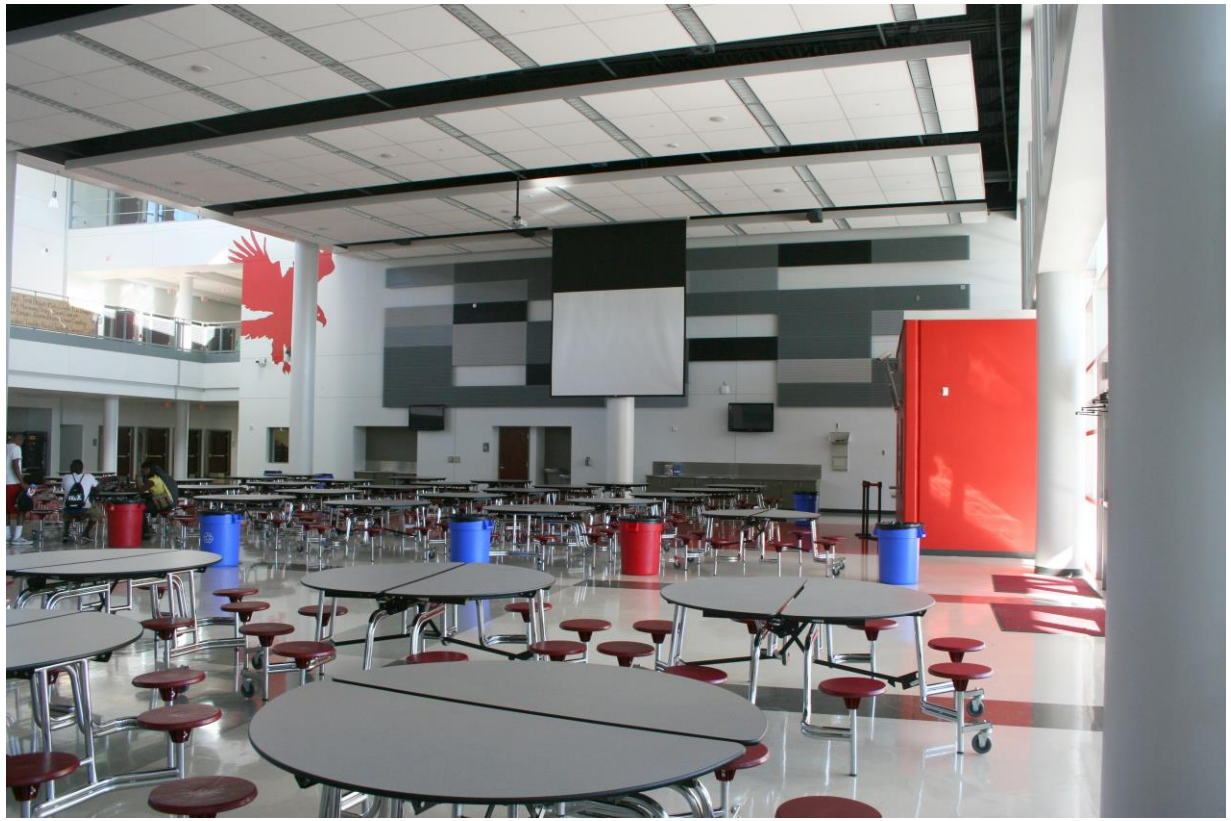
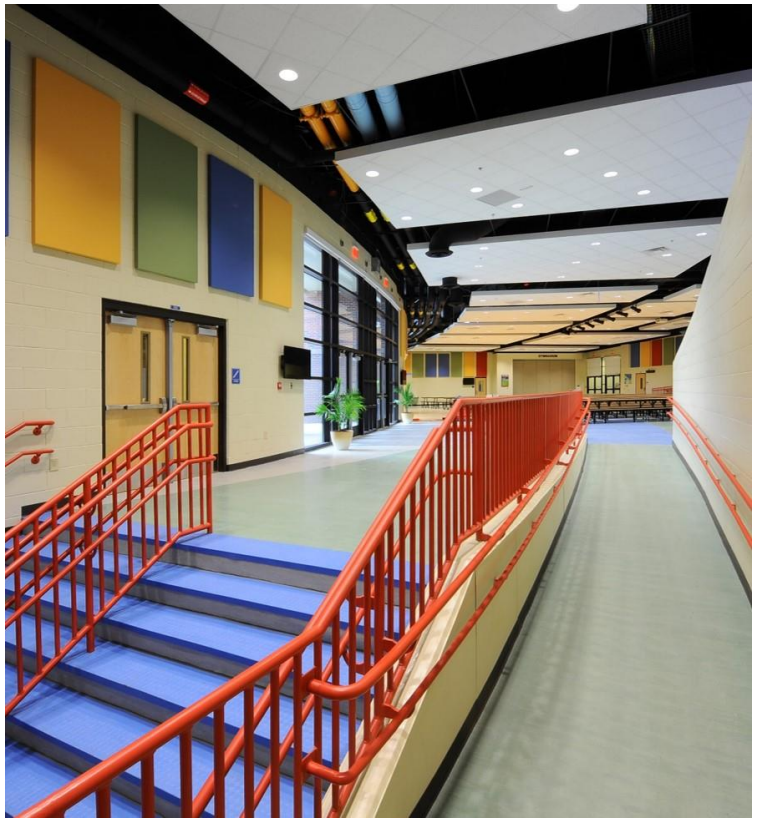
Acoustic Design Strategies for Education Facilities: New Acoustic Requirements in the Building Code

Keely M. Siebein, ASA, INCE, LEED AP BD+C

Matthew Vetterick, AIA, ASA





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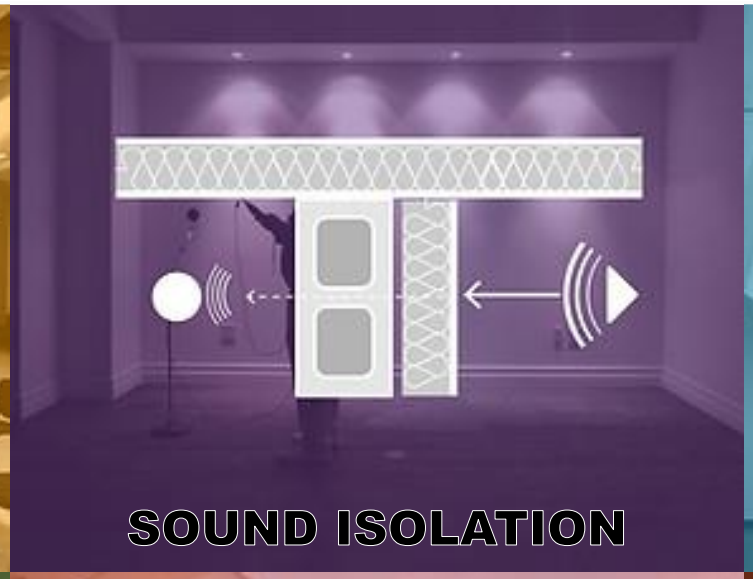

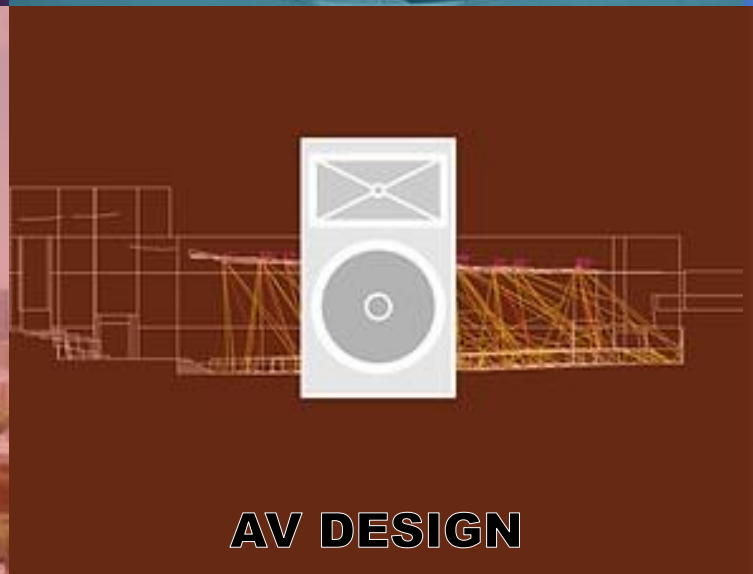

Acoustic Design Strategies for Education Facilities

New Acoustic Requirements in the Building Code

Presenters:
Siebein Acoustic
Keely M. Siebein, ASA, INCE, LEED AP BD+C –Principal Consultant
Matthew Vetterick, AIA, ASA – Senior Consultant

FEFPA

Thursday, January 30, 2025

9 am until 10 am

AIA

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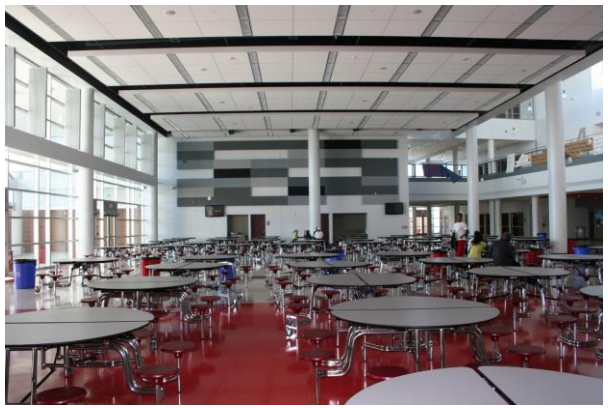
AIA

CONTINUING EDUCATION AIA

Copyright Materials

Learning Objectives



At the end of the this course, participants will be able to:

1. Understand **recent research** linking acoustical attributes of learning environments to student performance and perception of speech in 21st century learning environments.

2. Learn about appropriate **acoustic finish design** to optimize aural learning for children/students.

3. Understand conceptual **HVAC design strategies** for schools to optimize the acoustic environment to facilitate learning.

4. Understand appropriate **sound transmission design** for typical classroom spaces to improve communication and facilitate learning. This includes transmission loss of exterior assemblies for sites with loud sound levels.

AIA

CONTINUING EDUCATION

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ACOUS

AIA

Community – *communus* –

fellowship of relation or feelings

Life in association with others

An area with a people of a common character or identity

Body of people organized in some way

School comprised of learning communities

Many learning activities in classrooms involve verbal **communication**

Communication derived from Latin *communicat*

Make common to many, share

Give something intangible to another

Convey in speech, writing or signs

Communities are built through communication

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ACOUSTIC

EVERY day as much as 1/3 of children show up and hear as though they have a hearing impairment.

English as Second Language

Normal Hearing

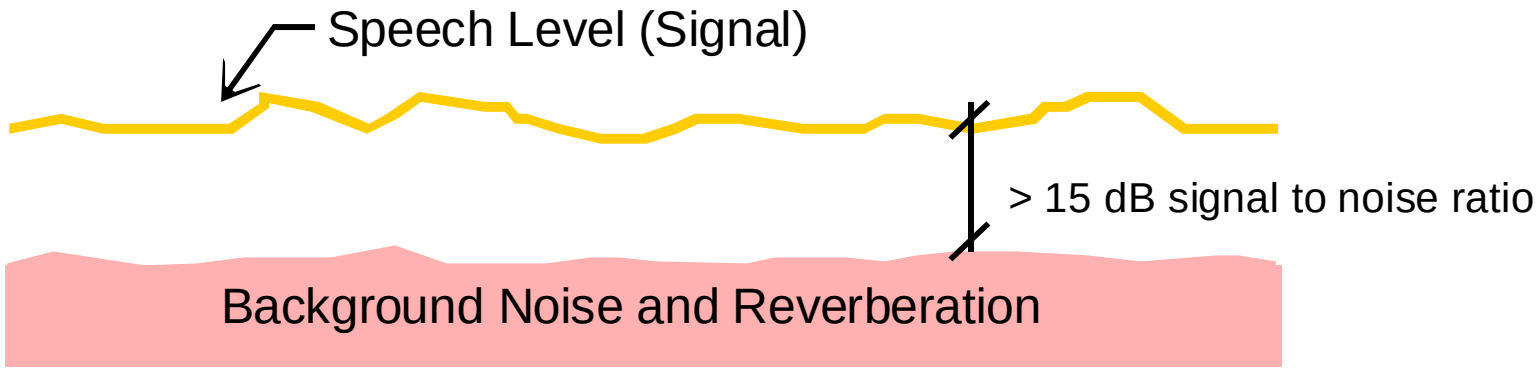
Autism Spectrum

Auditory Processing Disorders

Otitis media

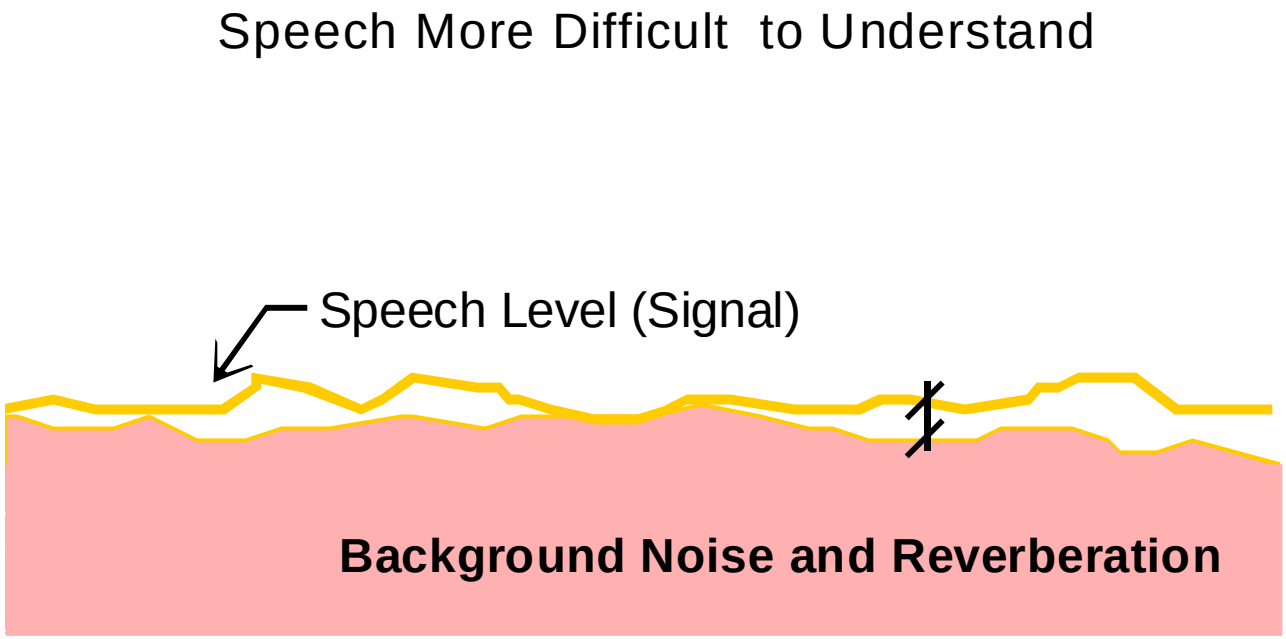
BACKGROUND NOISE RESEARCH

Speech Easy to Understand



Signal to noise ratio = Speech level – Background noise level in dB

BACKGROUND NOISE RESEARCH



Most of the studies cited in the development of the Standard used

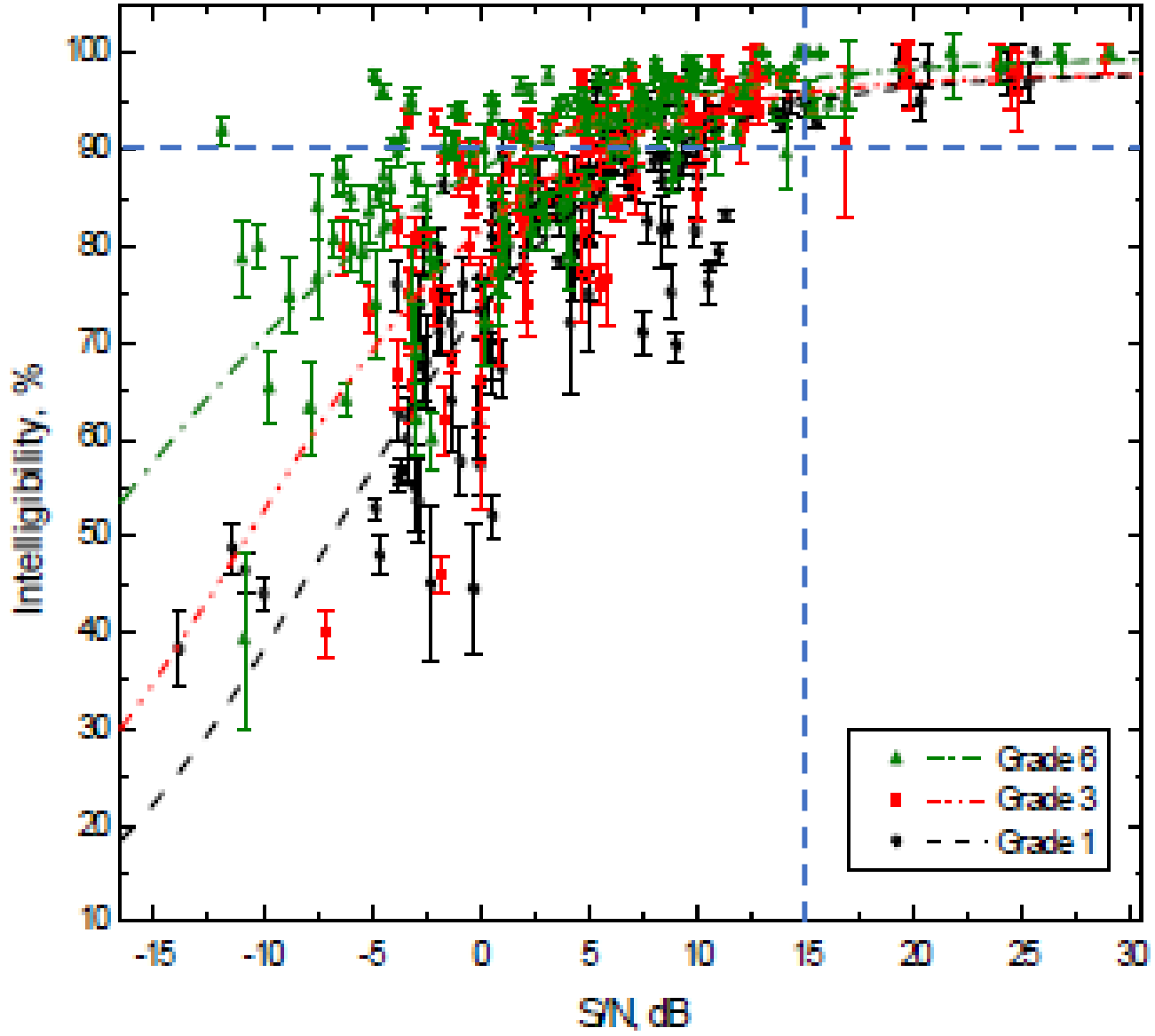
1. Multi babble talker
2. Speech shaped spectrum
3. Transportation noise

