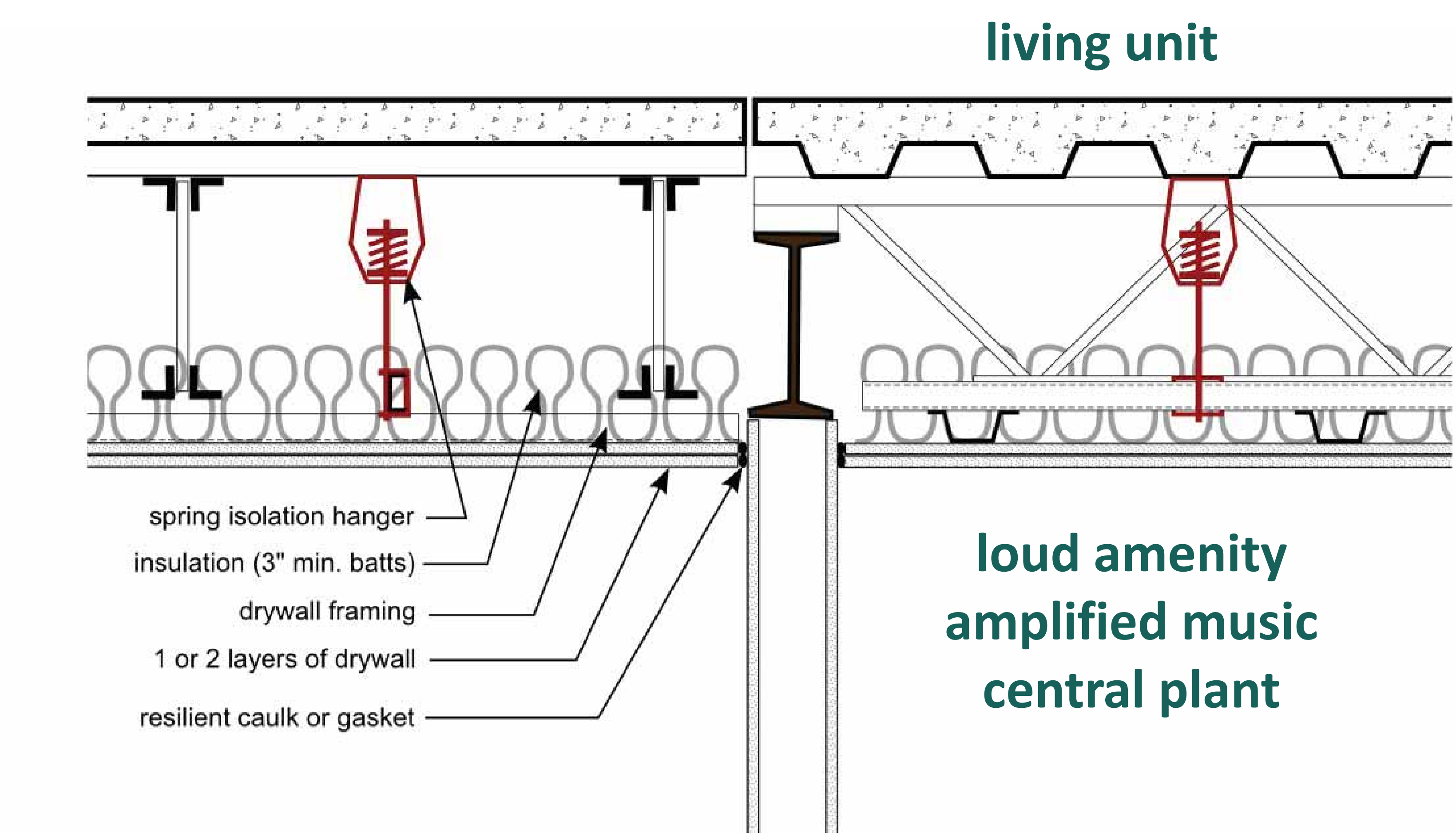


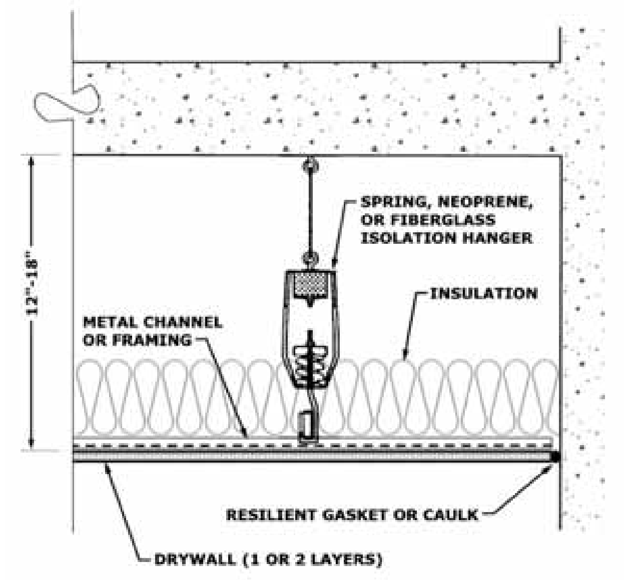


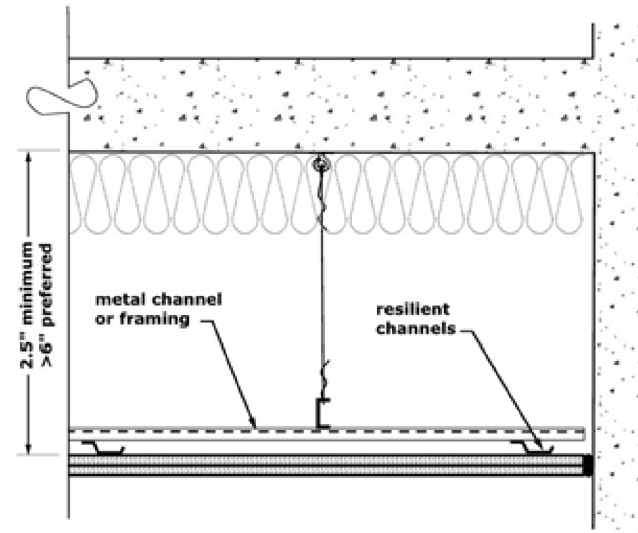


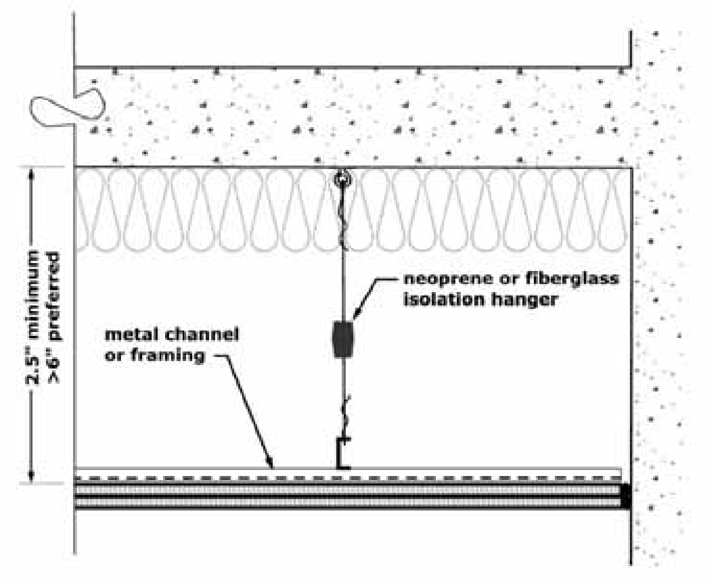


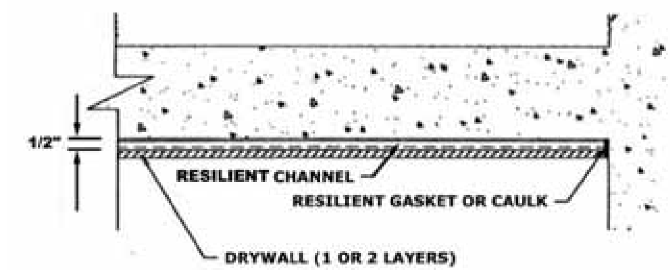
Suspended noise barrier

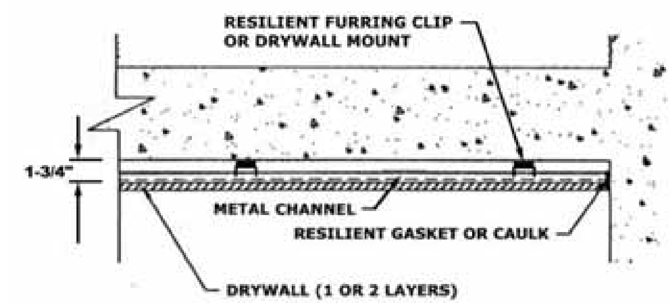



12"-18"
SPRING, NEOPRENE, OR FIBERGLASS ISOLATION HANGER
INSULATION
METAL CHANNEL OR FRAMING
RESILIENT GASKET OR CAULK
DRYWALL (1 OR 2 LAYERS)

