Acoustic Considerations for Wood Frame Construction

Wood*Works!*

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Consulting Engineers & Scientists

Introduction

Russ Lewis, M.Eng. P.Eng.

- Technical Director in Acoustics at RWDI
- 20+ years in acoustic consulting engineering.
- Experience in Canada, US and overseas.
- Experience in :
  - Residential (including wood frame)
  - Mid and high-rise mixed use
  - Secondary/post-secondary education and healthcare facilities
  - TV, radio and recording studios;
  - Performing arts centres;
  - Sports, fitness and leisure complexes;
  - Arenas, etc…

Introduction

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Outline:

- Building Acoustics Metrics (numerical ratings)
- Multi-Unit Residential Acoustic Criteria
- Noise Isolation
  - Airborne noise isolation (partitions & floor/ceiling)
  - Impact noise isolation (floor/ceiling)
  - Flanking paths (structure-borne noise isolation)
- Transfer of sound through walls and floors
- Look at performance of alternative constructions
- Example buildings
- Questions

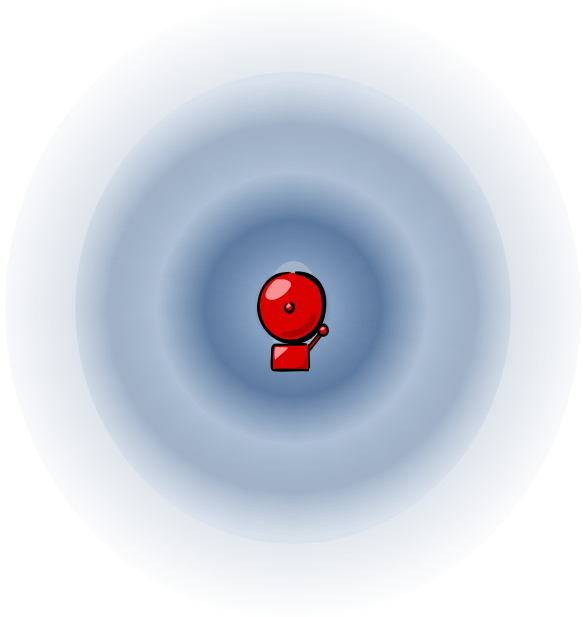
Introduction

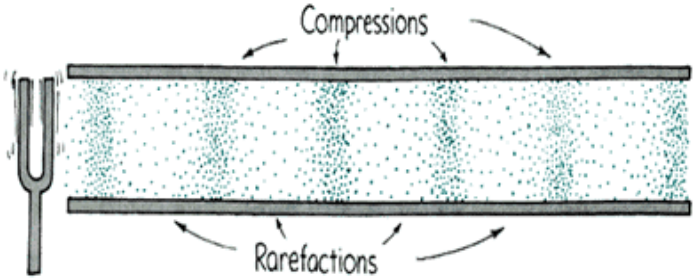
- Acoustics is a key challenge in wood-frame construction
  - Recent allowance of 6-storey buildings
  - Worldwide new buildings up to 26-storey
- Early planning and good design practice to ensure good acoustics
- Main goals – meet the sound isolation and impact isolation requirements for code compliance and occupant comfort

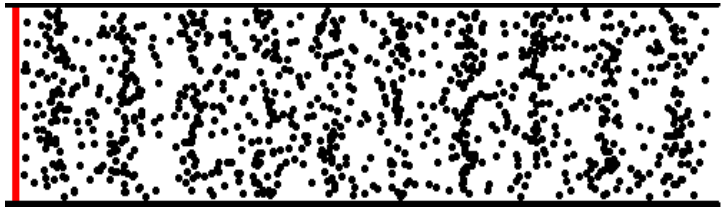
Airborne sound

- Sound is a Wave

  - Pressure wave moving through the air
  - Regions of high pressure (the peaks of the wave) and low pressure (the troughs)



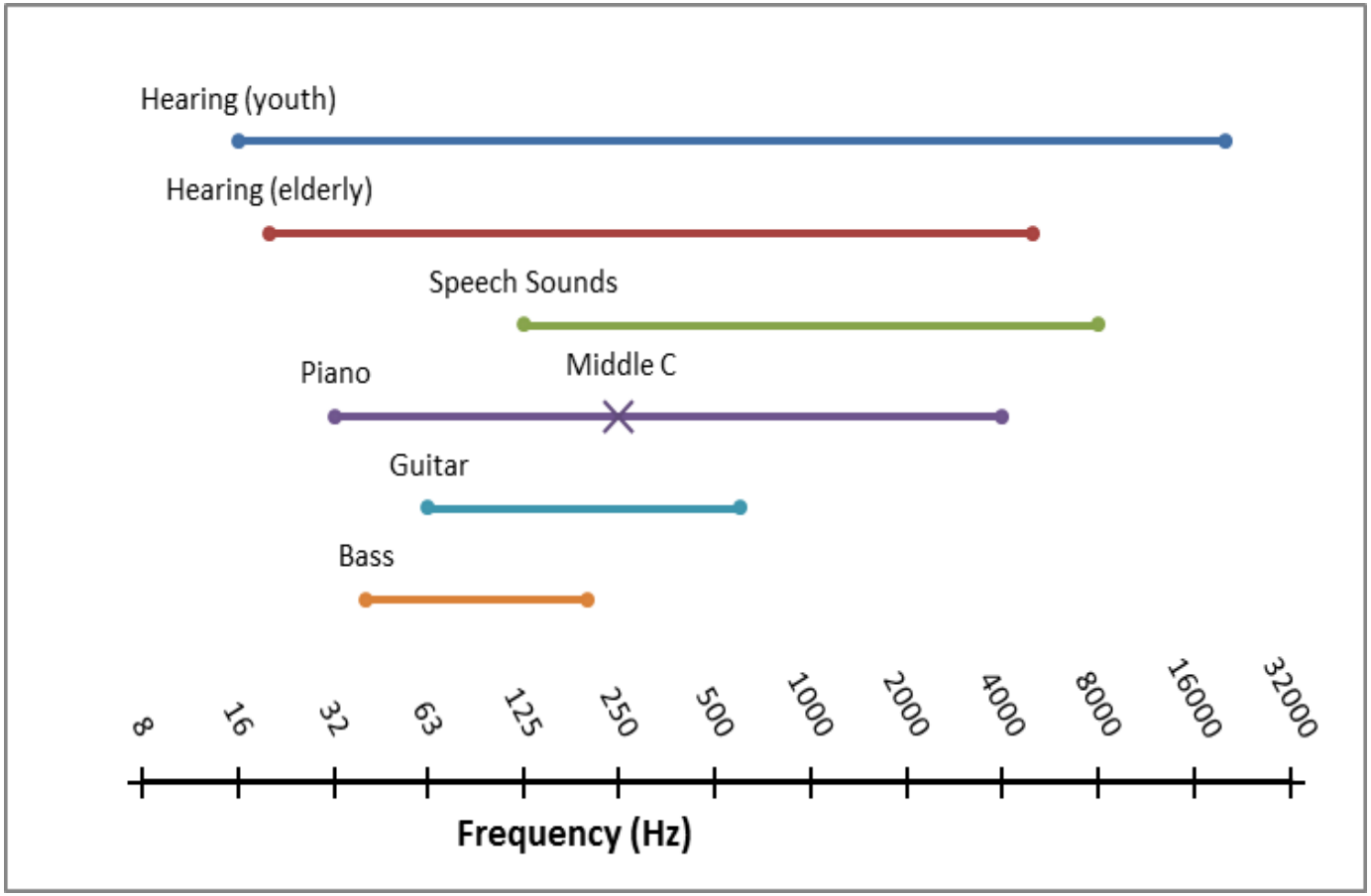




Graphics from: www.physics.uiowa.edu/~umallik/adventure/sound.htm

Acoustics Fundamentals

- Frequencies of Audible Sound



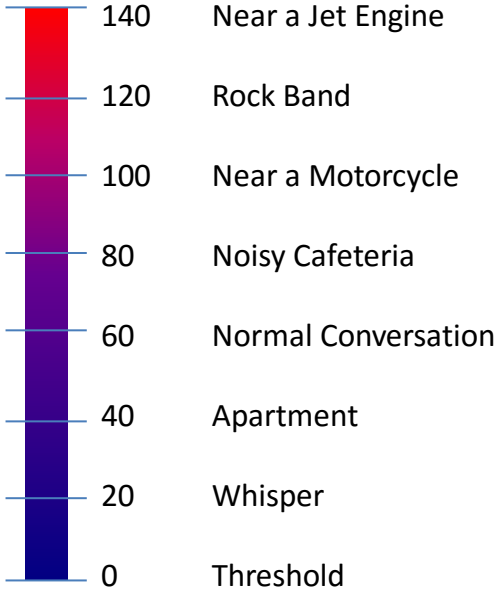
Acoustics Fundamentals

- Sound pressure levels – the decibel - dB

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

Human Perception
Twice as loud
+10dB

Common Sounds in dB



Single Number Ratings

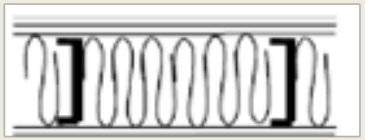
- Common in Codes, Specifications and Compliance Documents
  - Simple and handy
  - Simple, but don't always ensure occupant comfort
- Ratings for noise are based mainly on speech
  - not or your neighbour's subwoofers or low frequency mechanical noise …
- Some ratings are from laboratory, others are field-measured ratings

