INCREASING STUDENT PERFORMANCE WITH ACOUSTICS

Presented by:
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WHAT IS ACOUSTICS?

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

Steve Meszaros, M.Sc., P.Eng.
Technical Director / Associate – Acoustics, Noise, & Vibration

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

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

- Add two equal sources: 50 dB + 50 dB = 53 dB
- Human Perception: +/- 10 dB sounds twice as loud or half as loud

Equal Loudness Contours

Our ears are less sensitive to both low and high frequencies

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

Subjective impression to noise isolation:

<table>
<thead>
<tr>
<th>STC Rating</th>
<th>Degree of Acoustical Privacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40</td>
<td>Poor: Normal speech audible and usually intelligible</td>
</tr>
<tr>
<td>45</td>
<td>Marginal: Normal speech audible and sometimes intelligible</td>
</tr>
<tr>
<td>50</td>
<td>Good: Normal speech audible but not intelligible</td>
</tr>
<tr>
<td>55</td>
<td>Very Good: Raised voices usually audible but not intelligible</td>
</tr>
<tr>
<td>55+</td>
<td>Excellent: Raised voices not audible</td>
</tr>
</tbody>
</table>

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

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

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

15mm Concrete Floor
IIC: 28

Wood Joint Floor
IIC: 40
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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**Room Acoustics**

**Supports:**
- Speech
- Music
- Recording

**By giving attention to:**
- Occupant requirements
- Room Shape
- Volume
- Finishes

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**Reverberation (RT<sub>60</sub>)**

**Reverberation**
- Reverberation is the decay (or persistence) of a sound in an enclosed space. One measure is the time (RT<sub>60</sub>) 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<sub>60</sub> values while speech has higher clarity with low RT<sub>60</sub> times

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**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)

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**Impact Insulation Class (IIC)**

**Subjective impression to impact noise**

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

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**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

SAT scores decrease with poor acoustics

Bronzart (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 Marwell (1997)
- Chronic noise exposure reduced reading scores
  (even when tested in a quiet environment)
- Noise exposure is related to impairment in speech perception

- 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.

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 optimise conditions for teaching and learning.”

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

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

Reverberation time has an ideal point ~0.6 to 0.7 seconds

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’

Acoustic Targets and Criteria

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

Best Solution:
Communication between users and designers
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

Acoustic Targets and Criteria

Reducing External Distractions

Sound Isolation (STC)
• 50 – classroom to classroom

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

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

Flanking Paths to Consider:
• Ducts
• Penetrations
• Ceiling Plenum
• Grating
• Doors
• Electrical Boxes
• Etc.

Sound Isolation

Reducing External Distractions

Target Minimum STC 55
With Staggered or Double Stud Construction

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

Flanking Paths to Consider:
• Ducts
• Penetrations
• Ceiling Plenum
• Grating
• Doors
• Electrical Boxes
• Etc.
Floor/Ceiling Construction

<table>
<thead>
<tr>
<th>Layers (top to bottom)</th>
<th>Thickness</th>
<th>STC</th>
<th>IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite slab (concrete) on 75 mm steel deck</td>
<td>150 mm</td>
<td>51</td>
<td>21</td>
</tr>
<tr>
<td>- with vinyl floor</td>
<td>150 mm</td>
<td>51</td>
<td>33</td>
</tr>
<tr>
<td>- with carpet</td>
<td>150 mm</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>- with vinyl floor and ACT</td>
<td>518 mm</td>
<td>55</td>
<td>51</td>
</tr>
<tr>
<td>- with carpet and ACT</td>
<td>518 mm</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>- with vinyl floor and GWB ceiling plus ACT</td>
<td>684 mm</td>
<td>72</td>
<td>61</td>
</tr>
<tr>
<td>CLT (5-ply) 175 mm thick</td>
<td>175 mm</td>
<td>41</td>
<td>25</td>
</tr>
<tr>
<td>- with vinyl floor</td>
<td>175 mm</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td>- with carpet</td>
<td>175 mm</td>
<td>41</td>
<td>34</td>
</tr>
<tr>
<td>- with vinyl floor and ACT</td>
<td>526 mm</td>
<td>51</td>
<td>38</td>
</tr>
<tr>
<td>- with carpet and ACT</td>
<td>526 mm</td>
<td>51</td>
<td>40</td>
</tr>
<tr>
<td>- with vinyl floor and GWB ceiling plus ACT</td>
<td>634 mm</td>
<td>70</td>
<td>56</td>
</tr>
</tbody>
</table>

Concrete topping (regular weight) 38 mm thick
Rubber nuggets on bit 12.7 mm thick
CLT (5-ply) 175 mm thick

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

Room Acoustics (RT₆₀)
- 0.6 s for small classrooms (<283 m³)
- 0.7 s for large classrooms (>283 m³)
* Must be readily adaptable to meet 0.3 s

Enhancing Communication

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 - Room Requirements

<table>
<thead>
<tr>
<th>Acoustic Requirements</th>
<th>Small Volume</th>
<th>Medium Volume</th>
<th>Large Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special</td>
<td>Recording room</td>
<td>Music Room</td>
<td>Auditorium</td>
</tr>
<tr>
<td>High</td>
<td>Project Room</td>
<td>A/V Room</td>
<td>Gym</td>
</tr>
<tr>
<td>Medium</td>
<td>Quiet Room</td>
<td>Tele-Learning</td>
<td>Multi-purpose</td>
</tr>
<tr>
<td>Low</td>
<td>Private Office</td>
<td>Classroom</td>
<td>Library</td>
</tr>
<tr>
<td></td>
<td>WC Storage</td>
<td>Corridor</td>
<td>Lobby</td>
</tr>
</tbody>
</table>

Room Acoustics – Specialty Spaces
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.)

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

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 / 4” SC w batt / 5/8” Type X GWB)
- Concrete block (8”)

Windows
- 3/8” glass ~ STC 35 (OITC 32)
- 1/2” laminated glass ~ STC 38 (OITC 34)
- 1/2” lam / 1” airspace / 1/2” 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

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

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

Guidance Counselor’s Office

Guidance Counselor’s Office

Guidance Counselor’s Office

Guidance Counselor’s Office

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

Guidance Counselor’s Office

Guidance Counselor’s Office

Guidance Counselor’s Office

Guidance Counselor’s Office

Value of Acoustics

Room Acoustics
• Communication
• Calm Environment

Value of Acoustics

Room Acoustics
• Communication
• Calm Environment

Value of Acoustics

Background Noise
• Increase SNR (comprehension)

Value of Acoustics

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

Value of Acoustics

Solutions:
• Fibrous/porous (thicker or spaced from wall)
• Ceiling Tiles
• Staircases

Value of Acoustics

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• Fibrous/porous (thicker or spaced from wall)
• Ceiling Tiles
• Staircases

Cautions:
• Microphones
• Speakers

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Value of Acoustics

Mechanical Noise Controls
• Walls/ceilings (including ACT)
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• Vibration isolation (demo)
• Distance
Valuable Example

Mechanical Noise
- Noisy
- ‘Cross-talk’

Other Acoustic Considerations

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

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

Impact Noise
- Thumping footsteps

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

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

Thank you for your time.