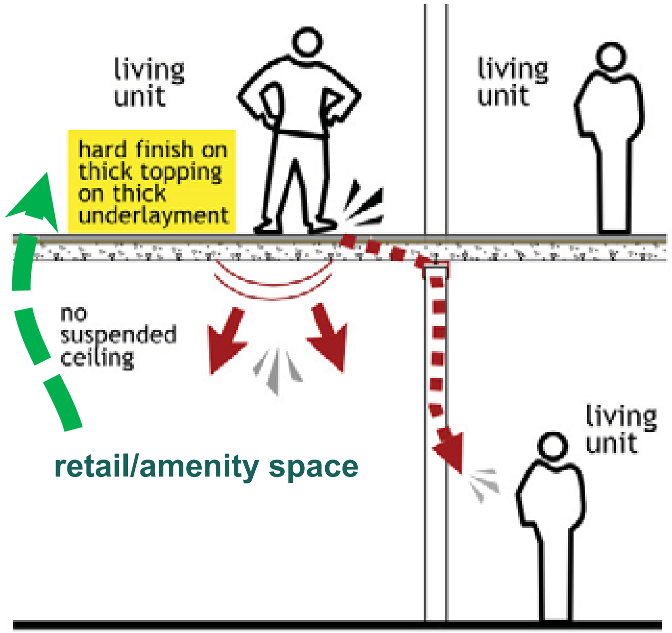

2.5" minimum
>6" preferred
metal channel or framing
resilient channels


2.5" minimum
>6" preferred
neoprene or fiberglass isolation hanger
metal channel or framing


1/2"
RESILIENT CHANNEL
RESILIENT GASKET OR CAULK
DRYWALL (1 OR 2 LAYERS)


RESILIENT FURRING CLIP OR DRYWALL MOUNT
1-3/4"
METAL CHANNEL
RESILIENT GASKET OR CAULK
DRYWALL (1 OR 2 LAYERS)

Sheet system above

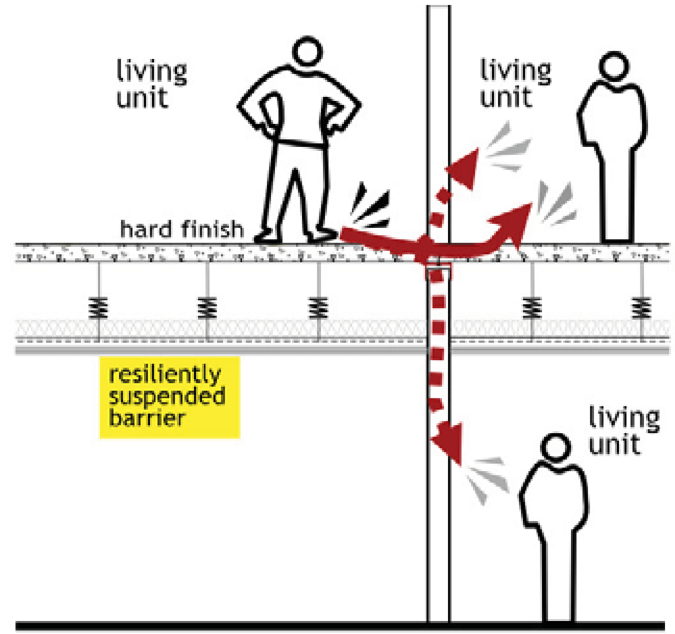


IIC 45-59

STC 50-55

Low frequency weakness & potential flanking paths

Hanger system below

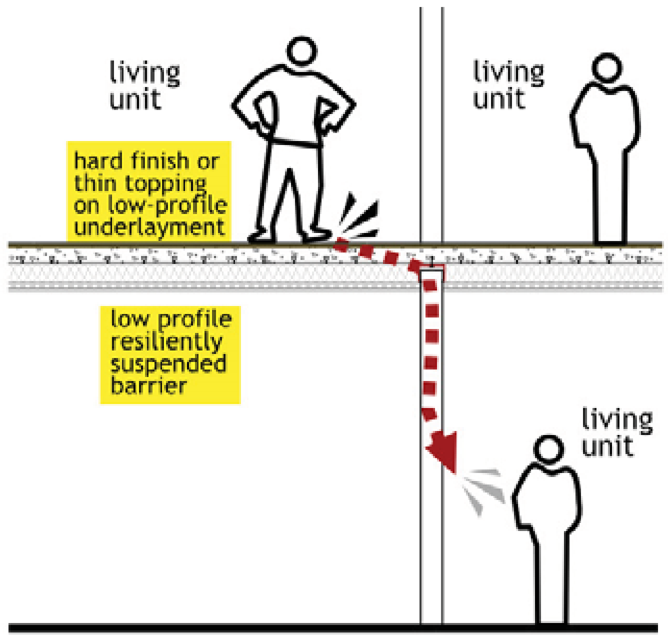


IIC 50-70

STC 65-75

Vertical and horizontal flanking paths

Hybrid system

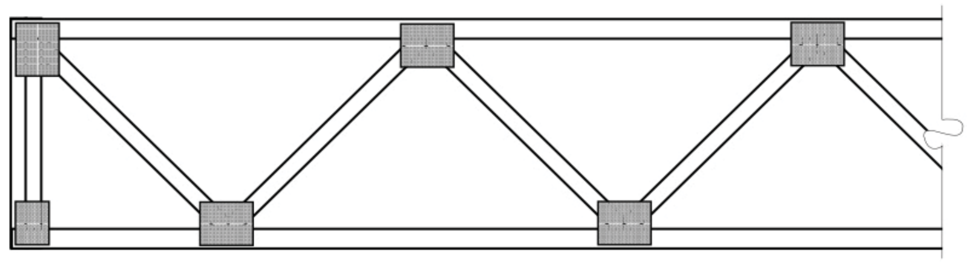


IIC 55-70

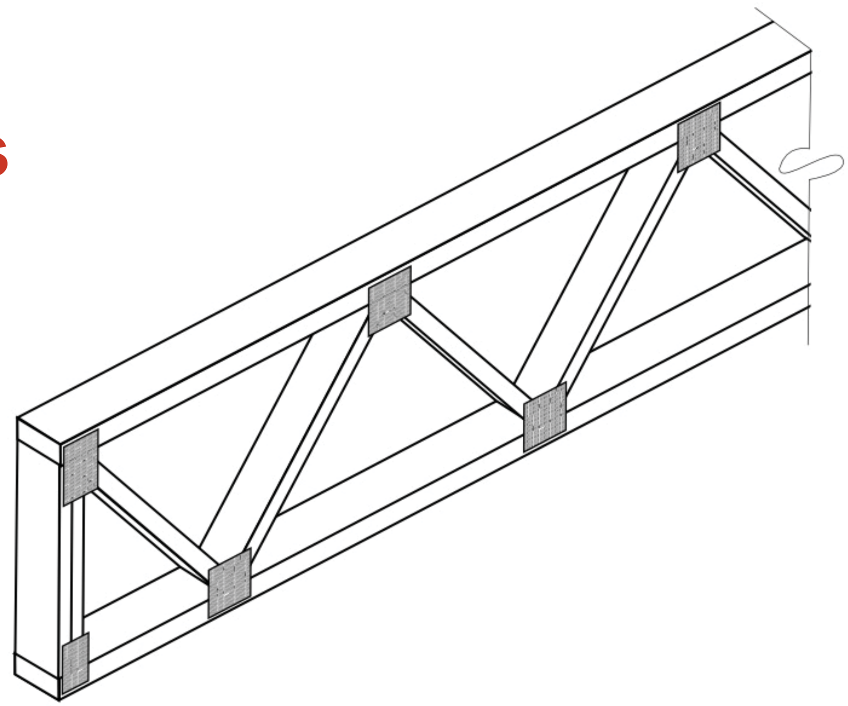
STC 60-75

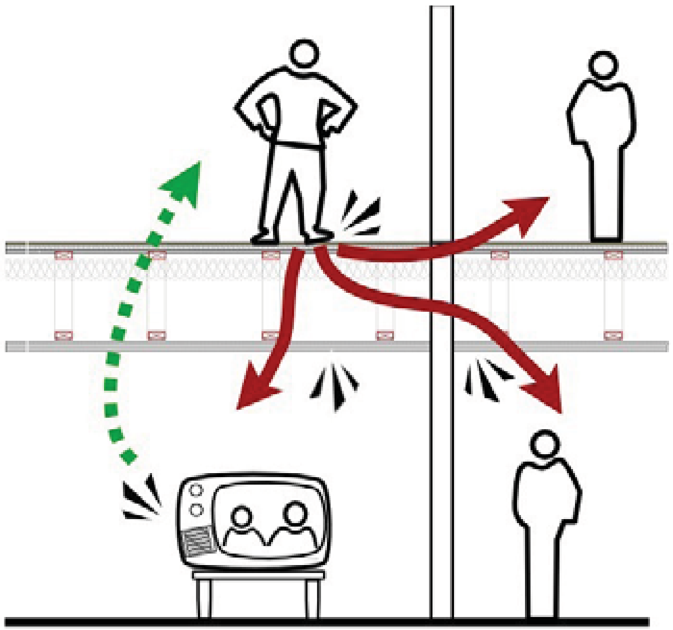
If it’s overall too thin, there’s still a potential for low frequency weakness

