INCREASING STUDENT PERFORMANCE WITH ACOUSTICS

Redefining possible.

Presented by:

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Education

- B.Sc. in Mechanical Engineering, University of Manitoba (1994).
- M.Sc. in Biosystems Engineering, University of Manitoba (1998).

Experience

- Consulting on Acoustics Noise & Vibration projects since 2000
  - Hospitals, University Labs, Research & Development Companies
  - Schools
  - Theatres, Auditoria, Lecture Halls, Studio
  - Office, Residential, and Hotel Towers
  - Airports, Rail Corridors, Helipads, and District Masterplanning

WHAT IS ACOUSTICS?

What do you know about acoustics?

WHAT IS ACOUSTICS?

1. Room Acoustics
2. Sound Isolation
3. Background Noise

Abstract

Schools are evolving to include more interactive learning and more technology in less traditional classrooms. The acoustic design is critical to student performance but is often seen as an enhancement rather than a requirement.

We will discuss the three main acoustic subjects in school design:

- reducing distraction
- enhancing communication
- creating a calm environment

We will provide clarity on the functional requirements and how to achieve them in a cost-effective manner, and demonstrate how good acoustics creates a healthy learning environment for both students and teachers.

Learning Objectives

1. Understand why acoustics is important for students and teachers.
2. Learn what acoustic targets are appropriate.
3. Learn how to incorporate good acoustic design into the overall design.
4. Understand construction requirements for meeting acoustic targets.

Summary

Acoustics Background / Metrics

1. Why acoustics are important
2. Functional requirements
3. Acoustic targets and criteria
   - reducing distraction *(sound isolation)*
   - enhancing communication *(room acoustics)*
   - creating a calm environment *(background noise)*
4. Value of acoustics/examples

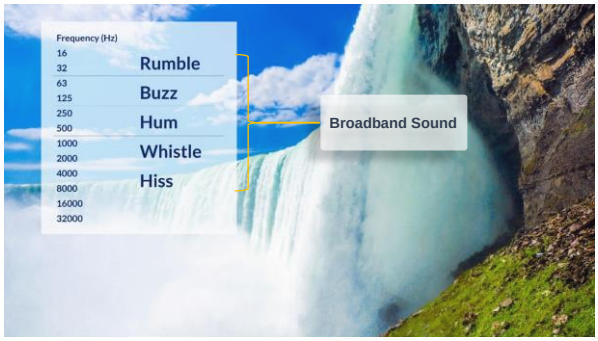
Sound Levels

Sound pressure levels
the decibel - dB

Sound level drops with distance

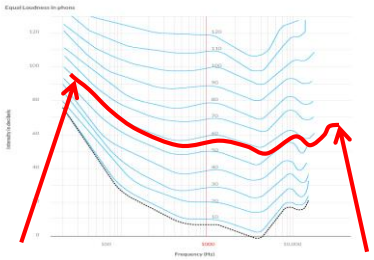
Add two equal sources:
50 dB + 50 dB = 53 dB

Human Perception:
+/- 10 dB sounds twice or half as loud

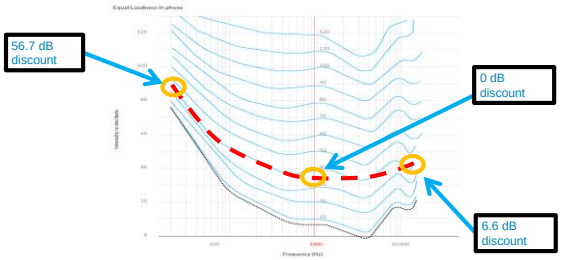


Our ears are less sensitive to both low and high frequencies

Equal Loudness Contours



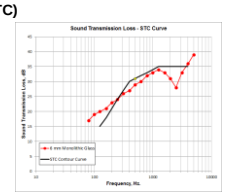
A-weighting Curve



Sound Transmission Class (STC)

Sound Transmission Class (STC)

- In common use
- Single number rating
- Based on sound transmission loss data
- Lab test under ideal conditions
- Sliding contour fit
- Available for most partitions
- Based on isolating human speech