As source of noise

Signal to Noise Ratio (S/N) approaches 0 dB when noise level approaches speech level

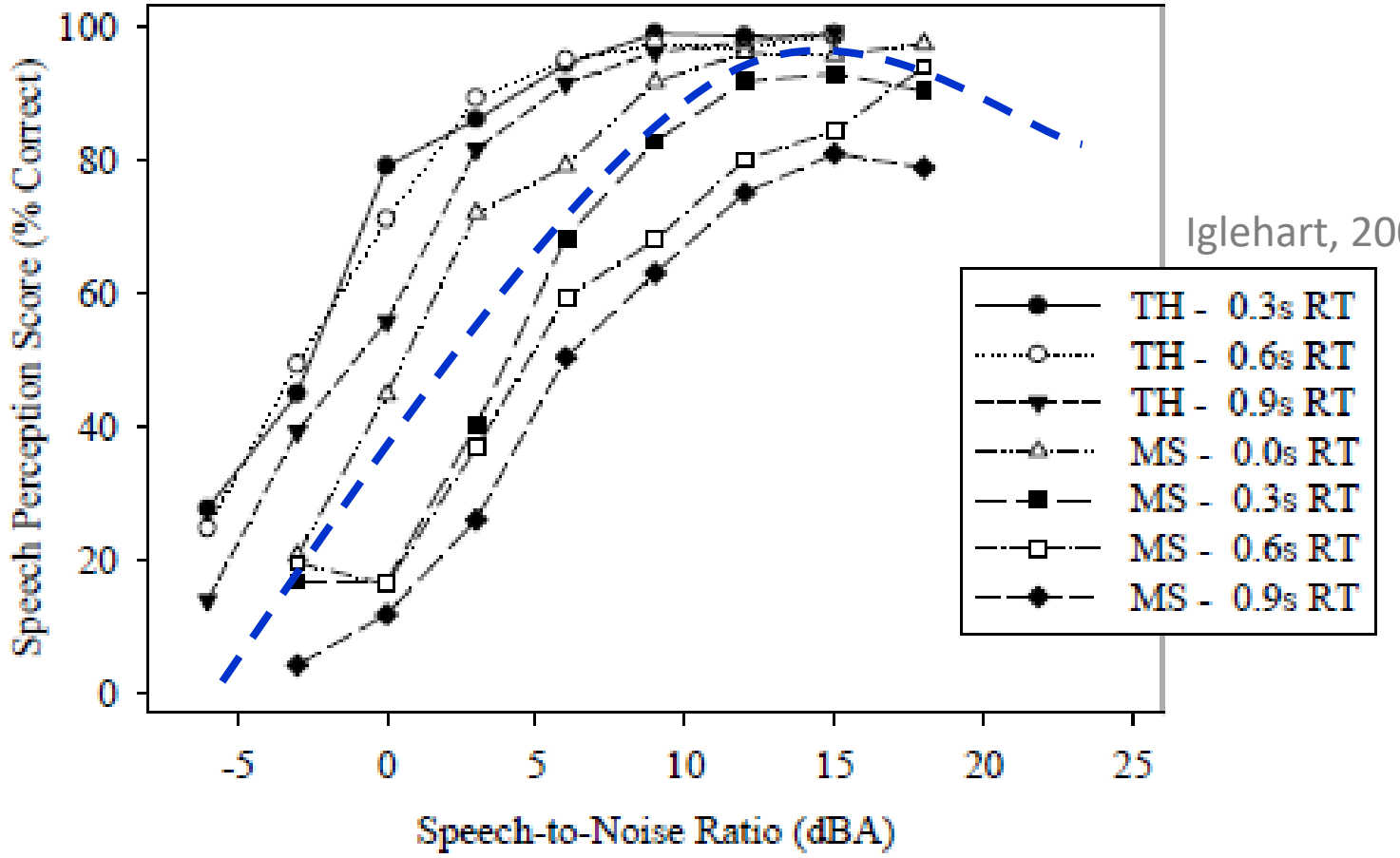
BACKGROUND NOISE RESEARCH

Mean speech intelligibility scores versus Signal-to-Noise Ratio by school grade



Bradley and Sato, 2004

BACKGROUND NOISE RESEARCH



Iglehart, 2009

Figure 4: Comparison of mean scores for participants with typical hearing (TH) and for participants with moderate or moderate-to-severe hearing loss (MS) and using hearing aids.

Students with hearing loss need quieter conditions and less reverberation than students with normal hearing

40% to 50% of 50 million students on any given day hear like they have a hearing loss!

BACKGROUND NOISE RESEARCH

Younger students need 5 dB or more quieter conditions than older students to maintain equal speech perception scores

Bradley, 2009

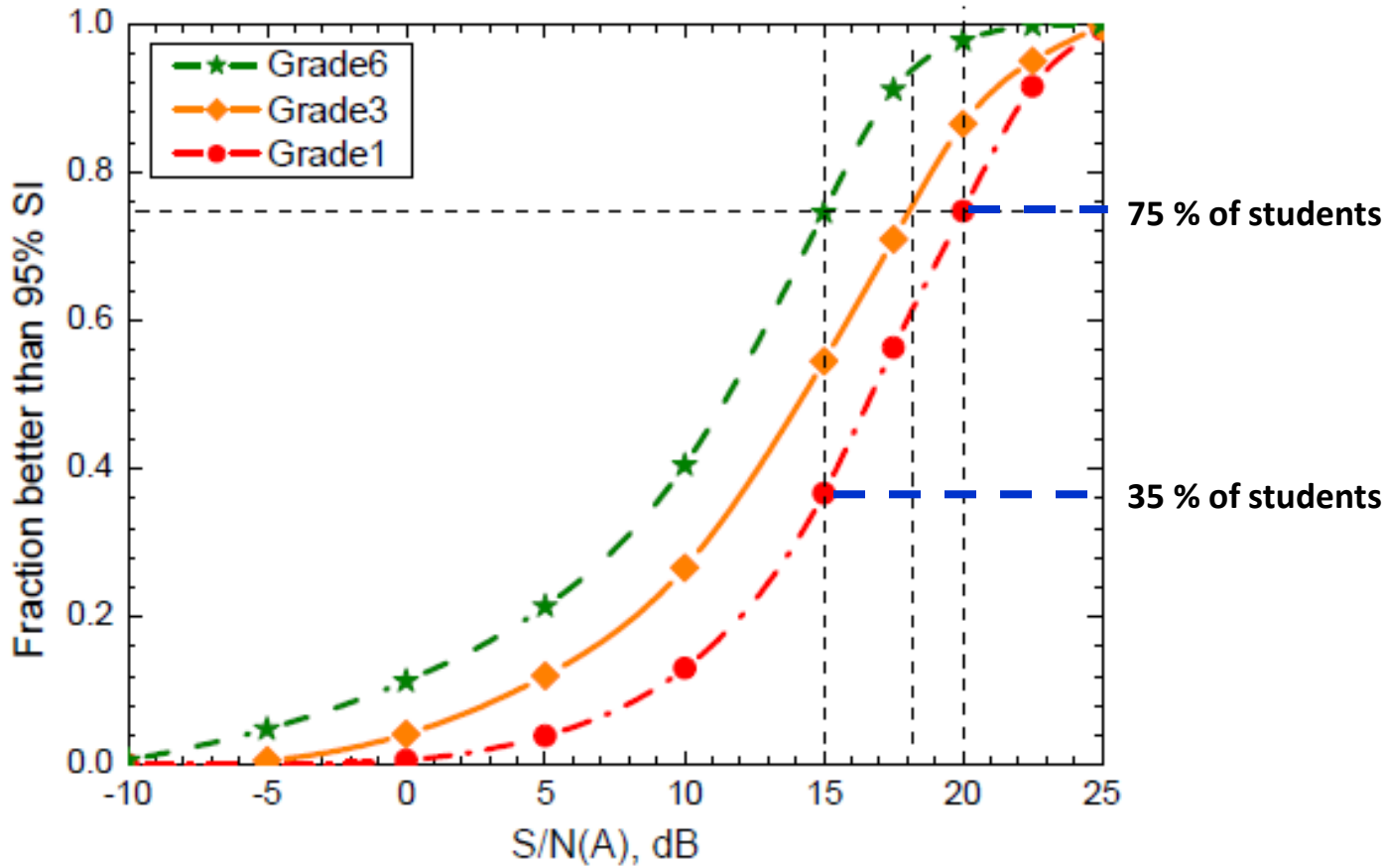
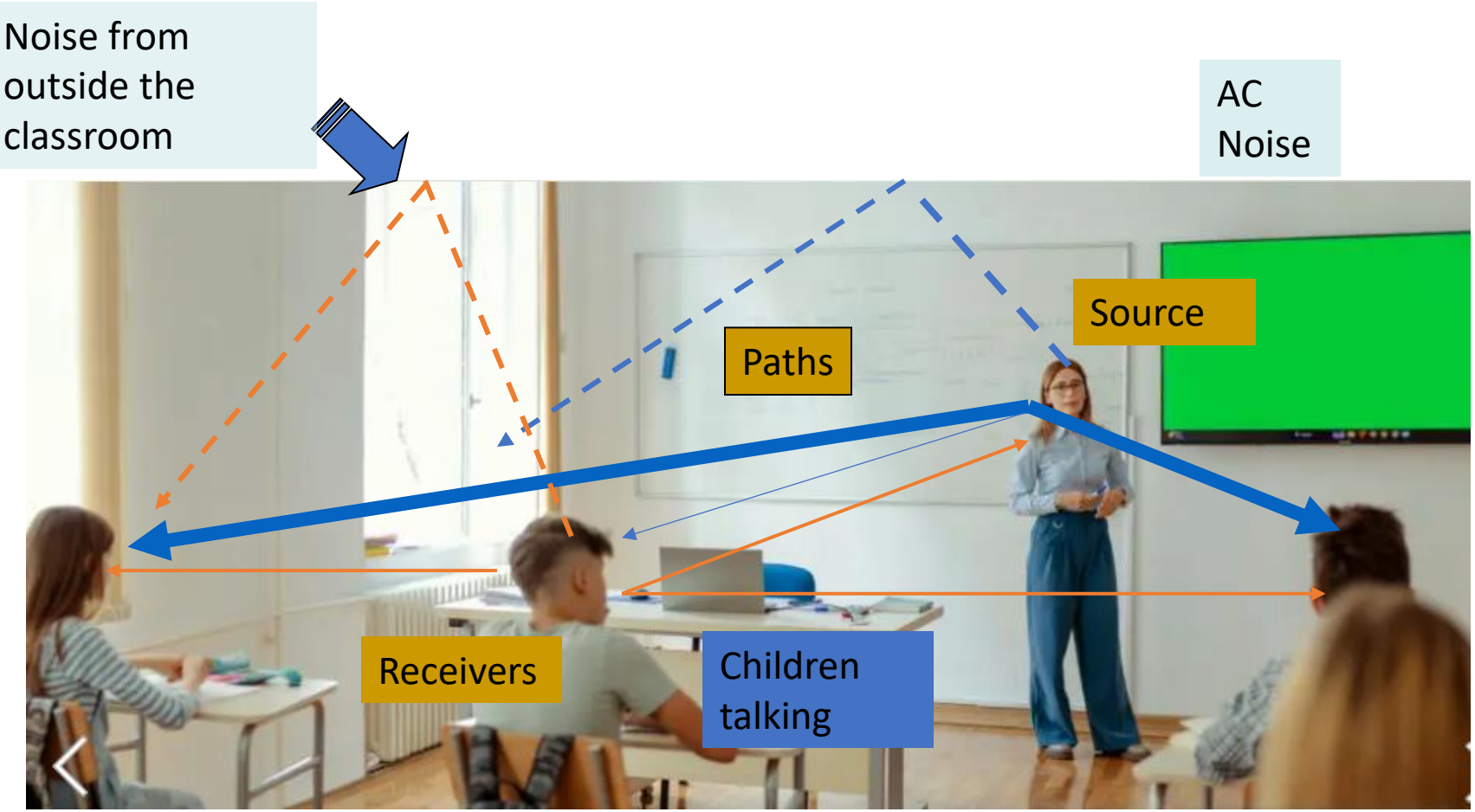


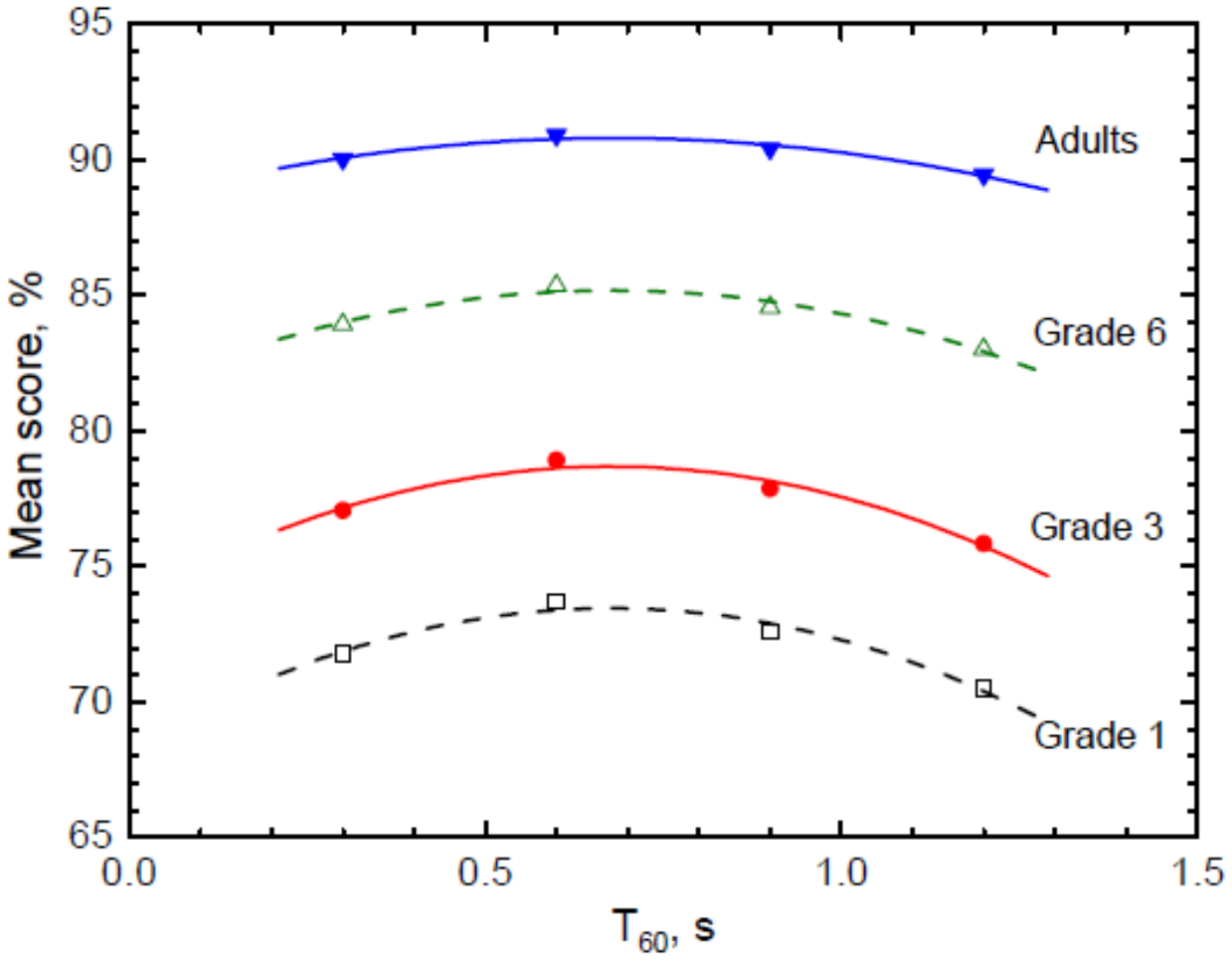
Fig. 2 Fraction of students with speech intelligibility (SI) scores ≥95% versus A-weighted signal-to-noise ratio (S/N(A)). (from Fig. 9 reference 3),

Components of the Speech Communication System in a Classroom



REVERBERATION TIME RESEARCH

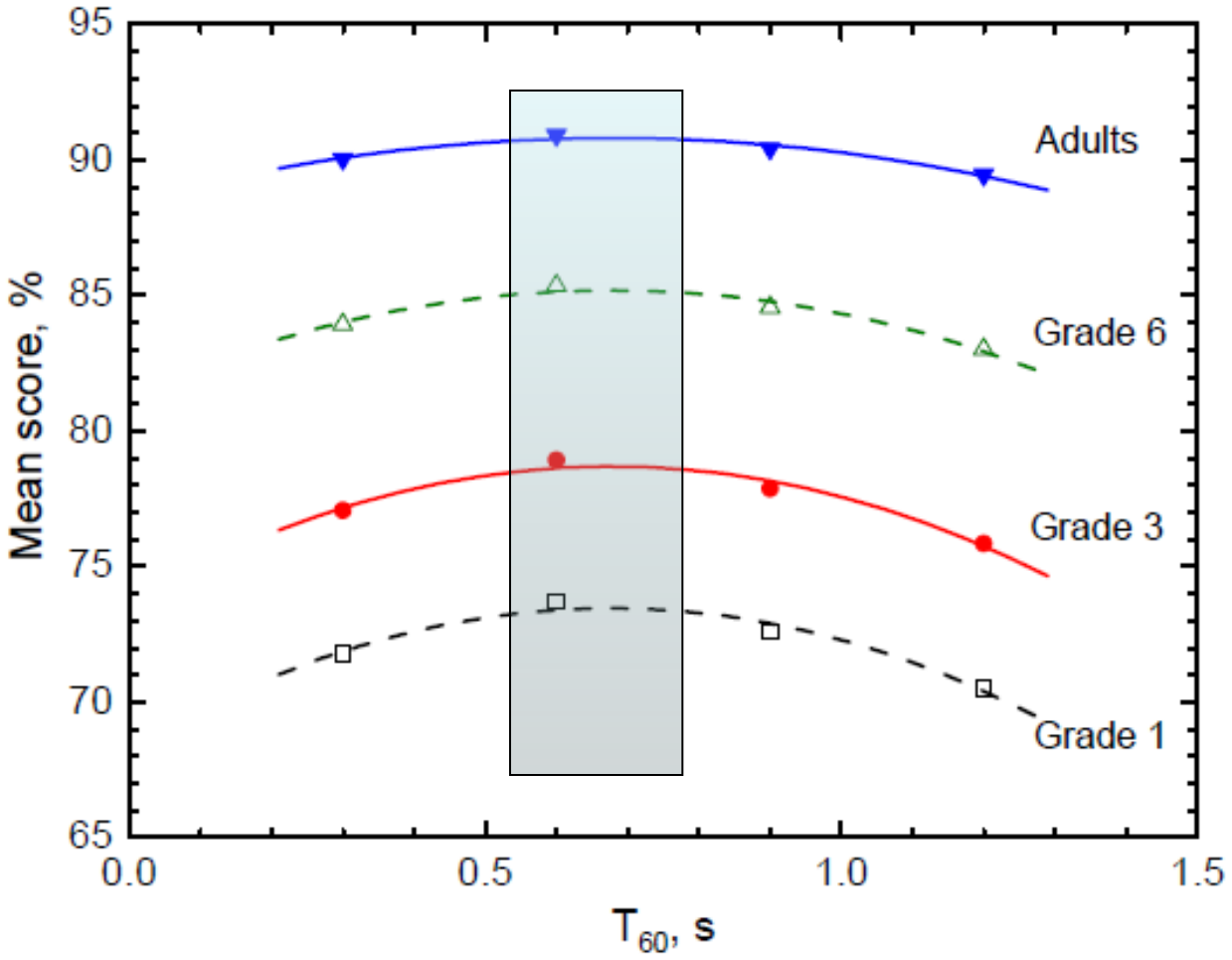
Speech Perception Scores vs Reverberation Times