Wood floor truss

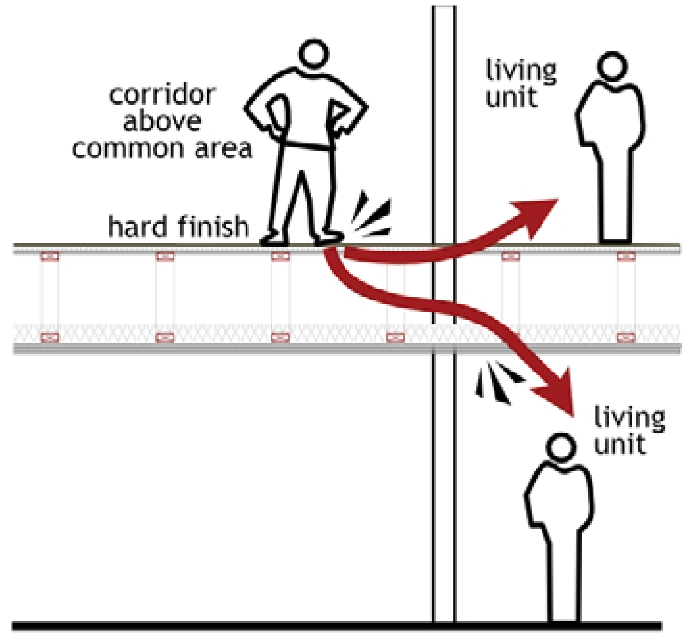


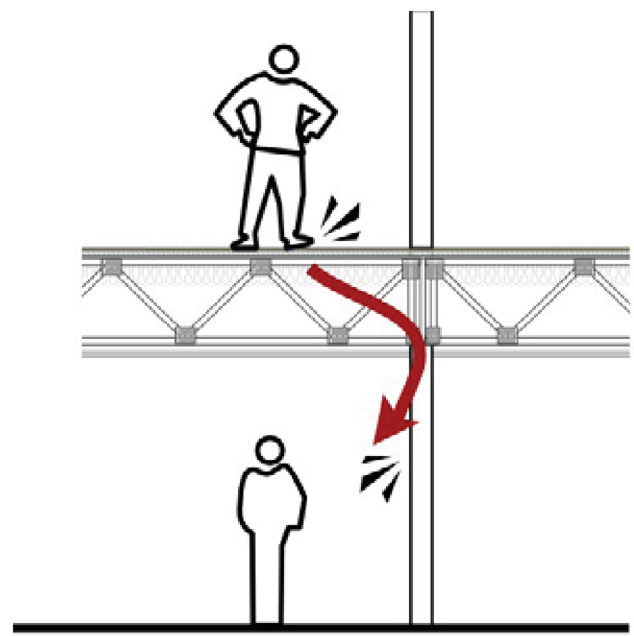
parallel chord or "flat" wood truss





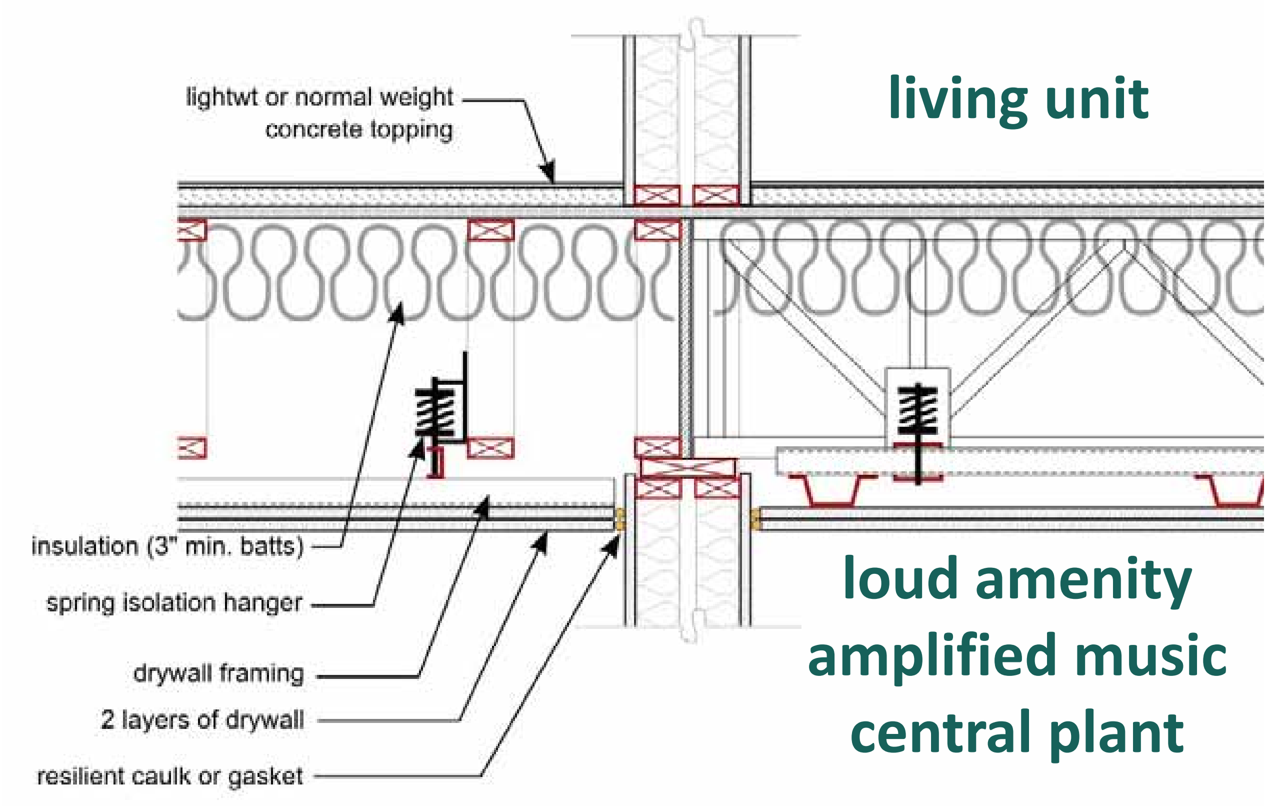
IIC 25-35
STC 43-49





With hybrid of isolation sheet above and hanger below:
IIC 50-55
STC 55-60

Suspended noise barrier ceiling



With less mass and lower stiffness than concrete slabs, wood frame floors suffer from various flanking paths along bearing walls and tend to allow low frequency noise transmission.