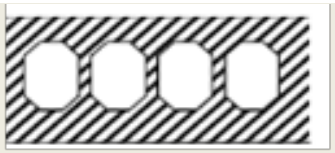
Building Acoustics Metrics – Noise Isolation

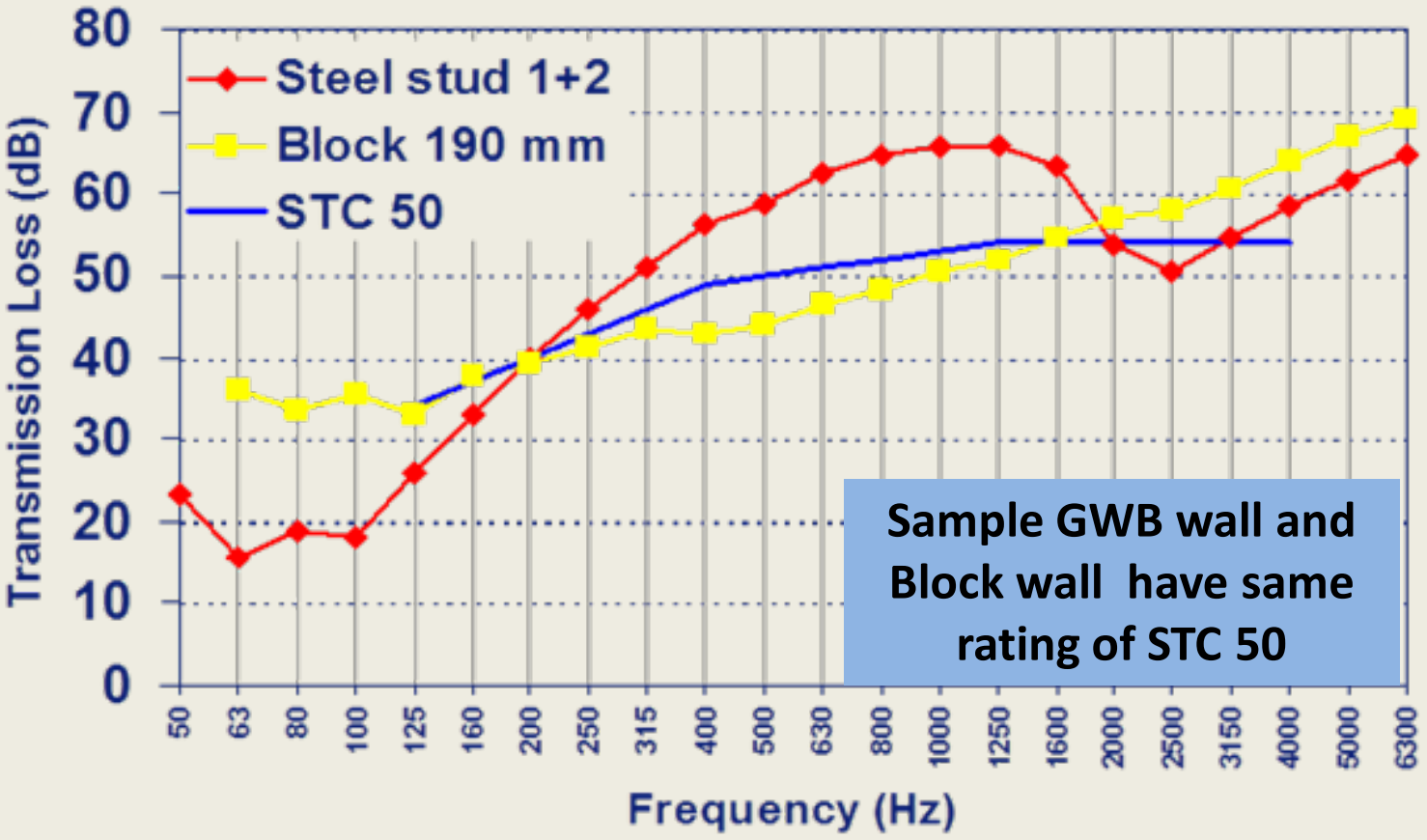
- Sound Transmission Class (STC) – laboratory
- Field Sound Transmission Class (FSTC) - field
- Apparent Sound Transmission Class (ASTC) - field
- Noise Isolation Class (NIC) - field

- Transmission Loss – drop in noise measured in dB at a particular frequency as it passes through a partition….

Limitations of STC …







Noise Isolation – single number ratings

Symbol	STC, FSTC, ASTC, NIC
Name	Sound Transmission Class
General Description	Single number rating of the sound isolation properties of a partition system. When evaluated in the field denoted by FSTC (flanking suppressed); ASTC, NIC (flanking included)
Standard	ASTM E413

Building Acoustics Metrics – Noise Isolation

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Sound Transmission Class (STC)

- Laboratory test
- Analytical calculation

Field Sound Transmission Class (FSTC)

- Field tested
- Includes some flanking paths but effort to suppress required during testing.
- Limitations on room sizes and dimensions
- Takes into account receiving room damping (reverberation time)

Building Acoustics Metrics – Noise Isolation

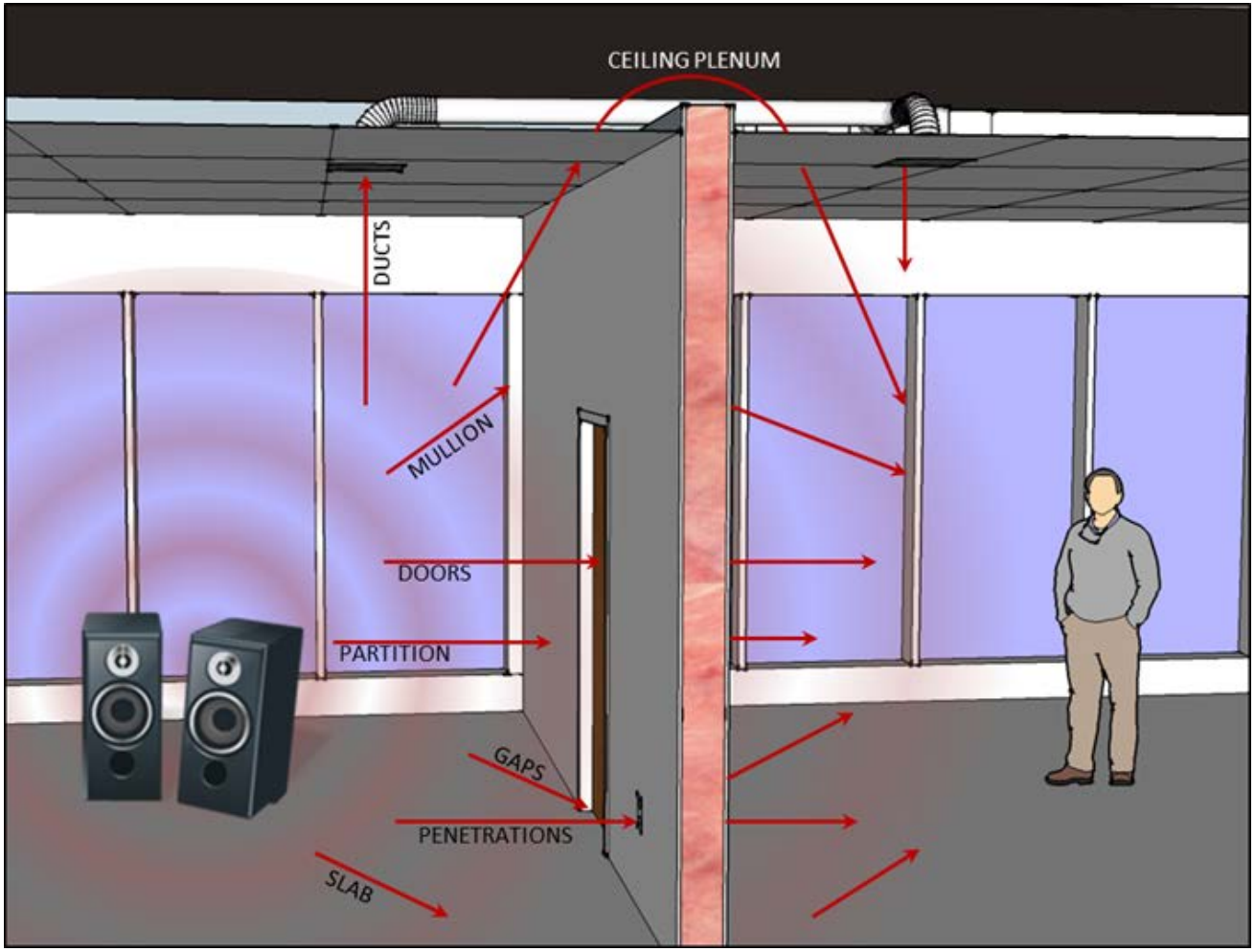
Apparent Sound Transmission Class (ASTC)