Bradley and Yang, 2009

REVERBERATION TIME RESEARCH

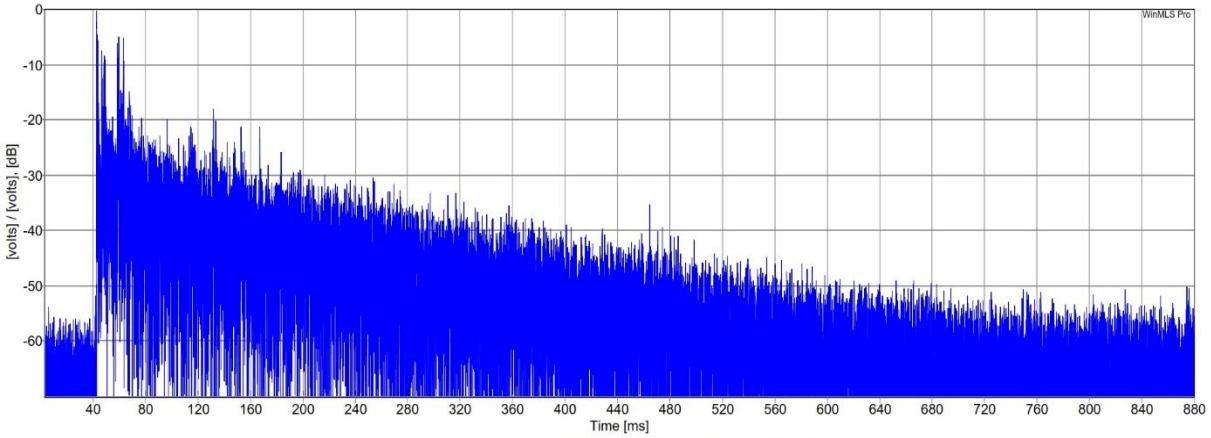
Speech Perception Scores vs Reverberation Times



Bradley and Yang, 2009

Deconstruct the Acoustical Response of a Room to Understand How Each Architectural Element Affects Sound:

- The basis of diagnostics is listening carefully
- The impulse response allows analysis of the architectural design features of rooms contribute to what people hear
- Shape of Room
- Volume
- Materials
- Noise levels



Designed with precision it (sound) becomes a building material." Bernhard Leitner

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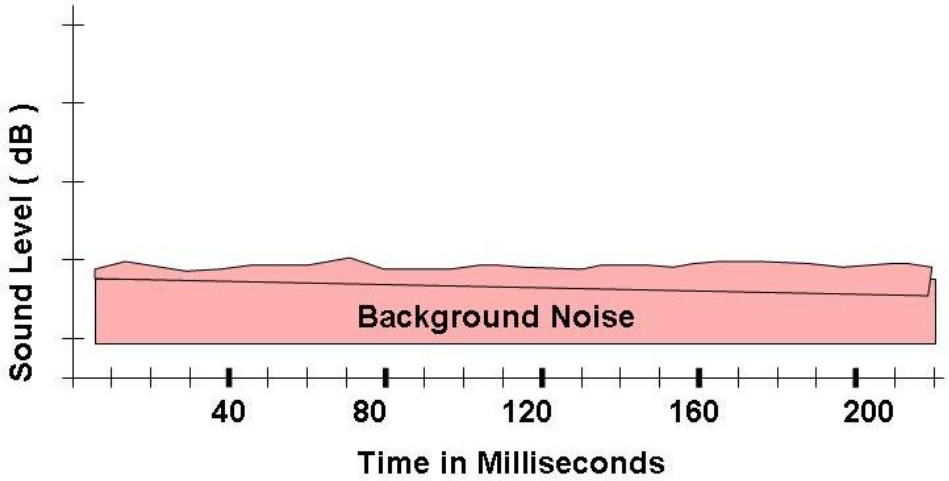
Background Noise

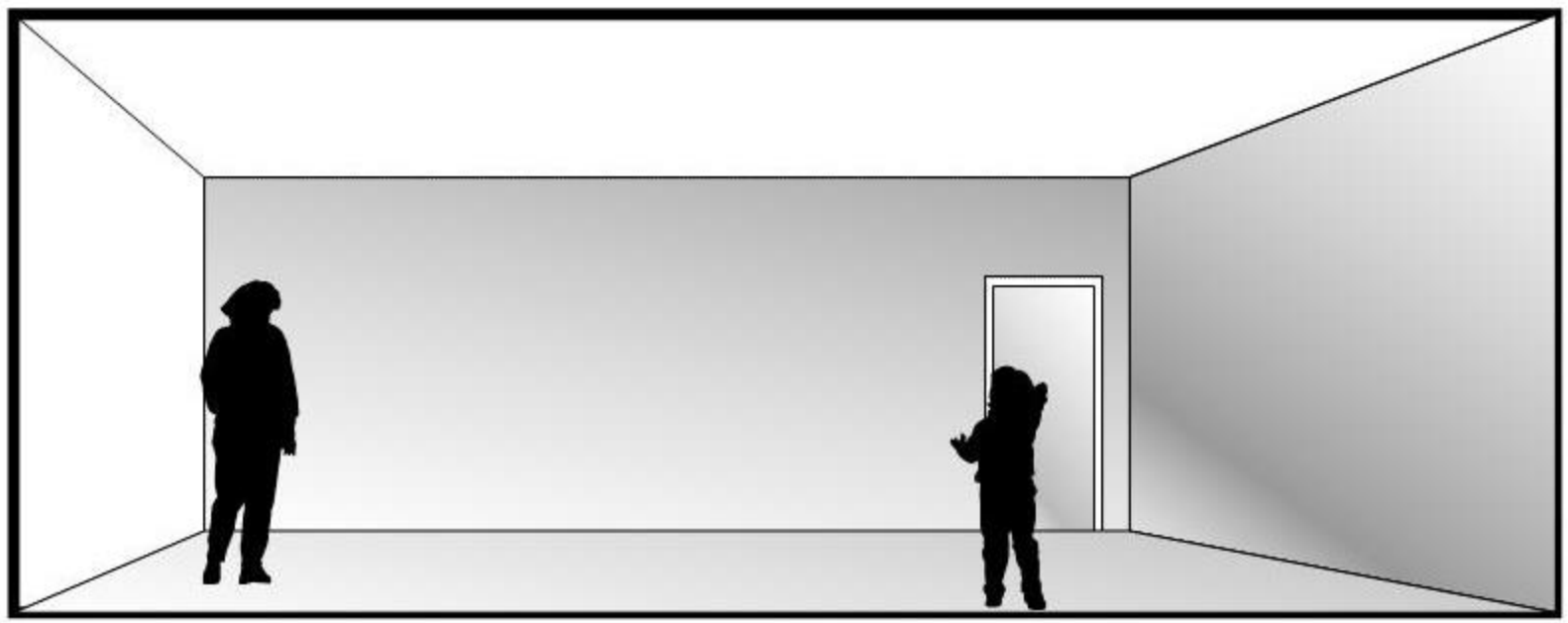
A/C Noise

Site Noise

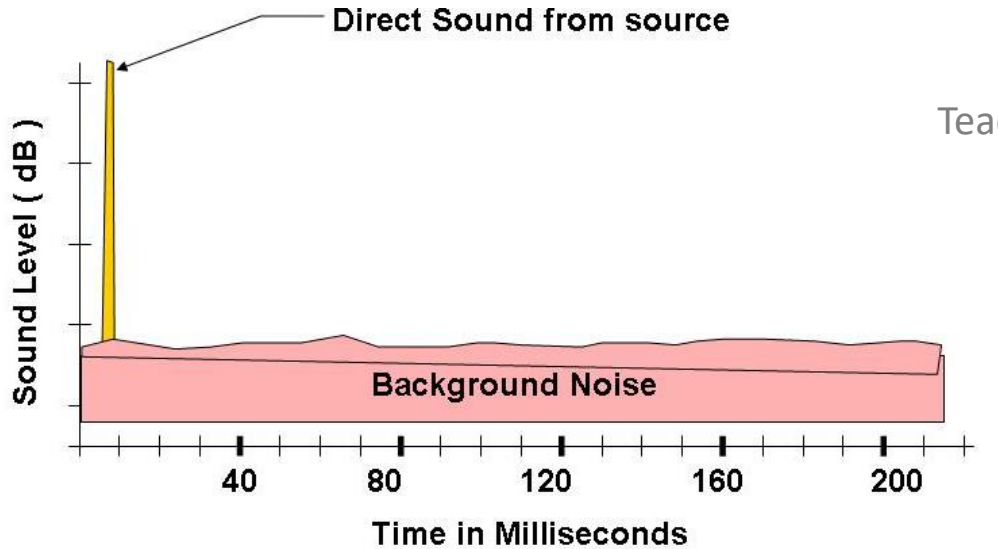
Students outside of class

Students in Class





SIEBEIN ACOUSTIC



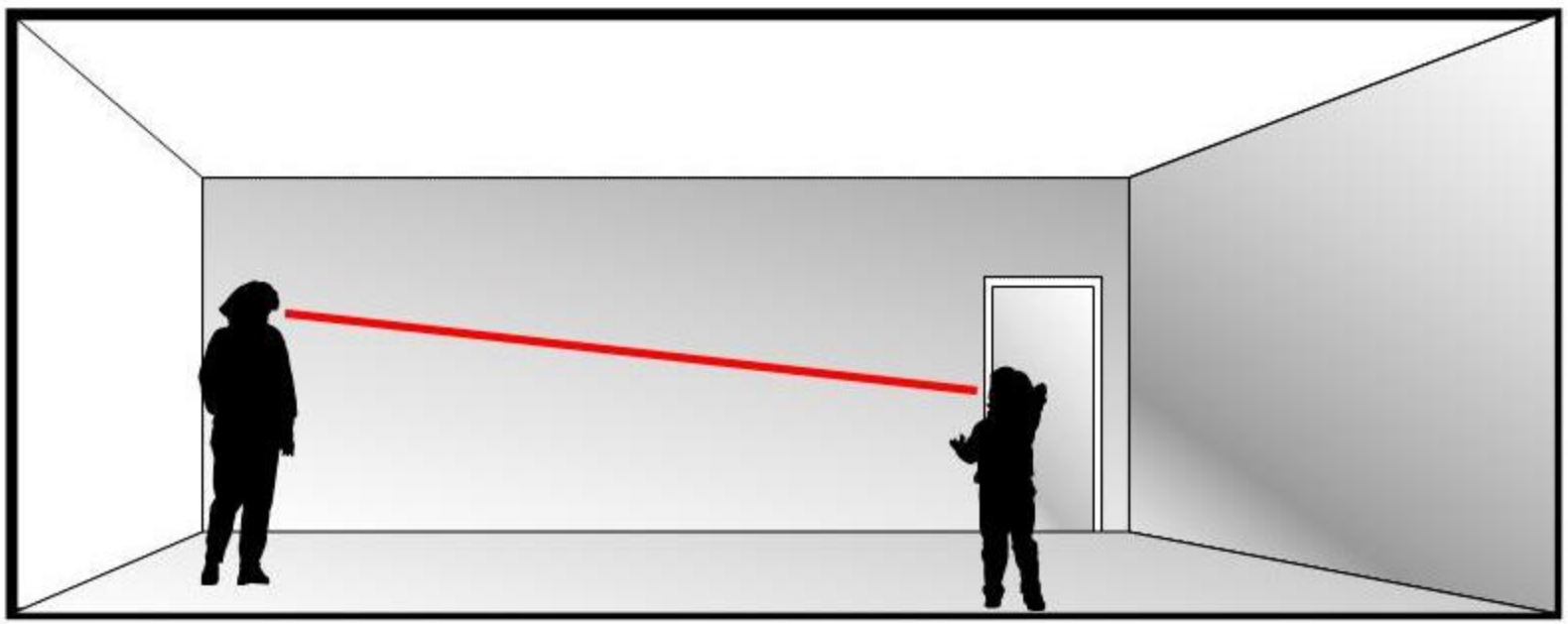
Maximize Direct Sound

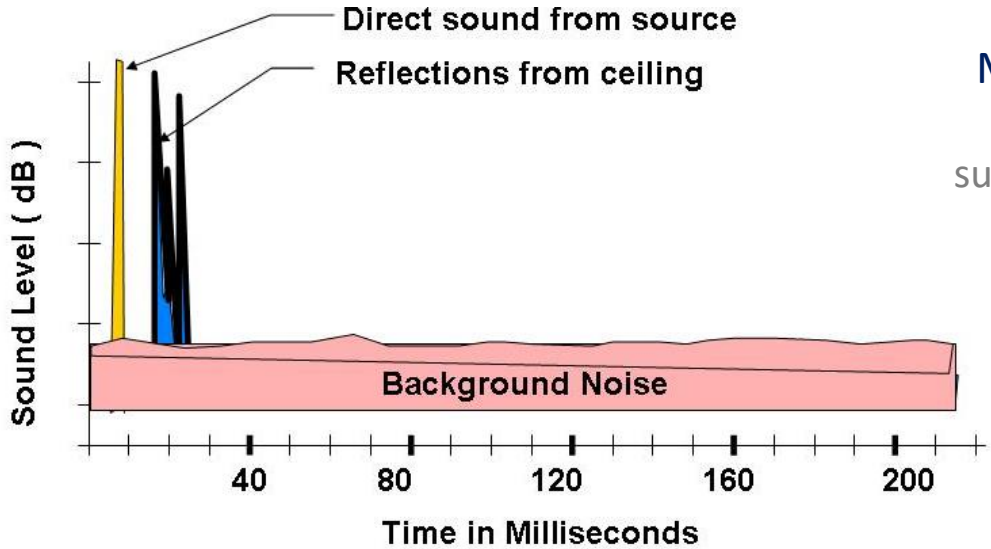
Teacher's voice (strength and direction)

Teacher's diction

Electronic amplification of teacher's voice, where necessary

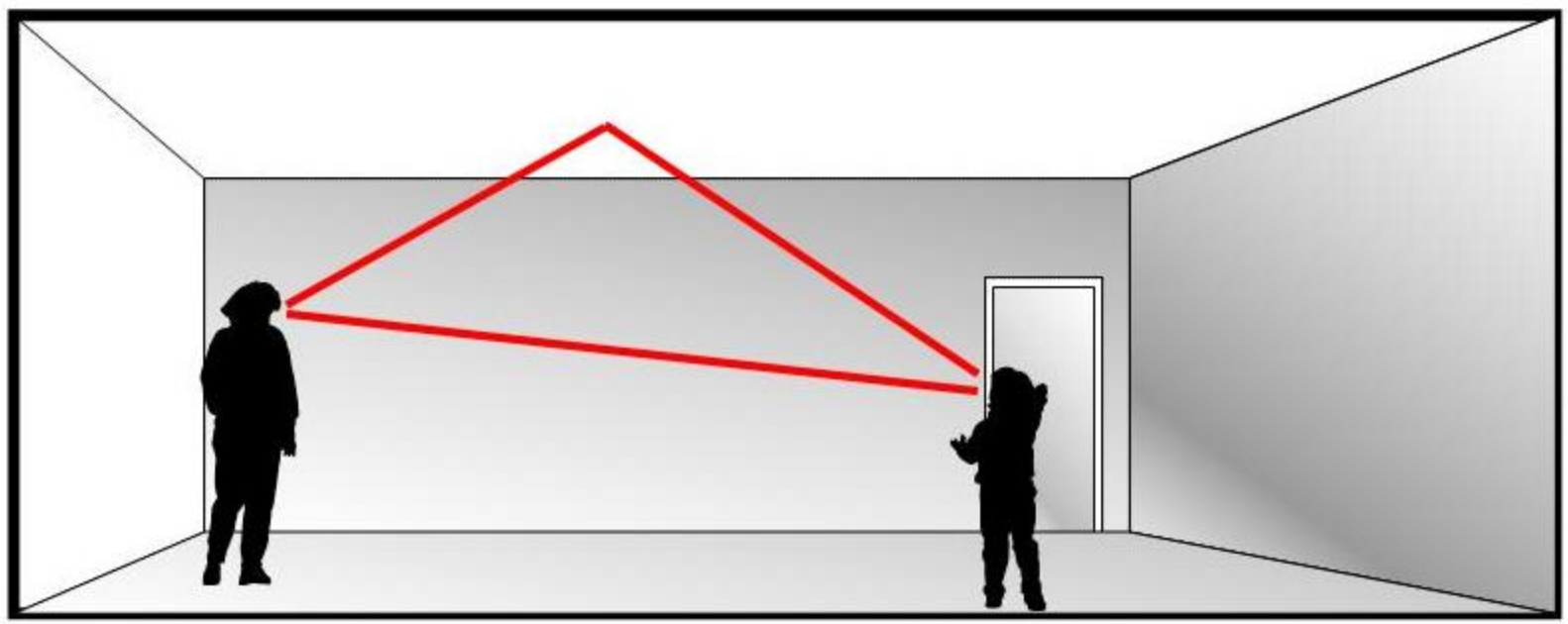
The distance between teacher and student