Sound Transmission Class (STC)

Benefits

- Simple to use
- Easy to compare various partitions

Disadvantages

- Not applicable to low frequency sources
  - Mechanical equipment
  - Subwoofers
- May not ensure occupant comfort or privacy

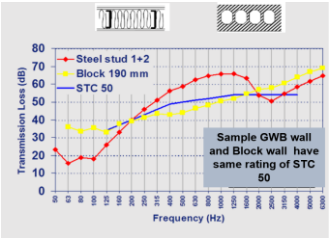
Sound Transmission Class (STC)

Subjective impression to noise isolation:

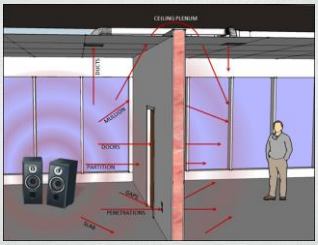
STC Rating	Degree of Acoustical Privacy	
<45	Poor:	Normal speech audible and usually intelligible
45	Marginal:	Normal speech audible and sometimes intelligible
50	Good:	Normal speech audible but not intelligible
55	Very Good:	Raised voices usually audible but not intelligible
60+	Excellent:	Raised voices not audible

*Assumes a quiet background sound level, typical for residential living areas (~35 dBA)

Same Rating – Different Results



Flanking Paths



Outdoor-Indoor Transmission Class (OITC)

Benefits

- Simple to use
- Appropriate for rank ordering exterior façade assemblies
- Intended to evaluate outdoor-to-indoor noise transfer from: ***vehicular, aircraft and railway traffic***
- Preferable over STC for exterior façade ranking because it includes lower frequencies (down to 80 Hz)

Disadvantages

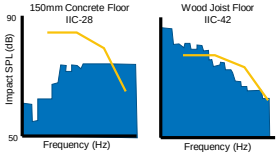
- Simplified single number ratings may hide deficiencies in critical applications

Source: National Research Council Canada Construction Technology Update No. 35: Controlling The Transmission of Impact Sound Through Floors, 1999.

Impact Insulation Class (IIC)

Impact Insulation Class (IIC)

A single number rating
Based on sound level measured in space below the source
Rates a floor/ceiling for transfer of impact sound (higher = better)
Sliding contour fit to measured sound levels
Adjusted for room acoustics



Impact Insulation Class (IIC)

Benefits

- Simple to use for preliminary selection
- Easy to compare various constructions and floor finishes

Disadvantages

- Inadequate where impact isolation is critical
- May not ensure occupant comfort

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Impact Insulation Class (IIC)

Subjective impression to impact noise

IIC Rating		Impressions of Impact/Footstep Noise Heard
<45	Poor:	Normal walking clearly audible below, other impacts, chair movement, dropped objects audible, unsuitable for multi-family units or where moderate isolation is required within same dwelling unit
45-55	Basic:	Normal walking (in hard shoes) still clearly audible, may be adequate between spaces within same dwelling unit, not suitable for most multi-family buildings,
55-60	Marginal:	Normal walking noise still clearly audible when background noise levels are fairly low; may be adequate for multi-family buildings in less critical situations
60-70	Good:	Normal walking audible only during very low background noise situations, adequate for most multi-family buildings
70-80	Very Good:	Normal walking largely inaudible, generally adequate for even most sensitive, (high quality, low background noise) situations
80+	Excellent:	Virtually no audible impact noise transmitted from walking, small dropped objects etc.