- Field tested or analytical calculation.
- Similar to FSTC, but no limitations to room sizes and dimensions.
- Includes flanking
- Takes into account receiving room damping (reverberation time)

Noise Insulation Class (NIC)

- Field tested
- Includes flanking
- Simple difference in sound level in various 1/3 octave band frequencies.
- Does not adjust for receiving room damping (reverberation time)

Flanking paths

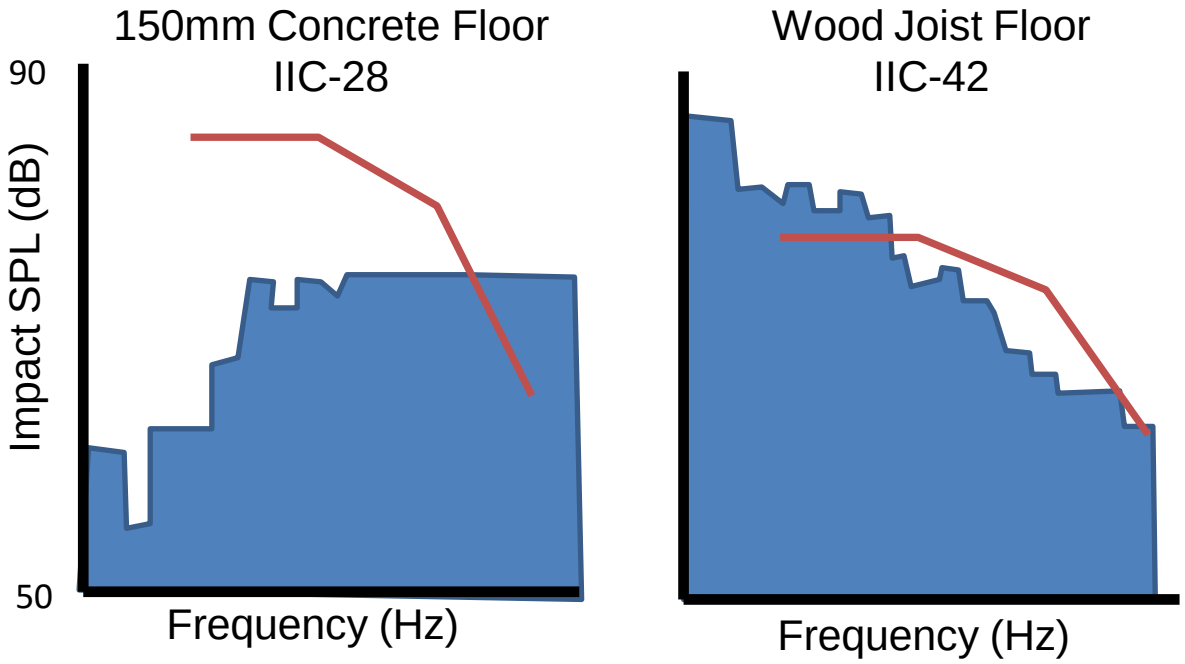


Building Acoustics Metrics – Impact Noise Isolation (IIC)

Symbol	IIC
Name	Impact Insulation Class, dB
General Description	Single number rating of the impact sound isolation properties of a floor/ceiling system. When evaluated in the field (considers flanking), denoted by FIIC. Higher rating is better.
Region	North America
Standard	ASTM E989

Building Acoustics Metrics – Impact Noise Isolation

- **Impact Insulation Class (IIC)**
- A single number rating of the effectiveness of a floor/ceiling system to stop the transmission of impact sound (higher = better isolation)
- Sliding contour that is fit to performance impact transmission loss (TL) data
- Developed for concrete structures



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

Acoustic Criteria

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Must meet building code requirements:

- National Building Code of Canada:
  - STC-50 for dwelling
  - STC-55 dwelling to elevator shaft
  - NBCC 2015: ASTC-47
- Impact Insulation Class (IIC):
  - No requirements in National Building Code:
  - Guideline of IIC-55
- Similar for U.S. International Building Code:
  - STC-50 or FSTC-45
  - IIC-50 or FIIC-45 is required

Acoustic Criteria

- Minimum building code requirements will not necessarily lead to occupant satisfaction.
- Higher noise isolation ratings are generally recommended (STC-60)
- Other requirements may also apply:
  - Ontario New Home Warranties Plan Act (Tarion)
    - Design review, field testing, sign-off by a qualified acoustic engineer.

Noise Isolation

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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)**

Noise Isolation

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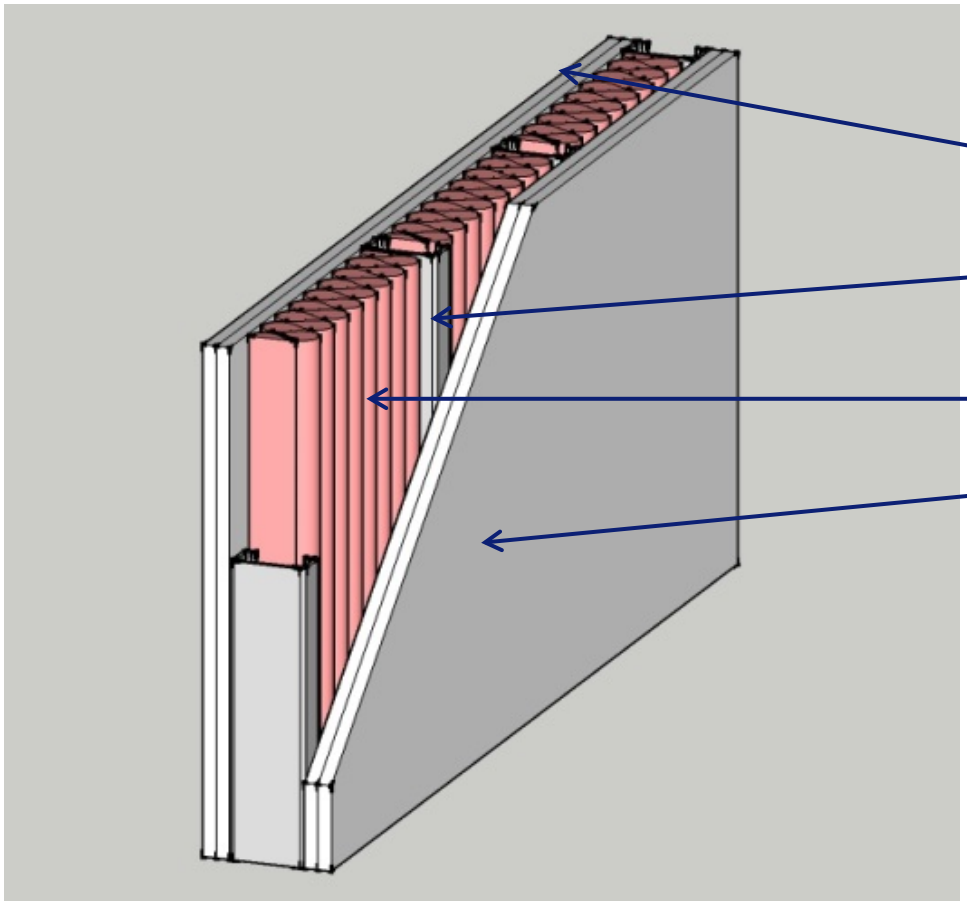
Airborne Sound Isolation Performance determined by:

- The number of layers of drywall (surface mass of the partition)
- Insulation in the stud cavity (damping)
- Stud stiffness or connection between sides of partition
- Stud spacing
- Flanking paths - airborne and structure-borne

Non-loadbearing (25 ga.) Steel Studs



NBCC Wall Type S6b:

2x15.9mm Type X GWB

41mm x 92mm **25 ga. non-loadbearing steel studs 400mm O.C.**

89mm mineral wool or batt

2x15.9mm Type X GWB

Width = 156mm

STC-55

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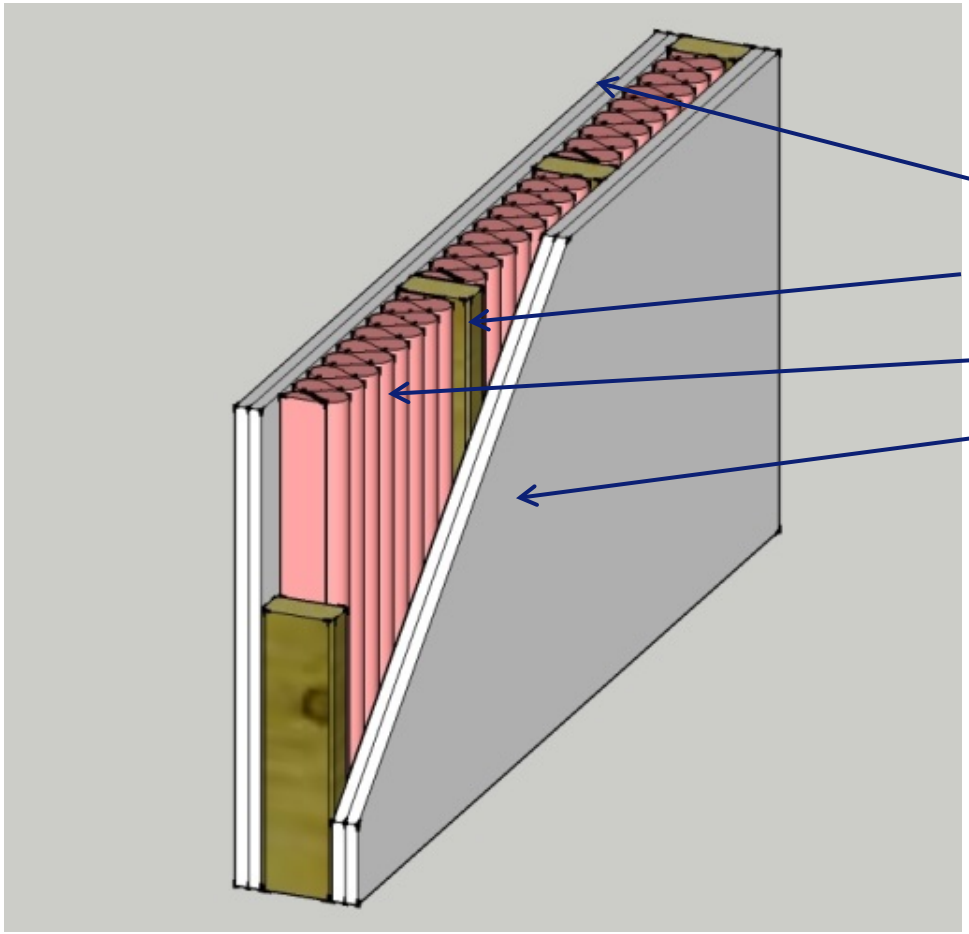
25 ga Studs Changed to Wood Studs



NBCC wall type W2a:

2x15.9mm Type X GWB
38mm x 89mm **wood studs 400mm O.C.**
89mm mineral wool or batt
2x15.9mm Type X GWB
Width = 153mm

STC-38

Consequence:
"Very Good" isolation (STC-55) becomes "Very Poor" isolation (STC-38)
No longer building code compliant

Noise Isolation - Partitions

- Noise isolation reduced due to:
  - stiffer studs
  - better coupling between sides of the partition.

- Required: flexible, resilient connection or physical break at the studs.

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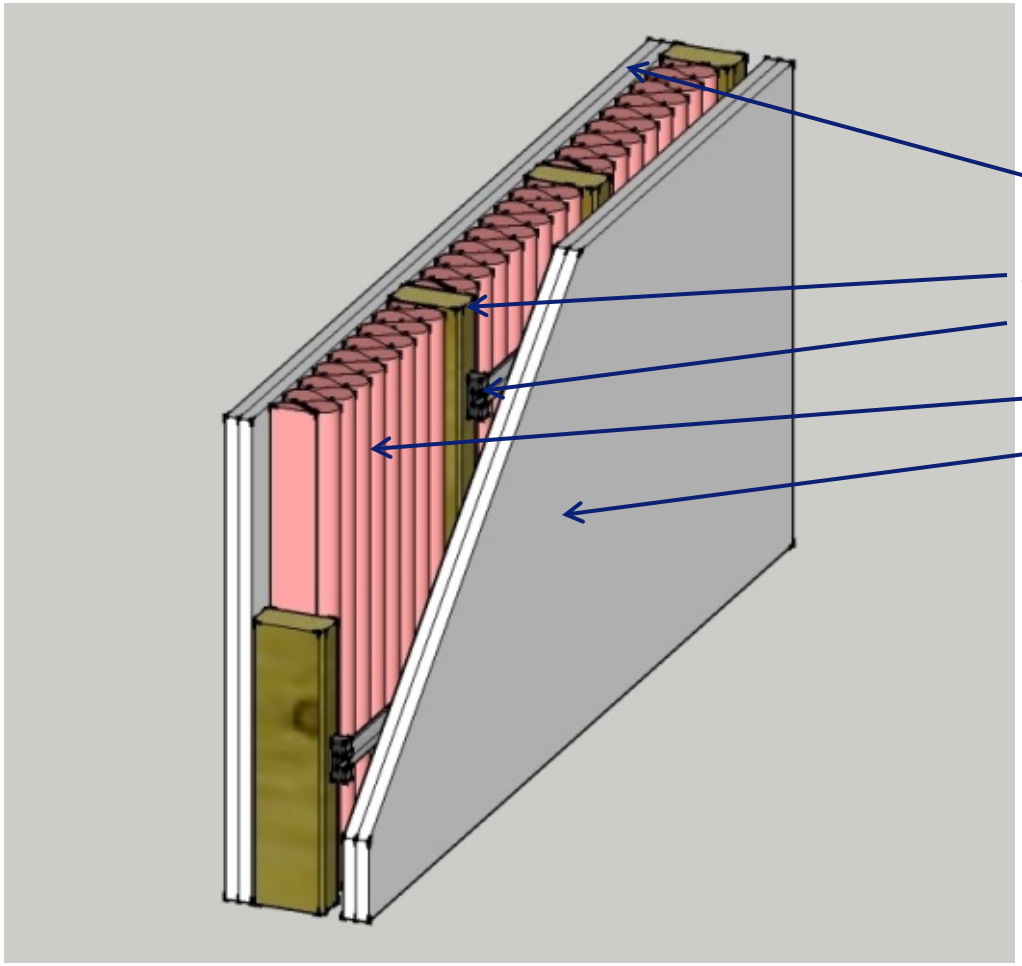
Added Resilient Channel



NBCC wall type W6a:
2x15.9mm Type X GWB
38mm x 89mm wood studs 400mm O.C.
Resilient channels spaced 400mm O.C.
89mm mineral wool or batt
2x15.9mm Type X GWB

Width is about 165mm

→ **STC-55**

Note:
Resilient Clip (commercially available) also an option in lieu of the resilient channel.

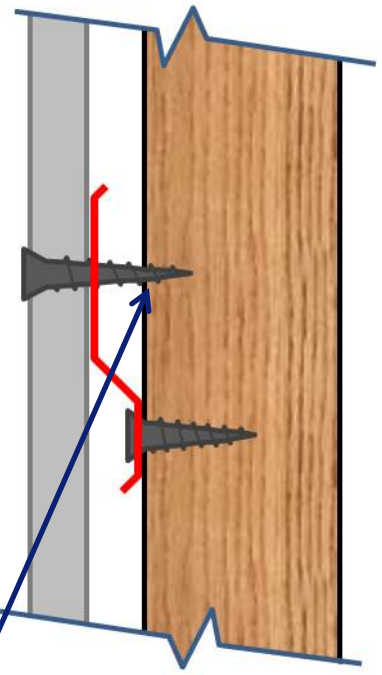
Noise Isolation – Resilient Channel

Potential difficulties with RC:

- Installation of RC upside down (experienced contractors required for these installations).
- Bridging through the RC to the stud behind (screws are too long, or fastening to RC not done between stud locations).
- Hanging of cabinets, shelving or TV (directly to studs, bridging the RC).

Consequence:

“Very Good” isolation (STC-55) becomes “Very Poor” isolation (STC-38)
No longer building code compliant



Noise Isolation – Partitions

- Better solution to add a physical break between sides of partition:
  - Staggered stud partition
  - Separate stud partition
- Physical break also attenuates potential impact noise, e.g. from wall mounted cupboards.