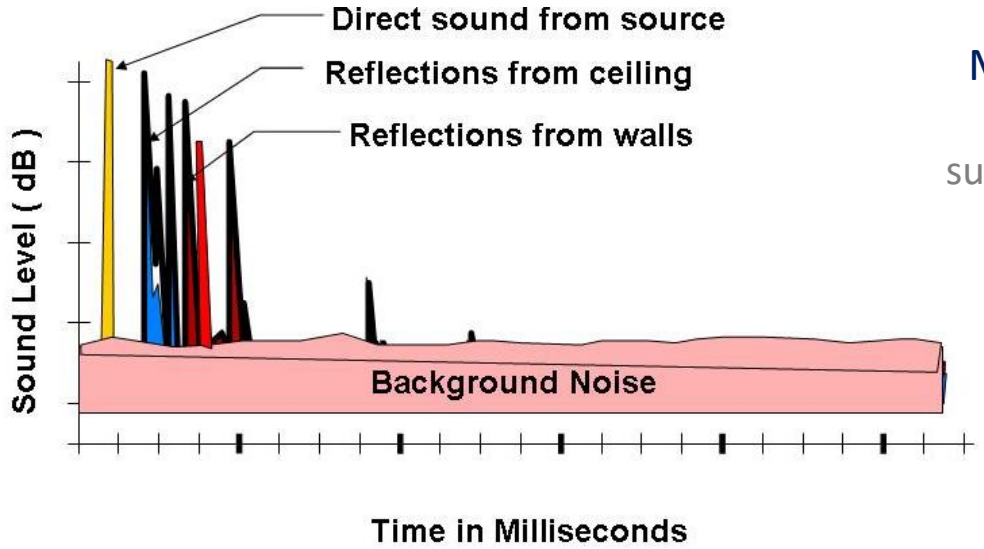




Maximize Early Sound Reflections

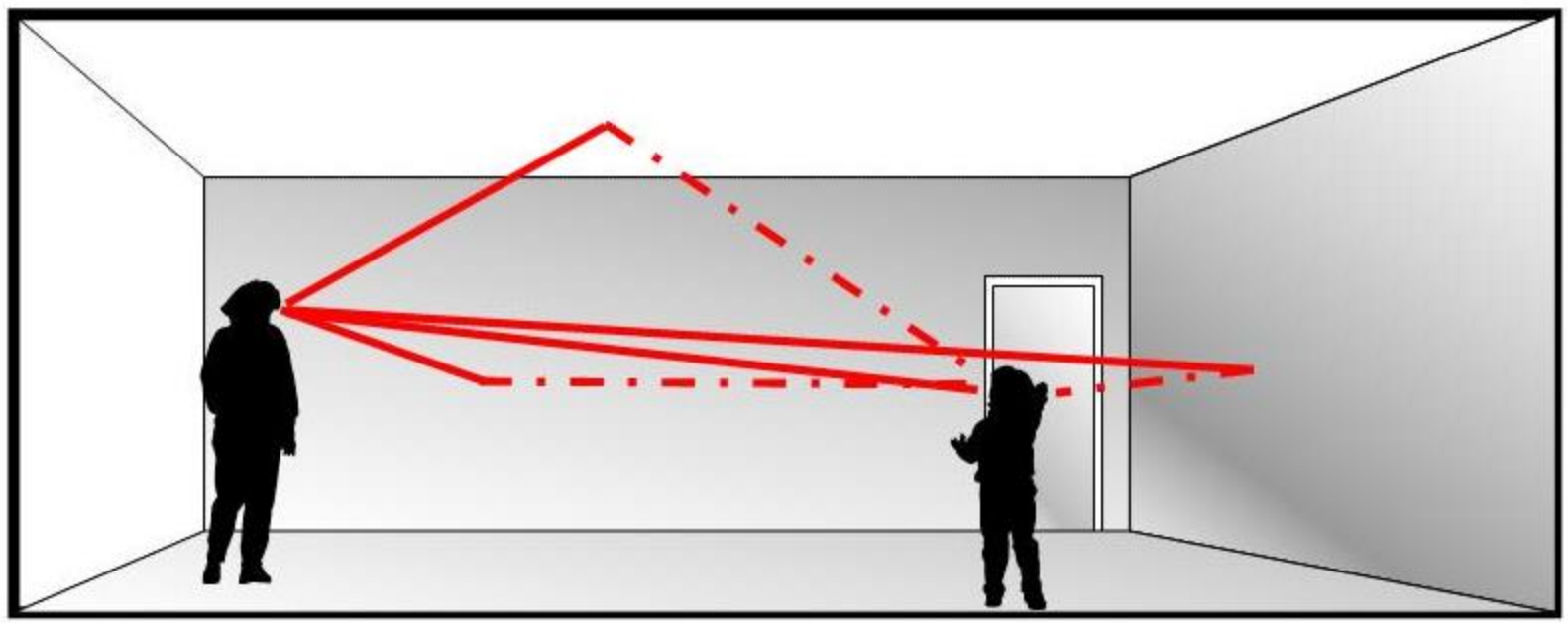
Strategically locate sound-reflecting surfaces near the teacher and students (primarily on the ceiling)

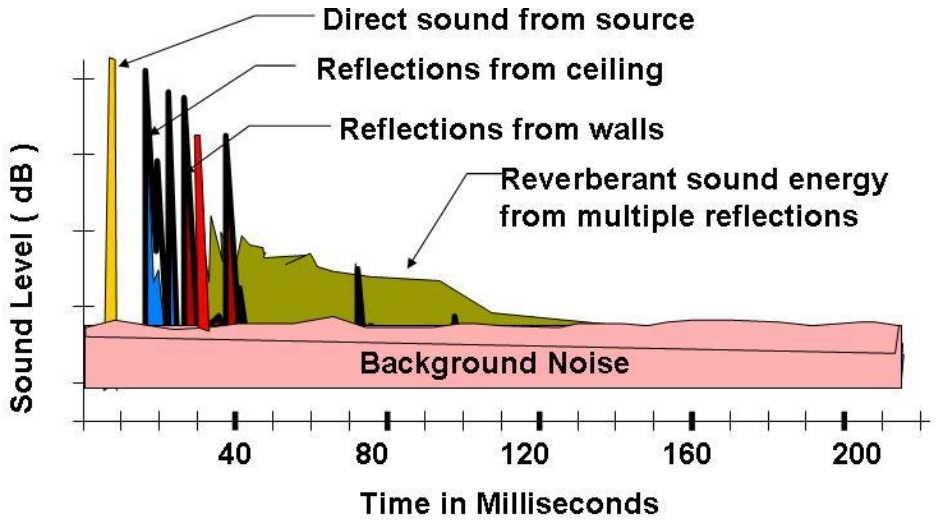




Maximize Early Sound Reflections

Strategically locate sound-reflecting surfaces near the teacher and students who will speak and should be heard

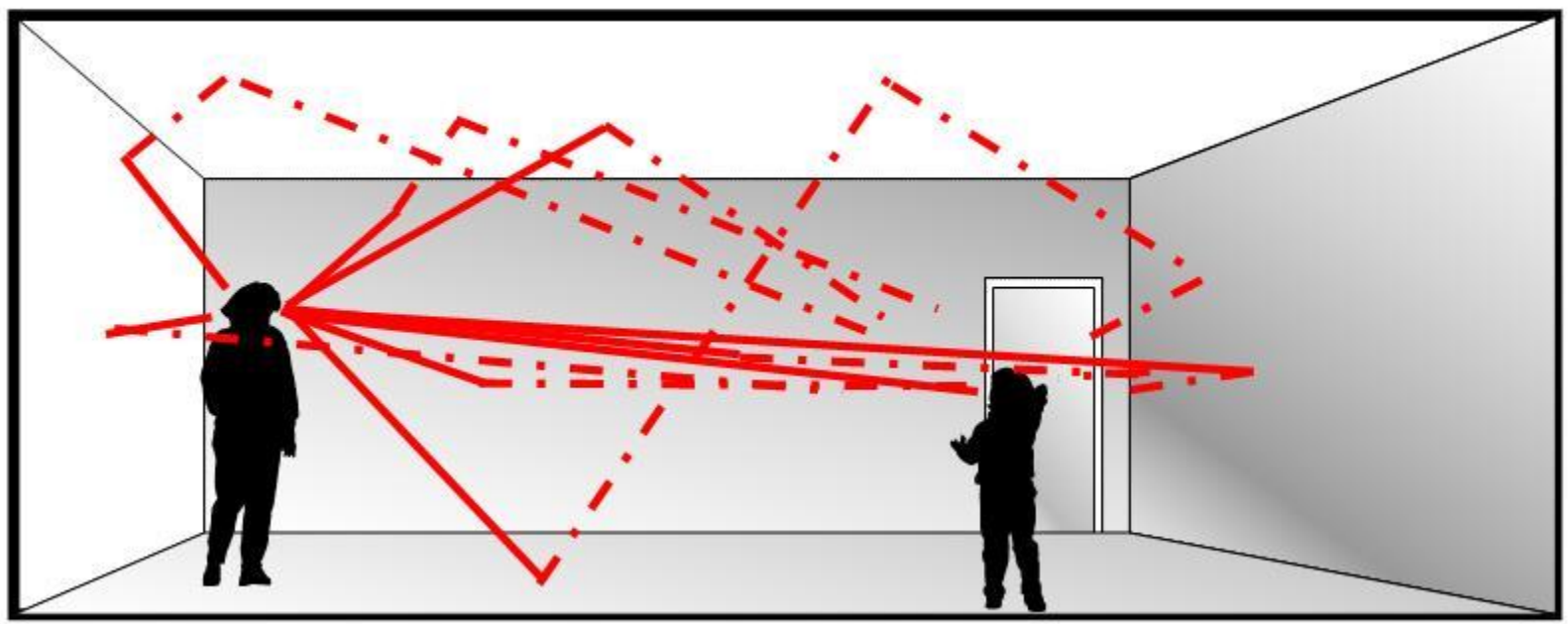




Minimize reverberant “tail”

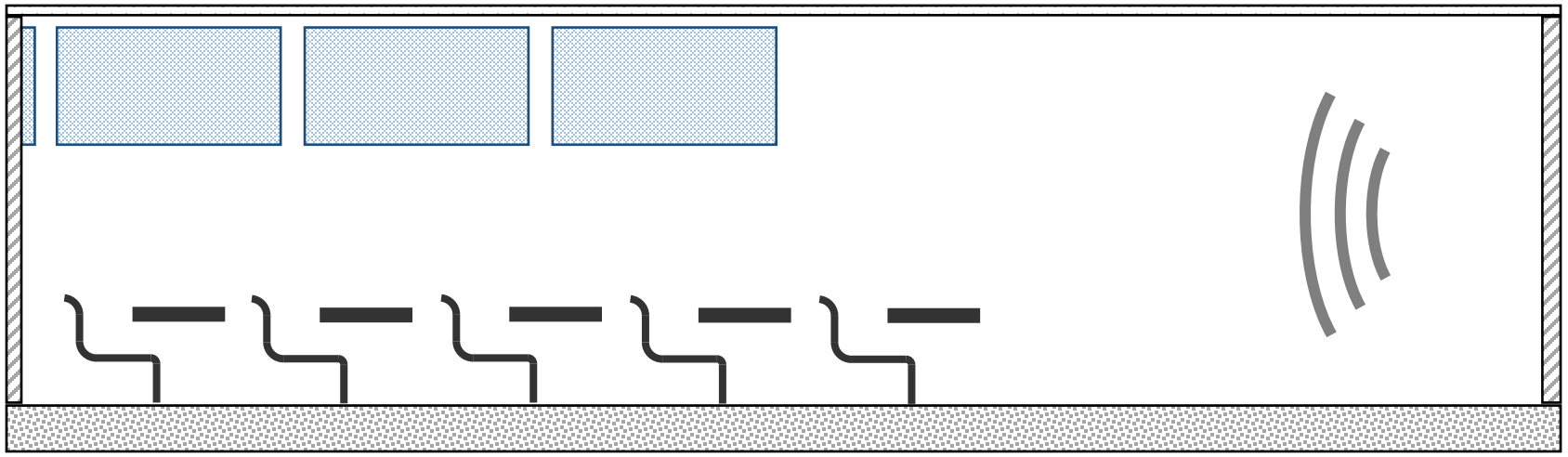
Maintain an appropriate room volume

Provide strategically located sound-absorbing surfaces

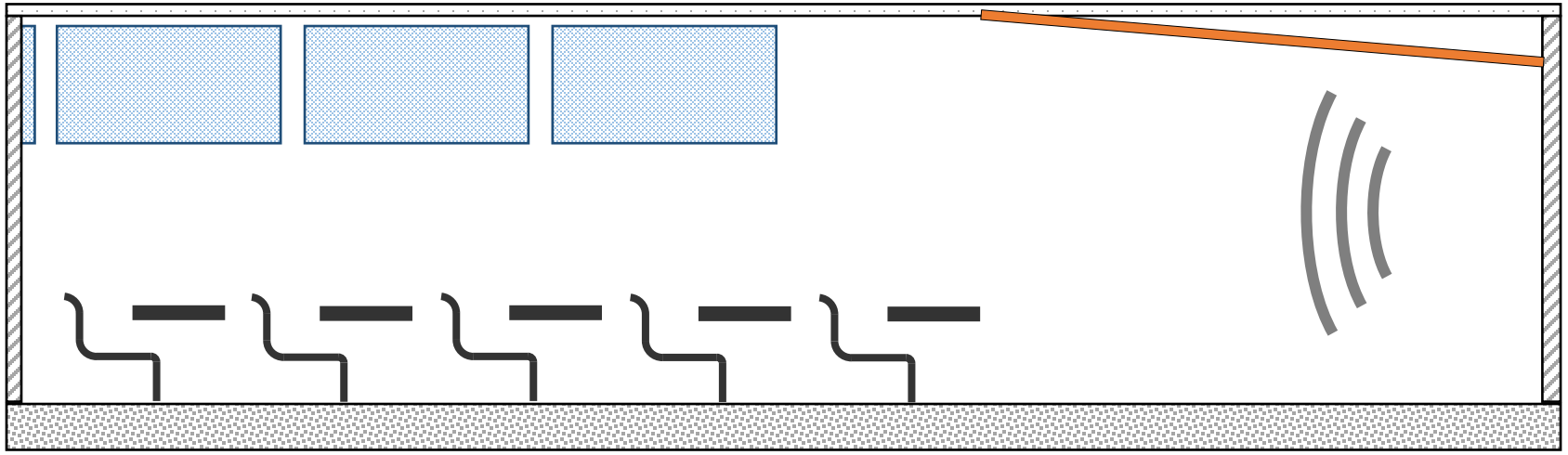


SIEBEIN ACOUSTIC

FINISH DESIGN FOR ACOUSTICS



Lecture Mode
ACT, NRC 0.70
1” Thick Acoustic Wall Panels



Enhanced Lecture Mode
ACT, NRC 0.70
Gypsum Board Reflecting Cloud
1” Thick Acoustic Wall Panels

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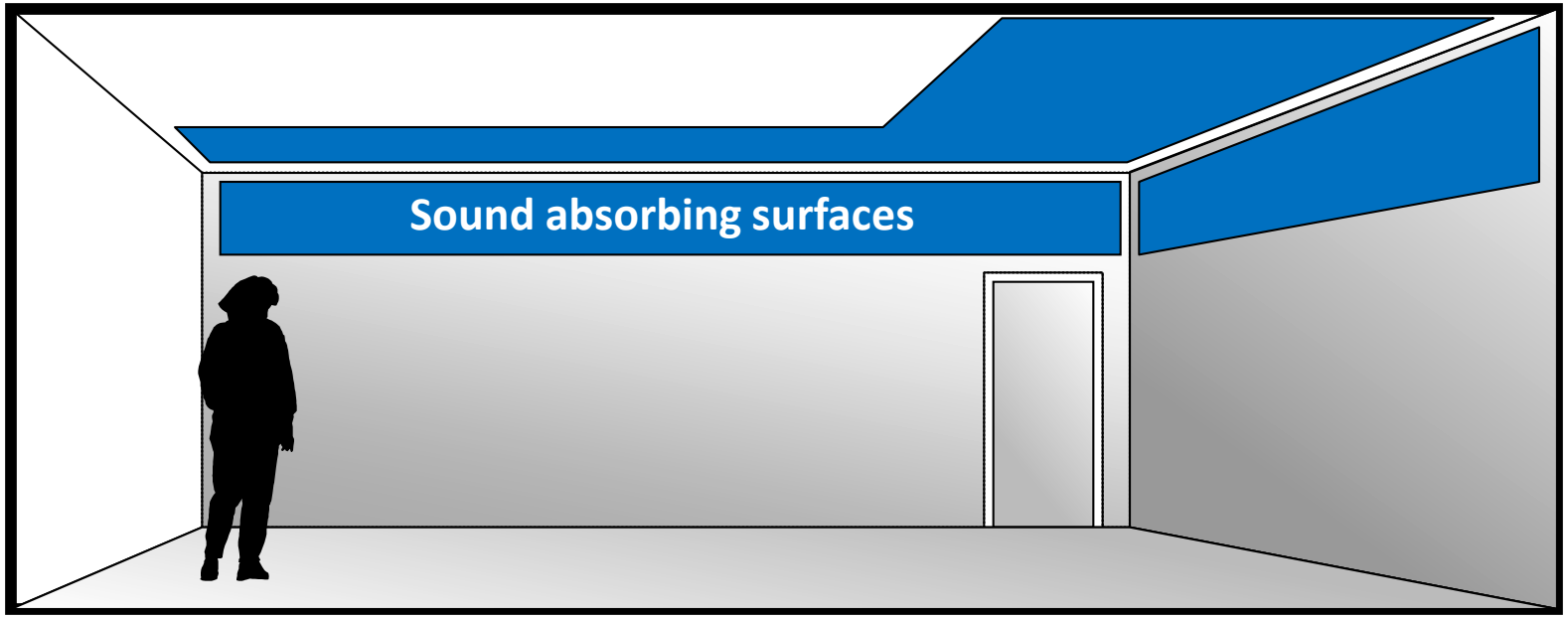
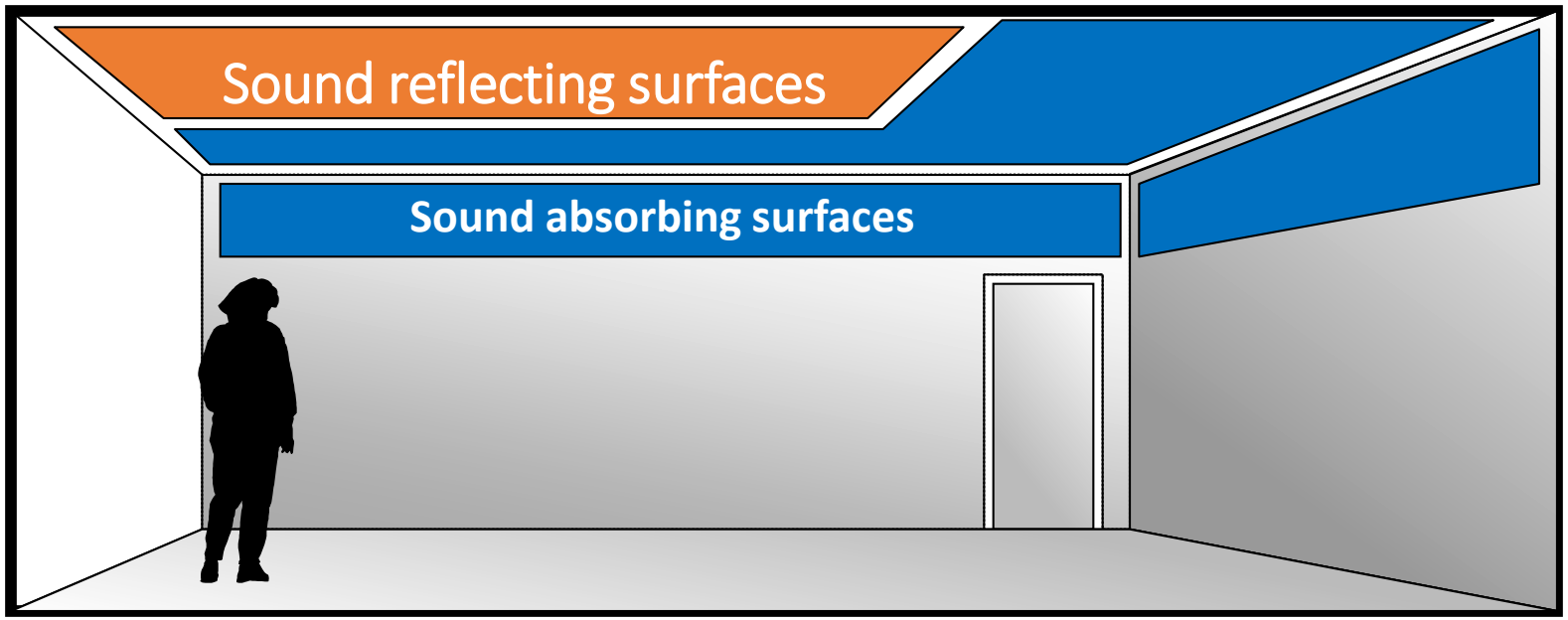