Taken from: City of Vancouver Noise Control Manual

Room Acoustics

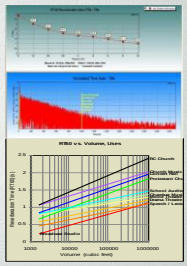
Supports:

- Speech
- Music
- Recording

By giving attention to:

- Occupant requirements
- Room Shape
- Volume
- Finishes

Reverberation (RT_{60})



Reverberation

- Reverberation is the decay (or persistence) of a sound in an enclosed space. One measure is the time (RT_{60}) required for the sound to diminish 60 dB
- The appropriate reverberation time depends on the use of the space and its volume
- Musical uses benefit from longer RT_{60} values while speech has higher clarity with low RT_{60} times

Background Noise

Supports:

- Calm environment
- Speech comprehension
- Recording
- Privacy*

By giving attention to:

- Occupant requirements
- External noise source control
  (environmental, adjacent spaces)
- Internal noise source control
  (occupants, activity)
- Mechanical system noise control
  (ducted, neighbouring, in-room, vibration isolation)

Background Noise (NC, dBA/dBC)

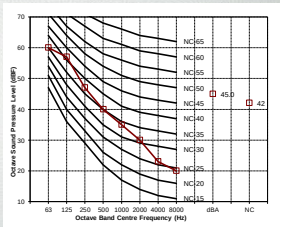
Simple, single number ratings:

NC (noise criteria)

- Uses tangential rating scheme
- Easy to apply in design

dBA/dBC (A- and C- weighted decibels)

- Good for evaluation
- More challenging for design
- Uses A and C weighting to address both mid- and low- frequency requirements



Why Acoustics Are Important

Why Acoustics are Important

SAT scores decrease with poor acoustics

Bronzaft (1975, 1981)

- Measured noise and test scores on two sides of a school
  - One side adjacent to train line
  - Before and after noise mitigation from the train line

Evans and Maxwell (1997)

- Chronic noise exposure reduced reading scores (even when tested in a quiet environment)
- Noise exposure is related to impairment in speech perception

Haines, Brentnall, Stansfeld and Klineberg (2003)

- "Results from recent quantitative research consistently demonstrate that children are a high risk group, vulnerable to the adverse effects of noise exposure, especially effects on cognitive performance, motivation and annoyance."

Why Acoustics are Important

SAT scores decrease with poor acoustics

Shield and Dockrell (2008)

"Activities affected by noise include memory, reading, motivation, and attention"

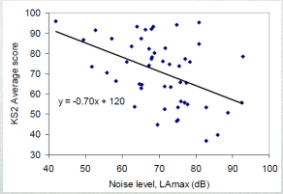
"Children with special educational needs were found to be more susceptible to the effects of classroom babble upon verbal tasks than other children."

"It is essential to give careful consideration to the acoustic design of a school in order to optimize conditions for teaching and learning.

Why Acoustics are Important

SAT scores decrease with poor acoustics

Shield and Dockrell (2008) – KS2 = English, Math, Science



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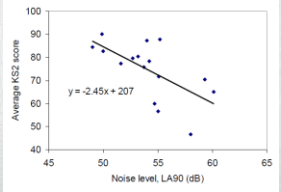


Why Acoustics are Important

Design "should consider the most acoustically sensitive activity" – John Bradley

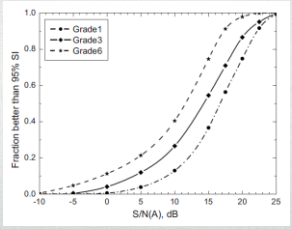
Speech communication is the most acoustically sensitive activity

Quiet

- Reduces strain on teachers voices
- Increases intelligibility (SNR)
- Young, hearing impairment, ESL need quiet

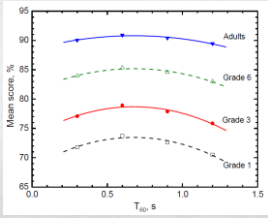
Why Acoustics are Important

Bradley and Sato (2008) – Average Teacher ~ 60 dBA



Why Acoustics are Important

Reverberation time has an ideal point ~0.6 to 0.7 seconds



2 Functional Requirements

Functional Requirements

4 Cs:
- Creativity
- Creative Thinking and Problem Solving
- Communication
- Collaboration

Multi-media (Audio/Video):
- Recording (microphones)
- Amplified sound (speakers)

Building Design:
- Open Classrooms
- Learning Commons
- 'Neighborhoods'