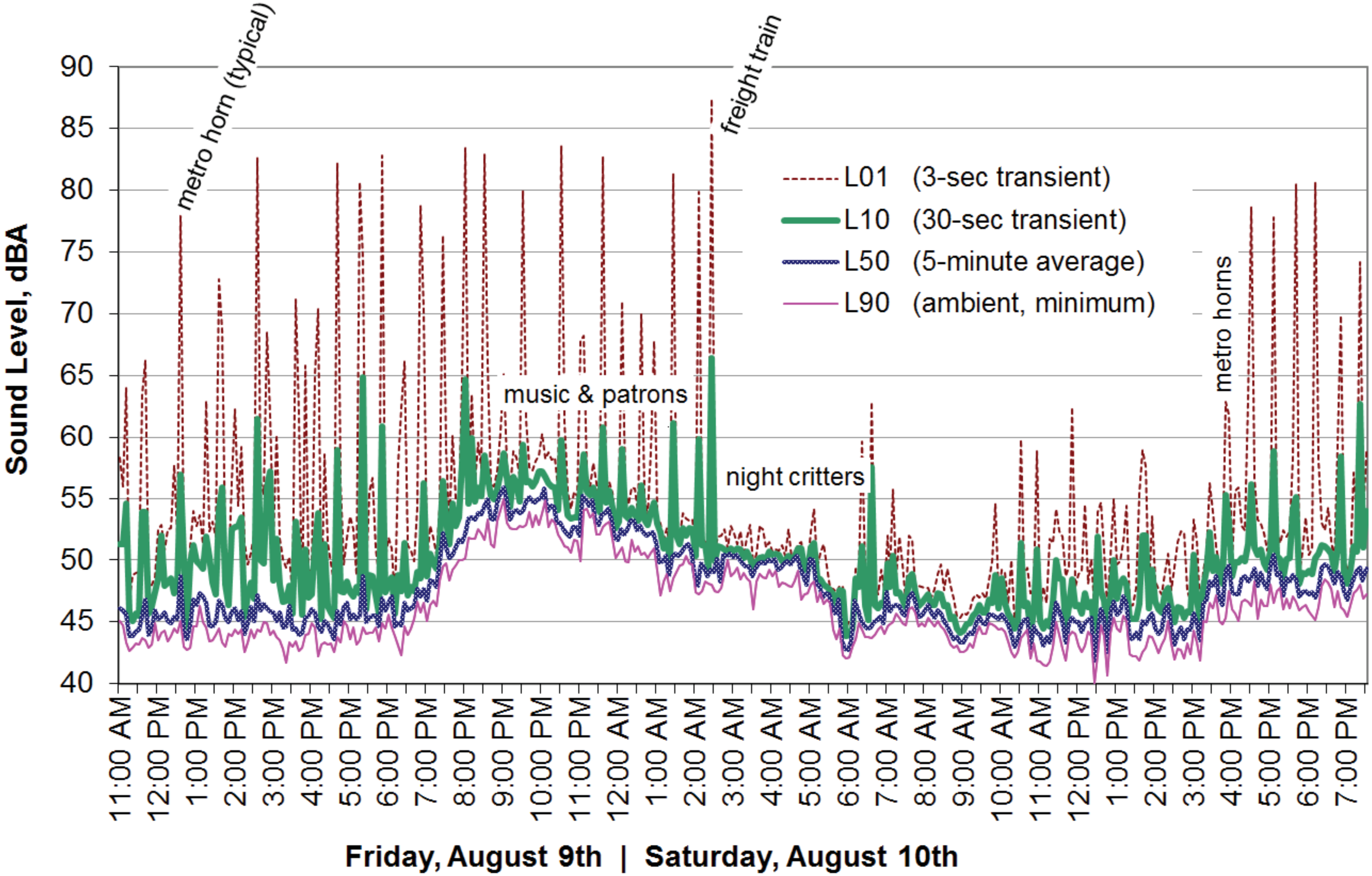
OITC - noise through building shell

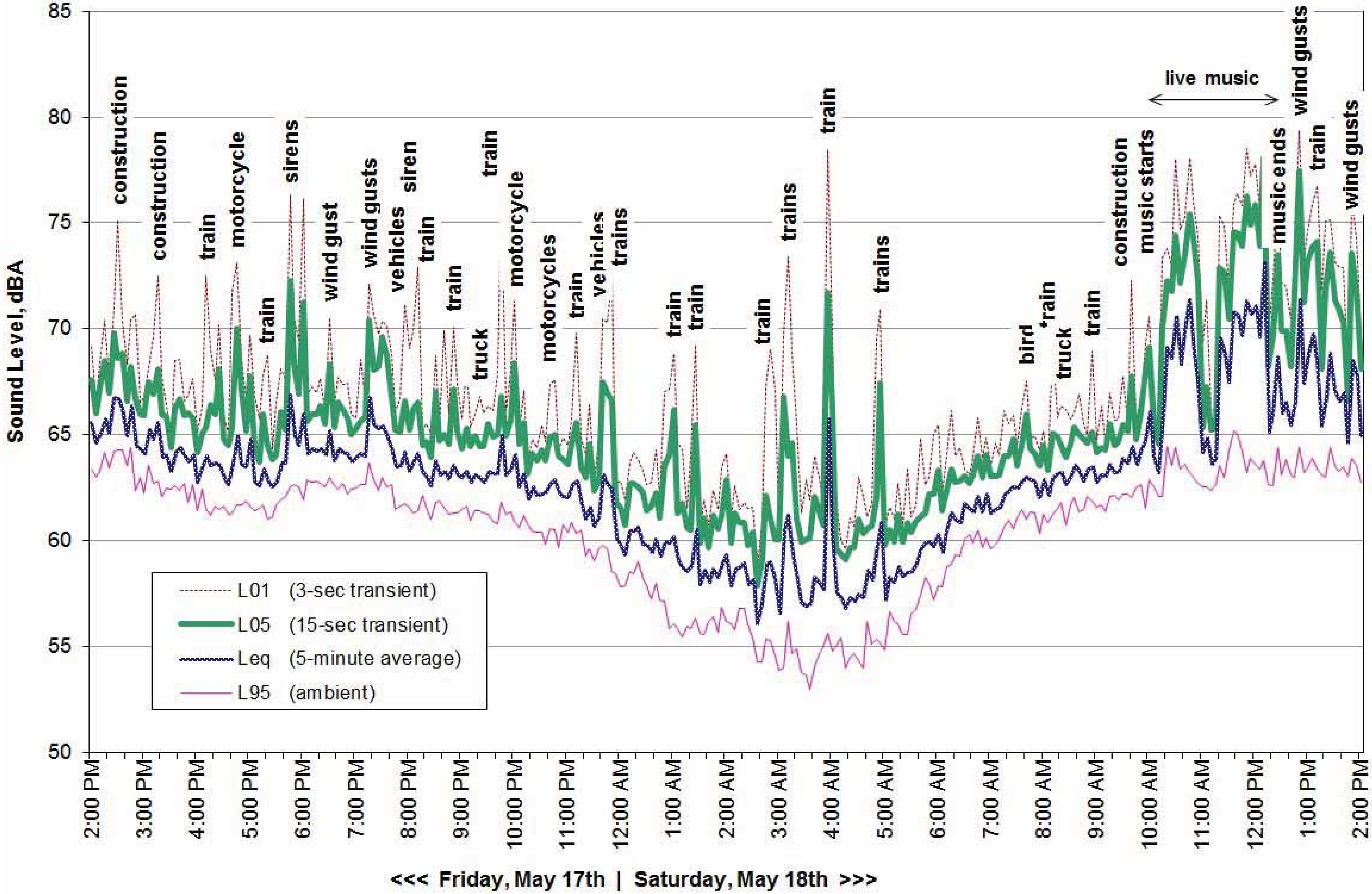
Noise through building shell

Not addressed by IBC or ICC. We may have other code or can rely on guidelines (HUD, LEED, WHO).

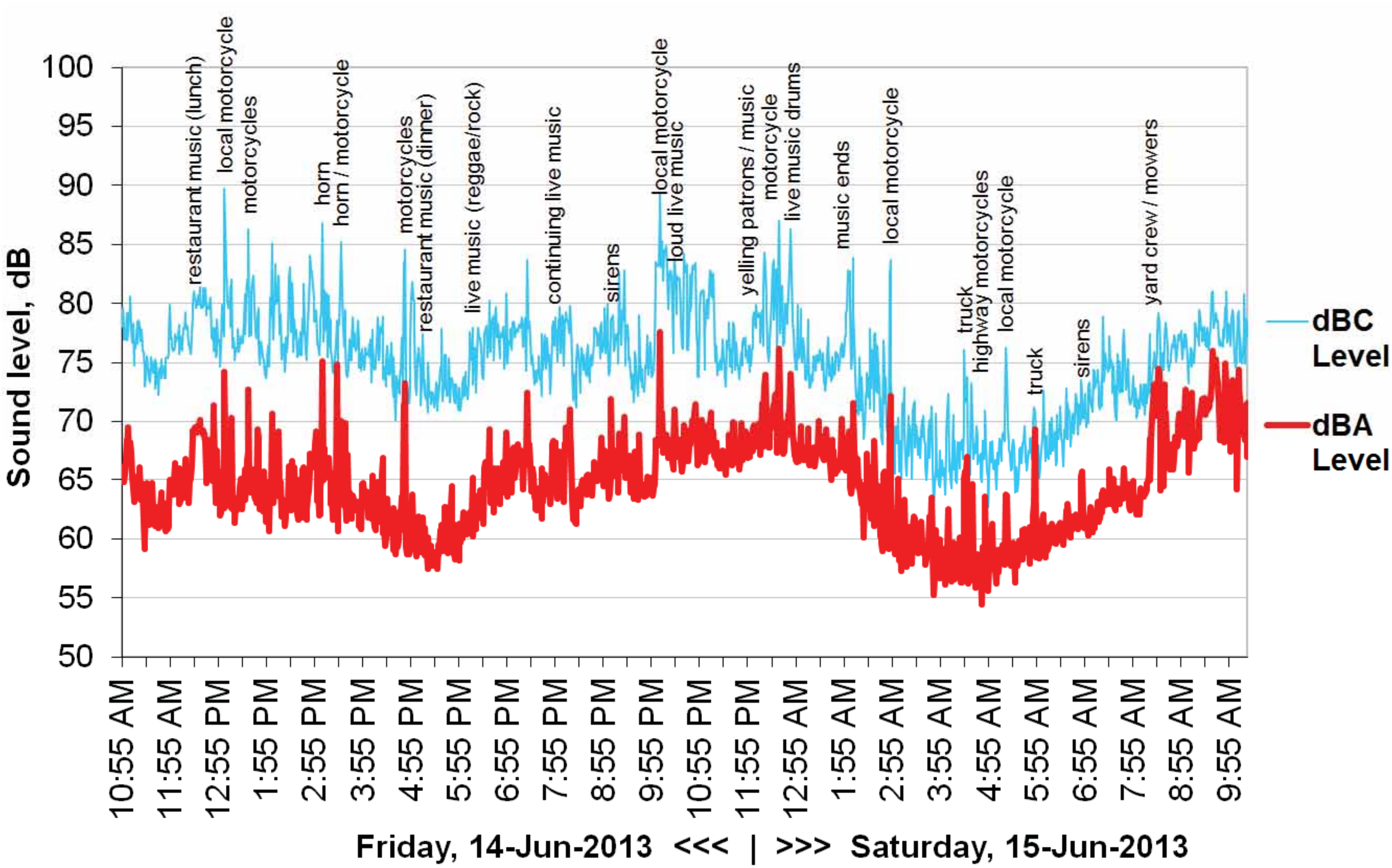
- Road traffic noise from buses, trucks, cars
- Railroads and airports
- Amplified music from restaurants, clubs
- On-site noise: pool terraces or courtyards
- On-site or off-site mechanical equipment