Limit Room Volume

Area of Absorption ≥ Area of Floor

Acoustical Ceiling Tile on Ceiling

Narrow band of acoustical wall panels on upper walls

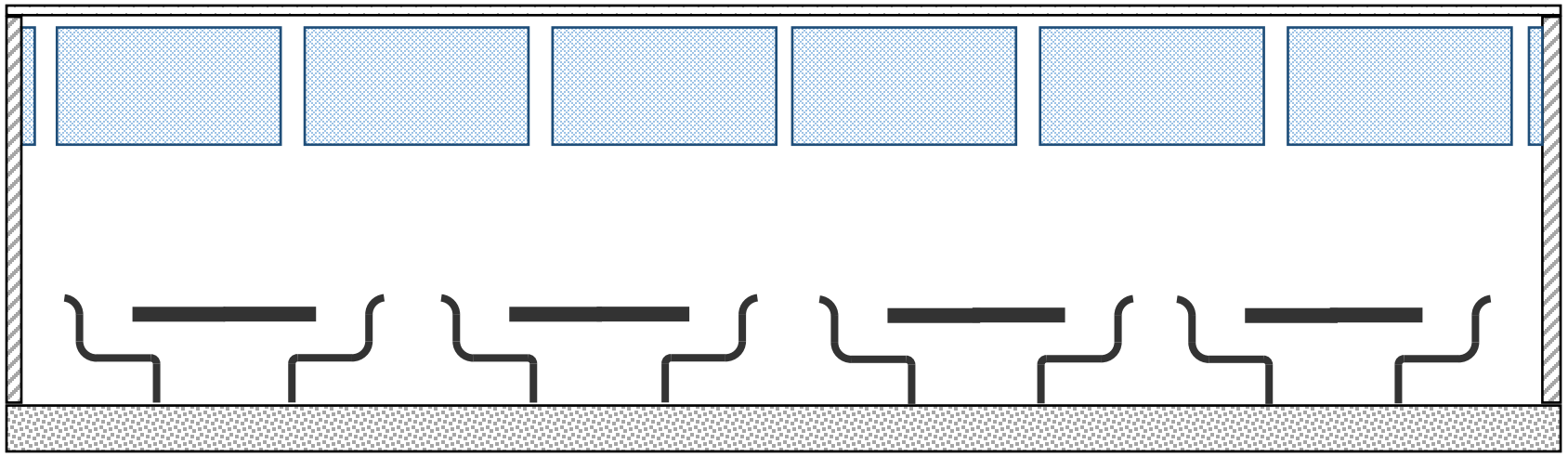


For lectures or in rooms where teaching will mostly occur from a fixed position:

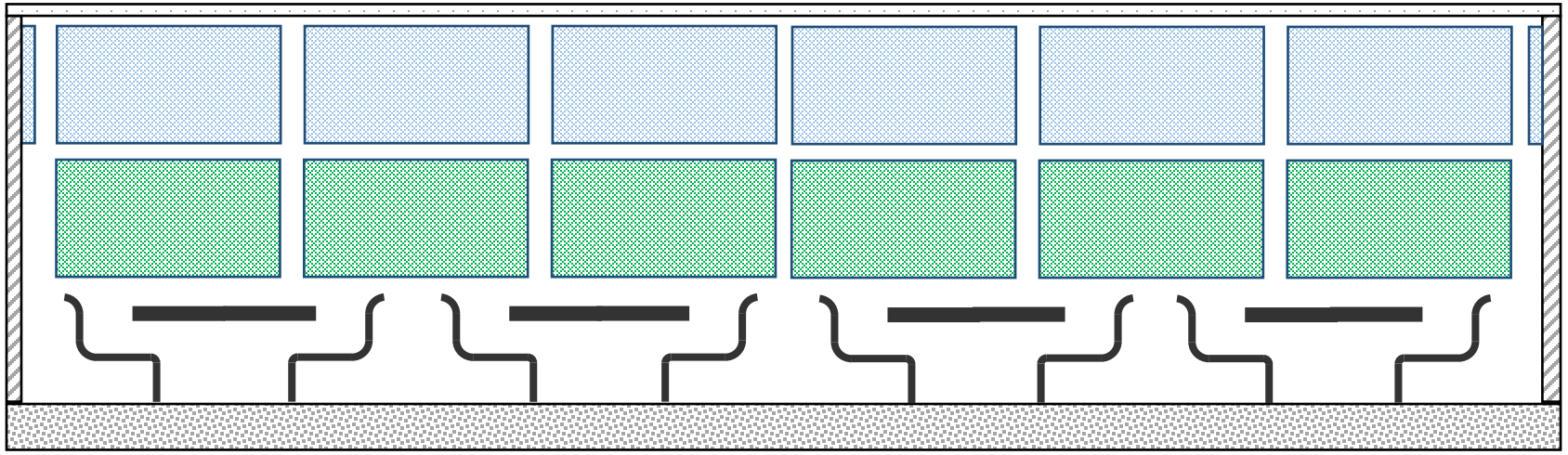
Install (sound-reflecting) gypsum board above the teacher’s location

Consider sound enhancement/reinforcement systems where appropriate

FINISH DESIGN FOR ACOUSTICS



Group Learning Mode
ACT, NRC 0.90
1” Thick Acoustic Wall Panels



Enhanced Group Learning Mode
ACT, NRC 90
1” Thick Acoustic Wall Panels

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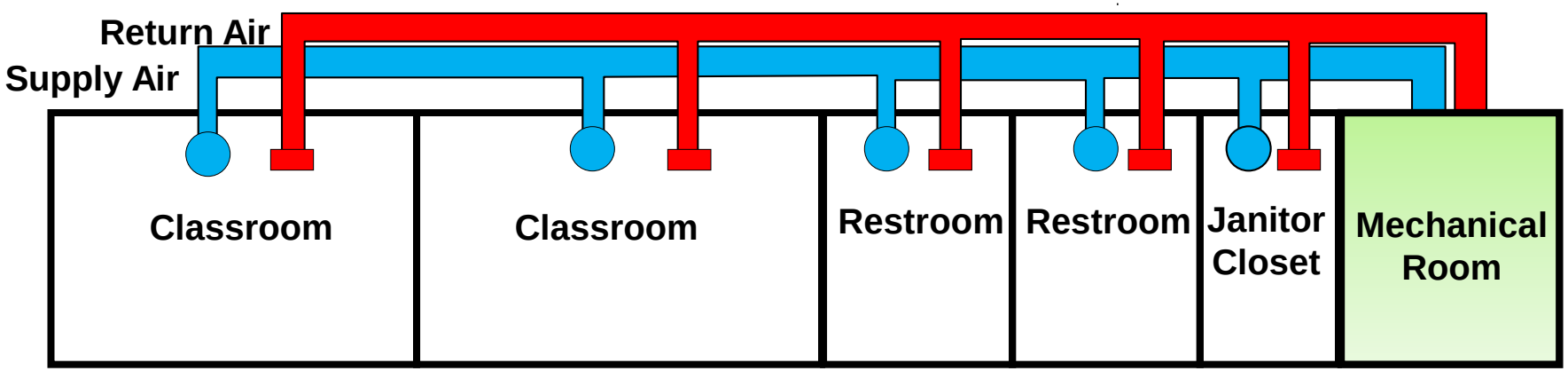
HVAC DESIGN FOR ACOUSTICS

Carefully Design and Select the Air-conditioning System for the School

- Ducted supply *and* return
- Long duct length to classrooms
- Distance between Mech. Room and Classroom
- Silencers on supply *and* return duct runs
- Moderate duct air velocities
- Correctly sized diffusers and grilles
- Vibration isolators for mechanical equipment



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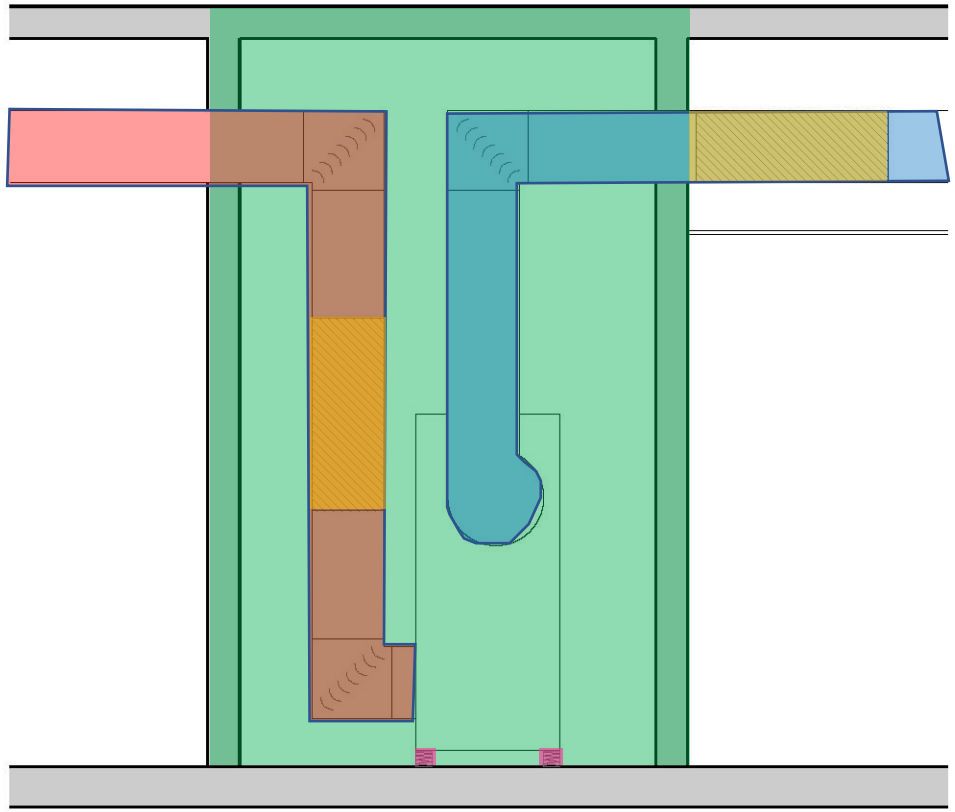
HVAC DESIGN FOR ACOUSTICS

Fan Coil Units in Closet



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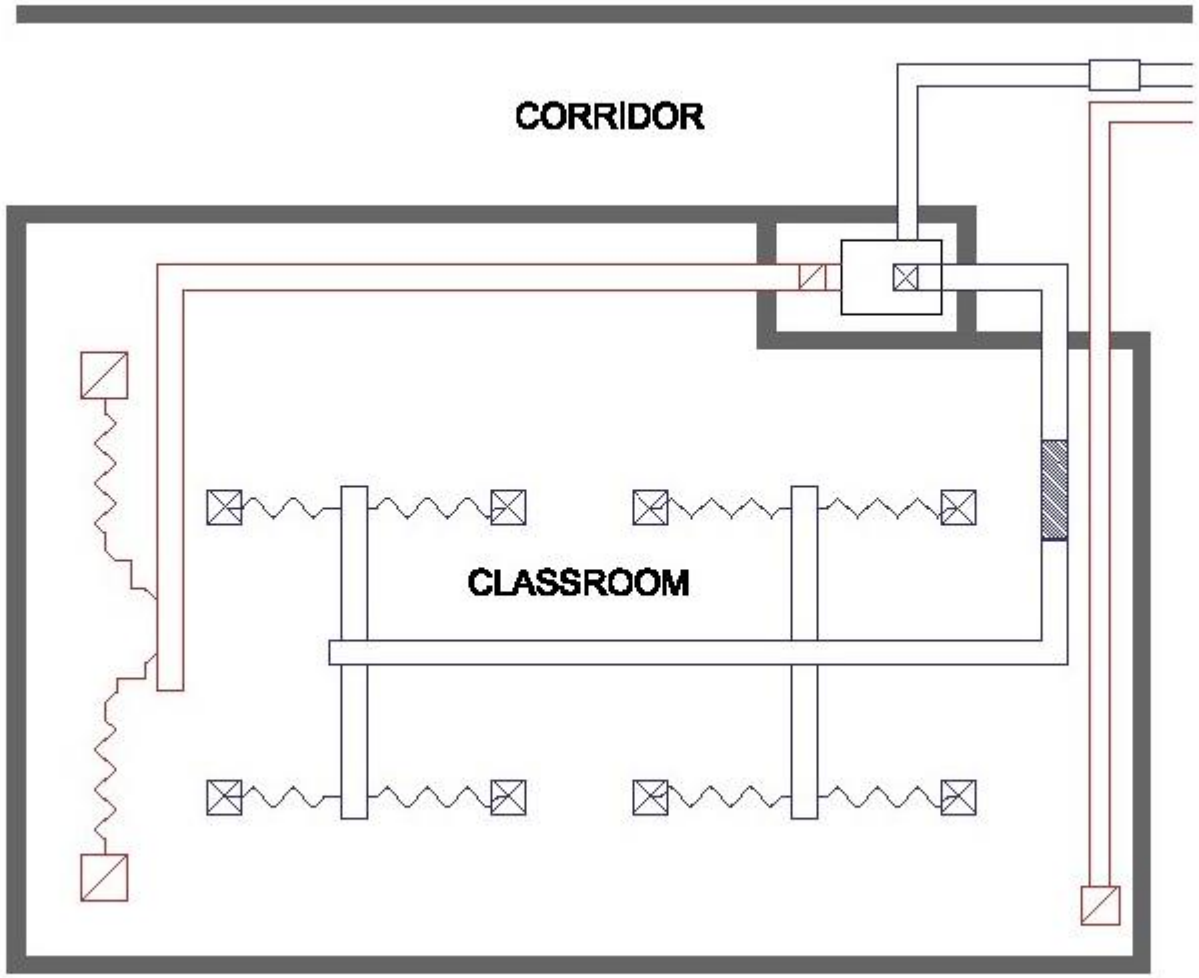
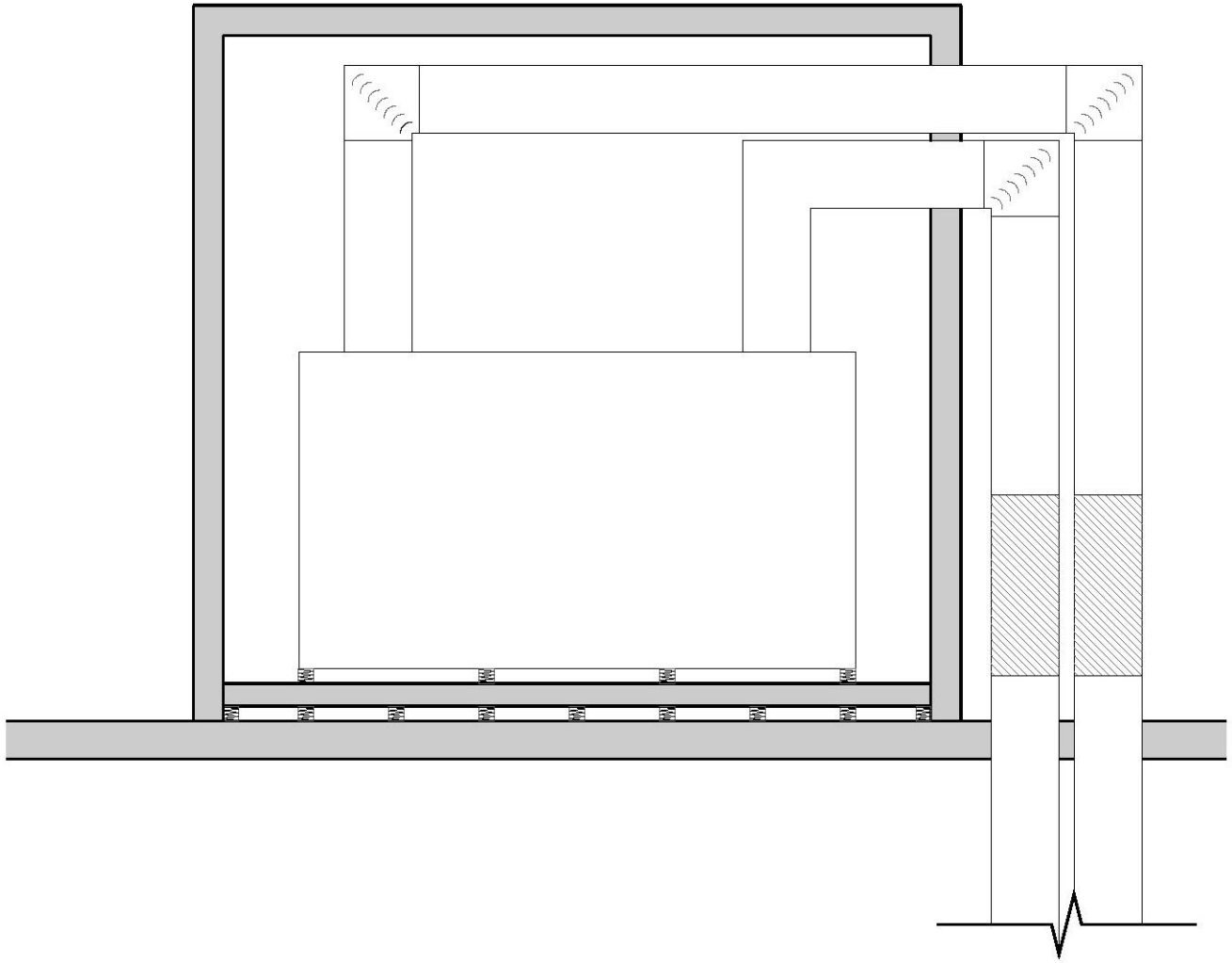
HVAC DESIGN FOR ACOUSTICS