Functional Requirements

Flexibility
Future-proofing
Matching design to actual use

Options to consider:
- Operable walls
- Modular construction
- No walls

Best Solution:
Communication between users and designers

3 Acoustic Targets and Criteria

Acoustic Targets and Criteria

Acoustical Society of America

ANSI/ASA S12.60-2010/Part 1 American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools

Key Points:

- **Focus on 'traditional' Classrooms**
- **Background Noise Levels <35 dBA**
- **Reverberation Time (RT60) = 0.6 – 0.7 s**
- **Sound Isolation (STC)**
  - 50 – classroom to classroom
  - 53 – classroom to W/C
  - 45 – classroom to corridor
  - 60 – classroom to music / auditorium / mechanical / gym / cafeteria
- **Impact Noise (IIC) 45 – classroom to classroom**

Reducing External Distractions

- **Sound Isolation (STC)**
  - 50 – classroom to classroom
  - 53 – classroom to W/C
  - 45 – classroom to corridor
  - 60 – classroom to music / auditorium / mechanical / gym / cafeteria
- **Impact Noise (IIC) 45 – classroom to classroom**

Reducing External Distractions

Sound Isolation (STC)

- **50 – classroom to classroom**

NOT ENOUGH IN CLASSROOMS WITH TECHNOLOGY

TARGET MINIMUM STC 55
With
STAGGERED OR DOUBLE STUD CONSTRUCTION

Reducing External Distractions

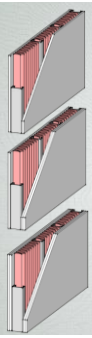
Impact Noise (IIC) 45 – classroom to classroom

Tested without floor finish

NOT ENOUGH IF NOT CARPETED

Final performance should be IIC 55 or higher

Wall Construction



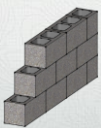
STC 47

STC 52

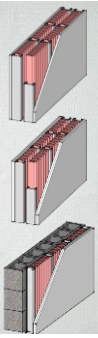
STC 55

Construction Materials:

- 16 mm 'Type X' GWB
- 92 mm 25 gauge steel studs 400 mm OC
- Batt insulation
- 190 mm CMU sealed with latex paint
- Air gaps



STC 50



STC 57

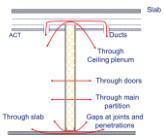
STC 66

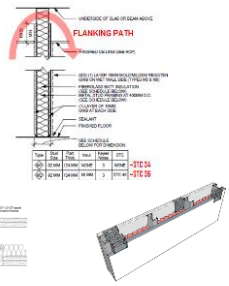
STC 65+

Flanking Paths to Consider:

- Ducts
- Penetrations
- Ceiling Plenum
- Glazing
- Doors
- Electrical Boxes
- Etc.

Sound Isolation

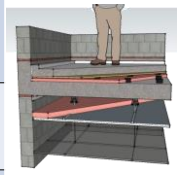




Floor/Ceiling Construction

Layers (top to bottom)	Thickness	STC	IIC
Composite slab (concrete) on 75 mm steel deck	150 mm	**51**	**21**
- with vinyl floor	150 mm	51	33
- with carpet	150 mm	51	55
- with vinyl floor and ACT	518 mm	55	51
- with carpet and ACT	518 mm	55	65
- with vinyl floor and GWB ceiling plus ACT	684 mm	72	61
CLT (5-ply) 175 mm thick	175 mm	**41**	**25**
- with vinyl floor	175 mm	41	29
- with carpet	175 mm	41	34
- with vinyl floor and ACT	526 mm	51	38
- with carpet and ACT	526 mm	51	40
- with vinyl floor and GWB ceiling plus ACT	634 mm	70	58
Concrete topping (regular weight) 38 mm thick Rubber nuggets on foil 12.7 mm thick CLT (5-ply) 175 mm thick	226 mm	**53**	**46**

***Bold values are test data, others are estimates, red meets target criteria*



Enhancing Communication

Room Acoustics (RT_{60})

- 0.6 s for small classrooms (<283 m^3)*
- 0.7 s for large classrooms (>283 m^3)