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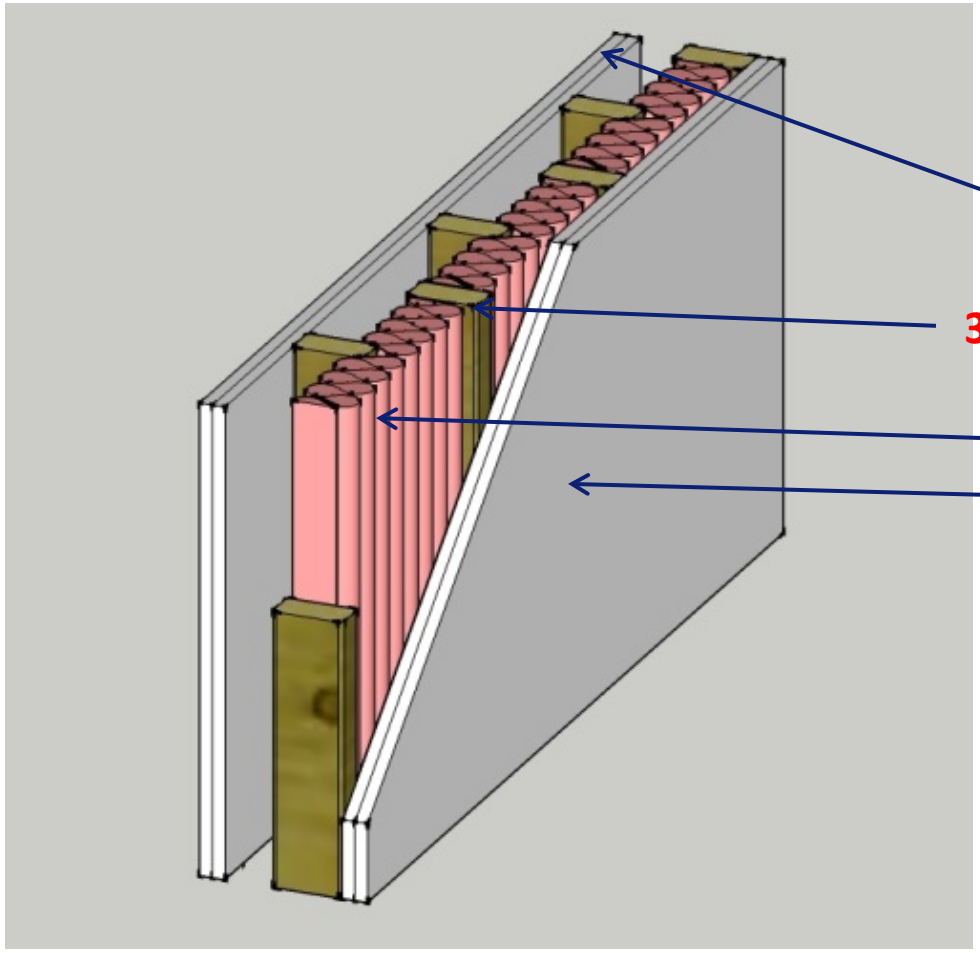
Staggered Stud Partition



NBCC wall type W9a:

2x15.9mm Type X GWB

38mm x 89mm staggered wood studs 400mm O.C. on 38mm x 140mm plate

89mm mineral wool or batt

2x15.9mm Type X GWB

Width is 204mm

STC-56

Add resilient channel to one side (NBCC wall type W10a): **STC-62**

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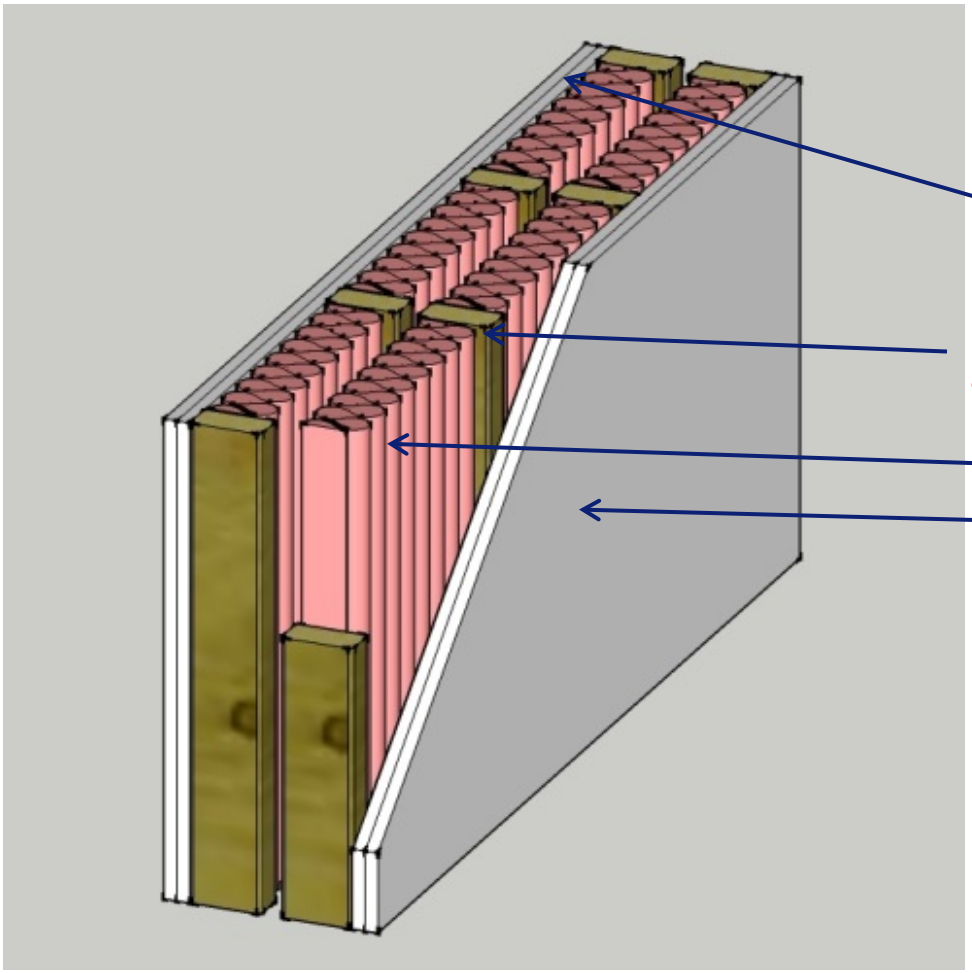
Separate Stud Partition



NBCC wall type W15a:

2x15.9mm Type X GWB
Two rows of 38mm x 89mm wood studs
400mm O.C. on separate 38mm x 89mm plates
set 25mm apart
89mm mineral wool or batt
2x15.9mm Type X GWB

Width is 267mm

STC-66

Noise Isolation - Separate stud wall: Sheathing

- Adding sheathing to separate stud wall will reduce STC (less TL at low frequencies)

  Consequence:

  “Excellent” STC-66 isolation becomes:

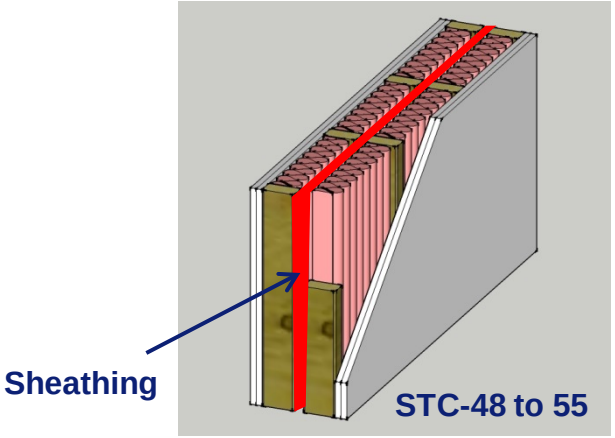
  Sheathing in cavity on one side:

  “Very Good” STC-55 isolation

  Sheathing in cavity on both sides:

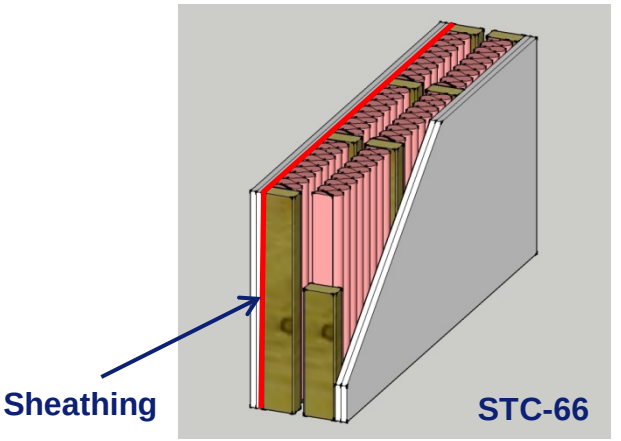
  “Good” STC-49 isolation

  Marginally meets building code



- Mitigation:
  - Add sheathing to outside of studs, under GWB.
  - Include RC or resilient clips on GWB

    ~STC-66



Noise Isolation - Separate stud wall: Cleats

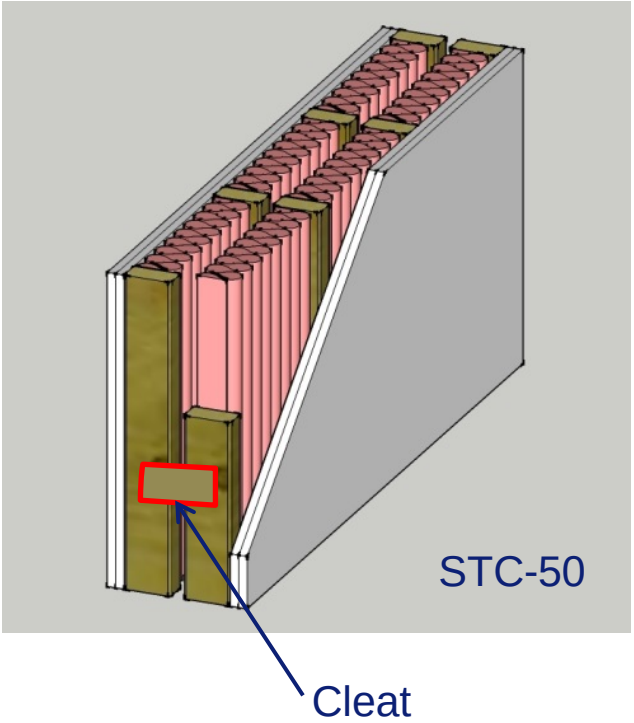
- Cleats often installed during framing separate stud walls:
  - If not removed, bridging occurs and noise isolation is degraded.