Measured ambient conditions

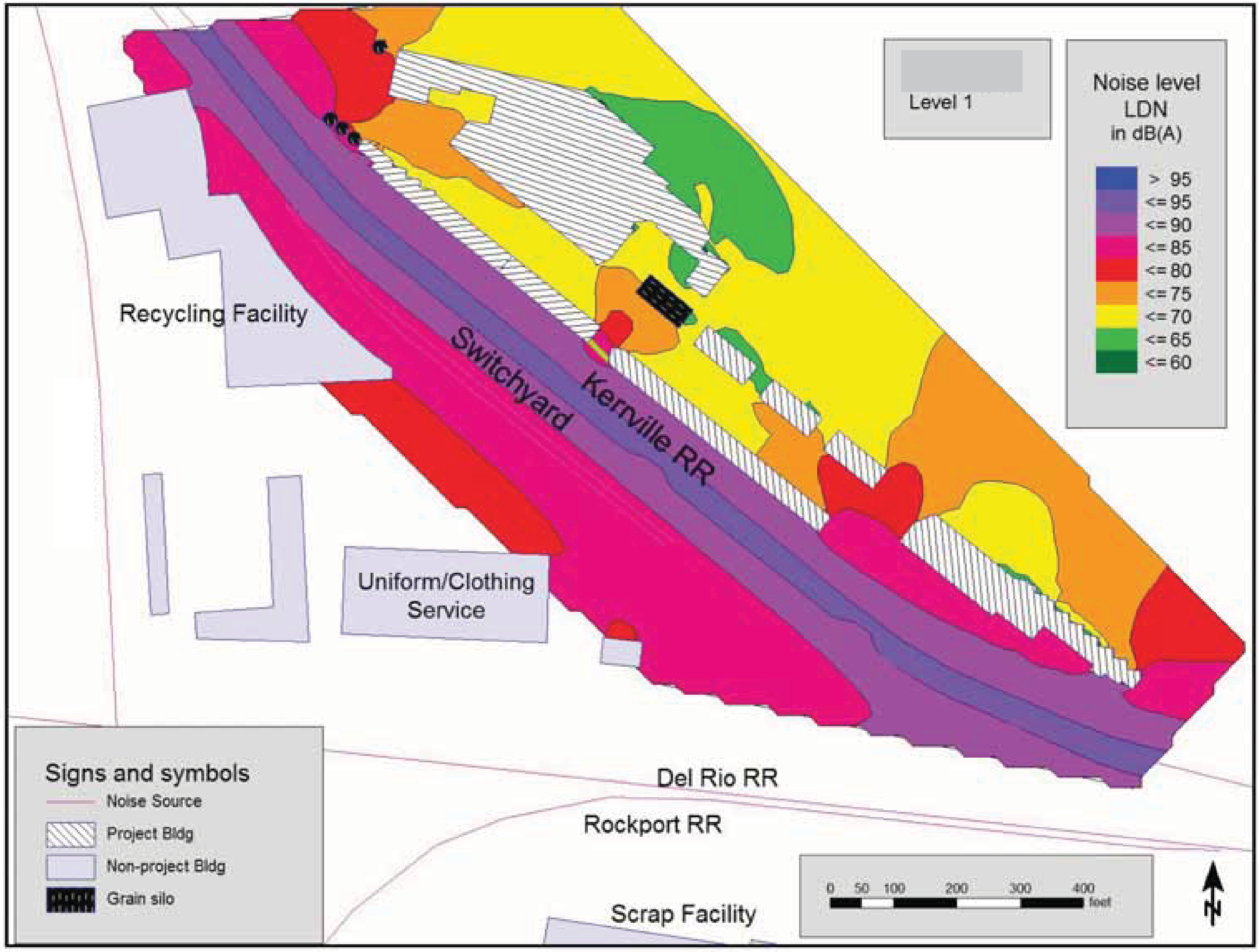



85
80
75
70
65
60
55
50
Sound Level, dBA
construction
construction
train
motorcycle
train
sirens
wind gust
wind gusts
vehicles
siren
train
train
truck
train
motorcycle
motorcycles
train
vehicles
trains
train
train
train
trains
train
trains
bird
train
truck
train
construction
music starts
live music
music ends
wind gusts
train
wind gusts
L01 (3-sec transient)
L05 (15-sec transient)
Leq (5-minute average)
L95 (ambient)
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
<<< Friday, May 17th | Saturday, May 18th >>>