* Must be readily adaptable to meet 0.3 s

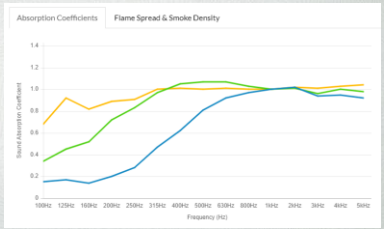
Room Acoustics - Finishes

NRC (noise reduction coefficient) - a simple, single number rating:

- Absorptive (1.0)
- Reflective (0.0)

Common Materials:

1" Acoustic Panel - .75
2" Acoustic Panel - .85
3" Acoustic Panel - .95
Mineral ACT - .55 - .70
F.G. ACT - .95
Wood - .10
GWB - .20
Carpet - .15 - .55 (1/8" – 1/2")
Concrete - .02



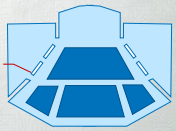
Room Acoustics

Multiple use spaces

- Speech and music
- Variable acoustics

Variable finishes

- Movable Panels
- Reverberation Chambers
- Heavy Curtains
- Electronically
- Etc.



Room Acoustics - Room Requirements

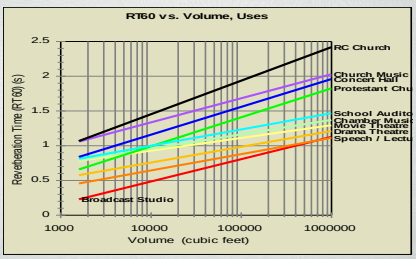
Acoustic Requirements	Small Volume	Medium Volume	Large Volume
Special	Recording room Music Practice Room	Music Room	Auditorium Theatre
High	Project Room Quiet Room	A/V Room Tele-Learning	Gym Multi-purpose
Medium	Private Office	Classroom	Library
Low	W/C Storage	Corridor	Lobby Atrium

SPECIFIC DESIGN

ACOUSTIC TILE CEILING TYPICALLY SUFFICIENT

Room Acoustics – Specialty Spaces

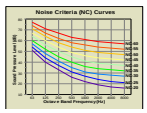
Reverberation Time (RT60)



Creating a Calm Environment

Background Noise Level (NC or dBA/dBC)
- NC 30, 35/55 dBA/dBC for small and large classrooms
- NC 35, 40/60 dBA/dBC for extra large core learning spaces and all ancillary learning spaces
- Outdoor play areas should not exceed 55 dBA

Sources
- MEP services are usually continuous noise sources
- Outdoor noise sources (transportation, industry, etc.



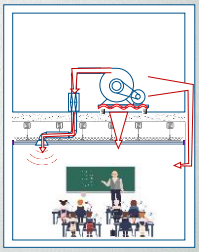
Building Services Noise Control

Duct-borne Noise
- Fan noise
- Flow generated noise
- VAV noise

Transmission through partitions
- Minimum wall/floor/ceiling construction
- Equipment enclosure

Structure-borne Noise (Vibration)
- Mechanical vibration, once in the structure, can be radiated as noise many floors / bays away
- Vibration Isolation of all vibrating equipment is important

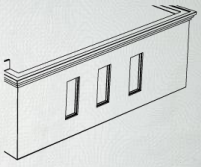
Combined overall noise level needs to meet the NC or dBA/dBC criteria specified for the space



Outdoor to Indoor Noise Control

Transmission through exterior partitions
- Must consider window and wall components (OITC ratings)
- Environmental sources include:
  - *Transportation (road, rail, air, marine)*
  - *Industry*
  - *Mechanical systems (both on and off site)*
- Consideration must also be given for noise levels in outdoor spaces (barriers, etc.)