Consequence:

“Excellent” STC-66 isolation becomes

“Good” STC-50 isolation

Marginally building code compliant.



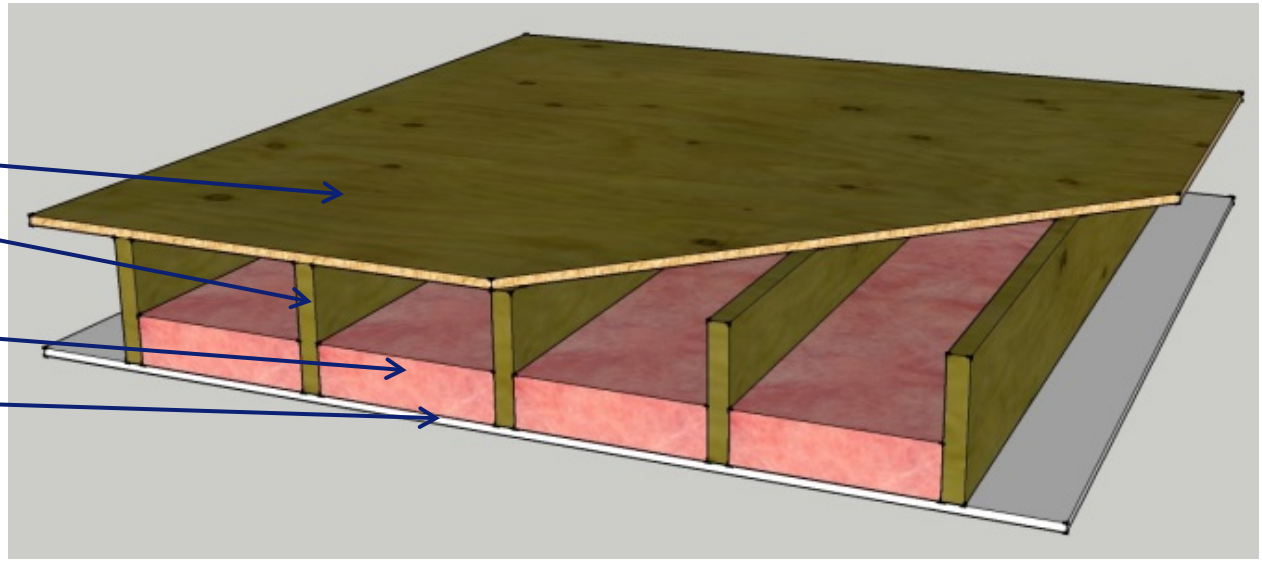
- Mitigation:
  - Remove cleats if not required for stability.
  - If cleats required for stability:
    - Acoustic sway braces (include rubber or neoprene isolation element).

Noise Isolation: Floor/Ceiling

Wood Joist Floor + GWB Ceiling

NBCC Floor Type F3b:

Plywood/OSB/TG subfloor
Wood joists or I-joists
400mm O.C.
mineral wool or batt in cavity
15.9mm Type X GWB



STC-31 | IIC-30

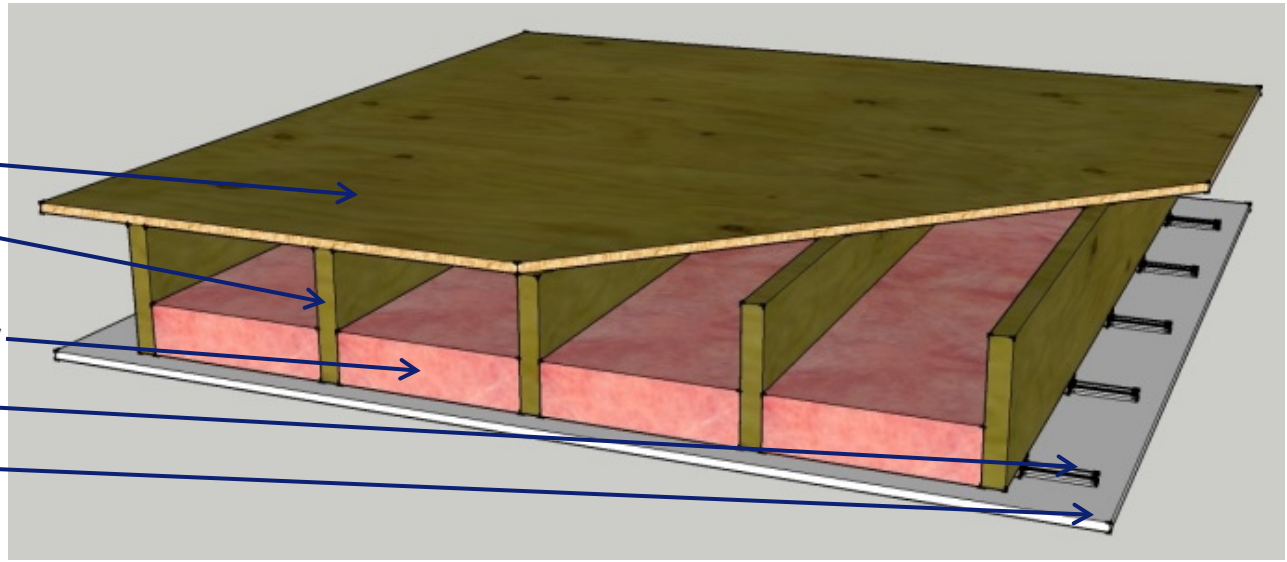
Want minimum STC-50 and IIC-55 (Guideline)

Noise Isolation: Floor/Ceiling

Wood Joist Floor + GWB Ceiling on Resilient Channel

NBCC Floor Type F5c:

Plywood/OSB/TG subfloor
Wood joists or I-joists
400mm O.C.
mineral wool or batt in cavity
Resilient Channel
15.9mm Type X GWB



STC-48| IIC-41

2x 15.9 Type X GWB:
STC-52 | IIC-46

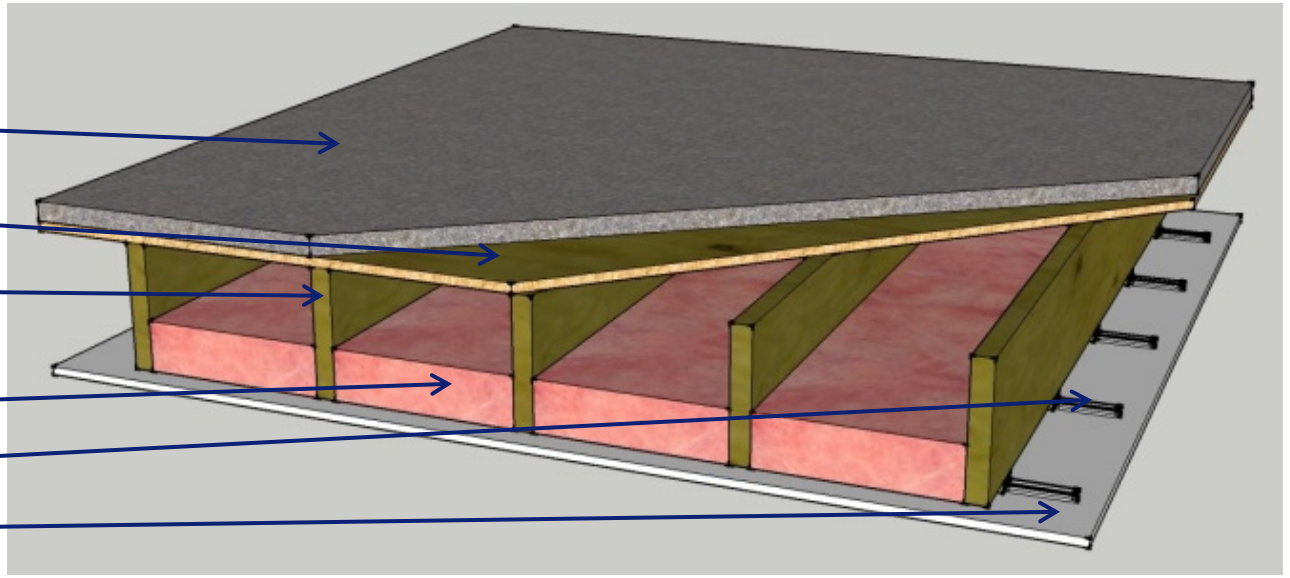
Note: Details required for e.g. lighting fixtures.