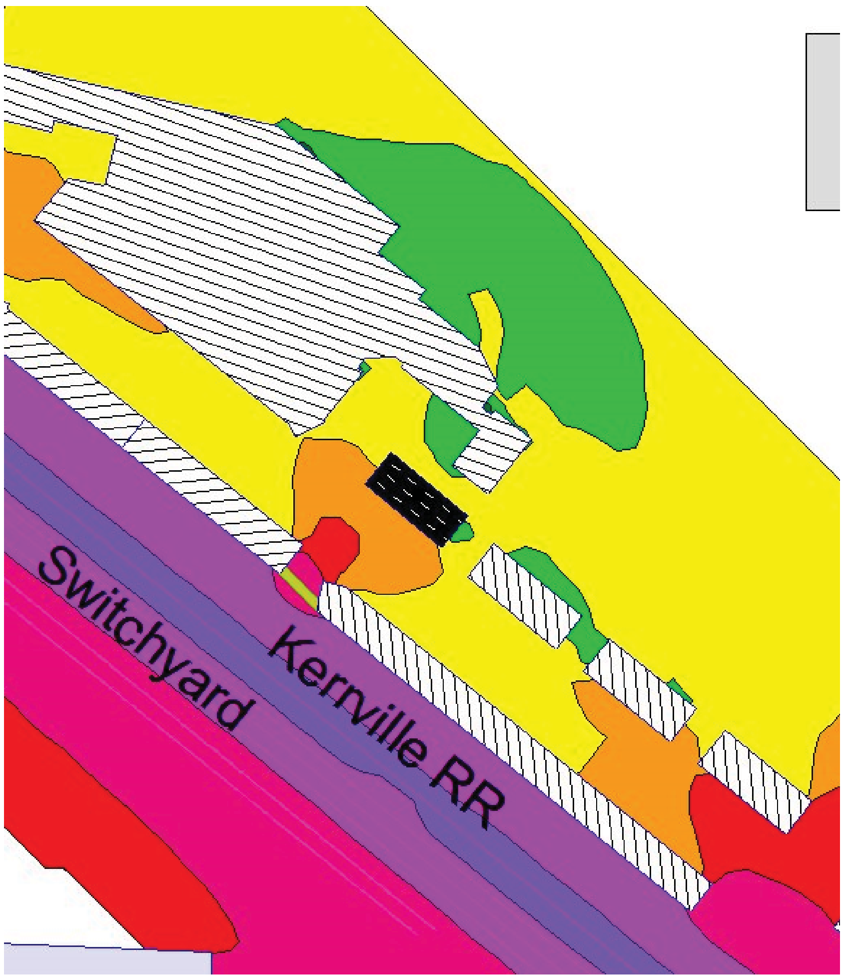
Measured ambient conditions

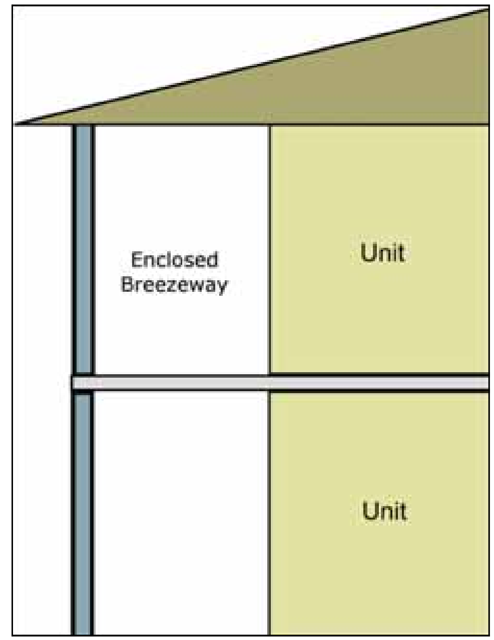


Analyzed conditions

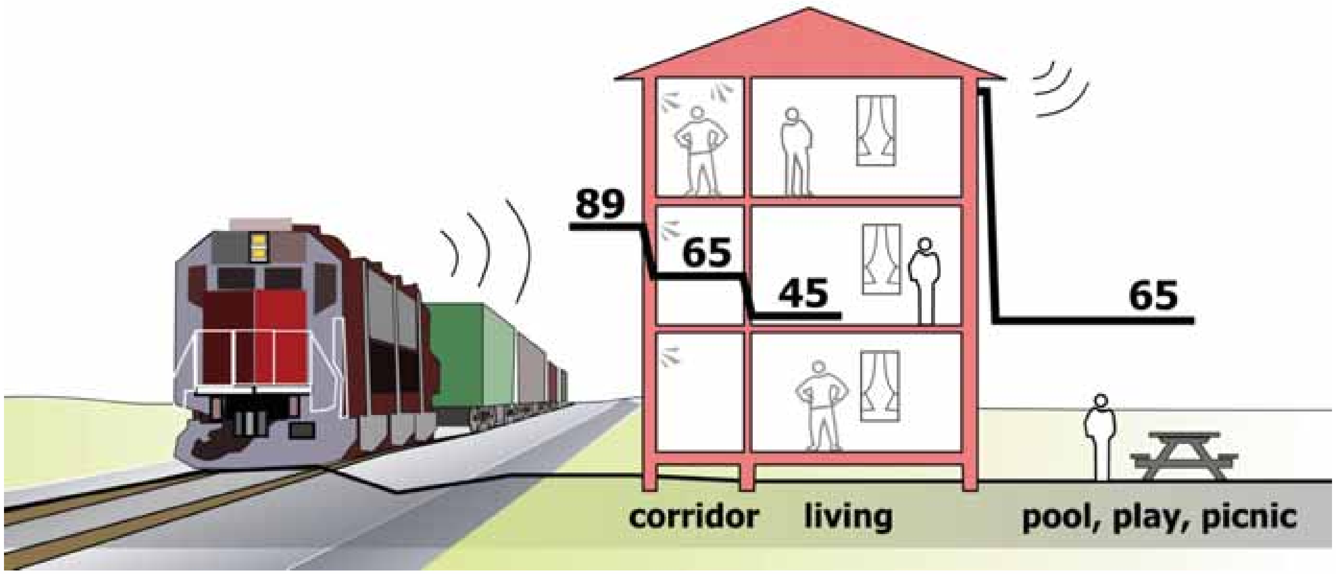


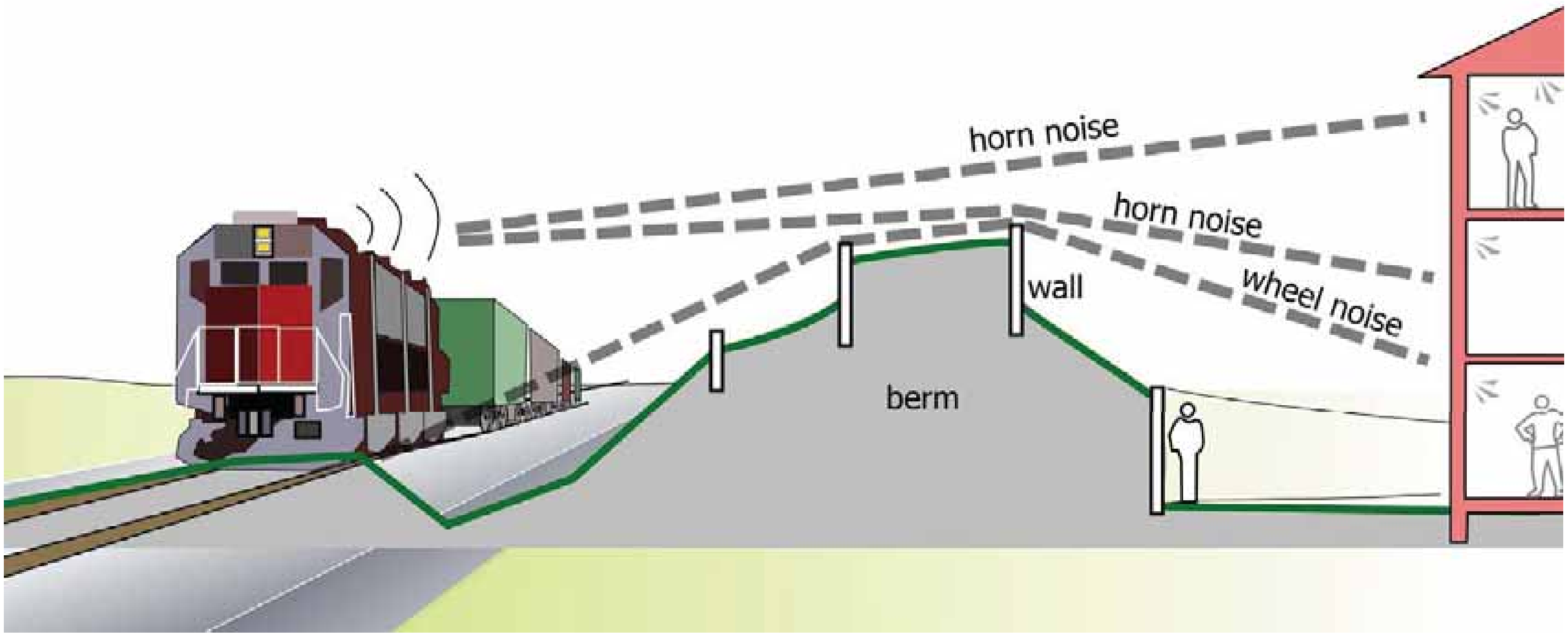
Analysis leads to concepts





An enclosed breezeway shields the dwellings inside one building, while that whole building shields other sensitive areas of the site.


89
65
45
65
corridor
living
pool, play, picnic


horn noise
horn noise
wheel noise
wall
berm

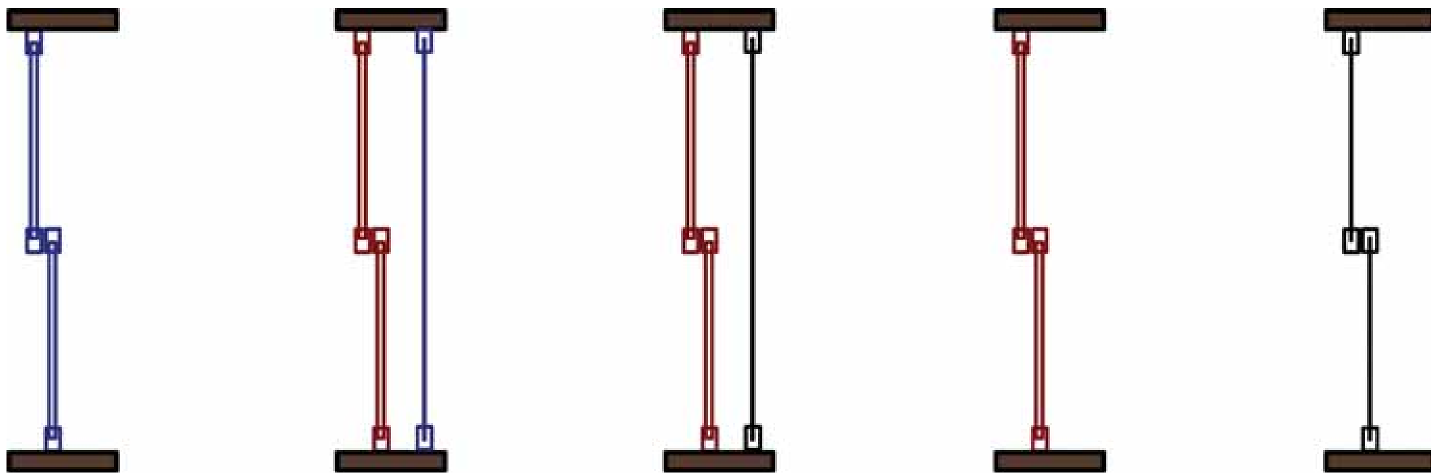

111 Probandt St
San Antonio, TX 78204 – approximate address
TX-536 Spur
Street View - Oct 2007
E Cevallos St
Clay St
Probandt St
Croffton Ave
Wickes St
536
Google

65-99 Probandt St
San Antonio, TX 78204 – approximate address
TX-536 Spur
Street View - Mar 2011
536
E Cevallos St
Clay St
Crofton Ave
Google


111 TX-536 Spur
TX-536 Spur
Street View - Apr 2013
TX-536 Spur
E Cevallos St
Clay St
Crofton Ave
Google


Probandt St
Probandt St
San Antonio, Texas
Street View - Jul 2014
536
S Alamo
E Cevallos St
Clay St
Blue Star
Crofton Ave
Wickes St
Google

Window types



1 double pane laminated glass, fixed or with good seals, acoustically tested curtain or storefront frame

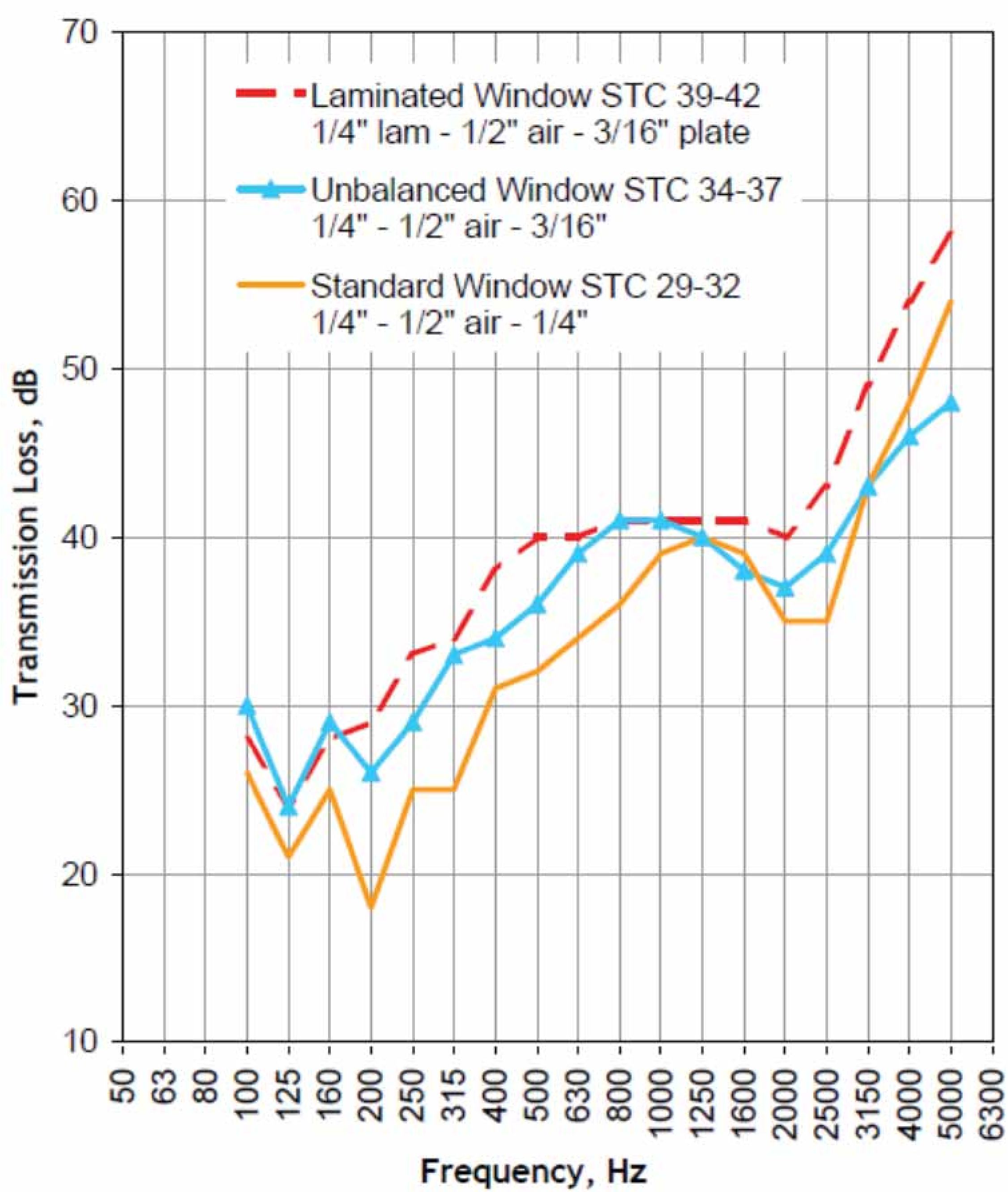
2 double pane plus interior laminated pane