Fan Coil Units in Closet



HVAC DESIGN FOR ACOUSTICS

Upper Floor or Rooftop Units



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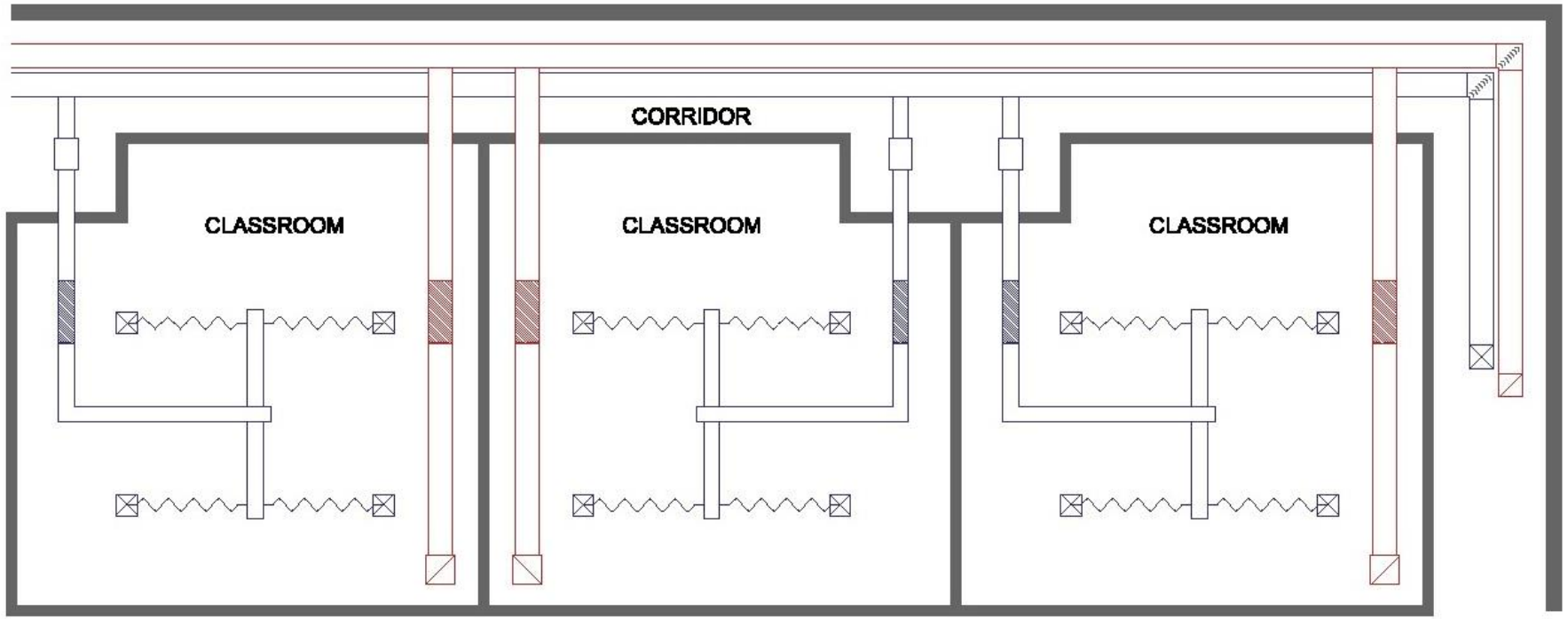
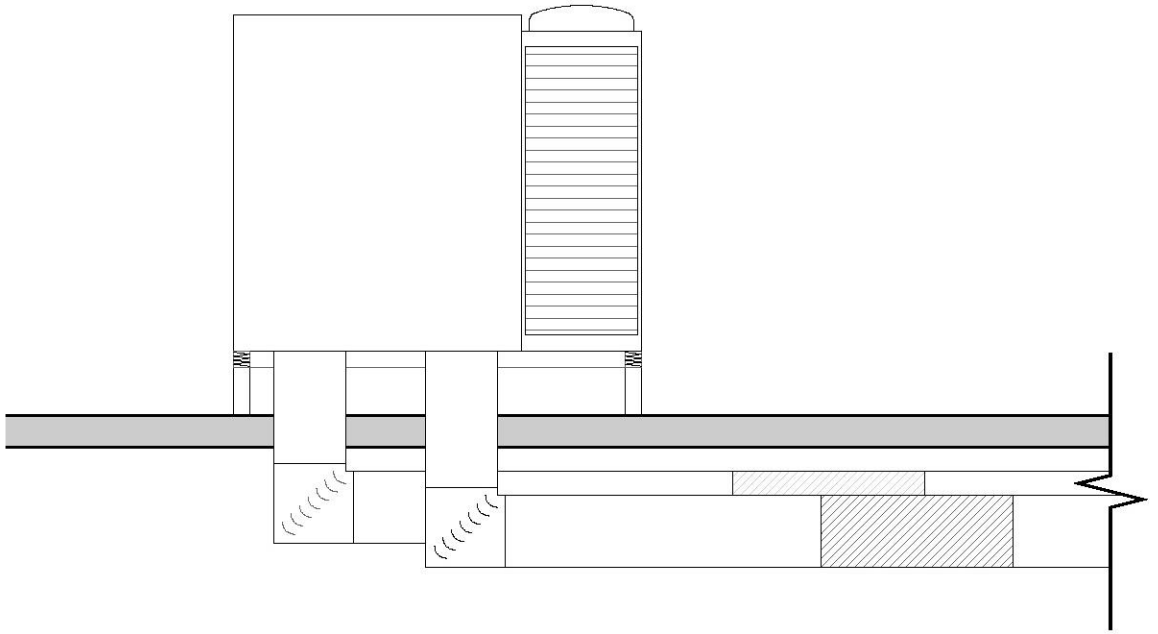
HVAC DESIGN FOR ACOUSTICS

Upper Floor or Rooftop Units



HVAC DESIGN FOR ACOUSTICS

Rooftop Package Units



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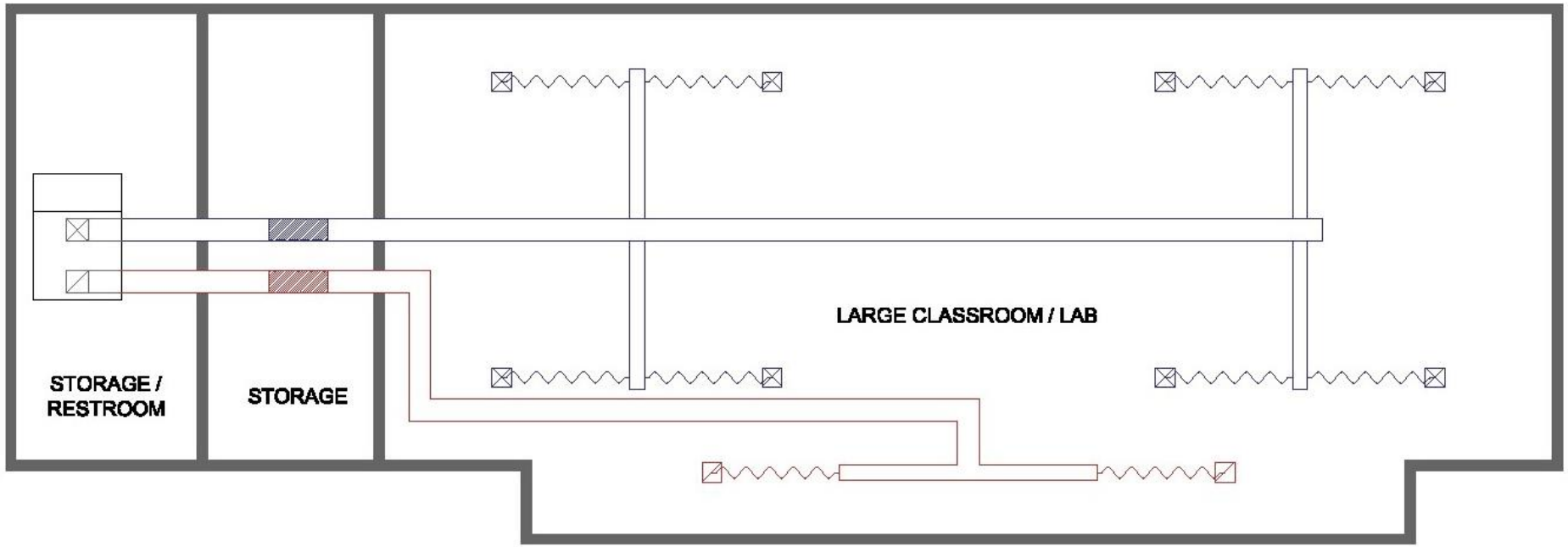
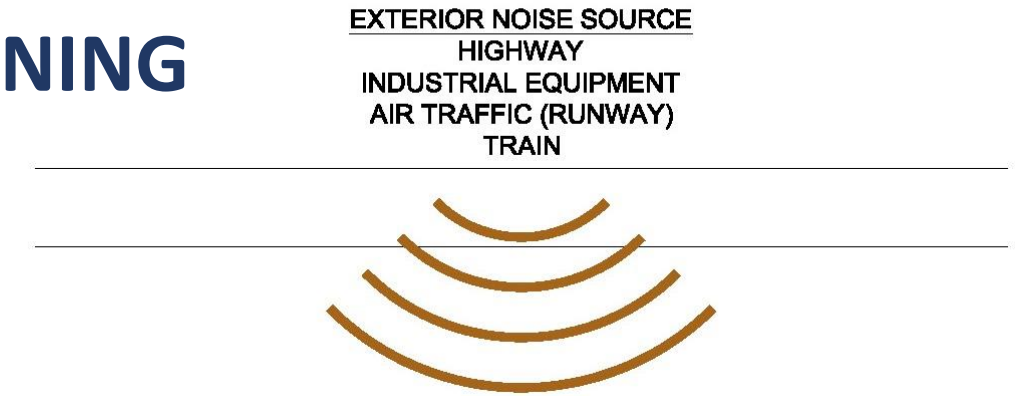
HVAC DESIGN FOR ACOUSTICS

Rooftop Package Units

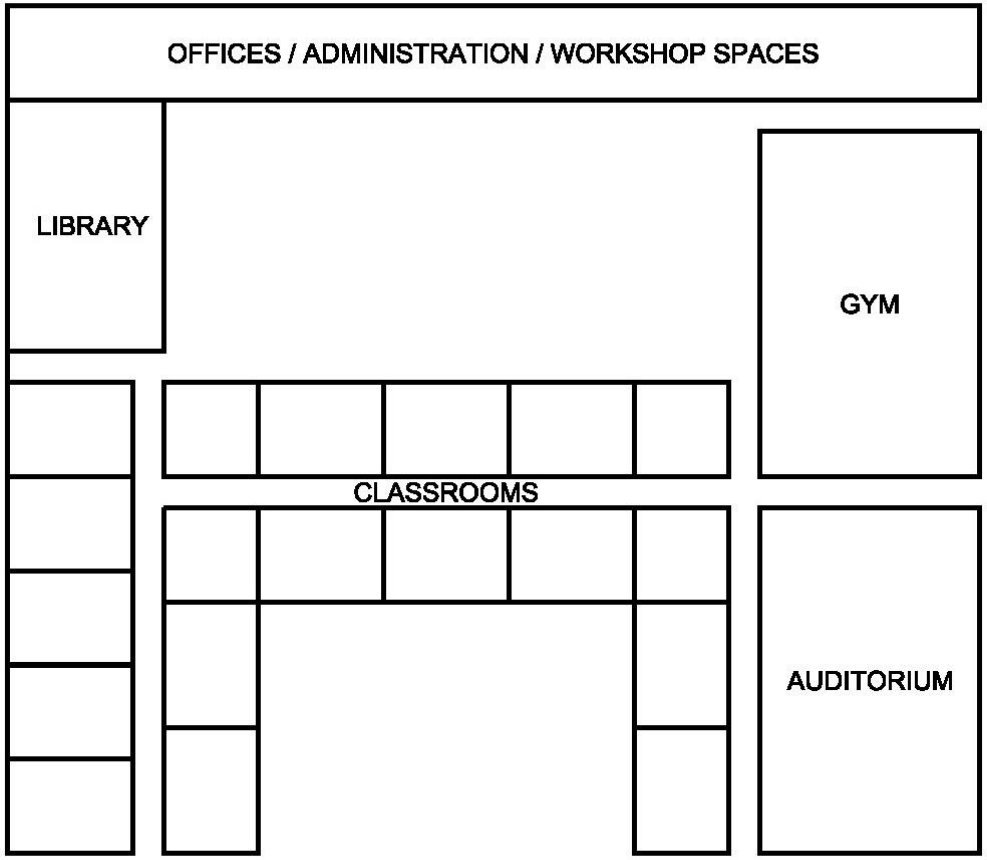


SITING + SPACE PLANNING FOR ACOUSTICS



Locate classrooms in quiet places on the site

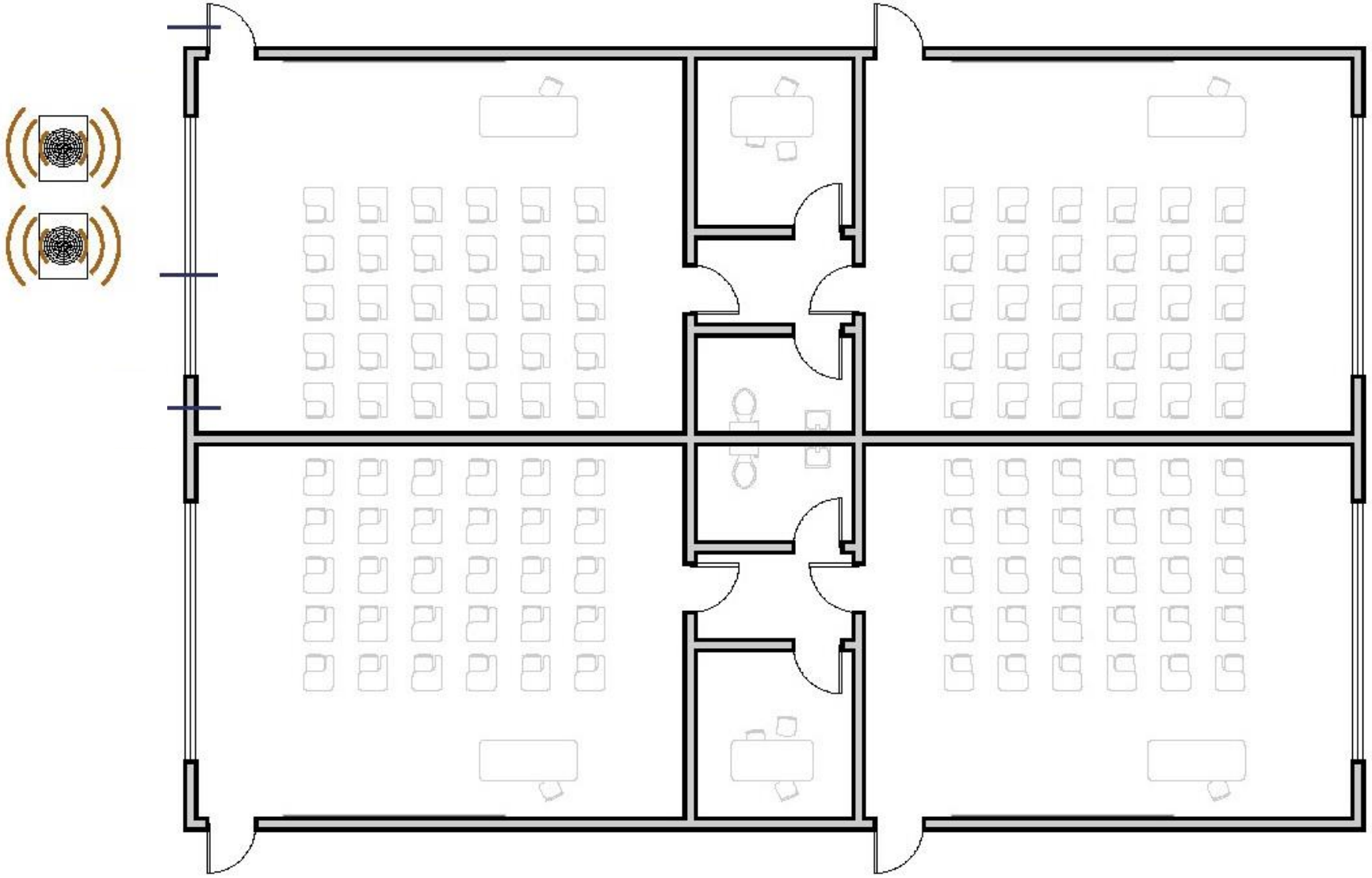
Be aware of locations for central plants and major equipment, playgrounds, delivery areas, etc



Separate quiet spaces from noisy spaces during initial planning

SITING FOR ACOUSTICS

OITC

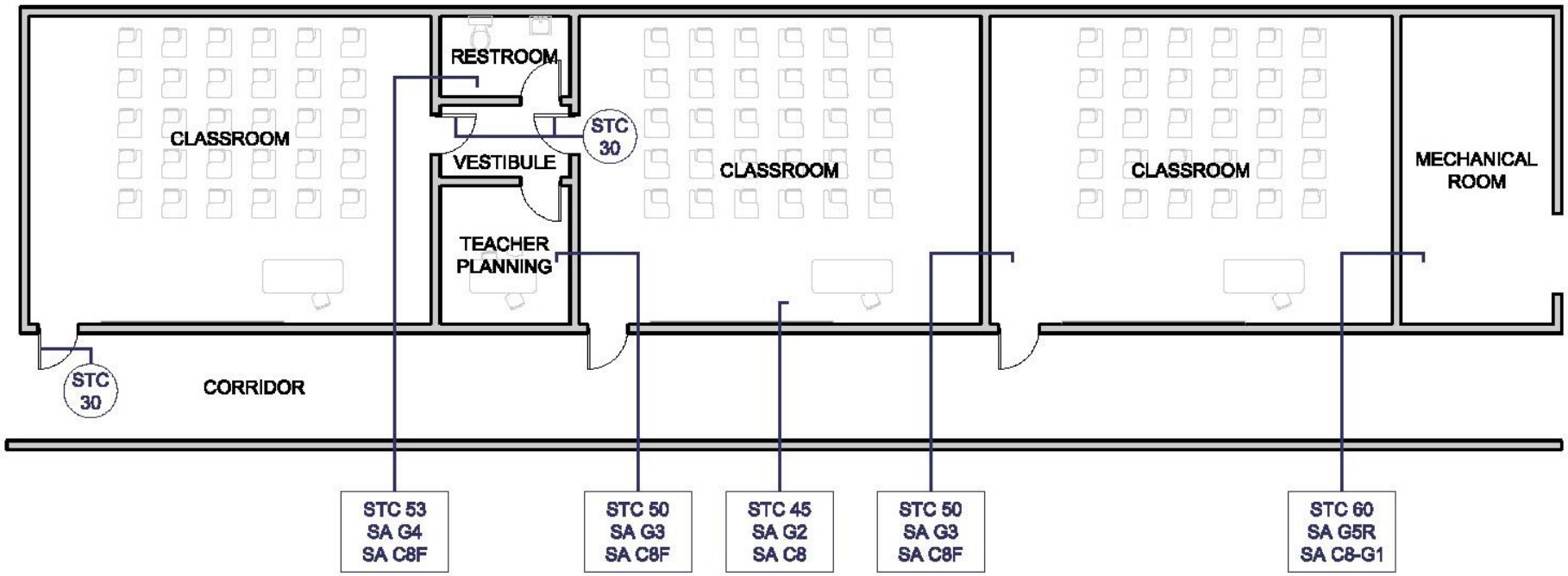


Select OITC for exterior wall, window, door and roof assemblies based on site noise levels