Combined overall noise level needs to meet the NC or dBA/dBC criteria specified for the space



Value of Acoustics

Value of Acoustics

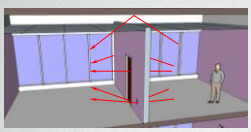
Sound Isolation
- Deal with stopping distraction (both indoor and outdoor)

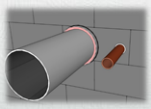
Walls
- Simple GWB and LIGHT GAUGE steel studs with fibrous insulation (5/8" Type 'X' GWB / 6" SS w batt / 5/8" Type 'X' GWB)
- Concrete block (8")

Windows
- 3/8" glass ~STC 35 (OITC 32)
- ½" laminated glass ~ STC 38 (OITC 34)
- ¼" lam / ½" airspace / ¼" lam ~ STC 42 (OITC 33)

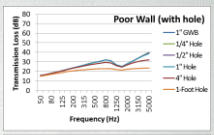
Doors
- Solid core wood or insulated metal, no seals ~ STC 20
- With full perimeter seals and drop seal ~ STC 30

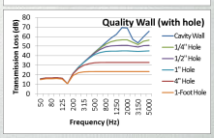
Value of Acoustics





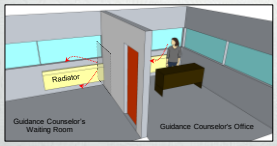
Flanking / Holes





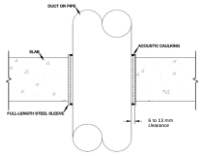
Valuable Example

Partition:
- High School Guidance Counselor's Office / Waiting Room
- Partition cut around radiator
- Radiator is continuous and open through wall



Valuable Example

Penetrations
- Sleeved for the full depth of the penetration grouted in place
- 6mm clearance filled with fiberglass
- Sealed both sides with non-hardening acoustic caulking



Value of Acoustics

Room Acoustics
- Communication
- Calm Environment

Solutions:
- Fibrous/porous (thicker or spaced from wall)
- Ceiling Tiles
- Baffles

Cautions:
- Microphones
- Speakers

Acoustic Requirements	Small Volume	Medium Volume	Large Volume
Special	Recording room Music Practice Room	Music Room	Auditorium Theatre
High	Project Room Quiet Room	A/V Room Tele-Learning	Gym Multi-purpose
Medium	Private Office	Classroom	Library
Low	W/C Storage	Corridor	Lobby Atrium

SPECIFIC DESIGN

ACOUSTIC TILE CEILING TYPICALLY SUFFICIENT

Valuable Example

Room Acoustics Issue
- Space with ¼" mineral fibre tiles glued to sloped ceiling
- Attempted to fix with PA systems

Value of Acoustics

Background Noise
- Increase SNR (comprehension)

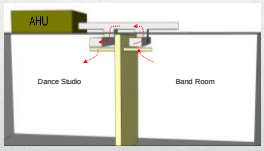
Sources
- Mechanical Rooms
- Rooftop mechanical
- Ducted mechanical
- Fan coil units

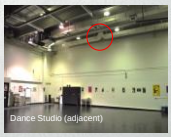
Value of Acoustics

Mechanical Noise Controls
- Walls/ceilings (including ACT)
- Duct silencers
- Vibration isolation (demo)
- Distance

Valuable Example

Mechanical Noise
- Noisy
- 'Cross-talk'





Other Acoustic Considerations

Environmental Noise
- Transportation and other external noises (including rooftop)
- Construction noise
- Impact on outdoor areas and indoors

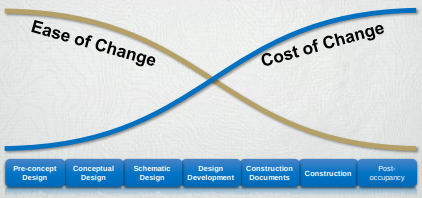
Floor Vibration
- Students walking in corridors causing upper floors to shake

Impact Noise
- Thumping footfalls

Details
- Acoustics details are paramount to success
- No 'silver bullet', ignoring one aspect can be problematic

Other Acoustic Considerations

The best time to consider acoustics is as early as possible when problems can be identified and corrective action can be easily incorporated.



Quick Summary

Background Noise
Room Acoustics
Sound Isolation

Redefining possible.

THANK YOU
FOR YOUR TIME

QUESTIONS ?

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