3 double pane plus interior glass pane

4 double pane with unbalanced glass panes

5 single pane or double with equal panes

Less effective →


Laminated Window STC 39-42
1/4" lam - 1/2" air - 3/16" plate
Unbalanced Window STC 34-37
1/4" - 1/2" air - 3/16"
Standard Window STC 29-32
1/4" - 1/2" air - 1/4"
Transmission Loss, dB
Frequency, Hz
70
60
50
40
30
20
10
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300

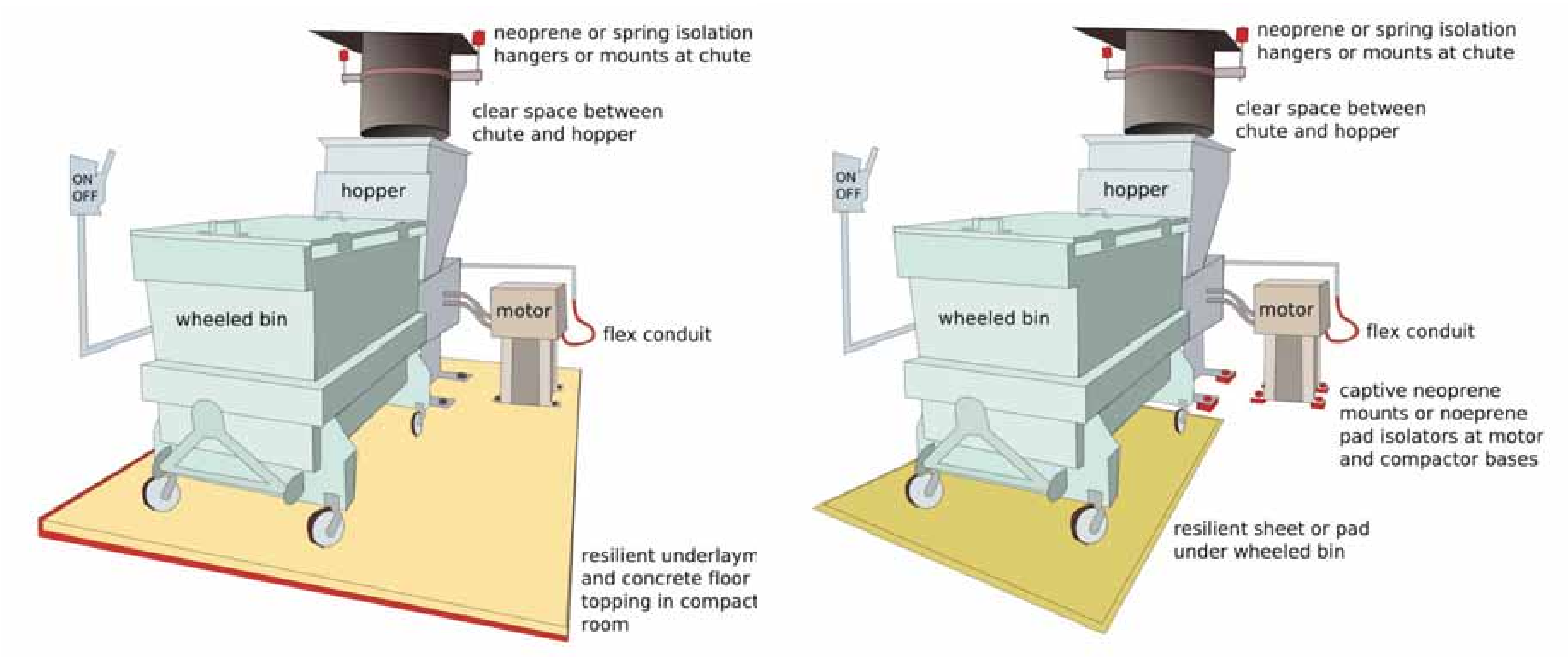
Secondary interior window

Noise control at windows

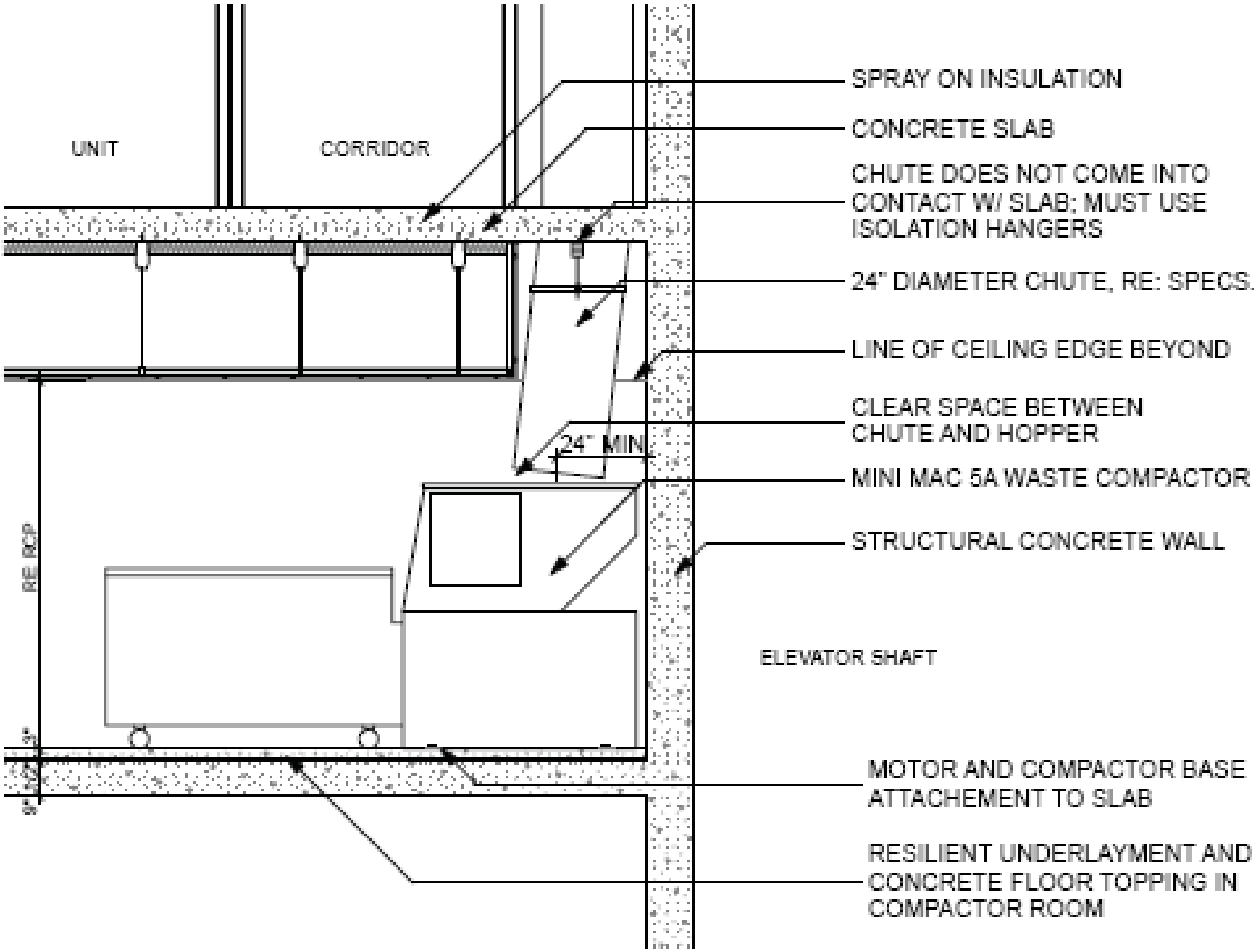
- Laminated glass panels (affects cost)
- Inner & outer panels with different thickness … 5/16" vs. 3/16"
- Specify STC test report for tested glass-and-frame
- Spec OITC rated assembly (tested at 80 – 100 Hz)
- Require acoustically tested curtain/storefront frame