ASSEMBLIES FOR ACOUSTICS

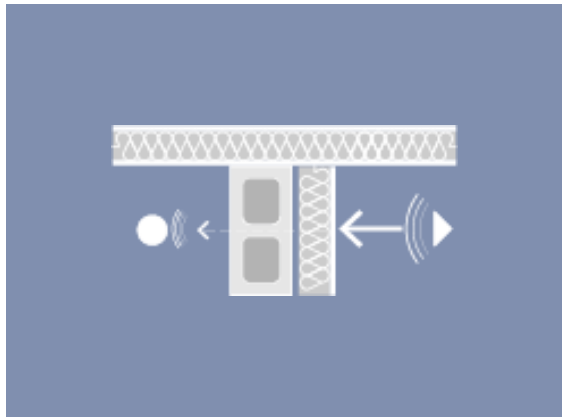
STC

Select walls, doors and windows to reduce sounds transmitted between spaces based on STC ratings or octave band transmission loss calculations for special situations especially those where amplified sound may occur with sub woofers included in the sound playback system

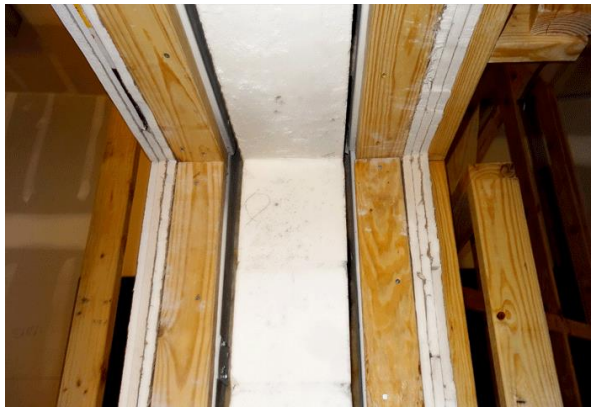


ASSEMBLIES FOR ACOUSTICS

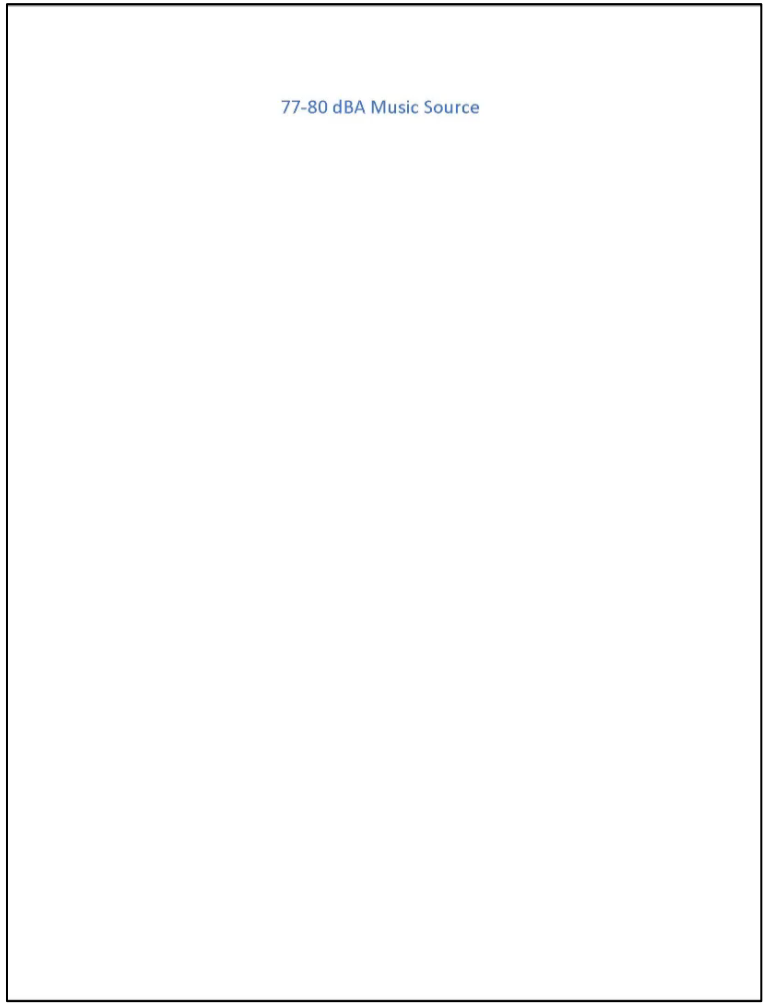
STC



- Wall, Floor/ceiling, roof assemblies to reduce sound bleed



AURALIZATIONS



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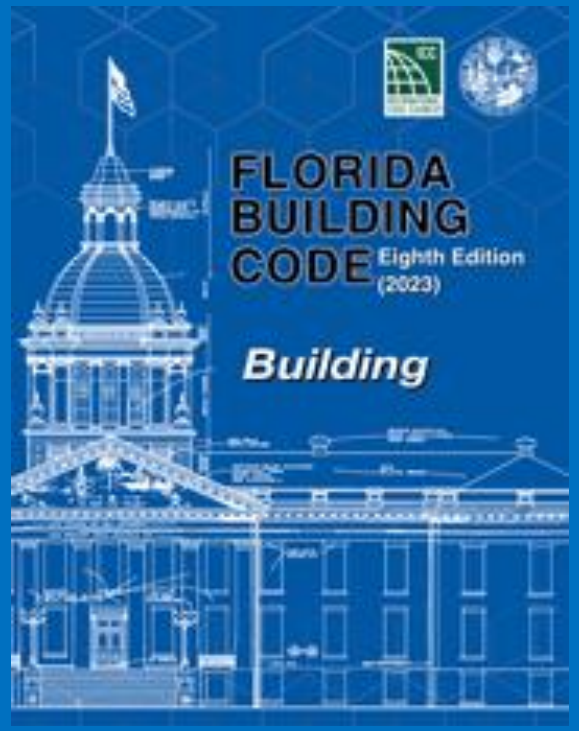
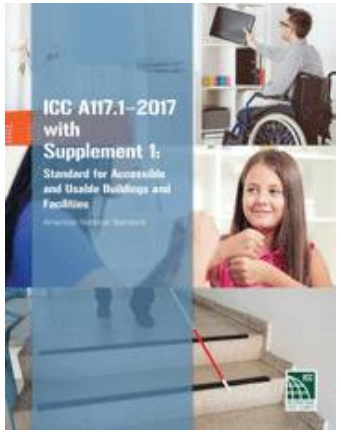
2023 Florida Building Code
Eighth Edition

Section 1211 Enhanced Classroom Acoustics



1211.1 General.
Enhanced classroom acoustics, where required in this section, shall comply with Section 808 of ICC A117.1.

1211.2 Where required.
In Group E occupancies, enhanced classroom acoustics shall be provided in all classrooms with a volume of 20,000 cubic feet (566 m^3) or less.



Section 808 Enhanced Acoustics for Classrooms

808.1 General.
Classrooms not exceeding 20,000 cubic feet (565 m^3) and required to provide enhanced acoustics shall comply with Section 808

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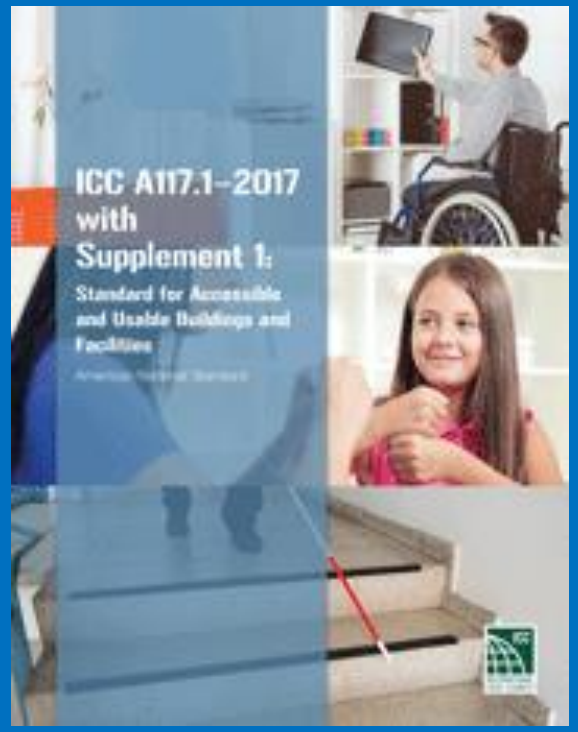
Florida Building Code, 8th Edition (2023): Building

ICC A117.1-2017

Section 808 Enhanced Acoustics for Classrooms



808.2 Reverberation Time.
Classroom Reverberations times shall comply with either section 808.2.1 or Section 808.2.2, depending on the size of the room.

808.2.1 Performance Method.
For each of the octave frequency bands with center frequencies of 500, 1000, and 2000 Hz, the reverberation time (T60) shall not exceed the times specified below:

1. **0.6 seconds** in classrooms with volumes up to and including 10,000 cubic feet (285 m^3).
2. **0.7 seconds** in classrooms with volumes of more than 10,000 cubic feet (285 m^3), but less than 20,000 cubic feet (566 m^3).

Reverberation times shall apply to fully-furnished, unoccupied classrooms. Reverberation times shall be field verified via measurements over a minimum 20 dB decay in each octave frequency band in accordance with ASTM E2235 listed in Section 106.2.13.

808.2.2 Prescriptive method.
The Noise Reduction Coefficient (NRC) ratings for floor, wall and ceiling surface finishes shall conform to the following equations:

For a classroom with a volume less than or equal to 10,000 cubic feet (285 m^3):
(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ Volume / 12

For a classroom with a between 10,000 cubic feet (285 m^3) and 20,000 cubic feet (565 m^3):
(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ Volume / 14

Example Calculation

28 ft x 32 ft room with 10 ft ceilings
Tile Floor – NRC 0.05
Gypsum Board Walls – NRC 0.05
ACT Ceiling – NRC 0.55

28 x 32 = 896 sq ft
896 x 10 = 8,960 cu ft

8,960 /12 = **746.67**

Floor = 896 x 0.05 = **44.8**

Ceiling = 896 x 0.55 = **492.8**

Walls = ((32 x 2)+(28 x 2)) x 10 = 1,200
1,200 x 0.05 = **60**

For a classroom with a volume less than or equal to 10,000 cubic feet (285 m^3):
(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ Volume / 12

(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ 8,960 /12

(0.05 x 896) + (0.55 x 896) + (0.05 x 1,200) ≥ Volume /12

(44.8) + (492.8) + (60) = **597.6 ≱ 746.67**

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Example Calculation

28 ft x 32 ft room with 10 ft ceilings
Tile Floor – NRC 0.05
Gypsum Board Walls – NRC 0.05
ACT Ceiling – NRC 0.75

28 x 32 = 896 sq ft
896 x 10 = 8,960 cu ft

8,960 /12 = **746.67**

Floor = 896 x 0.05 = **44.8**

Ceiling = 896 x 0.75 = 672

Walls = ((32 x 2)+(28 x 2)) x 10 = 1,200
1,200 x 0.05 = **60**

For a classroom with a volume less than or equal to 10,000 cubic feet (285 m^3):
(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ Volume / 12

(NRCFloor x SFloor) + (NRCCeiling x SCeiling) + (NRCWall x SWall) ≥ 8,960 /12

(0.05 x 896) + (0.55 x 896) + (0.05 x 1,200) ≥ Volume /12

(44.8) + (**672**) + (60) = **776.8 ≥ 746.67**

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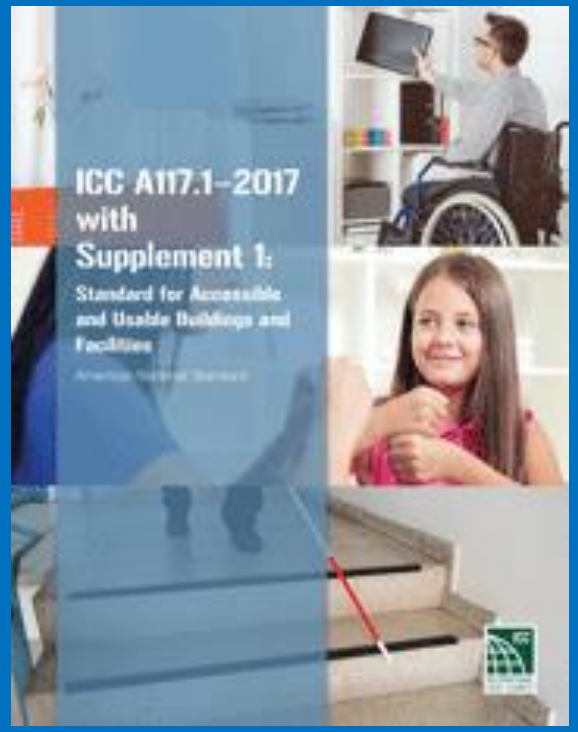

808.3 Ambient Sound Level.

Classroom ambient sound levels shall comply with Sections 808.3.1 and 808.3.2. Ambient sound levels for sound sources outside and inside the classroom shall be evaluated individually. **The greatest one-hour averaged sound levels** shall be evaluated **at the loudest usable location** in the room at a height 36 inches (915 mm) to 42 inches (1065 mm) above the floor and no closer than 36 inches (915 mm) from any wall, window or object. The ambient sound level limits shall apply to fully-furnished, unoccupied classrooms, and with only permanent HVAC, electrical and plumbing systems functioning. Classroom equipment, including, but not limited to, computers, printers and fish tank pumps shall be turned off during these measurements.

808.3.1 Sound sources outside of the classroom.

Classroom ambient sound levels shall not exceed **35 dBA** and **55 dBC** due to intruding noise from sound sources outside of the classroom, **whether from the exterior or from other interior spaces**.

808.3.2 Sound sources inside the classroom.

Classroom ambient sound levels shall not exceed **35 dBA** and **55 dBC** for noise from sound sources inside the classroom.

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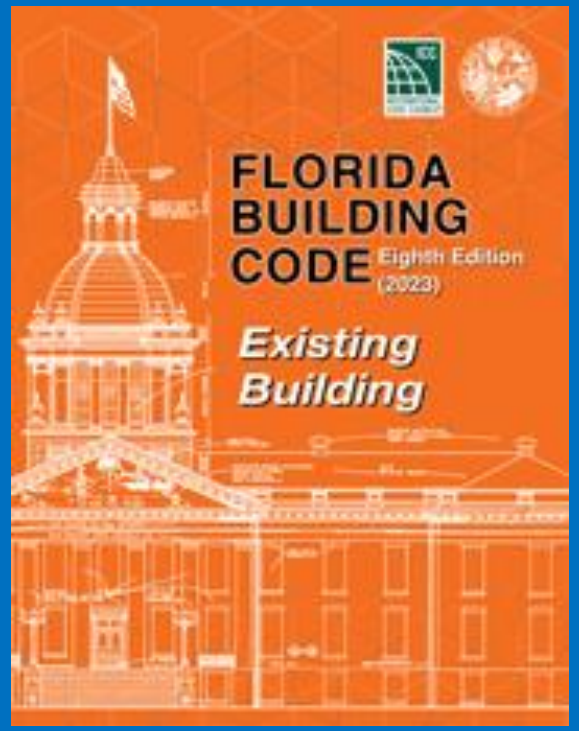
2023 Florida Building Code

Existing Building
Eighth Edition

Section 903.4 Enhanced Classroom Acoustics



903.4 Enhanced Classroom Acoustics

In Group E occupancies, where the work area is a Level 3 alteration, enhanced classroom acoustics shall be provided in all classrooms with a volume of 20,000 cubic feet (566 m^3) or less. Enhanced classroom acoustics shall comply with the reverberation time in Section 808 of ICC A117.1.