Noise Isolation: Floor/Ceiling

Wood Joist Floor + Concrete Topping + GWB Ceiling on Resilient Channel

NBCC Floor Type F20e:

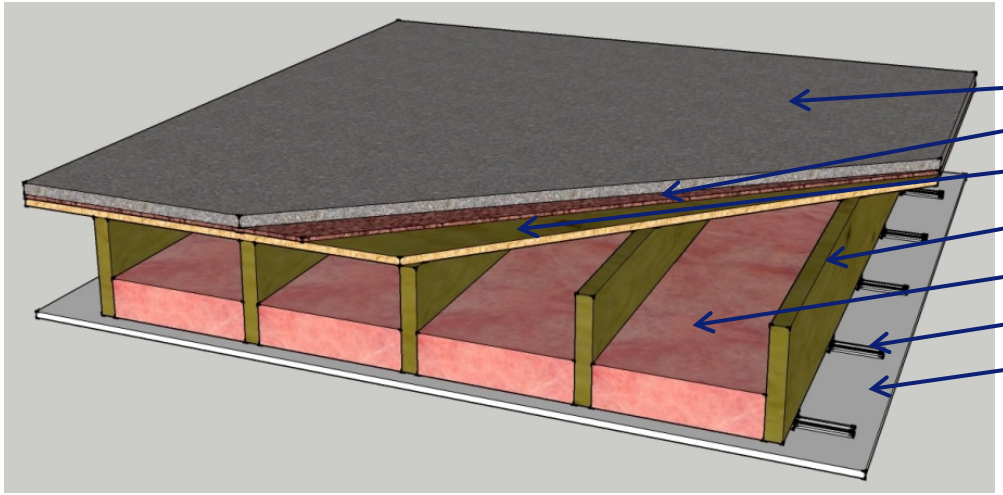
39mm conc. topping (min. 70 kg/m3)
Plywood/OSB/TG subfloor
Wood joists or I-joists 400mm O.C.
mineral wool or batt in cavity
Resilient Channel
15.9mm Type X GWB



STC-64 | IIC-40

Noise Isolation: Impact Noise (Floor/Ceiling)

- Ceiling suspended on RC:
  - IIC-55 NBCC guideline criterion is not met.
  - IIC-50 U.S. IBC criterion not met.



39mm conc. topping (min. 70 kg/m3)
Resilient Acoustic Underlayment
Plywood/OSB/TG subfloor
Wood joists or I-joists 400mm O.C.
mineral wool or batt in cavity
Resilient Channel
15.9mm Type X GWB

STC-64 | IIC-55 to 60

- Resilient underlayment + concrete topping is required to achieve IIC-55 to 60 rating.
  - Concrete topping + resilient underlayment also reduces flanking path via floor.
  - RC reduces flanking path via ceiling.

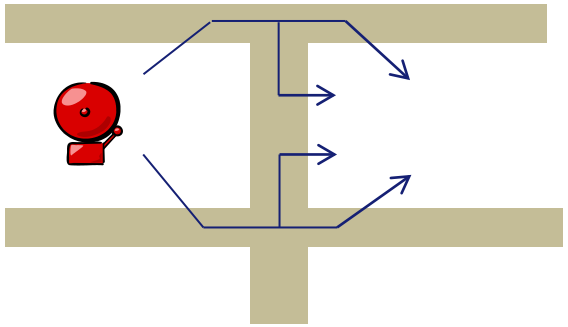
Noise Isolation: Structure-Borne Flanking Paths

Flanking paths

- More significant for timber framed construction than concrete structure

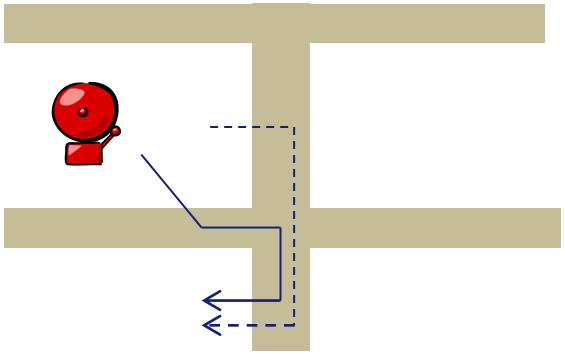
Horizontal:

- Airborne paths
- Via Floor
- Via Ceiling



Vertical:

- Airborne paths
- Via floor to wall
- Via wall to wall (not significant)



Noise Isolation: Flanking Paths

- Airborne flanking paths (partitions):
  - Electrical/cable boxes:
    - Avoid back-to-back
    - Min. 400mm separated,
    - Preferably in separate stud cavities.
  - Service penetrations
    - Sealed with non-hardening caulking
    - Avoid services in party wall – separate shaft wall next to party wall.
  - Seal top and bottom of wall with acoustic caulking (at GWB and header/sole-plate).

Electrical Boxes

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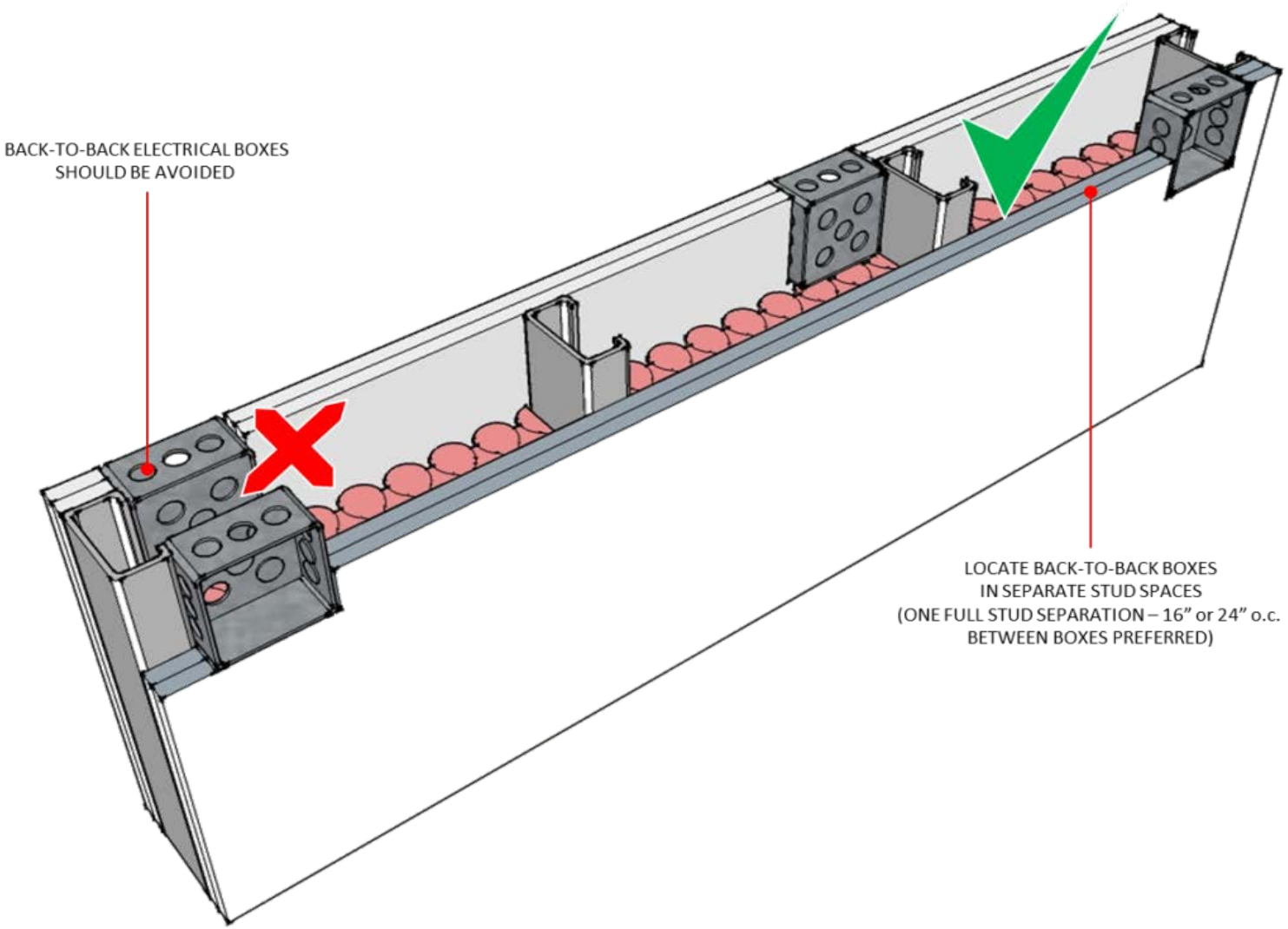