Avoid mechanical terraces at units

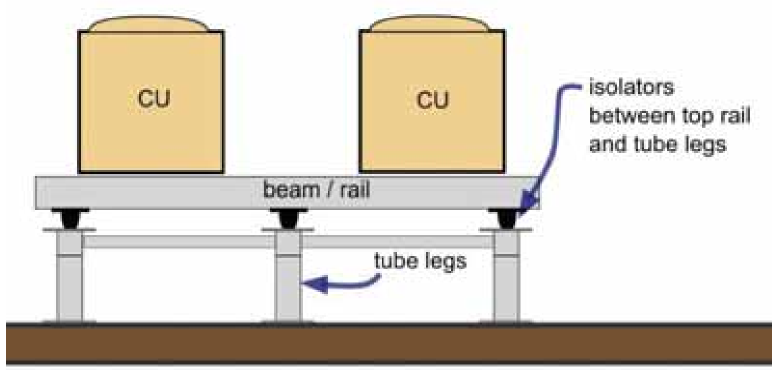
Trash compactor isolation

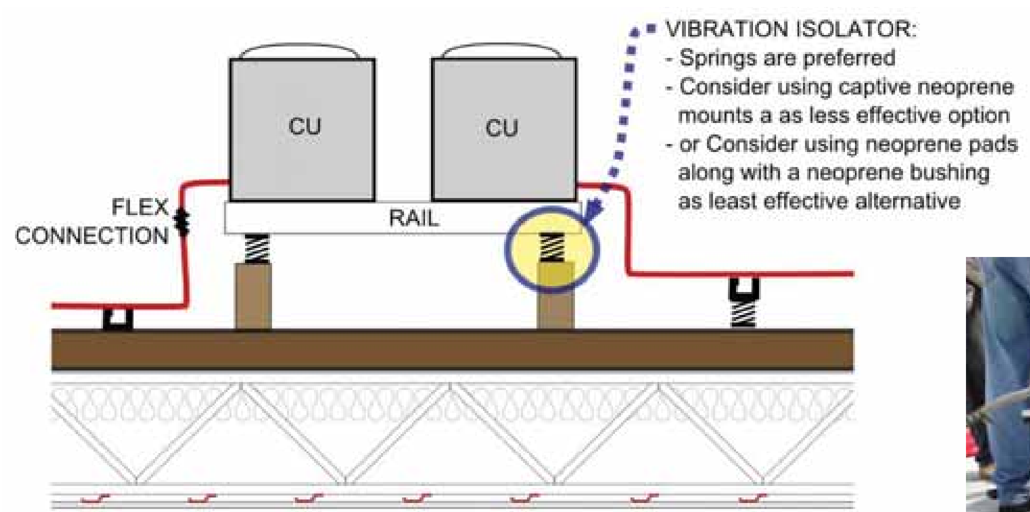


Trash chutes and compactors

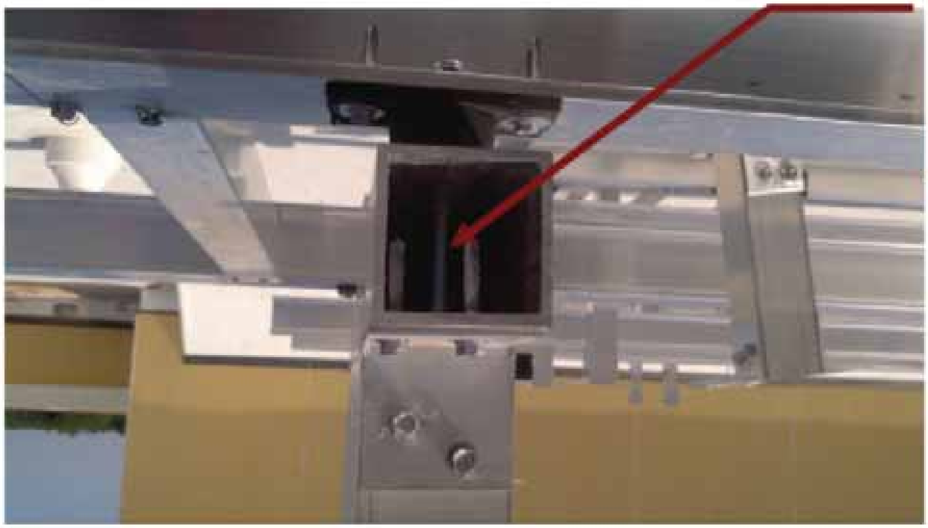


Rooftop equipment isolation



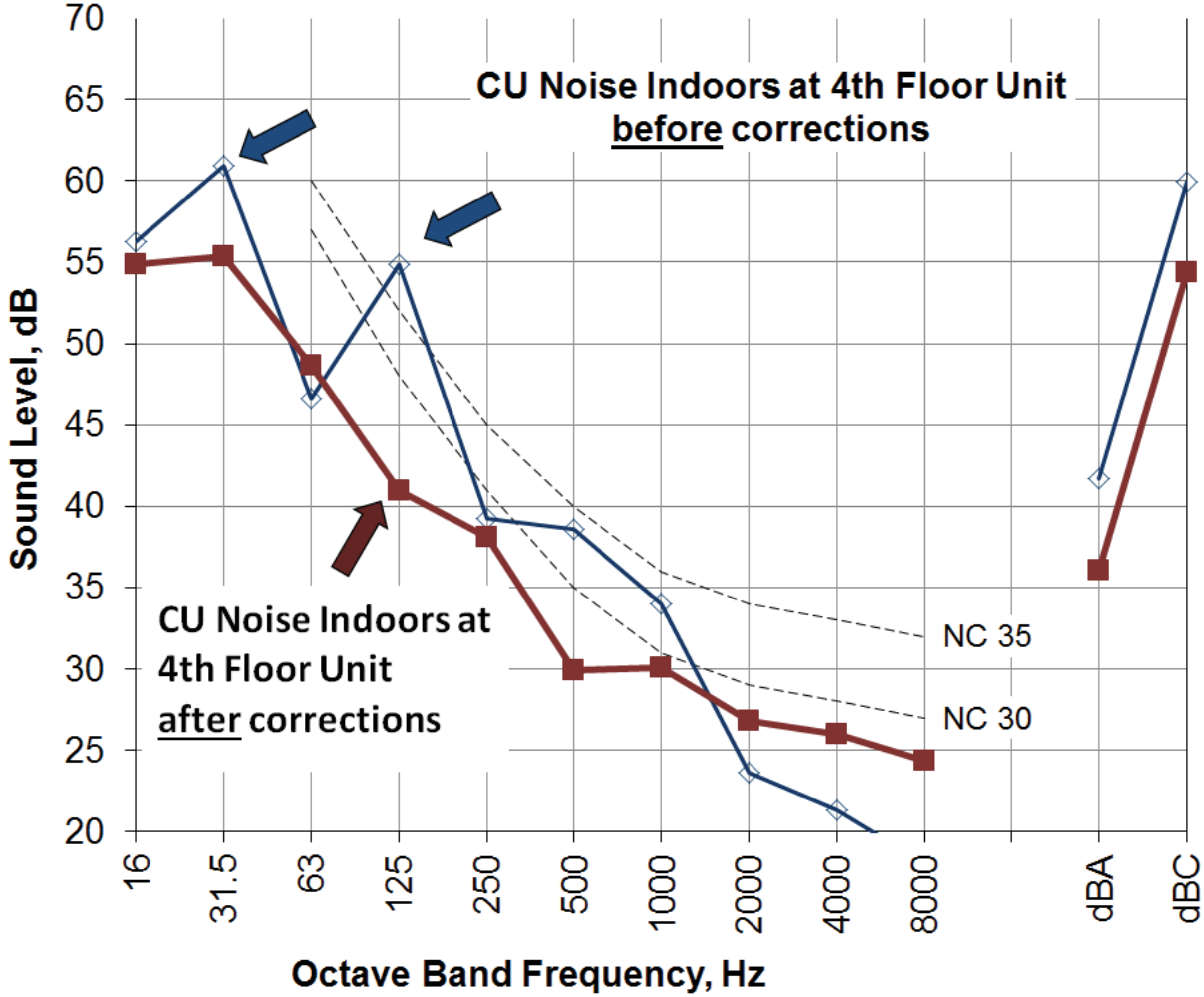


Rooftop equipment isolation

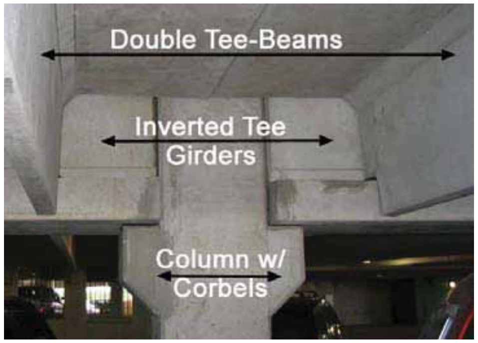


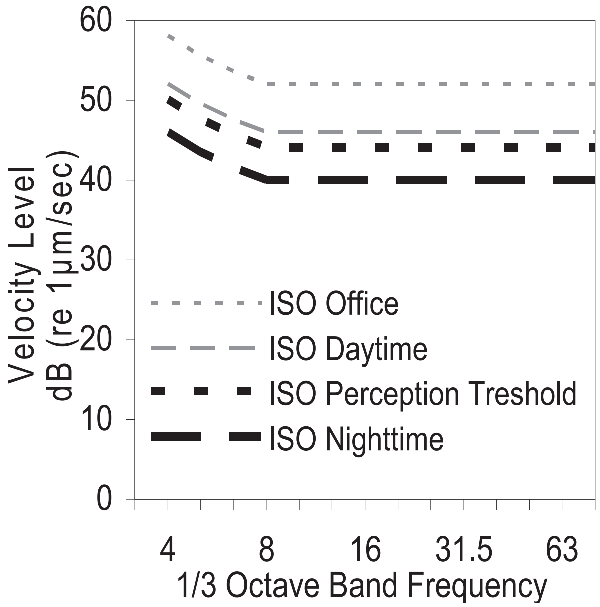
CU upper rail through-bolt anchor short circuits the rubber isolator.

Rooftop equipment isolation



Parking garage slab vibration with vehicle movement





Pre-stressed beams and post-tensioned slabs in garages tend to exhibit prominent resonant frequency

Structures analyzed against standard criteria for perception of floor slab vibration show potential for disturbance of residents in connected living unit structures.
Good structural separation is needed.

Objectives to control outdoor noise

- Use non-sensitive portions like corridors to shield sensitive portions from noise – **block paths to windows/doors; make protected courtyards or breezeways**.
- Plan outdoor equipment locations away from living spaces – **block paths to windows/doors; use vibration isolation**.
- Improve exterior building shell design for sound isolation – **window glazing and frames, door seals, penetrations**.

Objectives for indoor noise

- Identify noisy mixed uses and amenities, and address sound separation in building design.
- Plan ahead for sound separation and demising assemblies that achieve **better than IBC minimum** requirements; look to ICC, or develop or refine owners' design guidelines.
- Don't forget about **low frequency noise**.
- Plan equipment & utility locations away from living units – **buffer zones; use vibration isolation**

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Managing Metamorphosis, Building for Change

Seminar Evaluation

We hope you enjoyed this session…

Please take a moment to complete the evaluation form.

Thank you!

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