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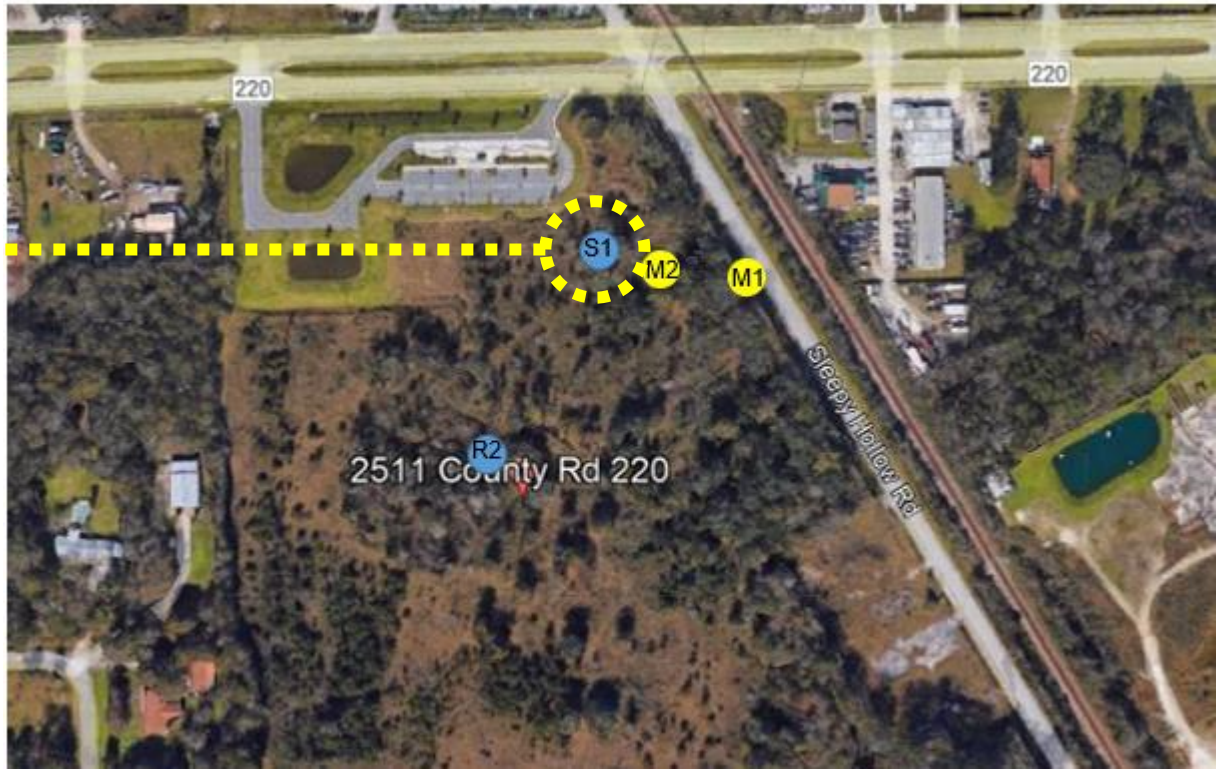
Florida Building Code, 8th Edition (2023): Existing Building

Site Acoustic Measurements



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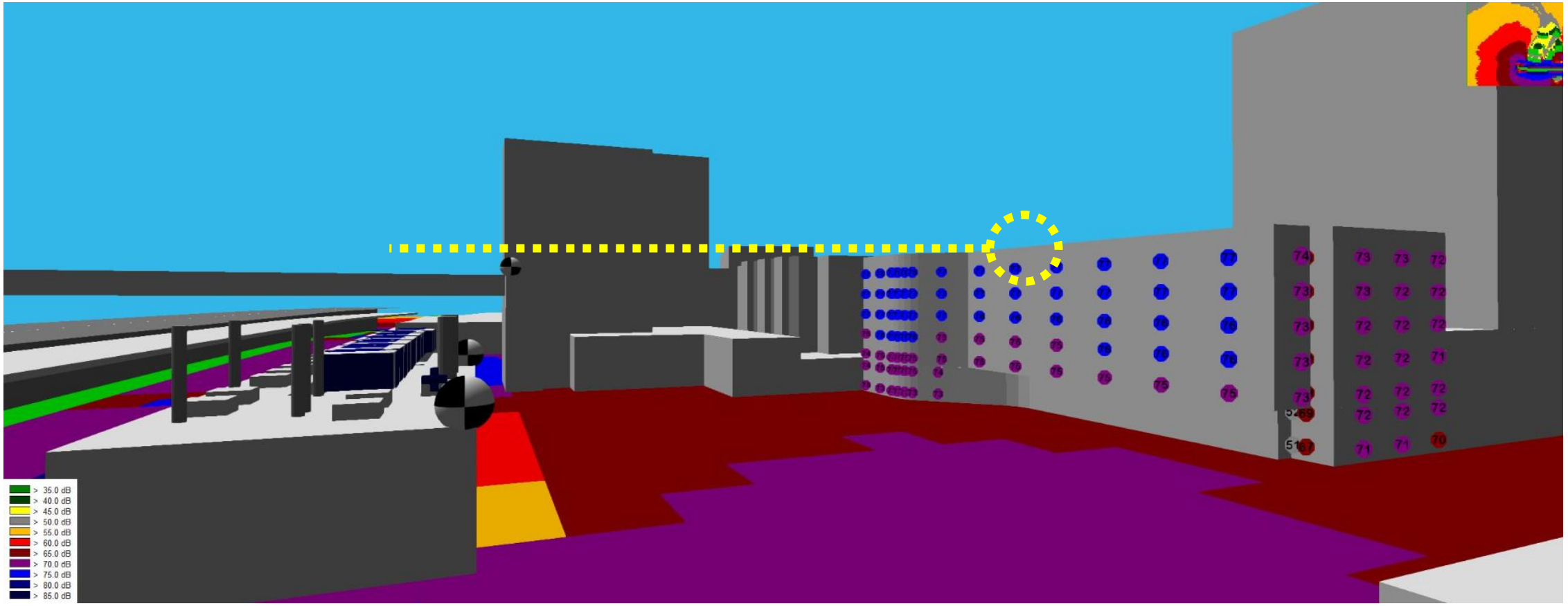
Façade Analysis



Determine if Ambient Sound level from Exterior is met

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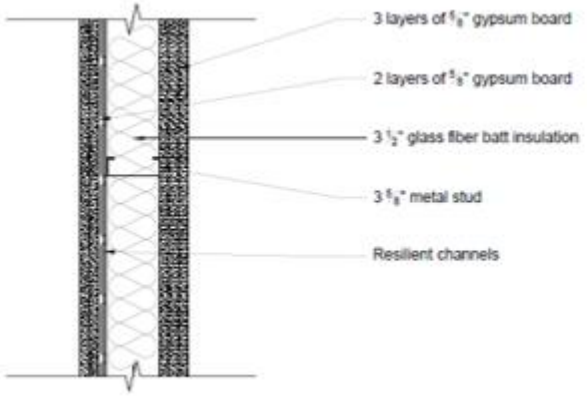
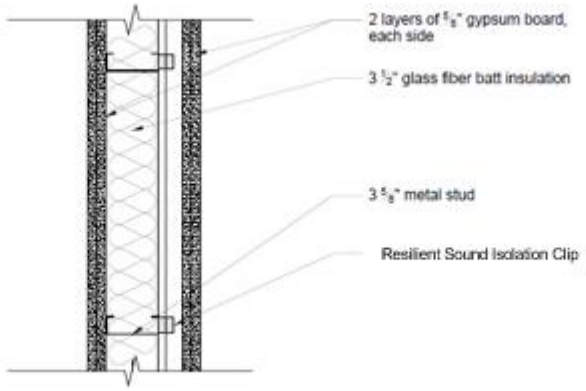
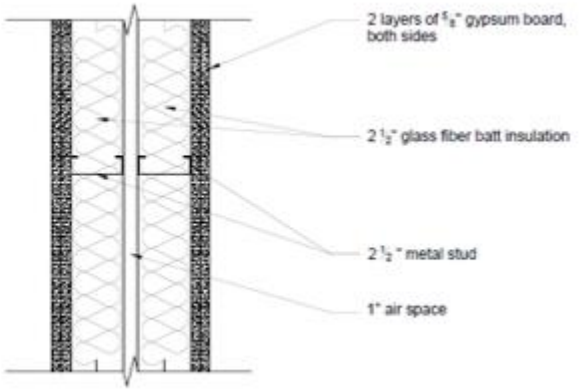
Interior Partition Analysis







WHAT WALLS ARE NEEDED WHERE?

Determine if Ambient Sound level from Interior sound sources is met

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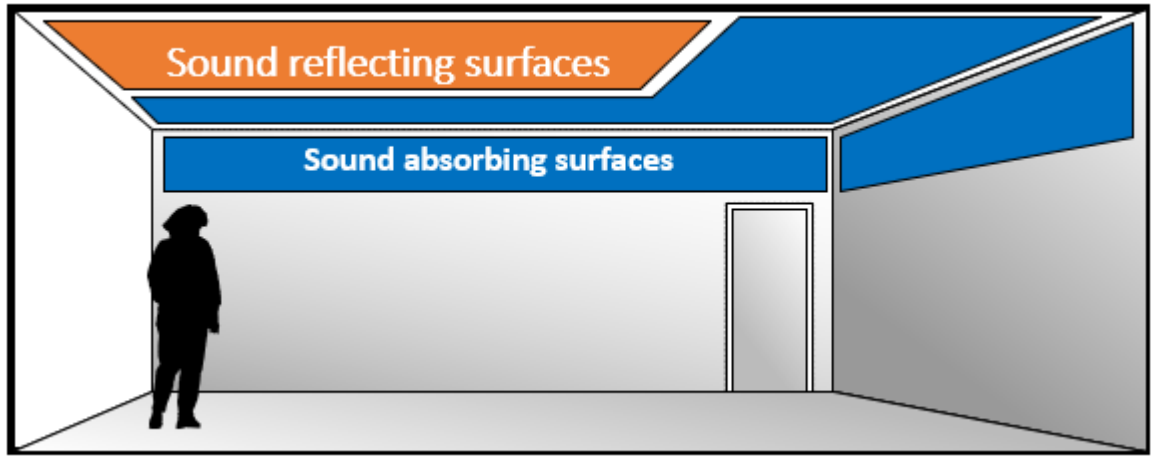
Reverberation Time Analysis



WHAT MATERIALS ARE NEEDED WHERE?

Determine if Reverberation Time criteria is met

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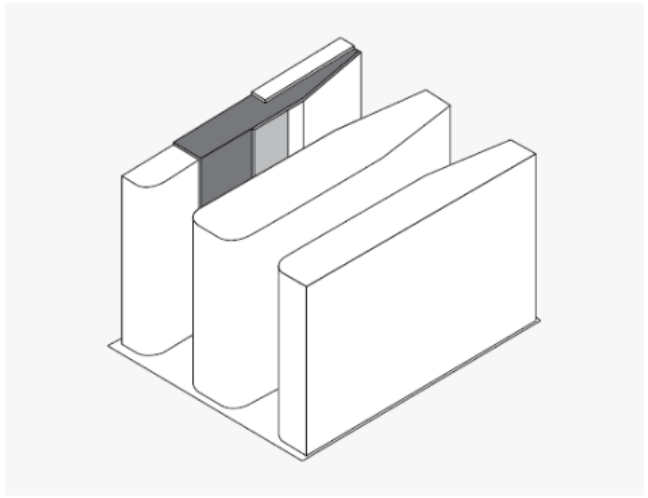
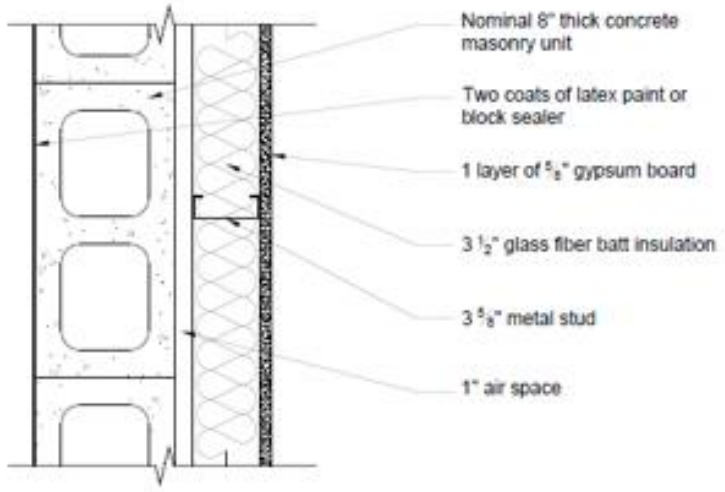
Mechanical Analysis





WHAT NOISE MITIGATION IS NEEDED? Silencers? Springs? Assemblies Needed?

Determine if Ambient Sound level from Mechanical sound sources is met

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Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools

ANSI Standard S12.60-2010
LEEDv4.1
WELLv2

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Exterior Source Noise Limits

Learning Space	Greatest 1 hr avg A & C weighted sound level (Exterior Noise)
Core learning space with volume ≤ 10,000 ft^3	35dBA/55dBC
Core learning space with volume > 10,000 ft^3 and ≤ 20,000 ft^3	35dBA/55dBC
Core learning space with volume ≥ 20,000 ft^3 + all ancillary learning spaces	35dBA/55dBC

Minimum OITC Ratings

Loudest 1 hr outdoor noise level (dBA)	OITC Rating Walls with windows	OITC Rating Roofs and Walls without windows
<55	30	36
60	35	41
65	39	45
70	43	49
75	47	53
80	50	56
>80	Not permitted	Not permitted

Table 3 — Minimum OITC rating for core learning spaces

A-weighted outdoor noise level (dB) [a), b)]	OITC rating walls with windows	OITC rating roofs and walls without windows
<55	30	36
56	31	37
57	32	38
58	33	39
59	34	40
60	35	41
61	35	41
62	36	42
63	37	43
64	38	44
65	39	45
66	39	45
67	40	46
68	41	47
69	42	48
70	43	49
71	43	49
72	44	50
73	45	51
74	46	52
75	47	53
76	47	53
77	48	54
78	49	55
79	50	56
80	50	56
>80	Not permitted	Not permitted

[a)] See 5.4.1.1.
[b)] See 5.2.1.

Interior Source Noise Limits

Learning Space	ANSI S12.60-2010 Greatest 1 hr avg A & C weighted sound level (Interior Noise)	LEED v4.1	WELL v2
Core learning space with volume ≤ 10,000 ft^3	35dBA/55dBC	Pre-req: 40 dBA 1 pt: 35 dBA or less (Follow ANSI S12.60)	Leq 3 pts: 35 dBA/60 dBC 2 pts: 40 dBA / 65 dBC 1 pt: 45 dBA / 70 dBC
Core learning space with volume >10,000 ft^3 and ≤ 20,000 ft^3	35dBA/55dBC	Pre-req: 40 dBA 1 pt: 35 dBA or less (Follow ANSI S12.60)	Leq 3 pts: 35 dBA/60 dBC 2 pts: 40 dBA / 65 dBC 1 pt: 45 dBA / 70 dBC
Core learning space with volume ≥ 20,000 ft^3 + all ancillary learning spaces	35dBA/55dBC	Pre-req: 40 dBA 1 pt: 35 dBA or less (Follow ANSI S12.60)	Leq 3 pts: 35 dBA/60 dBC 2 pts: 40 dBA / 65 dBC 1 pt: 45 dBA / 70 dBC

Reverberation Time Limits

Learning Space	ANSI S12.60-2010 Max RT in 500, 1,000 and 2,000Hz octave bands	LEED v4.1	WELL v2
Core learning space with volume ≤ 10,000 ft^3	0.6 s	Pre-req: 0.6 s (materials need NRC 0.70)	< 0.6s 1 pt NRC 0.7 on 50% ceiling 1 pt NRC 0.7 on 25% 2 walls 1 pt
Core learning space with volume ≥ 10,000 ft^3 and ≤ 20,000 ft^3	0.7 s	Pre-req: 0.7s (materials need NRC 0.70)	0.5 to 0.8 s 1 pt NRC 0.7 on 50% ceiling 1 pt NRC 0.7 on 25% 2 walls 1 pt
Core learning space with volume ≥ 20,000 ft^3 + all ancillary learning spaces	No requirement	Pre-req: up to 1.2 s, 1 s for special needs 1 point: Gym + Natatorium <2.0 s Performing Arts Space – varies by application Library < 1.0	0.6 to 1.0 s 1 pt NRC 0.7 on 50% ceiling 1 pt NRC 0.7 on 25% 2 walls 1 pt

STC Ratings

LEED v4.1 = Meet ANSI S12.60-2010

WELLv2 = Meet ANSI S12.60-2010 = 2 pts
Door = STC 30, gaskets at head and jambs, automatic drop seal or sweep at base, non hollow-core door = 1 pt

Receiving ancillary learning space	Adjacent Space			
	Corridor, staircase, public-use toilet room and bathing room	Music Room	Office or conference room	Mechanical equipment room, cafeteria, gym or indoor swimming pool
Corridor used as ancillary learning space	STC 45	STC 60	STC 45	STC 55
Music Room	STC 45	STC 60	STC 60	STC 60
Office or Conference Room	STC 45	STC 60	STC 45	STC 60

Interior Noise

ANSI S12.60			
Adjacent Space			
Other enclosed or open-plan core learning space, therapy room, healthcare room + space needing a high degree of acoustical privacy	Common-use + public-use toilet room and bathing room	Corridor, staircase, office or conference room	Music room, music performance space, auditorium, mechanical equipment room, cafeteria, gym or indoor swimming pool
STC 50	STC 53	STC 45	STC 60

Summary of Basic Classroom Acoustical Design Strategies

Component	Strategy	Means
Direct Sound	Maximize	Voice • Diction • Amplification • Teaching Methods
Early Reflections	Maximize	Sound-reflecting surfaces near Teacher
Reverberant Tail	Minimize, not eliminate	Room Volume • Absorbent Materials
Background Noise	Minimize, not eliminate	HVAC Design • Site Noise • Student Noise • Adjoining Rooms

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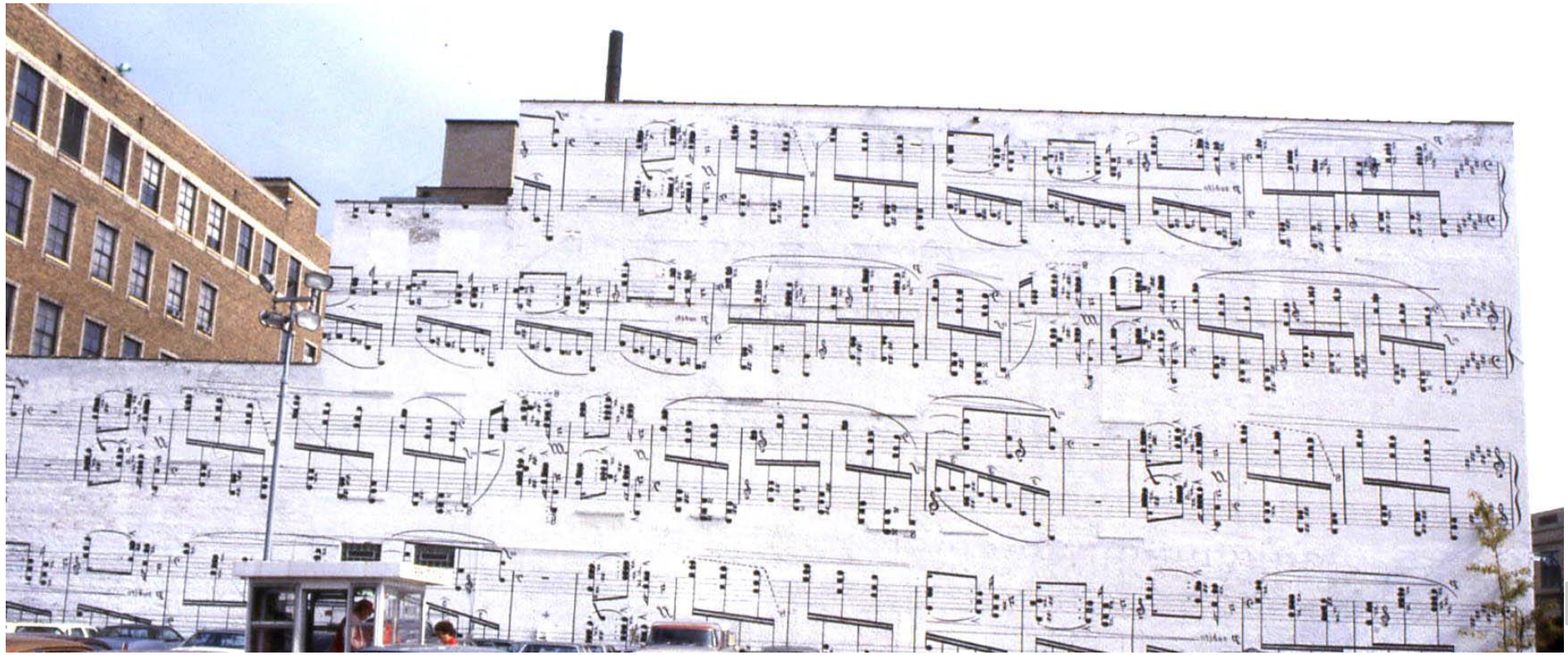

This concludes The American Institute of Architects
Continuing Education Systems Course

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