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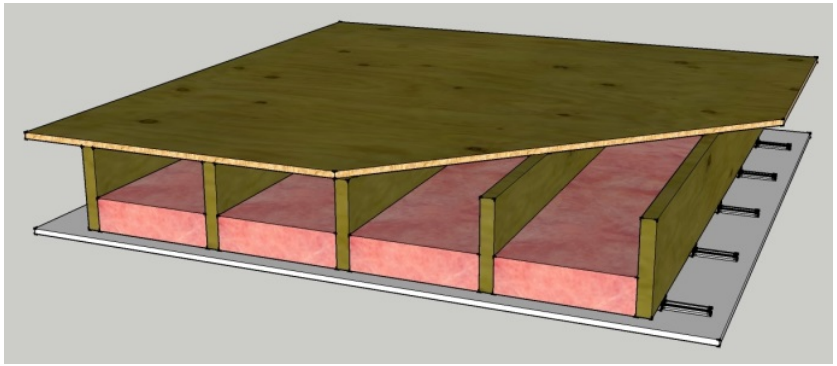
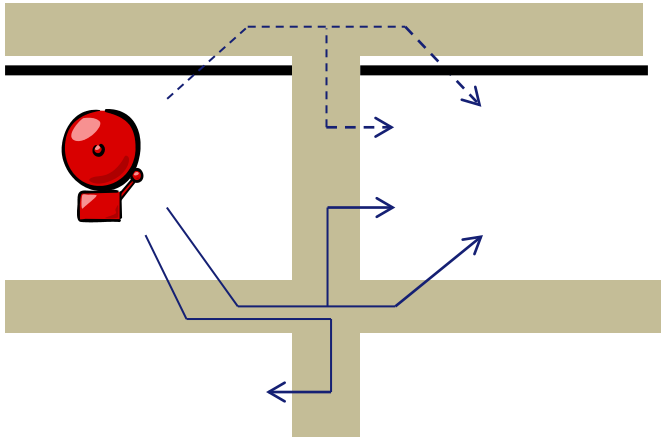
Structure-borne Flanking Paths



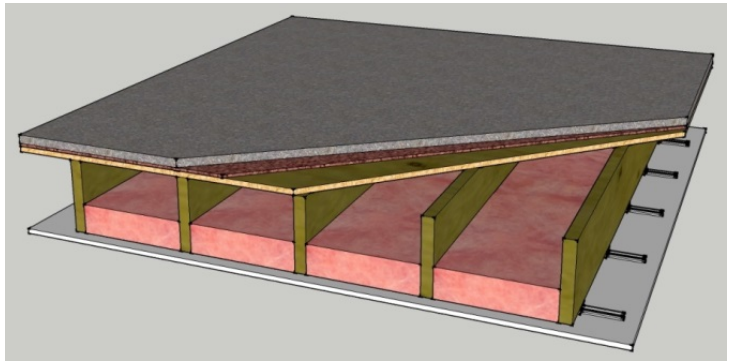
Ceiling surfaces isolated

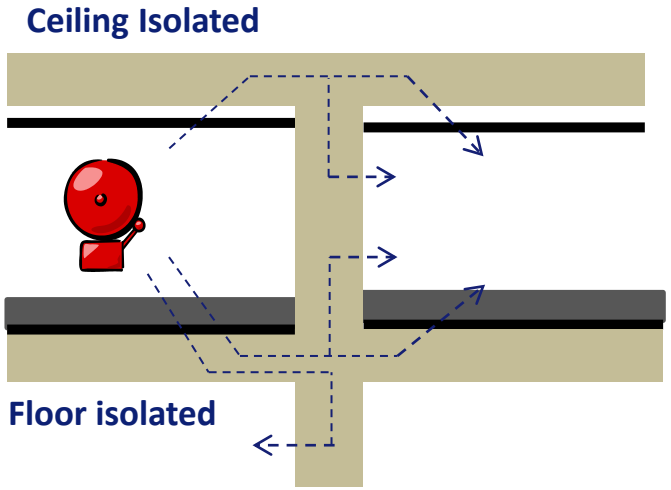


- Flanking via ceiling:
  - GWB ceiling on Resilient Channel or Clips.
    - Flanking path reduced by ~10 dB.
    - No longer significant flanking path

Structure-borne Flanking Paths

- Flanking via floor:
  - **Major flanking path:** If not addressed, can limit noise isolation to ~ ASTC-40 to 45.
- Mitigation:
  - **Concrete topping** either bonded to sub-floor, or, preferably **on resilient underlayment** is required to adequately attenuate this flanking path.
  - Concrete topping on resilient underlayment also attenuates:
    - Impact noise to suite below
    - Flanking to suite below



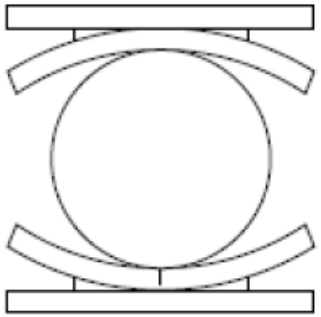


- Other considerations:
  - Floor joists parallel to party wall, or break in joists if perpendicular (across) party wall.
  - Break in sub-floor at party wall (may not be allowed due to seismic requirements).

Noise Isolation: Flanking Paths

Prefabricated panels:

- Noise/vibration isolation required between prefab floor sections and load bearing walls.
  - Neoprene/rubber element.
  - Other noise isolation device, e.g.:



Device to reduce flanking transmission by suppressing bending wave transfer from above to below: Cylinder (d=30-50mm) placed between conical shells.

Source: Vinnova Project 2007-01653, Acoustics in Wooden Buildings State of the Art 2008, SP, 2008.

Noise Isolation: HVAC

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Noise issues from HVAC:

- Low frequency dominant.
- Vibration isolation assumes a stiff and heavy (concrete) floor construction.
- Fan coil units (FCUs) installed inside suites.
- Light-weight structure susceptible to structure-borne noise.

Mitigation:

- Concrete floor required for mechanical rooms to ensure proper vibration isolation of equipment.
- Concrete topping and vibration isolation required for suite FCUs.
- Careful design and selection of vibration isolation.

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Floor Vibration Implications:

- Addition of significant amount of mass (concrete and GWB) to structure will lower floor's fundamental frequency.
- This helps to separate this frequency from the operating frequencies of mechanical equipment
- Planning for noise control ties into structural design (joist design, spacing).

Noise Isolation: Summary

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Summary of best practices design:

Walls:

- Separate stud, staggered stud or RC required.
  - Practical limitations for RC.

Ceiling:

- GWB suspended on RC.
  - Also suppressed flanking paths.

Floor:

- Concrete topping required to maintain floor/ceiling ASTC and to maintain partition (horizontal) ASTC by suppressing flanking paths.
- Concrete topping + resilient underlayment required to meet IIC-55 NBCC guideline and to better suppress flanking paths.

➡ **Flanking paths are critical to the noise isolation performance**

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The Wood Innovation and Design Centre (Prince George, BC)

More of a true wood-first design:

- 29.5 metres tall
- Six floors, with an actual height of about eight storeys.
- Established the acoustic design targets (reverberation time, noise criteria, STC requirements)
- Walls were double stud or staggered wood stud
- Floor/ceilings were a combination of exposed CLT (Cross-laminated timber) and CLT/gwb on RC for airborne sound and a complex carpet on plywood on rubber matts for IIC

Image Property of: Wood Innovation and Design Centre, Photos from Province of British Columbia, flickr, BC Gov Photos

Case Studies: Residences at UBC

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Residence at Brock Commons at UBC:

- 20 Storey Building
- Hybrid construction
- Concrete topping and GWB ceilings.
- Used metal studs for the party walls

6 storey student residence at UBC:

- Wood first project, but still has concrete topping and GWB/RC ceiling.
- Used double wood studs for the party walls between suites and staggered wood studs to corridors.

Case Studies: Clinical Services Building at Children's & Women's Hospital

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Clinical Services Building at Children's & Women's Hospital Campus Vancouver

- 3 storey building
- Wood framing: accepted lower STC design targets in order to utilize a single stud wood construction.
- Added electronic sound masking to increase speech privacy and to compensate for lower STC
- For areas where there was video conferencing, double stud construction was used

References

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Thank-you for listening!

Wood*WORKS!* – *April 2016*

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